AFRL FIGHT'S ON!

THE AIR FORCE RESEARCH LABORATORY

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711 HPW / RHW

WARFIGHTER INTERACTIONS AND READINESS DIVISION

USSF

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U.S. AIR FORCE

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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.

To view more issues, visit:
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Air National Guard photo by Master Sgt. Jonathan Young

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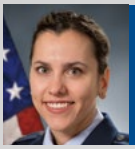

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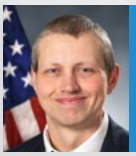

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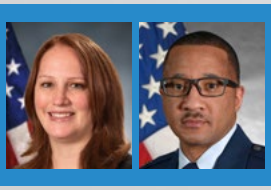

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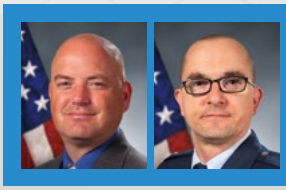

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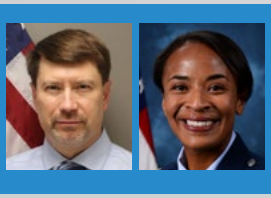

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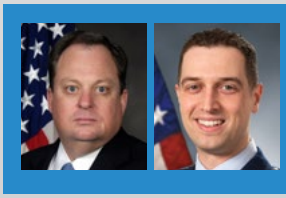

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- **Maj Matthew Fagan** (DO)

BC = BRANCH CHIEF | DO = DIRECTOR OF OPERATIONS

DECEMBER 2025

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

RHW
DIVISION INTRODUCTION

It has been another amazing year, filled with unprecedented challenges. However, RHW met these with determination and conviction! Amid uncertainty the Division continued supporting the user community and transitioning capabilities. I am excited and humbled to be the Chief of the extremely talented team that comprise the Warfighter Interactions & Readiness Division, RHW.

RHW remains at the tip of the spear for addressing all aspects of Human-Human, Human-Machine, and Machine-Machine Teaming, Integration, and Decision and Information Supremacy. This past year, our team supported multiple exercises, organized and presented at conferences, conducted studies, developed software, hit multiple scientific and technical transition milestones, and demoed novel capabilities to the warfighter. Congrats to the entire RHW team!

In line with RH's enduring mission of enabling, sustaining, and enhancing multi-domain capable warfighters and integrated operations, RHW is directly enabling a more informed, agile, and lethal force by delivering revolutionary capabilities and enhancing preparation and mission execution across the full range of military operations. RHW continues its history of collaboration across organizations, DoD, National, International, Academia, and Industry, to build/maintain touch points to expand our contribution to the warfighter. Additionally, RHW is leveraging the synergies that exist across the entirety of the Air Force Research Laboratory (AFRL) for the United States Air and Space Forces.

As the DAF and DoD move forward, Joint All-Domain Ops and the demand for autonomous technologies bring the need for warfighters to be adaptable, efficiently trained, provided decision-quality information, and have technologies that augment their abilities. There are common threads traversing training, preparedness, and operations; RHW's expertise and capabilities will address these connective tissues. I look forward to sharing future Warfighter Interactions and Readiness Division successes with you! ☆

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

Division Military Support

The 711 HPW/RHW military have been a high impact, award winning, integral part of the Division. Comprising 25% of our Government team, they have been working tirelessly alongside our Government civilian and contractor teammates to advance Human Performance Wing (HPW) research and enhance warfighters around the world.

Our military bring experience, subject matter expertise, and contributions from 19 career fields. They have provided their leadership and knowledge, served as test subjects, enabled tours, worked closely with users to get requirements and feedback, facilitated collaboration with partner nations, and collected research data both locally and in remote locations.

I want to draw attention to the heavy muscle movements of two of our career fields: program management and intelligence. First, this has been the year of the Program Manager with an extremely dynamic funding situation. Our program managers were called to be extremely flexible with the implementation of new funding practices early in this fiscal year as well as to have incredible attention to detail as they maintained laser focus on the status of every dollar spent. Additionally, part way through the year as our funding was redirected, they had to make difficult choices on how their programs would have to adapt. They were there every step of the way clearly communicating and providing solid recommendations so Division and Directorate leadership could make sound strategic decisions on the Human Performance portfolio.

Second, our Wing Intelligence Team is making impacts across the 711th and at AFRL. The team is integrating to inform Counter-Intelligence, Surveillance, and Reconnaissance (ISR) efforts in RHW, the Aeromedical Evacuation mission in U.S. Air Force School of Aerospace Medicine (USAFSAM), biotech research in the Airman Biosciences Division (RHB), and informing acquisition intelligence best practices for the Sensors Directorate (RY). In September, they delivered a series of intelligence briefings to Wing leaders and supervisors, focusing on adversary tech development in each Integrated Planning Team focus area. In addition to major Indo-Pacific Command (INDOPACOM) exercise experience, the team is bringing recent, real-world experience from operations protecting the Southern Border, in U.S. Central Command (USCENTCOM), and in the U.S. European Command area of responsibility (EUCOM AOR) to inform research efforts.

711 HPW/RHW military have stepped up to fill multi-month temporary Executive Officer taskings at the Directorate and Wing, two 6-month Honor Guard leadership taskings, and were selected to fill Executive Officer positions full time at both the Directorate and for AFRL Director of Staff. They answered the call for eight deployments, including 365-day taskings, to seven countries, and one of these taskings with only one day's notice.

