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US Army Combat Capabilities Development Command Army Research Laboratory South Research Summaries: Collaborations (2020–2021 Update)

edited by Heidi Maupin

NOTICES

Disclaimers

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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) in the ARL South region. The ARL South research summarized in this report is integral to the DEVCOM ARL 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.

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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, Texas. “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.

This document highlights the collaborative research efforts resulting from partnerships in the ARL South region. Not included in this document are many other excellent university research efforts funded by the ARL directorates and the ARL Army Research Office.

2. ARL South Research Summaries

2.1 ARL - Army Medical Center of Excellence (MEDCoE)

Title: Collaboration and Study Management

Modernization Priority: Soldier Lethality

Army Researcher: Gary Boykin (on-site)

ARL Core Competency: Humans in Complex Systems

Directorate: Human Research and Engineering Directorate (HRED)

Summary of Research: The Army ARL - Medical Center of Excellence, Joint Base San Antonio introduces a three-tiered approach to managing research studies. Through interconnected collaborations across ARL, the field element centers on developing research studies, establishing command-level Soldier touch points, and executing data collection procedures that are specific to Soldier populations. These efforts impact the advancement of ARL research that is of interest to Army Futures Command, ARL, and MEDCoE. Since the inception of the field element's paradigm shift, studies focusing on situational awareness and target detection through human-artificial intelligence (AI) teaming and performance impacts of post-traumatic stress disorder (PTSD) exclusively with Soldiers and veterans are advancing with great success. The field element has also introduced a newly developed isolation chamber. The chamber is designed to minimize volunteer-to-researcher contact during prolonged data collection procedures. This capability has positively impacted Army efforts toward lessening the spread of COVID-19 during the global pandemic.

2.2 Bell Innovation

Title: Autonomous Micro Unmanned Air Systems, Soldier Lethality

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

Core Competency: Weapons Sciences

Army Research Lead: John Hrynuk

Directorate: Weapons and Materials Research Directorate (WMRD), Computational and Information Sciences Directorate (CISD)

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 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 autopopulating 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.

2.3 Rice University

Title: Dynamic Optical Control via Metasurface Integrated Soft Robotic Skins

Modernization Priority: Next Generation Combat Vehicle

ARL Core Competency: Science of Extreme Materials

Army Researcher: Mark Griep

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POCs: Naomi Halas, Stephan Link, Ben Cerjan

Summary of Research: The goal of this project has been to produce a flexible color-changing surface that could be used as a "skin" on a given object to act as camouflage or a "cloaking" tool. To be successful, we have to overcome the daunting task to determine complex quantum physics phenomena and then use this knowledge to develop scalable manufacturing capabilities. We are utilizing methodologies that Rice researchers have already successfully demonstrated—along with the expertise of University of New Mexico in design and fabrication of nanostructures and metasurfaces and the knowledge and ARL's significant manufacturing experience—to overcome the challenges we face. The color response of substances we create can be directly tuned through mechanical deformation. Thus, we will produce our desired results by placing our structures on stretchable material whose dimensions can be easily changed by stretching or releasing the material. This work has been funded through the Laboratory University Collaboration Initiative.

Title: Diamond Electronics

Army Modernization Priorities: Air and Missile Defense, Future Vertical Lift, Network/C3I

Army Research Priority: RF Electronic Materials

Army Researcher: Tony Ivanov

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competencies: Electromagnetic Spectrum Sciences, RF Technology

Faculty POC: Pulickel Ajayan

Summary of Research: Our team is developing the fundamental science to enable next-generation radio frequency (RF) semiconductor technology. The collaborative effort aims to demonstrate electronic grade diamond/boron nitride semiconductor substrates and heterostructures, paving the way for RF power transistors with increased RF power density, reduced strength, weight, and power, and radiation hard operation. Rice University provides a team of renowned scientists, with expertise in semiconductor material theory, growth, metrology, and characterization. The team has established on the Rice University campus a dedicated diamond synthesis research laboratory, with unique equipment and capabilities.

