# AFRL FIGHT'S ON!

THE AIR FORCE RESEARCH LABORATORY

ISSUE 71
FALL 2023

## WARFIGHTER INTERACTIONS AND READINESS DIVISION


DECISION SUPERIORITY FOR MODERN WARFIGHTERS

I/ITSEC Edition

> **We must build on One Lab – Two Services by integrating our S&T across domains and disciplines, accelerating technologies for a multi-domain fight."**
>
> ***— Brig General Scott A. Cain***
> Commander, Air Force Research Laboratory

Photo by Staff Sgt. Jared Bounds

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Graphic Designer **Mr. Will Graver**
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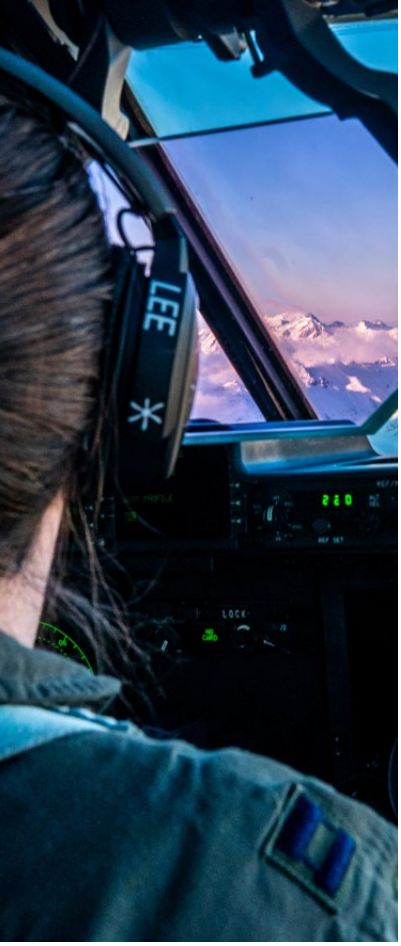
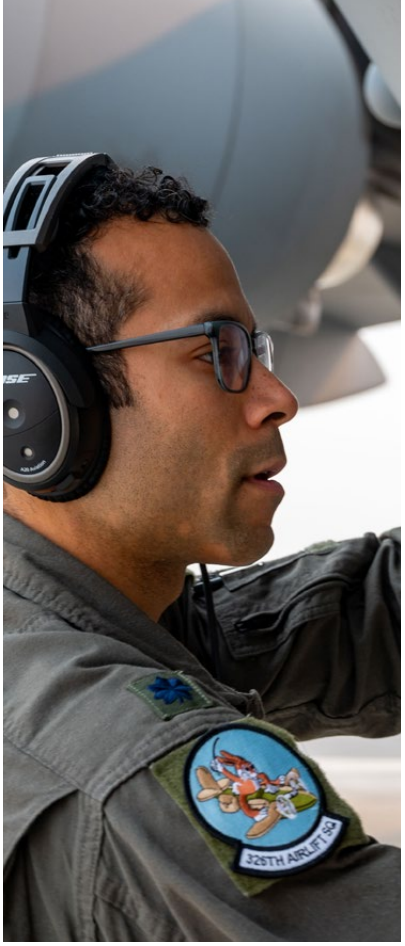

(Left) Photo by Staff Sgt. Megan Beatty
(Second to left) Photo Airman 1st Class / Amanda Jett
(Right) Photos by Mr. Will Graver (Ball Aerospace)

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.* ☆

**Dr. Louise Carter**
Division Chief, 711 HPW/RHW

**The times call for a renewed energy focused on the near peer fight, and we are committed to ensuring our warfighters' decision superiority in that fight."**

**— Dr. Louise Carter**
Division Chief, 711 HPW/RHW

# RHW
## DIVISION INTRODUCTION

It seems that we are always talking about change. Over the past year we completely reimagined our 6.2 research, focusing on the future needs of our Airmen and Guardians. We are also in the process of standing up a new Product Line, Intelligence Analytics and Sensemaking. Our directorate has returned to its roots by reclaiming the name Human Effectiveness Directorate. This is not change for change's sake. The times call for a renewed energy focused on the near peer fight, and we are committed to ensuring our warfighters' decision superiority in that fight. To that end, RHW is working collaboratively across AFRL and beyond to integrate and transition technologies.

As in the past, we are focused on the cognitive aspect of the mission. Enabling and enhancing our Airmen and Guardians with technologies for Joint All Domain Operations, Synthetic Operational Testing and Training, and Human Representation in Digital Engineering are our priorities. These require leveraging our historically strong expertise in cognitive modeling, human factors, and learning. We also are building our capabilities in human machine teaming, command and control, human and machine co-learning, and modeling for systems engineering and wargaming. While our partners are asking for more from us, we have made integration and teaming our way of business, change has made us stronger, and now the talented RHW team is poised to enable decision superiority for the USAF. ☆

**Dr. Louise Carter, Division Chief, 711 HPW/RHW**

# RHW ORGANIZATION

## WARFIGHTER INTERACTIONS & READINESS DIVISION
711 HPW/RHW

**DIVISION CHIEF**
Dr. Louise Carter

**DEPUTY CHIEF**
Col Alfredo Rivera

TECHNICAL ORGANIZATION

BRANCH LEADERSHIP

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**WARFIGHTER-MACHINE INTEGRATION**
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**INTELLIGENCE ANALYTICS & SENSEMAKING**
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**WARFIGHTER INTERFACES & TEAMING**
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**DISTRIBUTED TEAMING & COMMUNICATION**
Dr. Mike Tolston

**HUMAN-MACHINE INTERACTIONS**
Dr. Chris Brill

**Dr. Winston "Wink" Bennett**
Readiness Product Line Lead, 711 HPW/RHW

# READINESS
## PRODUCT LINE

Welcome to the 2023 I/ITSEC Edition of Fights On! and to the Readiness Product Line update for this year! For those of you who do not know, this will be my last posting as both the Product Line Lead and as an AFRL employee. Even though this is my last posting as the lead, there is plenty to talk about this year, and I am excited to share our research and field work as the continuing Readiness Product Line Lead for our Division.

Let's talk about the good things that have happened this year! First, I am very happy to share that the Department of the Air Force (DAF) Chief Modeling and Simulation Office, AFRL, and the Human Effectiveness Directorate leadership have endorsed the stand up of the initial Modeling and Simulation Integration Lab (MSIL) in Building 852 at Wright-Patterson Air Force Base (WPAFB)! This is a major steppingstone to supporting cross-AFRL M&S innovation integration for both the Joint Simulation Environment (JSE) and the larger M&S community of interest.

Second, as a part of this standup, we are now supporting Air Combat Command (ACC), Air Force Life Cycle Management Center (AFLCMC WNS), AFLCMC Architecture and Integration (XA), and the ops community to derisk innovation solutions for integration into the JSE for the USAF. We are creating an initial hardware baseline for hosting JSE components called a Franken-JSE In A Box (JIAB) so as not to be confused with the official, fielded JIABs. Since those deliveries are delayed until late fall to early winter, we wanted to lean into some of the initial work with software and functionality. We'll start with supporting a Multilevel Security collaboration with AFLCMC/XA and some early work to help further derisk interoperability between the JSE and Distributed Mission Operations (DMO). We hope to be up and running with a number of JSE capabilities before the new calendar year!

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Photo by Mr. Will Graver (Ball Aerospace)

Third, we formalized our growing collaboration with the Joint Program Office (JPO) and US Navy on developments and expansion of the Effects Based Simulator (EBS) capability we started with USAFE/AFRICOM Warfare Center (UAWC) a few years back. The work, now also sponsored by the DAF Chief Modeling and Simulation Office, includes collaboration on new software baselines supporting US and coalition training events, instrumentation for performance and readiness tracking, integration of collaborative combat aircraft capabilities, and continues our strong collaboration with the UAWC in Germany and other NATO partners as well. Finally, our Simulator Common Architecture Requirements and Standards (SCARS) team has had some really outstanding successes this year as a part of our collaboration with the AFLCMC/WNS SCARS program. You can read more about those in a separate article in this very issue.

This year also marks the start of our team's work supporting the laydown of the Combat Air Forces (CAF) Future Training Concepts Proficiency Based Training capabilities as part of the foundations for REFORGE. REFORGE is a large project being sponsored by the Headquarters Air Force (HAF) and CAF to change readiness training for the CAF starting with the F-22 FTU at Langley. Our work over this next year will define the Mission Essential Competency (MEC) baseline knowledge, skills, and developmental experiences for both the T-38 Aggressors and the F-22 personnel there. The baselines will be used to define proficiency levels, create new scenarios for each community (as well as for the combined ops they will fly), define metrics, integrate learning assessment and management tools without data lake capability and create a low-cost, multi-aircraft configurable virtual environment for the T-38 ops personnel to try out and evaluate. We will use the results to define low-cost, VR and mixed reality alternatives for everyone.

This summer we awarded seven new Direct-to-Phase II SBIRs in the space of data analytics and content and data standards. These awards are a follow-on to a successful product line effort as well as opportunities that were created in our AFWERX Big Data Challenge a couple years back. Given the variety of companies and their capabilities, we sponsored an initial event called Datapalooza. We expect recurring Datapalooza engagements over the next two years, but the goal of the effort is to create and grow a robust and op-representative data set (at the unclass level) level that can allow machine analytics, modeling, and additional data generation to happen. We hope to be able to share the results from the Datapalooza efforts with the broader communities of interest and practice as we move along. Stay tuned for updates!

We are continuing our work on a multidisciplinary effort to conduct research, development, and integration of science and technologies supporting HAF and ACC. The work is centered on a number of areas of need from the ops community and provides 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. It also supports 4th and 5th gen integrated training using the testbeds we have in the Division as well as integrating performance measurement and feedback technologies identified to support the CAF Future Training Concept into selected mission training center software integration labs. There is also support here for creating and transitioning blended training technologies and tools into ops training and rehearsal. We currently have our government-off-the-shelf (GOTS) tools running at a growing number of ops and research locations in the US and around the world, and we are using the feedback from those integrations to further advance the tools for broader use and capabilities.

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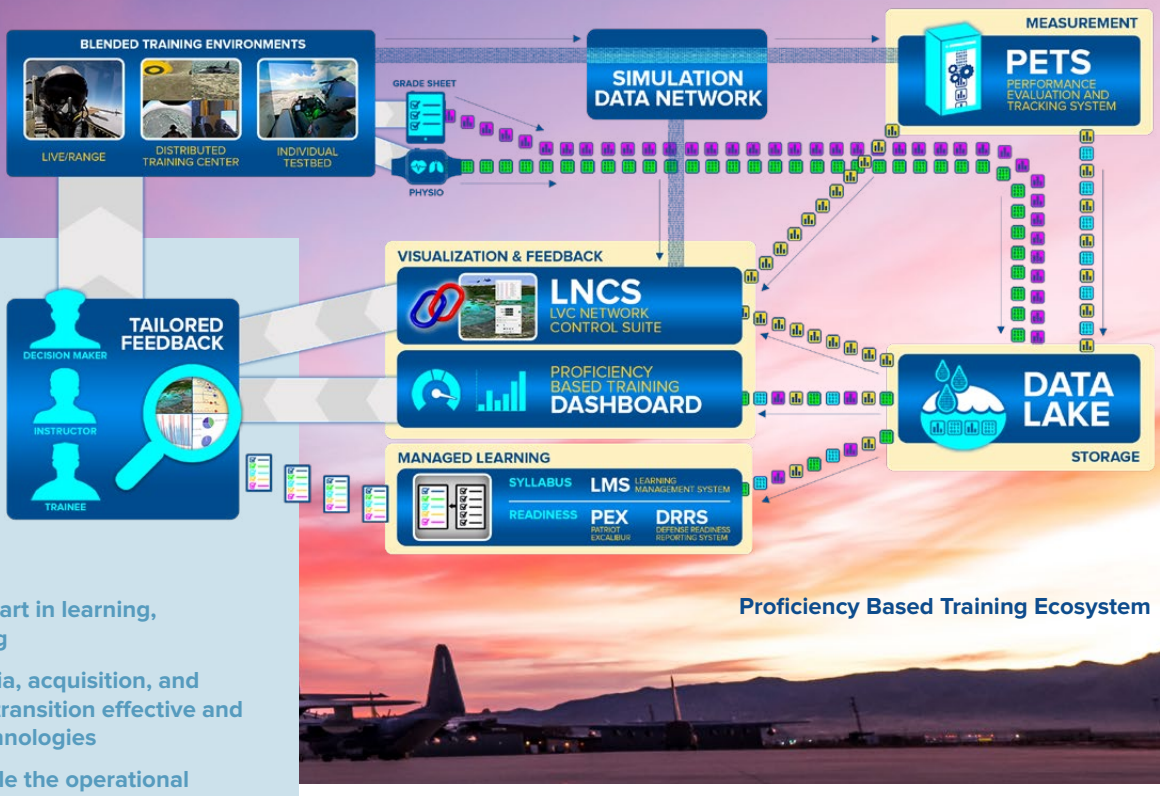
## OUR WORK

- Drives "Innovation at the Speed of Ops" in direct support of the SECAF's Operational Imperatives
- Helps to create human and machine interoperable training and assessment for Decision Superiority
- Advances the state-of-the art in learning, performance and modeling
- Aligns nicely with academia, acquisition, and industry to collaborate to transition effective and efficient methods and technologies
- Quantifies and helps enable the operational readiness of our Airmen




**Proficiency Based Training Ecosystem**

Graphic by Mr. Will Graver (Ball Aerospace)

This year we're completing on two efforts that were driven by General Mike Holmes at the end of his tenure as Commander of ACC. The first is developing a web-based repository that will allow USAF training content developers, instructional designers, and instructors to share and reuse critical augmented and virtual reality (AR/VR)-related technologies (e.g., reusable models, source code, executable code, application programming interfaces [APIs], software development kits (SDKs), performance measures, dashboards). We've continued to gather data virtually and are now heading to the field to meet directly with innovators and developers to capture more specific details and applications of the technologies in research and ops.

We also wrapped work on a collaboration with researchers at the Institute for Defense Analyses. This effort developed an effectiveness framework for AR/VR training based on scientific and empirical findings. It also documented current research and applications of the technologies in military education and training. We completed qualitative and quantitative reviews of the published literature to make recommendations for research and practice and created an interactive digital 'library' of the studies and framework. These efforts will provide deeper details for tracking, integration, and fielding of AR/VR-based solutions more quickly and cost-effectively. Folks will no longer need to reinvent the wheel each time a new application is developed or someone has a policy precedence for software and hardware accreditation, or certifications, and related lessons learned and other data artifacts. We're hoping to transition what we have developed into a sustainable ecosystem similar to Dynepic's MOTAR.

You can also see other contributions in this issue related to our Gaming Research Integration for Learning Lab® (GRILL®), GRILL West at the United States Air Force Academy (USAFA), workforce development and game based modeling and simulation, support to the Joint Service Mixed Reality SUPER GOGGLE AFWERX Challenge, Fighter Integration Training Research, Not So Grand Challenge rapid agent model development, and our Just In Time Multimission Airmen Warfighter efforts.

Finally, I want to say thank you to all for staying with the team and I over the years, through direct collaboration and also through your advocacy for our papers, presentations, and panels that have been a treasured part of my time with I/ITSEC (and TITE before that) and this community of passionate, dedicated professionals who know who we support and embrace the work and the mission as the calling that it is. I would also be remiss if I didn't say thank you to all joint and international collaborators, past and present, as well as the many great folks who are a part of the NATO Modeling and Simulation Group, SISO, and the larger global M&S community for their friendship and support over the years. As I depart, I can assure you that our academic, industry, and international partnerships are strong and continue to grow their interest and involvement in collaborations. We have a number of new agreements, partnerships, and contract activities underway. The future is bright for new S&T leadership and growing our already strong support of our international standards development and involvement in multinational research and technical groups.

I invite you to contact me or any of our team members to explore opportunities for collaboration and partnership. I'll hopefully see you around! ☆

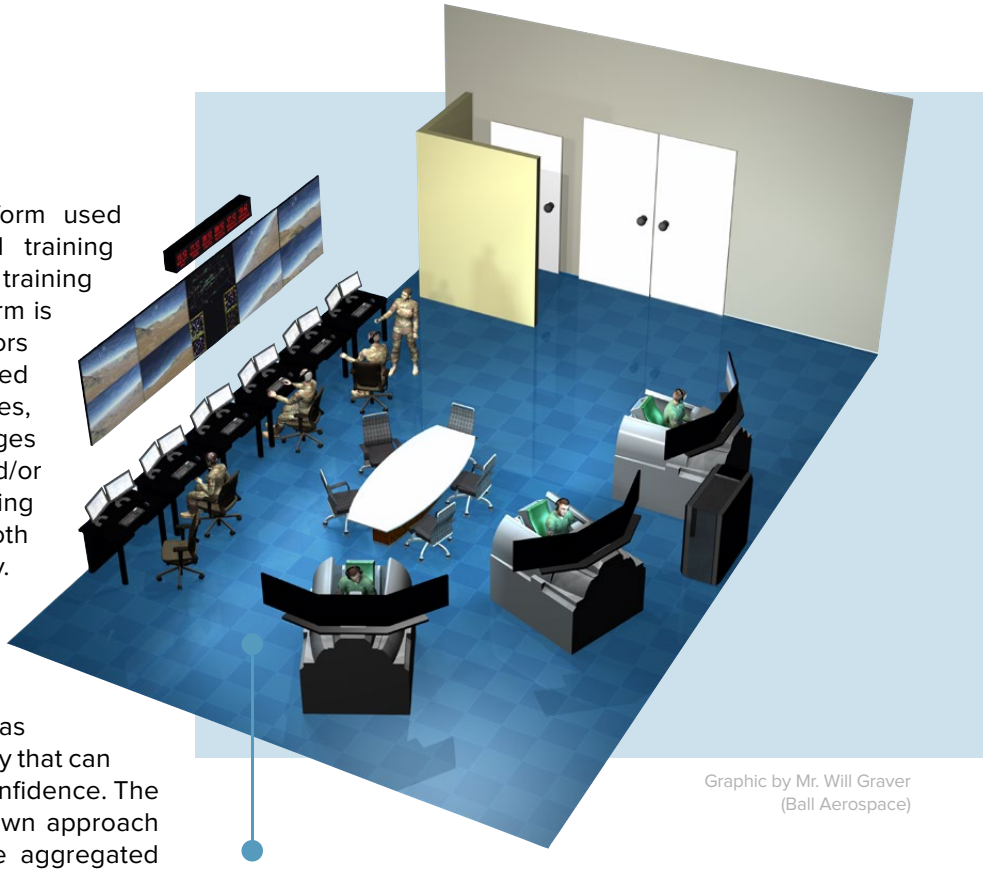
**Dr. Winston "Wink" Bennett, Outgoing Readiness Product Line Lead, RHW**

# SimMD™

SimMD™ is an encrypted, web-based platform used to examine the fidelity of simulator-based training throughout a simulator's lifecycle to ensure training needs are continuously being met. The platform is highly adaptable to a wide range of simulators and training devices and can therefore be used to examine a variety of different technologies, platforms, and environments. SimMD leverages the experiences of everyday trainees and/or operators to systematically gather data, producing a comprehensive report highlighting both simulator strengths and areas of deficiency. Such insights can include elements of simulator training that fail to provide the necessary experiences compared to high-fidelity training environments (e.g., live training or more robust simulators) as well as areas of adequate or exceptional training fidelity that can continue to be trained with a high degree of confidence. The standard evaluation process utilizes a drill-down approach to gather both quantitative data that can be aggregated across the evaluators as well as qualitative data that can be used to extract and document more specific and detailed information. As part of the report generation process, SimMD also leverages important statistical principles such as interrater reliability which can provide critical insights regarding the quality of the subjective feedback.

Ongoing SimMD evaluations include CONUS/OCONUS and active duty/Air National Guard (ANG) evaluations for the CRC platform. These evaluations are contributing to the development of a comprehensive data sample to facilitate actionable CRC training device assessments and decision making. 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. This includes, but is not limited to, the Distributed Mission Operations (DMO) stakeholders meeting, Global Tactical Advanced Communication Systems (GTACS) Summit, Department of the Air Force (DAF) Modeling and Simulation Summit, and I/ITSEC. Future work includes the development of an integrated, within-tool report dashboard to support decision making as well as the development of a version of SimMD for secure environments. Platforms such as Airborne Warning and Control System (AWACS), F-15, and F-16 have been identified for future evaluations including the development of an actionable data sample associated with each platform to support decision making. ☆

**Dr. Alexxa Bessey, Scientist, Aptima, Inc.**



Graphic by Mr. Will Graver
(Ball Aerospace)

# Fighter Integration Training Research (FITR)

## Training Research Week

The division successfully completed our first Fighter Integration-Training Research Week (FI-TRW) 23-1 with participating F-22 and F-16 current/qualified pilots. Linking our 5th and 4th gen fighter test beds together, pilots flew virtual simulator devices against constructive red adversary entities over multiple missionized scenarios. They completed multiple research surveys throughout the week and were able to provide valuable training to inexperienced F-16 pilots who have had very little exposure to live or virtual fighter integration (FI) flying. Lessons were learned on both sides and the FI-TRW effort is off and running with more TR weeks planned for FY24 and beyond. We plan to add Collaborative Combat Aircraft (CCA) to the FI simulation and capture data on pilot CCA training effectiveness throughout a variety of missionized scenarios. This will create an initial blueprint for pilot/CCA interfaces. ☆

**Mr. Scott Carpenter, Fighter SME, RCG**

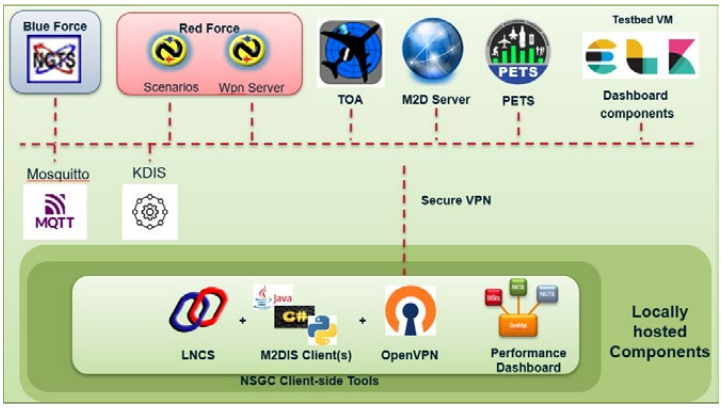
# Not So Grand Challenge

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 in a wargaming setting. 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 (e.g., AI agents), 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. The objective of this work is to develop multiple, alternate models to examine the effectiveness of different agents within a variety of U.S. Government and commercially available Computer Generated Force (CGF) environments (e.g., Next Generation Threat System [NGTS] or Advanced Simulation Combat Operations Trainer [ASCOT]). The next phase of work will also incorporate a common dataset for the performers to engage with to examine the effectiveness of the agents, as well as provide the Digital Librarian with a broader set of data to interact with for personalized training recommendations.

## COGNITIVE MODELS

Engagement in exercises is a proven way to enhance pilot training, particularly when conducted against experts in tactical flight. The use of 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 (in some cases through a machine learning technique) to learn scenario states and associated pilot actions. Other approaches include developing 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. The result is CGF-ready red agents with the needed complexity of behavior to carry out specific tasks within scenarios (e.g., pattern holding or flight escorts).

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




## TESTBED

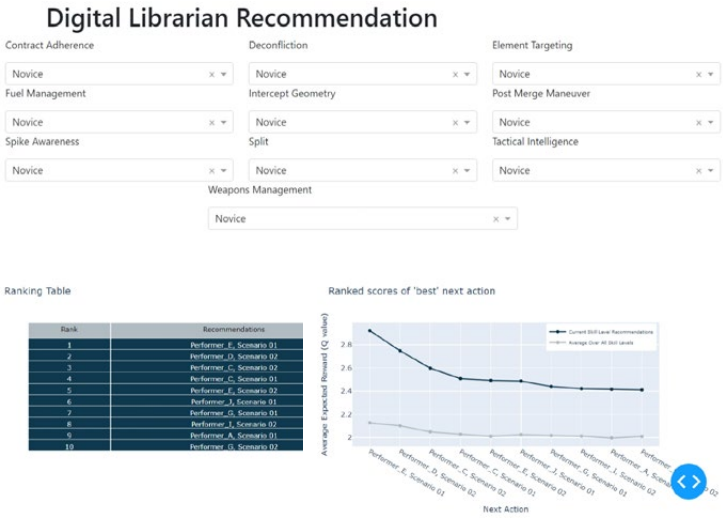
The NSGC Testbed utilizes many government-off-the-shelf (GOTS) software, such as NGTS, Network Integrated Constructive Environment (NICE), Tactical Observation Agent (TOA), Performance Evaluation and Tracking System (PETS), and Live, Virtual, and Constructive (LVC) Network Control Suite (LNCS). Aptima 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 CGF-agnostic, so that any CGF can be easily integrated and used.

