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DEVCOM ARMY RESEARCH LABORATORY

US Army Combat Capabilities Development Command Army Research Laboratory South Research Summaries: Collaborations (2021–2022 Update)

edited by Heidi Maupin

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14. ABSTRACT
This report updates highlights of the collaborative research efforts resulting from the US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory's (ARL's) partnerships in the ARL South region. The ARL South research summarized in this report is integral to ARL's overarching research strategy; each project is a component of one or more of ARL's foundational research portfolios. While ARL's research primarily falls in the basic research arena with projected longer-term transitions, critical shorter-term outcomes will be recognized and exploited along the way.

15. SUBJECT TERMS
Designer Partnerships, Army Foundational Research, Collaborative Research, Army Research Laboratory South, University, and Industry Partners, Biological and Biotechnology Sciences, Electromagnetic Spectrum Sciences, Energy Sciences, Humans in Complex Systems, Mechanical Sciences, Military Information Sciences, Network and Computational Sciences, Photonics, Electronics, and Quantum Sciences, Sciences of Extreme Materials, Terminal Effects, Weapons Sciences

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Jeff Hansberger

John Hrynuk

Randy Hughes

Sangguk Kang

Christopher Kuhs

Michael Geuss

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1. Introduction

In April 2017, the US Army Combat Capabilities Development Command (DEVCOM) Army Research Laboratory (ARL) extended its geographical presence to the southern region of the United States, centered in Austin, TX. "ARL South," as it is colloquially called, grew from a nascent effort to a robust ecosystem addressing high-priority Army problems with a continually expanding base of new talent. Researchers within the ARL South community are embedded in universities primarily in the state of Texas, with member connections reaching out to New Mexico, Oklahoma, Alabama, Florida, Georgia, and Pennsylvania. Through strategic collaborative efforts, ARL joined forces with the region's partners to identify areas of mutual technical interest resulting in an environment that fosters innovation, rapid development, and accelerated technology transitions.

Researchers working in the ARL South region summarized their projects in an ARL special report published in 2019. The report was updated in 2020, and this document further updates the research, including progress achieved in the past year. The ARL South research summarized in this document is integral to the ARL overarching research strategy. Each summary included in the report was written by the ARL South researcher and compiled and edited by the ARL South Region Lead.

2. ARL South Research Summaries

2.1 Joint Base San Antonio (JBSA) – Fort Sam Houston (FSH)

Title: Soldier Touch Points for Measures of Situational Awareness

Modernization Priority: Soldier Lethality

On-site Army Researchers: Gary Boykin and Kristin Schweitzer

ARL Competency: Humans in Complex Systems

Fort Sam Houston Collaborator: Chloe Callahan-Flintoft

Summary of Research: ARL researchers at Joint Base San Antonio – Fort Sam Houston assist in developing research studies and executing data collections that are specific to Soldier populations. The FY22 Soldier touch points focus on 1) quantifying and understanding behavioral and physiological markers of situational awareness in Post-Traumatic Stress Disorder (PTSD) and non-PTSD military populations, and 2) understanding how aided target recognition highlights affect

attentional deployment. The overarching research goal is to take advantage of opportunities to non-invasively sense Soldier cognitive states that can inform adaptive behaviors in supporting technologies.

2.2 Bell Innovation

Title: Autonomous Micro Unmanned Air Systems, Soldier Lethality

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle (NGCV), Soldier Lethality

Core Competency: Weapons Sciences

Army Research Lead: John Hrynuk

Industry POC: Andrea Chavez

Summary of Research: ARL researchers are collaborating with Bell Innovation to develop and demonstrate a unique Soldier-portable small unmanned aerial system (sUAS). The Micro UAS is a Soldier-portable UAS platform capable of vertical take-off and landing (VTOL) as well as transitioning to fixed-wing mode for forward flight.

The team has jointly developed and successfully demonstrated sUAS capability that, once planned and launched, the vehicle executes the mission fully autonomously, without need for a pilot or observation of an available live video feed. This system will provide unprecedented range and endurance compared to comparable platforms while leveraging onboard autonomy to provide new intelligence, surveillance, and reconnaissance (ISR) capabilities for the Army. The effort is occurring as a result of a cooperative research and development agreement (CRADA) that was established in Spring 2018. The co-developed vehicle was demonstrated at the Army Expeditionary Warrior Exchange (AEWE) event in late February 2021. During this event, the ARL/Bell research team trained Soldiers to program autonomous missions to specific waypoints using a touchscreen tablet. As part of the missions programed by the Soldiers, the vehicle collected ISR data by detecting and labeling objects of interest (people, vehicles, etc.) and auto-populating the map with those images while in flight. Other experiments performed during the AEWE event highlighted the capability of the vehicle to autonomously operate beyond line of sight, collecting data several kilometers from the takeoff location, and returning home to populate the Soldier interface with objects of interest.

