AFRL FIGHT'S ON!

THE AIR FORCE RESEARCH LABORATORY

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711 HPW / RHW

WARFIGHTER INTERACTIONS AND READINESS DIVISION

U.S. AIR FORCE

RHW

WARFIGHTER INTERACTIONS AND READINESS DIVISION

The United States Air Force stands at the forefront of progress, and ongoing initiatives reveal the promising tomorrow that can - and will - be earned. The Air Force Research Laboratory (AFRL) improves the preparation and execution needed for successful military operations through the Warfighter Interactions & Readiness Division (RHW). The Division is committed to establishing and securing the Warfighter's legacy of success and future efficiency by working with other Divisions and researchers to produce findings and training that improve the cognition and mental fortitude of our Airmen and Guardians. RHW's focus on bleeding edge research for modern and future warfighters is turning decision superiority into air superiority. Through the combined efforts of the RHW, the USAF will continue to grow into a single, united force that unwaveringly pursues and overcomes any and every challenge confronted: *One AFRL - One Fight.*

U.S. Air Force photo by Senior Airman Erica Webster

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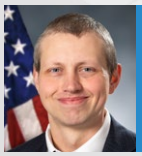

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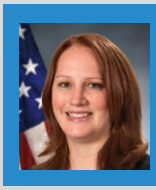

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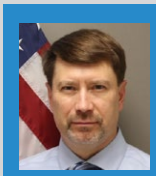

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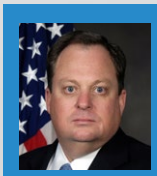

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Maj Chris Stephen (DO)

BC = BRANCH CHIEF | DO = DIRECTOR OF OPERATIONS

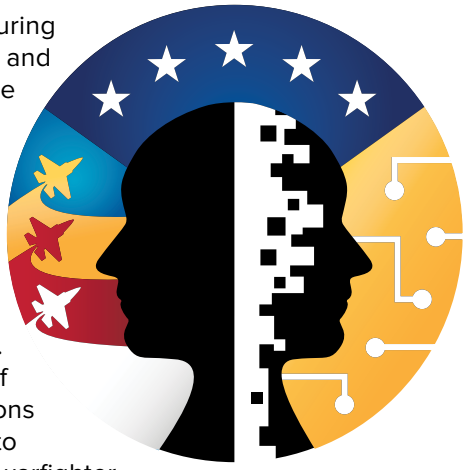
NOVEMBER 2024

Mr. Dean Berry
Division Chief, 711 HPW/RHW

> **"We are enabling a more informed, agile, and lethal force by delivering revolutionary capabilities and enhancing preparation and mission execution across the full range of military operations."**
>
> **— Mr. Dean Berry**
> Division Chief, 711 HPW/RHW

RHW
DIVISION INTRODUCTIONS

It has been another amazing year! I am excited to be the new Chief of the extremely talented team that comprises the Warfighter Interactions & Readiness Division, RHW. RHW is at the tip of the spear for addressing all aspects of Human-Human, Human-Machine, and Machine-Machine Integration and Decision and Information Supremacy. This past year our team supported multiple exercises, organized and presented at conferences, conducted studies, developed software, hit multiple scientific and technical transition milestones, and demoed novel capabilities to the warfighter. Congrats to the entire RHW Team!



RHW directly impacts RH's enduring mission of enabling, sustaining, and enhancing multi-domain capable warfighters and integrated operations. We are enabling a more informed, agile, and lethal force by delivering revolutionary capabilities and enhancing preparation and mission execution across the full range of military operations. RHW will continue our history of collaboration across organizations and building new touch points to expand our contribution to the warfighter. In addition, RHW is leveraging the synergies that exist within our diverse organization. As the Air Force and Department of Defense (DoD) move forward, Joint All Domain Ops and the demand for autonomy technologies bring the need for warfighters to be adaptable, efficiently trained, given decision-quality information, and have technologies that augment their abilities. There are common threads across training and operations; RHW's expertise and capabilities will address those connective tissues. I look forward to sharing future Warfighter Interactions and Readiness Division successes with you! ☆

Mr. Dean Berry, Division Chief, 711 HPW/RHW

Photo by Mr. Will Graver (BAE Systems, Inc)

Col(s) Michael D. Zollars, Ph.D.

Deputy Division Chief, 711 HPW/RHW

Much of my career has been in academia, but as I begin my position as the Deputy Chief, I cannot help but compare the two fields. Although the academic mission is defense focused, the influence on the warfighter is often lost as the work being conducted is predominantly 6.1 level research, many years from transition. In contrast, after just a few months in RHW, it has been astounding to see the technology development and impact the division is having on the warfighter today!

As a Professor, I learned to convey technology using different methods to reach the learning styles of my students. These consist of a strategic combination of classroom lecture, short review exercises, homework assignments, graphical analysis, coding, and one-on-one mentoring. Understanding how to creatively combine those learning styles for the greatest impact to the students is essential. Applying this methodology to RHW, it quickly becomes apparent how it is being utilized in Human-Machine Teaming and training through modification of displays, expanding sensory cues, and the connectivity of multiple simulation environments. The underlying theory and application of multiple methods for how we train and how to impact learning extends up and down the decision chain as well as across all domains, both for academia and tech application.

In academia, you discover that focusing on just one of the learning styles quickly leads to saturation, or boredom, of the student. Briefing a Power Point slide for 50 minutes with a monotone voice does not create the excitement for success, and often leads to the student losing interest after just a short period of time. Understanding those limits and how to keep students engaged is key to proficient learning. As I look around RHW, task saturation of the pilot is found in several of our research threads. The work this organization does in the development of the cognitive model and how to effectively handle not just a large amount of information, but the right information is instrumental for ACP, JADC2, and the tactical deployment of our assets. Further, understanding how the pilot learns and ingests information from the machine in order to streamline the battlespace is the foundation for decision superiority.

Finally, the implications of exogenous inputs cannot be ignored. We must understand how to be effective within the parameters of the environment we are in, that is, understanding how to deal with effects that we cannot control. In my experience, these inputs are those that affect the control of an unmanned aircraft such as wind gusts, turbulence, and electronic warfare. Viewing system inputs through the RHW lens now focuses on the human effectiveness side, where exogenous inputs are the noise, persistent vibration, temperature, and physical state of the pilot. Understanding these inputs to the human and how they affect performance is imperative to the management of our resources and the ultimate success of time critical and high stress missions.

As we progress through our professional careers, our previous experiences become the foundation for our future success. My time in academia, augmented with positions in test, system engineering, and research have given me a solid foundation to serve as the Deputy Chief. One of the greatest aspects of working in AFRL is the contribution we have in the Great Power Competition through lead-turning technology and driving our programs to successful transition knowing the reality that our adversaries are no longer near-peer, but peer to peer. Don't stop, don't get comfortable, bring the fight every day; for deterrence through technology innovation is our greatest strength! ☆

Col(s) Michael D. Zollars, Ph.D., Deputy Division Chief, 711 HPW/RHW

A Farewell to Dr. Louise Carter

The Warfighter Interactions and Readiness Division owes a great debt to our chief, Dr. Louise A. Carter, and we wish to celebrate her storied career as she retires. Dr. Carter's career at Wright-Patterson Air Force Base began in 1983, and over the next 41 years her efforts as an engineer, researcher, and leader have empowered the Air Force Research Laboratory to enhance preparation and mission execution and ensure decision superiority across the full range of military operations.

Throughout her career, Dr. Carter has participated in multiple NATO groups, including chairing an Exploratory Team that created a comprehensive collection of available biomechanics databases worldwide. She has developed neck injury criteria for helmet-mounted and ejection seat systems used by Air Force and Navy programs and has authored many papers on simulating human body dynamics and safety during aircraft ejections as well as aircraft and automobile accidents. Dr. Carter's research in biodynamics developing injury criteria, improving methods for modeling human body dynamics during aircraft ejection, and evaluating safety of aircrew equipment led to her serving for a decade as Chief of the Biomechanics Branch, and later the Vulnerability Analysis Branch. She has also served as Chief of both the Human-Centered Intelligence, Surveillance, and Reconnaissance (ISR) Division as well as the Warfighter Interfaces Division. In each of these roles, she has directed research and development portfolios focused on delivering capabilities to the operational community that has enabled and empowered analyst and operator performance and Airman-machine operations.

Dr. Carter is married to Maj (ret) Michael Carter whom she met when they both worked at WPAFB in Bldg. 441. They have three children: Liesl, a senior in mechanical engineering at the University of Dayton; Ian, a junior in math education at Bowling Green State University; and Keefe, a senior at Archbishop Alter High School.

Louise would like to thank the RHW team for their dedication and flexibility, from standing up the division during the COVID lockdown through the current challenges of the Great Power Competition (GPC). "I've been honored by your trust in me and am extremely proud of your ability to deliver amazing technologies for our warfighters. Keep taking on the next challenge and delivering." ☆

Mr. Dave Hubbell, Sr. Technical Writer, CAE USA

Photos by 711 HPW/RHW

Mr. David Malek
Readiness Product Line Lead,
711 HPW/RHW

READINESS
PRODUCT LINE

Welcome to the 2024 I/ITSEC Edition of Fights On! and to the Readiness Product Line update for this year! Some of you may be expecting to see Dr. Winston "Wink" Bennett's familiar face at the top of this page. Sadly for AFRL, but great for him, Wink retired earlier this year after a prolific 39-year career with the USAF. His commitment to the Air Force was unwavering and his dedication to this community we all serve at I/ITSEC will undoubtedly continue in his new role supporting the Department of the Air Force's (DAF) Chief Modeling and Simulation Office. When you see him on the floor this year, tell him thanks and congratulations!

PL OVERVIEW

The Readiness Product Line develops and extends technologies and tools for improving cognitive effectiveness, performance, and proficiency of Airmen and Guardians in current and future operational mission contexts.

Now, a little about me. For those who I haven't already met (but hope to soon), my name is Dave Malek and I am the new Readiness Product Line Lead after Wink's amazing run. I served the Product Line for the last couple of years, most recently as the Just-in-time Multimission Airmen/Warfighters (JITMMA/W) Product Lead. Prior to joining AFRL as a government civilian in November of 2020, I spent 30 years in industry serving DoD and industry clients, but primarily supported AFRL for the last 11 years. I'm honored to have been chosen to lead the Readiness Product Line and I'm very excited to guide us into the next phase of our vital role in researching and developing the tools and technologies that maintain our Airmen and Guardians as the best prepared and best performing in the world.

This past year saw a lot of progress in our efforts across the board. As Wink alluded to last year, the DAF Chief Modeling and Simulation Office and Air Force Research Lab's standup of the Modeling and Simulation Integration Laboratory (MSIL) at Wright-Patterson AFB has progressed to the point where we have taken large strides in our Joint Simulation Environment (JSE) derisking efforts as we explore and experiment with its fundamental software components, such as the Global Reusable Interface Domain (GRID). The MSIL is now the only USAF Science and Technology organization that operates a full-fledged JSE-in-a-box (JIAB) which positions our Division and the Readiness Product Line well for leading AFRL's Modeling and Simulation (M&S) innovation efforts. As the MSIL team continues to build out their infrastructure and capabilities, look for advances in high-fidelity, operationally relevant M&S technologies transitioning to warfighter use more quickly. See MSIL Lead, Dr. Glenn Gunzelmann, at the Department of the Air Force Modeling and Simulation booth for the lowdown on all the MSIL's exciting developments, but first see his article on MSIL later in this issue.

Continued on next page

Photo by Mr. Will Graver
(BAE Systems, Inc.)

Next, we were able to make a big impact with our application of Proficiency-Based Training as part of the foundation for what the USAF calls Synthetic Trainer Family of Systems (STFoS), formerly REFORGE, and now an official Program of Record. Our contribution has been to create and refresh Mission Essential Competencies working directly with the F-22 FTU at Langley and especially the T-38 Aggressors of the 7th Fighter Training Squadron and by incorporating the metrics established from that process into low-cost, small-footprint simulators, learning assessment and management tools, and mixed reality technologies to create a proficiency-based approach to operational training. We hope to complete that foundational effort in the spring of 2025 to provide a template for military flight training of the future. More aspects of this work can be found in other articles in this issue.

Our JITMMA/W product, designed and developed to provide just-in-time training and assessment to airmen and guardians at the edge and especially in austere environments, successfully demonstrated initial prototype capabilities at this year's Northern Strike 24-2 exercise. It was a true team effort as four different contractor teams (Aptima, Dynepic, Soar Technology, and Tangram Flex) collaborated with the government team to create impactful familiarization training content and task guidance capability for Airmen and Marines who, never having previously been trained on or performed Hot-pit Refueling of KC-135 tankers, actually refueled these aircraft for the first time. Special thanks to the Michigan Air National Guard for agreeing to partner with us to showcase this game-changing technology. See the article in this issue and catch demos of these technologies at the DAF Modeling and Simulation booth as well as booths for Dynepic and Soar Technology.

We continue to research, develop, and integrate science and technologies supporting HAF and ACC. For example, our team is heavily invested in the AFWERX Super Goggle Challenge led by Mr. Joseph "Rainman" Kendall and Dr. John Matyjas of ACC's Chief Scientist Office. Along with stakeholders at Naval Air Warfare Center Aircraft Division (NAWCAD) at Pax River and at the Joint Integrated Test and Training Center – Nellis (JITTC-N), among others, we anticipate seeing initial advancements in Mixed-Reality for military flight training applications soon and will begin to incorporate those advancements in the coming year.

We continue to focus much of our efforts on needs from the ops community and provide research and engineering support for those areas. Examples include creating rule sets for coalition DMO interoperability for tactical training and validating specifications for performance data and encryption of those data from live and simulator sources. We have also revitalized our support for 4th and 5th generation integrated training we conduct in our own labs we have in the Division. See the article in this issue on our Fighter Integration Training Research (FITR) for more details.

There are so many more initiatives we could tell you about, including SimMD (demonstrated at the Aptima booth), the Not So Grand Challenge (NSGC), our Datapalooza SBIR projects, and our work supporting the Air Force Lifecycle Management Center Advanced Training Capabilities Division's (AFLCMC/WNR) Simulator Common Architecture Requirements and Standards (SCARS) program, our REFORGE Foundations effort (now known as Surrogate Trainer Family of Systems), and Transforming Combat Medical Support for Agile Combat Employment (ACE). Instead, I'll let those teammates share with you what's been happening in 2024 and what is coming next in separate articles within this issue of Fight's On! The Readiness Product Line and its many partners have accomplished a lot this year and look forward to an extremely busy and impactful 2025. We'll be back to tell you all about it at I/ITSEC! ☆

Mr. David Malek, Readiness Product Line Lead, 711 HPW/RHW

SimMD™

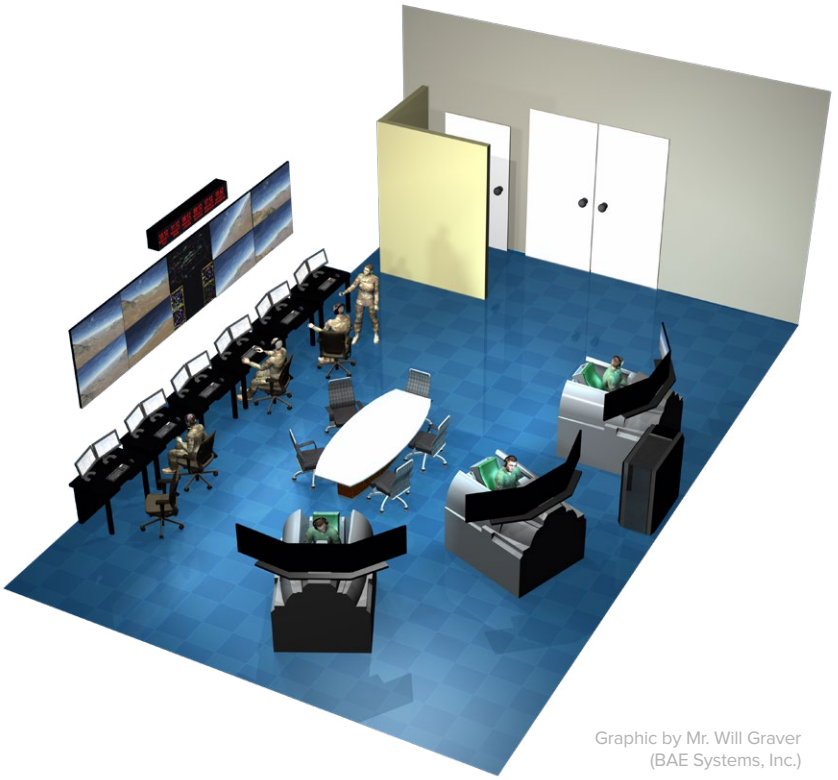
Virtual trainers, including simulators and other digital training tools, offer a range of cost-effective training solutions. Assessing the extent to which these tools can consistently provide high-quality training is essential to improving training outcomes like performance and readiness.

SimMD™ is an evaluation platform designed to align training requirements with virtual training capabilities, identifying strengths and areas for improvement in virtual training tools. Highly adaptable, SimMD can evaluate a wide variety of simulators, virtual devices, platforms, software, and environments, enabling comprehensive comparisons and assessments across different technologies. Through this capability, SimMD can support curriculum development, training requirements, and acquisition processes by highlighting both the strengths and limitations of virtual training.

The SimMD evaluation process captures insights from trainees, users, and operators, gathering quantitative, categorical, and qualitative data into a customizable dashboard that provides dynamic, actionable insights. These insights reveal aspects of virtual training that may fall short in delivering required training experiences, identify high-quality training areas, and offer comparative analyses across training approaches. Additionally, SimMD incorporates key statistical principles, such as interrater reliability, to enhance the validity of subjective feedback.

SimMD has evaluated various training components, including distributed and local Command and Control (C2) training, battle management software, simulator performance for individual platforms (e.g., F-15), and diverse training technologies like extended reality goggles. In addition, a key tenet of the work associated with SimMD has been to engage with relevant stakeholders and operators within the Air Force community. Large-scale virtual exercises have been identified for future evaluations to track desired learning objectives, map training requirements, identify opportunities for improvement, and support decision making. ☆

Dr. Alexxa Bessey, Scientist, Aptima, Inc.



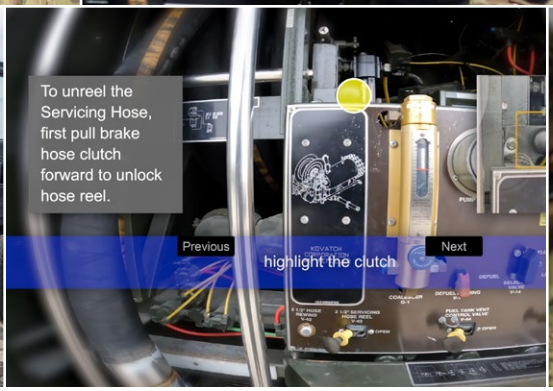
Graphic by Mr. Will Graver
(BAE Systems, Inc.)

Fighter Integration Training Research (FITR)

The first year of the division's Fighter Integration Training Research (FITR) has been instrumental developing a more comprehensive understanding of pilots' stress levels and workload, while also providing current and qualified pilots with the experience of flying against constructive red adversary entities over missionized scenarios. The purpose of the FITR effort was to connect our 5th (F-22) and 4th (F-16) generation virtual simulator devices in an environment that allows for integrated mission planning, execution, and debrief, an experience many pilots may not receive until they are deployed. Pilots have consistently reported this as being a valuable training opportunity, particularly among more inexperienced pilots. FY24 saw participation from Holloman, Langley, and Shaw AFBs, as well as the Indiana Air National Guard in Fort Wayne.

Data are collected from pilot cohorts over the course of a single week with an average of six VULs flown each day. In addition to the objective flight data summarized using Aptima's Performance Evaluation and Tracking System (PETS), pilots complete a task load index survey at the end of each mission set. Included as a measure of their cognitive workload during each mission, data collected from this survey are indicative not only of the complexity of piloting an aircraft as part of an integrated unit, but also the mental reserves that might be available for other tasks performed simultaneously. We are particularly interested in applying this insight to the development of user interfaces for Collaborative Combat Aircraft (CCA), with plans of incorporating them into our simulation devices in the coming years. ☆

Dr. Beth M. Hartzler, Research Psychologist, 711HPW/RHWOW
Mr. Scott Carpenter, Fighter SME, RCG



Photos by Mr. Will Graver (BAE Systems, Inc)
and Mr. Dave Malek, Readiness PL Lead, 711 HPW/RHW

A Focus on Operational Value:

Continuing Updates for Just-in-Time Multimission Airmen/Warfighters (JITMMA/W)

AFRL demonstrated progress on the Just-in-Time Multi Mission Airmen/Warfighters (JITMMA/W) project during the ANG Northern Strike 24-2 (NS24-2) exercise. JITMMA/W empowers Warfighters to execute a broader array of mission tasks in remote, challenging environments while using fewer personnel. It offers on-demand capabilities to address new tasks and situations, enhancing readiness by providing secure, continuous access to training materials and support tools exactly when needed.

During NS24-2, the Human Effectiveness Directorate's Warfighter Interactions and Readiness Division (711 HPW/RHW) provided just-in-time training for KC-135 Hot Pit Refueling at the Oscoda-Wurtsmith Airfield in Oscoda, Michigan. The Airfield served as an Agile Combat Employment (ACE) Contingency Location (CL) during the exercise. The JITMMA/W team focused on an ACE scenario at a FOB/Contingency Location where the appropriate POL/Maintenance (MX) personnel were unavailable but the mission of refueling the aircraft still had to be accomplished.

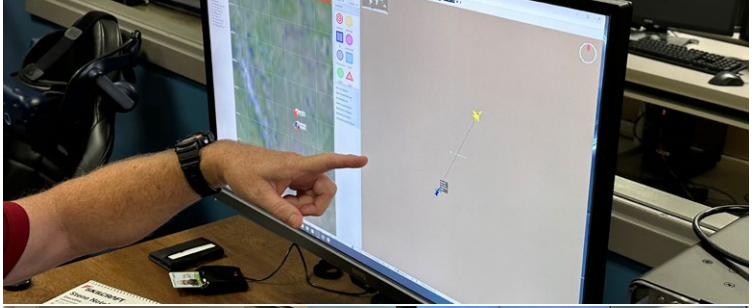
Participants were deliberately selected that had no prior POL or MX backgrounds/training. They received on-demand training which included a combination of static, tablet-based content and immersive Virtual Reality content. Following the training, they took an assessment to evaluate their understanding. When the KC-135 landed, participants wore Augmented Reality headsets or used mobile devices to guide them through the hands-on phase of refueling the aircraft with one of its engines running. The training included 2 distinct roles: a POL role and a MX role. The roles along with the associated content were selected based on the NS 24-2 scenarios. JITMMA/W is intended as a general just-in-time training capability for austere environments and not specifically tied to aircraft maintenance or refueling.

Five KC-135s landed at Oscoda, resulting in 10 participants completing the hands-on phase. These participants had backgrounds/training in ANG Combat Comms, ANG Security Forces, ANG Contingency Response and USMC Engineering Support. During the hands-on phase, a POL and a Mx Subject Matter Expert (SME) observed the performance of the participants and acted as safety monitors.

The exercise provided the team with significant feedback and lessons learned. It enabled the program to make great progress toward providing warfighters with a just-in-time training capability in austere environments. ☆

Mr. Stephen McGee, JITMMA/W Lead, 711 HPW/RHWOW

Scan the QR code or click **HERE** to view the JITMMA/W demo video



Photos by the GRILL®

Datapalooza

Representative Data for Pilot Training Innovation

Data remains one cornerstone of Air Combat Command and AFRL's effort to provide more effective and efficient pilot training. Building on decades of research and practical experience, data-driven insights help deliver the right training at the optimal time, augment instructor expertise, guide training priorities, justify budgets, and enhance readiness.

AFRL's Datapalooza effort, kicked off in 2023, is delivering unclassified data representative of the type, structure, and complexity found in modern distributed tactical training scenarios that USAF pilots face. Many organizations cannot perform classified work, and this new dataset allows them to explore innovative methods to address the big challenges the USAF faces. Seven direct-to-phase-II SBIR awardees and related stakeholders have leveraged this dataset, and the team is now enhancing the dataset with greater variations in pilot performance, larger sample sizes, and improved representations of learning trajectories. Trained pilots generated the initial dataset, and the team is investigating AI methods for further expanding the dataset with realistic synthetic representations.

Datapalooza supports the lab's longstanding Content and Data Standards research portfolio and the Readiness product line. The cross-organizational collaboration exemplified during Datapalooza is helping us accelerate the innovation driving training and operational excellence. Reach out if your organization would like to join the team, either providing representative data or new analysis approaches delivering actionable insights. ☆

Mr. Peter Neubauer, Principal Software Engineer, Aptima, Inc.

Dr. Mark Schroeder, Principal Scientist, Aptima, Inc.