Title: Synthesis and Processing of High-Strength and High-Toughness 2-D Kevlar

Modernization Priority: Soldier Lethality

ARL Core Competency: Science of Extreme Materials

Army Researcher: Emil Sandoz-Rosado

Directorate: Weapons and Materials Research Directorate (WMRD)

Faculty POC: Rafael Verduzco

Summary of Research: In a cooperative program with University of Texas, Dallas (UTD) and Rice University that is ending, we have synthesized novel 2D polymer films with exceptional mechanical properties with the intent of exceeding the performance of commercial ballistic fibers. In conjunction with Rice University, we measured the first ever strength and fracture mechanics of 2D polymer films, and they exhibit remarkable properties including flaw-insensitivity. This material can potentially enable better multi-hit capability in armor applications. ARL has independently been able to synthesize and measure 2D polymer films with strength

50% and stiffness 100% greater than commercial Kevlar fibers. Ongoing cooperative programs with the Massachusetts Institute of Technology, Rochester Institute of Technology, and Northeastern University will focus on creating films with even higher mechanical properties for body armor applications and thermal properties for applications such as hypersonics, as well as processing for industrial scaling and transition.

Title: Molecular Nanomachines for Biohybrid Vehicles

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle

Army Researcher: Frank Gardea (on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Mechanical Sciences

Faculty POC: James Tour (Rice)

Summary of Research: Our successful research will enable future energy efficient Army vehicles. Mimicking behavior found in nature, we are focusing on using molecular nanomachines to activate biological cells and achieve controllable biological muscle actuation. By implanting the molecular-driven biological components into nonliving parts, we will achieve biohybrid vehicles with biological-like adaptive reflexive mobility.

Title: Seek and Treat UAV Technologies for Combat Casualty Care

Modernization Priority: Future Vertical Lift

Army Researcher: Thaddeus P Thomas

Directorate: Human Research and Engineering Directorate (HRED)

ARL Core Competency: Biological and Biotechnology Sciences

Faculty POC: Paul Cherukuri

Summary of Research: The goal for this effort is to make Robotic and Autonomous Systems (RAS) more intelligent and capable in the medical treatment of military personnel. We are incorporating novel imaging technologies that measure physiology at range onto unmanned mobile platforms to support the remote identification and triage of battlefield casualties. This capability would enhance the speed and effectiveness of medical evacuation/triage crews and improve the likelihood of patient survival. Biosensor advancement and assessment tasks are being conducted at Rice University, ARL, and the US Army Medical

Research Institute of Chemical Defense. The University of Pittsburgh contributes medical expertise and Carnegie Mellon University is building robotic interventions and researching means for providing virtual help.

Title: Autonomous Networking

Modernization Priority: Network/C3I

Army Researchers: Gunjan Verma (ARL/UT Austin) and Ananthram Swami

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competency: Network Science and Computational Sciences

Faculty POC: Santiago Segarra

Summary of Research: We are developing algorithms for machine-learning-driven resource allocation in wireless networks. Our goal is to find more efficient, better quality autonomous networking solutions for multiple applications.

2.4 Texas A&M University

Title: Spanwise Extending Unmanned Aerial Systems

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle

Army Researcher: Francis Phillips (on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

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 in order to go fast and be more maneuverable, but for loiter segments, long wings are desirable in order to enable low-power, high-endurance flight. Still in its early stages, success of 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: Future Vertical Lift Army/Next Generation Combat Vehicle

ARL Researcher: Dino Mitsingas

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competency: Mechanical Sciences/Energy Sciences

Faculty POC: Moble Benedict

Summary of Research: DEVCOM ARL and Texas A&M University (TAMU) are developing computer models with prediction capabilities of the propulsion power needs of systems throughout their operational conditions. In particular, the models will be capable of analyzing hybrid-electric land, sea, and air vehicles that have become available due to the confluence of high power/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 will 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 endurance of a hybrid ISR capability in a high/hot battlefield. This past year, the team has been developing the appropriate rotor aerodynamic capabilities, having completed hover and working on axial flight. On the electric motor drive side, an efficiency model has been developed based on the power and torque requirements, and the team is currently working on adding sizing capabilities in terms of volume and weight. Future plans include experimental validation of the independent models utilizing facilities both in ARL and TAMU.