The research team continues to develop vehicle capabilities that support Army priorities. To further advance the micro UAS, ARL kicks off a new collaborative effort in August 2023 with Johns Hopkins University and Bell. The intended outcome of our collaborative research is to enable the vehicle to perform specific tasks that will include topological optimization, introduction of active materials to enable vehicle reconfiguration, and integration into the existing Bell Micro UAS platform along with updates to the flight control to account for vehicle reconfiguration.

2.3 Florida International University

Title: Dual Polarized Tightly Coupled Dipole Array

Modernization Priority: Network

Florida-based Army Researcher: Eric Adler

ARL Core Competencies: Photonics, Electronics, Quantum Sciences

Faculty POC: Satheesh Bojja Venkatakrishnan and John Volakis

Summary of Research: The objective of the research is to design and fabricate a dual-polarized tightly coupled dipole array with 20:1 bandwidth and high polarized isolation greater than 40 dB.

2.4 Rice University

Title: Autonomous Networking

Modernization Priority: Network/Command, Control, Communications and Intelligence (C3I)

Army Researcher: Gunjan Verma

ARL Core Competency: Network Science and Computational Sciences (NSCS)

Faculty POC: Santiago Segarra

Summary of Research: To date, we have developed several state-of-the-art algorithms for machine-learning-driven resource allocation in wireless networks. These algorithms run in a low-overhead, distributed manner to perform important networking functions like power allocation and link scheduling. We are currently working on machine-learning-based routing and network performance modeling.

Title: Next Generation Sensors

Modernization Priority: NGCVs

On-site Army Researcher: Christopher T Kuhs

ARL Core Competency: Photonics, Electronics, and Quantum Systems

Faculty POC: Naomi Halas, Peter Nordlander, Jun Lou, and Stephan Link

Summary of Research: Years of semiconductor design and manufacturing innovation has led to the natural limitations of classical semiconductor technologies. Therefore, for next-generation electronics to continue to advance in metrics such as power consumption, size, and sensitivity, a shift away from traditional semiconductor materials is a necessity. The ARL on-site researcher partners with university researchers and other ARL scientists to study novel materials and heterostructures for next-generation semiconductors for use in sensors and seekers. To perform these scientific investigations, we design and build custom spectroscopic and microscopic tools to determine the optical performance of these novel semiconductors.

2.5 Texas A&M University

Title: Spanwise Extending Unmanned Aerial Systems

Modernization Priority: Future Vertical Lift (FVL), NGCV

On-site Army Researcher: Francis Phillips

ARL Core Competency: Mechanical Sciences

Faculty POC: Darren Hartl

Summary of Research: Our research will advance capability of aerial systems by enabling them to modify their shape to respond to current situational needs. The concept sUAS will be able to actively change the span of the wings in response to mission profile, environmental conditions, and Soldier/vehicle command. The team reached a significant milestone in their 2-year research endeavor. They successfully demonstrated their design tool for an aircraft that will be able to optimize its performance through different phases of flight. The tool enables the structural autonomous optimization of a vehicle capable of such morphing. For example, during dash segments, short wings are desirable to go fast and be more maneuverable, but for loiter segments, long wings are desirable to enable low-power, high-endurance flight. Still in its early stages, success for this promising research will have a direct impact on the ability to additively manufacture affordable, customized, mission-specific vehicles for the Warfighter.

Title: Model Based Analysis for Hybrid-Electric Vertical Flight Aircraft Design and Vertical-Flight Aircraft Performance Analysis Models

Modernization Priority: FVL/NGCV

ARL Researcher: Dino Mitsingas

ARL Core Competency: Mechanical Sciences/Energy Sciences

Faculty POC: Moble Benedict

Summary of Research: ARL and Texas A&M University (TAMU) have been jointly developing computer models with prediction capabilities for the aerodynamic requirements of aircraft and the propulsion power needed to meet those requirements throughout their operational condition. The models analyze hybrid-electric land, sea, and air vehicles that have become available due to the confluence of high power-to-weight-ratio electronics, motors, and batteries. The primary focus of the collaboration with TAMU is on the propulsors (e.g., rotor and aerodynamics), energy source (e.g., battery), and power conversion (e.g., electric motor drive). The models predict each component's performance and losses at different operating conditions and size an optimal component for a given load based on a mission profile. System models will track power losses among different components, including secondary loads such as power-hungry payloads to predict the entire vehicle's performance throughout the mission, such as the endurance of a hybrid ISR capability in a high/hot battlefield. This past year, the team completed the aerodynamic models for different vehicle types (e.g., fixed-wing, quadrotor) and mission requirements (e.g., cruise, hover, and axial flight) while at the same time developing a user interface for the vehicle and mission profile definition. On the electric motor drive side, a scalable efficiency model has been developed and validated at small scales, based on the power and torque requirement, with sizing capabilities in terms of volume and weight. Future plans include expanding experimental validation to larger vehicle scales of the independent models utilizing facilities both in ARL and TAMU.