Mr. David Malek, Readiness Product Line Lead, AFMC 711 HPW/RHW

Dr. Lorraine Borghetti, Research Lead, Co-Learning for Adaptive Human-Machine Teams LOE, AFMC 711 HPW/RHWOH

AFRL SCARS Testbed

The AFRL SCARS Testbed is an ongoing research effort to provide insight into possible future increments of the AFLCMC SCARS program. In 2024, AFRL SCARS continued its work on virtualization/containerization,

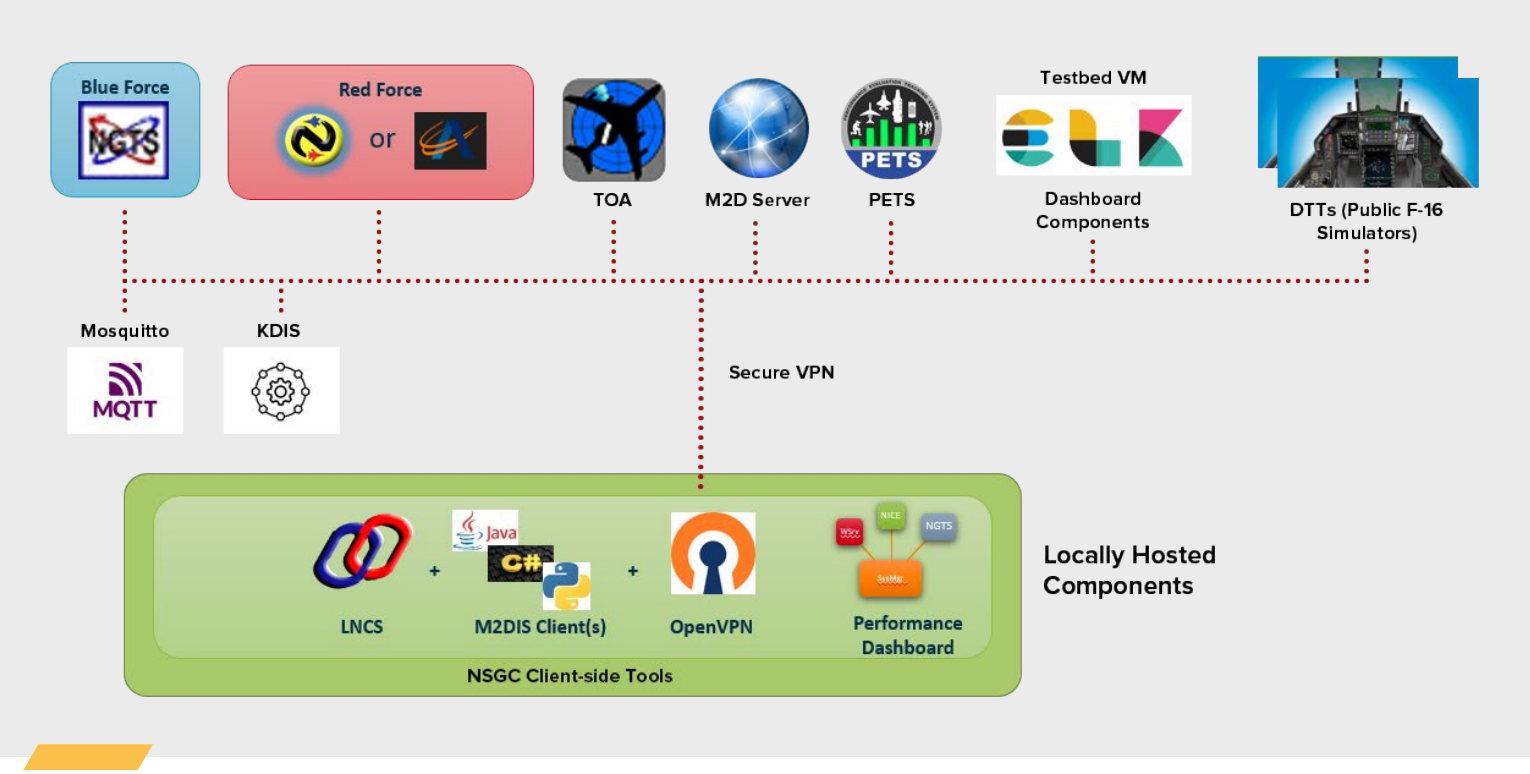
Building on AFRL's previous work putting the F-16 simulator into a Virtual Machine (VM), AFRL has successfully replaced five Windows 10 PCs with a new F-16 host computer capable of running the original F-16 sim host software as a guest Windows 11 VM and running additional VMs such as cockpit displays, debrief IG and sensor IG. This effort has shown savings in cost and labor and reduced latency, enabling simulators to migrate to VM sooner to meet SCARS requirements.

Working with WNR, AFRL has successfully added its GOTS proficiency-based training applications PETS and LNCS to the SCARS library. This will enable all SCARS affiliates to access the AFRL-developed software.

The AFRL SCARS team is currently working to build a SCARS 5th Generation testbed to provide insights on how to incorporate the 5th Gen Aircraft simulators into SCARS. AFRL has also started researching JSE/GRID to determine how GRID could become a SCARS standard. The research focuses on GRID message types, JSE/GRID services, JSE-chosen applications, and JSE simulations. ☆

Mr. James "Jeb" Bartosik, SCARS Systems Engineer, Tangram Flex

Graphic by Mr. Will Graver (BAE Systems, Inc.)



Graphic by Mr. Will Dupree
and Mr. Luke Waggenspack, Aptima, Inc.

Not So Grand Challenge (NSGC)

The Not So Grand Challenge (NSGC) is an ongoing research activity intended to enhance fighter pilot training by developing red force cognitive models to make smarter, more realistic adversary threats. Through a partnership of companies working across the DoD space (including Aptima, Charles River Analytics, CHI Systems, Eduworks, Soar Technology, Stottler-Henke, and TiER1 Performance Solutions), the project team is developing a variety of cognitive models, a Digital Librarian to store and recommend the utility of these models, and a virtual Testbed to access and engage with these models in a distributed work environment.

Cognitive Models

Engagement in exercises is a proven way to enhance pilot training, particularly when conducted against experts in tactical flight. The use of computer-generated forces (CGFs) allow for readily accessible and adaptive components to engage with pilots in a cost effective way. However, a gap exists in the development of intelligent adversary entities that go beyond the predictable behavior of red forces that presents the potential for negative transfer of bad lessons to real engagements. The NSGC project applies multiple approaches to developing intelligent adversary agents. Some apply a machine learning technique to learn scenario states and associated pilot actions. Others develop AI pilot agents by generating automated measurements (i.e., data) of agent performance in scenario runs, and encoding subject matter expert-guided (SME-guided) interpretation of those data into their diverse cognitive modeling architectures.

Testbed

The Testbed utilizes many government-off-the-shelf (GOTS) software, such as Next Generation Threat System (NGTS), Network Integrated Constructive Environment (NICE), Tactical Observation Agent (TOA), Performance Evaluation and Tracking System (PETS), and Live, Virtual, and Constructive (LVC) Network Control Suite (LNCS). Aptima developed the Model to DIS (M2D) Server and the M2DIS Clients to allow the cognitive models to seamlessly interact with the Testbed without deep knowledge of the Distributed Interoperability Simulation (DIS) protocol. To achieve this seamless interaction, numerous external Application Programming Interfaces (APIs) were developed. Testbed APIs include scenario control (queue, dequeue, and run time), entity data retrieval (location, orientation, radar tracking list, weapon load, and fuel status), and entity controls (maneuvers, weapon fire, and radar state). The Testbed is Computer Generated Force (CGF) agnostic, so that any CGF can be easily integrated and used.

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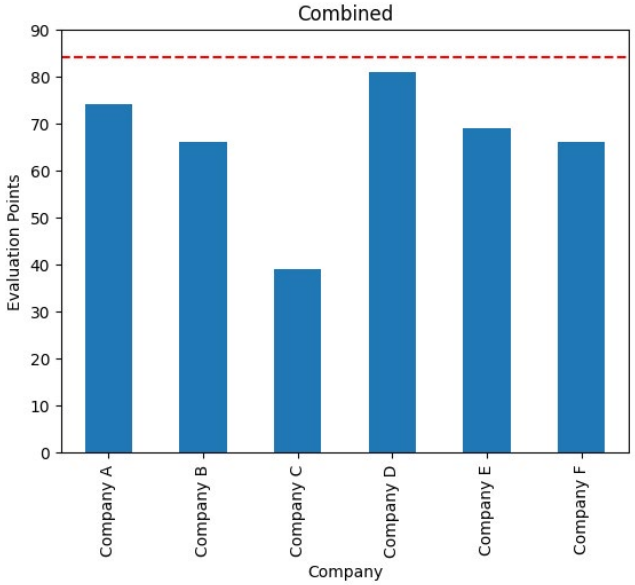
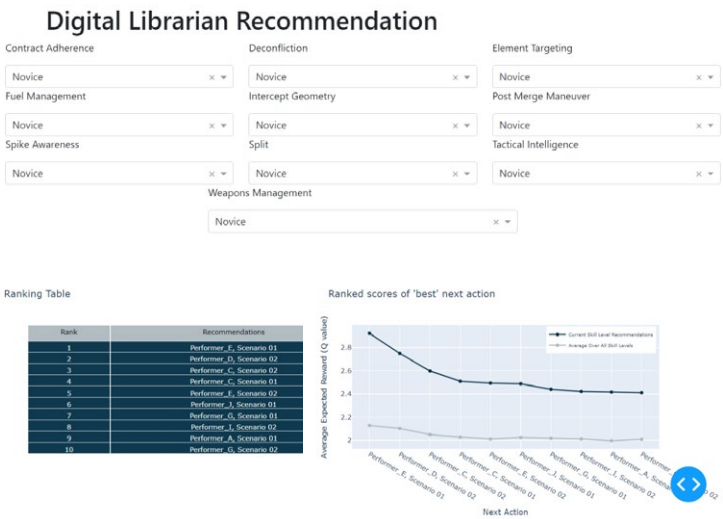
MILESTONES

- **Completion of Testbed and Client-side software to enable cognitive model development.**
- **Completion of models reflecting 1v2 pilot performance in basic scenarios involving human pilots.**
- **Successful evaluation of industry red agents to assess behavior under nuanced scenario conditions, allowed by subject matter expert human pilots.**



Red Agent's Evaluated Using DTTs

In a recent assessment conducted in September of 2024 we were able to test AI controlled red agent behavior against human pilots in a Deployable Tactical Trainer (DTT). The NSGC team evaluated red agents in an expert crafted engagement designed to push the boundaries against blue aircraft. Our agents performed well, with an average of 66 points out of 84 (judged by subject matter experts). The target scenario used for evaluation included a dogfight between two red agents, controlled by machine models, against a single blue aircraft piloted in the simulation by a human. The goal of the scenario is to test the ability of the red agents to react in a combat situation, engaging or evading with the blue air. Allowing the human to pilot the blue air gives the ability to explore red agent behavior via small, nuanced changes in overall scenario conditions (e.g., flight path or select red engagement). The insights gained from this exercise are crucial for debriefing purposes and will serve as a foundation for developing targeted training programs aimed at enhancing the red air forces' tactical performance. The data will inform future strategies to ensure that our red air capabilities are robust and can meet the demands of realistic combat scenarios.



Digital Librarian

The Digital Librarian is a machine learning (ML) tool developed to aid in the training of pilots who will interact with the Testbed in the future. The end goal is to enable pilots being trained, and the personnel overseeing the training, to intelligently select available scenarios and artificial intelligent (AI) agents in a way that maximizes the pilot's acquisition and building of skills. As the Testbed grows in complexity with a larger number of AI agents and possible scenarios to train against, the challenge of choosing the best training environments to maximize a set of skills becomes intractable across high dimensional tracking metrics for any single human to perform. In this case of high dimensionality, the Digital Librarian will leverage information about current skill level, scenarios, and AI agents to provide a ranked list of recommendations it perceives as the best scenario and agent pair for a human pilot to train against with the goal of increased effectiveness and skill growth. The Digital Librarian uses Markov Decision Process (MDP) and reinforcement learning (RL) inspired algorithms to optimize what is the next best "sparring scenario" for a given pilot. In the below image we share a prototype of the Digital Librarian. It is an interactive dashboard (currently using simulated stand-in data) that allows a user to set a trainee's current skill level and outputs recommendations of best-next-actions given the data it learned from. The left side table gives rank order of scenario/agent combinations. The right figure shows trend lines of expected outcome reward (larger is better) for current skill level in blue and average reward across all skill level combinations in gray. Reward here is the numerical value assigned to expected outcome of growing in skill level. ☆

Dr. Samantha Perry, Aptima, Product Manager

Dr. Will Dupree, Aptima, Sr. Research Engineer

Mr. Jacob Smith, Aptima, Testbed Engineer

Mr. Scott Carpenter, RCG, Fighter SME

Dr. Lorraine Borghetti, Research Lead, Co-Learning for Adaptive Human-Machine Teams LOE, 711 HPW/RHWOH

NSGC FUTURE WORK

- **Demonstrate models against manned virtual platforms in scenarios of added complexity (e.g., 2v2 engagements, fuel management, weapon management, airspace avoidance, escort missions, etc.).**
- **Integrate other CGF software into the Testbed: ASCOT-7 and AFSIM.**
- **Explore alternative modeling approaches, such as data driven machine learning methods that require beyond real-time testbed playback.**

Graphics and Charts by Mr. Will Dupree and Mr. Luke Waggenspack, Aptima , Inc.

Mission Essential Competencies (MECs)™

The Mission Essential Competency (MEC) process is a data-driven, warfighter-centric methodology that identifies the proficiencies required for mission readiness and success. MECs are higher order individual, team, and inter-team competencies that a fully prepared pilot, operator, crew, or flight requires for successful mission completion under adverse conditions in a nonpermissive environment. Applying a multi-method knowledge elicitation and analysis approach, the MEC process identifies MECs, supporting competencies, and knowledge/skills, as well as the experiences that help to develop those elements. The process then leverages data gathered on the MEC elements to identify any training gaps affecting operators' proficiency and explore potential solutions to address these gaps.

As part of the Surrogate Trainer Family of Systems (STFoS) effort, the MEC process developed and refined the requirements for mission success for T-38 ADAIR operators. The effort identified gaps for current training and SME conclusions about how to best mitigate those gaps. Results provide trainers with data to modify and enhance training pipelines and serve as the foundation for the proficiency-based training ecosystem, such as grade sheets, scenarios, performance metrics and systems.

Occasionally, MECs and their supporting elements need to be updated, or refreshed, to reflect changes in training requirements, capabilities, or mission sets for a given weapons system or organization. This produces an updated set of MECs, supporting competencies, knowledge/skills, experiences, and learning environments. A MEC refresh process is underway to update the F-22 MECs, initially developed in 2017. Upon completion, the results will offer updated and validated data to inform training approaches and resources. ☆

Ms. Rebecca Beard, Executive Vice President,
The Group for Organizational Effectiveness, Inc.

Dr. Jamie Levy, Vice President/Principal Consultant,
The Group for Organizational Effectiveness, Inc.

MEC MILESTONES

- **Completion of a MEC effort for T-38 ADAIR.**
- **Workshops, survey data collection, and tool development for the F-22 MEC refresh process.**

U.S. Air Force photo by Master Sergeant Burt Traynor/Released

REFORGE

This year, the team continued work to bring PBT capabilities to the T-38 aggressor squadron and F-22 field training unit at Langley AFB. This effort, known as REFORGE Foundations, is establishing the science and engineering underlying an effort from Headquarters Air Force (HAF) and the Combat Air Force (CAF) to advance readiness and training. AFRL's team and squadron personnel defined the Mission Essential Competency (MEC™) baseline knowledge, skills, and developmental experiences for both the T-38 aggressor role and the F-22. The baselines are currently being used to define proficiency levels, redesign syllabi, create new scenarios, define metrics, integrate learning assessment and management tools, and create a low-cost, multi-aircraft configurable virtual environment for the T-38 personnel to support instrument, local area orientation, and emergency procedures. Additional work includes integrating multiple AFRL-owned and commercial technologies to create a streamlined simulation and data capture training ecosystem, redefine the way grade sheets are approached to provide high value information with reduced instructor workload, and create dashboards for multiple levels of stakeholders to inform unit level efficiencies by identifying trainees that need supplemental training or are ready to progress to the next block while also providing overall trends for the unit. The results will help define low-cost, VR, and mixed reality flight training solutions to inform Surrogate Trainer Family of Systems (STFoS) initiatives. ☆

Mr. Peter Neubauer, Principal Software Engineer, Aptima, Inc.

Dr. Glenn Gunzelmann

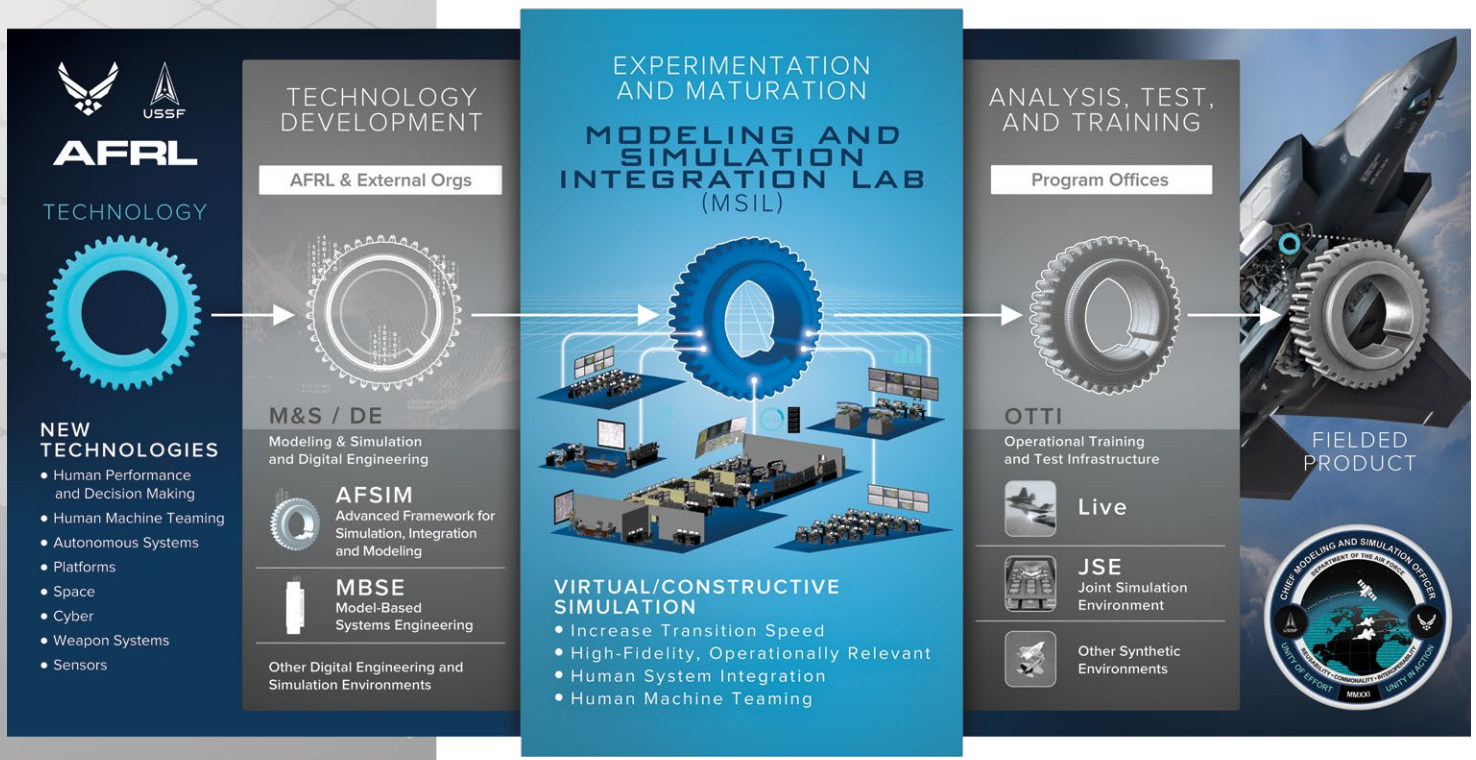
Modeling and Simulation Lead,
Warfighter Interactions and Readiness
Division, 711 HPW/RHW

MODELING AND SIMULATION INTEGRATION LAB (MSIL)

The Modeling and Simulation Integration Lab (MSIL) is an initiative originating with the Department of the Air Force's (DAF) Chief Modeling and Simulation Office (CMSO) to create an operationally relevant modeling and simulation (M&S) environment for technology experimentation, maturation, and transition. By emphasizing the Joint Simulation Environment as an initial centerpiece, the MSIL will help speed the delivery of new capabilities to the force by connecting science and technology (S&T) advances from the Air Force Research Laboratory (AFRL) to the broader operational training and test infrastructure (OTTI) for the DAF. In addition, the ecosystem will allow the DAF to address near-term program gaps, risks, and research needs on behalf of program offices across the AF while evolving to explore longer-term mission impacts of new technologies and warfighting concepts. A central motivation is to enable early contact with operators to explore human performance, integration, and machine teaming issues in high-fidelity, operationally relevant scenarios.

The long-term objective is to provide an enterprise capability to rapidly mature and integrate new technologies, capabilities, and concepts to facilitate adoption for operations. The MSIL has an initial operational capability that is being leveraged both to provide research support to program offices and an experimentation environment for laboratory technologies. ☆

Dr. Glenn Gunzelmann, Modeling and Simulation Lead,
Warfighter Interactions and Readiness Division, 711 HPW/RHW



Graphic by Mr. Will Graver (BAE Systems, Inc)

Dr. Deirdre Mahle
Warfighter-Machine Integration Lead, 711 HPW/RHW

WARFIGHTER-MACHINE INTEGRATION (WMI)
PRODUCT LINE

The Warfighter-Machine Integration (WMI) Product Line (PL) has had a very busy year with many significant activities. JADPACT (Joint All Domain Planner with Adaptive Collaborative/Control Technologies) – a multi-domain command station with AI interaction/cooperative planning and control enabling JAD (Joint All Domain) distributed operations – is finishing up the 6.2 effort and moving to 6.3. This October the team is conducting a review of the JADPACT R&D program concept development for a Joint All-Domain Battle Management Workstation (JADBMW). The JADBMW is an R&D concept that will be developed into a prototype that will use Human-Machine Teaming (symbiotic coupling of operators and artificial intelligence-aided decision support tools) to enable rapid, adaptive and resilient Battle Management of integrated multi-domain force packages. Subject matter experts from the air, space, and cyber domains will review the JADBMW through interactions with high-fidelity wireframes, validating the interface designs and proposed system functionality.

PL OVERVIEW

Identify and mature operator centric interfaces and human-machine teaming that increase Airmen and Guardians' combat capabilities through integrated solutions that develop synergies, maximize battlespace interoperability, situation awareness, and increase combat power and decision dominance while decreasing cognitive workloads.

IMPACT

The exciting news for the WMI product line that I would like to highlight in this newsletter is the transition of IMPACT (Intelligent Multi-UxV Planner w/Adaptive Collaborative Control Technologies) to the Medusa C2 Program of Record on schedule. Medusa (Multi-Environmental Domain Unmanned Systems Application) was developed to counter the increasing threat to USAF installations created by small unmanned aerial systems (sUAS). The original design provided a command-and-control architecture with a human-machine interface (HMI) permitting one

Continued on next page

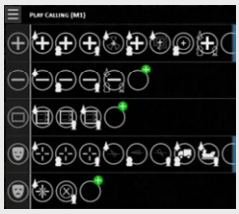
> **"The (IMPACT) team conducted extensive Cognitive Task Analyses (CTA) to identify challenges faced by Medusa operators detecting, identifying, tracking, and defeating hostile sUAS platforms."**
>
> **— Dr. Deirdre Mahle**
> Warfighter-Machine Integration Lead, 711 HPW/RHW

1 Task Management

Task Manager

2 Call Play

Play Calling Tile

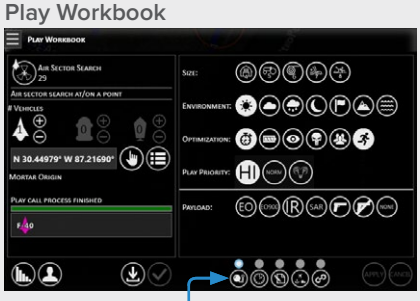


Speech
"Air Point Inspect at Bldg. 99"

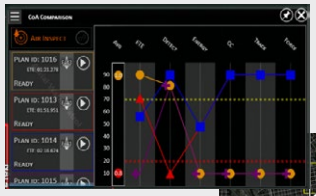
Map-based Radial Menus

3 Operator & Autonomy Team on Play's CoA

Play Workbook

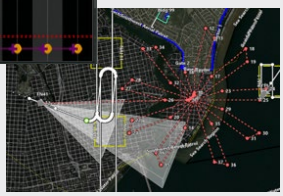


Tabs: Play Detail Pages



Tradeoffs of Autonomy's Top Play CoA's

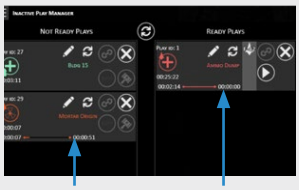
Play Preview



4 Operator & Autonomy Monitor Play Execution

Play Monitor

Inactive Plays



Constraints Not Met

Constraints Met

Active Plays

Background Behaviors

Sandbox Play Execution

Graphic by 711 HPW/RHW

IMPACT TESTBED: Intuitive Human-Machine Interfaces

operator to monitor protected airspaces and detect and defeat multiple sUAS incursions. Installations with busy surrounding airspaces, however, created challenges for operators and several unforeseen human factors and cognitive concerns. The IMPACT team, led by Mr. Allen Rowe, needed to address the potential workload issues and operator performance vulnerabilities associated with the current fixed-site Medusa HMI and develop recommended solutions that leveraged the IMPACT human-autonomy teaming testbed. The team conducted extensive Cognitive Task Analyses (CTA) to identify challenges faced by Medusa operators detecting, identifying, tracking, and defeating hostile sUAS platforms. Currently, a single operator is tasked with monitoring the protected airspace, a very manual process that imposes significant cognitive demand, leading even experienced operators to errors or disengagement from critical tasks. The insights gained from the CTA have informed HMI requirements and guided recommendations aimed at enhancing system performance. The challenges highlighted in the CTA were addressed through the planned integration of autonomy into the HMI design, leveraging IMPACT's human-machine teaming design concepts. Integration of decision aiding reduces working memory demands and cognitive workload overall, as well as reducing response times to emerging threats. The IMPACT team plans to continue their engagement with AFLCMC/HBU (Counter-UAS) and other stakeholders within the base defense enterprise. ☆

Dr. Deirdre Mahle,
Warfighter-Machine Integration Lead, 711 HPW/RHW

Dr. Jerred Holt

Intelligence Analytics & Sensemaking PL Lead and Senior Research Psychologist, 711 HPW/RHW

INTELLIGENCE ANALYTICS & SENSEMAKING

PRODUCT LINE

The Intelligence, Analysis and Sensemaking (IAS) Product Line kicked off in Jan of this year and has gained considerable momentum with the establishment and acceleration of multiple S&T efforts and has already demonstrated solid operational mission impact. With a strong baseline in traditional ISR process augmentation through the LEGION program, our focus has been on increasing involvement in the Space and Cognitive Warfare domains as well as building better interconnectivity between R&D systems.

The primary goal of IAS is to provide decision superiority to the AF and Joint intel community through tools, systems and process that augment the operator's ability to make timely, effective decisions in an increasingly organic and distributed battlespace. The diversity of expertise, responsibility and communication options present in the intel process presents an unparalleled challenge to our ability to executing complex kill webs with persistent target custody.