Title: Oil-Free Bearing Analysis Tool

Modernization Priority: Future Vertical Lift Army/Next Generation Combat Vehicle

ARL Researcher: Ryan McGowan

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Mechanical Sciences

Faculty POC: Adolfo Delgado

Summary of Research: The focus of the ARL/TAMU's research objective is to develop an oil-free bearing analysis tool that can be used to optimize bearing performance and design, and to predict bearing performance. Electrified turbomachinery would provide 1) increased boosting capability (i.e., higher power density at high altitudes), 2) improved survivability during descent (i.e., fast landing), and 3) increased onboard power generation using waste energy (i.e., increased range and endurance due to improved system efficiency). One of the major technical challenges is how to design the electrified turbomachinery compact and light. The team is designing a lightweight oil-free bearing that will be used for motor/generator or generator. This technical challenge is complex, multidisciplinary and includes multiple academia and industry partners such as University of Wisconsin-Madison, General Electric Global Research Center, and potentially Roush and Borg Warner.

Title: Advanced Gas Bearings for Compact High-Speed Turbocharger

Modernization Priority: Future Vertical Lift/Next Generation Combat Vehicle

Army Researcher: Ryan McGowan

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Mechanical Sciences

Faculty POCs: Luis San Andres and Adolfo Delgado

Summary of Research: ARL and TAMU are collaborating on high-pressure compact turbochargers (TCs) to support ARL's multifuel-capable hybrid-electric propulsion program. Our success in achieving oil-free TCs will reduce weight and friction, extend maintenance intervals, and certify reliability and availability. The project aims to advance innovative gas bearing technologies enabling oil-free TCs for ultra-efficient internal combustion engines (ICEs) in unmanned aerial vehicles

(UAVs). These oil-free TCs will improve the reliability, efficiency, and performance of ICEs for operation at increased power with more compact units free of mineral oil and other ancillary systems.

Title: Tube Launched Attritable Unmanned Aerial Systems

Modernization Priority: Future Vertical Lift

Army Researcher: Hao Kang

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Weapon Sciences

Faculty POC: Moble Benedict

Summary of Research: The goal of this project is to extend the overall range of operation of a hover-capable, micro air vehicle (MAV) by launching it from a 40-mm grenade launcher. In addition, this method could be used to propel the vehicle beyond line of sight or around other obstacles. The development of such aircraft requires the vehicle to be compact, maneuverable, and capable of transitioning from a projectile phase to hovering flight. ARL and TAMU research collaborators have reached substantial milestones of our tube-launched unmanned aerial system (UAS). We successfully developed novel and configurable rotary wing aircraft capable of sustained hover. The aircraft can be launched from air or ground using a launch tube. This method of deployment will allow the vehicle to reserve the entirety of the onboard battery for performing a desired mission such as ISR in a designated target area. The team designed the aircraft with a specialized counter rotating motor composed of two independently controlled motors. At the end of the launch phase, the rotor blades can be unfolded passively by using centrifugal force from spinning up. The aircraft will provide two assets at the company level. When launched from a 40-mm grenade launcher, the aircraft provides an organic asset at the company level with combined ISR. When launched as a projectile up to the point of operation, the aircraft can significantly improve the mission range for energy-constrained platforms. The aircraft can provide the Army with a vertical flight/hover capability that operates as a member of a team with other manned and unmanned platforms that can penetrate defense-in-depth, anti-access, and area-denial environments and disintegrate Integrated Air Defense Systems.

Title: Human-in-the-Loop Autonomy

Modernization Priority: Future Vertical Lift, Next Generation Combat Vehicle

Army Researchers: Vernon Lawhern, Nicholas Waytowich, and Greg Gremillion

Directorate: Human Research and Engineering Directorate (HRED)

ARL Core Competency: Humans in Complex Systems

Faculty POC: John Valasek

Summary of Research: The ARL/TAMU collaboration team is developing human-in-the-loop machine learning for autonomy with specific applications in real and simulated aerial platforms. By more tightly integrating a human operator into the learning process, autonomous agents learn faster and the learned behaviors can become tailored to the specific needs of the Warfighter.

Title: Tungsten Based Alloy Design, Processing, and Development

Modernization Priority: Soldier Lethality, Long Range Precision Fire

Army Researchers: Brady Butler and James Paramore (both on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Army Research Collaborators: ARL/DEVCOM Armaments Center

Industry Collaborator: Shear Form, Incorporated

Industry POCs: Ted Hartwig (Shear Form Incorporated) and Michael Demkowicz (CREDDS)

Summary of Research: The team is developing 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 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 DEVCOM Armaments Center's Center for Research Excellence on Dynamically Deformed Solids (CREDDS). Additional collaborative efforts with the Armaments Center have focused on improving reliability and performance in monolithic tungsten alloys.