Continued on next page

## NSGC MILESTONES

- **Completion of Testbed and Client-side software to enable cognitive model development**
- **Completion of models reflecting 1v1 pilot performance in a series of basic scenarios**
- **Completion of models reflecting 2v2 pilot performance with more complex scenarios**
- **Completion of models reflecting 2vX pilot performance in a more complex free-flowing scenario including numerous tasks: fuel & weapons management, air refueling, combat air patrol maneuvering, bomber escort, and no fly zone avoidance**

Screen Capture by Mr. Will Dupree
and Mr. Luke Waggenspack, Aptima , Inc.




## DIGITAL LIBRARIAN

Through the use of machine learning (ML), pilots who interact with the Testbed will get personalized training provided by intelligently selecting available scenarios and 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 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 uses Markov Decision Process (MDP) and reinforcement learning (RL) algorithms to 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. ☆

## NSGC FUTURE WORK

- **Demonstrate models against manned virtual platforms**
- **Develop Digital Librarian to ingest pilot performance measurements to determine which model is best for specific scenarios**
- **Integrate other USG and commercial CGF environments into the Testbed: ASCOT-7 and AFSIM**

**Dr. Winston "Wink" Bennett, Readiness Product Line Lead, 711 HPW/RHW**
**Dr. Samantha Perry, Product Manager, Aptima, Inc.**
**Dr. Will Dupree, Research Engineer, Aptima, Inc.**
**Mr. Jacob Smith, Testbed Engineer, Aptima, Inc.**
**Mr. Scott Carpenter, Fighter SME, RCG**


Photo by Airman 1st Class Brooke Moeder

# Datapalooza:

## Accelerating Innovation for USAF Pilot Training

Data is one cornerstone of Air Combat Command and AFRL's effort to provide more effective and efficient pilot training. Data-driven insights help deliver the right training at the optimal time, augment instructor expertise, guide training priorities, and justify budgets.

AFRL's Datapalooza workshop (September 6-7, 2023, in Dayton, OH) brought together more than 40 individuals representing the lab's internal team, small businesses, and other stakeholders to work on future-looking data generation and analytics requirements. This initial workshop focused on needs for an unclassified dataset representing the structure and characteristics of complex tactical training scenarios. Many organizations cannot perform classified work, and this new dataset will allow them to explore innovative methods to address the big challenges the USAF faces. AFRL will share an initial dataset this year with seven direct-to-phase-II SBIR awardees and related stakeholders.

Datapalooza contributes to the lab's longstanding Content and Data Standards research portfolio and builds upon the AFWERX/AFRL Data Lake Workshop in 2020. In future events Datapalooza participants will iteratively develop and refine datasets necessary to explore new methods delivering actionable insights to pilots, instructors, and decision makers. Reach out if your organization would like to join the Datapalooza team, either with requirements for data or complementary data sets. The cross-organizational collaboration exemplified during the first Datapalooza will help us accelerate the innovation driving training and operational excellence. ☆

**Mr. Peter Neubauer, Principal Research Engineer, Aptima, Inc.**

# AFRL SCARS Testbed

The AFRL Simulator Common Architecture Requirements Standards (SCARS) Testbed is an ongoing research effort to provide insight into possible future increments of the AFLCMC SCARS program. In 2023, AFRL SCARS has been focusing on virtualization/containerization, Modular Open System Architecture (MOSA), and determining what functions of the simulators can operate on the SCARS On Premises Equipment (OPE), SCARS cloud, and what has to remain with the simulator.

Building on previous work putting the F-16 simulator into a Virtual Machine (VM), AFRL has successfully tested the VM F-16 sim in Air-to-Air(A/A) and Air-to-Ground (A/G) missions. The Air-to-Air missions tested multiple air targets from a computer generated force (CGF), A/A radar, and Target Pod and A/A weapons on target. A/G missions included stationary and moving targets generated by a CGF, laser-guided weapons on target, and Targeting Pod. The F-16 SMEs did not notice a difference between the baseline F-16 SIM and the VM F-16 SIM. AFRL plans to continue testing the VM F-16 Sim while adding latency between the VM and Sim, reducing the resources available to the F-16 VM, and finally running the VM on the SCARS OPE.

Working to apply a modular open system architecture to the F-16 Simulator, the SCARS testbed has been researching the F-16 real-time executives to gain insight into the timing, synchronization, and data flow issues with decoupling subsystems from the simulation executives to run on the SCARS OPE or the SCARS cloud and containerizing these subsystems. AFRL SCARS testbed is also working to replace the F-16 Sim's shared memory partitions with Data Distribution Service (DDS) with the ownship, targeting pod, and Distributed Interactive Simulation (DIS) subsystems. Breaking up the simulator's subsystems and running them in separate VMs or containers enables the SCARS testbed to continue researching what simulator functions can operate on the SCARS OPE and the SCARS cloud. AFRL SCARS team is currently building a SCARS 5th Generation testbed to start providing insights on how to incorporate the 5th Gen Aircraft simulators into SCARS. AFRL has also begun to explore the JSE GRID service and how to integrate GRID into SCARS. ☆

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


Graphic by Mr. Will Graver (Ball Aerospace)

# Mission Essential Competencies (MECs)™

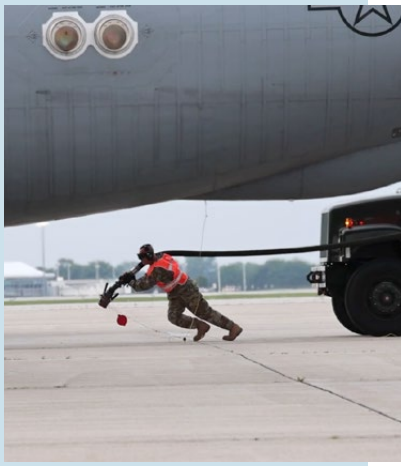
Mission Essential Competencies (MECs) are higher order individual, team, and inter-team competencies that a fully prepared pilot, operator, crew, or flight requires for successful mission completion under adverse conditions in a nonpermissive environment. The process identifies the proficiencies required for combat including MECs, supporting competencies, and knowledge/skills, as well as the experiences that help to develop those elements. Further work then determines any training gaps that are impacting operators' proficiency as well as potential solutions for addressing those gaps. The results feed into modifications to on-going training at various levels and for different purposes (e.g., requirements for updates or new ops system capabilities, future training requirements, ops unit training modifications, simulator/live scenario development, syllabus crosswalking and alignment, measurement systems) and have helped define the requirements for proficiency-based training and measurement.

**MILESTONES:**

- **Completion of MEC efforts for Control and Reporting Center (CRC) Operators, CRC Cyber and Squadron Communications, AWACS Mission Crew, and AWACS Flight Deck and Technicians**
- **Delivered briefing on CRC MEC process and outcomes at 2023 GTACS Summit**
- **Provided input into the UABMT Syllabus Review process and delivering brief at Tyndal AFB in support of UABMT syllabus review process** ☆

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

**Dr. Jamie Levy, Senior Consultant, The Group for Organizational Effectiveness, Inc.**



(Top) Image by SSgt River Bruce
(Middle) Images by SSgt Sean Moriarity
(Bottom) Images by TSgt Andrew Schumann

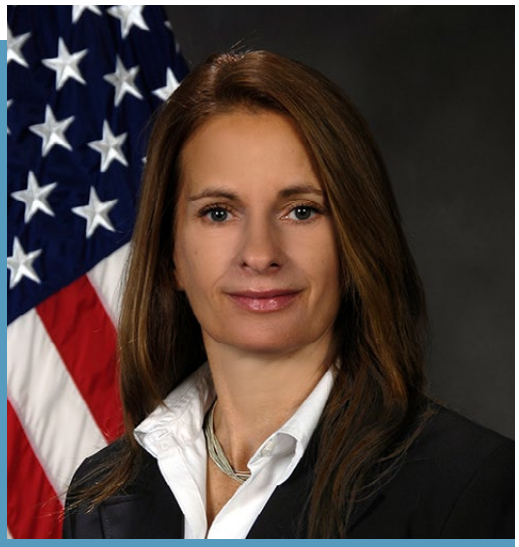
# A Focus on Operational Value:

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

The Just-in-Time Multimission Airmen/Warfighters (JITMMA/W) project continues to make progress and sharpen its focus. Last year the Human Effectiveness Directorate's Warfighter Interactions and Readiness Division (711 HPW/RHW) launched an exciting new project to create a training content creation, delivery, and assessment infrastructure. We are leveraging Commercial-off-the-Shelf (COTS) and Government-off-the-Shelf (GOTS) technologies wherever possible and delivering evolving capability through a series of technology evaluations and field experiments. While applications across the Air Force and Space Force for this kind of capability are numerous, we focused specifically on supporting maintainers in austere locations and in situations where warfighters need training and performance support on the Agile Combat Employment (ACE) fundamental tasks of Recover, Refuel, Re-arm, Launch, and Defend. Our vision is even broader, with designs to capture more of the ACE challenges than just direct combat sortie generation.

RHW is using model-based systems engineering processes and practices to design an agile and resilient infrastructure to integrate best-of-breed technologies in aiding/training agents, multimodal interfaces like speech recognition, and mixed reality (MR) technologies to deliver the right training content to the right Airmen and Guardians at the right time. So far, we have developed several Cameo models representing functions and workflows based on an aircraft divert to a contingency location scenario and a draft airman selection interface for operations supervisors to integrate with existing content delivery technologies and techniques. We also continue to design unobtrusive physiological sensing and analytics to assess training effectiveness, task performance, and Airman/Guardian state data to enhance overall performance and resilience. These models were developed based on field exercise observations, Subject-Matter Expert (SME) experience, and feedback from operational airmen at various ACE-focused exercises interacting with JITMMA/W-representative technologies. Our team of stakeholders, including representatives from AFRL, Air Education and Training Command (AETC), Air Combat Command (ACC) Agile Battle Lab, and industry partners, continued to observe ACE exercises and provided exemplary technology demonstrations to maintenance Airmen, leadership, and SME observers to continue garnering insights and gaining valuable feedback about the usability and utility of these technologies in a deployed, austere, ACE environment. As our technology integration efforts accelerate in the coming months, we're looking forward to demonstrating our progress at I/ITSEC 2024! ☆

**Mr. David Malek, JITMMA/W Product Lead, 711 HPW/RHWOW**



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

# WARFIGHTER-MACHINE INTEGRATION
## PRODUCT LINE

The Warfighter-Machine Integration (WMI) Product Line (PL) has been actively focused on technologies that enable Joint All Domain Command and Control (JADC2). While there is much discussion and, frankly, head scratching about what JADC2 really is, it is agreed that this concept will allow us to 'sense, make sense, and act'. Our research teams have developed several new efforts to increase our capabilities dramatically to provide resilient and agile decision making (make sense and act) in a distributed, yet digitally connected all domain environment. Human-machine teaming, where we seamlessly synergize human cognitive capability with intelligent machine teammates, will provide the speed needed to turn vast amounts of data into decision advantage. One key effort under the WMI PL is JADPACT (Joint All Domain Planner with Adaptive Collaborative/Control Technologies) – a multi-domain command station with AI interaction/cooperative planning and control (leveraging IMPACT - Intelligent Multi-UxV Planner w/Adaptive Collaborative Control Technologies), enabling JAD (Joint All Domain) distributed operations. JADPACT will evaluate and develop concepts for a JAD Mission Commander Control Station that will facilitate effective execution of integrated all domain effects.

> **Our research teams have developed several new efforts to increase our capabilities dramatically to provide resilient and agile decision making in a distributed, yet digitally connected all domain environment."**
>
> **— Dr. Deirdre Mahle**
> Warfighter-Machine Integration Lead, 711 HPW/RHW

ATLAS, the critical HMI (human machine integration) effort supporting the Skyborg Vanguard, has morphed into MOBIUS (Machine-Operator Blending for Integrated Uncrewed Systems), expanding the capabilities to look at the full Collaborative Combat Aircraft (CCA) mission cycle from mission planning to debrief. The challenges associated with autonomous, unmanned wingmen are not insignificant, but "...effectiveness of CCA in combat will be primarily driven by how well they team with humans..." (Mitchell Institute, Vol. 38, September 2022). MOBIUS will explore flexible HMI and CCA usage and support increased ratio of control while managing the operator's cognitive workload. Last but not least, the IMPACT and MOBIUS teams have worked diligently this past year to ensure a wildly successfully test of Project BOAR (Base Oversight of Autonomous Response) at the 2023 Air Force Marathon, leveraging critical user interface and human machine teaming technologies. Read on to learn more about this exciting demonstration. I'm looking forward to another productive year as we rise to meet the challenges of the future. ☆

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

# Project BOAR

## Base Oversight of Autonomous Response

Project BOAR (Base Oversight of Autonomous Response) is a combined effort between Wright Patterson AFB's 88 Air Base Wing (ABW) and AFRL to revolutionize infrastructure, processes, and policies to enable reliable, safe, and effective human-machine-teamed small unmanned aircraft systems (sUAS) operations. The machines execute low-level tasks, allowing the human to control and task multiple machines simultaneously and deliver integrated capabilities as enterprise solutions to DoD installation operations, emergency management, and Agile Combat Employment contexts.

**Integration of sUAS' into wing missions will:**

- Improve effectiveness
- Increase efficiency
- Maintain and improve resilience

Project BOAR is actively teaming with Air Mobility Command (AMC) and Air Force Materiel Command (AFMC) bases to create an enterprise solution for sUAS operations on USAF installations. The Project BOAR team completed its first integration event during the 2023 USAF Marathon. Several technologies were integrated to operate sUAS during the event to provide situation awareness to the Marathon incident command (IC) center. The team utilized the Skydio X2D and Teal's Teal 2 sUAS in conjunction with stationary cameras and the following AFRL technologies:

- Intelligent Multi-UxV Planner with Adaptive Collaborative/ Control Technologies (IMPACT)-BOAR referred to as IMBR (711 HPW RH)
- Ninja Counter-sUAS (AFRL RI)
- Assured Base Operations (ABO) (AFRL RI)
- Collaborative Low-Altitude UAS Integration Effort Unmanned Traffic Management (CLUE UTM) (AFRL RI)
- COPERS (Common Operating Picture for Event Response System) (AFRL RY)

The integration event was successfully operated with zero incidents. Project BOAR conducted a roof, facility envelope, and aircraft inspection as well as providing situation awareness to the Marathon IC, all while supporting four real-world taskings, including the identification of an unknown sUAS flying along the Marathon route. The initial BOAR capability demonstrated at the AF Marathon is being considered as the foundational multi-sUAS beyond visual line of site control technology suite by the 88 ABW (WPAFB), the 60th Air Mobility Wing (Travis AFB), and the 6th Air Refueling Wing (MacDill). The team is working to further integrate the technologies while incorporating other sUAS into the BOAR environment. ☆

**Ms. Kristen "Cuda" Barrera, BOAR, Multi-sUAS Control Lead, 711 HPW/RHWTC**



Photos by Mr. Allen Rowe, 711 HPW/RHWTC

(Top) **IMBR Station during USAF Marathon**
(Middle) **BOAR Operations Area**
(Bottom) **BOAR Operations Team**

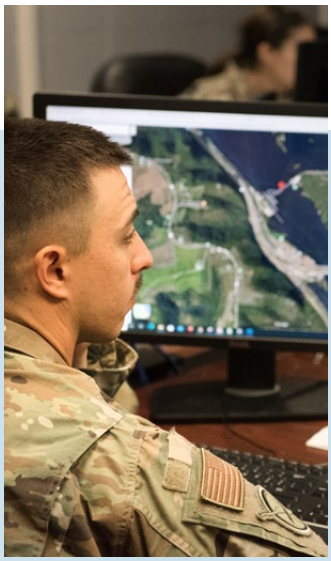
**Dr. Jerred Holt**

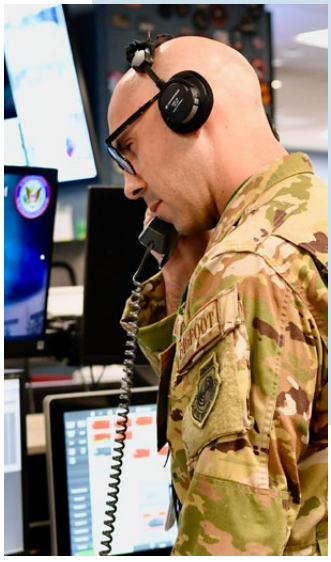
Intelligence Analytics & Sensemaking PL Lead and Senior Research Psychologist, 711 HPW/RHW

# INTELLIGENCE ANALYTICS & SENSEMAKING

## PRODUCT LINE

The new Intelligence Analytics & Sensemaking Product Line will 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. This product line will also leverage maturing technologies in augmented cognition, trust, and decision making to develop Cognitive Warfare tools and influence applications. ☆





(Top left) Photo by Senior Airman Callie Norton
(Top right) Photo by Mr. Timothy Sandland
(Lower left) Photo by Ms. Kimberly D. Burke
(Lower right) Photo by Airman 1st Class Jared Lovett

**Dr. Glenn Gunzelmann**
WARTECH Topic Lead, 711 HPW/RHW

# WARTECH

## Synthetic Operational Test and Training Infrastructure (S-OTTI) for Distributed Command, Control, and Communications for Battle Management (C3BM)

The expanding complexity of military operations resulting from increased threats from peer adversaries, increasing interconnectivity between warfighting systems, and the increasingly capable and challenging applications of artificial intelligence mean that current operational training and test infrastructure is no longer the kind of "train as we fight" construct that represents a fundamental tenet of Air Force and military readiness. Moreover, our physical ranges are no longer adequate for meeting this need, given the long-range capabilities of many of our operational systems and the cyber risks associated with utilizing the full range of capabilities of those advanced systems in the live environment.

The Department of the Air Force (DAF) has recognized these challenges and identified synthetic operational training and test infrastructure (S-OTTI) as a critical component of our future readiness ecosystem. The goal is to enable synthetic environments that allow our Airmen and Guardians to train like they fight, while also breaking down stovepipes between training and test to accelerate the pace of capability development and transition.

A strategic requirements document for Air Force S-OTTI was released in May of 2022. A similar document was released for the Space Force earlier this year. In these publications, the Chief of Staff of the Air Force designated the Joint Simulation Environment as key to the future of test, experimentation, and operational training, and directed that future aircraft, weapons, and systems be interoperable with Joint Simulation Environment (JSE). This rapid evolution in requirements and technologies for S-OTTI highlights the need for revolutionary change regarding technology and readiness to meet the needs of preparing for future conflict.

Continued on next page

> **This WARTECH effort is focused on creating the infrastructure to enable rapid evolution and effective implementation of new tactical C2 capabilities to meet the demands of the future volatile, uncertain, complex, and ambiguous (VUCA) operational environments."**
>
> **— Dr. Glenn Gunzelmann**
> WARTECH Topic Lead, 711 HPW/RHW

Graphic by Mr. Will Graver (Ball Aerospace)

The rapid change in policy and planning regarding S-OTTI is paralleled with a rapid evolution in our strategy and concepts of operation (CONOPS) for command and control (C2), particularly in the context of battle management. The emergence of a new Program Executive Office (PEO) for Command, Control, and Communications for Battle Management (C3BM) as the integrator for future C2 capabilities represents a significant scaling up with regard to the DAF's posture and goals associated with its Advanced Battle Management System (ABMS) strategy and investments. Taken together, emerging emphases on both S-OTTI and C3BM represent a substantial shift in the DAF's strategic approach to conflict, and point to a future that relies on speed and agility to succeed against a peer adversary in a contested and denied environment that is inundated with autonomous systems.

It is against this backdrop that a WARTECH effort has been developed, focused on S-OTTI for Distributed C3BM (S-ODC). The audacious vision for future joint all domain operations (JADO) must be met with bold investments in science and technology to enable and realize the required capabilities. S-ODC envisions infrastructure that facilitates the development, validation and testing of new technologies and CONOPS that support C2 in contested and denied environments, paving the way to efficiently integrate new technologies to address new threats, opportunities, and contexts in near real-time. An environment where these low-density, but mission critical operations can be explored and trained will be critical for success. Our Airmen and Guardians must be ready to execute new CONOPS effectively and efficiently from the first time they are employed.

This WARTECH effort is focused on creating the infrastructure to enable rapid evolution and effective implementation of new tactical C2 capabilities to meet the demands of the future volatile, uncertain, complex, and ambiguous (VUCA) operational environments. It creates a train as we fight capability for C2 operators, including rapid adaptation and evolution of CONOPS to meet emerging operational realities. In addition, this capability will interoperate with the JSE and incorporate multi-domain coordination for integrated kill-web effects with connections to space and cyber domains. The result will enable a true human-in-the-loop (HITL) multi-domain environment for training and test that moves us closer to an integrated, full-force environment for preparing for Night One conflict. ☆

**Dr. Glenn Gunzelmann, WARTECH Topic Lead, 711 HPW/RHW**

# HUMAN LEARNING & COGNITION

## CORE TECHNICAL COMPETENCY (CTC)

**Dr. Brian Simpson**
New HLC CTC Lead, 711 HPW/RHW

**Dr. Chris Myers**
Acting HLC CTC Lead (July 2023 - Dec 2023)
and Senior Cognitive Scientist, 711 HPW/RHW

**Dr. Glenn Gunzelmann**
Outgoing HLC CTC Lead (Aug 2018 - July 2023)
and WARTECH Topic Lead, 711 HPW/RHW

## Adapting to a Future of Evolving Threats

Where to begin... 2023 has been a challenging and exciting year as the Warfighter Interactions and Readiness Division (RHW) continues to press forward on addressing the Air Force's most critical challenges related to the human mind and how we interact with other people, autonomy, and other machine systems. To better capture the portfolio and increase the clarity in how we think and talk about our research, we launched 2023 with a new structure for our Core Technical Competencies (CTCs), which were announced and described in the Winter and Spring Issues of Fight's On! (find them here: www.afresearchlab.com/FightsOn). This new structure aligns our CTCs more explicitly with scientific disciplines and research areas, empowering our Product Lines to integrate across those disciplines to focus on operational capabilities and transition. This is a powerful way of organizing our research and is already demonstrating benefits for leveraging, collaboration, and integration across portfolios.

Within this new construct, the Human Learning and Cognition (HLC) CTC has been established as "the CTC of the human mind." This CTC takes as its mission, "enabling decision superiority by advancing the science and technology of human multisensory perception, learning, information processing, and action." This establishes a complementary and synergistic relationship with the other CTC in RHW, Warfighter Interfaces and Teaming (WIT), which emphasizes research on the interactions between people and external systems (human and machine). Of course, there are some gray areas in this delineation. These create opportunities for collaboration and leveraging synergies that capitalize on the unique expertise within each group. You will note a number of examples in the descriptions of specific research in both CTCs where those collaborations are critical to the overall success of the projects.

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Graphic by Mr. Will Graver (Ball Aerospace)

**For the HLC CTC, our portfolio is oriented around a central vision:**

*To be the Department of Defense and international leaders in advancing and applying science and technology to unleash the power of the human mind for decision superiority.*

This focus on decision superiority comes from a commitment from leadership within the Human Effectiveness Directorate (711 HPW/RH) to "Prioritize Decision Superiority Research & Development as the central focus for accelerating technology transition." That clear emphasis is shaping our investments and helping to drive collaboration not just across RHW, but across all of RH and with other AFRL Technology Directorates as well.

The role of human learning and cognition in decision superiority is clear – our perception, knowledge representation, learning, memory, and information processing provide the mechanisms underlying the most effective system we know for making decisions in volatile, uncertain, complex, and ambiguous environments like today's and tomorrow's operational environments. Understanding these representations and processes in humans and applying that understanding to concepts to enable and enhance both human and machine performance are at the core of establishing and maintaining decision superiority on the battlefield.