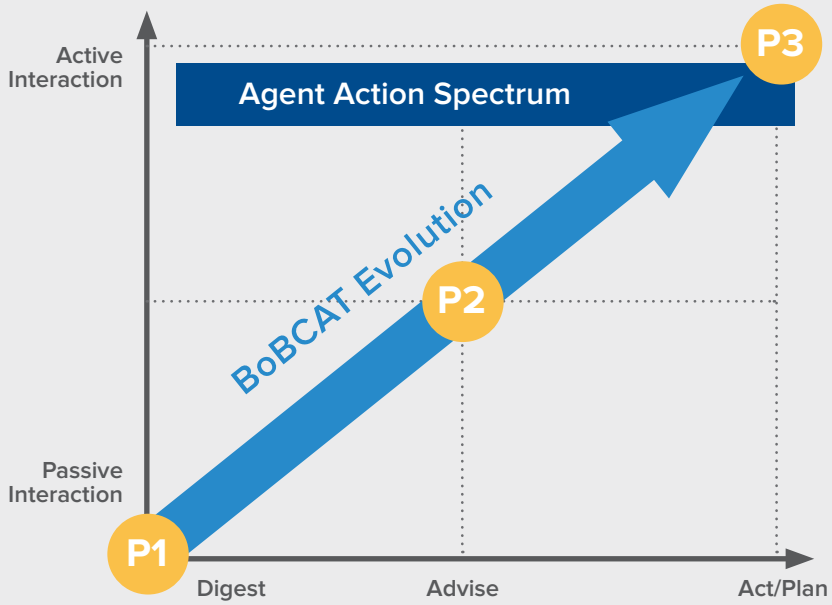
The LEGION program is a suite of services that aim to optimize the process of developing and executing intelligence requirements. It provides multi-role decision support through advanced modeling and simulation, databasing and AI/ML backends, coupled with empirically driven Human-Machine Interfaces (HMI). After a successful demonstration in December '24, LEGION has seen increased partnerships both within AFRL and our operational partners. These include deployments to PACOM, INDOPACOM EUCOM as well as tech integrations with AFRL efforts such as Fight Tonight, SAINT and Resolute Sentry.

PL OVERVIEW

Capture the full spectrum of data collection and exploitation, including novel intelligence planning/orchestration, enhanced analysis through advanced human-machine teaming, and rapid sensemaking through warfighter-centric analytic tools and visualization technologies in support of decision superiority. Leverage maturing technologies in augmented cognition, trust, and decision making to develop Cognitive Warfare tools and influence applications.

Two new key programs being stood up within the IAS PL include Best of Breed Configurable Adaptive Teammate (BOBCAT) and MORRIGAN. Both programs will leverage years of AFRL investments in foundational R&D to deliver capabilities that address critical AF demand signals. BOBCAT, as the name suggests, is an adaptive teammate architecture built on high fidelity speech interpretation/synthesis and bespoke large language models. It aims to provide a configurable framework that can support multiple operator roles and tasks. MORRIGAN focuses on strategic measures of cognitive warfare. The team will be building on a pedigree of RH Information Warfare research to provide a predictive modeling capability to support Indications & Warnings of enemy behavior. Read on to learn more about both cutting-edge programs. ☆

Dr. Jerred Holt, Intelligence Analytics & Sensemaking PL Lead and Senior Research Psychologist, 711 HPW/RHW



Graphics by 711 HPW/RHWT

BoBCAT: Best of Breed Configurable Adaptive Teammate

BoBCAT: Best of Breed Configurable Adaptive Teammate enables decision superiority by harnessing heterogeneous artificial intelligence (AI) models to empower human-machine teammates capable of adapting to user needs and conditions, providing explainability and transparency in system outputs. The Intelligent Agent will allow for natural, intuitive and customized interactions, along with the ability to ingest and process disparate data sources across multiple modalities. Not only will the component technology required to build such an agent be evaluated from a best of breed perspective, but the agent will be evaluated holistically from a human-machine teaming aspect to measure impacts on mission success. The end goal is to construct multiple customized synthetic agents that will interact seamlessly with other agents and human operators to provide real-time insights and recommendations enabling faster and more informed decision making.

The 711HPW/RHWTE Human Language Technology group has the knowledge and the expertise to intelligently integrate heterogenous streams of information from existing tools and sources, make sense of those disparate information streams via a series of AI-enhanced agent teammates and provide sensemaking to human teammates to catch things that would have otherwise been missed if only considering one source at a time.

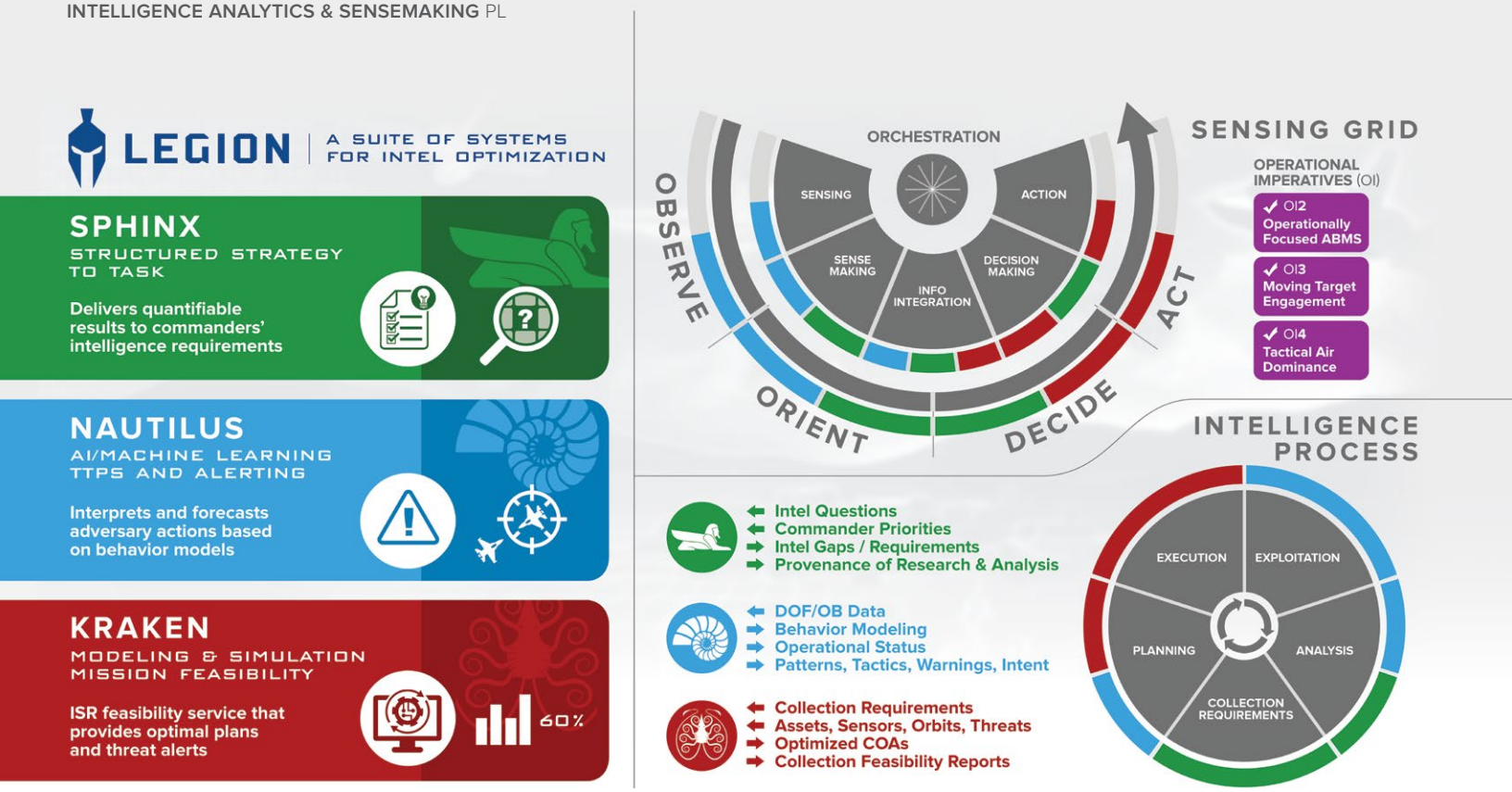
The DARPA AI Forward (https://www.darpa.mil/work-with-us/ai-forward) initiative states that despite progress in the field, AI and related technologies still require significant investment and advancement to develop technology that reliably operates, interacts appropriately with people, and meets the most pressing national security and societal needs in an ethical manner.

The following trustworthy AI research thrusts are important:

- Foundational theory to understand the art of the possible, bound the limits of particular system instantiations, and inform guardrails for AI systems in challenging domains such as national security.
- AI engineering to predictably build systems that work as intended in the real world and not just in the lab.
- Human-AI teaming to enable systems to serve as fluent, intuitive, trustworthy teammates to people with various backgrounds.

BoBCAT covers all three research thrusts, with a focus on the human-machine teaming aspect and how this technology will best enhance our warfighters and even adapt to their needs to make the most impact. BoBCAT provides intelligent, intuitive and mission-optimized information brokering between warfighter cognitive requirements and heterogeneous analytics and systems, directly enabling decision superiority across a variety of information-centric operations. ☆

Eric Hansen, Senior Electronics Engineer, 711 HPW/RHWTE



Graphic by Mr. Will Graver (BAE Systems, Inc)

Legion: AFRL's ISR Tool Suite

There are many potential hurdles intelligence analysts and planners face when completing the mission. The process of collecting intelligence can be slow, manual, and laborious as analysts work to sift through copious and sometimes overwhelming amounts of information. Intelligence collection requests can be difficult to track as they pass from one unit to another. With different shops using different applications to receive, organize, and respond to requests, data entry errors are prone to occur. These issues and others can muddle the intent behind the initial request, resulting in collects that do not provide leadership with the accurate information they need to make decisions at the highest levels.

Under the Intelligence Analytics & Sensemaking Product Line, Legion works to bring speed, accuracy, and transparency to the intelligence collection process with a focus on maintaining request intent from start to finish. Legion consists of three capabilities, Sphinx, Nautilus, and Kraken, which can operate both as stand-alone tools or as an integrated suite. These capabilities augment the analyst's work, providing faster, more-informed responses to collection requests and giving blue forces the decision advantage over our adversaries.

Starting with the initiation of the collection process, Sphinx is a web-based application that serves to provide a structured request workflow that enables the original intent of the request to be tracked and maintained as it passes to other systems and organizations for an answer. The capability allows the analyst to see where in the collection process the request is, as well as the origin of the response data, increasing confidence in the information provided. In other words, Sphinx delivers transparency along the collection process that has not existed before.

Aiding in the response of collection requests, Nautilus utilizes artificial intelligence and machine learning (AI/ML) to examine and make sense of massive amounts of information, recognizing behavior patterns and forecasting potential future actions of our adversaries. Behavior-based collection planning and analysis leads to greater collection success and a more comprehensive understanding of adversary state.

When a new collection is needed to answer an intelligence request, Legion's ISR feasibility engine, Kraken, assesses ISR route options and provides optimized courses of action (COA), using high-fidelity, physics-based modeling and simulation. It ingests collection requirements, accounts for theater constraints such as terrain, weather, and enemy threats, factors in aircraft and sensor capabilities, and calculates feasibility and risk scores. Kraken also allows for dynamic ISR planning, enabling schedulers to quickly identify the intelligence gains and losses as priority collection targets shift. Instead of taking hours or days to develop strategic COAs for execution, it can now be done in minutes or seconds.

Individually or together, the Legion capabilities work to deliver the decision superiority advantage to our analysts, planners, and leaders. ☆

Mr. Patrick Ederer, Legion Team Lead, 711 HPW/RHWIM

Graphic by Mr. Will Graver (BAE Systems, Inc)

Morrigan

In our nation's history, warfare was often portrayed as a game of chess: two players battling for ultimate dominance, often with the players' attention focused on the most powerful pieces. However, the Digital Revolution, the Age of Artificial Intelligence, and the spread of globalization have irrevocably altered the chessboard of strategic competition and the relationships between allies and adversaries. In other words, the objectives and strategy behind the "game" have shifted as Dr. Henry Kissinger illustrated in his quote comparing Western and Eastern perspectives of warfare: "Chess has only two outcomes: draw and checkmate. The objective of the game is total victory or defeat-and the battle is conducted head-on. . . The aim of Go is relative advantage; the game is played all over the board, and the objective is to increase one's options and reduce those of the adversary. The goal is less victory than persistent strategic progress." To maintain strategic advantage, the Air Force must develop an understanding of a nuanced information environment to gain a competitive edge over adversaries and defend against the non-kinetic components of Information and Cognitive Warfare.

All military operations have an informational aspect, and mission accomplishment can be furthered by properly leveraging the information environment to affect perceptions, decision-making processes, and the behaviors of groups, societies, and nations. Conversely, missions can become failures if this domain is not considered, such as when uninformed actions create counterproductive effects. Thus, understanding the Information Environment is key to all Air Force operations, air superiority, global strike, and rapid global mobility. RH is supporting operations in the information environment (OIE) through developing AI technology which will detect and characterize the information maneuvers in the IE; this technology must synthesize across languages, socio-cultural contexts, digital platforms, and multimodal data. This microservice tool has been named Morrigan, named after the Celtic goddess of prophecy and foreteller of victory or doom in battle. Morrigan will draw from an iterative, validated digital playbook and provide strategies to conduct & defend against specific maneuvers, which is a crucial component to maintaining the United States' strategic advantage in the Age of AI.

The Department of Defense's goal is to decisively defeat adversaries when conflict erupts but also to deter an enemy from ever initiating conflict. Adversary deterrence and defeat is inherently a cognitive outcome and mastering the information environment is part of the strategy to compel a potential opponent to stand down or a current enemy to surrender. The Morrigan tool will improve influence assessment capabilities & develop deeper understanding of the human domain in Information and Cognitive Warfare while optimizing tradecraft/ planning with updated analytics, models, and frameworks. Ultimately, to win at the ever-changing "game" and maintain strategic advantage in the Great Power Competition struggle, the AF must lead OIE assessment, tradecraft, and push the state-of-the-possible with tools such as Morrigan. ☆

Dr. Christine Vitiello
HPW Cognitive Warfare Working Group Lead, 711 HPW, RHWEM

Capt Patrick 'Alex' Laflam-McFall
OIC, Cognitive Research Team, 711 HPW, RHWEM

Dr. Brian Simpson

Human Learning and Cognition CTC Lead, 711 HPW/RHW

HUMAN LEARNING & COGNITION

CORE TECHNICAL COMPETENCY (CTC)

> **If we were asked tomorrow to go to war against a great power ... would we be really ready to do that?"**
>
> **— Hon. Frank Kendall**
> Secretary, United States Air Force

The needs of the United States Air Force (USAF) and United States Space Force (USSF) to prepare for Great Power Competition are many. We must move quickly to prepare for a different way of operating in increasingly complex, uncertain, and contested environments. The complexities associated with future operations will engage the human mind in new ways that we must anticipate, and for which we must prepare. The Human Learning and Cognition Core Technical Competency (HLC CTC) is focused on providing the tools and capabilities to ensure Warfighter Readiness through a program of research and development focused on measuring and modeling human information processing to enhance warfighter capabilities *before the fight,* so we can win the fight tonight and are prepared to win the fight tomorrow.

In order to ensure we can effectively carry out operations in the future environment, the HLC CTC enables *Decision Superiority* through the development and exploitation of models and tools for human perceptual and cognitive-social processing, decision-making, and learning to ensure readiness and enhance warfighter performance in complex operational environments.

Continued on next page

CTC OVERVIEW

Promote more lethal Air and Space Forces through research on human multisensory perception, learning, information processing, and action. Maximize mission effectiveness through personalized, proficiency-based readiness for multi-capable Airmen and Guardians in joint all-domain operations, enable teams of humans and machines to adapt and learn together in real time in training and operational settings, and advance considerations of human performance in system development and operational planning with digital models of perception, cognition, and action.

The long-term vision of our CTC includes the following high-level objectives:

- Development of a system for **Total Readiness Management**. This requires the creation of a persistent training ecosystem capable of replicating the operational complexities in Joint, All-Domain missions. A critical component in this ecosystem is the need for an ability to collect contextualized, purposeful data in *all* phases of learning - initial, refresher, during advanced exercises - yielding analytics for developmental training intervention and just-in-time learning.
- Development of tools to support **Collaborative, Interactive Learning**. These tools allow for real-time, context sensitive learning and adaptation that enables uniquely effective human and machine teams that learn *from and with* each other for optimized performance.
- The ability to generate **Individualized Human Digital Twins** - comprehensive, personalized models of human perceptual, cognitive, and social processing for simulating and predicting decision-making tailored to specific missions and domains, and integrating those models into larger USAF and USSF simulation environments.

The HLC CTC comprises two Core Research Areas (CRAs), each of which focuses on a set of goals in response to demand signals from DoD leadership. These CRAs, and the specific efforts that fall under each, are described in more detail in the following sections.

Human Learning & Cognition
CTC

Digital Models of Cognition
CRA

Learning & Operational Training
CRA

DIGITAL MODELS OF COGNITION

This CRA addresses the DoD's emphasis on a digital transformation, so that we may rapidly and effectively assess operational systems with human models in place in order to predict performance and mission success.

Efforts in this CRA include:

- Development of high-fidelity models of perceptual and cognitive capabilities and constraints required to simulate and predict decision-making
- Models of socio-cognitive processes and dynamics required to characterize and inform influence operations in the Information Environment

LEARNING AND OPERATIONAL TRAINING

This CRA represents AFRL's historical expertise research in elite operational training for pilots, JTACs, and other Warfighters in order to address leadership's demand for persistent readiness that can only be achieved through large-scale, Joint, All-Domain operational training exercises at a frequent cadence.

Efforts in this CRA include:

- Implementation of competency based training solutions for rapid skill acquisition, employing novel, blended training approaches and advanced modeling and simulation architectures
- The use of AI/ML to support human-machine co-learning, yielding Mission-Ready Warfighters capable of conducting Just-In-Time Operations

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Graphic by Mr. Will Graver (BAE Systems, Inc.)

The left-most section represents our efforts to develop computational, personalized models of cognitive processing that are mediated by low-level perception across the sensory systems, high-level socio-cognitive influences, and physio-cognitive stressors associated with performance in an operational environment. This modeling approach provides a framework for understanding perceptual and cognitive capabilities and constraints on an individualized level, producing insights regarding the encoding of information, and providing a foundation for understanding how individuals learn and perform tasks, how optimized performance may be maintained over time, and how new skills can be incorporated.

The fundamental understanding of human cognition resulting from these modeling efforts informs activities that support the development of effective training solutions to support readiness, as depicted in the middle section of the graphic. This phase of our research brings together the foundations of learning science with a high-fidelity, operational training infrastructure, allowing us to develop and test specific training interventions in operationally relevant testbeds.

The right-most section of the graphic represents the implementation of our modeling and training strategies set into motion in realistic, operationally-relevant, and large-scale USAF and USSF exercises, where real operators are engaged in operations across multiple domains, with Joint Forces, and measures of performance and effectiveness are collected in order to assess the true readiness of our forces.

Our research process is progressive and comprehensive, and the outputs of individual areas inform activities in the other research blocks – training data allow for the refinement and personalization of models, and data from advanced exercises measuring mission effectiveness allow us to assess the fidelity and appropriateness of our training approaches and infrastructure and further inform human modeling activities

As we continue to align our research portfolio to address the most challenging science and technology issues faced by the USAF and USSF, we will deliver capabilities to the Warfighter that will position the DoD to be the strongest fighting force in the world. ☆

Dr. Brian Simpson, Human Learning & Cognition CTC Lead, 711 HPW/RHW

Dr. Megan Morris

Digital Models of Cognition Core Research Area Lead, 711 HPW/RHWE

DIGITAL MODELS OF COGNITION

CORE RESEARCH AREA

The Digital Models of Cognition (DMC) Core Research Area (CRA) focuses on research that identifies computational and mathematical mechanisms to represent human perception, cognitive-social information processing, and behavior, including the integration of models that reflect the role of internal and external factors that modulate performance efficiency and effectiveness. The goal of our CRA is to develop holistic models that support quantitative understanding and prediction of mission effectiveness across domains and at different levels of abstraction for improved systems engineering, wargaming, operational planning, and training.

Two technical challenge areas (Lines of Effort) drive our CRA work. The first challenge area is Holistic Models for Decision-Making (HMDM), which focuses on developing multisensory models of performance and decision-making in two primary domains: multiple asset management and maximum endurance operations. These models allow us to simulate and predict decision-making in demanding, complex environments with myriad operational stressors, enabling enhanced and targeted training and readiness modeling techniques for warfighter decision-superiority. The second challenge area is Information Mastery in Cognitive Warfare (IMCW) which focuses on developing models, analytic methods, and tradecraft and researching mechanisms of information influence, enabling operators to improve Information-Related Capability and decision-making for the desired cognitive effects, social influence, and mastery of the Information Environment. The DMC CRA includes a diverse team of scientists, engineers, and business professionals developing innovative, integrated modeling capabilities and tools. Our CRA has had a successful FY24 and are looking forward to accelerating FY25 work to meet warfighter needs. Following this article are updates from our LOEs on the exciting work we have accomplished and what is yet to come! ☆

Dr. Megan Morris
Digital Models of Cognition CRA Lead, RHWE

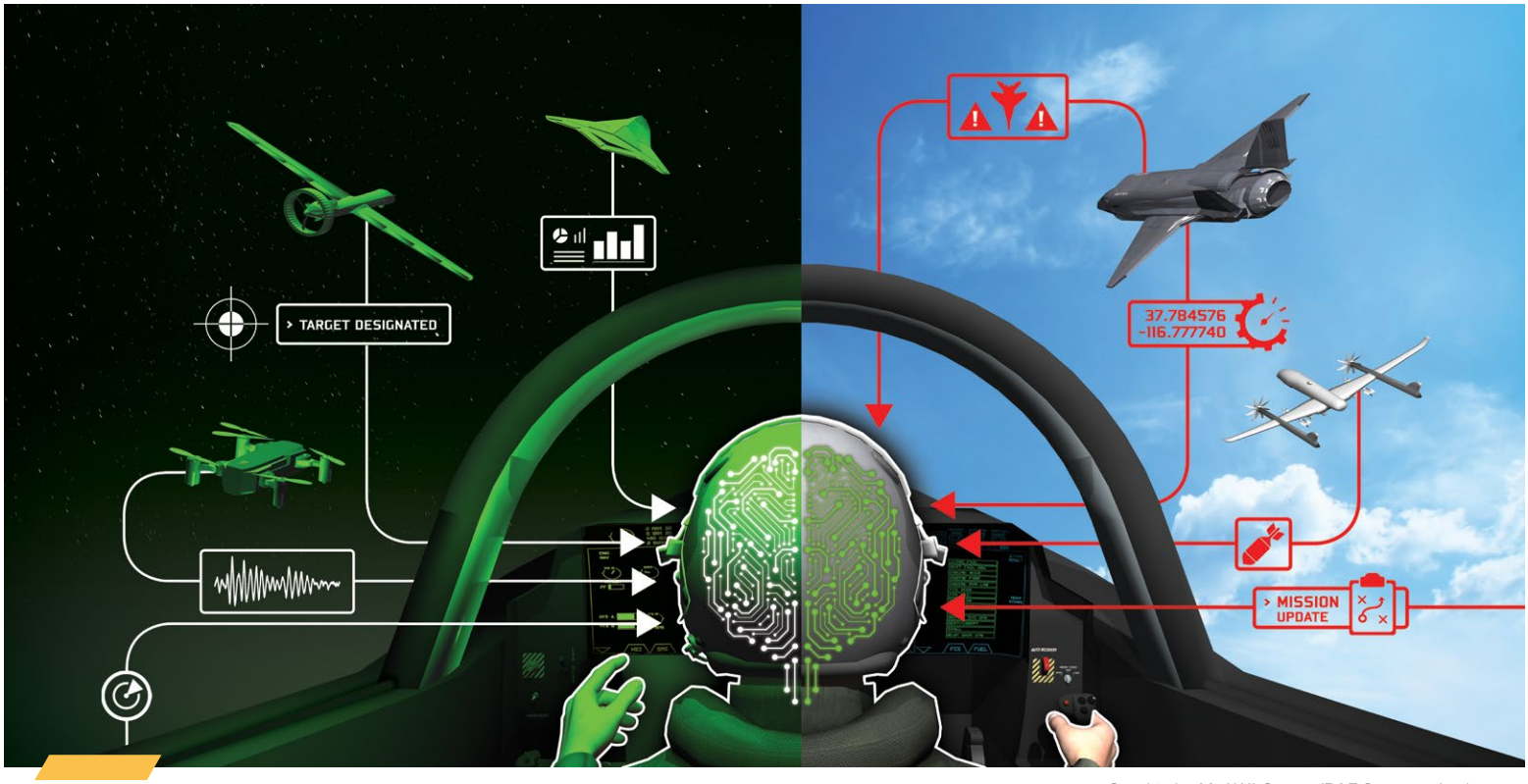
CRA OVERVIEW

Emphasize research to identify computational and mathematical mechanisms that represent human perception, information processing, and behavior. Integrate models to reflect the role of internal and external factors that modulate performance efficiency and effectiveness. Develop holistic models that capture a host of cognitive and social mechanisms and support quantitative understanding and prediction of mission effectiveness across domains and at different levels of abstraction for improved systems engineering, wargaming, operational planning, and training.

Digital Models of Cognition
CRA

Holistic Models for Decision-Making
LOE

Information Mastery for Cognitive Warfare
LOE



Graphic by Mr. Will Graver (BAE Systems, Inc.)

HOLISTIC MODELS FOR DECISION-MAKING

LINE OF EFFORT

The Holistic Models for Decision-Making (HMDM) Line of Effort (LOE) focuses on multi-sensory cognitive models that support decision superiority. Currently, HMDM delivers a digital library of cognitive models with a variety of data, modeling, simulation, and analysis tools in command of collaborative combat aircraft and cognitive state changes during long-duration mobility air missions. The line of effort examines, creates, and builds integrated generalized models of human perception, cognition, and behavior, and evaluates how these are influenced by external modulating factors.

The Collaborative Operations and Models for Managed Aircraft Navigation and Decision-Making (COMMAND) focus area combines research into the impact and influence of acoustic and visual environments on cognition with investigations into information complexity and other external stressors to generate models to evaluate cognitive states at diverse points within collaborative missions. One aspect of COMMAND is the impact of the noise level on cognitive fatigue. The Deleterious Effects of Noise on Cognition (DENC) effort is utilizing noise measurements from an F-35A interior at various levels to determine the reduction in response time and cognitive cost for a multi-tasking experiment, which was previously modeled in quiet.

The acoustic environment is coupled with the electronic systems that exist within modern aircraft. The perception of speech over the radio is altered and could become corrupted, making comprehension of speech difficult, if not impossible. The Digital Engineering Toolbox for Human Speech Communication and Reception (DETHSCAR) effort within COMMAND seeks to understand how the electro-acoustic attributes of the communication system impact the intelligibility of speech. Another aspect of military communication is the use of brevity code, and the Language Comprehension for Asset Management effort within COMMAND is studying how human cognition is altered to comprehend natural and brevity language.