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

Modernization Priorities: Soldier Lethality, Next Generation Combat Vehicle

Army Researchers: James Paramore and Brady Butler (both on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Ankit Srivastava

Summary of Research: The ARL/TAMU team is currently optimizing the sintering process they developed with their University of Utah partner to transform low-grade titanium to 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: Future Vertical Lift, Next Generation Combat Vehicle

Army Researcher: Frank Gardea (on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

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 and actuation) to achieve adaptive behavior in materials. We utilize advanced manufacturing methods, including additive manufacturing, to obtain properties that are unobtainable using conventional manufacturing.

Title: Fermented Vegetation for Efficiently Running Artificial Muscle

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: David Mackie and Frank Gardea (on-site)

Directorate: Sensors and Electron Devices Directorate (SEDD), Weapons and Materials Research Directorate (WMRD)

ARL Core Competencies: Mechanical Sciences

Faculty POC: Mohammad Naraghi (TAMU), Ray Baughman (UTD)

Summary of Research: Our desired outcome is to power artificial muscles using direct conversion of energetic chemicals. This capability will contribute to our overarching goal of an efficiently powered autonomous robotic mule. To date, we have demonstrated chemically powered artificial muscles with excellent performance. Our challenge is to scale up the size by several orders of magnitude in order to achieve chemically powered artificial muscles suitable for the legs of robotic mules. We have shown that fuel cells can work in an alternating current (AC) mode, and AC fuel cells will be fast enough for our applications. We have shown that we can make affordable chemically powered artificial muscles that are scalable and work well, with speed being the key challenge left to overcome.

Title: Compact, High Performance Electric Machines Using Magnetic Gears

Modernization Priorities: Future Vertical Lift, Sustainability, Next Generation Combat Vehicle

Army Researcher: Matthew Johnson (on-site)

Directorate: Sensors and Electron Devices Directorate (SEDD)

ARL Core Competency: Mechanical Sciences/Energy Sciences

Other Government Agency Collaborator: NASA

Faculty POC: Hamid Toliyat

Summary of Research: Our ultimate 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 platform drivetrains, including hybrid-electric aircraft and UAVs. We will 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, 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 Texas A&M as part of their Phase I NASA Small Business Innovation Research (SBIR) project with an industry partner. This particular magnetic gear prototype offers tremendous potential to achieve extremely high gear ratios in relatively lightweight, compact packages. 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. One of our next steps is to design, fabricate, and test a fault-tolerant multiphase electric motor used in conjunction with the magnetic gear to offer potential increased reliability benefits. Based on the lessons learned from the discrete combination of the multiphase electric motor and the magnetic gear, we will design, build, and evaluate an integrated magnetic gear and multiphase electric motor, which offers the potential for a smaller and lighter package for interfacing with high torque loads, as compared with the discrete combination of an electric motor and magnetic gear.

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

Modernization Priority: Soldier Lethality

Army Researcher: John D Clayton

Directorate: Weapons and Materials Research Directorate (WMRD)

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.

2.5 Texas A&M Commerce

Title: Human Understanding of Complex Visualizations Using Virtual Reality

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: Jonathan Bakdash (On-site, UTD), Laura Marusich-Cooper (On-site, UT Arlington), and Michael Geuss and Shannon Moore (HRED)

Directorate: Human Research and Engineering Directorate (HRED)

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 collaborative behavioral research on human understanding of complex visualizations using immersive virtual reality. Human understanding is quantified using the time and accuracy for drawing inferences about relationships and patterns among variables in graphs. We aim to predict and enhance human understanding of complex and uncertain information by investigating underlying perceptual factors that influence the utility of different visualization techniques.