Our military have brought back the hardware with annual 711 Human Performance Wing wins for Field Grade Officer, Company Grade Officer, Technology Transition Award Direct to Warfighter Team, and Mission Support Award Team. Additionally, our intelligence military are AFMC nominees for the 2025 Air Force ISR Awards Program in the categories of 1) Field Grade Officer of the year and 2) Outstanding Operational Group Intelligence/Operations Support Squadrons and Operational Support Flight ISR Unit of the year. Finally, our resident and recently departed members have been selected for promotion to Technical Sergeant, Senior Master Sergeant, Lieutenant Colonel, and Colonel. ☆

Lt Col Ray Scholz, Director of Operations, 711 HPW/RHW
Maj Matthew Fagan, Senior Intelligence Officer, 711 HPW
Capt Matthew Rainwater, Chief, Wing Acquisitions Intelligence, 711 HPW

Photo (top left) by Mr. Will Graver (SierTek, Ltd)
Photo (bottom right) by Mr. Rick Eldridge, 711 HPW CAG

19 CAREER FIELDS

45 MILITARY PERSONNEL

RHW

8 DEPLOYMENTS

25% OF GOV TEAM

Mr. David Malek
Readiness PL Lead,
711 HPW/RHW

READINESS
PRODUCT LINE

Welcome to the 2025 edition of Fights On! and to the Readiness Product Line update for this year! In an era of accelerating change, the Readiness Product Line is dedicated to a single, critical mission: ensuring our Airmen and Guardians possess the decisive cognitive and performance advantages needed to dominate any future conflict. Our focus remains squarely on the warfighter, developing and extending the technologies that enhance proficiency for current and future operational challenges. The work highlighted in the following pages demonstrates our relentless pursuit of this goal and reflects a deep commitment to forging the world's most formidable fighting force.

While this past year has presented many challenges, it also has been one of tremendous progress, driven by the evolving needs of the warfighter. A prime example is our Just-in-Time Multimission Airmen/Warfighters (JITMMA/W) program, which, as you will read in the following pages, successfully demonstrated a powerful just-in-time training capability at the Northern Strike 25-2 exercise. JITMMA/W is revolutionizing how we deliver on-demand training for Agile Combat Employment (ACE), enabling Airmen to rapidly acquire new skills in austere environments and enabling the mission to continue.

PL OVERVIEW

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

Similarly, our foundational work for the Surrogate Training Family of Systems (STFOS) has provided an opportunity to mature our Proficiency-based Training (PBT) tools and technologies while providing the 7th Fighter Training Squadron a state-of-the-art training capability. We are establishing a new paradigm for pilot training by integrating mixed-reality simulators and advanced data analytics to master mission-essential competencies. This data-centric approach delivers personalized training focused on proficiency gaps in specific competencies, which in turn streamlines squadron operations, accelerates learning, and provides decision-makers with the artificial intelligence (AI)-driven insights needed to maximize mission readiness against evolving threats. See the article by Dr. Summer Rebensky to learn more.

Our commitment to providing a decisive edge extends deep into the world of advanced modeling and simulation. The Fighter Integration Training Research (FITR) effort, detailed later in this issue, is breaking ground by operating our 4th and 5th generation virtual simulators in common scenarios to create a truly integrated training environment. See the article by Dr. Beth Hartzler and Mr. Scott “Carp” Carpenter for more details.

Continued on next page

Photos by (top) Mr. Will Graver (SierTek, Ltd), (middle) the 7th Fighter Training Squadron, and (bottom) Airman 1st Class Megan Delaine

Each of these initiatives from just-in-time training at the tactical edge to complex, multi-platform simulated environments represents a critical thread in the fabric of total readiness."

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

This work, alongside initiatives like the Not-So-Grand Challenge (NSGC) which develops more intelligent and realistic adversary models, ensures our training is as demanding as the real-world threats our warfighters face. Look for the article by Dr. Lorraine Borghetti, Dr. Samantha Perry, Dr. Will Dupree, Mr. Jacob Smith, Mr. Scott Carpenter, and me for a deeper dive.

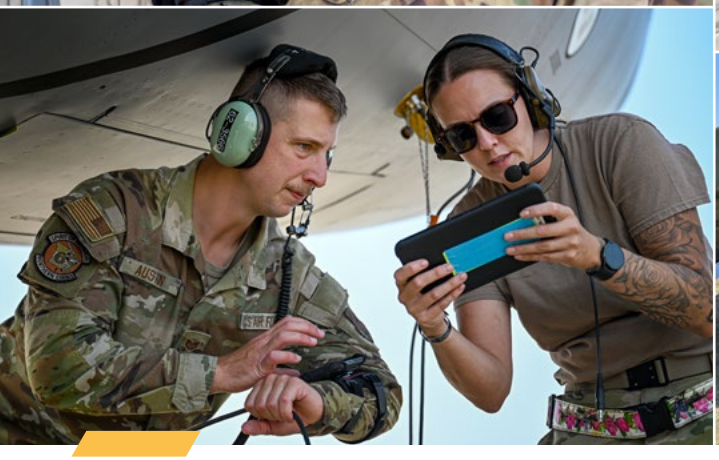
Looking further ahead, ALTR is pioneering a new approach to human-machine teaming, preparing our forces for the collaborative combat operations of the future. See the article later in this issue authored by Maj Nicholas “Bane” Caraballo and Maj Caitlin “Cat” Harris for more.

And last but not least to highlight is our work with the Simulator Common Architecture Requirements and Standards (SCARS) program to help discover the art of the possible and provide recommendations and feedback to the SCARS acquisition program. Look for the article by Mr. Brad Pfefferle and Mr. Cody Reichard.