Program Leads

LOE LEAD
Dr. Frank Mobley

PROGRAM MANAGER
Capt Shinae Wagner

PROGRAM MANAGER
Ms. Kayelin Tiggs

As the Air Force continues to explore the Next Generation Air Dominance doctrine, they are considering additional platforms for control of the collaborative aircraft in the future battlespace, which opens the integration of night vision goggle (NVG) modeling with collaborative aircraft into COMMAND. The Visual Perception for Night Operations team is examining perception in visual search tasks with computational models to understand low-level cognitive and perceptual processes that underlie both aided and unaided vision, which leads to understanding of visual perception in unaided, low-light conditions, and with augmentation through NVGs.

Continued on next page

The Visual Perception for Night Operations researchers are working with NAMRU-D on the effects of green and white phosphor night vision goggles on fatigue. Researchers at NAMRU-D collect the data, while the HMDM researchers are assisting with calibration and task generation, as well as data analysis and model development.

COMMAND Successes

1. Gathered information on Air Battle Manager training from local SME.
2. Engaging with AFLCMC on communication system requirements and characterization of MH-139.
3. Completed pilot and main data collection for cognitive impairment of multi-tasking in various levels of noise.
4. Initiated data collection on command of collaborative aircraft in real-world scenario with rated pilots.
5. Engaged with NAMRU-D on fatigue of visual system research project.
6. Continued development of visualization of training states that assists with determining when the more robust cognitive models are required rather than statistical-based models.

FAST Successes

1. Initiated communication with AFLCMC groups for characterization of interior noise and light contamination during typical mobility missions.
2. Built simulator environment to replicate task load, acoustic environment, and provide cognitive testing for long-duration missions of C-130.
3. Developing initial physiocognitive model of Modafinil effects on fatigued performance based on archival dataset with NAMRU-D and developing protocol on ctVNS as a fatigue countermeasure to develop abstracted, individualized physiocognitive model.
4. Collaborating with NAMRU-D to determine the influence of night vision goggles (both green and white phosphor) on sleep fatigue.

An additional data collection effort from the Multi-Cue Decision-Making effort is exploring the impact of wingmen composition. This element of COMMAND examines pilots' decision-making strategies while controlling their own ship and commanding four collaborative aircraft. Rated pilots will be provided with either a homogenous (all aircraft are equivalent) or heterogeneous (all aircraft are distinct and different) and asked to conduct a strike mission. From this experiment a variety of task analyses can be extracted to feed further research efforts.

One application of the task analyses from COMMAND will be adaptation of cognitive and statistical models of learning to the commanding of collaborative aircraft, adapting models of knowledge and skill acquisition. With an understanding of the variety of tasks involved in the command of autonomous aircraft, these models can be altered to represent how pilots train to work with collaborative aircraft. This work is an extension of the models from the Hybrid Cognitive Models effort developed with AETC and the Defense Language Institute and will feed into the Warfighter Learning Technologies LOE.

A second focus area for HMDM is the impact of fatigue on the endurance missions that are central to operations in US Indo-Pacific Command (USINDOPACOM) and the Great Power Competition. Air Force assets that participate within USINDOPACOM will be required to operate at extreme ranges, which lead to extended duration sorties. The COMMAND research demonstrates noise fatigues the mental capacities of airmen. However, the Fatigue from Acoustic, Stimulants, and Tiredness (FAST) demonstrates that it is the length of exposure in addition to level that must be considered. An experiment is beginning that requires participants to sit for multiple hours, conducting typical tasks for a Combat Systems Officer (CSO). Once each hour, they will perform a series of cognitive tasks to estimate the current cognitive load.

It is expected that these longer duration missions will task the airmen to their cognitive limits, so another research area investigates countermeasures to overcome fatigue. Collaborating with researchers in RHB, projects seek to understand the limits of the current physiological monitoring, partnering with current fatigue tracking capabilities, so that physiocognitive models of fatigue can inform use of stimulants such as Modafinil and cervical transcutaneous vagal nerve stimulation (ctVNS) to combat fatigue. These models will provide individualized countermeasure suggestions to Warfighters based on stimulant uses.

Together, COMMAND and FAST are building cognitive models of individualized processes for the specific customers, but a library of these models provides points of integration. HMDM is working with other researchers across the 711th Human Performance Wing to explore the integration of these independent models. This provides a single library that possesses elements that can be switched on or off depending on the situation. ☆

Dr. Frank Mobley, Holistic Models for Decision-Making LOE Lead, 711 HPW/RHWEO

Graphic by Mr. Will Graver (BAE Systems, Inc.)

INFORMATION MASTERY IN COGNITIVE WARFARE

LINE OF EFFORT

The Information Mastery in Cognitive Warfare (IMCW) Line of Effort (LOE) fosters a unique blend of research from various disciplines, including computational modeling, computer science, and cognitive and social psychology. IMCW aims to tackle issues related to information maneuvers, influence strategies, and developing scalable models that combine cognitive and social realism. We evaluate the triggers of influence and connections between online and offline behaviors, such as online discussions leading to mobilized protests. Our goal is to integrate various sources and modalities of data to create a holistic picture of the Information Environment, that also captures the nuances of culture and hierarchies within social structures. Uncertainty in this domain poses a challenge, as information flows are constantly in flux and can be contradictory, degraded, denied, destroyed, or disrupted.

Our ultimate goal is to create workflows and tools while leading research that will aid Information Warfare (IW) practitioners in understanding influence tactics for decision-making and planning. We explore both AF/DoD's Information Warfare (i.e., controlling information flow) and NATO's Cognitive Warfare (i.e., exploiting information for conflict). Our adversaries primarily use non-kinetic warfare to undermine trust, making it crucial for us to leverage cognitive and social psychology expertise. By staying current with the IW community and developing Air Combat Command (ACC) relationships, we ensure our research remains state-of-the-art and applicable to the USAF.

The LOE fosters a unique blend of research from various disciplines, including computational modeling, computer science, and cognitive and social psychology.

Program Leads

LOE LEAD
Dr. Katie Larson

PROGRAM MANAGERS
Capt Denita Guthery
Ms. Kirsten Rice

Our three main research thrusts are:

1. **Characterization of Operations in the Information Environment (OIE):** This involves developing descriptive and predictive analytics from network and content data to inform assessment and decision-making, focusing on information maneuvers and anticipatory analytics for forecasting.
2. **Scalable Models for Cognitive Warfare:** We will create models at varying scales to study social dynamics and vulnerabilities impacting individual and group-level cognition.
3. **Resilience to Malign Influence:** Through experimentation, we will explore the psychological mechanisms of influence, testing methods aimed at reinforcing "blue force" resilience or diminishing "red force" cognition.

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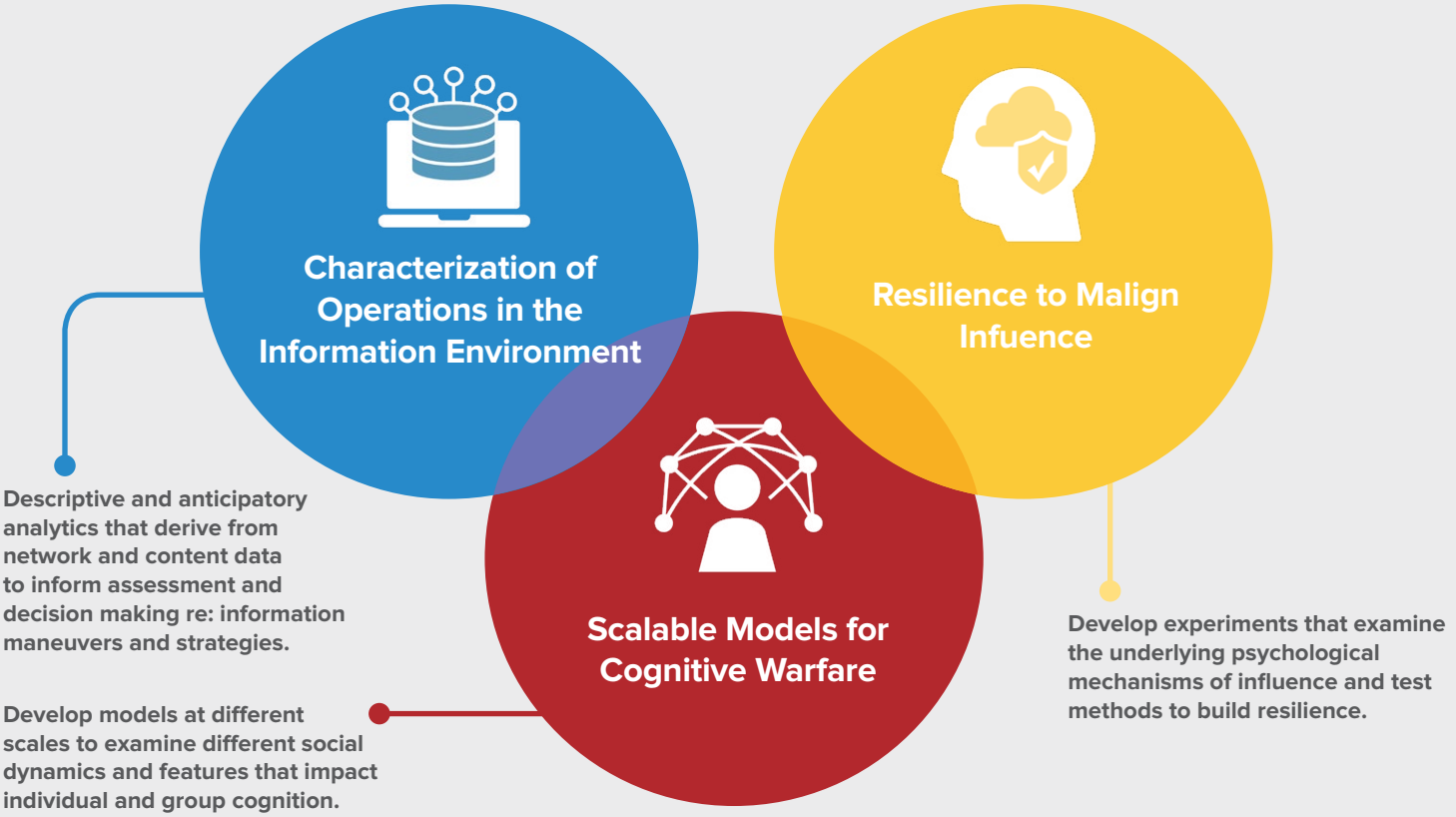
The Information Mastery in Cognitive Warfare LOE enables warfighters to anticipate, operate, and adapt to rapid changes in the information environment.



Multiscale Modeling for the Continued Influence Effect

Research Leads: Dr. Taylor Curley & Dr. Alex Hough

The Scalable Models for Cognitive Warfare task has continued to explore the cognitive vulnerabilities underlying misinformation and deception, particularly in the case of misleading information that has a lasting influence, i.e., the continued influence effect (CIE). Importantly, the task has established computational models that explore these topics at several different models of analysis. At the level of the individual, we have leveraged the Adaptive Control of Thought–Rational (ACT-R) architecture to simulate how memory dynamics and the core-affect theory of emotion can lead to CIE. At higher levels, we have used agent-based modeling (ABM) comprised of social agents with memory mechanisms from ACT-R and belief adoption rules from Social Sampling Theory (SST) to simulate misinformation and polarization in social networks. We have presented the results of these studies at forums ranging from academic conferences, such as the International Conference on Cognitive Modeling (ICCM), to international technical panels, such as the NATO committee on Meaningful Human Control in Information Warfare (NATO HFM-377).

Utilizing Deep Learning for Detecting Auditory Deepfakes

Research Leads: Dr. Wen Dong, Dr. Sarah Bibyk, Ms. Olivia Leung

Detecting auditory deepfakes is crucial to our mission objectives, where misinformation can compromise operations, mislead personnel, and threaten national security. With the increasing sophistication of synthetic audio technologies, the ability to discern authentic communications from deepfakes becomes vital for maintaining trust and operational integrity. Additionally, recent advances in deep learning, such as generative AI and large language models, have amplified the threat posed by synthetic audio, making robust detection even more critical. To address this challenge, we are utilizing a proprietary toolbox, PyTimbre, which can extract key auditory features such as pitch, timbre, and rhythm, enabling us to identify subtle discrepancies between genuine voices and their manipulated counterparts. Furthermore, incorporating human subject data can enhance our detection capabilities, providing a rich set of acoustic features that reflect natural speech patterns. This combined approach aims to improve our algorithms and bolster military readiness against the risks posed by auditory deception.

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Supporting Training Requests from the 39th Information Operations Squadron & ACC

Team Lead: Capt P. Alex LaFlam-McFall

Given the challenges of conducting Information Warfare (IW), the operational community needs a capability that can properly simulate US activities chosen to influence target audiences towards behavior change. This could boost real-world operations, but also initial qualification trainings and skill refinement in wargames or exercises. To assist, RHWE initiated a project to develop a software that can simulate the actions and consequences of information warfare maneuvers by liaising directly with the 39th Information Operations Squadron to create a capability that can refine tactics, techniques, and procedures for Information Operations planners. If successful, it aims to become a permanent tool at the Hurlburt Field schoolhouse that instructors can use to train and evaluate students pursuing information warfare qualifications or that "white cell" evaluators can use to measure the effectiveness of operations in which outcomes are difficult to predict.

With the 39th Information Operations Squadron (IOS), the RHWE team discussed the genuine need that would be met by the development of software that could ingest data about the information environment, including the political, military, economic, social/cultural, or infrastructure layouts of geographical places with defined populations. This data could then be manipulated to test a variety of conflict/competition scenarios, enabling experimentation and feedback on options that is not currently permitted by traditional "map and whiteboard" training. The output of these computations through the software's interface would be an assessment of which information operations plans are more likely to achieve the desired results, and which would be ineffective or even detrimental. This would only be possible through the creation of a simulated environment with tailorable conditions to specific but realistic scenarios that will help educate and train the force while serving as a testbed for future concepts and experimentation in the information environment.

The scheme of maneuver termed Agile Combat Employment is a crucial but complicated and challenging concept for military operations in a potential conflict in the Pacific Ocean against national adversaries. As such, flexibility and adaptability are necessary for resource management and the use of kinetic and non-kinetic assets to achieve effects. As such, RHWE is also partnering with the Navy's Disruptive Technologies Laboratory (DTL) to spearhead a cross-service effort to develop a joint training program focused on "Improvisational Warfare," in which servicemembers will be training in fundamental ways of thinking and with fundamental skills to leverage what may be unconventional resources and assets in unconventional environments to still achieve their assigned mission. There is an identified lack of training and education in the Air Force that would enable Airmen to fight from a position of disadvantage, given historical asymmetry towards US advantage. Given that all military assets have an inherent psychological effect of some sort, Information Operations is a compelling space to experiment within and practice the concepts of improvisational warfare because of the room for creativity and the propensity to have to use unconventional assets for solutions. ACC, the lead MAJCOM for IW, is directly tied to this joint effort with the Navy's DTL and has identified AFRL as a stakeholder in this effort.

RHWE aims to create course content pertinent to cognitive warfare, cognition, or perception, and to provide measures of effectiveness for student learning assessed via biological, neurological, or behavioral changes. We aim not only to create a new capability for the training of warfighters, but to also demonstrate the Human Learning and Cognition (HL&C) Core Technical Competency (CTC)'s expertise in experimental, modeling, and research domains to a lead MAJCOM. This would require diverse expertise from across the Directorate, leveraging the cognitive and modeling research of RHW and the physiological/neurological research of RHB to better enable warfighter training, education, and ultimately, readiness for conflict or flexible deterrence. Successful support to this project would permit branch and cross-division participation in eminent focus areas for the Air Force from a strategic standpoint, being both Agile Combat Support and competition with adversaries through Operations in the Information Environment/IW. ☆

Dr. Christopher Stevens

Learning and Operational Training CRA Lead and Research Psychologist, 711 HPW/RHWE

LEARNING & OPERATIONAL TRAINING

CORE RESEARCH AREA

The wars of tomorrow will be fought by teams consisting of humans and autonomous agents. These Human-Machine teams must be able to understand each other, flexibly learn new content, adapt to uncertain, rapidly changing combat situations, and maintain decision superiority. Training technology and methods must reflect this new reality. The Learning and Operational Training (LOT) Core Research Area (CRA) aims to improve learning and understanding in the context of the technology and battlefields of tomorrow. Specifically, the research focuses on supporting ecosystems that maximize mission effectiveness, minimize costs, personalize training requirements, and enable uniquely effective human-machine teams.

Two technical challenge areas (Lines of Effort or LOEs) drive our CRA work: Warfighter Learning Technologies and Co-Learning for Adaptive Human and Machine Teams.

Warfighter Learning Technologies

This LOE applies cognitive and learning science to develop ecosystems, analytics, and interventions that enable robust warfighter skill acquisition. The LOE achieves this through two primary initiatives. The first is Fidelity Requirements for Proficiency Based Training. Fidelity refers to the extent to which an aspect of the training environment emulates the real operational environment. This initiative seeks to investigate the relationship between the various possible degrees and types of fidelity and learning outcomes. This will culminate in tools for front-end analysis to inform design, selection, and adaptation of training ecosystems. Second, the Learner Competency Modeling initiative seeks to develop novel models and predictive analytics to track learner operational proficiencies, anticipate decay, transfer, and interference in those proficiencies, and provide inputs for adaptive ecosystems to support individualized training.

Co-Learning for Adaptive Human and Machine Teams

This interdisciplinary LOE to investigate and enhance interactive learning and collaborative training of humans and AI-enabled machines. Research in this LOE elucidates the ways in which humans and AI learn with and from each other. The unique learning dynamics of human and machine teammates present novel challenges in training research and application. These challenges include establishing common ground and shared mental models among teammates, developing metrics for learning in complex, uncertain domains, and identifying knowledge gaps in team members to apply just-in-time tutoring.

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> **"We aim to provide our warfighters and the autonomy that supports them with the training tools they need to adapt, fight, and win."**
>
> **— Dr. Christopher Stevens**
> Learning and Operational Training CRA Lead and Research Psychologist, 711 HPW/RHWE

Graphic by Mr. Will Graver (BAE Systems, Inc.)

CRA OVERVIEW

Establish an ecosystem that maximizes mission effectiveness while minimizing costs by matching technologies to learning and performance needs; supporting high resolution human and system measurement and quantitative, proficiency-centric readiness assessment and prediction at the individual and team levels. Explore how to enable human and machine co-learning to support mutual adaptation and understanding in human-machine teams.

The LOE's research also seeks to improve the training and adaptation of AI teammates in real time based on human input. Planned use cases for this work include improved training and decision support tools for Space Domain Awareness, Cislunar Operations, and AF/SF/Joint wargaming.

We envision work from both LOEs culminating into intelligent tutors, decision support tools, autonomous teammates, novel AI-powered metrics for measuring and augmenting Warfighter proficiencies, and improved ecosystems supporting the training of human teams and human-machine teams in operational domains. We aim to provide our Warfighters and the autonomy that supports them with the training tools they need to adapt, fight, and win. ☆

Dr. Christopher Stevens
Learning and Operational Training CRA Lead
and Research Psychologist, 711 HPW/RHWO

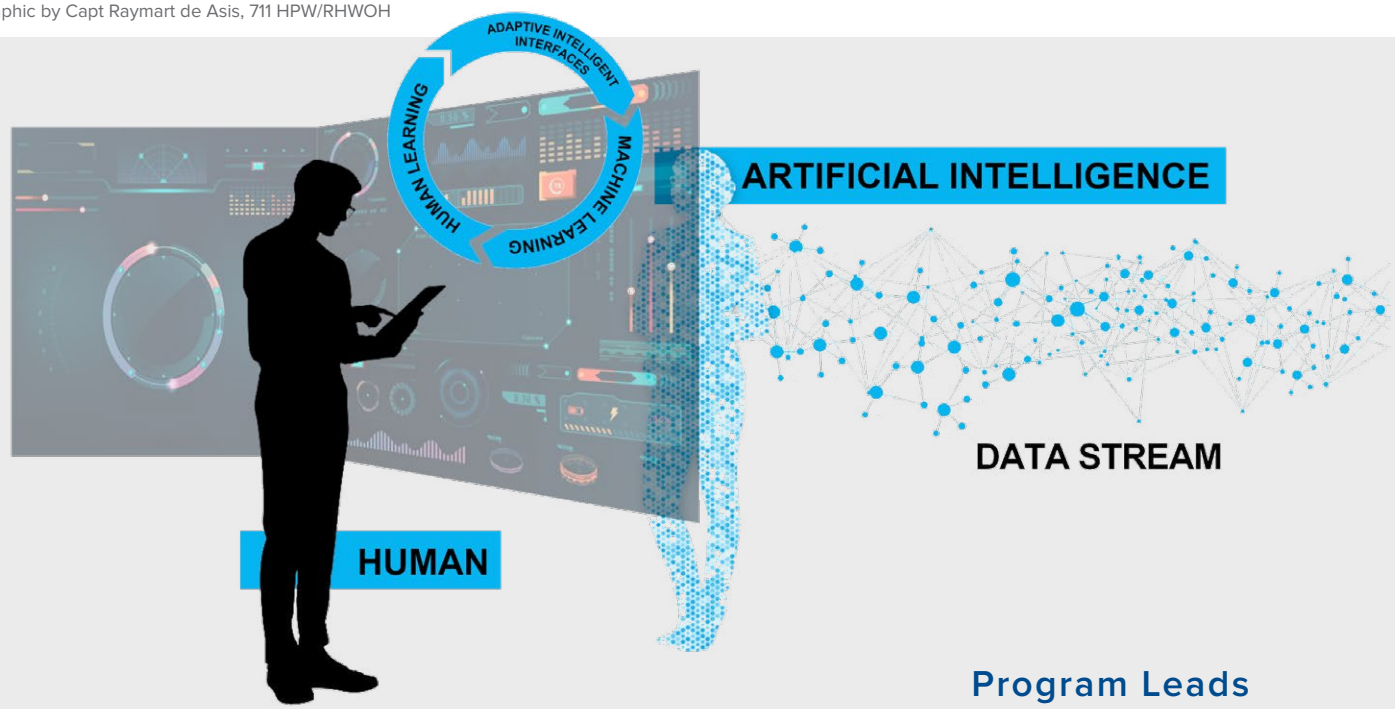
Learning and Operational Training
CRA

Co-Learning for Adaptive Human & Machine Teams
LOE

Warfighter Learning Technologies
LOE

Gaming Research Integration for Learning Laboratory®
GRILL®

Graphic by Capt Raymart de Asis, 711 HPW/RHWOH



CO-LEARNING FOR ADAPTIVE HUMAN-MACHINE TEAMS

LINE OF EFFORT

Program Leads

LOE LEAD
Dr. Lorraine Borghetti

PROGRAM MANAGER
Capt Jaren Boyken

"Co-Learning" LOE Tackles Challenges for Nascent Technology

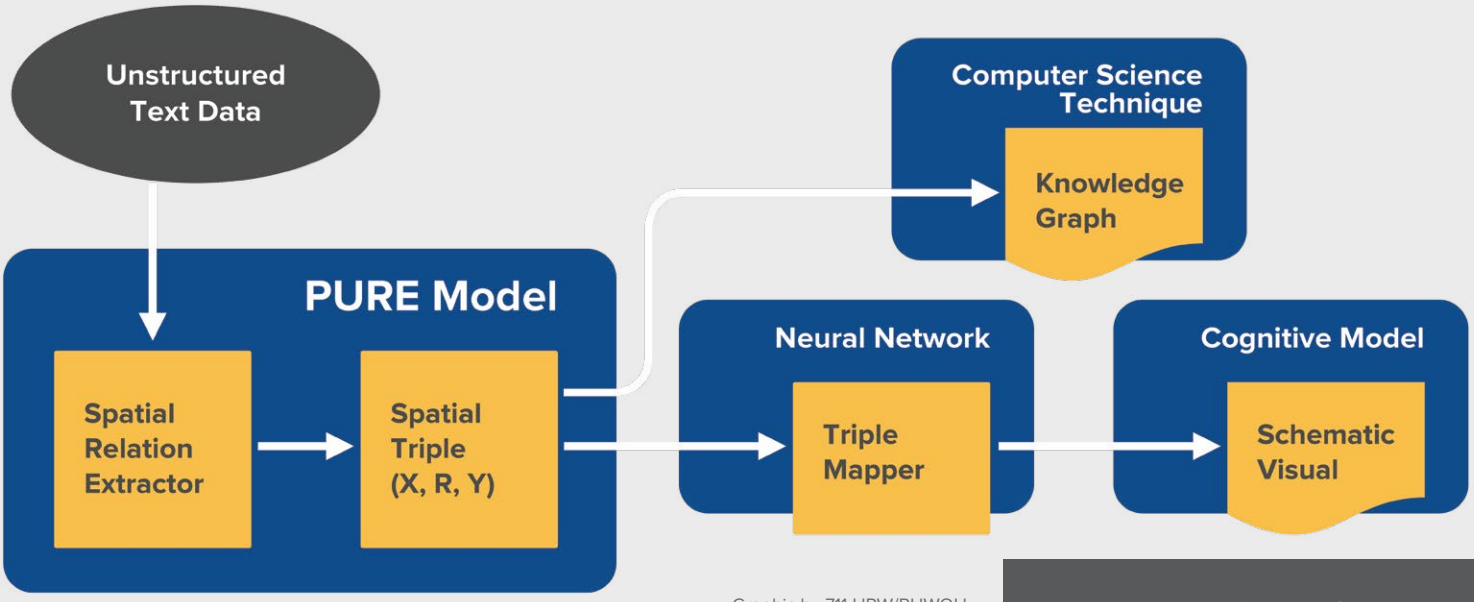
The Co-Learning for Adaptive Human-Machine Teams LOE (Co-Learning, for short) aims to investigate an emerging technology where, together, a human operator and a machine teammate learn from interactions with one another as well as from novel events within dynamic, uncertain environments. Here, machine refers to Artificial Intelligence (AI) agents, which range from Generative AI (GenAI) to deep neural networks to rule-based models.

Our emphasis explores operator teaming with autonomous agents: human and machine teammates who work interdependently towards a shared goal. Here, autonomy can vary from considerable human oversight to an autonomous system with a high-level of independence in responsibility and decision-making. Due to the diverse expertise required to explore this unique Human-Machine Teaming problem space, the Co-Learning team is appropriately interdisciplinary, leveraging cognitive scientists, research psychologists, computer scientists, neuroscientists, data scientists, and computer engineers.