2.6 Texas Tech University: Hispanic-Serving Institution (HSI)

Title: Wireless Power Transfer for Unmanned Aerial Vehicles

Modernization Priority: Future Vertical Lift

Army Researcher: Argenis Bilbao (on-site)

Directorate: Sensors and Electron Devices Directorate (SEDD)

ARL Core Competency: Energy Sciences

Faculty POC: Stephen Bayne

Summary of Research: We are performing research on wireless power transfer to efficiently recharge UAVs. Wireless power transfer is the ideal and primary candidate to recharge battery powered UAVs due to the increased reliability, convenience, and reduced logistics burden that it provides over recharging through wires using metallic contacts. In August 2019, we successfully demonstrated wireless power transfer to a small UAV. In our demonstration, the UAV autonomously landed on a designated landing platform to wirelessly recharge its battery. Our next milestone is to successfully transfer power while both the UAV and the manned or unmanned land vehicle with the charging device are in motion. Our successful technology is first of its kind, relying on inductive-resonant wireless power transfer method that features "Maximum Power Point Tracking" to achieve higher recharge rates and/or increased efficiency under nonideal conditions.

2.7 University of Alabama, Huntsville

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

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Jeff Hansberger (on-site)

Directorate: Human Research and Engineering Directorate (HRED)

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Nathan Tenhundfeld (Professor, University of Alabama in Huntsville) and Chao Peng (Professor, Rochester Institute of Technology)

Summary of Research: ARL is partnering with the University of Alabama in Huntsville (UAH) on project Vitreous to perform applied research on ways to enhance situation awareness and decision-making of Next Generation Combat Vehicle (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 Ground Vehicle Systems Center.

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

Title: Design of Novel Metals, Ceramics, and Additively Manufactured Structures for Protection Applications

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: Jeff Lloyd, Chris Cummins, Tom Scharf (ARL Joint Faculty Appointment on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Rajiv Mishra

Summary of Research: Quad City Manufacturing, ARL, and University of North Texas (UNT) researchers have demonstrated that small-scale prototypes produced using AM techniques are representative of the full-scale vehicle structure. Using our validated results reduce assessment time from years to weeks and rapidly provide new solutions for blast-resistant structures and reduce research and development costs by 98%. Over the last 4 years, more than 40 West Point cadets and Naval Academy midshipmen have used computational tools and scaled experimentation to design blast-mitigating structures as part of a senior design competition. In this program we are also producing novel materials (e.g., high entropy alloys and composite ceramics) having lighter and/or ultrahigh toughness to enhance personnel and vehicle protection. In addition to our materials research, we are using additive manufacturing to design new structural concepts to defeat existing and emergent kinetic energy threats.

Title: Modulate Mechanical Properties under Applied Magnetic Fields

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Heather Murdoch

Directorate: Weapons and Materials Research Directorate (WMRD)

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 are able to 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: Future Vertical Lift Army/Next Generation Combat Vehicle

ARL Researcher: Stephen Berkebile

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Diana Berman

Other Partners: University of Delaware, Argonne National Laboratory

Summary of Research: DEVCOM 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 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: Combustion Coating Material Technologies

Modernization Priority: Future Vertical Lift/Next Generation Combat Vehicle

Army Researcher: Jon-Erik Mogonye

Directorate: Vehicle Technology Directorate (VTD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Samir Aouadi

Summary of Research: Internal combustion engineers that operate on heavy fuels at high-altitude conditions, such as those experienced by UAVs, experience thermomechanical stress states that differ drastically from ground vehicle applications and cause premature material failure. These failures primarily occur in current coating materials applied to combustion-chamber alloys and can lead to higher sensitivity to fuel properties, reduced power and mission capability, and loss of the asset. Our project is focused on understanding the current material-failure mechanisms and evaluating new coating materials and processing methods to improve material performance. Primarily, the material failures of greatest concern have been located at the interface between coating and engine alloy. The collaborators will jointly develop an experimental schedule to evaluate new materials and coating technologies that improve the adhesive strength through diffusional and mechanical methods and optimize their processing conditions to achieve the multiple material requirements of the dynamic combustion-chamber interface.

This collaboration project has been concluded based on program alignments.

Title: Magnetic Freeze Casting of Ceramic Structures

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Raymond Brennan

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

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

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 is underway on porous, bulk, and composite structures.

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

Title: Human Dynamics of Cyber Security

Modernization Priority: Soldier Lethality

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

Directorate: Human Research and Engineering Directorate (HRED)

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, Principal 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 significant finding of our research that significant filtering impedes falsification and overestimates effects.