Each of these initiatives from just-in-time training at the tactical edge to complex, multi-platform simulated environments represents a critical thread in the fabric of total readiness. The following articles provide a deeper look into the incredible work our team and partners have accomplished this year. We are proud of our achievements and are energized to face the challenges of 2026 as we continue to deliver the tools that forge the world's most formidable fighting force. ☆

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






Photos by Mr. Stephen McGee, JITMMA/W Lead, U.S. Air National Guard Senior Airman Phoenix Lietch, and Airman 1st Class Megan Delaine

Northern Strike Integrates AFRL's Just-in-Time Training for Agile Combat Employment

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

AFRL Combat Employment (ACE) demands multi-skilled Airmen and Warfighters that are ready to tackle unfamiliar tasks in austere environments. How do you quickly upskill personnel with limited prior experience while maintaining operational tempo? AFRL is tackling this challenge head-on with the Just-in-Time Multi Mission Airmen/Warfighters (JITMMA/W) program, and a prototype recently saw action at the Northern Strike 25-2 Exercise.

During this Joint Readiness exercise, AFRL deployed JITMMA/W across three Michigan locations, creating an ideal proving ground for 90 Air Force and Marine participants from diverse Air Force Specialty Codes (AFSCs) and Military Occupational Specialties (MOSs). The focus for this technical use case was KC-135 Hot Pit Refueling (HPR), a critical task for maintaining airpower projection.

JITMMA/W employs multiple integrated technologies. Trainees began with tablet-based static content then immersed themselves in Virtual Reality (VR) scenarios, simulating tasks with the fuel truck and fuel control panel. "The VR training was really good," one trainee remarked. "Doing the refueling really helped the instructions sink in; it gets stuck in your memory." Participants praised the ability to repeatedly practice tasks in a low-stress virtual environment. Finally, a select few put their newfound knowledge to the test on live, running KC-135 aircraft, guided by Augmented Reality (AR) technology. This AR system provided real-time, step-by-step instructions and visual cues.

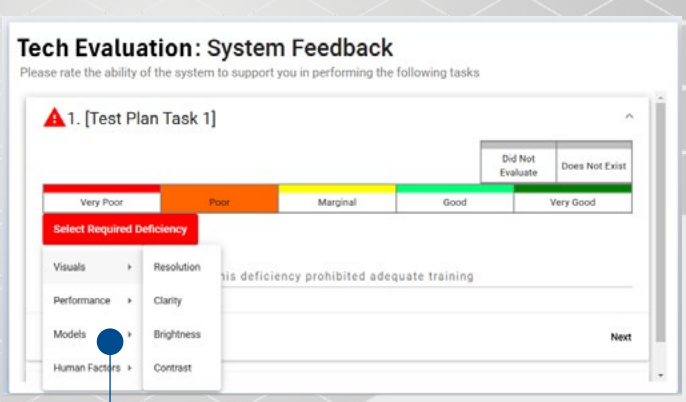
The results were overwhelmingly positive. Trainees found the tablet training intuitive and easy to use. "Everything was laid out as far as the material that we needed to know in a very user-friendly way; step by step, it would be easy for someone who hasn't done it before to read the steps and do the task," one participant shared. Overall, trainees valued the inclusion of PDFs, guides, and videos that made information easier to digest, and noted that VR training was especially engaging and memorable, particularly for newer participants.

AFRL is using the data and feedback from Northern Strike 25-2 to refine the JITMMA/W capability. The ultimate goal is to transition JITMMA/W into an operational asset, enabling a rapid, readiness solution for ACE operations in austere environments and sustaining a crucial advantage over adversaries in contested and rapidly evolving theaters. ☆

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

Ariel Molnar, JITMMA/W Program Manager, 711 HPW/RHWOW

Scan the QR code to view the JITMMA/W demo video



Test pilots from the 586th Flight Test Squadron complete SimMD evaluations after live fly tests.

Photo by Dr. Summer Rebensky, Aptima, Inc.
Screen Capture by Aptima, Inc.

The views presented here are those of the authors and are provided to demonstrate the value of AFRL partnerships. They do not convey or imply endorsement from the Department of the Air Force or any other governmental organization.

Partnership Success: SimMD™

Military organizations are continuing to leverage simulators, extended reality systems, and other digital training tools to deliver affordable and scalable training. The true value of these technologies depends on how well they replicate required training experiences and prepare warfighters for operational demands.

SimMD™ was developed to close this gap by providing a structured way to evaluate virtual training technologies against real training requirements and informing leadership on where to best invest fundings and where gaps still exist. The platform was created through a Small Business Innovation Research (SBIR) program with the Air Force Research Laboratory (AFRL) in order to support assessment of simulator fidelity and has since been used to directly support evaluations across the Air Force. It can be applied across a wide range of systems, from immersive virtual reality (VR) headsets and cockpit simulators to command-and-control platforms and battle management software, giving organizations a clear picture of each tool's effectiveness, limitations, and role in the broader training ecosystem.

SimMD's methodology integrates inputs from operators, instructors, and trainees, combining quantitative metrics with structured qualitative feedback. Robust statistical practices, such as checks on interrater reliability, further ensure the rigor of the results.

A major advancement in SimMD over the past year is the addition of a dynamic, interactive dashboard. Previously, evaluations were delivered in static reports, which limited how results could be consumed and compared. The new dashboard transforms that process, allowing leaders to explore findings in real time, drill down into specific dimensions of performance, and generate comparisons across platforms. By turning raw evaluation data into visual, interactive insights, decision-makers can act more quickly and confidently when making training investments.

The platform is already being applied in diverse contexts. At Kirtland Air Force Base, SimMD has been used to directly compare the training value of VR headsets with traditional cockpit simulators, providing decision-makers with side-by-side evidence on the effectiveness of these approaches. In support of the AFRL and broader DoD, recent SimMD evaluations of cutting-edge technology include: live flight formal test and evaluation of novel augmented reality (AR) technology, iterative evaluation of high end virtual reality pilot training solutions; and evaluation of artificial intelligence (AI) and software based solutions in air battle management. Beyond this work, SimMD continues to expand into large-scale virtual exercises, helping map training requirements, track learning objectives, and highlight opportunities for improvement.