Title: Oil-Free Bearing Analysis Tool

Modernization Priority: FVL/NGCV

ARL Researcher: Sangguk Kang

ARL Core Competency: Mechanical Sciences

Faculty POC: Adolfo Delgado

Summary of Research: Electrified compact lightweight turbomachinery is one of key components for the Army's UAS that requires ever-increasing power demand. The bearing systems to support the turbomachinery should not only be light and compact, but also able to function properly at altitudes, which needs design requirements quite different from those on the ground. Oil-less bearings such as foil and hybrid bearings are good candidates; however, it is difficult to find oil-less bearing design analysis tools that are specifically customized for the Army's needs.

Therefore, the focus of the ARL and TAMU research objective is to develop an oil-free bearing analysis tool that can be used to predict bearing performance and design, and to optimize bearing performance.

This past year, the team developed a preliminary oil-less bearing analysis tool framework with graphic user interface. The tool, Gas Lubricated Interactive Design Environment (GLIDE), can predict static and dynamic performances of foil and compliant hybrid bearings. It has a modular structure and thus it is straightforward to add or remove specific features. Currently, a thermal module is being developed to incorporate accurate predictive capability of the thermal response and performance of the oil-less bearing system. In addition, continuous efforts to validate and improve the analysis tool is ongoing.

Title: Tungsten Based Alloy Design, Processing, and Development

Modernization Priority: Soldier Lethality, Long Range Precision Fire

On-site Army Researchers: Brady Butler and James Paramore

ARL Core Competency: Science of Extreme Materials

DEVCOM Army Research Collaborators: Armaments Command (AC)

Industry Collaborator: Shear Form, Incorporated

Industry POCs: Ted Hartwig (Shear Form Incorporated) and Michael Demkowicz (Center for Research Excellence on Dynamically Deformed Solids [CREDDS])

Summary of Research: Development of new high-density refractory metal alloys through microstructure and process/alloy design strategies. The goal is to exploit novel properties and deformation mechanisms that are suitable for use in various kinetic energy (KE) munition technologies. Advanced deformation processes, developed by Shear Form, Incorporated (SFI) produce tungsten and tungsten alloys that show a strong potential for surpassing performance of medium and large-caliber penetrator technologies. Material process developments and advanced mechanical characterization is currently underway with AC's CREDDS. Additional collaborative efforts with AC have focused on improving reliability and performance in monolithic tungsten alloys.

Title: Hydrogen Assisted Processing of Ti-6Al-4V

Modernization Priorities: Soldier Lethality (SL), NGCV

On-site Army Researchers: James Paramore and Brady Butler

ARL Core Competency: Science of Extreme Materials

Faculty POC: Ankit Srivastava

Summary of Research: The ARL/TAMU team is currently optimizing the sintering process ARL developed with ARL's University of Utah partner to transform low-grade titanium into an alloy exhibiting properties equivalent to conventionally manufactured high-grade titanium alloys—without the need of expensive mechanical working of the alloy. Additionally, a heat treatment has been developed based on the sintering work, which can treat bulk titanium components and produce similar high-performance properties by healing defects and engineering the microstructure. The process enables shape and size retention, making it amenable for additive manufacturing (AM) and casting technologies. Titanium is a material of interest that could be used for replacement parts at the point of need; this process will be cost effective for point-of-need part production. The research is being combined with near-net-shaping and AM process technologies for prototyping titanium alloy components with exceptional mechanical properties. Three companies have made offers to license the technology. DEVCOM Ground Vehicle Systems Center (GVSC) is currently investigating this technology in conjunction with large-scale AM for incorporation in ground vehicle systems.

Title: Adaptive Material Behavior

Modernization Priority: FVL/NGCV

On-Site Army Researcher: Frank Gardea

ARL Core Competency: Mechanical Sciences

Faculty POC: Svetlana Sukhishvili (TAMU)

Summary of Research: Our advanced materials will contribute to a sophisticated vehicle system that will sense and adapt to current threats. We strive for on-demand tailoring of material properties and functionalities (e.g., self-healing, actuation) to achieve adaptive behavior in materials. We utilize advanced manufacturing methods, including AM, to obtain properties that are unobtainable using conventional manufacturing.