2.10 University of Texas at Austin

Title: ARL/UT Austin/Uber Elevate 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

Directorate: Vehicle Technology Directorate (VTD)

ARL Core Competency: Weapons Sciences

Faculty POC: Jayant Sirohi

Summary of Research: ARL and University of Texas (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 lessons from the last year's collaborative experimental and analytical efforts have led to improvement in the methods for modeling of aerodynamic interactions between the rotor blades. This knowledge has been transitioned into the computational rotorcraft-aeromechanics analysis software, Rotorcraft Comprehensive Analysis System, used by the vertical-flight S&T community, and is being used to support the Future Vertical Lift's Future Attack and Reconnaissance (FARA). Acoustics evaluation of the stacked rotor is underway. Uber funded part of the effort by UT Austin in support of the ARL/Uber CRADA. This past year, Uber Elevate was purchased by another company and is assessing whether to continue this partnership through a new CRADA with ARL.

Title: Human-in-the-Loop Autonomy

Modernization Priority: Next Generation Combat Vehicle

Army Researchers: Garrett Warnell (on-site)

Directorate: Computational and Information Sciences Directorate (CISD)

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 nonexpert 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: Pareto Optimal Streaming Unsupervised Classification for Human–Autonomy Interaction for Intelligent Squad Weapons (HAI2SW)

Modernization Priorities: Soldier Lethality

Army Researcher: Brent Lance and Steven Gutstein

Directorate: Human Research and Engineering Directorate (HRED)

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Sanjay Shakkotai

Summary of Research: We will improve the way neural nets are prepared for transfer learning. We are studying the influence of source task training upon a net's ability to learn an arbitrary target task. By applying this knowledge, we will provide Soldiers with neural nets that are better suited to learn novel tasks discovered in the field.

Title: Synthetic Biology

Modernization Priority: Soldier Lethality

Army Researchers: Jimmy Gollihar, Randy Hughes, Daniel Boutz, Raghav Schroff, and Thomas Segall-Shapiro (all on-site)

ARL Core Competency: Biological and Biotechnology Sciences

Faculty POCs: Andrew Ellington, Edward Marcotte, Ilya Finkelstein, Jason McLellan, Jeff Barrick, George Georgiou, and Bryan Davies

Summary of Research: During the COVID-19 pandemic, the ARL synthetic biology team, including those at UT Austin, along with our partnering universities, government agencies, and industry, collaboratively developed technology to produce effective antibody treatment for the disease. 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. By building an advanced biomanufacturing capability, we are able 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, 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: Large-Scale Multiphysics Modeling and Simulation for Advanced Electronic and Electromechanical Systems

Modernization Priority: Next Generation Combat Vehicle

Army Collaborator: Bruce Geil

Directorate: Sensors and Electron Devices Directorate (SEDD)

ARL Core Competency: Energy Sciences

Faculty POCs: Shannon Strank (Joint Faculty Appointment), Vaibhav Bahadur, and Hamid Ouroua

Summary of Research: Technological advancements discovered through this collaborative project will revolutionize power capabilities. The final electronics package will include advanced materials robust enough to withstand extreme conditions, including electrical frequencies, and thermal and mechanical cycles. Critical to our success is a multiphysics model that will predict behavior of the designed package and will be used to evaluate innovative material selection for the power package. We will maximize performance gains garnered by emerging dielectric materials, new packaging techniques (including 3-D printing), and various power packaging applications.

Title: Aerosol Deposition of Metal and Ceramic Powders

Modernization Priority: Long Range Precision Fires

Army Researcher: Michael Gammage (on-site)

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Desi Kovar

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

Title: Aluminum-Based Nanogalvanic Powder Materials for Hydrogen Fuel

Modernization Priority: Next Generation Combat Vehicle

Army Researcher: Anit Giri

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Michael Lewis

Summary of Research: Our low-cost nanogalvanic aluminum alloys (US patent publication #20190024216A1/January 24, 2019) promise to deliver a safe and reliable mechanism for storing and provisioning hydrogen to a fuel-cell power system. This type of solution can be helpful in multiple mission scenarios where power is scarce. The powder has been shown to react with even the smallest amount of liquid that contains water to form hydrogen. The first case will consider cannibalizing a part of the vehicle/drone for immediate limp-home power. The second case will consider strategic power plants fueled by this powder dropped near any body of water for refueling of drones.