By evolving from static reporting to interactive, data-driven insights, SimMD is giving leaders the tools they need to assess emerging technologies and shape the future of military training. ☆

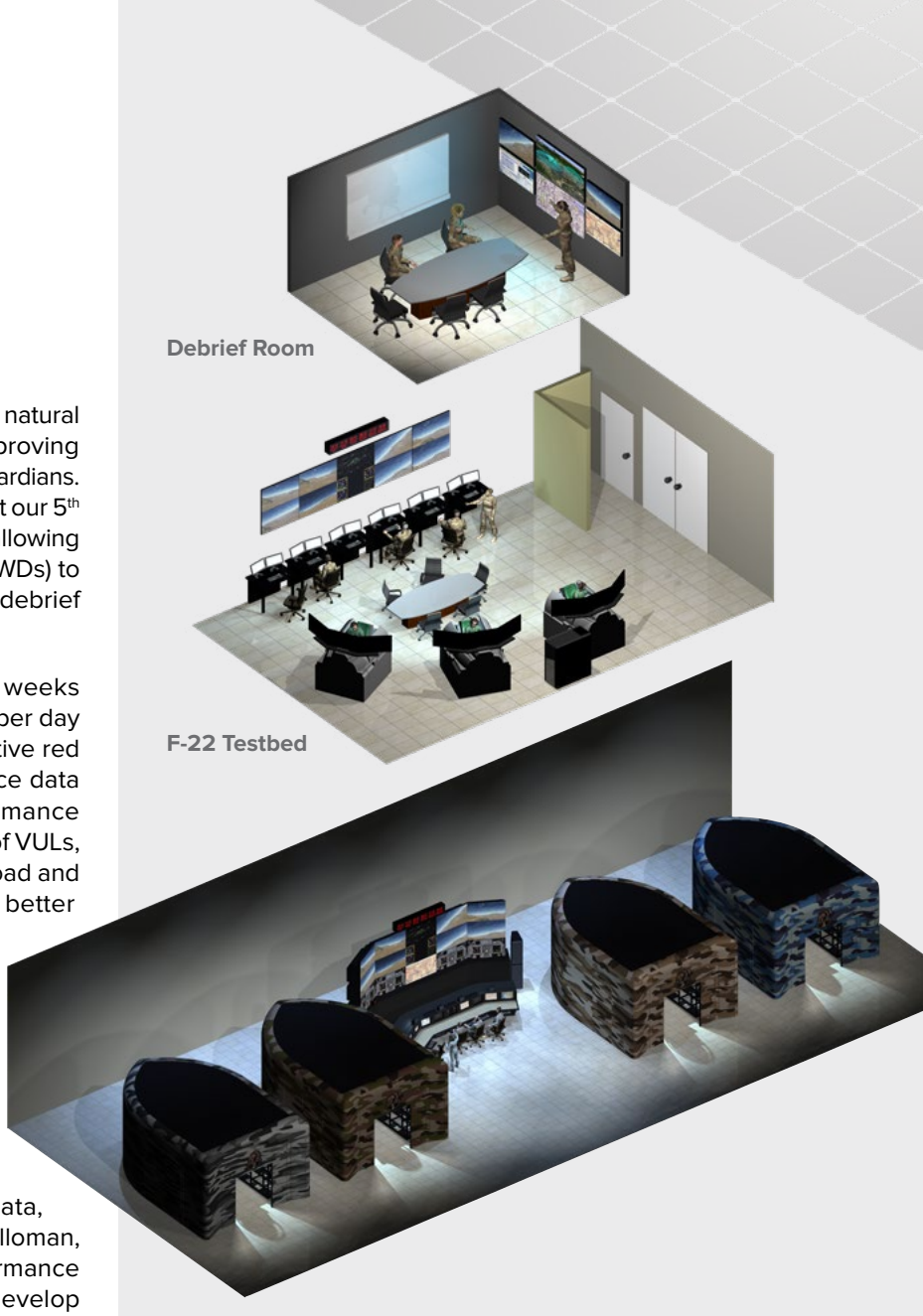
Dr. Alexxa Bessey, Senior Scientist, Aptima, Inc.
Dr. Summer Rebensky, Senior Scientist, Aptima, Inc.

Fighter Integration Training Research (FITR)

The Fighter Integration Training Research (FITR) effort is a natural extension of the Readiness Product Line's focus on improving training opportunities and resources for DAF Airmen and Guardians. Officially starting in 2023, the purpose of FITR is to connect our 5th (F-22) and 4th (F-16) generation virtual simulator devices, allowing pilots and Air Battle Managers/Weapons Directors (ABM/WDs) to experience integrated mission briefing, execution, and debrief situations unique to a FI simulator environment.

These exercises are conducted as training research weeks (TRWs), with pilots flying six vulnerability periods (VULs) per day on average for 2 to 4 days. As they fly against constructive red adversary entities in missionized scenarios, performance data are collected then summarized using Aptima's Performance Evaluation and Tracking System (PETS). Following a set of VULs, pilots and ABM/WDs are surveyed regarding their workload and stress levels during the simulated mission, enabling a better understanding of their recent experience as well as an estimate of the mental reserves potentially available to perform other simultaneous tasks.

We started the year with a successful TRW in February, attended by three F-22 pilots, six F-16 pilots, and two ABM/WDs. This TRW coincided with a demo by the Modeling and Simulation Integration Lab (MSIL), allowing visitors an opportunity to see the technology advanced in our labs in use and serving USAF Airmen. These data, along with those of other pilots from Langley-Eustis, Holloman, and Shaw, are being used to identify changes in performance during TRWs, identify patterns in training needs, and develop predictive models that may be useful in establishing guidelines for proficiency-based training (PBT).