Title: Actuation of Responsive Polymers

Modernization Priority: NGCV

On-site Army Researchers: Frank Gardea

ARL Core Competencies: Mechanical Sciences

Faculty POC: Mohammad Naraghi (TAMU)

Summary of Research: This research is centered on developing soft actuators that will enable adaptive, reflexive mobility, once integrated into a robotic system. The goal is to introduce characteristics into polymeric materials that will more closely mimic the behavior observed in biological muscle. We investigate how actuation performance can be enhanced by the type of architecture, stimulus, and chemical structure used.

Title: Compact, High Performance Electric Machines Using Noncontact Backlash-Free Magnetic Gears

Modernization Priorities: FVL, Sustainability, NGCV

On-site Army Researcher: Matthew Johnson

ARL Core Competency: Energy Sciences/Mechanical Sciences

Other Government Agency Collaborator: NASA

Faculty POC: Hamid Toliyat

Summary of Research: Our goal in this partnership is to provide the power performance that our newly modernized Army technology will demand. This research focuses on the design of compact, high-performance, and high-reliability electric machines and magnetic gears for Army systems, including ground vehicles, hybrid-electric aircraft, and UAVs. We are working to reduce the size and weight of magnetic gears while enabling them to achieve higher gear ratios and operating

speeds without sacrificing high efficiencies. The noncontact operation offers numerous potential advantages over traditional mechanical gears, including inherent overload protection, reduced maintenance requirements, decreased acoustic noise, elimination of backlash, and physical isolation between the input and output shafts. Since the start of our collaboration, we have designed, fabricated, and tested a small-scale magnetic gear prototype with a gear ratio of 4.67:1, which achieved efficiencies of 99% or higher at some operating points. We have also designed and tested a two-stage cycloidal magnetic gear prototype with a 1000:1 gear ratio that was developed in conjunction with TAMU as part of their Phase I NASA Small Business Innovation Research (SBIR) project with an industry partner. In addition to designing and building prototypes, we are also developing a physics-based simulation infrastructure on TAMU's high-performance research computing resources, which enables rapid, cost-effective evaluation and optimization of numerous design concepts and design variations. TAMU research partners are currently working on the design, fabrication, and testing of a fault-tolerant multiphase electric motor used in conjunction with a magnetic gear to offer potential increased reliability benefits, as well as experimental characterization of a magnetic gear's acoustic noise signature.

Title: Multi-Scale Mechanics of Lung during Blunt Trauma: Alveolar Sacs to/from Parenchyma

Modernization Priority: Soldier Lethality

Army Researcher: John D Clayton

ARL Core Competency: Terminal Effects

University POC: Alan D Freed (ARL Joint Faculty Appointment)

Summary of Research: Soldiers are placed at risk of incurring Behind Armor Blunt Trauma (BABT) on a field of battle whenever their personal protective equipment (PPE) suffers a ballistic impact from a weapon or blast wave from an explosion. The objective of this project is to provide design engineers a realistic tool to produce the next generation of PPE for our Soldiers. We will develop material models that will be capable of describing soft-tissue responses under ballistic impact conditions. Our multiscale models will predict lung-tissue damage that affects breathing from tissue stiffness and internal bleeding.

2.6 Texas A&M Commerce: Emerging Hispanic-Serving Institution

Title: Embodied Cognition and Cognitive Control in the Lab and Real-World

Modernization Priority: Soldier Lethality

Army Researchers: Jonathan Bakdash (on-site, University of Texas [UT] Dallas) and Laura Marusich-Cooper (on-site, UT Arlington), and Kristin Schweitzer (on-site, UT at San Antonio [SA])

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Shulan Lu (Psychology and Special Education) and Derek Harter (Computer Science)

Summary of Research: We are conducting research on body posture and cognitive task performance in the lab and in the real-world using augmented reality (AR). This research effort has potential applications to adaptive systems in AR such as enhancing user performance using dynamic display of information depending on the user's body posture.

2.7 University of Alabama at Huntsville

Title: Situational Awareness and Decision-making Enhancements with Digital Eyewear

Modernization Priority: NGCV

On-site Army Researcher: Jeff Hansberger (on-site)

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Nathan Tenhundfeld (Professor, University of Alabama at Huntsville [UAH]) and Chao Peng (Professor, Rochester Institute of Technology)

Summary of Research: ARL is partnering with UAH on Project Vitreous to perform applied research on ways to enhance situation awareness and decision-making of NGCV crew members. Human–computer-interaction research with UAH focuses on three areas: information visualization, multimodal interface input, and virtual reality/augmented reality/mixed reality (VR/AR/MR) interfaces. Guided by task analysis, our research into information visualization explores new ways to visualize information and data to users in order to make decisions faster and easier. Multimodal-input approaches allow us to explore new ways to interact with digital information that integrates natural modalities including eye gaze, speech, and hand gestures. These

culminate in the development of virtual information dashboards and interfaces using digital eyewear technology (VR/AR/MR). NGCV role-specific visualizations and interfaces for digital eyewear are being developed for experimentation in collaboration with UAH and the GVSC.