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

Modernization Priority: Network

Army Researcher: Gunjan Verma

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competency: Network Science and Computational Sciences

Faculty POC: Atlas Wang, UT-Austin

Summary of Research: We are working on machine learning algorithms which flexibly optimize across accuracy, robustness, and performance objectives. Classical approaches typically focus on one of these at the exclusion of others, or require a prespecified and fixed weighted tradeoff among competing objectives. Traditionally, each of a set of different weightings is optimized separately, comprising an ensemble of models. This approach is expensive and does not scale well. Our idea instead 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.

2.11 University of Texas at Dallas

Title: Adversarial Machine Learning

Modernization Priority: Cyber Security/Army Network (Network Command, Control, Communications and Intelligence).

Army Researchers: Jonathan Bakdash (on-site), Laura Marusich-Cooper (at UT Arlington)

Directorate: Human Research and Engineering Directorate (HRED)

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Murat Kantarcioglu and Yan Zhao (Computer Science), Yulia Gel (Mathematical Sciences), and Daniel Krawczyk (Brain and Behavioral Sciences)

Summary of Research: We are investigating the use of artificial intelligence (AI) for human decision-making. Specifically, we will determine if and when eXplainable AI (XAI) can improve, or even impair, human decision-making. We will also examine representing uncertainty in XAI and conditions when adversarial attacks on XAI may deceive human decision-makers. In addition, we are conducting research to augment detection of deception using multiple approaches, which include AI detection of deception and time-limited presentation of deceptive materials in behavioral experiments (paradoxically, detection of deception for people may be better with less information). In other research, we are evaluating the widely theorized relationships among situation awareness and decision-making.

Title: Mechanically Robust, Hydrogen Bond Stabilized Covalent Organic Frameworks

Modernization Priority: Soldier Lethality

Army Researcher: Robert Lambeth

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Ronald Smaldone

University Partners: Rice University and Massachusetts Institute of Technology (MIT)

Summary of Research: To achieve materials with unsurpassed properties, we are preparing new 2-D covalent organic frameworks (COFs) with hydrogen bonding between 2-D layers to improve properties. Initial work focuses on chemistry and characterization to produce COFs with a high degree of regular order. Later work will focus on the mechanical properties of ideal COF chemistries. To date, we have been able to synthesize layers of 2-D material that interact strongly with each other, which we expect will result in superior mechanical properties. These materials are currently being characterized by ARL for mechanical evaluation. In our collaboration, in addition to characterizing material properties, ARL provides computational design to UTD, which synthesizes the materials. This effort is also being supported by additional collaborations between ARL and scientists at Rice and MIT.

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

Title: Autonomous Active Cybersecurity Defense

Modernization Priorities: Network/C3I, Sustainability

Army Researcher: Jaime C Acosta (on-site)

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competency: Network Science and Computational Sciences

Faculty POC: Salamah Salamah

Summary of Research: ARL and University of Texas at El Paso (UTEP) are collaborating through several vehicles including coursework and leveraging National Science Foundation/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 fuel 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, 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

Title: Rapid Acceleration of Additive Manufacturing

Modernization Priority: Long Range Precision Fires

Army Researchers: Brandon McWilliams and Jian Yu

Directorate: Weapons and Materials Research Directorate (WMRD)

ARL Core Competency: Science of Extreme Materials

Faculty POC: Raymond Rumpf and Francisco Medina

Summary of Research: Our research will accelerate and advance manufacturing readiness of metal and hybrid electronic additive manufacturing (AM) technology. Through our partnership, we have designed and prototyped a ceramic Luneburg Lens for extreme high-temperature application, which can only be made by AM. Luneburg Lens is a high-gain radio antenna that can be used with several feeds looking in different directions without moving the antenna. Also, its aperture blockage is minimal comparing to conventional parabolic antenna. ARL and UTEP, working in joint collaboration with Lockheed Martin Missiles and Fire Control, have successfully produced the first ever bronze-infiltrated binder-jet-printed tungsten heavy alloy for fragmenting munition applications. UTEP is at the leading edge when it comes to metal printing and multimaterial prints for electronic applications. In addition to UTEP's well-equipped manufacturing facility, we rely on its modeling and design expertise to develop tools to print 3-D electronics. ARL's contribution to our partnership is our characterization expertise and facilities capable of optimizing performance of the new designs. We focus on rapid development of AM alloys, new AM strategies for printing refractory alloys using binder jet and electron beam melting (EBM) powder bed fusion technology, AM process qualification and verification, and development of augmented and virtual reality applications for in-field training aids for AM.