The Co-Learning portfolio currently focuses on multiple research efforts within Space and Air domains. These efforts address: (1) team and/or individual readiness needs and (2) operational decision-making. The research is positioned to contribute to mission sets involving dynamic environments such as fighter pilot training, Space Situational Awareness (SSA), and wargaming, to name a few. These projects are expected to produce critical insights as well as 6.2 level prototypes for integration into and/or transition to higher Technology Readiness Level efforts. These mission-oriented projects are enabled through additional Co-Learning research investigations that provide foundational insights. These investigations include mental model elicitation pipelines for spatial reasoning and team-task cognition, novel metrics for Co-Learning investigations and prototypes, simulations of geo-synchronous and cislunar orbital space modelled within innovative software engines such as Basilisk and RESONAATE, and the development of a cislunar trajectory forecasting model.

Whether foundational or applied, the nascent area of co-learning requires innovative techniques and approaches to develop machines that can learn from humans. To help advance this early-stage research, the Co-learning team also collaborates with experts within AFRL (RHWT, RV, RI, RD), at AFIT's Center for Space Research and Assurance (CSRA), and with leaders in the field at academic institutions (Ohio State University, Virginia Tech, University of Colorado-Boulder, Arizona State University, University of Michigan, University of Dayton Research Institute). ☆

Dr. Lorraine Borghetti, Research Lead,
Co-Learning for Adaptive Human-Machine Teams LOE



Graphic by 711 HPW/RHWOH

Figure 1. This is a diagram of the Spatial Interactive Representation Alignment pipeline. The pipeline intakes unstructured text and passes it through the PURE Model. PURE outputs spatial triples from the unstructured text and passes that information to the Triple Mapper and the knowledge graph module. The Triple Mapper maps the spatial triples on a spatial array and outputs a schematic representation of the spatial relationships extracted from the unstructured text while the knowledge graph modules intakes the same elicited spatial triples and represents them in a knowledge graph.

"Are You Thinking What I am Thinking?"

Investigating Approaches for Autonomous Elicitation and Representation of Human Spatial Mental Models in Human Autonomous Teams for Satellite Operations

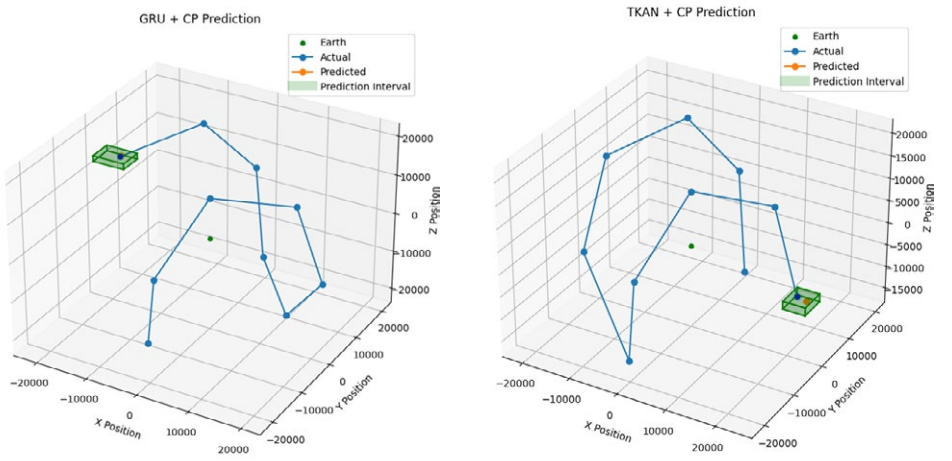
United States Space Force (USSF) strategic documents call for human-artificial intelligence teaming (HATs) to augment decision making within USSF operations. Subject Matter Experts (SME) from AFRL Space Vehicles Directorate (RV) have noted high reluctancy amongst satellite operators to accept artificial intelligence (AI) tools and integrate them into their workflow. One noted possible contributing factor is a general sense of a lack of trust and transparency amongst satellite operators when using AI tools integrated into their systems. Some operators have expressed that the risk is simply "too high" for them to use an AI system that they cannot predict and have limited experience with. The Co-Learning for Adaptive Human Machine Teams Line of Effort (LOE) has been investigating Human- AI Co-Learning, synergistic learning over time between humans and AI agents, using satellite operations (i.e., proximity operations and situational awareness) as a use case. One of our research portfolios, Interactive Representation Alignment (IRA), is specifically investigating shared mental models within HATs, through representing human mental models in AI systems. Our Spatial Interaction Representation Alignment (SIRA) project aims to identify and validate approaches for autonomously eliciting and representing spatial mental models in AI agents. We hypothesize that, through representing human mental models in AI systems, AI systems can align their aid, information, and probes with the human operator's mental model, reducing the unpredictability and supporting trust within HATs. This is particularly imperative in satellite operations, where operators are conducting teleoperations in the absence of a common operating picture depicting the spatial scene in which they are conducting operations. In these cases, operators may rely even more on their spatial mental model of their mission space, using it as their primary common operating picture. In order to effectively integrate AI tools within satellite operations, AI tools may benefit from a model of the satellite operator's spatial mental model of their mission space. Then, the AI tool can query the human's spatial mental model to identify key gaps, misalignment with truth data, and store valuable context situated information/cues to increase shared mental models and trust within the HAT.

This year the IRA team has made significant progress on the SIRA project. Our team identified key requirements for autonomous spatial mental model elicitation and representation, developed a prototype SIRA pipeline, and conducted a preliminary evaluation on pipeline performance. The SIRA pipeline employs a multi-disciplinary approach using methods and techniques from both cognitive modeling and computer science. The SIRA pipeline is designed to intake unstructured text, such as operator conversations. These conversations are often embedded with rich information about the mission space, current mission status, and coordination amongst a team. SIRA takes that information and extracts information related to the spatial relationships between key entities in the mission space (i.e., satellite position, orientation, etc.). To extract this information, we are using the Princeton

Continued on next page

University Relation Extraction system (PURE). PURE identifies the entities and spatial relation terms in the unstructured text. Then PURE uses those entities and relation terms to create triples. Triples are a common way for representing relationships between entities and distills the information to simple subject, entity, relation annotations. These triples are then sent to a small neural network we developed called "The Triple Mapper" this module simply maps the elicited triples into a 2D spatial array, this approach was borrowed from state-of-the-art cognitive model approaches for spatial reasoning. The spatial array schematically depicts the spatial relationships between the entities by placing using the relation term to place entities on the spatial array. Lastly, the elicited triples are also sent to a knowledge graph module that will represent the same triple that was represented in the spatial array as a knowledge graph. These two representations depict the relational and hierarchical relationships inherent in spatial relationships. These representations are commonly used in the computer science and cognitive modeling field. Initial preliminary evaluation of the SIRA pipeline suggest that SIRA can accurately elicit and represent simple qualitative spatial descriptions with 2-4 spatial relationships. Future work will include a more robust evaluation of the SIRA pipeline and expanding its ability to intake more vague, complex, and content rich unstructured text. Additionally, we aim to explore real-time approaches for AI agent driven querying of these human operator spatial mental model representations. This may enable real-time identification of operator knowledge gaps, cues, and errors. We suggest that this can support shared mental models within HATs and increase efficient trust calibration. Lastly, we aim to continue to mature these methods to help decrease the perceived risk incurred by satellite operators when using AI tools to support their work. ☆

Dr. Jayde King, Research Psychologist, 711 HPW/RHWOH



Graphics by 711 HPW/RHWOH

Figure 1. **These plots illustrate predicted satellite vector states based on the nine preceding true values from historical data. The central green point represents Earth's position, with blue points indicating the actual historical values of the orbit. The orange point marks the model's prediction for the tenth value, and the green shaded region depicts the prediction interval. The left plot employs a GRU model augmented with Conformal Prediction, while the plot on the right makes use of a TKAN model with Conformal Prediction.**

Predicting Cislunar Trajectories using Machine Learning and Conformal Prediction

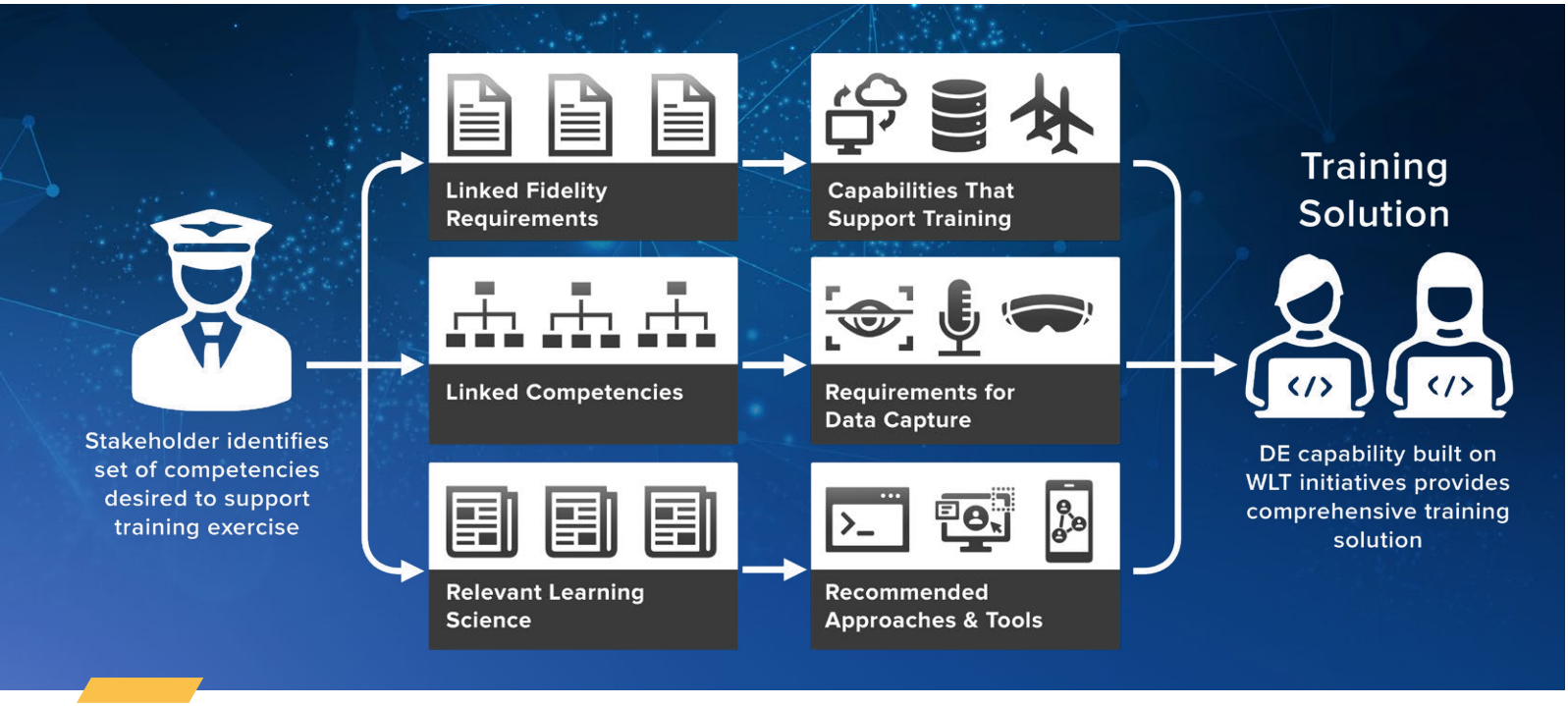
Space serves as a critical use-case for segments of the Adaptive Human-Machine Team Co-learning LOE's research. The space domain, historically, has not been supportive of Artificial Intelligence/Machine Learning (AI/ML) methodologies regarding satellite trajectory forecasting, relying on computationally intensive classical physics models to make predictions. As part of the "machine side" of the Co-Learning thrust, we developed novel approaches to predicting cislunar trajectories using Machine Learning augmented with Conformal Prediction techniques. Classical models such as Simplified General Perturbations (SGP), Simplified Deep Space Perturbations (SDP), and Circular Restricted Three Body Problem (CR3BP) face limitations in the complex and chaotic environment of cislunar space, necessitating more sophisticated methods. Furthermore, the more generalized n-body problem quickly becomes complex and very computationally expensive, prompting the investigation into methods of approximation that would be more efficient but with similar analytical results. We explored a range of machine learning models including Long Short-Term Memory Networks (LSTMs), Gated Recurrent Units (GRUs), Temporal Kolmogorov-Arnold Networks (TKANs), eXtreme Gradient Boosting (XGBoost), and Random Forests, to address these challenges.

Our study demonstrated that deep learning methods yield impressive predictive performance, even compared to more conventional approaches, although they still struggle with data gaps and irregularities. By also integrating Conformal Prediction, reliable prediction intervals are provided regardless of the underlying model's distribution, thereby enhancing the robustness and usability of the predictions in operational settings. Furthermore, we highlighted ongoing developments with Kolmogorov-Arnold Networks, which promise improved accuracy and explainability. These networks leverage the universal approximation capabilities of Kolmogorov-Arnold superpositions, offering a potential breakthrough in trajectory prediction for space operations. Our preliminary results indicated that this combined methodology can significantly enhance decision support for operators by providing more accurate and reliable predictions in the highly dynamic cislunar environment. ☆

R. Nolan Kramer, MS
Data Scientist/Computer Engineer, 711 HPW/RHWOH

Capt John Patrick O'Donnell, MS
Data Scientist/Operations Research 711 HPW/RHWOH

OVERVIEW OF WLT INITIATIVE SUPPORTED CONOPS



Graphic by Dr. Ryan Wohleber, 711HPW/RHWOW

WARFIGHTER LEARNING TECHNOLOGIES

LINE OF EFFORT

The Great Power Competition will demand that we "pull all the capability out of every single Airmen that we put into harm's way, and…un-constrain them from the functional stovepipes that we grow them in today." (Chief Master Sergeant of the Air Force David A. Flosi; Air & Space Forces Magazine, 2024). Creating and sustaining a readiness and warfighter capability advantage consistent with this 'Mission-Ready Airmen' concept will require robust, reliable, and innovative training approaches and capabilities. Accordingly, the aim of the Warfighter Learning Technologies (WLT) Line of Effort (LOE) is to advance the state-of-the-art in Warfighter training by breaking new ground in training system design, learner proficiency estimation capability, intervention design, and training strategy. WLT's aim is to integrate these innovations into mission-oriented training solutions across the Air Force and validate their impact through initial feasibility testing and longitudinal analysis. Work currently underway includes 1) development of a just-in-time training capability for maintainers that uses training theory to accelerate skill acquisition and minimize the time needed to train a novice to necessary proficiency levels, 2) the development of instructor tools that gauge medical warfighter team proficiency in combat casualty air transport by analyzing communication, movement, and equipment interactions providing instructors with quantitative insights to gauge learner proficiency and inform decisions about training needs, and 3) development of training concepts and instructional tools for human-autonomy teaming, including learning that improves trust calibration, to support collaborative combat aircraft concepts.

To advance the state-of-the-art in training, WLT focuses on supporting an individualized, proficiency-based, experiential learning approach to training. As such, much of WLT's work is designed to support, inform, and operate within distributed live, virtual, and constructive environments or more simply, "blended environments". These environments provide immersion, instructor control, reduced cost, and flexibility, supporting critical teams and teams-of-teams reps in realistic environments. Importantly, blended environments can support a digital engineering infrastructure that provides real-time data about mission events and learner interactions. To make use of this observable information, competency models can be created to underpin learner proficiency estimates to inform adaptive interventions, instructor and learner feedback tools, and learning technology development. In WLT we utilize several in-house blended solutions from the Gaming Research Integration for Learning Laboratory (GRILL), which focuses on the repurposing of Commercial Off-The-Shelf technologies to provide low-cost training solutions, to the Multi-Domain Operational Test and Training Infrastructure (MDOTTI) which is used to investigate best practices and demonstrate data infrastructure integration across multiple environments. With this approach and infrastructure, WLT is pursuing two major capability-enabling initiatives.

Program Leads

LOE LEAD
Dr. Ryan Wohleber

PROGRAM MANAGER
Lt Alexandra Weisenburger

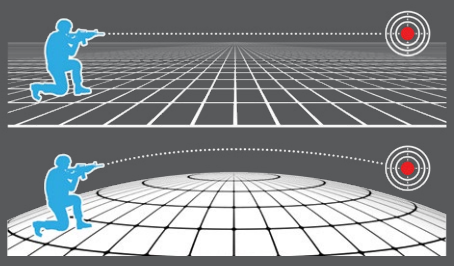
Continued on next page

ILLUSTRATIVE FIDELITY CHALLENGES

Engineers must contend with a myriad of fidelity challenges in the development of blended training environments, including upholding standards for accuracy, temporality, and entity interaction.

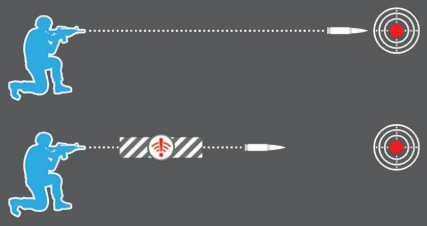
Accuracy

Accuracy of a bullet flying through an environment on a different trajectory because one component of the blended sim is rendering based on a flat world and another based on a spherical one.



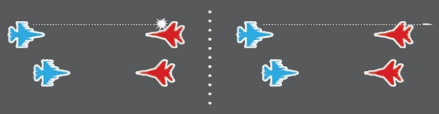
Temporality

Temporality or the coordination of the bullet position such that the bullet is in the right place at the right time (disrupted by network issues) – tolerance is the disparity/delay in bullet position



Interaction

Interaction is the validity of the response to the object's effects, in this case the bullet striking something – it is problematic if one system component (an F16 sim) ignores the interaction (no damage or no visual indicator of damage that DID occur) or if two systems render different responses to the interaction.



Graphics by Mr. Will Graver (BAE Systems, Inc)

The First Initiative

Proficiency-based Training Fidelity Requirements (PTFR) – is, as the name suggests, designed to improve warfighter training by developing a front-end analysis process for training environment fidelity. Currently, development of these environments leans heavily on developer intuition, which typically centers on a general goal of increasing realism. However, creating blended environments involves coping with complex, time consuming, and costly challenges. Actionable information about how to optimize resources is needed. Specifically, developers need fidelity threshold requirements to ensure that synthetic environment solutions support specific training targets. While fidelity assessments exist, these provide only high-level, qualitative insights for existing systems. Their outputs require interpretation by developers and are typically aligned to broadly defined use cases or execution of specific tasks. However, the PTFR initiative will provide training system agnostic requirements ahead of time for the design or identification of suitable environments. Further, it will support a proficiency-based training approach by establish those requirements against specific competencies, such as Mission Essential Competencies (MEC). The PTFR process will be compatible with existing processes for constructing competency models including MEC workshops; fidelity requirements can be identified while competencies themselves are created and specified utilizing the same set of SMEs. Finally, the PTFR process will systemically identify research opportunities by discovering gaps in scientific understanding where little information exists to anchor and inform SME's estimations.

The Second Initiative

The Learner Competency Modeling (LCM) initiative – will support development of a range of training technologies and scientific efforts while establishing a robust proficiency estimation capability to underpin all future WLT work. Currently, development of new learning approaches and capabilities also requires the identification of suitable metrics to ascertain the impact of interventions on the intended learner population. However, the development of a digital library of validated mission-oriented competency models under the LCM initiative will allow WLT to gauge proficiency quantitatively across relevant use cases with little project impact. This ability to take models "off the shelf" and use them to gauge proficiency from data collected during missions will drastically reduce the lift of learning technology development and validation. As a result, our relatively small WLT team will be better positioned to conduct ambitious core research initiatives while staying responsive to emerging learning technology-related needs across the Air Force. As we kick off this initiative, WLT researchers are leveraging several efforts in the medical and fast jet domains (examples discussed in this issue) to canvas the state-of-the-art in learner competency modeling, evaluate these approaches, and identify capability gaps.

As WLT continues to conduct important, targeted learning technology research and development, the PTFR and LCM initiatives will help us orient to the Great Power Competition by providing the precursors to a digital engineering infrastructure. Such an infrastructure has the potential to be a force multiplier not just for WLT researchers hoping to conduct efficient learning sciences-oriented work, but for instructors and course designers that need to identify suitable blended training capabilities and outfit them with the technologies WLT develops. Future use cases would have instructor provide competency targets and receive 1) validated recommendations for training systems that have appropriate fidelity to train to those targets, 2) proficiency estimation capabilities linked to those competency targets, and 3) a set of learner technologies, approaches, and interventions to optimize training (see LOE overview figure). As WLT works to realize such a vision, we are excited to collaborate across Human Performance Wing Lines of Effort, across the Air Force, and with other DoD services to align our capabilities with the broader needs of the United States military. As resources become increasingly strained to outpace our peer competitors, WLT is committed to optimizing the Air Force's approach to training and providing new capabilities to support exciting emerging warfighting concepts. ☆

Dr. Ryan W. Wohleber
Warfighter Learning Technologies LOE Lead and Research Psychologist, 711 HPW/RHWOW

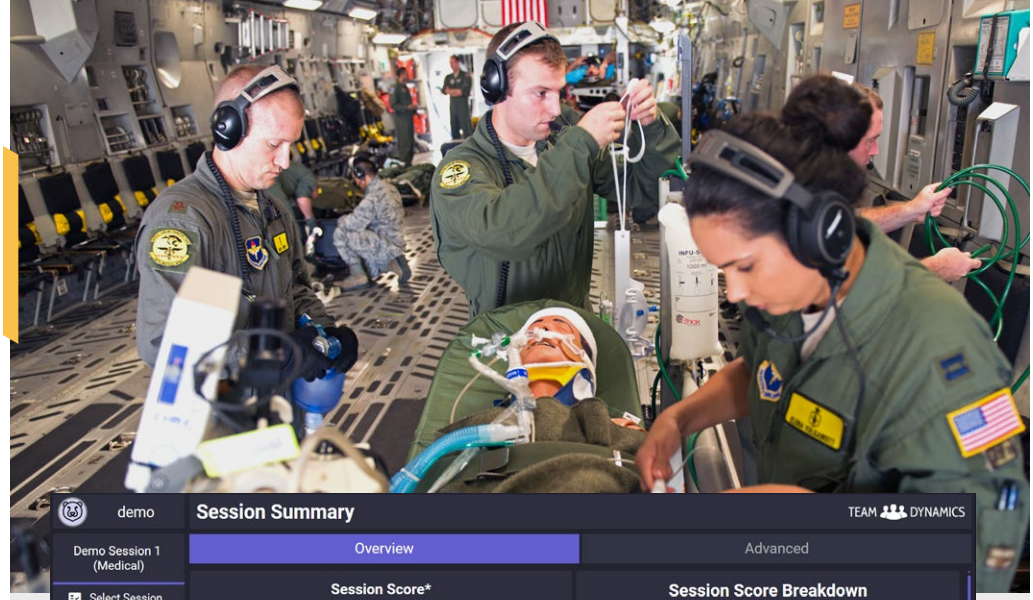
Scalable Training Solutions

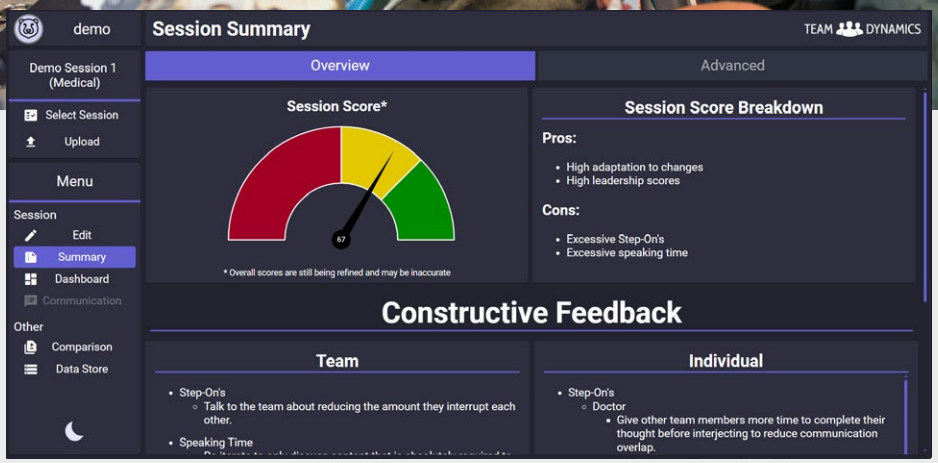
The Warfighter Learning Technologies Line of Effort outlines its mission with the following goals: measure learner proficiency, enhance training approaches, and deliver optimized training platforms. Scalable Training Solutions is using validated scientific measurements to develop technologies to produce objective, non-intrusive training assessment for near-real-time training applications.

In real-world training environments, methods to objectively quantify team coordination and performance in complex mission scenarios are lacking. The Scalable Training Solutions project is addressing this gap by developing analytic tools to link scenario performance and proficiencies in individuals and teams of learners. This work is leveraging over a decade of research from partnerships with Georgia Institute of Technology, Arizona State University, CAE USA, University of Cincinnati, Naval Medical Research Unit – Dayton (NAMRU-D), US Army DEVCOM Soldier Center, and Vanderbilt University. Together, we are developing multiple tools to augment performance evaluation within analytic software suites.

The Team Dynamics Measurement System utilizes audio data to provide continuous team coordination reports and automated transcripts throughout a simulation-based training scenario. By consulting with expert instructors from USAF School of Aerospace Medicine, we have enhanced this tool with instructor-based interactions to support multifaceted learner feedback and After-Action Reviews. Additionally, a video analytics tool in development with our partners integrates cutting edge AI computer vision to extract performance ground truth data and unobtrusive measures for identifying task saturation. Taken together, these analytics will inform future use cases for providing sufficient discrimination between levels of achievement for team and individual performance.