2.8 University of Florida

Title: Collaborative Timing Estimation in GPS-denied Environments

Modernization Priority: Network

Florida Army Researcher: Eric Adler

ARL Core Competencies:

Faculty POC: David J Greene, Dr Tan F Wong, and D. John M. Shea

Summary of Research: The objective is collaborative timing estimation in GPS-denied environments using computer simulations as well as measurements to extrapolate the sounding signal bandwidth, clock accuracy, and other system requirements that are needed to support synchronization at different nodes in an ad hoc network.

2.9 University of North Texas: Hispanic-Serving Institution (HSI)

Title: Modulate Mechanical Properties under Applied Magnetic Fields

Modernization Priority: NGCV

DEVCOM Army Researcher: Heather Murdoch

ARL Core Competency: Science of Extreme Materials

Faculty POC: Rajiv Mishra

Summary of Research: This advanced materials research will result in greatly improved lightweight vehicle and Soldier protection with responsive capabilities not currently available. By determining how materials behave under applied magnetic fields, we can design processing techniques to produce materials with unique and desired properties that can counteract enemy assault, both physical and possibly energy-generated. We are focusing on the lightweight metals aluminum, magnesium, and titanium alloys. We are also examining a novel steel referred to as TRIP high-entropy alloy (HEA) steel. TRIP stands for transformation induced plasticity, which means that when subjected to certain stresses, it will change its

structure and volume, and thus change its strength and other mechanical properties. We have developed a robust testing frame incorporating variations in magnetic field strength to investigate tension, compression, and fatigue properties of strength. To date, we have observed strength changes under low magnetic fields in aluminum, magnesium, and titanium alloys. We use this frame for our magnetic processing model development to design and produce desired alloys for superior Army vehicle and Soldier armor.

Title: Tribological Materials for Low Viscosity Fuels

Modernization Priority: FVL/NGCV

ARL Researcher: Dr Stephen Berkebile

ARL Core Competency: Science of Extreme Materials

Faculty POC: Professor Diana Berman

Other Partners: University of Delaware, Northwestern University, Argonne National Laboratory

Summary of Research: ARL and UNT are collaborating on research of materials and coatings for mechanical interfaces lubricated with low-viscosity fuels. New materials and coatings that are robust under dynamic sliding and pressure conditions would provide reliable and sustainable operation of high-pressure fuel-injection components. The current boundary conditions for the material development are selected for intermittent combustion engines, specifically targeted for transition to the Future Tactical Unmanned Aircraft System (FTUAS) block upgrade. The challenge for the Army is that F-24 jet fuel does not provide the same lubricating properties as commercial heavy fuels, and other fuels such as synthetic jet and ethanol mixtures are even less lubricious. Therefore, the materials must be strong enough to sustain the harsh mechanical conditions or even provide their own lubrication. Our partners on this effort include University of Delaware, Argonne National Laboratory, coatings companies, and a manufacturer of high-pressure fuel components, and each brings a niche area of expertise to solve the material problem. UNT's niche contribution is understanding and improving the fuel-lubricating capability of high-performing industrial coatings, novel tribocatalytic coatings, and solid-lubricant surface modifications.

Title: Magnetic Freeze Casting of Ceramic Structures

Modernization Priority: NGCV

Army Researcher: Raymond Brennan

ARL Core Competency: Science of Extreme Materials

Faculty POCs: Marcus Young, Diana Berman, and Samir Aouadi

Summary of Research: We are pursuing an advanced ceramic material that will provide lightweight armor protection for vehicles. ARL is collaborating on a two-step task for generating porous ceramic structures via magnetic field-assisted freeze casting, followed by secondary phase/material infiltration to form dense bulk metal/ceramic matrix composites (MMCs) capable of sustaining high strain rates. Variables such as magnetic field orientation, magnetic strength, freeze-casting cooling rate, and magnetic particle type and size are being explored on aluminum/boron carbide MMCs. Mechanical testing coupled with microstructural imaging of porous, bulk, and composite structures demonstrated improved strength and toughness of materials created. Experimental results are being coupled with finite element analysis simulations to analyze the anisotropic effect of boron carbide channel alignment on mechanical properties.

2.10 The University of South Florida

Title: Additive Manufacturing Process to Form Active Phased Antenna Array

Modernization Priority: Network

Army Researcher: Eric Adler

ARL Core Competencies:

Faculty POC: Ruoke Liu, Jeremy Braun, Dr Gokhan Mumcu, and Dr Jing Wang

Summary of Research: The objective of this collaboration is to design and demonstrate an AM process for structural packaging a beamforming integrated circuit (BFIC) to form an active phased antenna array.