Graphic by Mr. Will Graver (SierTek, Ltd.)

In addition to ongoing data collection, 2025 has seen a greater emphasis on improving our resources and expanding research capabilities. Updated operational flight programs (OFPs) have been installed in both the F-22 and F-16 testbeds and are awaiting validation testing by active-duty pilots. We've also begun updating and expanding on the performance metrics used, increasing sensitivity for platform- and mission-specific guidelines (e.g., target airspeed and distance from adversaries) while integrating additional measures unique to 5th generation aircraft. To augment existing debrief capabilities, we will soon implement a data-driven dashboard summarizing details such as shot performance and kill ratio.

This pattern of growth and improved research capabilities will continue as we move into 2026. Our most immediate goal for the simulators is implementing the aircraft models and controls for collaborative combat aircraft (CCA). Offering flight simulator opportunities where fighter pilots would simultaneously fly and control an unmanned aircraft further increases the experiential benefit for them, while enabling our research team to evaluate training needs for skill acquisition. Our potential for readiness training research will be further expanded with the finalization of a new F-35 testbed, enabling integrated training experiences between three fighter platforms.

Future developments also include plans to analyze radio comms data collected during the simulated missions as an objective indicator of pilots' workload and stress level in the scenario. In the near-term, we will start using individual TRW events to introduce and test scenario elements including contested and degraded operations (CDO), having pilots fly against manned air threats rather than simulated adversaries, and air-to-ground operations. With this progress and so much more to come, we remain well-poised to address the evolving training needs of tomorrow's warfighter. ☆

Dr. Beth M. Hartzler, Research Psychologist, 711HPW/RHWOW

Mr. Scott "Carp" Carpenter, Fighter SME, RCG

Graphic by Maj Cat Harris, SAF/CDM

Weapon School's Approach to Human-Machine Teaming

Imagine a future mission in the Pacific. An F-47 pilot leads an effort in an All-Domain Combat Power Pulse. The formation is comprised of Collaborative Combat Aircraft (CCA), and they are penetrating deep into a communications-denied battlespace. The tempo is blistering. Data links fail. Machines adapt, but the mission still hinges on the human—on their ability to perceive, decide, and team with autonomy in real time.

The future of warfare will not be defined solely by machines, but by how effectively humans can team with them under extreme conditions. The U.S. Air Force must reassess its approach to preparing its warfighters if it hopes to maintain a decisive edge in future conflicts.

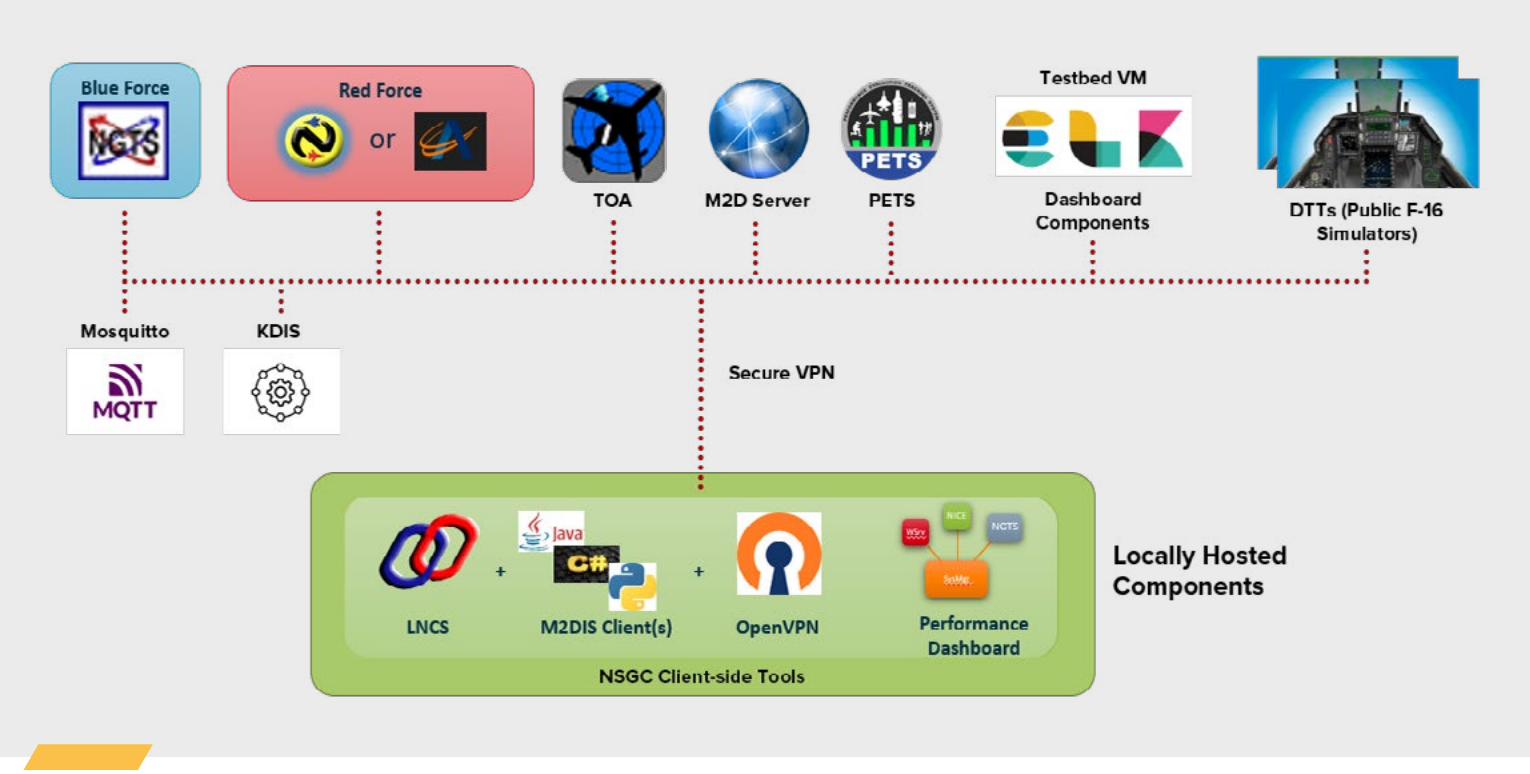
Over the years, the Air Force has invested heavily in human performance programs to improve health and readiness. These efforts built a strong foundation but often focused on general wellness over direct mission outcomes. The next step is clear: systems that measure what matters, directly link human capability to operational effectiveness, and align with the culture of performance-driven communities.