**The current goals we are addressing within the CTC include the following:**

1. Establish a persistent, global experimentation, test, and training ecosystem that supports personalized, proficiency-based readiness for Airmen and Guardians in joint all-domain operations
2. Use digital modeling to advance considerations of human perception, cognition, and action in system development and operational planning
3. Inform strategy and create capabilities for influence operations through experimentation, models, and analytics
4. Enable real-time learning and adaptation in teams of humans and machines in training and operational settings

These goals orient our research toward critical areas and capabilities for the Department of the Air Force. They emphasize the need to capture our understanding of the human mind in computational and mathematical forms that enable rapid application to immediate challenges and well as prediction to inform future strategy and planning. Furthermore, they recognize the increasing importance of the information environment and autonomy and artificial intelligence (AAI) in modern military operations. This research is positioned to establish the foundational understanding we require in a generalizable form that can be leveraged across Products Lines for war-winning capabilities across the operational spectrum. Though the CTC is no longer titled 'Training,' it remains committed to maximizing the learning and cognition of our Airmen and Guardians to enable and ensure decision superiority in air, space, and cyberspace.

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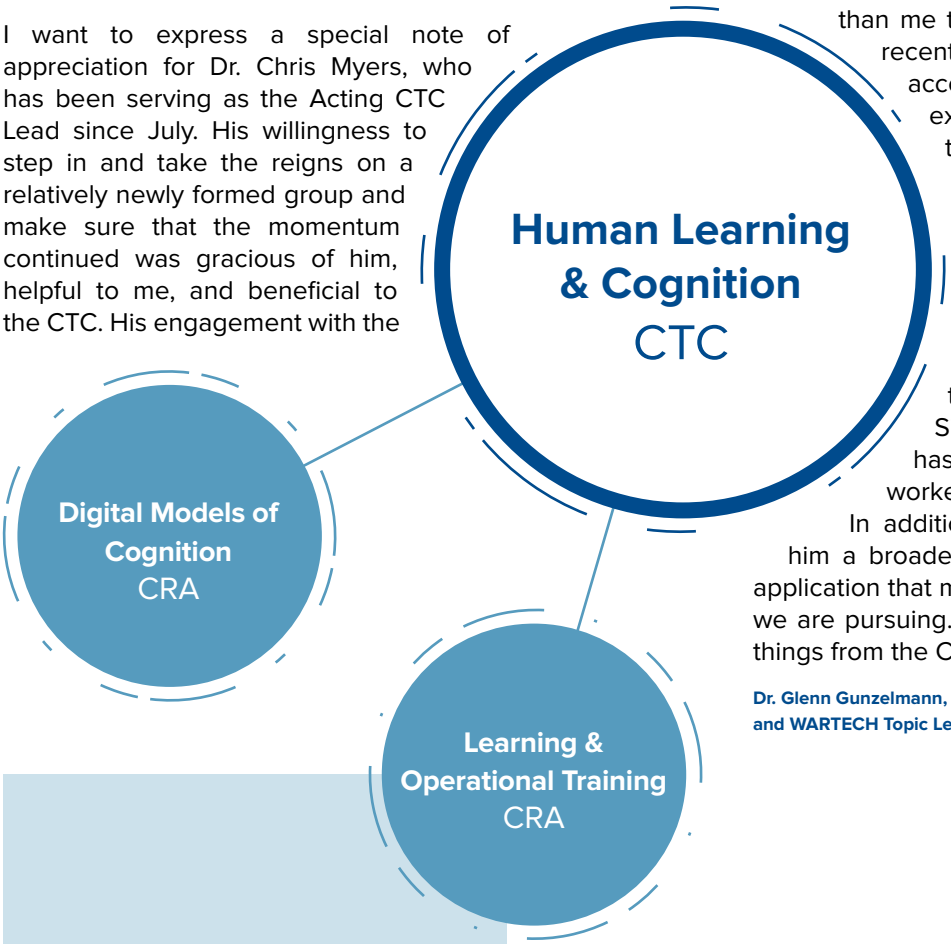
**Strategic competition is driving the need for accelerated, integrated S&T solutions that enable the Joint fight. AFRL's role in this competition is to be responsive to the threat, but moreover it is to drive the future fight... The first essential to driving the fight is a fierce focus on the warfighter."**

**— Brig Gen Scott A. Cain**
AFRL/CC, AFRL's Commander's Intent

I will note that this will be my last CTC overview for Fight's On! Over the summer, I assumed the role of Topic Lead for an AFRL WARTECH effort called Synthetic Operational Training and Test Infrastructure (S-OTTI) for Distributed Command, Control, and Communications for Battle Management (C3BM), or S-ODC. You can see a brief description of that project on page 17 of this issue. I am truly a little sad to leave this role behind – leading a group focused on human learning and cognition fits perfectly with my background and interests. However, ensuring that we have the right technologies and infrastructure in place to maintain our technological and human performance advantage into the future presents a challenge that capitalizes on my background and expertise while challenging me to acquire new skills and knowledge.

I want to express a special note of appreciation for Dr. Chris Myers, who has been serving as the Acting CTC Lead since July. His willingness to step in and take the reigns on a relatively newly formed group and make sure that the momentum continued was gracious of him, helpful to me, and beneficial to the CTC. His engagement with the scientists and engineers to provide mentorship, direction, and support was tireless. At the same time, he expertly advocated for the CTC with leadership in the organization. In these and numerous other ways, Chris has moved the CTC forward and helped to advance the mission and goals.




To close, I have always said that my two most important responsibilities as a leader are to (1) leave the organization better than how I found it, and (2) find someone better than me to take over when I do leave. I believe the recent restructuring of the CTCs within RHW has accomplished the first of these goals, and I am excited to see what these groups accomplish in the coming years. We are in a better position than ever to contribute to the Air Force by advancing our research, and the scientists, engineers, program managers, supervisors, and support staff are exceptionally capable and working together to make it happen.

For my second leadership imperative, I am thrilled and humbled to share that Dr. Brian Simpson is taking over as the CTC Lead. He has substantial experience in AFRL and has worked closely with many of us in the HLC CTC. In addition, he has industry experience that gives him a broader perspective on technology, science, and application that make him a perfect fit for the ambitious goals we are pursuing. There is no doubt that you will hear great things from the CTC and from Brian in the future. ☆

**Dr. Glenn Gunzelmann, Outgoing Human Learning & Cognition CTC Lead and WARTECH Topic Lead, 711 HPW/RHW**

# DIGITAL MODELS OF COGNITION
## CORE RESEARCH AREA

**Dr. Megan Morris**
Digital Models of Cognition Core Research Area Lead, 711 HPW/RHWE

The Digital Models of Cognition (DMC) Core Research Area (CRA) focuses on research that identifies computational and mathematical mechanisms to represent human perception, 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 integrated models of human behavior that support quantitative understanding and prediction of mission effectiveness across domains and at different levels of abstraction for improved systems engineering, wargaming, and operational planning.

Two technical challenge areas (Lines of Effort) drive our work. The first is Holistic Models for Decision-Making (HMDM), which focuses on developing models of cognitive systems that support quantitative understanding and prediction of mission effectiveness involved in controlling crewed aircraft and Collaborative Combat Aircraft within the Next Generation Air Dominance family of systems for decision superiority. The second challenge area is Information Mastery in Cognitive Warfare (IMCW), which focuses on developing models, analytic methods, and tradecraft that enables operators to improve Information-Related Capability for the desired cognitive effects, social influence, and mastery of the Information Environment.

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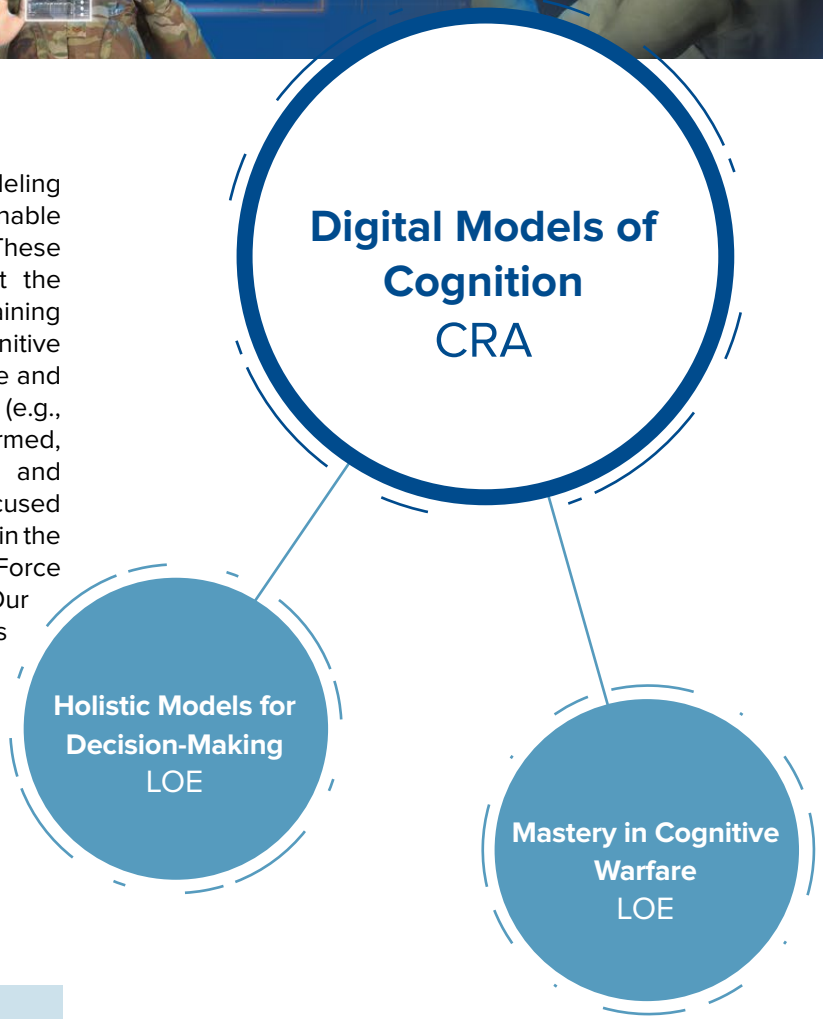
**The goal of (Digital Models of Cognition) is to develop integrated models of human behavior that support quantitative understanding and prediction of mission effectiveness across domains and at different levels of abstraction for improved systems engineering, wargaming, and operational planning."**

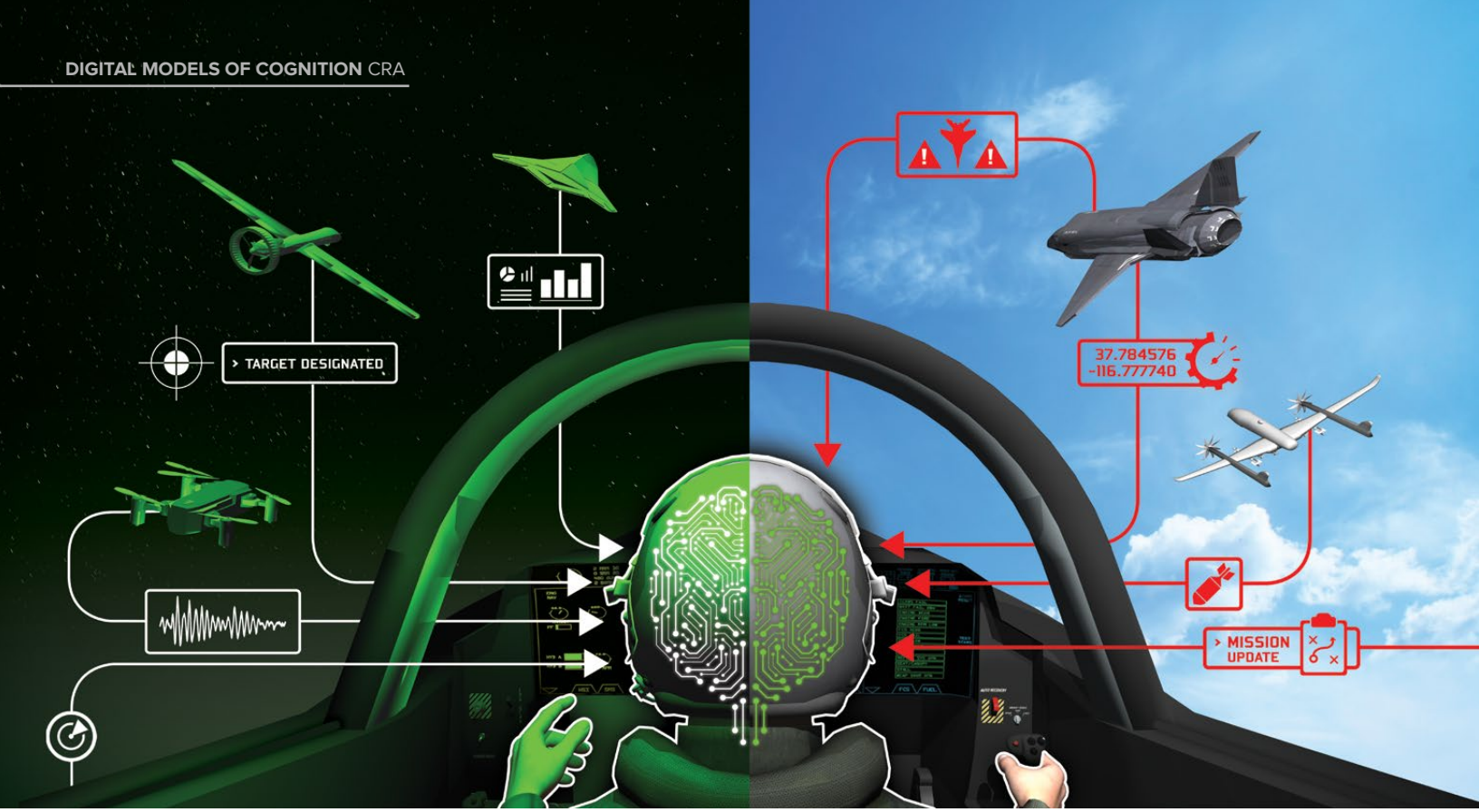
**— Dr. Megan Morris**
Digital Models of Cognition
Core Research Area Lead, 711 HPW/RHWE


Graphic by Mr. Will Graver (Ball Aerospace)

We envision work from both LOEs culminating into modeling and simulation capabilities that can be utilized to enable decision-superiority for the Airman and Guardian. These capabilities can be integrated together to represent the human in complex systems such as wargaming and training scenarios, where it is essential to account for human cognitive capabilities/limitations, the influence of others (both blue and red forces), and the complexity of the environment (e.g., operational stressors). The DMC CRA was recently formed, integrating a diverse team of scientists, engineers, and business professionals from three legacy branches focused on perception, cognitive modeling, and meaning-making in the information environment to address critical gaps in Air Force Operational Imperatives and other strategic guidance. Our CRA has been busy planning our new research task areas within the LOEs which will primarily kick-off at the start of FY24 as we wrap up research for our legacy LOEs. As the CRA Lead, I have been extremely impressed with the innovativeness, collaboration, and comradery of our new team to meet Warfighter challenges and am excited to see what we accomplish! ☆

**Dr. Megan Morris, Digital Models of Cognition CRA Lead, 711 HPW/RHWE**






Graphic by Mr. Will Graver (Ball Aerospace)

# HOLISTIC MODELS FOR DECISION-MAKING

## LINE OF EFFORT

The Holistic Models for Decision-Making (HMDM) LOE develops cognitive system models supporting quantitative understanding and prediction of effectiveness for controlling crewed aircraft and Collaborative Combat Aircraft (CCA) within the Next Generation Air Dominance (NGAD) systems. The LOE has three primary thrusts: 1) developing computational and mathematical models that represent human perception, information processing, decision making, and action within tactical environments (Cognitive Models of Perception to Decision-Making), 2) integrating factors that modulate performance efficiency and effectiveness (Cognitive Models of Operational Modulators), and 3) the development of learning theories and mechanisms to advance robust models with high predictive validity and interpretability (Cognitive Models of Learning and Optimization).

One aspect of HMDM is devices provided to humans for transfer of information and perception enhancement. Night vision goggles (NVGs) are commonly worn within military operational environments, but high-fidelity NVG models and studies on their effect on human perception and cognition do not yet exist. Recent NVG upgrades incorporate the addition of blue light, producing a broader spectral white phosphor image than the legacy green phosphor image. The long-term fatigue effects of this upgrade are largely unknown.

**These research projects will develop integrated, high-cognitive fidelity, scalable models and simulations that can help answer critical questions and train for asset management with collaborative unmanned aircraft."**

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

Cognitive researchers are partnering with NVG experts to model the impact that this has on visual acuity and target identification accuracy.

Digital Engineering Toolbox for Human Speech Communication and Reception (DETHSCAR) is the auditory corollary exploring the devices that exist between speech production and speech reception. DETHSCAR models the modification of speech through electroacoustic attributes of the microphone, comm-matrix unit (including vocoding), transmission to the receiver, and reproduction of the signal

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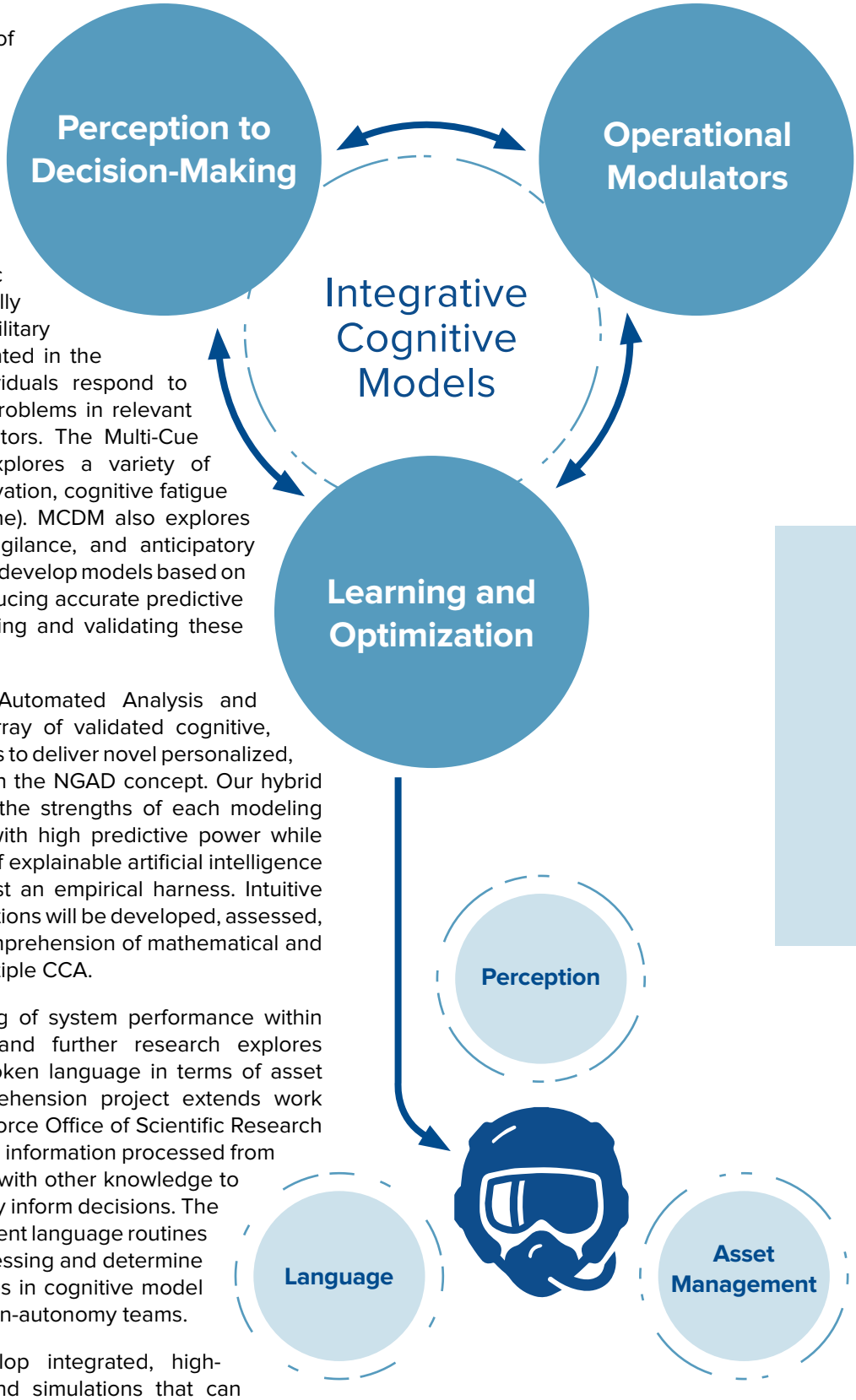
to the receiver to predict the impact of the communication system on human performance. DETHSCAR utilizes world-class facilities to measure these electroacoustic attributes and the resultant behavioral responses.

The Deleterious Effects of Noise on Cognition (DENC) project seeks to understand the influence of acoustic environments on cognition, especially the more intense noise levels of military aircraft that are not typically represented in the literature. DENC explores how individuals respond to complex multi-tasking management problems in relevant noise environments for NGAD operators. The Multi-Cue Decision-Making (MCDM) project explores a variety of external modulators like oxygen deprivation, cognitive fatigue and load, and stimulants (e.g., caffeine). MCDM also explores individual strategies for workload, vigilance, and anticipatory thinking under these insults. MCDM will develop models based on Instance-Based Learning Theory, producing accurate predictive performance capabilities, and extending and validating these models in the NGAD problem.

The Hybrid Cognitive Models for Automated Analysis and Visualization project integrates an array of validated cognitive, machine learning, and statistical models to deliver novel personalized, prescriptive learning capabilities within the NGAD concept. Our hybrid model integrations will capitalize on the strengths of each modeling flavor, enabling high interpretability with high predictive power while pushing us toward the gold standard of explainable artificial intelligence (XAI) as they are stress tested against an empirical harness. Intuitive performance dashboards and visualizations will be developed, assessed, and utilized to provide meaningful comprehension of mathematical and statistical information to control of multiple CCA.

These projects provide understanding of system performance within the NGAD operational test case, and further research explores how information is processed via spoken language in terms of asset management. The Language Comprehension project extends work conducted with support from the Air Force Office of Scientific Research (AFOSR) to understand and model how information processed from spoken communications is integrated with other knowledge to form situation awareness and ultimately inform decisions. The goals are to explore the impact of different language routines within military communication on processing and determine whether adaptive language capabilities in cognitive model agents improves performance in human-autonomy teams.

These research projects will develop integrated, high-cognitive fidelity, scalable models and simulations that can help answer critical questions and train for asset management with collaborative unmanned aircraft. ☆




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


Graphic by Mr. Will Graver (Ball Aerospace)

# INFORMATION MASTERY IN COGNITIVE WARFARE

## LINE OF EFFORT

The Information Mastery in Cognitive Warfare LOE conducts research to enhance the warfighter's ability to assess influence, leverage information, anticipate adversary actions, and defend against malign influence attempts. Information mastery refers to the ability to examine data across domains (e.g., social media, broadcast media, etc.) and platforms to understand 'the forest for the trees' regarding influence tactics and impacts. Similarly, cognitive warfare is the human and machine exploitation of information and employment of other non-kinetic means to achieve decision superiority and maintain strategic advantage over adversaries. Together, information mastery connotes the ability to make meaning of the noisy Information Environment (IE) and cognitive warfare consists of offensive and defensive strategies.

One IMCW LOE task, Characterization of Operations in the Information Environment, focuses on developing descriptive and anticipatory analytics from network and content data to inform assessment and decision-making. For example, when does online chatter and group polarization reach the threshold of threat that could signal mobilization/offline protests? To address such a question requires a deep understanding of language that can be examined with Natural Language Processing (NLP) techniques. However, non-text approaches (e.g., knowledge graphs) are also crucial as social media relies heavily on visual content. For example, specific image-based memes and emojis are often used to signal the in-group identity of grassroot movements. Characterizing networks are another important aspect of operations in the IE as we endeavor not only to document social structures but also how information spreads. For example, information spread tactics include sophisticated coordinated actions, including employing botnets to manipulate a recommender algorithm. Work in this area has been funded by external agencies such as the Defense Advanced Research Projects Agency (DARPA) and the Defense Health Agency (DHA).