2.11 University of Texas at Arlington: Hispanic-Serving Institution (HSI)

Title: Human Dynamics of Cyber Security

Modernization Priority: Soldier Lethality

Army Researchers: Laura Marusich (onsite), Jonathan Bakdash (ARL South/UT Dallas), and Katherine Gamble Cox, Michael Geuss, and Erin Zaroukian (Aberdeen Proving Ground)

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Paul Paulus and Jared Kenworthy (Psychology), Gautam Das and Chengkai Li (Computer Science and Engineering), Kay-Yut Chen and Jingguo Wang (Information Systems and Operations Management)

Summary of Research: We are engaged in several lines of research focused on teaming and decision-making as well as building a credible open knowledge network. One line of research focuses on effective team formation and collaboration, particularly the influence of top performers on the performance of other team members. Another project takes a behavioral game theory perspective combined with agent-based modeling to explore human decision-making. The open knowledge network project is National Science Foundation (NSF)-funded (C-Accel pilot, primary investigator: Chengkai Li) and aims to build easy-to-use tools and technology for transparent access to large-scale real-world knowledge. This project has potential applications for intelligence analysis, particularly Open Source Intelligence. In other work, we are evaluating the magnitude and variability in the widely theorized relationships among situation awareness (i.e., knowing what is going on) and human decision-making. A recent remarkable finding of our research is that significant filtering impedes falsification and overestimates effects.

2.12 University of Texas at Austin

THE UNIVERSITY OF TEXAS AT AUSTIN

Title: Stacked Co-axial Rotor for Quieter Vertical Lift Air Vehicles

Modernization Priority: Future Vertical Lift

Army Researcher: Rajneesh Singh

Collaborators: Uber Elevate/UT Austin

ARL Core Competency: Weapons Sciences

Faculty POC: Jayant Sirohi

Summary of Research: ARL and UT Austin are investigating innovative rotor concepts to enable quieter operations of vertical lift and have a better flight-control capability. We are conducting experiments to measure aeromechanics performance and noise characteristics of the coaxial rotor to evaluate feasibility of using it for UAVs and manned air-taxi operations. Key findings from the last year have quantified the effects of various design parameters on the thrust magnitude, efficiency, and acoustics performance. ARL and UT Austin have jointly published papers to disseminate the research findings.

Title: Coordination in Multi-Agent Problem Spaces

Modernization Priorities: NGCV, FVL

On-site Army Researchers: Rolando Fernandez, Garret Warnell, Derik Asher, and Michael Dorothy

ARL Core Competencies: Mechanical Sciences and Military Information Sciences

Faculty POC: Peter Stone

Summary of Research: By studying and developing methods that can better control/impact coordination in multi-agent systems, future squads of artificial agents can be more effective and exhibit faster adaptation to new tasks, environments, and partners. ARL is partnering with UT Austin to perform basic research on coordination in multi-agent systems for a variety of simulated environments and ultimately applying the work to physical autonomous systems. Multiple methods of defining coordination relationships—static (defined at start of task) and dynamic (evolving throughout the task)—are being studied for the purpose of exploiting coordination in squads of agents, increasing the efficacy of learned autonomous behaviors, and increasing the speed at which the agents learn to accomplish a given mission.

Title: Synthetic Biology

Modernization Priority: Soldier Lethality

Army Researchers On-site: Randy Hughes, Randi Pullen

ARL Core Competency: Biological & Biotechnology Sciences

Faculty POCs: Andrew Ellington, Edward Marcotte, Ilya Finkelstein, Jeff Barrick, Bryan Davies, and Eric Anslyn

Summary of Research: ARL and our synthetic biology partners are collaborating to realize our vision to achieve next-generation materials, biological sensor platforms, and rapid-response biological countermeasures for Soldier protection. We have built a state-of-the-art biological foundry at UT Austin with synthesis and automation pipelines for facile engineering of biological systems and components. Building an advanced biomanufacturing capability will enable us to synthesize, assemble, and rapidly prototype a wide range of biological constructs that will be of utility across the Army and the Department of Defense. The Army biological foundry leads ARL's research efforts toward the development of molecular tools and chassis organisms. The multidomain capabilities we aim to achieve include

agile organism engineering, novel biomaterial development, advanced sense-and respond capabilities, bioremediation and reclamation of resources, and rapid-response biological countermeasures. Examples of intended outcomes are advanced optical materials, production of novel adaptive biomaterials, and synthetic circuits for metabolic regulation.