In collaboration with the 711 Human Performance Wing, the U.S. Air Force Weapons School is pioneering the next step with a first-of-its-kind initiative called ALTR—a program designed to operationalize human performance by quantifying what the mission demands and how the warfighter delivers it. ALTR brings scientific rigor together with the Air Force's warrior ethos. At its core, ALTR employs a model-based, data-driven approach to understand how fundamental human capabilities, such as memory, motor control, and visual processing, impact performance on complex mission tasks. Grounded in General Systems Performance Theory and using Model-Based Human Systems Integration, ALTR identifies which Basic Performance Resources limit High-Level Task Performance. This enables targeted training, measurable improvement, and forecastable outcomes. The result is a repeatable, scalable framework directly tied to operational effectiveness.

Science alone is not enough if it is not integrated into the force. Culture matters, and ALTR tackles this head-on by aligning its framework with the identity of the elite warfighter. Mastery, sacrifice, and competition still matter; checklists are replaced with challenges, and compliance replaced with conviction. ALTR re-centers human performance around this elite warfighter identity. It does more than track metrics; it builds purpose, resilience, and a shared standard of excellence that the force can rally around.

The imperative is clear: if we want to build warfighters capable of leading in the era of autonomy, we must invest, not just in machines, but in the human systems that will team with them. The Weapon School ALTR program offers a tested, scalable path forward, turning performance into something measurable, trainable, and operationally relevant. In doing so, it supports the Secretary of the Air Force's call to restore a true Culture of Fitness, one defined by capability rather than compliance.
If readiness, lethality, and integration are our goals, ALTR is not optional, but essential. ☆

Maj Nicholas "Bane" Caraballo, 53rd Wing A3 Director of Integrations
Maj Cat Harris, SAF/CDM Director of Human Weapon Systems



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

Not So Grand Challenge (NSGC)

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

Cognitive Models

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

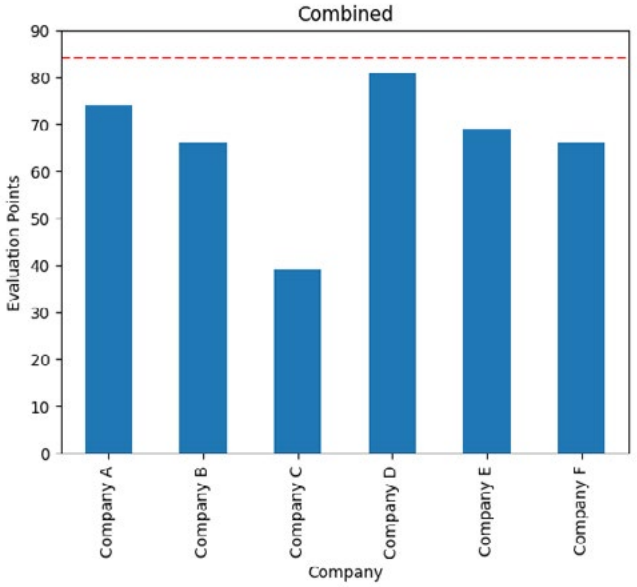
Testbed

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

Continued on next page

MILESTONES

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



Red Agent's Evaluated Using DTTs

In two recent assessments, conducted in September of 2024 and April of 2025, we were able to test AI controlled red agent behavior (e.g., simulated adversaries) against human pilots in a Deployable Tactical Trainer (DTT). The NSGC team evaluated red agents in two expert crafted engagements designed to push the boundaries against blue aircraft. Our agents performed well, with average performance scores at or above 70% when judged by SMEs. The target scenarios used for evaluation included a dogfight between two red agents, as well as a red bomber escort mission. The red aircraft were controlled by machine models, while blue aircraft were piloted in the simulation by a human. The goal of the scenarios was to test the ability of the red agents to react in a combat situation, engaging or evading with the blue air. Allowing the human to pilot the blue air gives the ability to explore red agent behavior via small, nuanced changes in overall scenario conditions (e.g., flight path or select red engagement). The insights gained from these exercises are crucial for debriefing purposes and will serve as a foundation for developing targeted training programs aimed at enhancing the red air forces' tactical performance. The data will inform future strategies to ensure that our red air capabilities are robust and can meet the demands of realistic combat scenarios.