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

Title: Modeling, Analyzing and Predicting Cyber Attacks

Modernization Priority: Network/C3I Army

Army Researchers: Ray Bateman (CISD) and Kristin Schweitzer (HRED)

Directorate: Computational and Information Sciences Directorate (CISD)

ARL Core Competency: Network Science and Computational Sciences

Faculty POC: Shouhuai Xu (formerly UTSA, currently University of Colorado – Colorado Springs (UCCS) Computer Science Department)

Summary of Research: We have been collaborating with Professor Shouhuai Xu and his PhD students in pursuing two thrusts of research. One thrust is to understand, characterize, and defend against cyberattacks that exploit COVID-19 as a means, dubbed "COVID-19 themed cyber-attacks." The other ongoing research thrust is to investigate how to automate cyber defense. In order to sustain the collaboration, we plan to create an ARL-UCCS CRADA.

Title: Human-Machine Performance in Mixed Reality on Edge Cloud

Modernization Priority: Next Generation Combat Vehicles

Army Researchers: Kristin Schweitzer (HRED) and Ray Bateman (CISD)

Directorate: Human Research and Engineering Directorate (HRED)

ARL Core Competency: Humans in Complex Systems

Faculty POCs: Paul Rad (UTSA Open Cloud Institute) and John Quarles (UTSA Computer Science Department)

Summary of Research: The research focus is on scalable augmented reality and virtual reality (VR) use within virtual machines on an edge cloud architecture. ARL, University of Texas at San Antonio (UTSA), and other government researchers are contributing expertise and resources to build a collaborative multi-user VR environment. The setup allows researchers to automatically collect human and machine performance data in an ELK Stack, and it enables visualization of near real-time analytics on an interactive dashboard within the VR environment.

3. Conclusion

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

List of Symbols, Abbreviations, and Acronyms

2-D	2-dimensional
3-D	3-dimensional
AC	Armaments Center
AEWE	Army Expeditionary Warrior Exchange
AI	artificial intelligence
AM	additive manufacturing
AR	augmented reality
ARL	Army Research Laboratory
BABT	Behind Armor Blunt Trauma
CISD	Computational and Information Sciences Directorate
COF	covalent organic framework
CRADA	cooperative research and development agreement
CREDDS	Center for Research Excellence on Dynamically Deformed Solids
CyberRIG	cybersecurity rapid innovation group
DEVCOM	US Army Combat Capabilities Development Command
EBM	electron beam melting
FARA	Future Attack and Reconnaissance
FBI	Federal Bureau of Investigation
FTUAS	Future Tactical Unmanned Aircraft System
GVSC	Ground Vehicle Systems Center
HEA	high entropy alloy
HRED	Human Research and Engineering Directorate
ICE	internal combustion engine
ISR	intelligence, surveillance, and reconnaissance
MAV	micro air vehicle

MEDCoE	Army Medical Center of Excellence
MIT	Massachusetts Institute of Technology
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
RAS	Robotic and Autonomous Systems
SBIR	Small Business Innovation Research
SEDD	Sensors and Electron Devices Directorate
SFI	Shear Form, Incorporated
sUAS	small unmanned aerial system
TAMU	Texas A&M University
TC	turbocharger
TRIP	transformation induced plasticity
UAH	University of Alabama, Huntsville
UAS	unmanned aerial system
UAV	unmanned aerial vehicle
UCCS	University of Colorado – Colorado Springs
UNT	University of North Texas
UT	University of Texas
UTD	University Texas, Dallas
UTEP	University of Texas at El Paso
UTSA	University of Texas at San Antonio

VR	virtual reality
VTD	Vehicle Technology Directorate
WMRD	Weapons and Materials Research Directorate
XAI	eXplainable artificial intelligence

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