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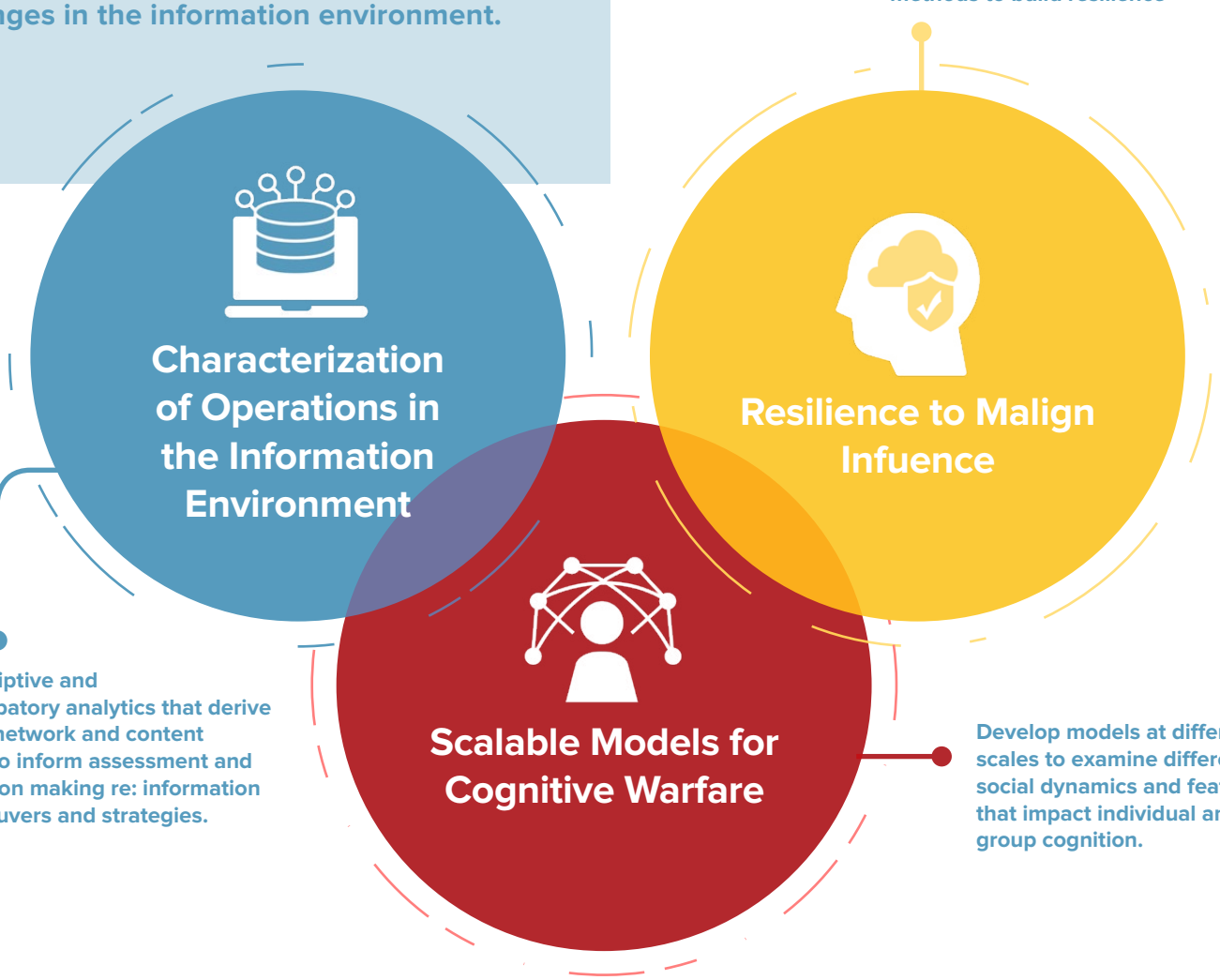
> **Information mastery refers to the ability to examine data across domains (e.g., social media, broadcast media, etc.) and platforms to understand 'the forest for the trees' regarding influence tactics and impacts."**
>
> **— Dr. Katie Larson,**
> Information Mastery in Cognitive Warfare LOE Lead 711 HPW/RHWEM

Under the Scalable Models for Cognitive Warfare task, we are developing novel computational models that combine the cognitive and social dynamics of the IE. For example, disinformation susceptibility consists of cognitive elements because some messages are more 'sticky' or persuasive, especially if they are coherent and easy to remember; however, there are also social elements, such as the decision to share or distribute disinformation within a person's network. Social media users are often less focused on making rational decisions and instead share information that will signal their social identity and world views. To this end, our first effort in this area will model the continued influence effect (CIE), which is when malign information is influential even after it has been corrected. We will employ an integrated modeling approach with Instance-based Learning (IBL) used to model the individual level and an agent-based framework for the group level.

Finally, the Resilience to Malign Influence task seeks to conduct human subjects experiments that examine the psychological underpinnings of influence. For example, one effort, funded by Air Force Office of Scientific Research (AFOSR), looks at different factors that impact social media messaging and how to tailor messaging for different segments of the population. Another effort examines the human's ability to detect auditory deepfakes (e.g., voice clones) and how context influences this process. Ultimately, we will apply results from these experiments to develop evidence-based approaches and strategies to build resilience against malign influence. Additionally, results will inform which external factors to model and ensure the social media analytics are grounded in social science. All three tasks add to the operators' armory as they navigate within the IE and strive to win the 21st century battle of the minds. ☆

**Dr. Katie Larson, Information Mastery in Cognitive Warfare LOE Lead, 711 HPW, RHWEM**

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



# Human Factors in Wargaming: COMBAT-AFRL

Wargaming smarter, faster, and more efficiently than our adversaries contributes to our decision superiority, shortens our Observe, Orient, Decide, Act (OODA) loop, and strengthens coordination with our allies. Human factors have long been considered in wargames, but there is a significant lack of modeling and simulation tools available for wargamers to represent human factors rigorously and accurately at a scale relevant for wargames. As part of work in the Human Representation in Digital Engineering (HRDE) product, we have been collaborating with Air Force Futures and Booz Allen Hamilton to augment the Combat Operations Mission and Basing Analysis Tool (COMBAT) with human factors models. This integrated software enables wargame players and adjudicators to include human factor constraints in wargames and for enhanced real-world fidelity.

This effort includes integration of two HRDE human factor models into the COMBAT platform. The first represents the effects of fatigue on cognitive performance and sustained attention. This model uses an implementation of the biomathematical Sleep, Activity, Fatigue, and Task Effectiveness (SAFTE) model to project an individual's circadian rhythm throughout a mission and compute periods where they will be ready (green), at mild risk of a fatigue impairment (yellow), or at serious risk of a fatigue impairment (red). The model determines this risk based on the individual's recent sleep/wake schedules, time of day, and time zone information. The second model represents the effects of ground-based laser dazzlers on mission effectiveness. Users can select which bases in the scenario have ground-based laser weapons nearby. The models then predict which sorties will be at risk based on the presence of fatigue and weapons and flags those sorties for analysis.

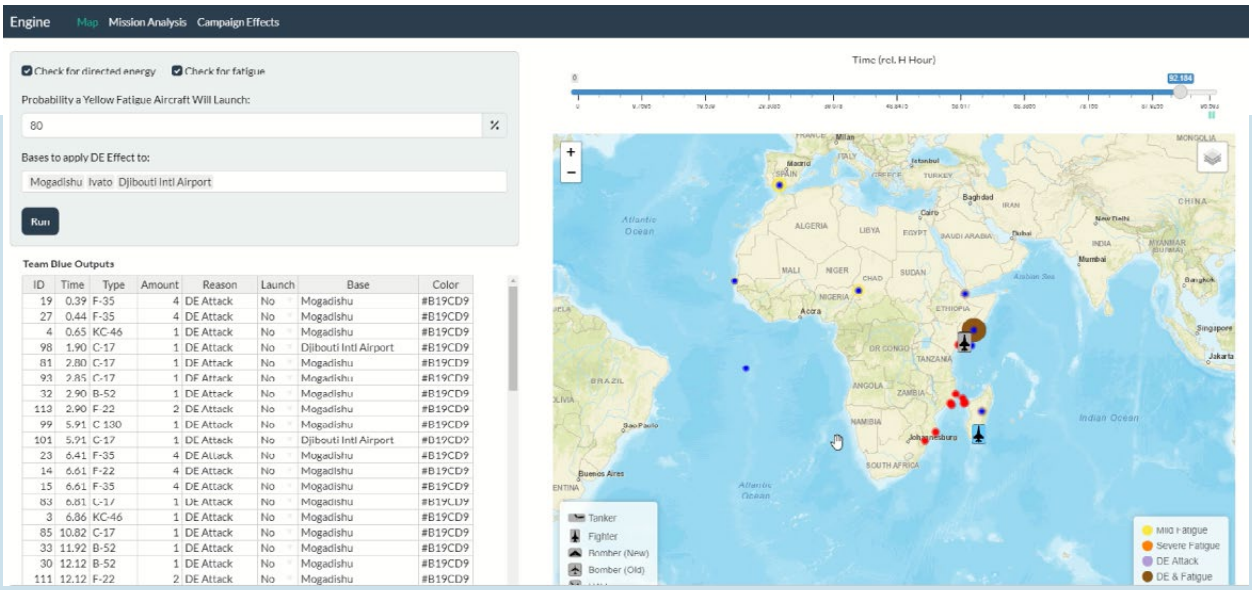
Once the at-risk scenarios have been identified, the players and adjudicators may determine the effect on the game. The players may elect to forgo the at-risk sorties (or a portion of them) or to ignore the risks depending on the scenario and the level of acceptable risk. Adjudicators may use the risk information to determine which sorties succeed or fail. Based on these decisions, the COMBAT systems can display a series of mission analysis graphs to help wargamers understand the mission impacts of these human factors risks in the scenario. The analysis reveals to what extent certain objectives (e.g., fires or deliveries) were accomplished and which bases and assets were most affected. Players can also watch the simulated mission unfold in real time on the platform's integrated map. The human factor risks and cancelled sorties are highlighted for the user.

The researchers determined a valid approach for this proof of concept was to allow the players and adjudicators to determine whether a sortie succeeds for fails directly in COMBAT's interface. In the future, we aim to introduce the capability for automatically computing sortie outcome based on mission risk. We further plan to introduce a wider selection of human factor risks, such as personnel training and readiness, in future iterations. The realism enabled by this effort will improve the insights drawn from Title 10 and other wargaming efforts, reduce the cognitive load associated with representing human factors in wargames, and better prepare warfighters to make optimal decisions in real operations where human factor constraints have a decisive influence. ☆

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

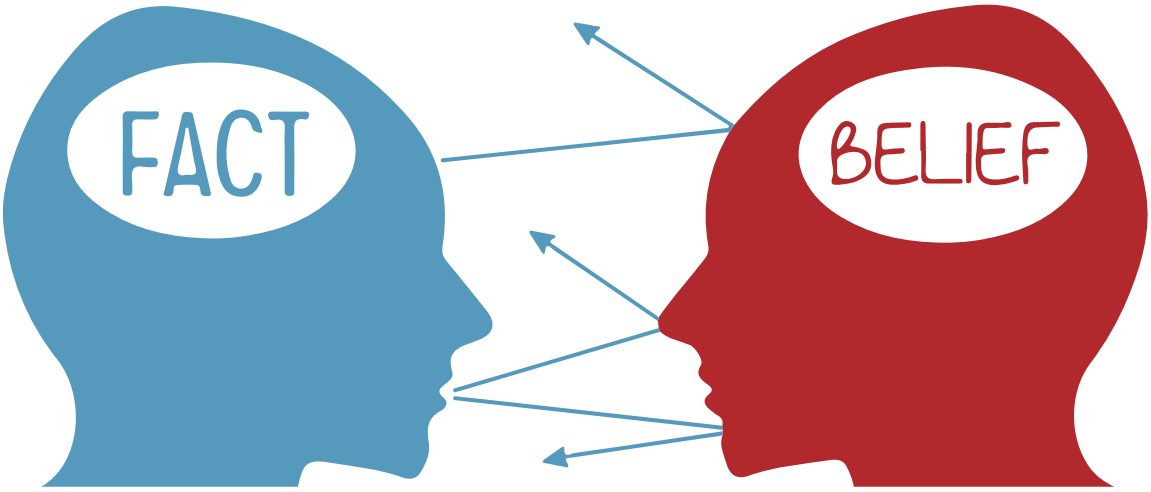
**Dr. Megan Morris, Digital Models of Cognition CRA Lead and Research Psychologist, 711 HPW/RHWE**

**Mr. Aaron Hoffman, Physicist, 711 HPW/RHDO**




Screen Capture by AFRL

**C**ombat
**O**perations
**M**ission and
**B**asing
**A**nalysis
**T**ool




Graphic from Lewis (2018)

# Understanding Cognitive Vulnerabilities and Biases in Cognitive Warfare

Humans have cognitive vulnerabilities and biases that can be exploited to influence individuals or groups and degrade decision-making. Misinformation and deception have been used to successfully mislead adversaries in past conflicts to gain a military advantage. Advances in technology and social media have increased the rate and scale that individuals can influence social networks. It is important to understand how individuals can be misled to identify deception attempts and develop defensive strategies. A potential bias that could be exploited is the lasting influence of misleading information or beliefs, even after it has been corrected or factual discrediting information is learned. This is called the continued influence effect (CIE) and often involves structured narratives, events, or emotionally charged content. The CIE is one reason why propaganda and deception have been successful in past conflicts. For instance, in World War 2 the Allied Forces' D-Day misinformation campaign was so effective that German intelligence continued to believe that the main attack was north of Normandy, even days after the invasion and with sufficient evidence that Normandy was the target.

Narrative-based experiments have identified several hypotheses regarding the underlying cognitive mechanisms of the CIE. However, there are no cognitive models that have thoroughly tested these hypotheses to explain, predict, and simulate the CIE and how it may spread across social networks. The Scalable Models for Cognitive Warfare task in the new Information Mastery in Cognitive Warfare LOE aims to develop an integrated model of the CIE spanning individual and group levels to address these gaps. Our initial effort uses an established theory of learning and decision making, called instance-based learning, which serves as the basis for modeling memory dynamics, and an implementation of the core-affect theory of emotion provides mechanisms for how emotion influences memory and decision making. The Adaptive Control of Thought – Rational (ACT-R) cognitive architecture is used to model the cognitive processes underlying how the CIE emerges within an individual. Using ACT-R, we were able to demonstrate the CIE in a simple decision-making task by providing the model with initial misinformation and feedback over time that served as corrections. Performance was initially degraded, the model was faster to respond due to the bias, and it took many repeated corrections in the form of feedback to eliminate the CIE. We use agent-based modeling (ABM) to model social networks and simulate how information spreads within groups as a function of memory dynamics within agents and patterns of interaction. Initial demonstrations showed a few agents with misinformation spread the effect within a group, a few corrections had little effect on the presence of misinformation in the group, and agents with higher social status spread more misinformation. Our integrated approach uses the individual model to describe cognitive and emotional processes that can be implemented in ABM to provide a comprehensive account of the CIE.

We presented our initial work at the 2023 International Conference on Social Computing, Behavioral-Cultural Modeling & Prediction and Behavior Representation in Modeling and Simulation (SPB-BRiMS) conference and plan to build on this framework while shifting our focus to key cognitive vulnerabilities identified in cognitive warfare research to help identify offensive and defensive strategies. ☆

**Dr. Alexander Hough, Research Psychologist, 711HPW/RHWEO**

**Dr. Taylor Curley, Research Psychologist, 711HPW/RHWEM**

Lewis, R. (2018). What actually is a belief? And why is it so hard to change? *Psychology Today, 7.* Sussex Publishers, LLC. Retrieved from: https://www.psychologytoday.com/us/blog/finding-purpose/201810/what-actually-is-belief-and-why-is-it-so-hard-change

# LEARNING & OPERATIONAL TRAINING
## CORE RESEARCH AREA

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

**Ms. Jennifer Winner**
Former Learning and Operational Training CRA Lead and Research Psychologist, 711 HPW/RHWO

The wars of tomorrow will be fought by teams consisting of humans, machines, and artificial intelligence. These human-machine teams must be able to understand each other, flexibly learn new content, adapt to uncertain and rapidly changing combat situations, and maintain decision superiority over our adversaries. Our 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 establishing an ecosystem that maximizes mission effectiveness, minimizes vulnerabilities, personalizes training requirements, and enables uniquely effective human-machine teams.

> **Human-machine teams must be able to understand each other, flexibly learn new content, adapt to uncertain and rapidly changing combat situations, and maintain decision superiority over our adversaries."**
>
> **— Dr. Christopher Stevens**
> Acting Learning and Operational Training CRA Lead and Research Psychologist, 711 HPW/RHWE

Two technical challenge areas (Lines of Effort) drive our work. The first is Warfighter Learning Technologies, which focuses on researching, demonstrating, and transitioning learning technologies, methods, and infrastructure for personalized, proficiency-based readiness. We achieve this by developing and applying state-of-the-art learning theories and models to enable rapid skill acquisition, identifying and digitizing data to track warfighter proficiencies, and developing novel multi-domain Operational Test and Training Infrastructure (OTTI) to enhance warfighter learning. Our efforts to accelerate skill acquisition emphasize pedagogically and scientifically sound instructional design methods, error recognition and recovery, and deliberate, rapid-cycle practice at the team level. We work with multiple USAF and USSF mission areas to define and validate Digital Models of Training that are contextualized in specific missions and create schemas for representing and storing training data. Finally, we create prototype blended OTTI concepts integrated across Air, Ground, Cyber, and Space domains.

Continued on next page

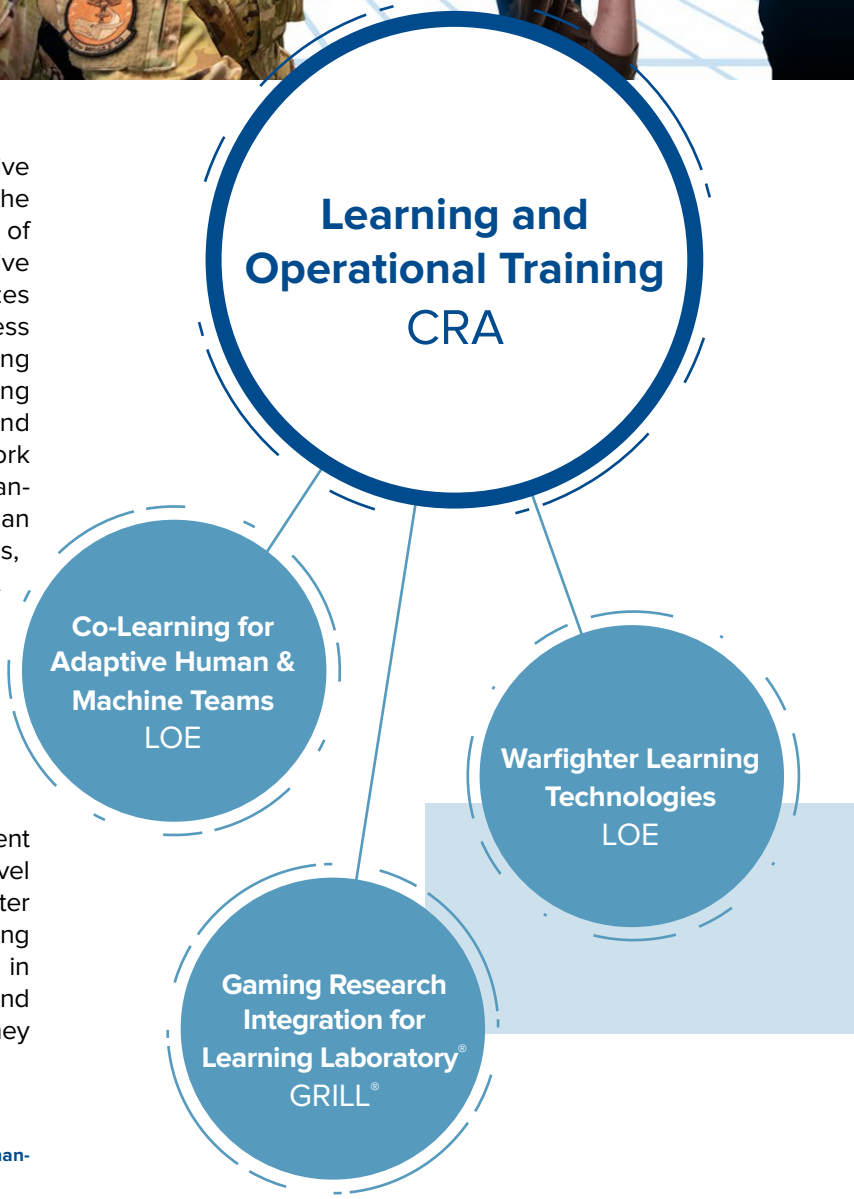

Graphic by Mr. Will Graver (Ball Aerospace)

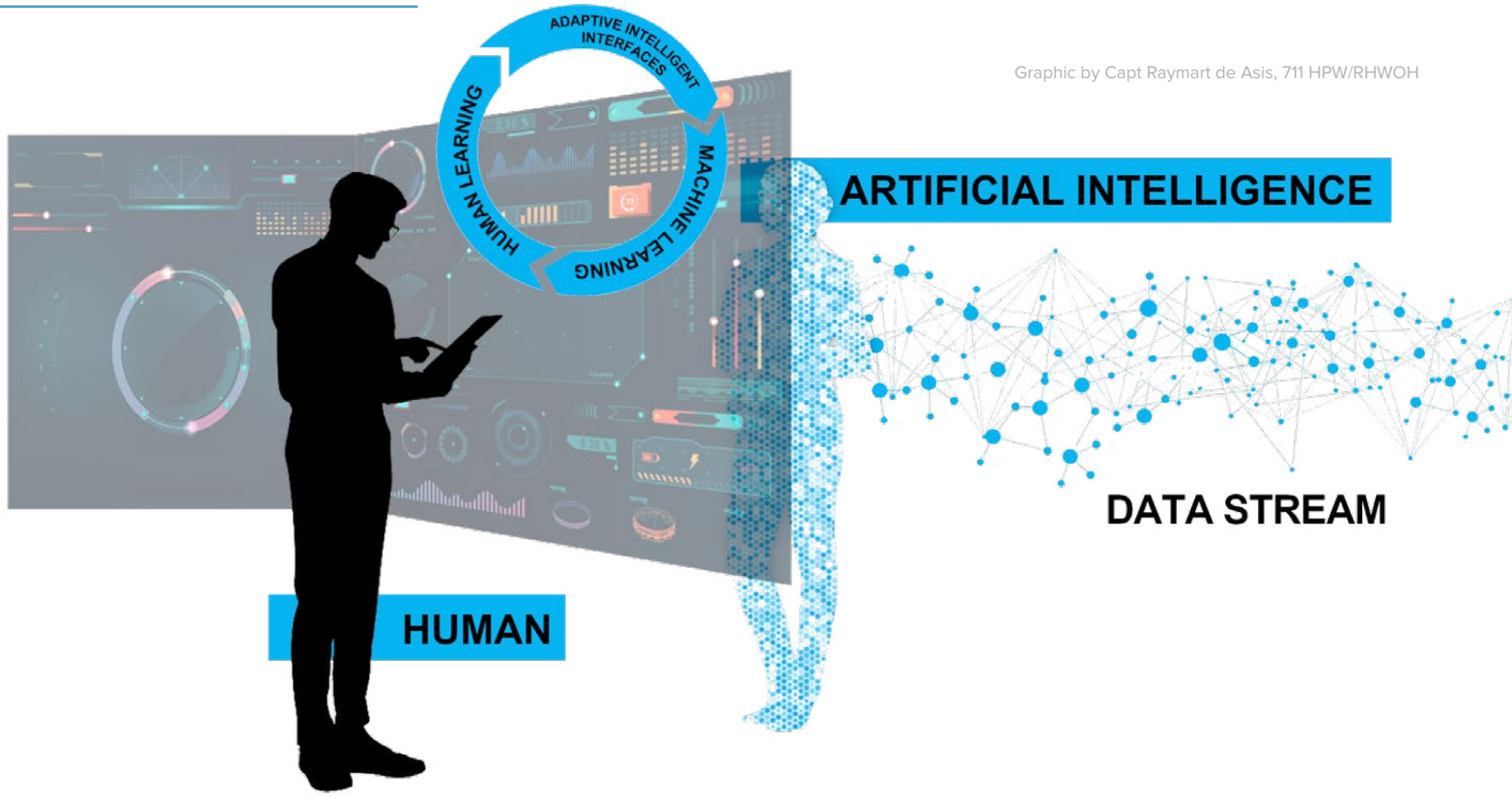
The second challenge area is Co-Learning for Adaptive Human & Machine Teams, which focuses on establishing the foundation for interactive learning and collaborative training of humans and AI-enabled machines to enable uniquely effective human-autonomy teams. This line of effort emphasizes building shared representations and situation awareness among members of human-machine teams, enhancing context sensitivity and decision accuracy in rapidly changing operational situations, and developing methods for testing and evaluating co-learning in human-machine teams. This work emphasizes learning through interactions between human-machine teammates and seeks to understand how human and AI partners can enhance each other's mental models, competency, and decision accuracy. One current project within this LOE focuses on shared spatial models between human and AI partners, facilitating team communication and reasoning in a domain that is traditionally challenging for human-machine teams. Planned use cases for this work include improved training tools for OTTI, distributed mission control, 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 an improved infrastructure 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, Acting Learning and Operational Training CRA Lead and Research Psychologist, 711 HPW/RHWE**

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






Graphic by Capt Raymart de Asis, 711 HPW/RHWOH

# CO-LEARNING FOR ADAPTIVE HUMAN-MACHINE TEAMS

## LINE OF EFFORT

The newly established Co-Learning for Adaptive Human-Machine Teams LOE seeks to optimize collaborative learning and performance between human warfighters and AI-enabled teammates in dynamic and uncertain operational environments. Co-learning refers to the ability of a human and AI team to learn *with* as well as *from* each other to achieve superior results beyond what can be achieved independently. This requires that teammates understand each other's capabilities (shared and distinct), acquire a mutual understanding of the mission and landscape, co-adapt task behavior in real-time to unexpected and novel situations, and maintain a communicative process driven by performance improvement. To address the complexity inherent to human-AI team co-learning, the LOE leverages a multidisciplinary team of data scientists, human factors researchers, statisticians, software engineers, and cognitive scientists. The multidisciplinary approach integrates advances in machine/deep learning, data visualization, computational cognitive models, theories of collaborative learning, communication, and the psychology of team behavior to develop new theories, models, technologies, and evaluation metrics specifically adapted to Air and Space training needs and operational demands. In order to build a foundation with transferable applications, initial efforts emphasize the tenets of co-learning, particularly (1) AI-enabled knowledge capture, (2) context sensitivity, and (3) engineering foundations.