NSGC FUTURE WORK

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

Digital Librarian

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

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

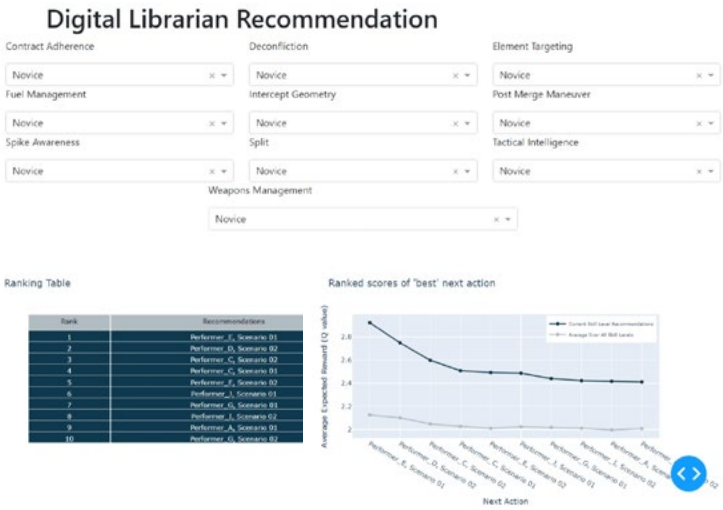
Dr. Lorraine Borghetti, Research Lead, Co-Learning for Adaptive Human-Machine Teams LOE, 711 HPW/RHWOH

Dr. Samantha Perry, Aptima, Product Manager

Dr. Will Dupree, Aptima, Sr. Research Engineer

Mr. Jacob Smith, Aptima, Testbed Engineer

Mr. Scott Carpenter, RCG, Fighter SME



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

Scaling Readiness: Surrogate Training Family of Systems and Proficiency-Based Training

The Air Force Research Laboratory (AFRL) and Air Combat Command (ACC) are continuing to transform pilot training and readiness at scale. The Surrogate Training Family of Systems (STFoS) effort is building a system of systems streamlining interactions and processes across squadrons, including training, scheduling, planning, and stan/eval. Today, STFoS is delivering reconfigurable mixed-reality training simulators integrated with electronic grade sheets and the Proficiency-Based Training (PBT) ecosystem to the 7th Fighter Training Squadron at Langley AFB. AFRL's PBT system enables data-driven individualized training through measurement, assessment, and tracking of human performance with after-action review, mission reconstruction, and analysis capabilities. The team expects these AI-assisted data-driven insights and workflow automations to make planning, syllabus flow, and Ready Aircrew Program (RAP) tasking more predictable and manageable as well as supporting future syllabus development. The result is training focused on the Mission Essential Competency gaps of the warfighter. Trainees move through training faster and decision makers can pivot to maximize the mission ready status of the squadron with early artificial intelligence (AI)-enabled identification of training challenges and highlight paths forward.

To meet the evolving requirements of STFoS, AFRL is enhancing the Performance Evaluation and Tracking System (PETS), a foundational component of PBT, to expedite delivery of new operationally-relevant validated measurements and analytics. Building on off-the-shelf data engineering tools and decades of training research, AFRL's multi-disciplinary team is turning multi-modal multi-format data streams into training insights. The expanded PETS system architecture adds data pipelines supporting machine learning and AI for potential readiness multipliers. These updates will rapidly reduce the time to update key metrics to keep pace with evolving tactics, techniques, and procedures of tomorrow's adversaries.

"Scaling readiness" has been the theme for the past year with multiple complementary efforts. AFRL is scaling data-ready training devices, data collection, human performance measurement authoring, and actionable training insights through a system-of-systems approach. Over the next year, AFRL will expand integration across squadron functions and deliver data-driven insights directly to pilots. ☆

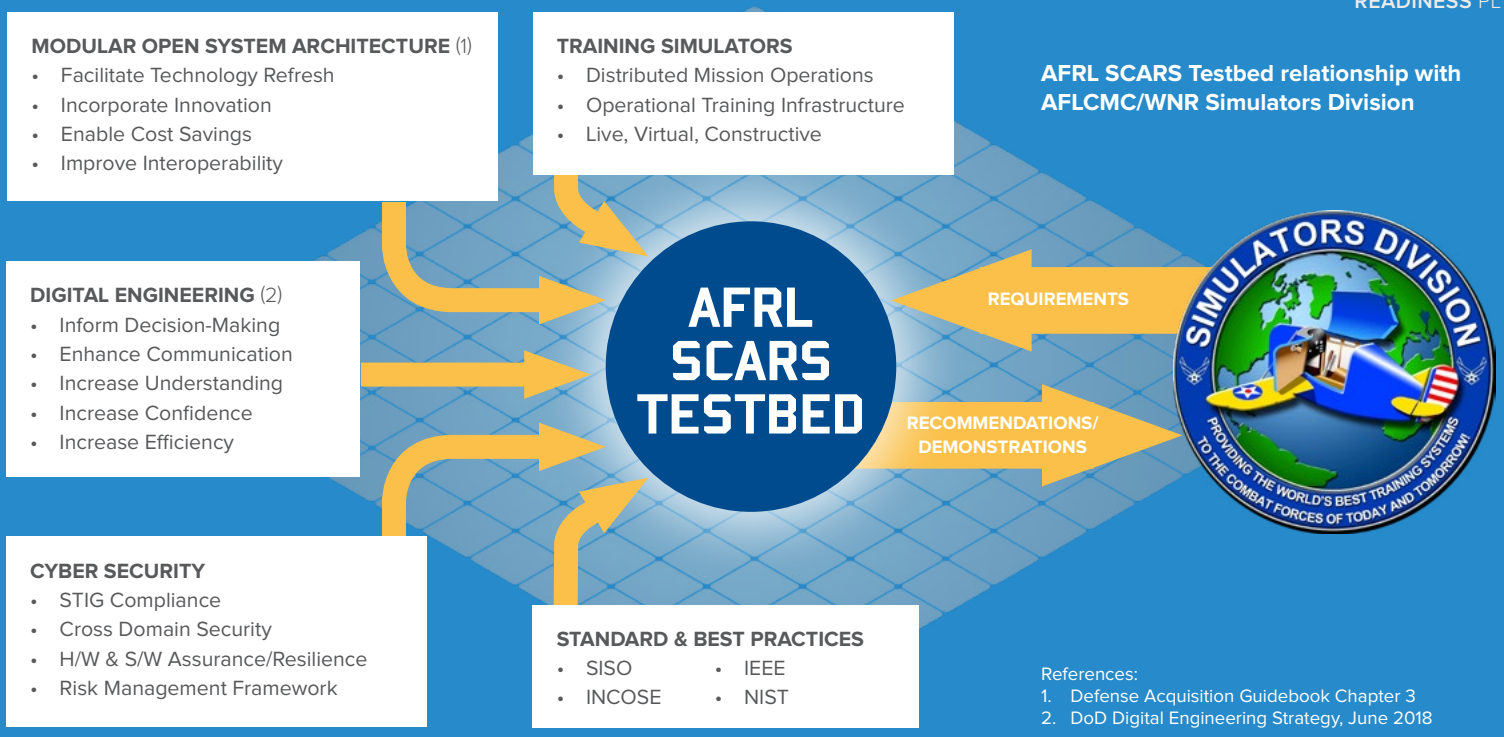
Mr. Peter Neubauer, Software Engineer, Aptima, Inc.
Dr. Summer Rebensky, Senior Scientist, Aptima, Inc.