Our first use case for implementing these analytics is Critical Care Air Transport (CCAT) teams. In partnership with 711 HPW / RHB, the USAF School of Aerospace Medicine, and the 59th Medical Wing, we are demonstrating quantitative measures for both individual and team CCAT performance and developing near real-time assessment tools to supplement the information available to instructors and learners. Demonstration of these analytic tools in the medical context will pave the way for team-level analytics in other tactical training settings. ☆





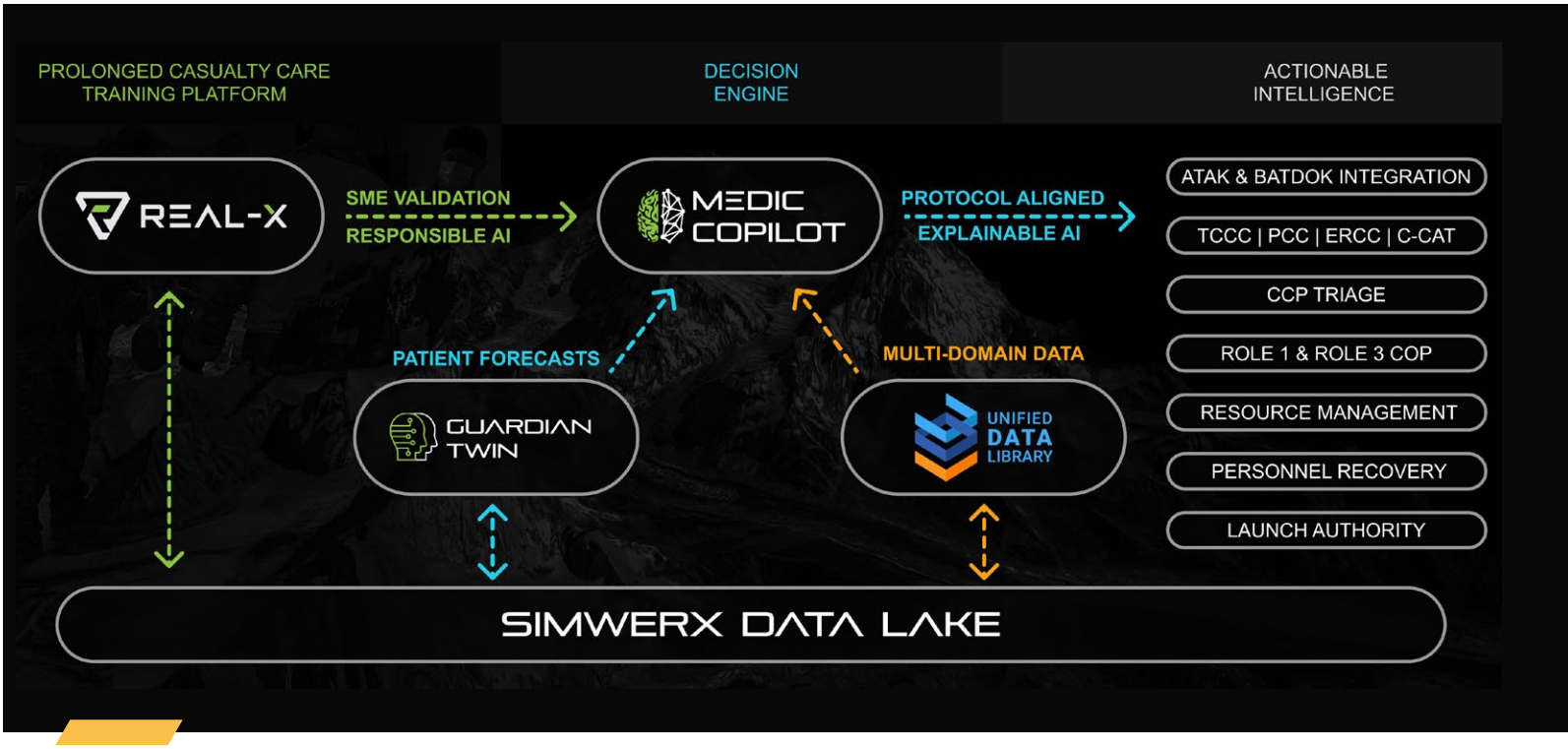
The Team Dynamics Measurement System (TDMS) automatically generates an empirically-based overview of how the team coordinated given the uploaded audio file.

TDMS allows users to focus on how a specific speaker's score changes over time.

Photo (top) by Senior Airman Stefan Alvarez / Screen captures by 711 HPW/RHWOW

Dr. Kent Etherton
Research Psychologist, 711 HPW/RHWOW

Katelyn Kay
Research Psychologist, 711 HPW/RHWOW



Graphic by SimWerx™

Transforming Combat Medical Support for Agile Combat Employment (ACE)

As modern warfare becomes more complex and unpredictable, the need for adaptive and responsive human machine teaming systems has increased. AFRL Warfighter Interactions and Readiness Division's Just-in-Time Multi-Mission Airmen (JITMMA) program, in collaboration with SimWerx™ are supporting the Agile Combat Employment (ACE) initiatives. ACE requires multi-capable Airmen to quickly gain proficiency in combat tasks which will allow them to operate competently in high-risk environments regardless of their primary area of specialization (AFSC). SimWerx™ has developed a cutting-edge medical ecosystem of solutions that ensure warfighters are mission-ready and equipped with the tools and knowledge to respond effectively to dynamic and resource-constrained combat environments.

At the heart of SimWerx™ ecosystem is Medic Copilot, an AI-powered decision support tool that assists medics at the point of injury. Medic Copilot is integrated with the Battlefield Assisted Trauma Distributed Observation Kit (BATDOK), an AFRL-developed software tool for smartphones and tablets. Together with *Guardian Twin*, these tools use real-time physiological data and predictive analytics to continuously assess and reprioritize casualties based on medical urgency, resource availability, and operational constraints. This combination allows warfighters to make faster, data-backed decisions, while optimizing casualty outcomes and ensuring the efficient use of critical resources.

To ensure these tools perform reliably under realistic combat scenarios, SimWerx™ developed *REAL-X*, a dedicated platform for training and validating AI models before operational use. Within this training environment, AI models undergo rigorous testing through Reinforcement Learning from Human Feedback (RLHF). By simulating complex battlefield conditions, *REAL-X* helps refine the AI algorithms in *Medic Copilot* and *Guardian Twin*, enabling these tools to provide end users with reliable AI recommendations. The AI models validated in REAL-X are operationalized to enhance prehospital decision-making. This assures that the AI systems used on the battlefield have been thoroughly tested and proven in realistic simulations, mitigating bias and building trust. In addition, these tools are integrated with the Unified Data Library (UDL), a cloud-based data repository that consolidates commercial and Government data, ensuring secure, real-time data collection and analysis across disconnected environments. This capability is crucial for JITMMA operations, where connectivity can be limited but the need for up-to-date data remains critical.

From training with *REAL-X* to live operations supported by *Medic Copilot* and *Guardian Twin*, these AI-driven systems support the USAF's ACE vision by delivering flexible, on-demand solutions that increase readiness and ensure multi-capable Airmen are prepared for the challenges of future warfare. ☆

Maj Cat Harris, SOF/PR Innovations Branch Chief, Air Force Futures

THE GAMING RESEARCH INTEGRATION FOR LEARNING LABORATORY®

GRILL® Vision

The Gaming Research Integration for Learning Laboratory (GRILL®) leverages low-cost, high-fidelity, commercial off-the-shelf technology to create a variety of solutions for partners in the Department of Defense (DoD).

By pursuing these objectives, the team provides a greater return on investment for the DoD. Through utilizing existing technology to close training and simulation gaps, we reduce manpower costs by removing the need to develop tools from the ground up. Additionally, by utilizing platforms revolving around well-established game engines, the team ensures the continuity of our simulators by having tools that are frequently updated and compatible with emerging state-of-the-art hardware. The team's vision is to serve partners in the industry, academia, and the DoD as a resource for the integration and application of game-based hardware and software to address Air and Space Force needs. By way of collaboration with our partners throughout the United States, the GRILL® supports the development of training and simulation tools as well as a highly-qualified technical and scientific workforce.

GRILL® Participates in Blended Training

This fall, the GRILL® participated in a blended training demonstration at Calamityville in Fairborn, Ohio, that demonstrated how Distributed Interactive Simulation (DIS) technology can work together to form realistic training scenarios. The training demonstration consisted of numerous physical elements, including mobile targeting robots and human-operated Humvees. Autonomous agents were included in the scenario and were generated from the Modern Air Combat Environment (MACE) software. Multiple virtual simulators participated in the training as well, including various flight simulators, a VR joint fires trainer, and the GRILL®'s Mixed-reality Environment Advanced Threat Simulation (MEATS), a mixed reality RPG sim made in Unreal Engine. Thanks to the GRILL® DIS for Unreal plugin, a scenario viewer was made available that captured all the DIS traffic in the blended training demonstration and displayed it in one location to give spectators a more digestible viewing experience. The GRILL®'s DIS plugin is open-source and provides Unreal Engine with the capability to both receive and send DIS data with options for customization. It is being added to various GRILL® projects, including their Parachute Simulator and VR Joint Terminal Attack Controller simulator, to offer more robust blended training experiences. ☆

Mr. Jerry Huggins, Software Engineer, BAE Systems, Inc.

Mr. Tyler Frost, Software Engineer, BAE Systems, Inc.

Program Leads

GRILL® TEAM LEAD
Mr. Stephen McGee

PROGRAM MANAGER
Capt Lukas Texeira

For additional information, visit the GRILL's® website:

WWW.AF-GRILL.COM

Photos by Mr. Will Graver (BAE Systems, Inc)

Summer at the GRILL®

This summer, the GRILL® hosted 19 Wright Scholars, 6 teachers, 5 United States Air Force Academy (USAFA) cadets, 1 LEGACY student, 3 Strategic Ohio Council for Higher Education (SOCHE) interns, 1 student intern. and faculty researchers Kendall Carmody (Florida Institute of Technology), and Dr. Stephanie Fussell (Kent State University). These participants worked collaboratively on the following community-driven challenge problems.

The Wright Scholar program is enhanced by experienced engineers, real-world customers, and team-based learning, impacting their future STEM career opportunities and the broader community.

1 Immersive Aerial Refueling (AR) With Various Receivers

The Aerial Refueling project was proposed by the Air Force Life Cycle Management Center (AFLCMC) to better research training and development of aerial refueling boom operator stations. The program is being developed as a virtual reality (VR) simulator in Unreal Engine 5, in which the participant acts as the boom operator on one of two optional tanker aircraft in order to successfully connect and fuel one of six possible receiver aircraft. The program will allow the researchers to change a number of options in the menu such as tanker aircraft, receiver aircraft, weather conditions, background, time of day, altitude, speed, and refueling path.

2 Watchstanders VR Sim

The Watchstanders Virtual Reality Simulation utilizes Unreal Engine 5 to create a learning environment for watchstander trainees to be able to practice watchstanding and lookout jobs on a Navy ship. The team, consisting of AFRL Wright Scholars and their GRILL Mentors, developed a research testbed utilizing SME's from SoarTech. This testbed can serve as a basis for conducting future research in maritime navigation training, team situation awareness, human-machine teaming, and more. The final product will be provided to our customer, Ryan Wohleber, who is the LOE lead for RHWOW.

3 Extended Reality (XR) Sim

This Extended Reality (XR) simulation aims to provide a research platform for evaluating the impact of laser dazzling on shooting performance. Participants will partake in a shooting task under the influence of customizable laser dazzle configurations, using a prop rifle to engage quasi-random threat target sequences. The simulation also includes a virtual representation of many commonly used laser eye protection (LEP) goggles, allowing laser dazzle mitigation methods to be examined. The user's performance and actions are continuously tracked and logged throughout the simulation. This project is designed for the NATO SET-249 task force, consisting of researchers from AFRL RHDO (Optical Radiation Bioeffects Branch), the Royal Military Academy of Belgium, and the Fraunhofer Institute of Optronics in Germany.

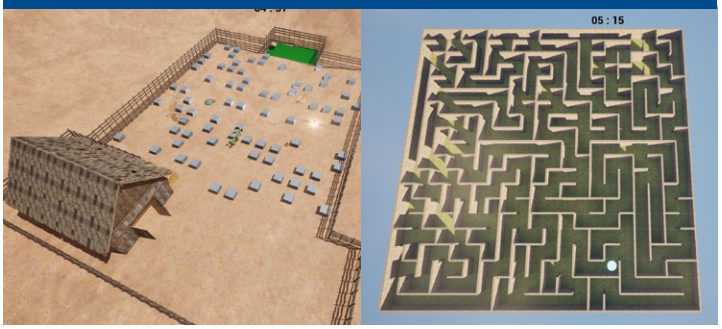
Screen Captures by the GRILL® / Photos by Mr. Will Graver (BAE Systems, Inc)

Summer Challenge Problems

4 NVG Displays

This project offers users an immersive night vision goggle simulation experience accessible via desktop or virtual reality. Participants have the capability to customize their environment, including selecting NVG types, lighting conditions, and targets. Throughout gameplay, users undertake tasks amid challenges like diverse lighting effects, identification of targets, and overcoming physical obstacles. As they navigate through the simulation, the project tracks and logs various facets of player performance. This project will be used for supporting behavioral science research on soldier performance under the effects of NVGs and serving as a preliminary training tool for soldier NVG training programs.

5 Multi-Player Educational Role Playing Game (MPERPG)



MPERPG has been put together for Air University, a prestigious university that aims to develop leaders who will impact the air and space forces of today. Our game promotes teamwork and encourages the students to take on a leadership role throughout a series of minigames. Our project includes navigation games, like maze and minefield traversing, and coordination games, like a bridge-building game. These games are structured so that the players must depend on one another and work together to clear the level. It also forces the players to make the decisions of who should take on what role to complete the level efficiently. Through this project, we aim to create a gaming environment that brings teams together and encourages dependency and leadership.

Screen Captures by the GRILL® / Photo by Mr. Will Graver (BAE Systems, Inc)

USAFA Project

Land Engagement Adjudication Platform (LEAP)

Land Engagement Adjudication Platform (LEAP), developed for the United States Air Force Academy's (USAFA) Multi Domain Lab (MDL), marks a significant leap forward in wargame simulation training at the academy. Cadets at the GRILL USAFA developed an enhancement to an exisiting wargame platform allowing young warfighters to study pivotal tactics of land-based engagements. LEAP goes beyond traditional education methods by allowing cadets to implement real tactics in land-based scenarios, integrating their strategies directly into engagement calculations. The development team undertook a focused five-week agile software journey, addressing specific customer needs and applying their skills in website development, project management, and human factors. Using React as their primary tool, they rapidly produced a functional web application that showcases their proficiency in these disciplines.

LEAP was announced as a finalist in the 2024 Serious Games Showcase & Challenge at the Interservice/Industry Training Simulation and Education Conference (I/ITSEC).

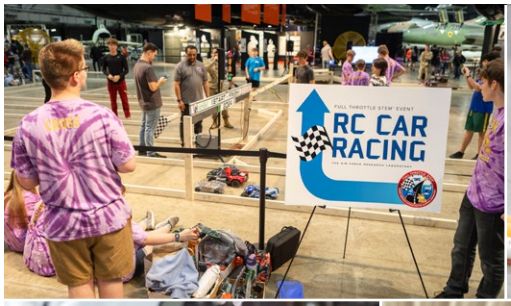
6 Skycargo Express

Sky Cargo Express is a touch-screen application for Windows and Android designed to gamify the logistics of transporting packages with remote-controlled aircraft. The application provides a variety of customizable user settings, such as difficulty, to enable the construction of different research plans. Timestamped performance data, such as difficulty level reached, is output to a CSV file after every trial. This project supports a study by Dr. Frank Mobley to gauge performance variations due to long term flight conditions, like continuous C-130 noise exposure.

STEM Education

In support of STEM education, summer educators at the GRILL® worked to develop robust toolkits of educational content and activities for schools and teachers to use in the classroom, after school, or during independent research. One team of educators created engineering design choice boards for overarching topics, such as measurement, geometry, and life science for middle and high school students. A coding camp was established to provide students with the opportunity to think and problem solve through code with resources such as Code.org and AdaFruit Circuit Playground. The camp also fostered relationships with Wright Scholars, creating a pathway for campers to become Wright Scholars themselves in the future. Another team created digital escape games tailored to Ohio's 6th grade science standards that reinforce students' understanding through fun, interactive practice. The games can be easily distributed via any Learning Management System, such as Google Classroom. Educators conducted a Space Camp to build problem solving skills and teach children about space exploration. Highlights included building and launching rockets and programming rovers to navigate simulated Martian terrain. Camp concluded with students planting Tomatosphere™ seeds that had spent six months aboard the International Space Station.

Several educators made notable contributions at the individual level. Jennifer Corder expanded her expertise in coding and mentored a FIRST® LEGO® League team. Macy Timmerman created natural disaster and national park STEAM units for students with various science, technology, engineering, art, and mathematics challenges. Lisa Galpin created a professional development book study for teachers on *AI for Educators* by Matt Miller that encourages student engagement and personalized training in an AI-driven world. Jill Weaver's project challenges middle school students to design and 3D print CubeSats for a high-altitude balloon powered stratospheric egg drop challenge. Jack Hu created a semester's curriculum for a game design class as well as four hours of workshop presentation content for the GRILL® that will be presented at I/ITSEC. Finally, Bridgett Williams created in-depth projects and engaging activities for a 7th grade engineering course including an introduction to hydraulics, circuit and soldering activities, and an innovative elevator design project.



Full Throttle STEM®

The Full Throttle STEM® (FTS) event, now hosted at both the Eldora Speedway in Darke County, OH, and in its third year at the National Museum of the United States Air Force, continues to be a fun-filled STEM experience. Drawing students primarily from Darke County, Montgomery County, and Cincinnati, the event showcased many science exhibits from several schools. The drone challenge this year required precise finite maneuvering skills with students using downdraft from drones to move ping-pong balls into position. The challenge had a large student turnout, reflecting the growing relevance of and interest in Unmanned Aerial Systems (UAS) in industry and military.

The highlight of FTS involved students from different schools designing and racing remote-controlled cars while tweaking multiple variables to optimize speed. Both events had multiple schools attend, crafting their own racecars, competing in drone races after practicing during the school year, and at FTS Dayton, students explored exhibits at the Air Force Museum. The GRILL® enhanced the experience by displaying simulators and offering insights into software development.

Designed to ignite passion for STEM among rural students, FTS continues to provide a day of STEM immersion. This year's event, attended by 10 schools and close to 250 students, was a roaring success, celebrating STEM in a hands-on, engaging manner.

Photos by Mr. Will Graver (BAE Systems, Inc)

Dr. Mark Draper

Warfighter Interfaces & Teaming Core Technical Competency Lead and Principal Engineering Research Psychologist, 711 HPW/RHW

WARFIGHTER INTERFACES & TEAMING

CORE TECHNICAL COMPETENCY (CTC)

Operator interfaces are omnipresent throughout the entirety of the Air and Space Forces; they provide critical communication connections between warfighters as well as between warfighters and machines for all mission applications. Teams of Airmen and Guardians employ warfighting power by optimally engaging and interfacing with increasingly complex and intelligent machines and data analytics while under constant threats of data uncertainty and information subterfuge. Given that future wars will increasingly manifest as wars of cognition, victory will likely be decided by those who are best able to combine human cognitive abilities with machine capabilities in order to operate rapidly and effectively within the opponent's decision-making process.

The Warfighter Interfaces and Teaming (WIT) CTC conducts research to enable decision superiority across our Air and Space Forces by optimizing the integration of warfighter cognition with increasingly complex and intelligent machines/systems, thus creating maximally effective and resilient warfighting teams. WIT CTC research focuses on discovering, developing, evaluating, and transitioning adaptive warfighter

Continued on next page

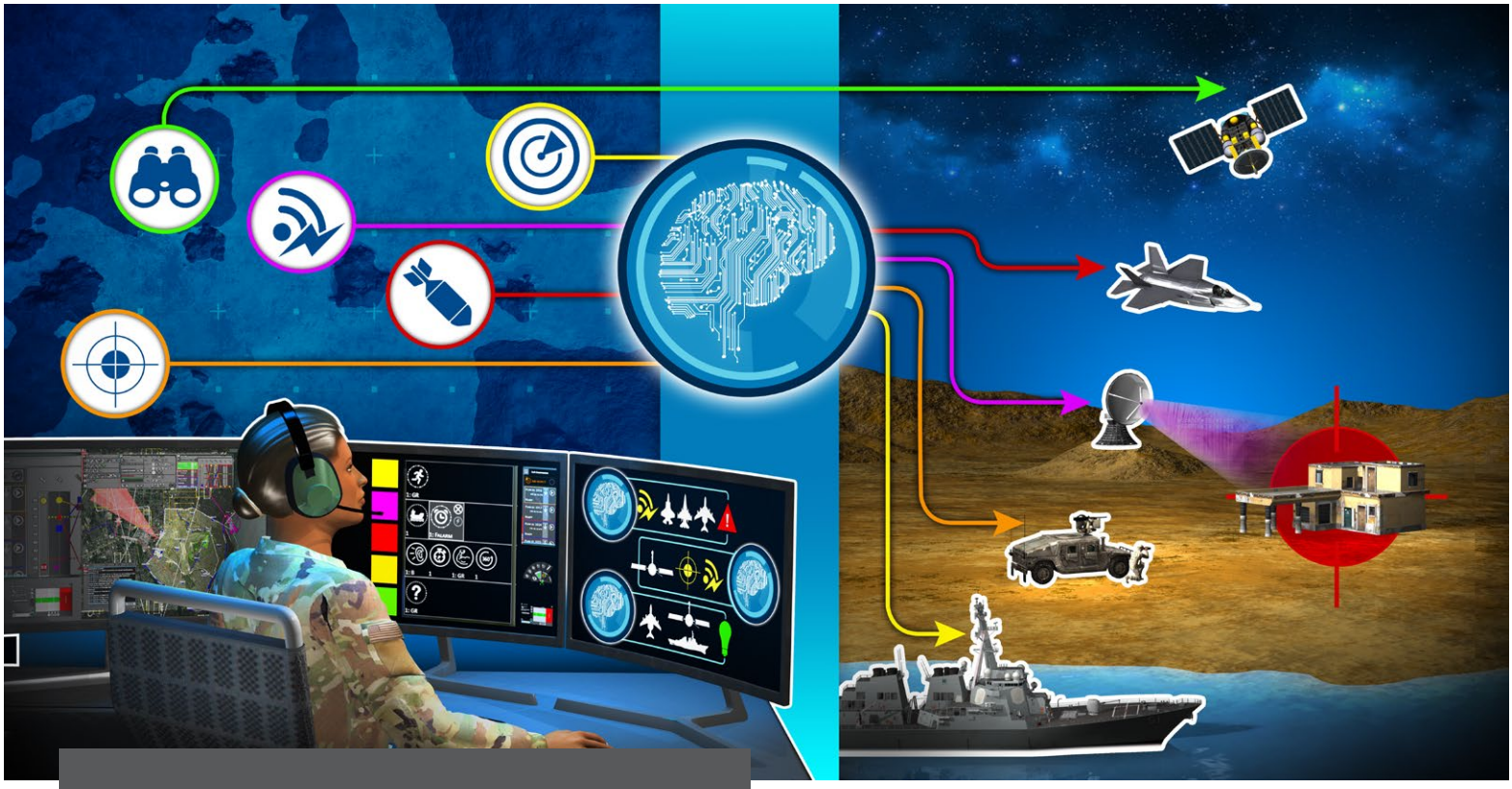
Warfighter Interfaces & Teaming CTC

Distributed Teaming & Communication CRA

Human-Machine Interactions CRA

CTC OVERVIEW

Conduct research to enable robust decision superiority across our Air and Space Forces by dynamically optimizing the integration of warfighter cognition with increasingly complex and intelligent machines/systems, creating maximally effective and resilient warfighting teams. Discover, develop, evaluate, and transition advanced adaptive warfighter interface technology, mission-optimized distributed team performance enhancements, communication management processes, and context-tailored intelligent decision aids/analytics to achieve and maintain decision superiority in uncertain environments against peer threats.



Joint All Domain Mission Commander Control Station. Situation awareness is enhanced through the display of integrated data from different domains (air, space, cyber, EW) and cross-domain courses of action are generated using AI to enable desired effects.

Graphic by Mr. Will Graver (BAE Systems, Inc.)

interface technology, mission-optimized distributed team performance enhancements, communication management processes, and context-tailored intelligent decision aids/analytics in order to achieve and maintain decision advantage in uncertain environments. This CTC consists of two core research areas: 1) advanced human-machine interfaces (with an emphasis on AI and autonomy), and 2) distributed teaming and communications.

Automation and artificial interface (AI) technology can be exceptionally powerful tools when operating within well-defined situations/environments. However, they can become unreliable when operating near the edge or outside of their competency envelopes. Corresponding system design processes often relegate the human role in these systems to addressing any remaining or 'leftover' failures and gaps in automation/AI capability. Thus, an out-of-the-loop warfighter is often expected to rapidly intervene and 'save the day' with little time and resources available to properly assess and understand the situation. This dilemma is often exacerbated by automation/AI designed with little-to-no explanatory ability as to its underlying functioning and reasoning. An alternative approach to system design is to consider the human and machine as a joint-cognitive system upfront, where cognitive capabilities from each can be effectively and dynamically interleaved to continually maximize performance.

In addition to these expanding machine capabilities, future fights will also be characterized by increasingly distributed and networked operations in order to effectively address adversary threats. Agile Combat Employment (ACE) and Joint All Domain Command and Control (JADC2) concepts are premised on the ability to conduct robust distributed planning and mission execution activities across heterogenous teams of warfighters (and machines). Not only will these teams need to be distributed, but there will be little guarantee of stable and reliable communications among team members. Therefore, research is critically needed to better understand distributed teaming characteristics, challenges, assessment methods, and collaborative solutions throughout a range of variable, degraded, and denied communication environments.

Continued on next page

In order to achieve and maintain decision advantage in uncertain environments, the WIT CTC research focuses on:

- **Discovering, developing, evaluating, and transitioning adaptive warfighter interface technology**
- **Mission-optimized distributed team performance enhancements**
- **Communication management processes**
- **Context-tailored intelligent decision aids/analytics**

The WIT CTC is dedicated to conducting R&D that directly informs distributed teams and joint-cognitive systems by focusing on the highly complex, uncertain, and edge-case environments that will characterize future warfare. To further enhance its value proposition, the WIT CTC focuses on advancing and aggregating individual research projects into larger, more integrative solutions that enable high-priority Air & Space Force mission capability goals. Areas of specific concentration include JADC2 battle management, Space domain awareness, and a variety of crewed-uncrewed operations.

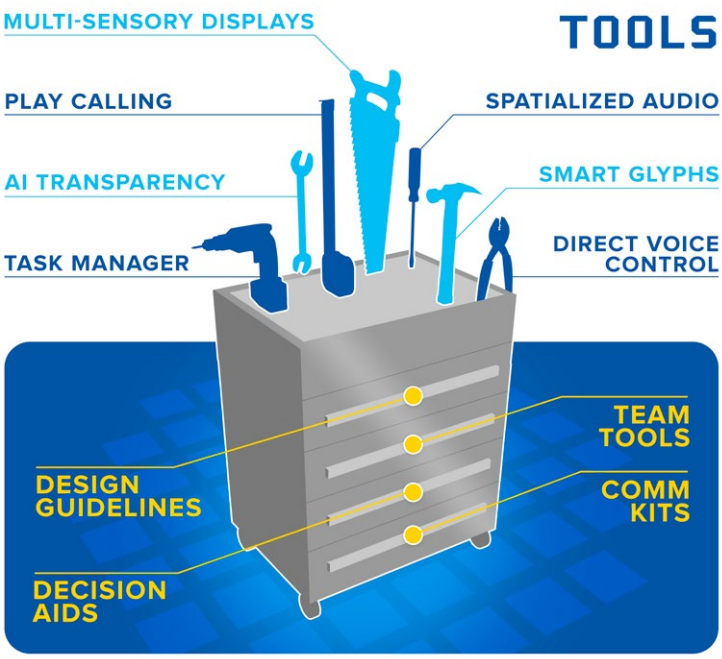
So, what does the WIT CTC contribute to the fight? We strive to provide a toolset of interaction and teaming solutions that empower Airmen and Guardians to accomplish their missions more rapidly and effectively, thus providing robust decision superiority to our forces. Specific outputs of our research include advanced operator interface knowledge, guidelines and designs, teaming assessment metrics and collaboration aids, agile communication enhancements, adaptive decision support methods, and advanced visualization tools.