**Co-learning refers to the ability of a human and AI team to learn *with* as well as *from* each other to achieve superior results beyond what can be achieved independently."**

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

### 1. AI-ENABLED KNOWLEDGE CAPTURE

As a prerequisite for performance superiority, human-AI teams must share the same representation (or mental model) of the environment. Initial research focuses on spatial mental models. Spatial knowledge is critical for timely, effective mission planning and assessments in rapidly evolving operational landscapes. We first develop a method for an AI teammate to learn and match the human's spatial mental model through interactions, and then use the shared knowledge to perform a task requiring spatial reasoning.

Continued on next page

## 2. CONTEXT-SENSITIVITY

Rapid, uncertain, and even novel changes in the operational environment alter the decision-making context and the consequences of decisions. As a result, human-AI teams must co-traverse a sequence of internal reasoning processes: recognize how (or if) new events alter an existing context, interpret implications for mission accomplishment, and determine the optimal decision. One early effort uses a sequential reasoning paradigm along with probability theory to demonstrate how interactions leverage the unique capabilities of human (inference making) and AI (computational capacity) teammates, respectively, to update future event predictions and adapt decisions in real-time as well as to subsequent changes in context. Another early effort extends prior dynamic decision-making research to the task of adaptive mission planning by human-AI teams.

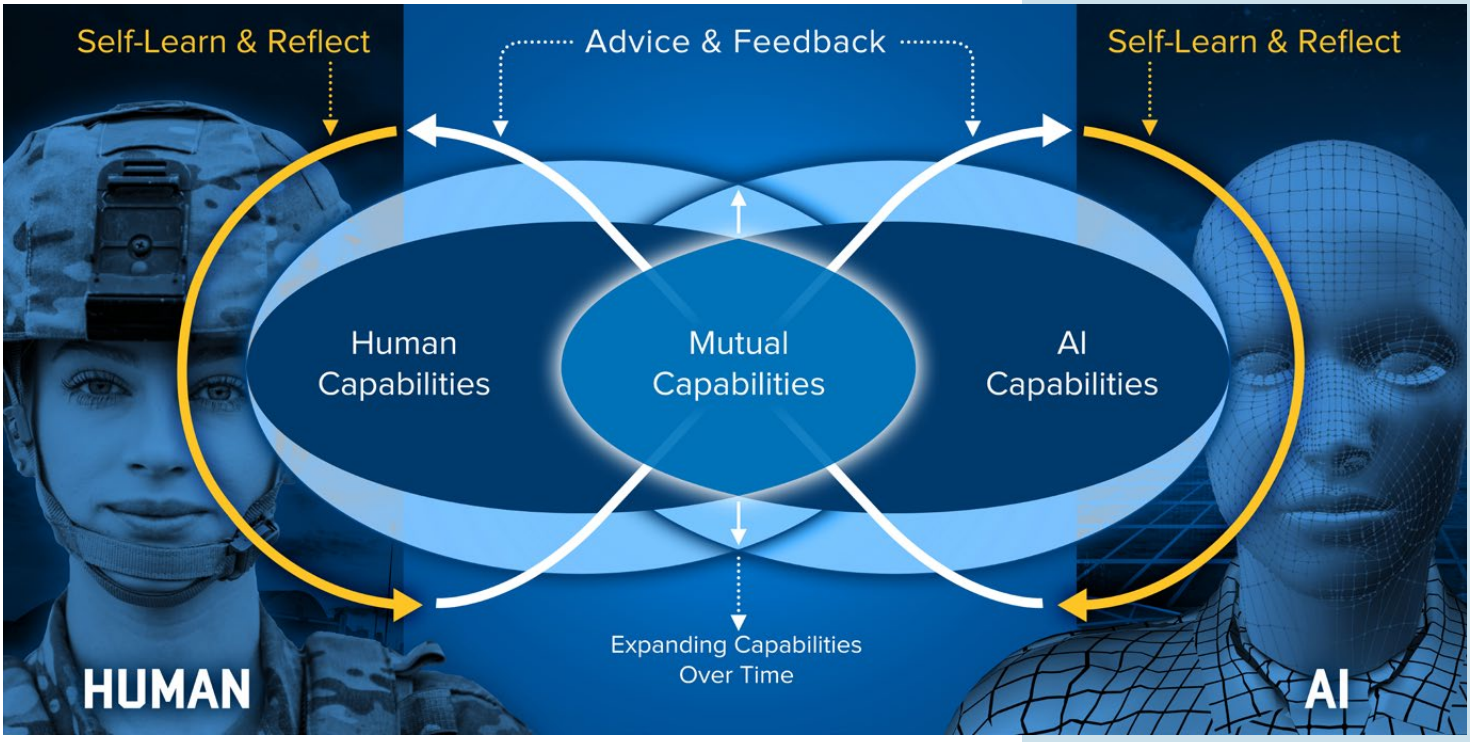
## 3. ENGINEERING FOUNDATIONS

Advances in human-AI teaming are expected to accelerate substantially even as team co-learning remains a novel endeavor. In order to maximize opportunities while minimizing vulnerabilities, the LOE seeks to develop disciplined methods to test and evaluate human-AI co-learning as well as identify computing requirements for systems and architectures implementing the AI teammate.

With the maturation of research into co-learning and teaming tenets, the LOE will shift focus to specific use-cases aligning human-AI team performance with Air and Space operational demands. For example, results are anticipated to inform advances in operational testing and training infrastructure (OTTI), distributed mission control, and AF/SF/Joint wargaming and simulations, to name a few. ☆

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

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




Graphic by Mr. Will Graver (Ball Aerospace)

# Silo

## Machine Learning as a Service

As the fourth technological revolution unfolds, optimizing decision making strategies and expertly navigating vast data landscapes proves an evolving challenge. In response to this challenge, we must merge sophisticated machine learning techniques with advanced human factors design. The union of these fields empower decision-makers to engage effectively with the forefront of artificial intelligence (AI). To achieve this, we must resolve complexity to make better decisions, faster.



Screen Captures by Mr. Ian Stewart Joyce

The Co-Learning for Adaptive Human Machine Teams LOE, in collaboration with U.S. Air Force School of Aerospace Medicine (USAFSAM), has embraced this multi-modal challenge by developing the Silo dashboard. This platform offers Machine Learning as a Service strategically designed to address the most critical issues currently faced by the USAF and USSF. Silo was born in response to the USAF's call for uncompromising data security—a machine learning dashboard designed for deployment in any standalone setting. By leveraging our Machine Learning as a Service model, researchers can explore their data with advanced explainable AI algorithms, all within a personalized Silo environment.

Silo has been custom built to ingest and visualize multi-modal data such as sensor data, time series and tabular data. The Topological Hierarchical Decomposition (THD) algorithm – which applies a topological data analysis to noisy and challenging data – is designed to replicate the hierarchical structure and visualization of scientific taxonomies for enhanced human cognition. THD additionally harnesses Algorithmic Cognitive Chunking to navigate vast data and identify taxonomies in underlying data, visualized as dendrograms for intuitive comprehension (see dashboard images for examples). Notably, the union of machine learning like THD and human factors research may enable statisticians to resolve Simpson's Paradox, facilitating rapid and accurate assessment of complex data to promote decision superiority.

Currently, Silo is being used to predict pilot candidate success using data gathered by USAFSAM Ophthalmologists. Early results are promising and can potentially increase the number of pilots successfully completing training, saving both time and resources. This technology could increase the number of pilots completing Undergraduate Pilot Training and, ultimately, the lethality of the USAF through air superiority.

As demonstrated by recent projects, Silo is a utility providing robust predictive accuracy and a comprehensive understanding of the underlying data that informs decisions for effective and data-driven interventions with statistically robust results within a secure environment. The Silo dashboard enables decision-makers to dive deeper into the data, spot trends, and magnify cognitive reach. Moreover, by using unsupervised machine learning, specifically the THD algorithm, with human factors-inspired visualization, Silo enables users to effectively interact with machine learning models, such that the user can learn from the model. The next step within the LOE is for the models to be enabled to learn from the user. This interactive approach is poised to advance the state of the art in human-AI teaming. ☆

**Mr. Ian Stewart Joyce, Data Scientist, 711 HPW/RHWOH**

> **Aggressive action is required by the DoD otherwise the test ranges will be physically and technically inadequate to address the future fight."**
>
> **— National Academy of Sciences**

Graphic by Mr. Will Graver (Ball Aerospace)

# WARFIGHTER LEARNING TECHNOLOGIES

## LINE OF EFFORT

The application of coordinated multi-domain effects into the fight drives the need for increased fidelity and integration across synthetic and blended training environments. The Warfighting Learning Technologies Line of Effort (LOE) seeks to research, demonstrate, and transition learning technologies, methods, and infrastructure for personalized, proficiency-based readiness. This investment directly addresses 1) training data infrastructure, 2) training data analytics, and 3) just-in-time training methods. These goals aim to improve the efficacy and realism of simulated training across any combination of live, virtual, and/or constructive environments, with implications for multi-domain operations.

Our investments into data infrastructure needs and maintenance increases infrastructure capability to bridge domains and enable greater insight into actions, decisions, and outcomes in training. There presently exists a gap in the number of integrated training ranges and environments that enable integrated live, virtual, and constructive ('blended') environments. This LOE aims to fill that gap with effective best practices and demonstrations of data infrastructure integration across multiple environments (i.e., multi-domain operational test and training infrastructure [OTTI]). Also, identifying and standardizing data infrastructure requirements across multiple testbeds means more analytics solutions will easily transport to novel environments.

Data analytics increases the contextualization of captured data to enable deeper understanding of readiness gains. Our LOE is identifying the types of data necessary to provide trainers with comprehensive, robust training analytics for evaluation. Collecting data such as audio communications or position and movement can inform higher-order performance constructs. For example, given appropriate input from subject matter experts, a trainee's 'teamwork' or 'leadership' skill may be inferable from certain patterns of communication or movement. These analytics are contingent upon building the necessary export capabilities into training data collection systems. Such analytics increase the timeliness and quality of insights necessary to enable dynamic training injects and effective feedback.

Just-in-time training methods are key to enable future warfighting successes where some warfighters may be suddenly called upon to learn and execute technical tasks they have minimal to no experience with. This effort leverages training theory to accelerate skill acquisition and minimize the time needed to train a novice to necessary proficiency levels. We are developing and demonstrating the efficacy of novel methods of delivering training quickly and effectively in a variety of domains (e.g., medical, maintenance).

Training effectively for future engagements requires novel technical requirements and training methods. Data infrastructure, analytics, and just in time training methods come together to evaluate existing, and inform future USAF training environments. Developing such solutions to work in a variety of simulation (live, virtual, constructive, synthetic, blended) and warfighting (cognitive, space, air, land, maritime) domains is a near-term USAF priority to prepare for future engagements. As such, future training methods and technological testbed requirements will be informed by the result of ongoing WLT work. ☆

**Mr. Ted Harmer, Electronics Engineer and Warfighter Learning Technologies LOE Lead, 711 HPW/RHWO**

**Dr. Kent Etherton, Research Psychologist, 711 HPW/RHWOW**

# Scalable Training Solutions

## Team Assessment in En Route Care and Beyond

A top priority within the Warfighter Learning Technologies Line of Effort is to define and objectively quantify readiness standards for individuals and teams. In real-world training environments, methods to quantify team coordination performance in complex mission scenarios are lacking. Our team is tackling these challenges in collaboration with the 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. This work is leveraging over a decade of research within the team coordination and computer vision space, enabling application of existing measures of team coordination to USAF use cases.

We are developing a performance evaluation suite of analytics to utilize audio, video, questionnaire, and a variety of other simulation-based training and event data. The Team Dynamics Measurement System is being developed to handle audio data with automated transcription and diarization (identifying distinct speakers) capabilities. Once data are imported and transcribed, we leverage natural language processing to generate both flow- and content-based metrics of team coordination. For video, we are integrating 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.

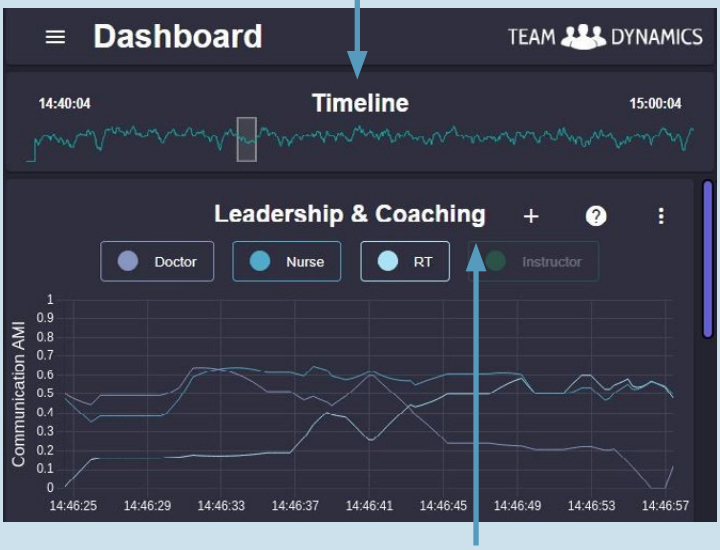
Our first use case for implementing these analytics is Critical Care Air Transport (CCAT) teams. In partnership with 711 HPW/RHB and the USAF School of Aerospace Medicine and the 59th Medical Wing, we are demonstrating quantitative measures for both individual and team CCAT performance and developing 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. ☆

**Dr. Kent Etherton, Research Psychologist, 711 HPW/RHWOW**

(Above) USAF Photo by Maj Dale Greer
Screen Capture by 711 HPW/RHWO

Critical Care Air Transport (CCAT) training.

**Interface allows for playback of audio with synchronized team coordination metrics separated by speaker.**

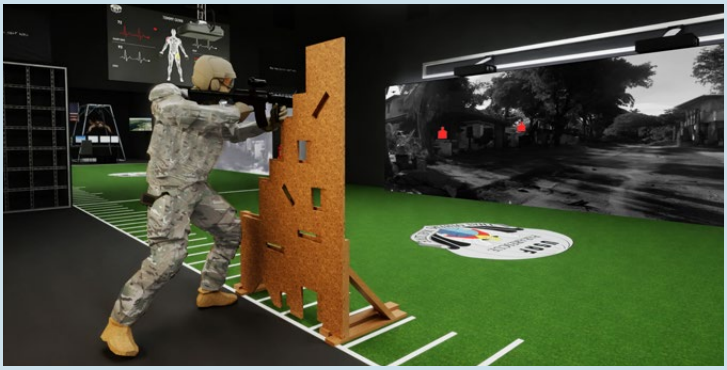


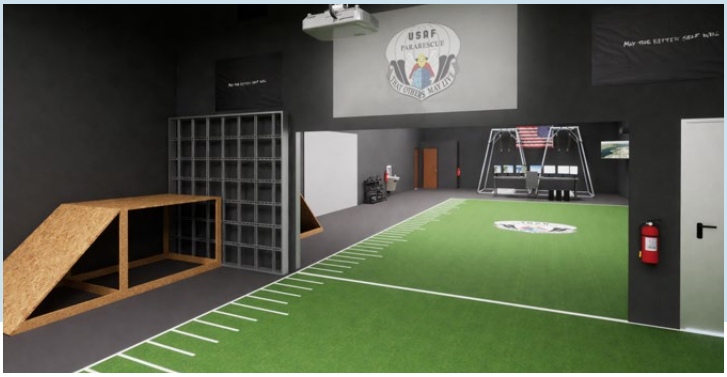

**One of multiple metrics in TDMS: speaker influence measured by speech flow patterns.**

TDMS interface displaying Leadership & Coaching metric for CCAT audio sample.

## RECENT PUBLICATION

Robinson, F. E., Grimm, D., Horning, D., Gorman, J. C., Wiese, C., Winner, J., French, D., & Everidge, R. (2023). Integrating content-based analyses into an automated measure of closed-loop communication. Paper presented at the *Military Health System Research Symposium*. Kissimmee, FL.





Graphics by Improve Group

# Transforming Training

## The Vision of Special Warfare Training Wing

In an era characterized by rapid technological advancement and an ever-evolving combat landscape, traditional training paradigms are being challenged. The U.S. Air Force's Special Warfare Training Wing (SWTW) embodies this shift, pioneering new methods to ensure Airmen are not only ready for today's missions but are also primed for the unknowns of tomorrow.

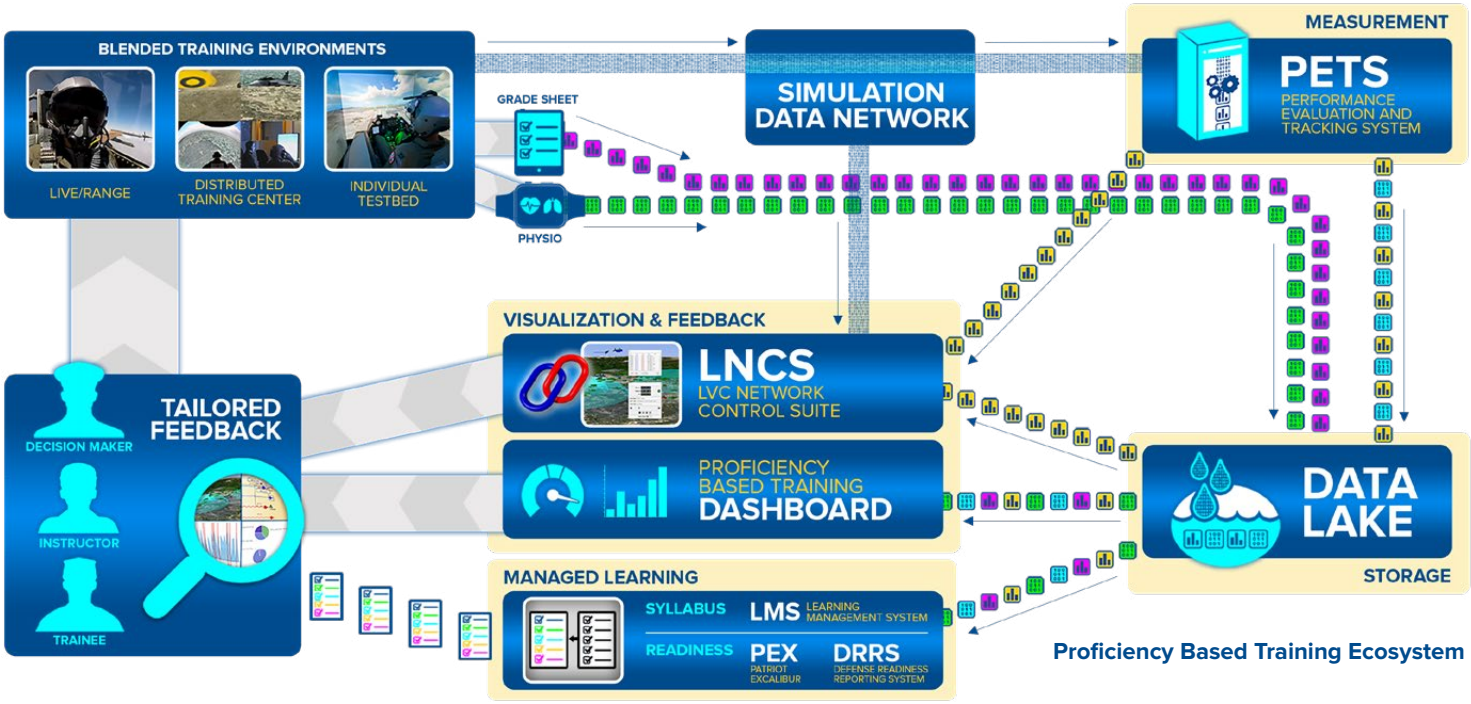
SWTW's mission is to assess, select, and develop ground combat forces that specialize in global access, precision strike, and personnel recovery. Their focus goes beyond the immediate; it's a forward-thinking organization, deeply invested in transforming training. This transformation is not just about incorporating new technologies but is a holistic reimagining of how Airmen learn, adapt, and apply their skills in real-world situations.

Central to this transformative vision is the introduction of a simulation lab being developed at the 351 Special Warfare Training Squadron's Pararescue and Combat Rescue Officer Apprentice course. In concert with the Air Force Research Laboratory (AFRL) Warfighter Interactions and Readiness Division (711 Human Performance Wing/RHW) and the Defense Innovation Unit, SWTW is interweaving advanced technologies with innovative learning methodologies.

The new simulation lab is a self-paced, immersive individualized training aid created by Improve Group™ to mimic operational realism. The lab's augmented reality (AR) environment is combined with virtual reality (VR) simulators such as Inveris™ weapons trainer, HAVIK's™ ground operator call-for-fire trainer, and SimX™ medical simulator to optimize student performance in a controlled environment. In addition to improving students' physical skills, their knowledge is also being enhanced through Blank Slate™ cognitive learning and retention tool. The data from these technologies is then centralized into the Kitman Labs™ performance platform which generates real-time analytics and identifies areas of improvement while providing actionable information that allows instructors to tailor their teaching methods, ensuring optimal outcomes.