Title: Quantum Technology

Modernization Priority: Network/C3I

On-site Army Collaborator: Paul Kunz

ARL Core Competency: Photonics, Electronics, and Quantum Sciences

Faculty POCs: Daniel Heinzen and Elaine Li

Summary of Research: Quantum information science has potential applications in high-performance computing, quantum networks, and quantum-enhanced sensing. This project has the dual aim of advancing quantum sensing technology for precision wide-band electromagnetic field measurements and developing photonic tools for hybrid quantum networks all at room temperature. Quantum technologies and methodologies that do not require cryogenic cooling and can operate with low size, weight, and power parameters are crucial for bringing these capabilities out of the lab and into the field. Rydberg quantum sensors are pushing the state-of-the-art in field sensing, allowing greater electromagnetic situational awareness, yet there is still much room for improvement before fundamental sensitivity limits are reached. Ultimately, various quantum technology nodes will need to interface with each other to leverage different strengths of qubit platforms (atomic, photonic, ion, solid state, etc.). Our collaborative effort will make critical strides towards these goals.

Title: Human-in-the-Loop Autonomy

Modernization Priority: NGCV

On-site Army Researcher: Garrett Warnell

ARL Core Competencies: Mechanical Sciences and Military Information Sciences

Faculty POC: Peter Stone (Professor, UT Austin)

Summary of Research: By studying and developing methods that can more tightly integrate human operators into autonomous systems, future artificial agents can be more effective and exhibit faster adaptation to new environments. ARL is

partnering with UT Austin to perform basic research on human-in-the-loop autonomy for a variety of simulated (early-stage research) and physical (mid- to late-stage research) autonomous systems. Multiple modalities of human input—including passive (e.g., video) and explicit (e.g., teleop) demonstration and feedback—are being studied for the purposes of enhancing human control of robotic systems, increasing the efficacy of autonomous behaviors, and increasing the speed of autonomous-behavior acquisition. New methods for sharing control of platforms between humans and artificial agents in teleop-like control scenarios are being developed and validated, and new machine-learning algorithms that seek to allow non-expert humans to teach new behaviors to artificial agents are also being developed and validated. One project seeks to extend classical imitation learning methods such that future autonomous agents can learn new behaviors directly from video demonstrations (e.g., YouTube videos).

Title: Aerosol Deposition of Metal and Ceramic Powders

Modernization Priority: Long Range Precision Fires

On-site Army Researcher: Michael Gammage

ARL Core Competency: Science of Extreme Materials

Faculty POC: Desi Kovar

Summary of Research: We are developing a new technique to complement current AM electronics technologies. With this technique we can print electronics into structural parts and antennae on conformal surfaces to save space and weight. We will design these electronics to sustain the high g-forces of munitions launch and cannot be produced using traditional manufacturing processes.

Title: Performance-Resilience Tradeoffs on the Internet of Battlefield Things

Modernization Priority: Network

Army Researcher: Gunjan Verma

ARL Core Competency: NSCS

Faculty POC: Atlas Wang, UT Austin

Summary of Research: We are working on ML algorithms that flexibly optimize across accuracy, robustness, and performance objectives. Classical approaches typically focus on one of these at the exclusion of others or require a pre-specified and fixed weighted tradeoff among competing objectives. Traditionally, each of a set of different weightings is optimized separately, which compromises an

ensemble of models. This approach is expensive and does not scale well. Instead, our approach is to train a single model that inputs the desired tradeoff during run-time and flexibly adjusts its behavior accordingly to optimize in real-time for different target run-time objectives.

2.13 University of Texas at Dallas

Title: Collaborative Adaptive Augmented Reality Environment (CAARE)

Modernization Priority: Soldier Lethality and Network C3I

Army Researchers: Jonathan Bakdash (on-site), Laura Marusich-Cooper (on-site UT Arlington), Mark Dennison (ARL West), and Kristin Schweitzer (on-site University of Texas San Antonio [UTSA])

ARL Core Competency: Humans in Complex Systems, Military Information Science

Faculty POCs: Balakrishnan Prabhakaran (Computer Science)

Summary of Research: This research is to develop research software CAARE. CAARE provides capabilities for adaptive representations of complex virtual information in AR and is compatible with the ARL AURORA (Accelerated User Reasoning for Operations, Research, and Analysis) system to share information. We will use CAARE to evaluate tradeoffs in cognitive performance for different representation of information in AR.