The WIT CTC is executing specialized, warfighter-centric interface and teaming research that addresses high priority USAF needs and optimizes warfighter decision making. With active projects focused on improving warfighter performance across Air, Space, Electronic Warfare (EW), ISR, Cyber and JADC2 environments, FY25 looks to be another exciting and productive year! ☆

Dr. Mark Draper
Warfighter Interfaces & Teaming CRA Lead and Principal Engineering Research Psychologist, 711 HPW/RHW

We strive to provide a toolset of interaction and teaming solutions that empower Airmen and Guardians to accomplish their missions more rapidly and effectively, thus providing robust decision superiority to our forces."

—Dr. Mark Draper
Warfighter Interfaces & Teaming CRA Lead and Principal Engineering Research Psychologist, 711 HPW/RHW



Graphics by AFRL and 711 HPW/RHW

Dr. Michael Tolston

Distributed Teaming & Communication Core Research Area Lead, 711 HPW/ RHWTE

DISTRIBUTED TEAMING & COMMUNICATION

CORE RESEARCH AREA

Future wars will be waged with multi-echelon kill-chains comprised in part by distributed teams of warfighters and intelligent machines vying with adversaries for decision superiority in uncertain contested and denied environments. These distributed units will have to overcome significant teaming difficulties, including non-overlapping shared mental models, potential language and cultural barriers, limited knowledge of teammate skills and abilities, and challenges associated with temporary team membership, as well as multilevel communications, coordination of disparate assets, and complex distributed decision making. In addition to these fundamental teaming challenges, there will likely be real time problems caused by denied or degraded communications networks resulting in missing, incomplete, or incorrect information; delayed information; potential misinformation; information saturation and information bottlenecks; and fog of war. Future teams will have to increasingly rely on technology that will enable faster team formation, resilient team performance, and more accurate situation assessment by ensuring common operational understanding across distributed settings to optimize real-time tactical adjustments for decision-making. To meet these demands, the Distributed Teaming and Communications Core Research Area (CRA) is focused on developing technology and methods to enhance the formation, assessment, and performance of distributed teams of warfighters, including human-human and human-autonomy teams.

Our research focuses on factors that influence or enhance team formation and team performance across human-human and human-autonomy teams; methods and metrics to dynamically monitor and assess team performance; interventions that allow teams to rapidly recover from degradations; and novel contextually aware communication management and collaboration aids. Our applications include ensuring decision superiority across our Air and Space Forces through research on distributed collaborative teaming and communications enhancements that facilitate resilient distributed teaming and rapid joint-cognitive awareness and sensemaking. To this end, the Distributed Teaming and Communications CRA is made up of two Lines of Effort (LOE): Dynamic Team Performance Assessment and Team Optimization and Recovery.

CRA OVERVIEW

Explore the rapid formation, real-time assessment, and dynamically optimized performance of distributed, heterogeneous teams of warfighters and human-machine teams to enable rapid, agile, and robust mission operations. Enable the rapid formation of mission-effective heterogeneous teams, dynamic monitoring and assessment of team performance via optimal assemblage of novel and existing metrics, adaptive tactics for recovery from real or predicted team performance degradations, and novel distributed communication and collaboration tools, technologies and management methods that are responsive to variable network environments.

Continued on next page

Graphic by Mr. Will Graver (BAE Systems, Inc.)

The Dynamic Team Performance Assessment (DPTA) LOE is working to enable the rapid formation, real-time assessment, and dynamically optimized performance of distributed heterogeneous teams of warfighters as well as human-machine teams to promote rapid, agile, and robust mission operations. Simply put, the DTPA LOE is focused on quantifying and modeling team processes and performance. Research areas include factors that influence the formation of mission-effective heterogeneous teams, dynamic monitoring of team performance via optimal assemblage of novel and existing metrics, and real-time contextual aids from team communication. To complement DTPAs measurement and modeling of teams, the Team Optimization and Recovery (TORE) LOE focuses on developing tools for distributed heterogeneous team coordination, collaboration, and agility to maximize team performance. The TORE LOE is focused on optimizing teams with intelligent aids, adaptive displays, and informed teaming interventions. Research areas in this LOE includes designing, developing, and evaluating team optimization and recovery technologies to enhance communication, coordination, and decision making among distributed teams; developing interfaces to support joint tasking and team shared awareness (SA) across multiple domains; and conversational AI technologies to enable high bandwidth natural communications with agent teammates.

In sum, the work conducted in the Distributed Teaming and Communications CRA will enable warfighters to coordinate the integration of information from disparate sources, attend to a greater number of concurrent tasks through efficient teamwork, and collaborate across distributed teams in contested or denied environments. Expected outcomes from our research will empower enhanced teaming via dynamic measures and models of team performance and processes, naturalistic interactions with autonomous teammates, integrated cross-domain interfaces, and robust information exchange. ☆

Distributed Teaming & Communication
CRA

Dynamic Team Performance Assessment
LOE

Team Optimization and Recovery
LOE

Dr. Michael Tolston, Distributed Teaming & Communication CRA Lead, 711 HPW/RHWTE

DYNAMIC TEAM PERFORMANCE ASSESSMENT

LINE OF EFFORT

Program Leads

LOE LEAD
Dr. Greg Funk

PROGRAM MANAGER
Capt Mathew Kinneer

Team Performance Metrics

The Air Force relies on teams of airmen for the success of critical missions with many demanding features, such as high tempo operations, long shift durations, and distributed team environments (e.g., joint all domain command and control [JADC2]). These demands can cause teams to underperform and jeopardize mission success. Therefore, developing metrics and methods to monitor, evaluate, and eventually augment teams in distributed settings is an important AF mission. At AFRL, we are accomplishing this by applying state-of-the-art assessment methodologies based on nonlinear dynamical systems analysis, network-based methods, and topological data analysis to derive metrics of critical team processes, such as workload, situation awareness, communication, and decision making from multiple physiological and behavioral signals presented in distributed team settings. These methods will help to ensure that teams perform optimally, even when team members are operating in different domains or far away from one another (e.g., JADC2).

In FY25 we will begin development of a new project in conjunction with colleagues in the Warfighter Learning Technologies LOE, the *Framework for Language Analysis and Resilience Enhancement* (FLARE). FLARE is a technology for automatic management of distributed communications. Teams operating in congested, contested, and communications-denied environments see real time tactical knowledge gaps in their communication networks that cause a disconnect from ground truth in command and control (C2) and edge nodes and impair decision making processes. FLARE will transform raw data into actionable measures of team processes to accelerate and improve training and operational readiness while comprising a comprehensive framework for processing distributed teaming communications. Features of the project will include hardware and software solutions to capture operator communications during live exercises, data aggregation and processing, natural language processing contextualization, analysis, and interactive visualization and playback. ☆

Dr. Michael Tolston, Distributed Teaming & Communication CRA Lead, 711 HPW/RHWTE

Dr. Greg Funke, Senior Research Psychologist, 711 HPW/RHWTE

Teamwork Fundamentals

Understanding the fundamentals of teamwork is essential in various aspects of life, from academic projects to professional environments. Effective teamwork involves more than just a group of people working together; it requires a deep understanding of each member's role, strengths, and weaknesses. When a team understands these fundamentals, they can collaborate more efficiently, leverage each other's strengths, and compensate for individual weaknesses. This leads to higher productivity, creativity, and the ability to tackle complex tasks that would be challenging for an individual. Moreover, a solid grasp of teamwork fundamentals fosters better communication within the group. Team members who understand the importance of open, honest, and respectful communication are more likely to share ideas, give constructive feedback, and resolve conflicts amicably. This creates a positive work environment where everyone feels valued and heard, which is crucial for maintaining morale and motivation.

Understanding teamwork fundamentals helps in building trust among team members. Trust is the foundation of any successful team; without it, collaboration can break down, leading to inefficiency and discord. When team members trust each other, they are more likely to take risks, share ideas, and support each other in achieving the team's goals. This trust is built through reliability, consistency, and mutual respect, all of which are grounded in a solid understanding of teamwork principles. Lastly, a team that understands the fundamentals of teamwork is better equipped to adapt to challenges and changes. In today's fast-paced world, teams often face unexpected obstacles or shifts in their goals. A strong foundation in teamwork allows the group to navigate these challenges with agility, adjusting their strategies and roles as needed to stay on track. This adaptability is key to long-term success in any collaborative effort. ☆

Dr. Michael Tolston, Distributed Teaming & Communication CRA Lead, 711 HPW/RHWTE

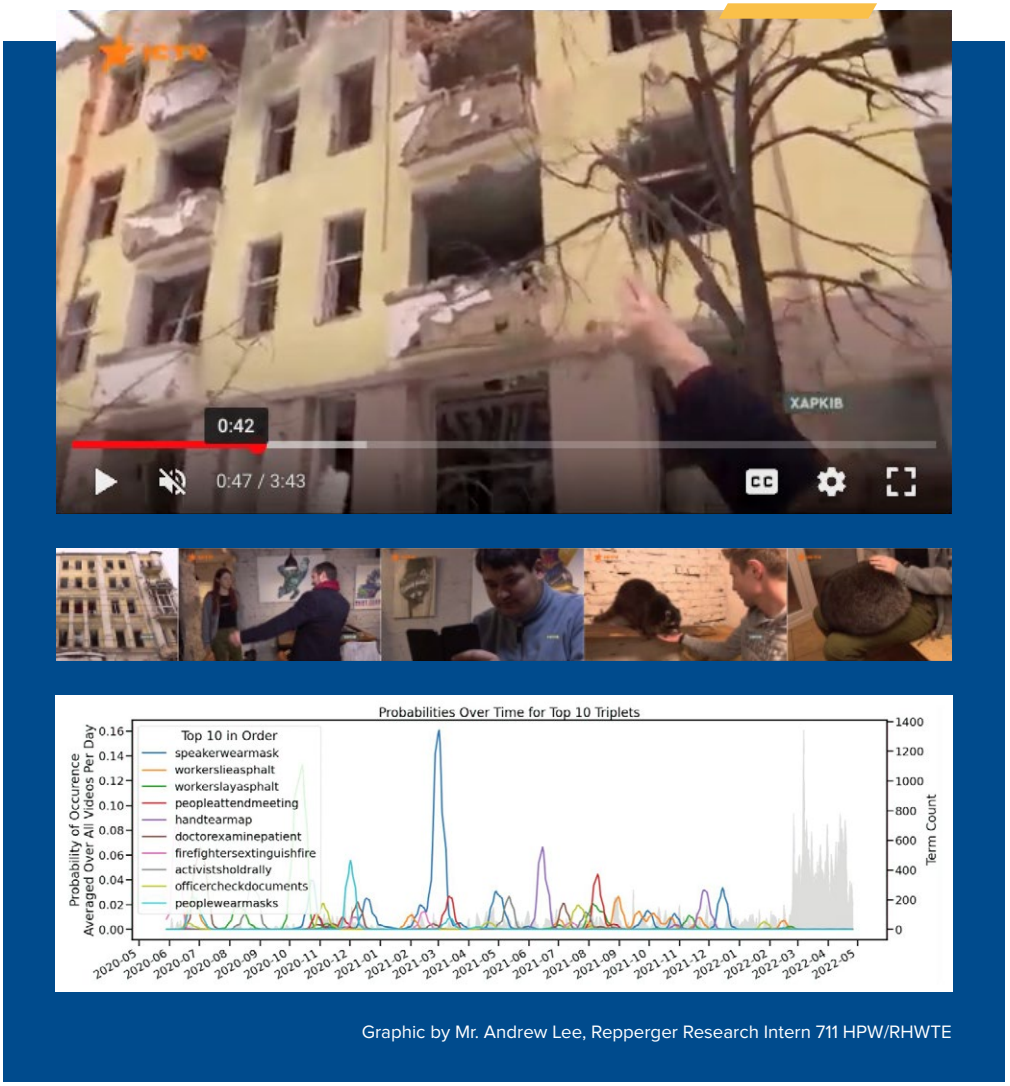
Dr. Greg Funke, Senior Research Psychologist, 711 HPW/RHWTE

Contextualized Communication Machine Learning (CCML)

The Contextualized Communication Machine Learning (CCML) research effort leverages cutting edge Machine Learning (ML) and Artificial Intelligence (AI) techniques to process multimodal information streams (such as text, video, images and audio) which aid in contextualized sensemaking when presenting these sources to the operator. These capabilities were applied to multiple use cases at the June 2024 EUCOM Bravo 101 Hackathon sponsored by the Office of the Secretary of Defense's (OSD) Chief Digital and AI Office (CDAO). CCML researchers utilized Large Language Models (LLMs) to digest heterogeneous sources of information and present the user with a summary of the important points. Techniques such as Retrieval Augmented Generation (RAG) help ensure accuracy and on-premises, self-hosted LLMs ensure data privacy and security to avoid leaking sensitive information.

Continuing last year's work on the customized Automatic Speech Recognition (ASR) system tailored to the specific style and language of air traffic controllers at the Federal Aviation Administration (FAA) Domestic Events Network (DEN), CCML researchers refined these custom systems to operating in a streaming manner to better support the need for near real-time, accurate transcription and automatic event detection enhancing the air traffic controller's performance.

The academic partnership with The Ohio State University Computer Vision Lab (CVL) continues to yield productive research investigating explainability in multimodal Vision-Language Models (VLM). This work provides insight to which portions of various input streams contribute to a VLM's output which can increase confidence in results for tasks such as object detection, question answering, and visual understanding.



Graphic by Mr. Andrew Lee, Repperger Research Intern 711 HPW/RHWTE

Models and methodologies for CCML are currently being tested on an operational mirrored video dataset collected from publicly available news broadcasts covering the first two months of the Ukraine-Russian conflict. Using RHWTE's "Haystack" Multilingual Multimedia Information Extraction and Retrieval system, summer interns with the Repperger Research program were able to use the processed videos with English translations to extract named entities and additional metadata to provide preliminary sensemaking to a corpus of over 14,000 videos. An investigative tool was built to rapidly visualize topics of interest and their changing dynamic to other topics over time. Additionally, object-action-subject relations within the videos that were not always aligned with the dialogue in the video were automatically labeled, increasing the contextualized content. Rapidly assessing multimodal information streams is crucial to support analysts tasked with processing vast amounts of data quickly – these techniques can assess information trends over time, enabling warfighters to better detect the next threat. ☆

Dr. Jeremy Gwinnup
Senior Research Computer Scientist, 711 HPW/RHWTE

TEAM OPTIMIZATION AND RECOVERY
LINE OF EFFORT

Team Collaboration and Resilience

Program Leads

LOE LEAD
Ms. Jessica Bartik

PROGRAM MANAGER
Ms. Lauren Morse

Our success in future fights will squarely hinge on distributed multi-domain teams' ability to effectively collaborate and rapidly adjust to evolving wartime situations. In addition to teams being configured in a way that supports efficient interactions, team members will need access to tools that enable them to maintain shared awareness in complex and unpredictable mission environments. RHWT's new project 'Team Collaboration and Resilience' is an effort focused on designing and evaluating novel interface concepts for robust distributed teaming. Specifically, this effort aims to identify and understand the critical teaming factors and collaboration requirements necessary for non-collocated teams to successfully coordinate and engage in joint tasking while operating in contested and/or denied settings. This information can then be leveraged to develop interfaces maximally optimized for distributed teaming, both human-human and human-autonomy. Interface concepts include task management techniques that support rapid alerting and replanning as well as resynchronization tools that aid in the reestablishment of common ground across teammates after a loss of communications.

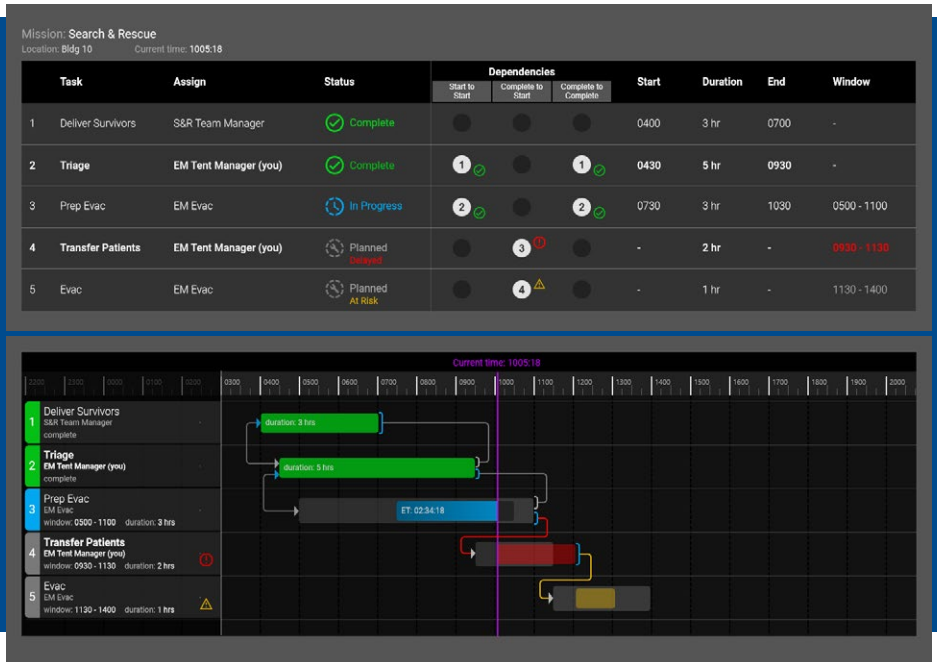
The team just completed data collection (n = 24) for a study comparing several mid-fidelity task management representations (1. Checklist, 2. Timeline, 3. Combination) designed to support a distributed operator in monitoring the execution of interdependent emergency medicine tasks. The team is interested to learn which representations best aided participants in accurately and quickly identifying who is responsible for a task, the nature of interdependent task relationships, task temporal constraints, and the cause of alerts associated with ongoing tasks. The results of this initial study will be used to inform the design and formal evaluation of a high-fidelity, fully interactive task management interface that can support future Joint All Domain Command and Control (JADC2) operations.

With near-peer competitors demonstrating an increased ability to deny, disrupt, and destroy information and networks during conflict, future work will focus on enabling distributed team resilience in contested environments. Specifically, the team plans to use cognitive task analysis techniques to pinpoint the evolving information requirements known to be associated with the loss and subsequent recovery of communications. Findings will inform the refinement and/or enhancement of existing interfaces such that distributed teammates can quickly recognize disparate information and restore mission execution. Evaluations will include both part-task, lower-fidelity simulation/usability evaluations, as well as full-scale experimentation in a high-fidelity testbed. Resultant interface designs and corresponding evaluations will feed technical efforts that address future envisioned, multi-domain teams. ☆

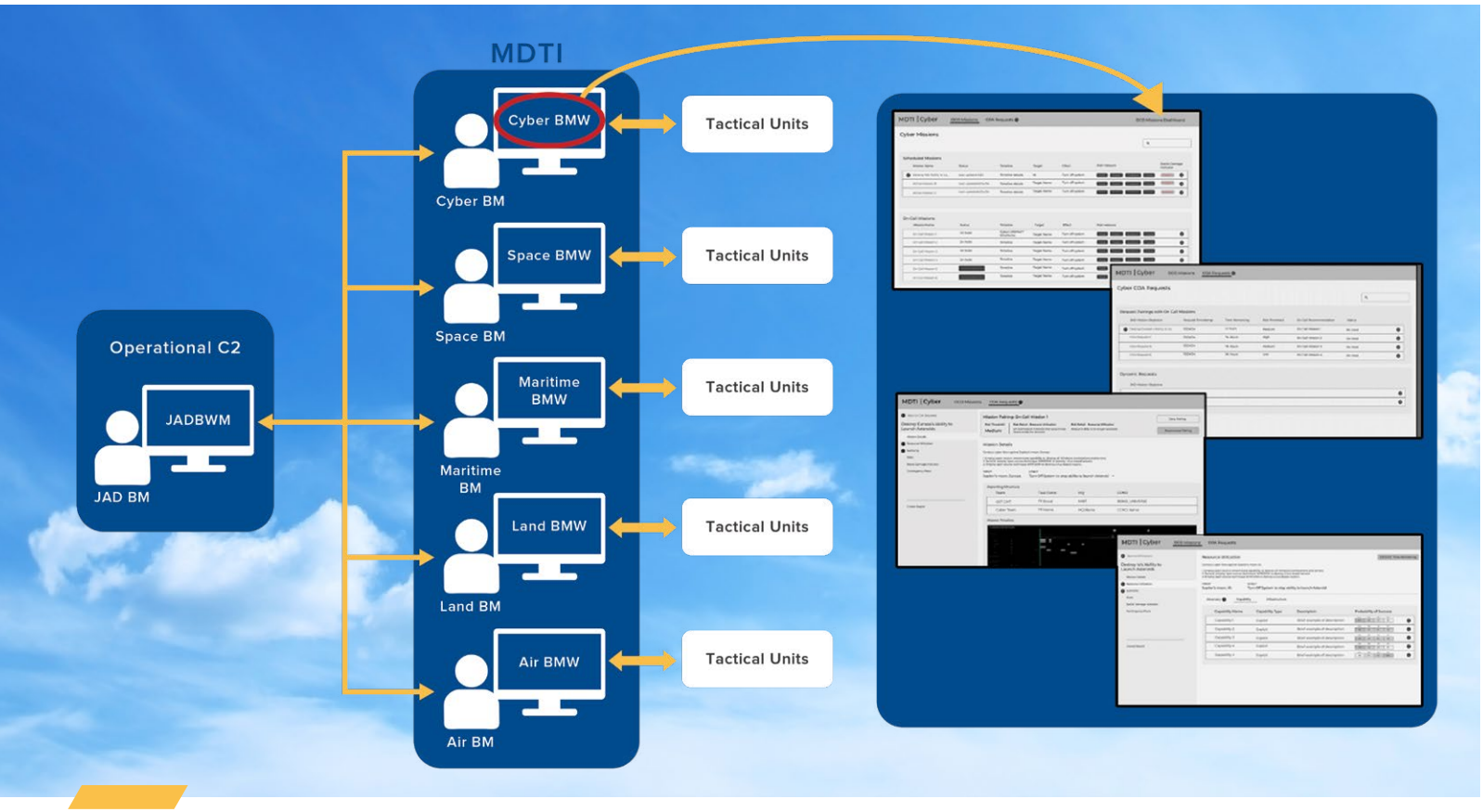
Ms. Jessica Bartik
Research Psychologist, 711 HPW/RHWT

Dr. Elizabeth Frost
Research Psychologist, 711 HPW/RHWTC

Dr. Hunter Oldham
Research General Engineer, 711 HPW/RHWTC



Screen Captures by Ms. Jessica Bartik



Graphic by 711 HPW/RHWTE

Multi-domain Team Integration (MDTI)

Future Joint All Domain (JAD) operations will require distributed teams from different domains to work in harmony to understand a common operating environment. With varying objectives and lines of communication, teams working in the physical domain (on the ground or air) will not operate on the same beat as the teams in the logical domain (on the cyber networks). Therefore, information displays that integrate the physical and logical domains will be needed. The Multi-Domain Team Integration (MDTI) research effort is focused on understanding the complexities of communicating cyber plans, and the implications of those plans within the context of other domains to create a shared understanding across a Joint All Domain team.

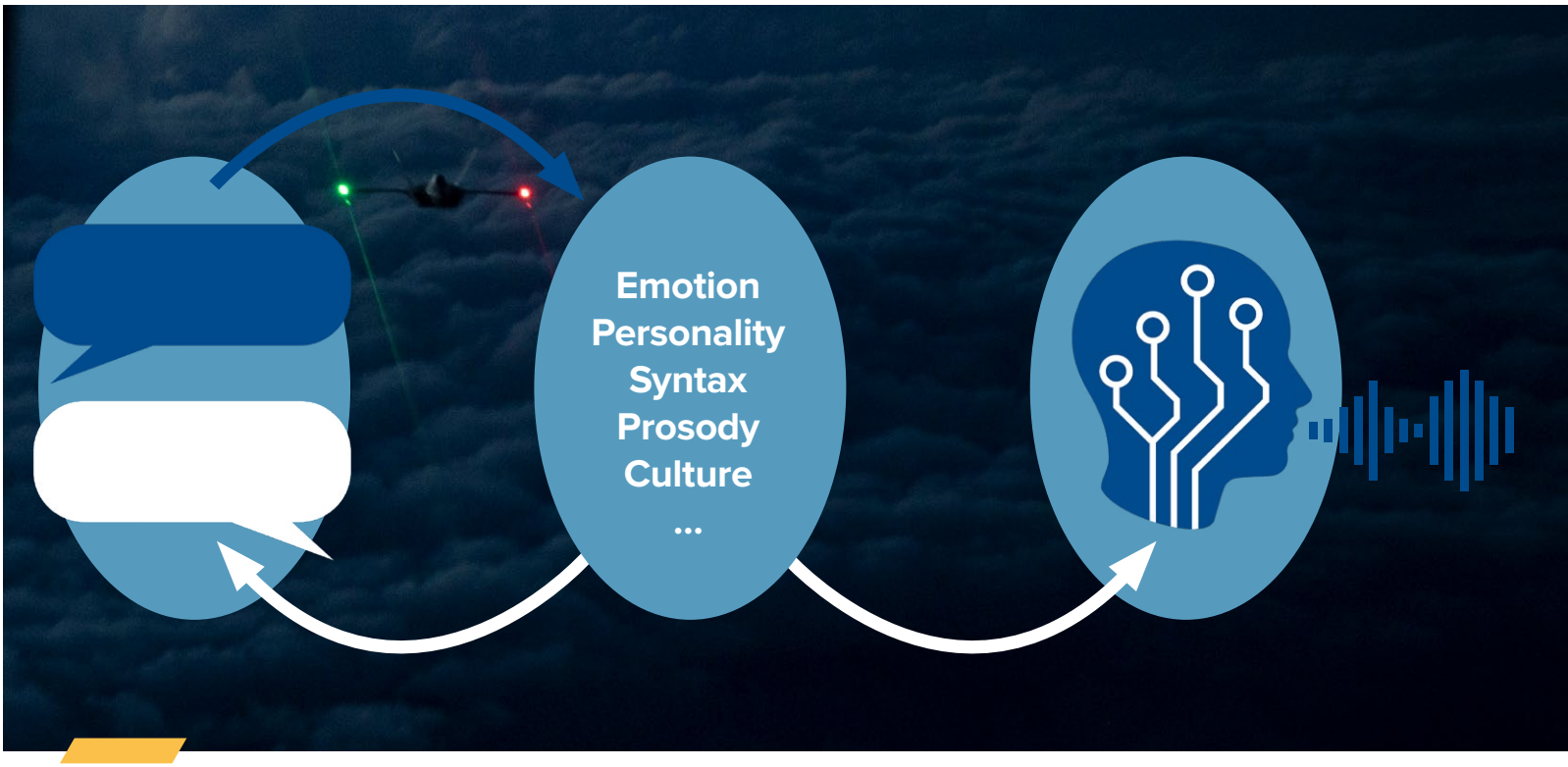
This research explores the complexities and goals of connecting all domain operational command and control (C2) with the tactical level. The cyber domain is the first domain that was explored. The outcome will inform the larger multi-domain picture in terms of what information is important for a cyber expert to communicate to operational C2 and how that information impacts other domains. This effort also aims to identify ways to represent the pertinent aspects of cyber plans in the context of multi-domain operations by developing innovative interface design concepts that enable the cyber relevant information to be quickly and accurately understood by other domains. Initially, the focus is on cyber 'on-call' missions that are ready to deploy along with the continuous monitoring of scheduled cyber missions that are being executed. Ongoing conversations with internal offensive cyber operations (OCO) subject matter experts (SMEs) model the understanding of the problem space by developing artifacts that align an envisioned cyber operator and their goals within the context of a multi-domain team, while also creating the context for a scenario used to evaluate the candidate interface design concepts.