SWTW, through its simulation lab and its broader vision, is crafting a future where training fosters adaptability, critical thinking, and a deep-seated readiness for any challenge. Additionally, the Wing's latest endeavor aligns perfectly with Second Air Force's vision for technical training transformation and sixth-generation learning environments seeking to break free from the constraints of traditional instruction and offer flexible learning pathways. The simulations lab is emblematic of this shift, offering a dynamic learning environment where training is individualized, flexible, and immersive. The Special Warfare Training Wing stands at the forefront of a training revolution, championing methods and techniques that promise to keep the U.S. Air Force at the pinnacle of military excellence for years to come. ☆

**Maj Caitlin Harris, Program Manager, Special Warfare Training Wing, AETC**




**Proficiency Based Training Ecosystem**

Graphic by Mr. Will Graver (Ball Aerospace)

# Proficiency-Based Training (PBT)

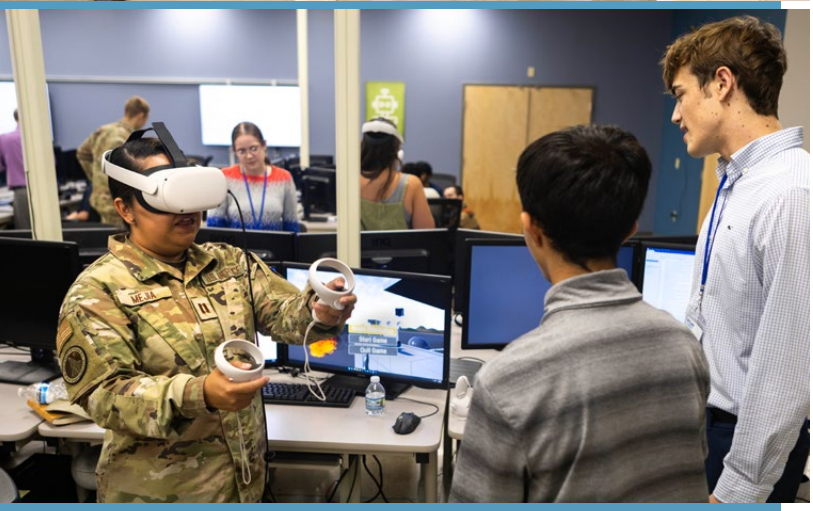
There is an ongoing transformation in training doctrine shifting from rote, one-size-fits-all training to a personalized, data-driven approach focused on streamlining individualized training at scale to enhance readiness. AFRL and RHW are embracing this transformation through Proficiency-Based Training (PBT). The PBT system measures and tracks warfighter performance, then compares it against learning objectives. The system helps target proficiency gaps for more efficient and effective training. Learners advance based on mastering the competencies and skills linked to their job or mission. Instructors have a proficiency record for each trainee, making logistics easier and instructor expertise more potent. The USAF can address deficiencies through more tailored, individualized learning to close the readiness loop. Ultimately, PBT provides commanders better insight into force and unit-level readiness.

This past year, the AFRL team has continued work towards operationally relevant science and engineering-backed innovations fulfilling PBT's potential. The team has fielded and maintained PBT tools at multiple training centers and is advancing to meet emerging training capabilities. The team has created new tailored reports delivering actionable insights to operators, streamlined creation of new human performance measurements, collaborated with government and industry partners to foster innovation through shareable PBT data sets and to integrate the best of breed capabilities and advanced adaptive training methods. In the next year, we expect maturation of our data platform and integration with additional training environments while advancing the underlying learning science. ☆

**Mr. Peter Neubauer, Principal Research Engineer, Aptima, Inc.**

> **Our current training framework, which is based on completion of specified numbers of training events has carried us well for the last two decades... but the keys to success will depend on the ability ...to integrate training environments, measure performance, and remediate deficiencies at all layers of the training hierarchy."**
>
> **—Air Combat Command - Future Training Concept**

# THE GAMING RESEARCH INTEGRATION FOR LEARNING LABORATORY®



Photos by Mr. Will Graver (Ball Aerospace)

## 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.

**"The technical expertise of the (GRILL®) staff and their willingness to help mentor us really allowed us to thrive and come up with innovative solutions to solve our challenge problem."**

**—Mr. Daniel Hayase**
US Air Force Academy Cadet

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

**WWW.AF-GRILL.COM**

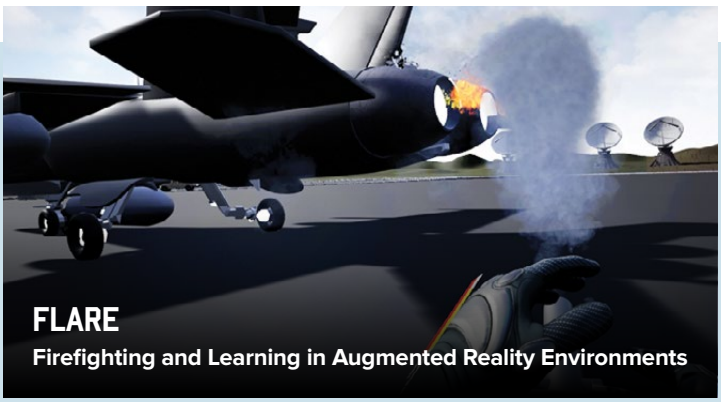
## SUMMER AT THE GRILL®

This summer, the Gaming Research Integration for Learning Laboratory (GRILL®) hosted 16 Wright Scholars, 4 undergrad interns, 8 teachers, 4 U.S. Air Force Academy (USAFA) cadets, 3 student interns, 2 Legacy students, and faculty researchers Kendall Carmody (Florida Institute of Technology), Dr. Stephanie Fussell (Kent State University) and Dr. Denny Yu (Purdue University). These participants worked collaboratively on community-driven challenge problems.

Cadets at the GRILL U.S. Air Force Academy (USAFA) developed a new software for use in USAFA's Multi-Domain Laboratory (MDL). Overseen by the Military and Strategic Studies (MSS) Department, the MDL provides advanced wargaming capabilities for USAFA. The cadets' project, the Coalition Space Operation Console (CSOC), was developed to simulate space operations in higher fidelity than current capabilities, and was specially designed to fulfill the MDL's requirements. CSOC was developed in Unity, a powerful and versatile game design software, and is highly customizable. At the end of the cadets' six-week development timeframe, the main user interface is complete, and the current MDL scenario, Operation Northern Eclipse, is built into the program. Future development goals include integration with ASCOT 7 and MIRC chat, the primary wargaming software used in the MDL. CSOC will be used during the culminating wargame of MSS 251, a core course taken by all cadets, where the cadets will roleplay as space operators in a Combined Joint Task Force. The Cadets' development of the COSC at the GRILL this summer represents a step forward in military education, promising to enhance wargaming capabilities and provide immersive training environments for future leaders. The Air Force's push for immersive training solutions falls in line with General Brown's 'Accelerate Change or Lose' initiative and facilitates the production of quality warfighters.

## SUMMER CHALLENGE PROBLEMS


**CLAIM (Cultural Language AI Model) is an innovative project aiming to improve language learning with cultural awareness and advanced AI. The team developed a plugin/prototype for interactive exploration of language nuances, social expectations, and cultural mannerisms. Using cutting-edge language processing, CLAIM fosters understanding of diverse cultures and effective communication. CLAIM offers a unique learning experience by addressing contemporary language acquisition obstacles.**




**FLARE (Firefighting and Learning in Augmented Reality Environments) is an AR/VR/MR training simulation teaching airmen how to use a Halon fire extinguisher on aircraft engine fires. Intended to augment current training and provide a more immersive, inexpensive, and low risk training experience, FLARE can arm future airmen with the knowledge, skills, and abilities required to be successful. Within FLARE, users can extinguish fires on several aircraft in various conditions with optional fire spread and weather systems. The experience culminates in a performance score analyzing the use of the "Pull, Aim, Squeeze, and Sweep" method to fight fires.**

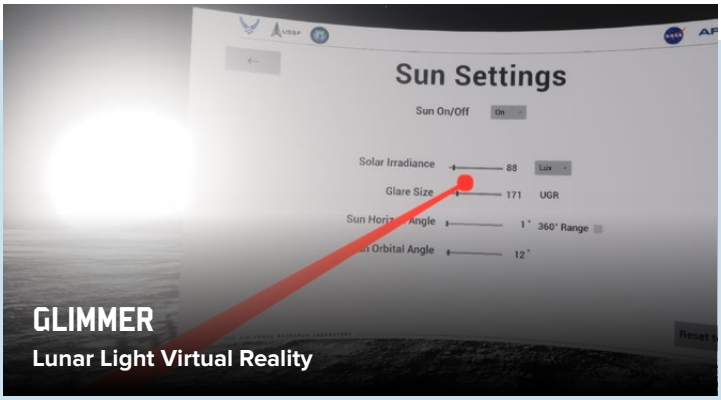
Screen Captures by the GRILL®
Photos (top right) by Mr. Will Graver (Ball Aerospace)

## STEM EDUCATION

In support of STEM education, summer educators at the GRILL® developed a comprehensive toolkit for school usage, from classroom instruction to independent research. This initiative also opened doors for postdoctoral research, with educators delving into innovative projects that span from flight training to the application of virtual reality in team training. The UP & AWAY Team formulated a complete fifth-grade science curriculum equipped with projects, lesson plans, and more. Meanwhile, the LEGO Team crafted interdisciplinary challenges for students from kindergarten to fourth grade, blending Science, Mathematics, Reading, and Social Studies into cohesive units. Furthermore, a special program called Summer Camps was launched for rising fifth and sixth graders. This program, emphasizing hands-on STEM experiences, allowed students to engage in tasks like building cardboard motorized cars. On another front, educators organized Knowledge Shares, which were mini-professional development sessions focusing on a wide array of STEM topics. The STEM in a Bin initiative was particularly ingenious; designed to aid a K-5 educator transitioning to a STEM classroom, these bins contained materials and challenges appropriate for all grade levels.

On an individual level, many educators made notable contributions. Jennifer Corder developed an educational unit centered on the 4 Cs of Learning: Critical Thinking, Communication, Collaboration, and Creativity. Lisa Galpin worked to bridge the gap between home and school learning through her Family STEM Night program. Dawn Kincer showcased her versatility by designing STEM bins for intermediate students and introducing innovative tools like one pound bots, drones, and 3D printing into the educational mix. Robert Potts crafted invaluable resources to aid educators looking to integrate video game design into their lesson plans. Macy Timmerman introduced a novel approach to Digital Citizenship education by creating virtual escape rooms. Christy van Schagen produced an enriching interactive STEM booklet for caregivers and crafted a comprehensive science unit on light energy. Jill Weaver made technology accessible by building low-cost microscopes compatible with cellphones and designed Arduino-based Astrobotany projects. Bridgett Williams's focus lay in the realm of Python, using it to enhance engineering content. She also underwent specialized training for Bird Brain Technologies and Python.

## SUMMER CHALLENGE PROBLEMS




GLIMMER (Geological Landscape illumination and Mapping of Moon's Environment and Reflections) aims to utilize Unreal Engine 5 to create a highly realistic and immersive virtual model of the Lunar south pole (LSP) in preparation for NASA's Artemis 3 mission in 2025 and 2028. Our team collaborated with NASA and RHDO to capture the intricate details of the lunar surface, including its cratered landscape and rough textures, while emphasizing the specific lighting conditions characterized by low sun angles and elongated shadows.


The Pollution Damage Simulation aims to enhance understanding of pollution accumulation and accurately predict emission particle concentrations at any location. The capability to accurately recreate scenarios through the analysis of emission particle concentrations could significantly improve public health. Unreal Engine and the Niagara Particle System are utilized to build out a simulation that accurately visualizes the movement of vehicle emission particles over time.

Screen Captures by the GRILL®

## FULL THROTTLE STEM®

The Full Throttle STEM® (FTS) event, now hosted at both the Eldora Speedway in Darke County, OH, and in its second 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 and Dayton, 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 12 schools and over 200 kids, was a roaring success, celebrating STEM in a hands-on, engaging manner.

## GRILL® DIS FOR UNREAL

Recently, the use of Unreal Engine for modeling and simulation has gained prominence, especially with the introduction of Project Anywhere and enhanced precision features in Unreal Engine 5. The inclusion of the Distributed Interactive Simulation (DIS) protocol, a standard predominantly used in military defense, amplifies this growth. The GRILL® introduced a plugin, GRILL® DIS for Unreal, leveraging the open-source Open-DIS maintained by the Naval Postgraduate School. Presented at the Geospatial Intelligence Symposium, this plugin allows the Unreal Engine to both receive and send out DIS data, with options for customization.

Excitingly, multiple countries have now confirmed their use of this plugin for training exercises. Moreover, the Unreal Engine plugin version has surpassed 40,000 downloads, reflecting its widespread acceptance. It's been updated to be compatible with Unreal Engine 5.3. For enthusiasts and developers, a sample project showcasing this plugin's capabilities is available for download from GitHub. ☆

**Mr. Jonathan Diemunsch, Research Computer Scientist, 711 HPW/RHWOW**

**Capt Eric Lawson, GRILL Program Manager, 711 HPW/RHWOW**

**Dr. Summer Rebensky, Research Scientist, Aptima, Inc.**

## SUMMER CHALLENGE PROBLEMS


**The Virtual Medkit Project is an interactive mobile platform designed to create an immersive learning simulation of a $200,000 medkit, offering students valuable and cost-effective training. Utilizing photogrammetry and Unreal Engine, this project provides a highly realistic simulation that enhances combat readiness on the battlefield. Through the integration of realistic 3D models and engaging interaction, students can expand their knowledge of the medkit through interactive quiz and graphical exploration modes. The primary aim of this project is to establish an immersive learning environment that enhances the combat readiness of future combat nurses.**


**The VR Elevated Radial Maze is a customizable VR environment that will serve as a testbed for studying human approach-avoidance behavior in response to elevation and non-lethal weapons (NLWs). The simulation enables researchers in RHDO (AFRL Optical Radiation Bioeffects Branch) to vary environmental conditions, elevation, maze size, user tasks, and the presence of NLWs. RHDO will use this environment to study task accuracy and biometric responses to these otherwise harmful conditions in a controlled VR environment.**

Screen Captures by the GRILL® / Photos (top) by Mr. Will Graver (Ball Aerospace)

# WARFIGHTER INTERFACES & TEAMING

## CORE TECHNICAL COMPETENCY (CTC)

**Dr. Mark Draper**

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

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 interface technology, mission-optimized distributed team performance

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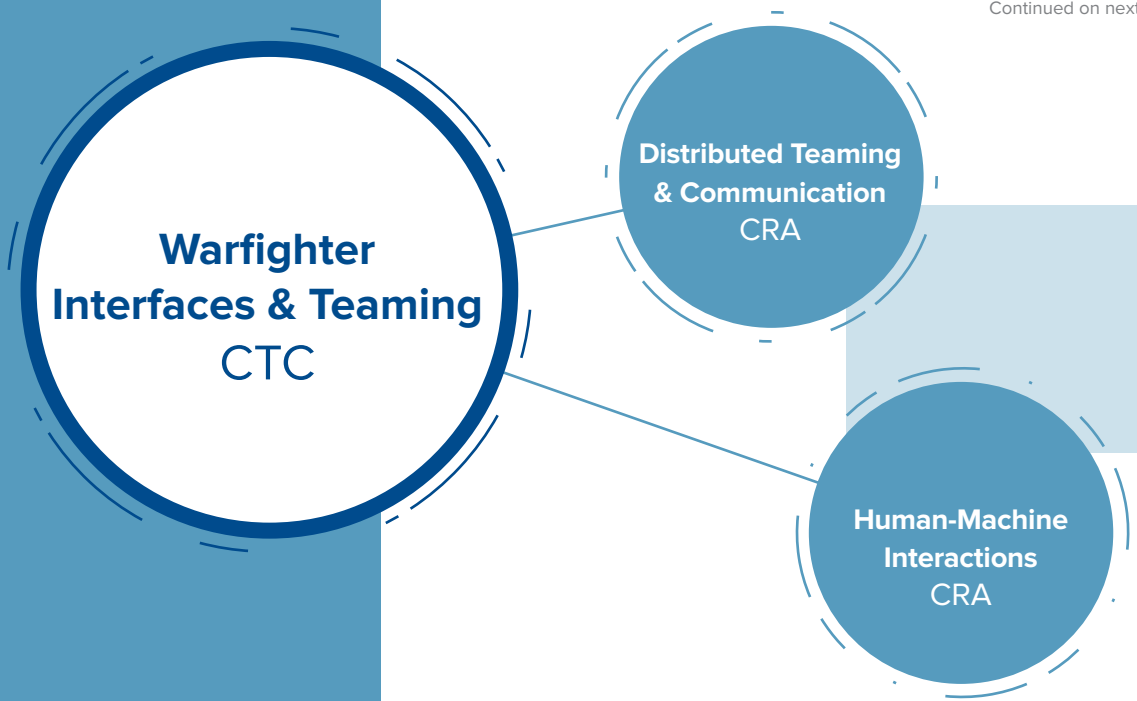

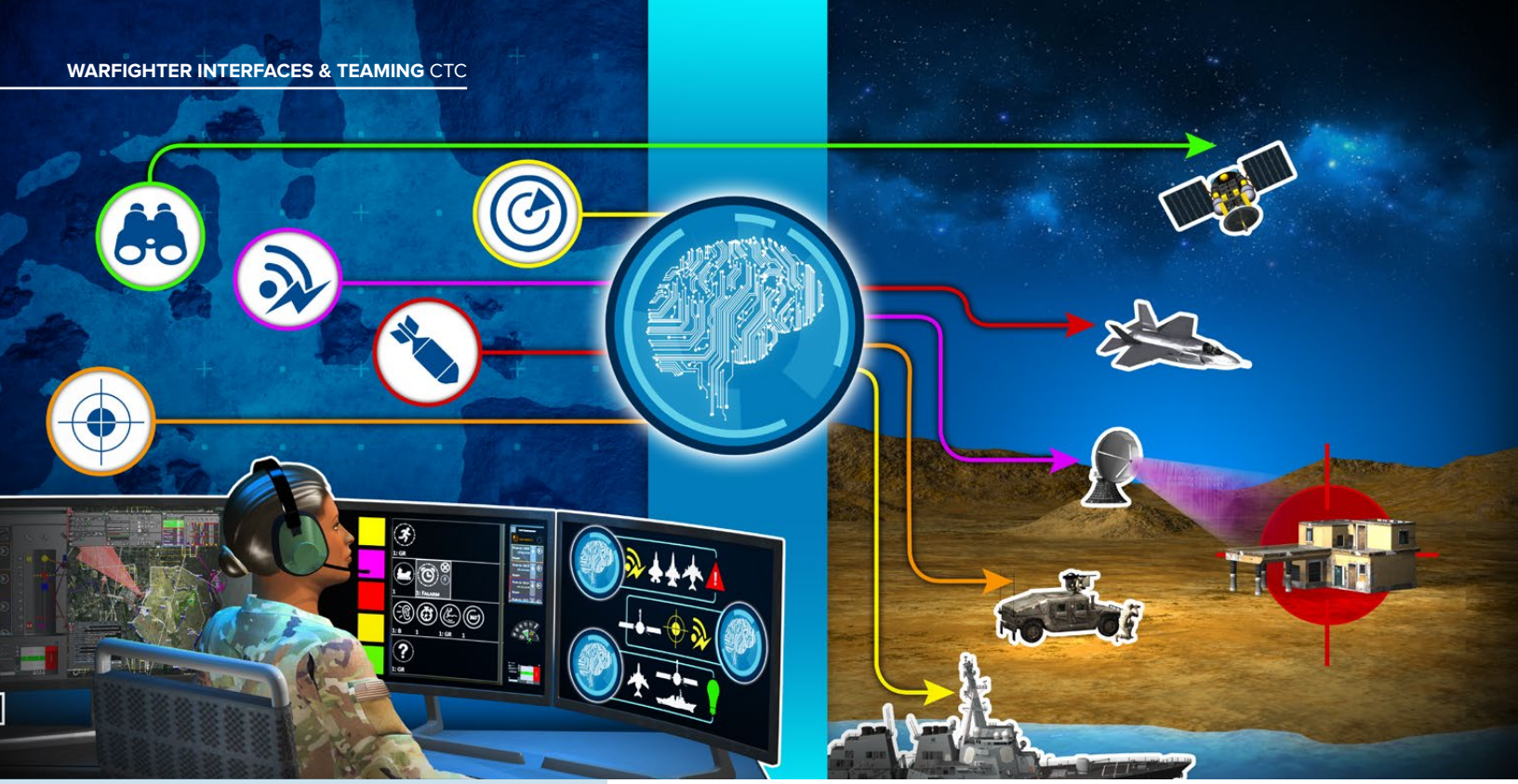

Graphic by Mr. Will Graver (Ball Aerospace)

**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.**

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.

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**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.

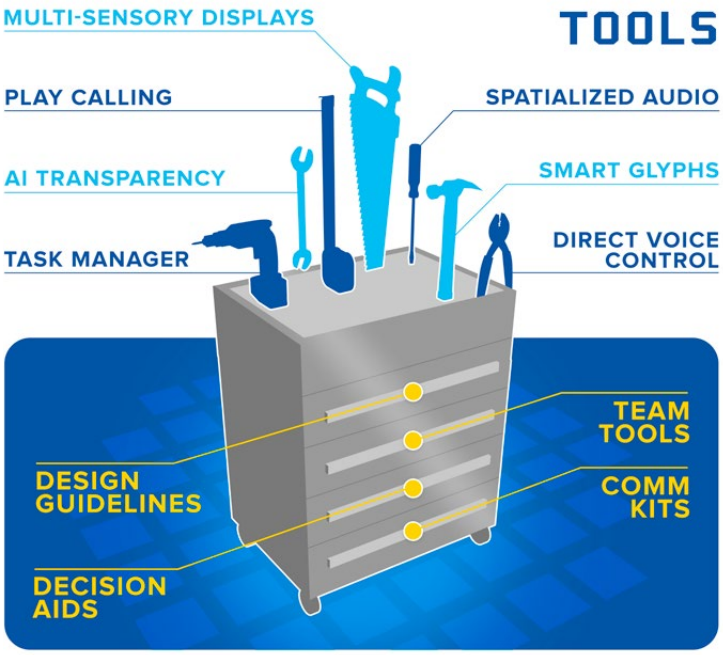
So, what does the WIT CTC contribute to the fight? We strive to provide a toolset of interaction and teaming solutions that empower Airmen and Guardians to accomplish their missions more rapidly and effectively, thus providing robust decision superiority to our forces. Specific outputs of our research 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, FY24 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




Graphic by AFRL

# DISTRIBUTED TEAMING & COMMUNICATION

## CORE RESEARCH AREA

**Dr. Michael Tolston**
Distributed Teaming & Communication Core Research Area Lead, 711 HPW/RHWTE

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.

The Dynamic Team Performance Assessment (DPTA) LOE is working to enable the rapid formation, real-time assessment, and dynamically optimized performance of distributed heterogeneous

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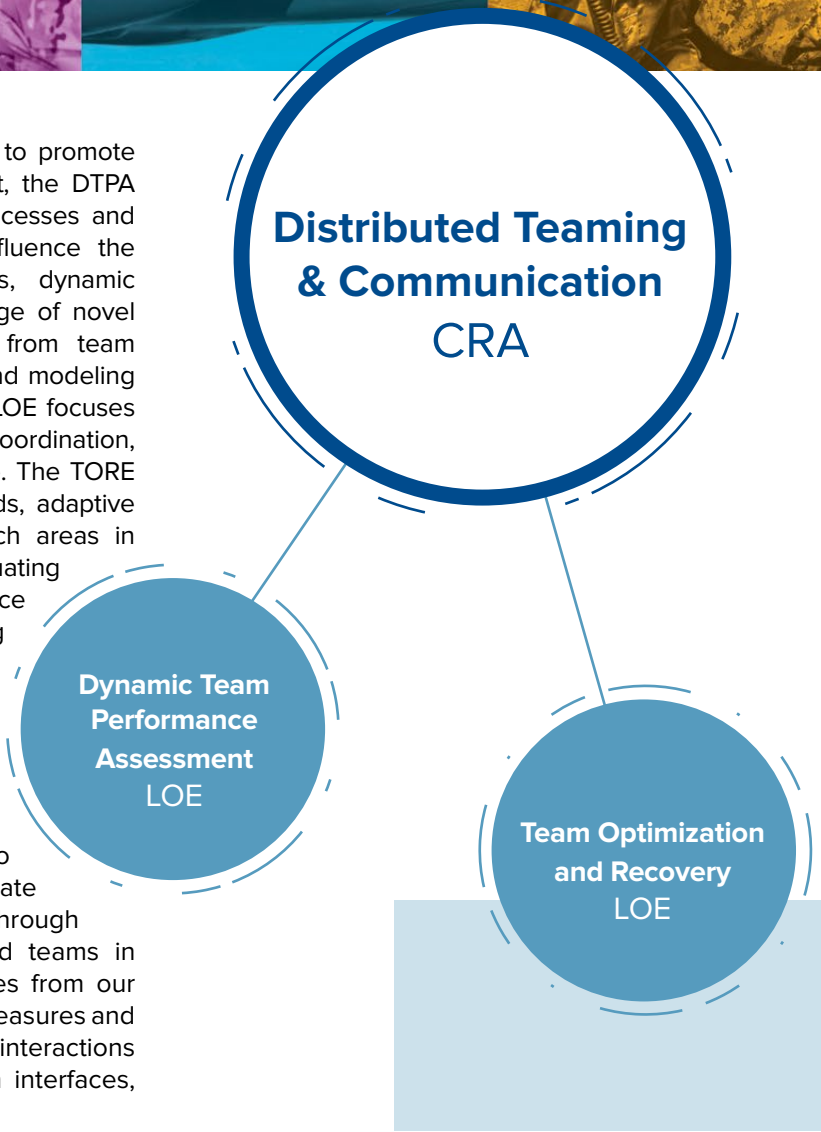
Graphic by Mr. Will Graver (Ball Aerospace)

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.