2.14 University of Texas at El Paso (UTEP): Hispanic-Serving Institution (HSI)

Title: Autonomous Active Cybersecurity Defense

Modernization Priorities: Network/C3I, Sustainability

On-site Army Researcher: Jaime C Acosta

ARL Core Competency: Network and Computational Sciences

Faculty POC: Salamah Salamah

Summary of Research: ARL and UTEP are collaborating through several vehicles including coursework and leveraging NSF/Department of Homeland Security designated scholarship for service students as part of the ARL South Cybersecurity Rapid Innovation Group (CyberRIG), consisting of cybersecurity professionals, faculty, and students. The collaboration has yielded research, software, and

hardware infrastructures, and a rapid workflow that fuels technologies that enable rapid experimentation, data collection, and analysis for empirically based autonomous active cyber defense. This work is already being used to develop cybersecurity scenarios, data, and models for automated network analysis, communication, and defense in next-generation, heterogeneous, network configurations. Research-Focused Collaboration Activities include the following:

- Collaborative Curriculum Development – CS5389 (Software Engineering Practicum) Capstone Projects (semester cycle) for small- to medium-sized prototype development
- Collaborative Curriculum Development – CS5375 (Software Reverse Engineering) Project Development (yearly cycle) for binary and network analysis research
- Collaborative Curriculum Development – CS4177 (Software Vulnerabilities) Projects for training, grounding, and innovation
- Joint Hackathons, including the ARL South Cyber Hackathon and TracerFire with Sandia National Laboratories, FBI, and several other federal partners for innovative research and prototypes
- Joint innovation exercise workshops focused on autonomous defense with Infragard, FBI, and several other industry and federal partners for grounding, collaborative solicitation, and innovation

2.15 University of Texas at San Antonio: Hispanic-Serving Institution (HSI)

Title: Cyber Security for Tactical Autonomous Active Cyber Defense

Modernization Priority: Network

On-site Army Researchers: Ray Bateman, Marius Necsoiu, and Kristin Schweitzer

ARL Core Competencies: Network, Cyber, and Computational Sciences, Electromagnetic Spectrum Sciences, Humans in Complex Systems, and Military Information Sciences

Faculty POC: Oren Upton (UTSA Cyber Center for Security and Analytics)

Summary of Research: The research focus is on active and autonomous security for resource-constrained devices. Our project scope includes understanding

hardware architectures, non-destructive data extraction methods, exploitation of vulnerabilities, and development of embedded security and techniques to autonomously defend the devices.

Title: Artificial Intelligence and Machine Learning for Radio Frequency Sensing

Modernization Priorities: Air and Missile Defense, Network

On-site Army Researchers: Marius Necsoiu, Raymond Bateman, and Kristin Schweitzer

ARL Core Competencies: Electromagnetic Spectrum Sciences (EMSS), Network, Cyber, and Computational Sciences (NCCS), Humans in Complex Systems (HCxS), and Military Information Sciences (MIS)

Faculty POCs: David Akopian and Dhireesha Kudithipudi (UTSA College of Engineering)

Summary of Research: The research focus is on 1) new methods and new technical approaches based on artificial intelligence (AI)/ML to enable detection of complex RF emitters and modulation recognition in congested and contested electromagnetic spectrum; 2) methods to determine and evaluate the effectiveness of AI/ML in RF signal processing and sensing; 3) new labeling techniques and tools for developing high-quality training ML data sets, and 4) user interface and user experience that help automate tasks on adaptive and cognitive radars to maximize operator efficiency and support effective decision-making.

3. Conclusion

Collaboration with strategic partners is an essential component in the Army's strategy to maintain global cutting-edge technical dominance. Progress continues in our research areas at a quick pace in the ARL South region, and we will publish updates regularly.

List of Symbols, Abbreviations, and Acronyms

AC	Armaments Command
AEWE	Army Expeditionary Warrior Exchange
AI	artificial intelligence
AM	additive manufacturing
AR	augmented reality
ARL	Army Research Laboratory
BABT	Behind Armor Blunt Trauma
CAARE	Collaborative Adaptive Augmented Reality Environment
CRADA	cooperative research and development agreement
CREDDS	Center for Research Excellence on Dynamically Deformed Solids
DEVCOM	US Army Combat Capabilities Development Command
FBI	Federal Bureau of Investigation
FTUAS	Future Tactical Unmanned Aircraft System
FVL	Future Vertical Lift
GPS	global positioning system
GVSC	Ground Vehicle Systems Center
HSI	Hispanic-Serving Institution
ISR	intelligence, surveillance, and reconnaissance
ML	machine learning
MMC	metal/ceramic matrix composite
MR	mixed reality
NASA	National Aeronautics and Space Administration
NGCV	Next Generation Combat Vehicle
NSF	National Science Foundation
POC	point of contact
PPE	personal protective equipment

PTSD	Post-Traumatic Stress Disorder
RF	radio frequency
sUAS	small unmanned aerial system
TAMU	Texas A&M University
UAH	University of Alabama at Huntsville
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UNT	University of North Texas
UT	University of Texas
UTEP	University of Texas at El Paso
UTSA	University of Texas San Antonio
VR	virtual reality

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