This effort will build on previous research that developed several iterations of design concepts that represented cyber plan information identified as critical by cyber SMEs. Initial low-fidelity prototypes have been refined based on data collection from cyber and OCO SMEs. The outcome of the study resulted in new concepts for what information needs to be communicated to the JAD operational picture, as well as how domain battle managers may have to interact with each other to resolve requests from the JAD battle manager. Future research will use a similar cyclical process of defining information requirements, design, and evaluation to understand the requirements of the other domain battle managers. The outcomes of this effort will support future multi-domain teams by providing information requirements and display concepts that enable cross-domain operations understanding, necessary for collaboration across multi-domain teams. ☆

Mr Peter Venero, Research Psychologist, 711 HPW/RHWTC

Ms. Jessica Bartik, Research Psychologist, 711 HPW/RHWTC

Dr. Elizabeth Frost, Research Psychologist, 711 HPW/RHWTC



Graphic by Ms. Emily Conway, 711 HPW/RHWTE

TEDS and SAVAGE

Tailored Expressive Dialogue System (TEDS) leverages the highest performing Large Language Models (LLMs) to optimize communication through user state tracking and simulating appropriate response with controlled personality, emotions, communication style, stress mitigation, and more. With the push for integration of LLMs in everyday work life, TEDS addresses the need for that integration in an operational environment while also addressing the reality of high stress levels of personnel in that environment and aims to mitigate and reduce that stress in warfighters. Secondly, with these technologies, TEDS implementation in communication with foreign allies can assist warfighters in preventing cultural misunderstandings. Over the summer a cadre of four summer interns explored various methodologies of stress detection and stress mitigation which will be integrated into the TEDS framework. Concurrently, one summer intern set the groundwork for effective cross-cultural communication using statistical analysis over foreign conversations. Commercial systems for LLMs lack a level of control and often implement safety guardrails which conflict with necessary mission requirements. The technologies developed for TEDS provide the control necessary for various military applications such as Red Force simulations, realistic foreign language training simulations, and deepfake simulations.

The Synthetic Agent Voice Analysis Generation and Exploitation (SAVAGE) Project is utilizing current advancements in neural Text-To-Speech (TTS) and advancing these tools and techniques to generate natural sounding and emotional speech in English and foreign languages. Current commercial TTS systems do not support mission requirements and allow for the fine detailed control of emotion and pronunciation control to handle the military specific needs required of these synthetic agents SAVAGE will empower. As the Warfighter Interfaces and Teaming CTC builds out toolsets of interaction and teaming solutions, SAVAGE will provide a voice to these virtual and synthetic agents that will have to exist in these future distributed teaming scenarios. It is important to have the precise control and ability to not only customize these voices, but run them on our operator's networks and evaluate how the manner of speech impacts how these synthetic agents synergize as teammates in our growing Human Machine Teaming environment. The TTS capabilities being developed under SAVAGE will empower agents for both blue forces, and red forces for simulated training and drills. In particular, foreign speech generation to simulate red forces is a requirement for a specific customer's training requirements.

The integration of SAVAGE, TEDS, and Contextualized Communication Machine Learning (CCML) is the beginning of a fully intelligent teammate or agent. This synthetic agent would provide both control over how the context and tone of the agent is generated, as well as the understanding and sensemaking of multimodal content to provide a unique technological advantage to the warfighter. ☆

Ms. Emily Conway, Research Mathematician, 711 HPW/RHWTE

Mr. Eric Hansen, Senior Electronics Engineer, 711 HPW/RHWTE

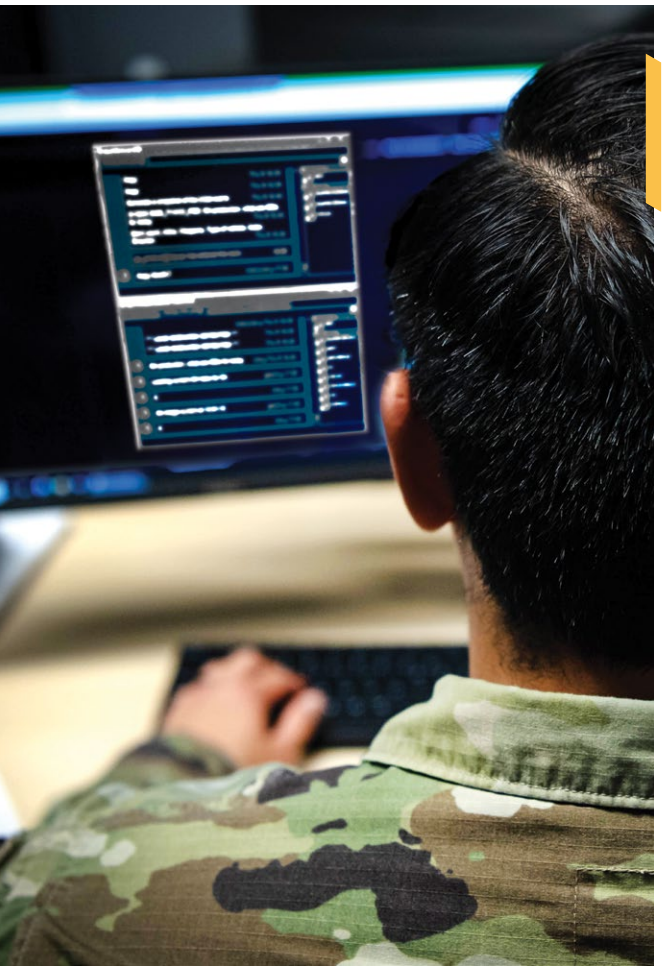


Photo by Airman 1st Class Jared Lovett

Conversational AI Assessment

Conversational Artificial Intelligence (CAI) includes analytics that translate user verbal or textual input into actionable machine analytics, giving a user some type of output using Generative AI (GenAI). NIPR GPT , released this summer, has 85,000 users and is growing over 1000 users daily. People across the DoD are enthusiastically finding ways in which GenAI can enhance their job performance. However, there has been very little research on how using this technology influences human cognition. Additionally, state-of-the-art conversational systems cannot dynamically adapt to different levels of user expertise across domains. We are working with the Information Directorate to develop and test an intelligent conversational agent tailored to expert and novice intelligence analysts. Our high-level vision is to use CAI to accelerate expert analysts' processes while observing their methodology and learning from them. The CAI's observations could then be translated to an agent tailored to novice analysts to provide instructional feedback for on-the-job training. Additionally, we are conducting human research studies to understand the cognitive impact of using CAI. This research focuses on user decision-making and analytic processes using GenAI compared to an internet browser. We are interested in how well users acquire and retain information curated and summarized by GenAI compared to conducting the research themselves. We are also investigating how users recognize incorrect or misleading responses (coherence, validity, quality), identify information sources, understand GenAI's content summarization methods, and modeling the human-GenAI interaction (i.e., GenAI humanness, trust, transparency, and effectiveness). ☆

Dr. Kellie Turner, Research Psychologist, 711 HPW/RHWID

Expert

What ships were in a 50mi radius of San Diego yesterday morning?

There were 3 ships in 50mi radius of San Diego yesterday between 0500 and 1000 PST.

<Info gathered from Database>

Planes in the Area | **Ships near Los Angeles**

Novice

What ships were near San Diego yesterday?

There were more than 100 ships near San Diego yesterday. Here is a list of 12 that were in a 50mi radius for longer than 12 hrs.

<Info gathered from Database>

Most analysts will search for other vehicles in the area around the same time frame. Would you like to do that?

Previous work in RH and RI explored how inserting conversational artificial intelligence (CAI) into the analysts' workflow could support them throughout the analysis process, with the most beneficial support centered on two of the most cognitively challenging steps, Research and Analysis. CAI can accelerate research by accessing structured data across disparate sources and automatically running analytics, resulting in a quicker jump to the analysis stage of the process (Turner, Kancler, Roller, & McCloskey, 2023).

Dr. Chris Brill

Human-Machine Interactions Core Research Area Lead, 711 HPW/RHWI

HUMAN-MACHINE INTERACTIONS

CORE RESEARCH AREA

The Human-Machine Interactions (HMI) Core Research Area focuses on how operators interact with systems, ranging from Pilot Vehicle Interfaces (PVI) to advanced automation and AI-enabled decision support and analysis tools. In short, our research investigates how operators interact with a single system or component of a larger system, rather than large-scale human-machine teams. Indeed, ours is a vital endeavor to achieve large scale Joint All-Domain Operations (JADO). Our CRA members are experts in human factors design, sensory perception, knowledge elicitation, decision making, data representation, and trust and transparency. Application areas include next-generation cockpit interfaces, exploring adaptive systems that adjust their behavior and modify interfaces based on operator states, developing human-centric tools for intelligence analysis, applying design guidelines to establish trustworthy and transparent intelligent systems, and solving the problem of transforming 'big data' into intuitive, quickly comprehensible representations that can be leveraged by operators. Lastly, the CRA explores novel interface concepts for Cognitive Warfare applications. The 711 Human Performance Wing (711HPW) has prioritized Cognitive Warfare as a thrust area, and a portion of our portfolio reflects this new investment area. ☆

Dr. Chris Brill
Human-Machine Interactions CRA Lead, 711 HPW/RHWI

Human-Machine Interactions CRA

HMI-enabled Decision Superiority LOE

Rapid Joint Cognitive Awareness LOE

CRA OVERVIEW

Identify principles of human interaction with highly complex systems, including advanced automation and increasingly intelligent AI-enabled machines.
Achieve and sustain decision superiority and performance across complex and uncertain mission environments.
Identify, characterize, and overcome key challenges to warfighter interactions with complex and intelligent systems such as situationally-adaptive interface design and usability, knowledge representation across sensory modalities, system observability and transparency, directability, joint cognitive decision making, and maintaining calibrated trust across changing conditions.

HMI-ENABLED DECISION SUPERIORITY
LINE OF EFFORT

Program Leads

LOE LEAD
Dr. Eric Geiselman

PROGRAM MANAGER
Capt Marco Pirozzoli

Next-Generation Human/Machine Interface Research (TASK)

Future Air Force operations will continue to grow in complexity, requiring coordinated activities across distributed agents, supporting missions taking place across multiple operational domains. Operators will have access to large amounts of quickly changing information as the basis of critical decision-making and action activities. The Next Generation Human/Machine Interface (NG-HMI) research task endeavors to deliver future operator interface affordances where the right information is presented at the right time for the right reasons in the right way. The NG-HMI research team is comprised of a diverse group of research professionals including in-house operational subject matter experts, experienced developers, and senor scientists working in a facility referred to as the Conceptual Pilot/Vehicle Interface (CPVI) laboratory. Additionally, the team works closely with the test and evaluation community through contracted flight test activities and collaborations with the USAF Test Pilot School (TPS). The CPVI lab development philosophy is one of exploration of the "art-of-the-possible" through agile processes to produce vetted problem definition, rapid prototyping, operator-in-the-loop evaluation, technology maturation, and continuous customer transition. As display and other interface hardware approaches are considered for tactical use across both the combat and mobility air forces, the CPVI lab exercises a "blank slate" approach toward supporting operator information needs and efficient decision aiding untethered to legacy solutions. To-date, the NGH-HMI team has developed and evaluated 30+ unique interface concepts that have been evaluated as performance enhancing transition PVI candidates. While successful rapid prototyping of concepts at the component level continues to be valued, an overarching objective of the NG-HMI team is to produce standardized or common operating picture for future combat and mobility air force Airmen. ☆

Dr. Eric Geiselman, Senior Research Psychologist, 711 HPW/RHWIM

Dr. Paul Havig, Senior Research Psychologist, 711 HPW/RHWID

Graphic by 711 HPW/RHWI

Joint All Domain Integrated Intelligence, Surveillance, and Reconnaissance (JADII) Research

Intelligence, Surveillance, and Reconnaissance (ISR) analysts are tasked in supporting critical questions and providing data-driven recommendations to military leaders in order to make informed decisions in near-real time. The processing, exploitation, and dissemination (PED) of collected intelligence can be extremely overwhelming and manually intensive on the human operator. To augment and enhance this process, the 711th HPW/RHWIM Joint All-Domain Integrated ISR (JADII) Team has developed Legion. Legion is a suite of interoperable capabilities, which can be applied at critical junctures of the intelligence process, to enhance ISR proficiency. Legion is comprised of three main capabilities including Sphinx, Nautilus, and Kraken.

Sphinx is a web-based, fronted application, that drives analytic workflow methodologies and can be personalized to reflect individual AOC's and DGSs workflow structure. It allows analysts the ability to develop, track, and take action on requests for information and link strategic priorities to commanders intent. Nautilus is a graphical behavioral database built on tactics, techniques, and procedures (TTP) to identify pattern of life (PoL) over time. In addition, Nautilus combines artificial intelligence and machine learning (AI/ML) analytics to identify anomalies. Kraken is an ISR feasibility engine built on high fidelity, physics-based modeling and simulation (M&S). It is capable of ingesting collection plans into a synthetic environment with sensor pairings and perform mathematical permutations in significantly less time to represent collection feasibility, along with intel gain/loss (IGL), threat, and priority data metrics. Each capability is independent, but working in concert Legion has the ability to augment, enhance, and accelerate the entire intelligence process.

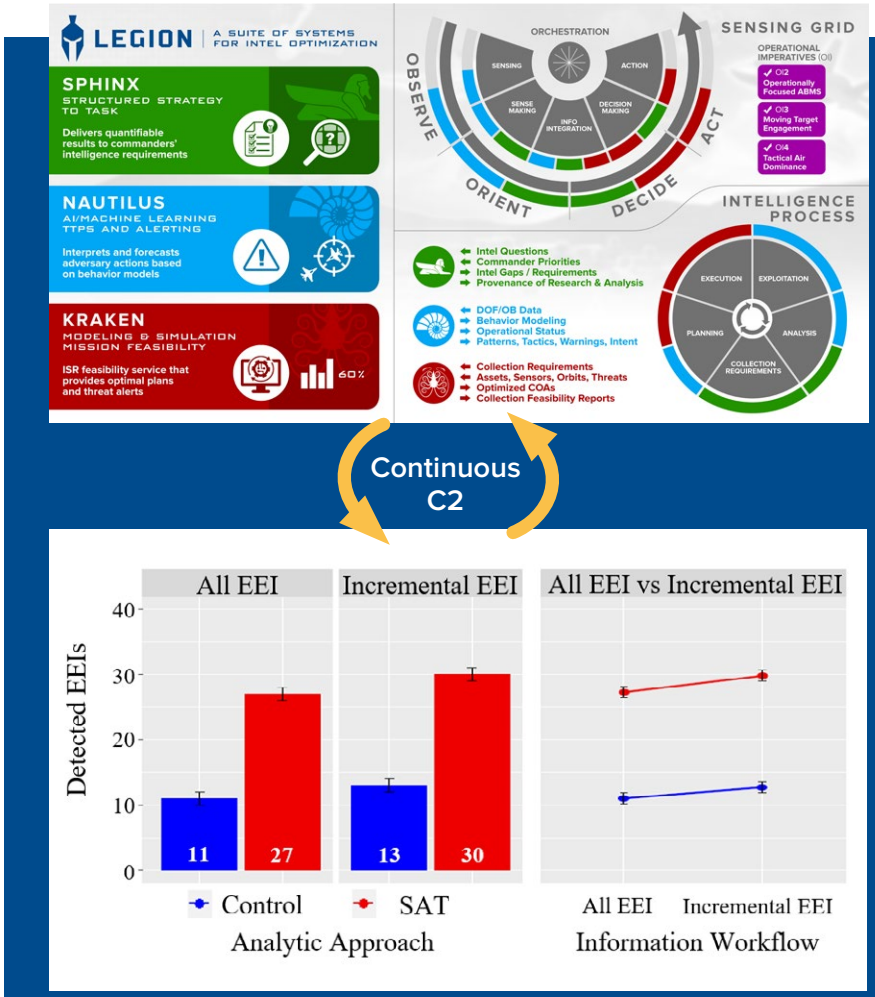
To support the development of Legion and provide critical information to the larger community, Joint All-Domain Integrated ISR (JADII) has stood-up the Continuous Command and Control (C2) 6.2 Research team led by Dr. Justin Nelson. The premise of C2 6.2 is to provide bookend solutions to optimize ISR operations through data-driven discoveries. More recently, Dr. Nelson and team developed a research study to evaluate if structured analytic techniques (SATs) coupled with information workflow methodologies could enhance the detection of subtle essential elements of information (EEI) resulting in improved performance metrics. The study consisted of four groups of 10 active-duty military personnel. Participants were randomly assigned to either a SAT or Control and provided vague/ill-defined content in incremental sections or all at once. The findings discovered that providing participants with a SAT coupled with an incremental workflow methodology resulted in the highest solution accuracy compared to all other conditions. Moreover, participants that were provided with a SAT detected significantly more EEIs compared to the Control condition ($p<0.01$). This discovery provides value to the community and supports future architecture design of the Legion capabilities. ☆

Dr. Justin Nelson, C2 6.2 JADII Research Lead, 711 HPW/RHWIM

Mr. Patrick Ederer, Legion Team Lead, 711 HPW/RHWIM

Mr. Stephen Plassman, JADII Team Lead, 711 HPW/RHWIM

Graphics by 711 HPW/RHWIM



EEI Detection based on Group Assignment and Information Workflow

RAPID JOINT COGNITIVE AWARENESS
LINE OF EFFORT

Multilevel Transparency for Human-Autonomy Interaction

Program Leads

LOE LEAD
Dr. Jim Bliss

PROGRAM MANAGER
Lt Arianna Martinez

The Multilevel Transparency for Human-Autonomy Interaction (MTHAI) Project builds on the Warfighter Interaction and Readiness Division's (RHW) legacy research investigating trust in human-human and human-non-human interactions. Transparency is a multidimensional construct relating the development of shared awareness and intent between humans and machines (Lyons, 2013). Transparency has been noted as a critical aspect for effective human-autonomy teaming (NAS, 2021), but there is a lack of human-centered research on transparency in complex, emerging AI/ML systems (Alarcon & Willis, 2023), which is particularly challenging given that humans will be expected to coordinate with said systems in a variety of contexts.

As transparency in human-autonomy interaction will act as a force multiplier in the Joint All Domain Command and Control (JADC2) enterprise, research explicating when, why, and for whom transparency is relevant in human-machine interaction becomes increasingly necessary. The MTHAI Project currently has a two-pronged approach to investigating these aspects. The first focus is on transparency in human-AI/ML interaction. By leveraging the nascent literature on these complex machine systems, as well as current psychological, human-centered approaches to human-XAI interaction (e.g., Alarcon & Willis, 2023), the team is manipulating features which have influenced trustworthiness toward human and non-human systems in past work (e.g., Alarcon, Capiola, et al., 2023) and measuring their effects in novel human-AI/ML interaction contexts. The second focus is on AI/ML in decision-support tools, specifically when best to leverage these technologies and how to display their outputs and processes by which they reach a decision. This latter aspect is key, as humans cannot always track the complexities of AI/ML decision processes directly (Lyons et al., 2021). Moreover, if these benefits are to be utilized, appropriate display of their processes and outputs will be key for human adoption of said systems.

In addition to legacy work on trust within RHW, inputs for this project include (but are not limited to) a successful 3-year collaboration between the Human Effectiveness Directorate (RH) and the Information Directorate (RI) on an Air Force Office of Scientific Research (AFOSR) funded laboratory task investigating human-ML interaction with calibrated classification models in image-based classification tasks (e.g., Alarcon et al., 2024; Harris, Capiola, et al., 2024; Meyers, Capiola, et al., 2024), as well as ongoing RHW-led efforts investigating the trust process in human-AI/ML/XAI interaction, both of which demonstrate successful, RHW involvement in AFOSR Laboratory Research Initiation Requests. Leverage points for this project include ongoing collaboration with the Air and Space Biosciences Division (RHB) investigating transparency affordances for decision-support systems in emergency aeromedical evacuation and international collaboration with NATO partnering nations on human-centered design promoting successful human-robotic swarm interactions. One transition path for this project includes promoting transparency in AI/ML-enabled candidate product technologies. Deliverables include transparency guidelines for advanced technology development programs, as well as inputs for inter-division candidate products and cross-directorate stakeholders. The MTHAI Project explicates effective human-AI/ML/XAI interactions, an emerging human-machine teaming context, to promote the 711 HPW's Decision Superiority Operational Concept. ☆

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>
> **— Multilevel Transparency for Human-Autonomy Interaction Team**

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Human Autonomy Interaction (HAI) Adaptations

Technological advances for intelligence, surveillance, and reconnaissance (ISR) have enabled increased task sharing between human operators and automated tools. However, the effectiveness of such Human-Automation Interactions (HAIs) during complex scenarios often suffers because of degraded human-automation trust, transparency, and situation awareness. The problem is also of prime concern for collaborative combat aircraft scenarios, during which interactions between humans and automation must be seamless.

If implemented adaptively, transferring control to automation may reduce fatigue, stress and cognitive workload. If time and resources are available, automation can use retrospective performance data to switch control optimally. However, such shifts may be achieved more efficiently if the automation were sensitive to the cognitive state of the human prior to major lapses in the human's performance.

This project is using robust physiological measures to examine the performance effects of demanding sessions in a relevant ISR task environment. Investigators plan to combine a variety of mature, readily available and deployable physiological measures such as heart rate variability and ocular activity to instigate changes in task control. These measures will enable characterization of extended shift effects on performance and identify physiological fluctuations that can guide real-time task environment adaptations. Previous research has demonstrated the sensitivity of such measures to cognitive workload and information seeking behaviors that reflect situation awareness. Relying on physiological signals as triggering mechanisms, through technically possible, could ultimately confuse human operators who fail to understand when and why transfer of control is occurring. One purpose of this research is to identify and investigate interface design strategies that could ensure operator awareness of control automation mode shifts. By increasing transparency, such strategies should optimize human operator awareness and reactivity during periods of compromised readiness such as task resumption following control shift interruptions. Highlighting information to cue attention, presenting running displays of physiological parameters, and augmenting existing display components are possible candidates.

Complementary research efforts have been pursued in recent years at AFRL. For example, investigators associated with the Fatigue Optimized Cognition Under Stress (FOCUS) program have leveraged data from mobile fitness applications, wearable sensors, and visualizations to reflect when pilots' physical states may be compromised. However, implementing strategies for display optimization in concert with physiologically driven task switching has been largely unexplored. Drawing from complementary research at AFRL as well as from research across the Department of Defense, researchers will leverage solutions from a variety of mission sets that transcend ISR.
During the initial year of the project, members of the RHWI research team and contractors have collaborated with contractor and civilian researchers from RHB to populate a research laboratory with physiological measurement equipment. Initial data collection has targeted the impact of control shifting on operator preferences and performance. The next steps will include incorporation of physiological triggers and testing of interface modifications. Ultimately, comprehensive task control switching and interface design guidelines will benefit numerous investigations that feature human-automation teaming. ☆

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RHW FY24 SUCCESSES

F-35 Auto-GCAS Algorithm Fix
Uncovered unknown error causing erroneous system activations during low-level flight that interfered with training and operations. Transitioned to F-35 Joint Program Office (FY23)

Base Oversite of Autonomous Response (BOAR) United States Air Force Marathon Support

Networked Integrated Training Environment (NITE)
Transitioned to 1st Joint Special Operations Air Component

Led Aerial Refueling Battle Management (ARBM) for Next Generation Air-Refueling System (NGAS) to Chartering as Vanguard Prospect

IMPACT (Intelligent Multi-UxV Planner with Adaptive Collaborative/Control Technologies)
Transitioned to AFLCMC/HBUC/Medusa Program of Record (FY24)

Halon Fire Extinguisher Virtual Reality Trainer
Transitioned to 2nd Air Force, Detachment 23 (FY23)

Content Data Standards (CDS)
Transitioned to ACC/A3T/A5T and AFLCMC/WNS (FY23)

Adaptive Teamwork with Layered Airman-Machine Interfaces and Systems (ATLAS)
Transitioned to AFLCMC/WA (FY23)

Speech Intelligibility Calculator
Transitioned to VC-25B Program Office to Support Requirement Relaxation Decisions

Transitioned Social Media Emulator Software to USAFA and University of Colorado Boulder to Facilitate Cognitive Warfare Research

Formal Kickoff of Competency Based, Personalized Bystander Intervention Total Force Training in My Learning

Integrated Extended Human Factors Fatigue Model into the Combat Operations Mission & Basing Analysis Tool – AFRL/711 (COMBAT-AFRL/711) Software

Geological Landscape Illumination and Mapping of Moon's Environment and Reflections (GLIMMER)
Transitioned to AFLCMC/WA (FY23)

Cyber Effects Simulator And Relay (CESAR)
Transitioned to USAFA MDL FY 2023

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711 HPW/RHW Core Research Areas:
- **Digital Models of Cognition**
- **Distributed Teaming & Communication**
- **Human-Machine Interactions**
- **Learning & Operational Training**