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. ☆




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

# DYNAMIC TEAM PERFORMANCE ASSESSMENT
## LINE OF EFFORT

## Team Performance Metrics and Team Trust Contagion

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).

We have been engaged in a joint research study with researchers Dr. Nathan McNeese (Clemson University) and Dr. Jamie Gorman (Arizona State University) to explore how trust and distrust of an autonomous teammate can be spread through a Human-Autonomy Team (HAT). In the experiment, a human participant was paired with what they thought were another human teammate acting as the team's navigator and an artificially intelligence (AI) acting as the pilot in a multi-person unmanned aerial vehicle (UAV) supervisory control task. Unbeknownst to the participant, however, their 'teammates' were confederates of the experimenters. The goals of the study were to examine how the behavior of the AI pilot and the expressed trust or distrust of the pilot by the navigator would then influence the participant's trust of both teammates. The results of our study indicated that the behavior of the AI pilot had a strong influence on the participant's trust in it, but trust was further influenced by communications with the navigator. The study advances our understanding of how behavioral and verbal trust spread within a human-autonomy team through the influence of trusted teammates. It also led to the development of a new measure of human-AI trust that can be implemented in HATs to measure the spread of trust or distrust in real-time.

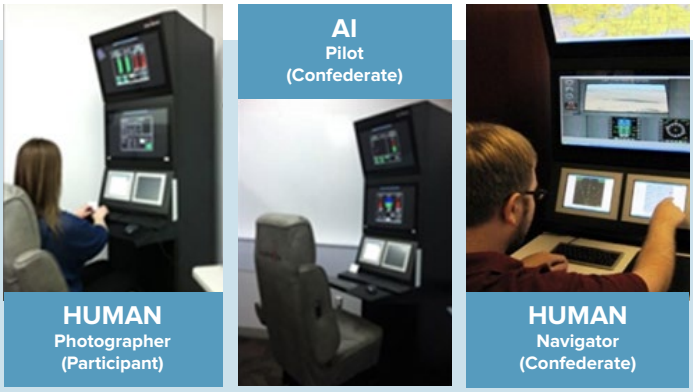


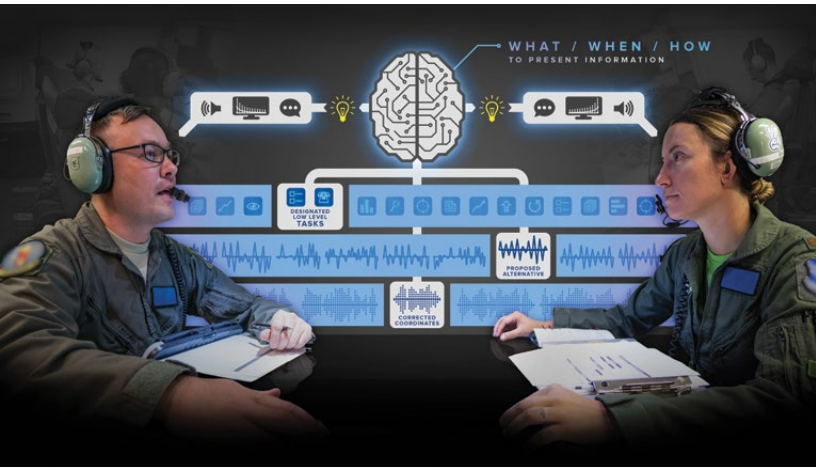

**Diagram of the HAT UAV supervisory control task team roles.** (Photos by Dr. Jamie Gorman)


**Participants at UDRI will work simultaneously with participants at ASU in a multi-team UAV supervisory control task, allowing us to better understand distributed team dynamics and how trust/distrust in one HAT team may spread to others.** (Graphic by Dr. Nathan McNeese)

Our next step in this research project is to assess how trust and distrust spread in distributed, multi-team HAT cooperative tasks. Unmanned Aerial Vehicle (UAV) teams at the University of Dayton Research Institute (Dayton, OH) will be linked with UAV teams at Arizona State University (Phoenix, AZ), allowing us to examine distributed team dynamics and performance in a cooperative task. We will examine how the behavior of an AI pilot on one team, and the expressed trust/distrust of the navigator of the same team, influence the trust of partner participants in a different, but coordinating HAT team, including using our new human-AI trust measure. We believe that this research will provide valuable insight into human-AI trust in distributed multi-team operations. ☆

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

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




# Agile Communications

Teams form the essential substrate of military operations and for them to perform well, team members must communicate effectively. This requires teammates to possess a common understanding of the team's abilities, distal goals, near objectives, and the context under which they all work. In other words, effective teamwork requires the establishment and alignment of shared understanding between teammates.

Importantly, both teams and contexts are always in flux: team members can be added or removed; task objectives are eventually realized and new ones are identified; team goals are reviewed and altered; and task demands change in intensity. Consequently, in the real world, conceptual alignment between teammates must occur across a range of time scales and requires constant monitoring, maintenance, and negotiation as old information becomes irrelevant and new information is acquired and disseminated. This process of continuous alignment is especially important in denied or degraded communication environments, in which miscommunication or missed communication can cause critical teaming errors with cascading negative effects.

To help teams communicate effectively, the agile communications research effort is investigating methods to quantify team communications and derive shared conceptual understanding from bottom-up models that are also influenced by top-down understanding of specific task environments and demands. We are investigating how large-language models can be optimized for specific task environments through fine-tuning and data augmentation strategies. We are using these numeric representations of communications to derive teaming metrics that include topic models that represent semantic spaces, measures of conceptual alignment over time between teammates, measures of cognitive dynamics, and the rate and efficiency of the exploration and integration of information spaces by team members. Outcomes from this work will include indicators of team shared mental models, shared situation awareness, and cognitive dynamics that can be used to assess teams in real time for suboptimal communications. ☆

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

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



Photo by Airman Delanie Brown

**Photo of a weapons platform where the platform wagon has been highlighted by a region segmentation computer vision algorithm. The highlighted region can help translation systems choose the proper version of a word that fits the accompanying scene.**

# Contextualized Communication Machine Learning (CCML)

711HPW/RHWTE is developing methods to extract additional context from visual or audio cues to improve the quality and accuracy of automatic speech recognition (ASR) and language understanding. The Contextualized Communication Machine Learning (CCML) research effort focuses on leveraging information from multiple modalities to better understand the context of information being processed to enhance analytic systems designed to enhance an operator's effectiveness.

One such application is the use of an AFRL-developed ASR system customized to the Domestic Events Network, a 24/7 Federal Aviation Administration (FAA) sponsored conference call used to provide timely information to the appropriate authorities when there is an emerging air-related incident. This ASR system is enabling the development of an event detection system, allowing prioritization and triage of events resulting in enhanced air traffic controller performance.

Another application considers the visual contents of a foreign-language video and infers the correct context for ASR transcription and translation when a word by itself may be ambiguous (e.g., a 'buck' in English may refer to either a dollar or a male deer). Adding this contextual information to a neural network-based translation system can improve translation quality and can reduce errors in critical use cases. ☆

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

# TEAM OPTIMIZATION AND RECOVERY
LINE OF EFFORT

## Team Performance Metrics and Team Trust Contagion

In the future of warfighting, it will be important to have distributed multi-domain teams that are agile and able to adapt to rapidly changing situations. These teams will need to be configured in a way that supports efficient interactions between team members and provides them with the tools that enable them to maintain effective collaboration in complex and unpredictable mission environments. RHWT's project 'Team Collaboration and Resilience' is a new effort focused on robust distributed teaming via novel coordination technologies. This includes the design, development, and evaluation of interface concepts that enable distributed teams to successfully coordinate and engage in joint tasking while operating in contested and/or denied settings. Both human-human and human-autonomy teams will be considered. The effort aims to identify and understand the critical teaming factors and collaboration needs to enable resilient teams across multiple domains that have interdependent taskings. This work will explore the implications of team structure and evaluate viable task management techniques that support joint tasking and awareness of the global mission status, while considering how artificial intelligence tools could be leveraged and the premise of pre-existing contracts.

The team is currently planning a study that will compare several low-fidelity task management/coordination representations designed to support an operator working with distributed teammates to complete individual and inter-dependent tasks. We are interested in learning which representation best aids the distributed operators in accurately and quickly identifying who is responsible for a task, the nature of inter-dependent task relationships, task temporal constraints, and the cause of issues for ongoing tasks when they arise. The results of this initial study will be used to inform the design of a high-fidelity, fully interactive Task Management Interface that can support Joint All Domain operations.

Future research will include both part-task, lower-fidelity simulation/usability evaluations, as well as full-scale experimentation in a high-fidelity testbed, to evaluate alternative approaches to candidate team structures, temporal coordination tools for tactical operations, and interface/work-aiding design concepts that support joint tasking, distributed coordination, and team/mission status awareness. The results of the designs and corresponding evaluations will feed technical efforts that address future envisioned, multi-domain teams and Joint All Domain Command and Control Operations. ☆

**Dr. Elizabeth Frost, Research Psychologist, 711 HPW/RHWTC**
**Ms. Jessica Bartik, Research Psychologist, 711 HPW/RHWTC**
**Dr. Hunter Rogers, Research Psychologist, 711 HPW/RHWTC**

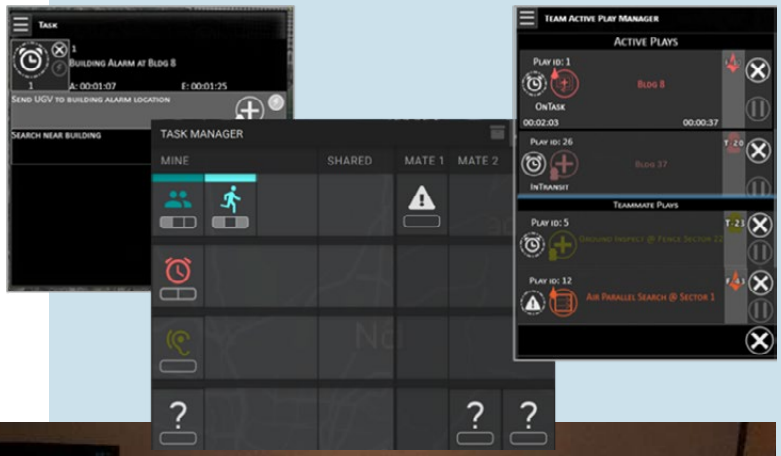
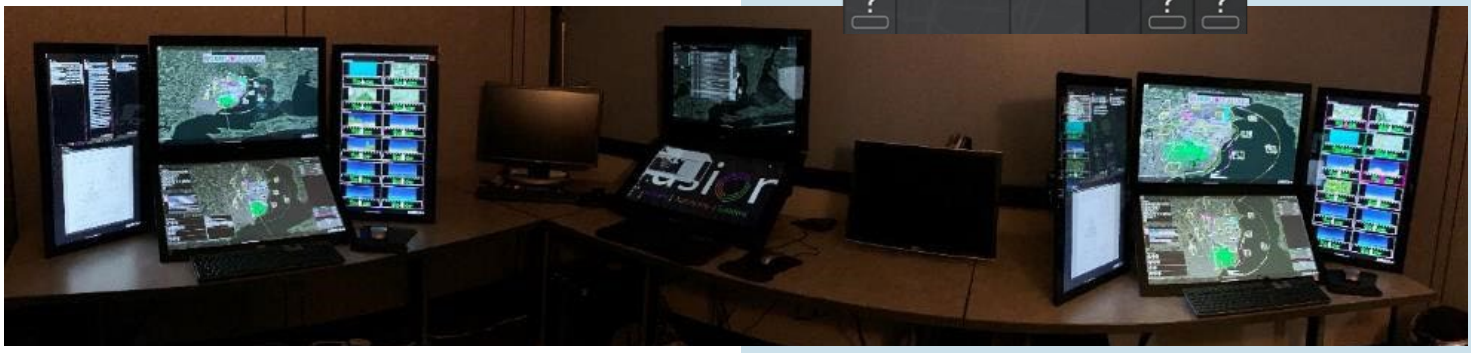
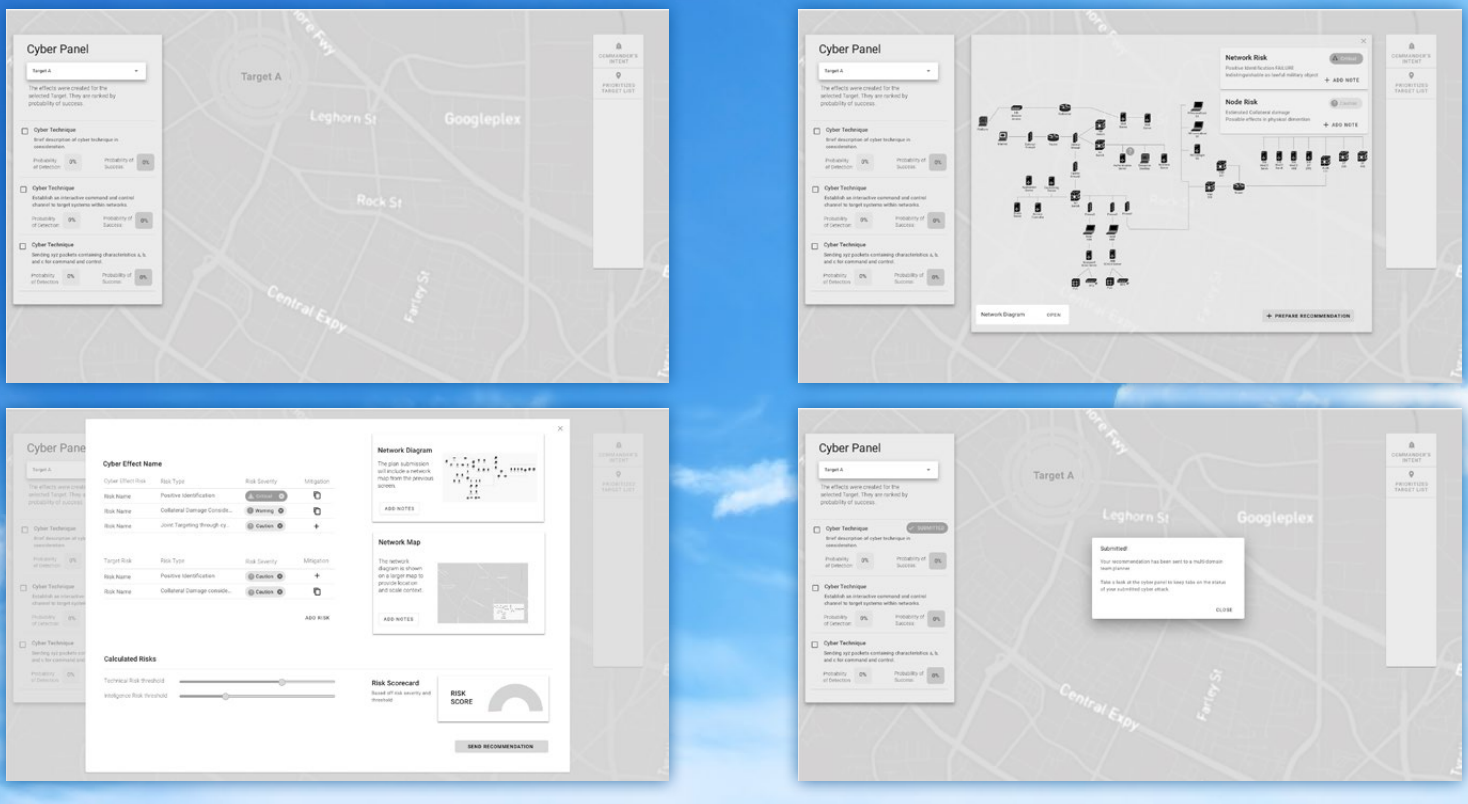



Photo and Screen Captures by Dr. Elizabeth Frost






Screen Captures by Emily Quinn

# Multi-domain Teaming

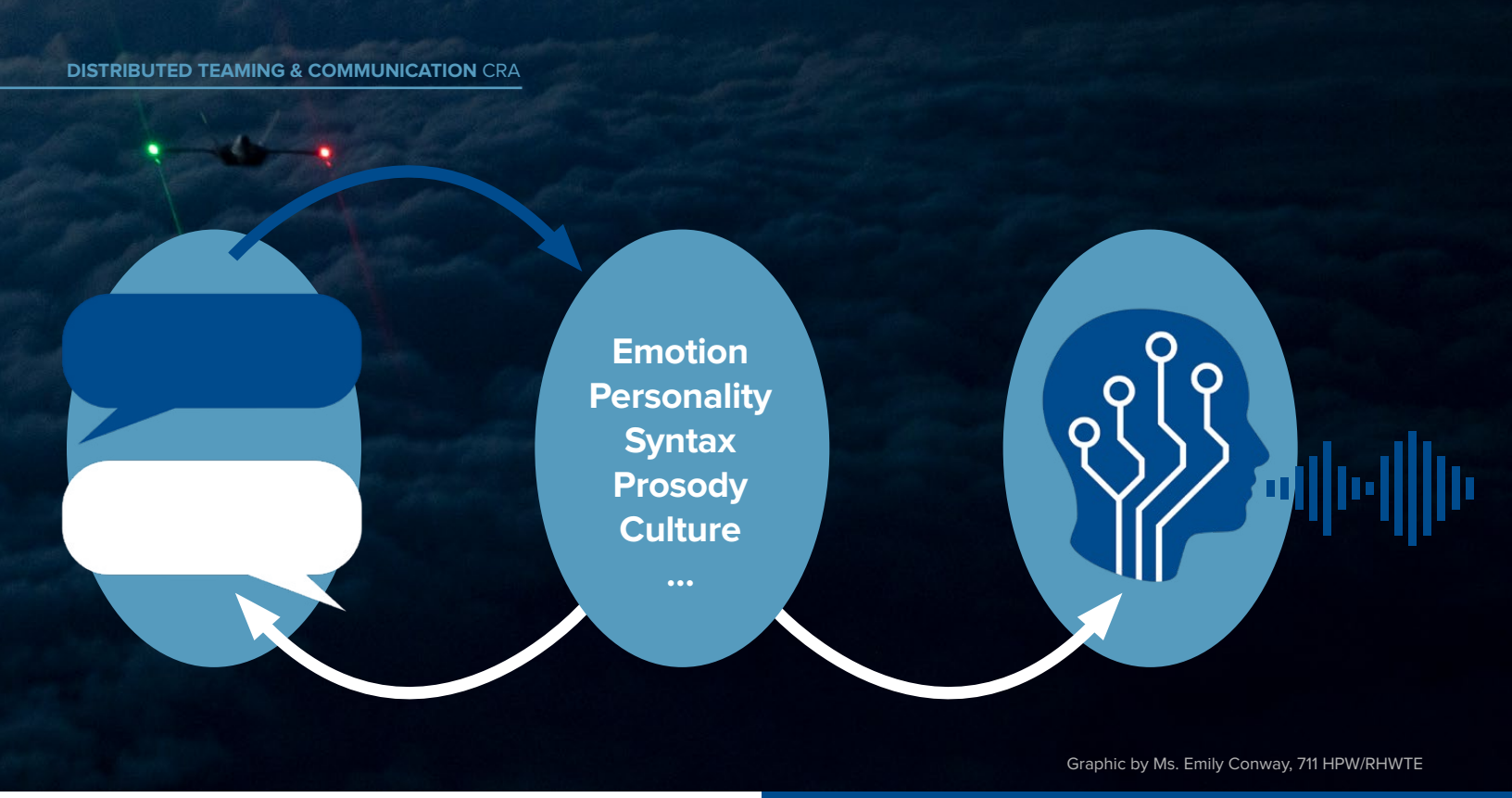
Future Joint All Domain (JAD) operations will require distributed teams from different domains to work in harmony to understand a common operating environment. With varying objectives and lines of communication, teams working in the physical domain (on the ground or air) will not operate on the same 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 new Multi-Domain Teaming 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 JAD team.

This research explores the complexities and goals of the cyber domain at a tactical level and the overarching operational picture of a cyber plan to identify disparate requirements for the unique characteristics and intricacies of the cyber domain. The outcome of this exploration will inform the larger multi-domain picture in terms of what information is important for a cyber expert to communicate and how that information impacts other domains. This effort also aims to identify ways to represent cyber plans in the context of multi-domain operations by developing innovative interface design concepts that enable the relevant cyber information to be quickly and accurately understood by other domains. Initially, the focus is on planning the cyber techniques that are ready to deploy along with the continuous monitoring of multi-domain plan execution and relevant alerting during plan execution. Ongoing conversations with internal subject matter experts (SMEs) are being conducted to 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. Low-fidelity prototypes of the final design concepts were then used in an exploratory research study that was conducted to gather common themes and further iterate on the information requirements and representations. The outcome of the study not only resulted in new concepts for what information needs to be communicated to the JAD operational picture, but also what information the cyber domain operators need from the JAD operational picture. Future research will use a similar cyclical process of defining information requirements, design, and evaluation. 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. ☆

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

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




Graphic by Ms. Emily Conway, 711 HPW/RHWTE

# TEDS and SAVAGE

**> TEDS**
Tailored Expressive Dialogue System

**> SAVAGE**
Synthetic Agent Voice Analysis Generation and Exploitation

With the release of ChatGPT, large language models (LLMs) have been a hot topic in the news for both computer scientists, who have been researching the models since their conception in the 1960s, and laymen who can now utilize these models to assist in task completion. Since the spotlight has been placed on LMMs, there have been newer (and, developers often claim, superior) LLMs released nearly weekly. With this persistently rapidly improving technology, how can we maintain the advantage and accelerate change in our favor?

711HPW/RHWTE is developing Tailored Expressive Dialogue System (TEDS), which utilizes these ever-improving LLMs and integrates personalization, emotion, personality, syntax, communication style and more, all to suit 1 of 3 tasks: monitoring users' burnout with a personalized assistant, engaging phishing scammers while collecting information about the scammer, and aiding in foreign language learning with a realistic conversational tool. With the industry and academia leaning into safe mode and hospitality, developing controls to personalize based on the user and task is now more important than ever. Tools developed for TEDS are currently being utilized in the RH RI cross-directorate Chief Scientist's C-Fast effort Experience Personalization in Intelligent Conversational agents (EPIC).

An extension of the research into LLMs focuses on speech synthesis. In the world of deep fakes it is easy to find speech generation models posing as celebrities or prominent political figures. To maintain the technological advantage, defend against adversarial deep fakes, and organically integrate synthetic teammates, we need to develop our own in-house capabilities for generating natural and emotional speech. 711HPW/RHWTE is currently working on Synthetic Agent Voice Analysis Generation and Exploitation (SAVAGE) to bring naturalness to speech synthesis through features such as prosodic structure, emotion, spectral characteristics, and more. The beginning stages of this work are currently being utilized in studies within 711HPW/RHWEM to determine the inherent believability of information given by the synthesis model versus a real person. Beyond the current uses', SAVAGE and TEDS combined will unlock opportunities for human-machine teaming research through efficient and flawless communication. ☆

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

# 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. With the release of Open AI's Chat GPT4 in the past year, technology in this area is growing at a rapid pace. However, Large Language Models (LLMs) used in existing systems are not tailored for the military domain and there is a dearth of annotated dialogue data sets with military-specific applications. Additionally, state-of-the-art conversational systems cannot dynamically adapt to different levels of user expertise across domains. Some of our CAI work with the Information Directorate is geared towards developing and testing an intelligent conversational agent tailored to expert and novice intelligence analysts. Our high-level vision is to use CAI to not only accelerate expert analysts' process, but to observe their methodology and learn from them. The CAI's observations could then be translated to the agent and tailored to novice analysts to provide instructional feedback for on-the-job training. We are also conducting human research studies to understand the cognitive impact of using CAI. For example, we are interested in how using CAI will affect an intelligence analyst's depth of analysis or rigor. The goal is to inform how CAI can be designed to encourage a deeper level of analysis by engaging, strengthening, or confirming what an analyst thinks without becoming complacent or over-trusting the CAI. ☆

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

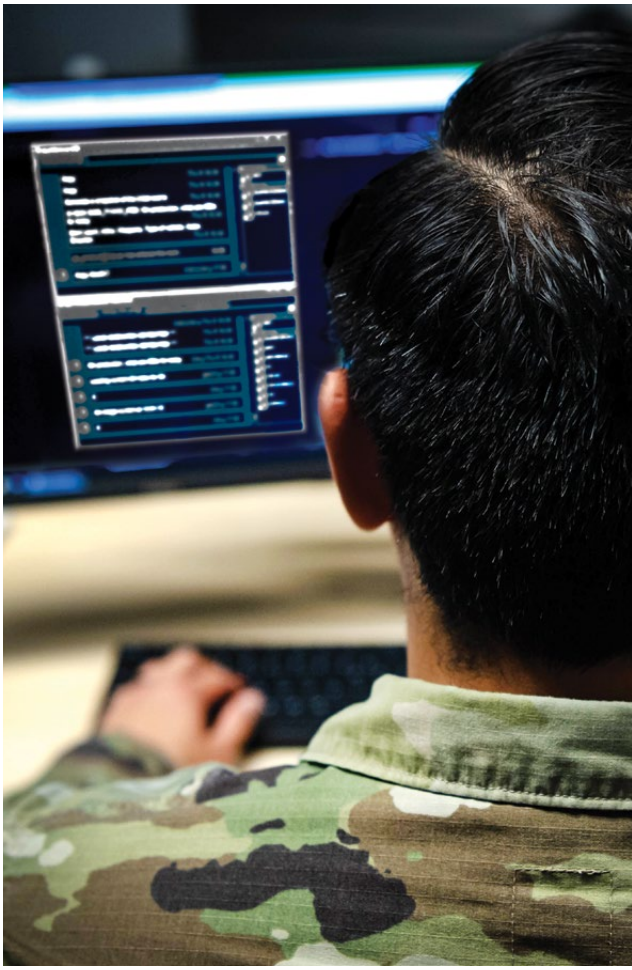


Photo by Airman 1st Class Jared Lovett

## 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?

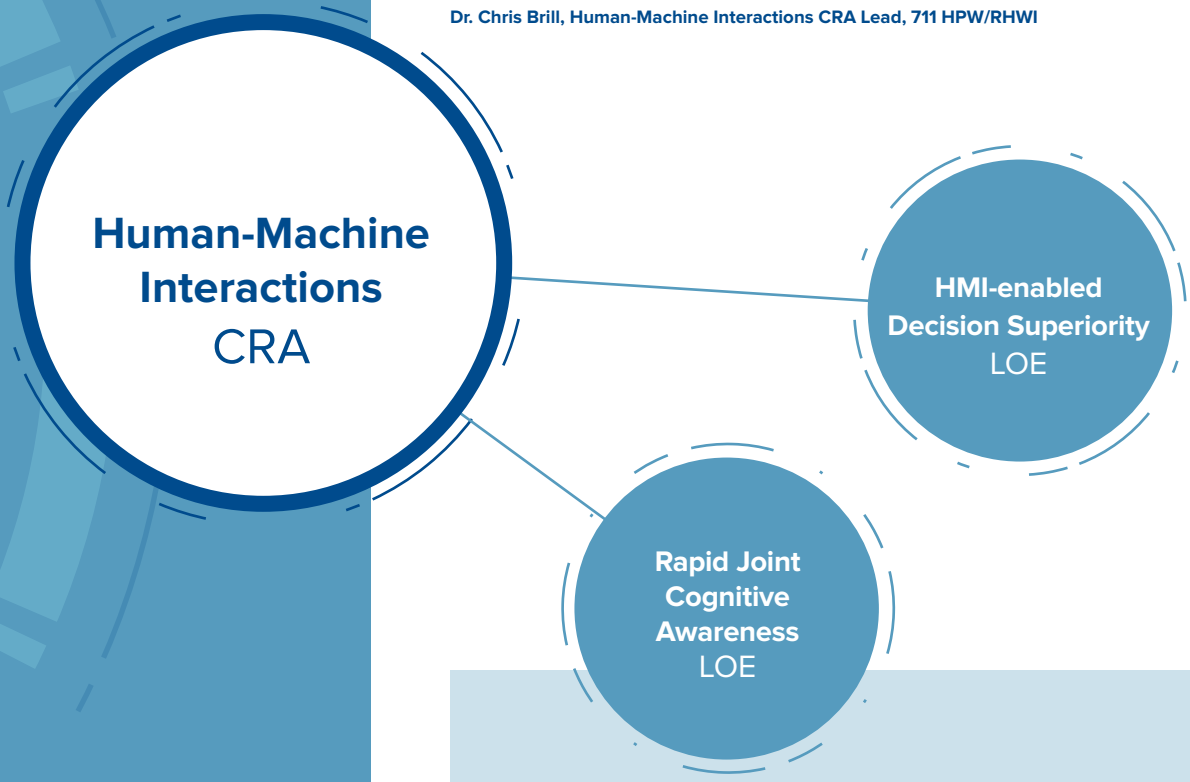
**Previous work in RH and RI explored how inserting conversational artificial intelligence (CAI) into the analysts' workflow could support them throughout the analysis process, with the most beneficial support centered on two of the most cognitively challenging steps, Research and Analysis. CAI can accelerate 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).

# HUMAN-MACHINE INTERACTIONS
## CORE RESEARCH AREA

**Dr. Chris Brill**
Human-Machine Interactions Core Research Area Lead, 711 HPW/RHWI

The new 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 will explore 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**



# HMI-ENABLED DECISION SUPERIORITY
LINE OF EFFORT

## Next-Generation Human/Machine Interface Research

Future Air Force operations will continue to grow in complexity, requiring coordinated activities across distributed agents to support 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.

Graphic by 711 HPW/RHWI

The NG-HMI research team is comprised of a diverse group of research professionals including in-house operational subject matter experts, experienced developers, and senior scientists working in our 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 the combat and mobility air forces, the CPVI lab exercises a blank slate approach toward supporting operator information needs and efficient decision aiding. To-date, the NGH-HMI team has developed and evaluated some 20 unique interface concepts that have been evaluated as performance-enhancing transition Pilot/Vehicle Interface (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 Airmen. ☆

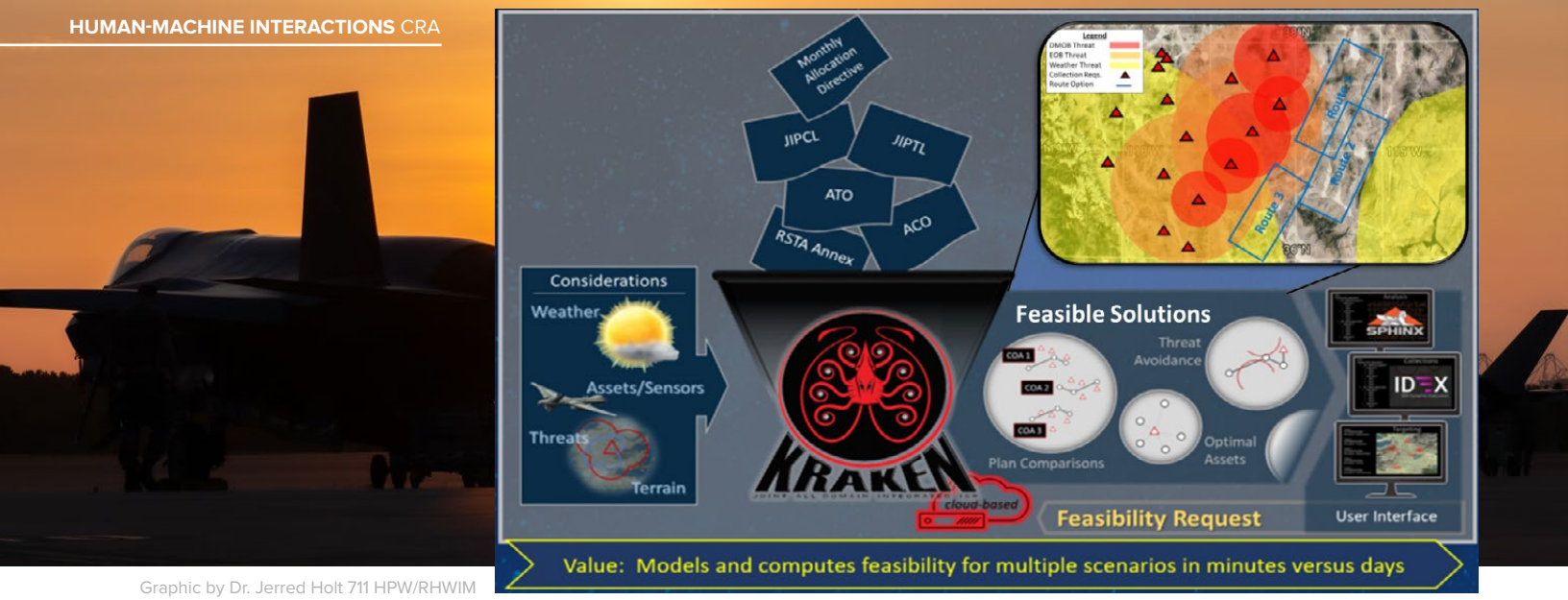
**Dr. Eric Geiselman, Senior Research Psychologist, 711 HPW/RHWIM**

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

## Displays for Cognitive Warfare

The 711HPW's new Cognitive Warfare thrust manifests through multiple engagements within and across services and with international partners, but also through our own in-house technical work. To this end, a new line of research on Cognitive Warfare Interfaces launches in FY24. Cognitive Warfare has been defined many ways but is, at its core, the exploitation of information to affect adversary decision making, attitudes, and beliefs, while also defending our forces from like interventions. Given the breadth of the Cognitive Warfare domain, this technical effort will begin with a scoping exercise to determine the application areas requiring the most urgent attention. ☆

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




Graphic by Dr. Jerred Holt 711 HPW/RHWIM

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

Research tool development, advancing systems, and improving processes embodies the primary focus of the 711th HPW/RHWIM Joint All-Domain Integrated ISR (JADII) Team. This effort includes the processes which support the integration and fusion of multi-domain, multi-source capabilities through the intelligence cycle; all of which culminated in the development of a 6.3 program called Legion. Legion addresses gaps in the ISR cycle by incorporating and integrating three separate applications. Nautilus (Dynamic disposition of force [DoF] and tactics, techniques, and procedures [TTP] capability), Sphinx (Collaborative Predictive Analytics), and Kraken (ISR feasibility, planning, and optimization service) encapsulate the ISR cycle and help to provide an end-to-end solution to warfighters, planners, and decision makers. Legion is working toward a solution that will efficiently shorten the ISR cycle while maximizing production quality. Our program is concerned with tackling Operational Imperatives 2, 3, & 4, leading to collaborations with ACC/A2's functional requirements for the Sensing Grid, the Army's Tactical Feasibility and Scheduling service, and other DoD and intelligence community (IC) partners. Legion component Kraken gained considerable interest and advocacy over the past year, resulting in funded, collaborative efforts which facilitate the capabilities used by operators today.

ISR operations is an incredibly overwhelming discipline which requires analysts and mission planners to create routes to satisfy multiple sources of requirements, decipher the plethora of incoming information, and disseminate the learned material to appropriate places as quickly as possible. All of the knowledge gathered from this process is crucial to understanding adversaries, keeping leadership better informed, and enabling effective strategic decision making critical to maintaining operational superiority. Kraken's user interface development originated from the 607th Air Operations Center (AOC) request to improve the route selection and planning process. Initially, Kraken development focused more on ISR planning, collection, and analysis from unit level to AOC/Joint-Level duties by accelerating operational tempo through human-machine teaming. Kraken is also working toward dynamic requirements due to ACC A22 adoption, continued advances in threat visualization and integration of weather parameters, and other DoD/IC requests. Kraken currently calculates and visualizes physical constraints, theater threats (including weather), and shortens the mission planning process from hours to mere seconds. After ingesting a few files, Kraken returns collection probabilities, feasibility reports (threat and terrain), and optimized suggested courses of actions (COAs) direct to the warfighter or to other planning applications via an open Application Programming Interface (API) standard.

The most recent Kraken efforts include an emerging capability involving modeling weather effects in AFSIM to support ISR collection management, which sparked discussion and collaboration during the Simulation Technical Interchange Meeting (SimTIM). SimTIM provides a forum centered around the capabilities provided and experience obtained during the development and application of both real-time and non-real-time simulations. The Kraken team received additional resource recommendations from an AFRL Principal Investigator for Modeling & Simulation and Studies, Directed Energy Military Utility Program, and other military and academic attendees. Another recent effort resulted from a recent trip to the 607th AOC, US Forces Korea; where end users explained the impact of atmospherics and the nuances this poses to planning. To address these problems, the team developed a model to better represent/visualize atmospheric effects on collections. ☆

**Dr. Jerred Holt, Senior Research Psychologist, JADII Program Lead 711 HPW/RHWIM**
**Mr. Samuel Johnston, Kraken Project Lead, 711 HPW/RHWIM**

# RAPID JOINT COGNITIVE AWARENESS
LINE OF EFFORT

## Multilevel Transparency for Human-Autonomy Interaction

The Multilevel Transparency for Human-Autonomy Interaction 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). Recently, 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 ML/AI 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 Multilevel Transparency for Human-Autonomy Interaction project currently has a two-pronged approach to investigating these aspects. The first focus is on transparency in human-ML/AI 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 non-human systems in past work (e.g., Alarcon, Capiola, et al., 2023) and measuring their effects in novel human-ML/AI interaction contexts.

The second focus is on ML/AI 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 ML/AI 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) collaboration between the Human Effectiveness Directorate (RH) and the Air Force Office of Scientific Research (AFOSR) on AI ethics comprising academic, industry, and defense participation and 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), along with academic partners at Clemson, University of Michigan, and University of Colorado Boulder, as well as the Center of Excellence on Human Machine Teaming at Carnegie Mellon University. One transition path for this project includes promoting transparency for space autonomy that could include ML-based algorithms via collaborations with the Space Vehicles Directorate (RV) and ACT-3. Deliverables include transparency guidelines for advanced technology development programs, as well as inputs for inter-division candidate products and cross-directorate stakeholders. ☆

**As transparency in human-autonomy interaction will act as a force multiplier in the JADC2 enterprise, research explicating when, why, and for whom transparency is relevant in human-machine interaction becomes increasingly necessary."**

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

**Dr. Joseph Lyons, Principal Research Psychologist, 711 HPW/RHWID**

**Dr. August Capiola, Research Psychologist, 711 HPW/RHWID**

**Dr. Gene Alarcon, Senior Research Psychologist, 711 HPW/RHWID**


Graphic by 711 HPW/RHWID

# Human Autonomy Interaction (HAI) Adaptations

Technological advances have led to increased task sharing between human operators and automated teammates. The efficiency of such Human-Automation Interactions (HAIs) during long-haul scenarios often suffers because of degraded human-automation trust, transparency, and situation awareness. The problem is further compounded by excessive fatigue, stress, and cognitive workload. If implemented adaptively, advanced automation can help combat these problems. Highlighting relevant information to cue attention and build human situation awareness, changing the level of automated aiding to moderate cognitive workload, and selectively assigning tasks to human or automated control all reflect adaptive strategies.

In some cases, automation can use its own data to identify an essential adaptation. However, better overall HAI performance may be achieved if the automation were sensitive to the cognitive state of the human prior to major lapses in the human's performance. One possible solution is to assign task control by relying on physiological signals as triggering mechanisms. However, this strategy could ultimately confuse task operators who fail to anticipate and understand when and why transfer of control occurs. The purpose of this research is to investigate strategies for interface design that could maximize operator awareness of control automation mode shifts.

This project will use robust physiological measures to examine the performance effects of fatigue-inducing extended sessions in a relevant Air Force task environment. The impact of multi-hour sessions on real-time physiology has been largely unexplored. Investigators plan to combine a variety of traditional physiological measures to implement changes in task control. These measures will enable characterization of extended shift effects on performance and identify physiological signals that can guide real-time task environment adaptations. The research will employ mature, readily available, deployable technologies such as heart and eye activity sensors. Previous research has demonstrated the sensitivity of such measures to cognitive workload and information seeking behaviors that reflect situation awareness.

Based on these measures, the appropriateness of HAI interventions that are based on task aiding or shedding to alleviate cognitive demand or leverage attention cuing to build situation awareness can be identified and implemented. The research team will also investigate options for display and control refinement to optimize human operator awareness and reactivity during periods of compromised readiness such as task resumption following control shift interruptions.

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. The current research will investigate a possible countermeasure: immediate transfer of task responsibilities to an automated partner. Success, however, will rely on display and control task interfaces that reflect and adapt to varieties of human-automation teaming status. This effort will leverage classic interface design guidelines and foundational research concerning human-autonomy teaming to test and evaluate an adaptive automation system. ☆

**Dr. Michael Vidulich, Senior Research Psychologist, 711 HPW/RHWID**

**Dr. James Bliss, Senior Research Psychologist, 711 HPW/RHWID**

# Information Visualization

The statistician John Tukey once said, “The greatest value of a picture is when it forces us to notice what we never expected to see.” As a proponent of the field of exploratory data analysis, this quote signifies the need to have the ability to dig through, and ‘be’ with the data. While Tukey did this by digging through statistics, the information visualization program seeks to exploit visualization techniques along with statistical and mathematical analysis to support better understanding of data for various user communities. Launched in FY23 as a one-year investigation into state-of-the-art and art-of-the-possible for information visualization, this program (formally starting FY24) has had several scientists immerse themselves in the understanding of information visualization techniques. The result has been a firm grounding in techniques while documenting what presentation techniques work best, when, and for what type of data leading to the inception of an interactive tool. The purpose of this tool will be to help guide users to the best visualization for their need. This is especially important as not all visualizations work in all situations, and choices of available visualizations are overwhelming. The development of this guiding tool is intended to help develop new and innovative visualizations for currently un-visualized problems. As a concurrent track, we are working with colleagues in both RHW and AFIT to develop a similar tool that would help to guide the user to the best statistical analysis for their data. The interaction of the two fields will be key, as the mathematical/statistical assessment techniques need to be tightly integrated with visualizations as data sets become larger and more complex.

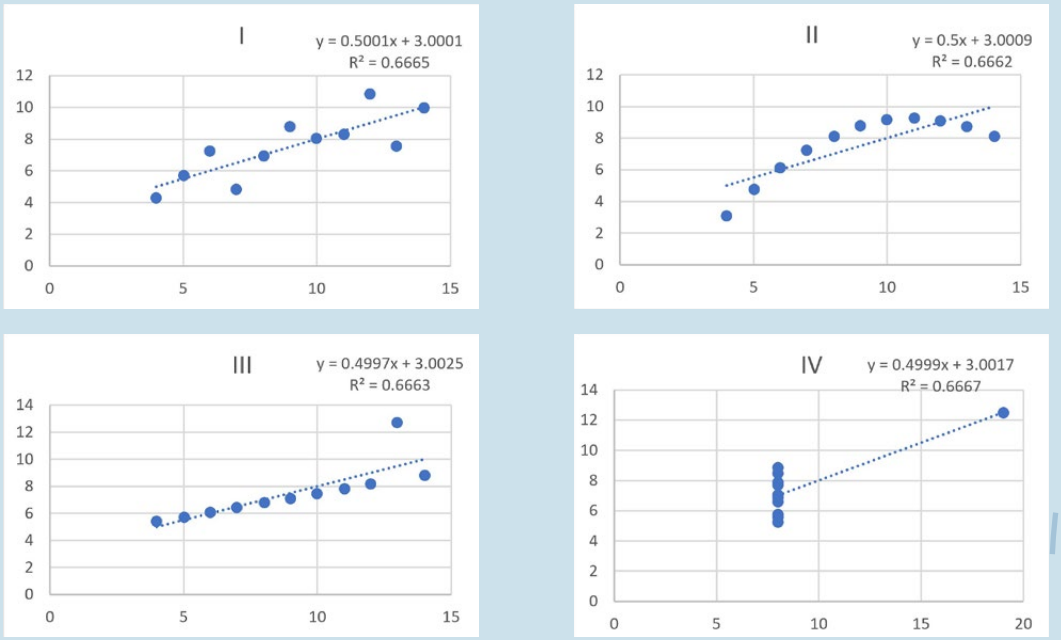
One may ask why these questions (i.e., developing visualizations and implementing statistical techniques) do not have a simple answer. The problem often lies in how humans process what they see. We are collectively extremely good at seeing patterns, almost to a fault. If one looks at their data the same way each time, human cognitive biases may come in to play, such as: assuming an answer based on past experiences, overconfidence due to the ‘answer always being presented that way’, complacency, group think, etc. Breaking these biases is hard, yet enforcing exploratory data analysis, statistical analysis, and proper presentation techniques are crucial to breaking these biases.

As a very telling demonstration of how statistics and visualization go together, we leave the example of Francis Anscombe’s quartet, constructed to show the importance of graphing data while analyzing it, thus showing the effect of outliers and other influential observations on statistical properties. Anscombe created four datasets of eleven (x,y) points that had nearly identical simple descriptive statistics. However, as shown in the figure below, appear very different when graphed. In this case, statistics only tell one story, and the visualization tells another. We aim in this program to join the two in order to guide better statistical and visualization techniques for Air Force needs. ☆

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

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

**Mr. Timothy Sears, M.S., Research Psychologist, 711 HPW/RHWID**




Graphic by 711 HPW/RHWID

# RHW FY23 SUCCESSES

Kraken Intelligence, Surveillance, and Reconnaissance planning tool deployed to the 607th AOC collection managers, senior intel duty officers, and Distributed Ground System sensor planners and analysts.

Supported Air Combat Command (ACC) and Air Education and Training Command (AETC) technology integration and live flight evaluations of Red 6 Aerospace's Augmented Reality technology for pilot training.

Established the first Department of the Air Force Chief Modeling and Simulation Office Modeling and Simulation Integration Laboratory for innovation evaluation and integration opportunities.

Helped guide Space Mobility and Logistics tactical C2 during the Space Systems Command (SSC) Director of Operations-sponsored Parallax Rising 2.2 (PR-2.2) Tabletop Exercise.

Developed a set of cognitive models with Naval Systems Sea Command that represent effects of cognitive stressors, models are being integrated into the Human Representation in Digital Engineering library.

Transitions to F-35 Joint Program Office:

- Guidance to incorporate activation reporting into maintenance debriefs, resulting in an Air Force Instruction and guidance to USN.
- Guidance to upgrade the Digital Terrain Elevation Database (DTED) and improve safety.
- Operational requirement validation for F-35 air collision avoidance technologies.

Integrated Fatigue effects into Combat Operations Mission and Basing Analysis Tool (COMBAT). Transitioning to Booz Allen Hamilton and Air Force Futures to support wargaming exercises.

Network monitoring, diagnostic, and proficiency-based training tools transitioned into the Live Mission Operations Capability and Distributed Training Center baselines.

Developed initial capabilities to support risk mitigation technology integration and interoperability for the Joint Simulation Environment.

Psycholinguistic text analytics and forecasting/modeling toolkits transitioned to Joint Warfighter Analysis Center (JWAC) classified systems for the Strategic Competition Analysis Team.

Fighter Integration Training Research team collaboration with DARPA Air Combat Evolution to fly Secure LVC Advanced Training Environment pod on the F-16 VISTA aircraft at Edwards AFB for high-speed data sharing and capture.

Fighter Integration Training Research's new, innovative testbeds and instrumentation:

- Program of record, high fidelity 4th and 5th gen simulators
- Effects Based Simulators
- Joint Simulation Environment exemplars
- New testbed support with novel modeling and simulation integration

Transition of Site Application Entity text and forecasting analytic toolkits to Air Mobility Command to support new anticipatory analysis requirement has been initiated with the Office of the Secretary of Defense Transitions SBIR/STTR Technology program.

Submitted CONOPS report to the F-35 Joint Program Office for F-35A aircraft performing engine runs inside overseas hardened aircraft shelters (HAS).

EST. 2001

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711 HPW/RHW Core Research Areas:

- Digital Models of Cognition
- Distributed Teaming & Communication
- Human-Machine Interactions
- Learning & Operational Training