LOW-COST, SMALL-FOOTPRINT SIMULATORS

LEARNING ASSESSMENT/ MANAGEMENT TOOLS

MIXED REALITY TECHNOLOGIES

Photos by the 7th Fighter Training Squadron



Air Force Research Laboratory (AFRL) Simulator Common Architecture Requirements and Standards (SCARS)

The AFRL SCARS Testbed was first developed under the 711 Human Performance Wing's Warfighter Readiness Research Division between September 2017 and April 2020. Since then, the AFRL SCARS Testbed has been supported by 711 HPW's Warfighter Interactions and Readiness Research Division (711HPW/RHW).

The research edge of SCARS works to discover the art of the possible. The team has provided standards guidance for Model-Based Systems Engineering (MBSE), proven that system components can be broken apart and supported with virtualization and cloud solutions, and also conducted research across the Air Force solutions to provide recommendations and standardizations using existing government-off-the-shelf (GOTS) software, increasing awareness of existing solutions across a variety of platforms.

Virtualization Research

The testbed team has researched the ability to take Operational Flight Program (OFP) software and virtualize the components. The objective is to reduce the amount of hardware needed to run a Flight Simulator, which will reduce the cost when standing up new sims. The team successfully containerized the “stores” component to be external to the existing hardware. Additionally, we ran studies on containerizing all pieces of the OFP software, while testing the validity and latency, to ensure that the simulators still run to the expected standards.

CGF Research

The use of Computer Generated Forces (CGF) software to develop and execute missions is essential for training. However, there is a gap when trying to reuse said scenarios within different CGF applications as they all have their own “Scenario Language”. The focus of the team’s CGF research was to find a commonality between the exported scenario files as compared to the Military Scenario Definition Language (MSDL). The benefits of this would reduce the cost and time to recreate generated scenarios by Trainers and provide a Dictionary of already created scenarios they can reuse.

Testbed

The testbed contains and utilizes many government-off-the-shelf (GOTS) software products such as Performance Evaluation and Tracking System (PETS), Live, Virtual, and Constructive Network Control Suite (LNCS), and TaskView and continues to research the existence of GOTS technologies that can be added to support standardization of testbed capabilities. Additionally, the team has a SCARS On-Premise Equipment (OPE) and plans to integrate it into the test bed to research and test new applications. Being able to test and validate new applications makes it easier and quicker for the trainers to get the new software integrated and working without having to run these test themselves, which could take away from actual training that is needed.

Overall, the SCARS testbed works to research and provide feedback regarding the SCARS standardizations processes, identify gaps, and provide recommendations and feedback to minimize confusion. ☆

Mr. Brad Pfefferle, Principal Software Engineer, Aptima, Inc.
Mr. Cody Reichard, Software Engineer, Aptima, Inc.

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

WARFIGHTER-MACHINE INTEGRATION (WMI)

PRODUCT LINE

Welcome back to the fall issue of Fight's On! It has been five years since I stepped into the role of Lead for the Warfighter-Machine Integration (WMI) Product Line (PL), and I will retire at the end of this year. It has truly been a wild ride! The expertise of the research teams and their commitment to delivering human machine teaming capabilities to the operators never cease to impress me. From ATLAS supporting the human machine integration (HMI) for Skyborg, IMPACT developing the Command and Control (C2) interface for the Medusa program of record (PoR), Legion at the forefront of Intelligence, Surveillance, and Reconnaissance (ISR) optimization to JADPACT which is central to the next Transformational Capabilities Office (TCO) effort enabling C2 at scale, this PL has always been focused on delivering decision superiority to the DAF. I couldn't be more honored to have worked with these dedicated teams.

For the WMI PL, 2025 has been an intense, productive year with many significant achievements. In 2023, we highlighted the successful test of Project BOAR (Base Oversight of Autonomous Response) at the 2023 Air Force Marathon. BOAR leveraged critical user interface and human machine teaming technologies from IMPACT, leading to the RH effort called IMBR (IMPACT-BOAR). This year, IMBR 1.0, under the guidance of Allen Rowe, was demonstrated and delivered to AFIMSC (Air Force Installation and Mission Support Center), completing a rapid turnaround in under two years. We hope to continue developing these capabilities for base defense.

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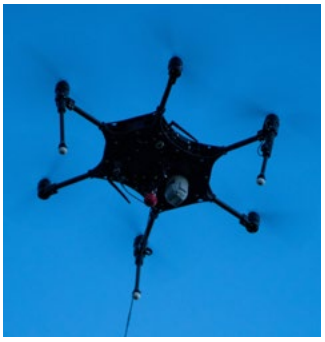
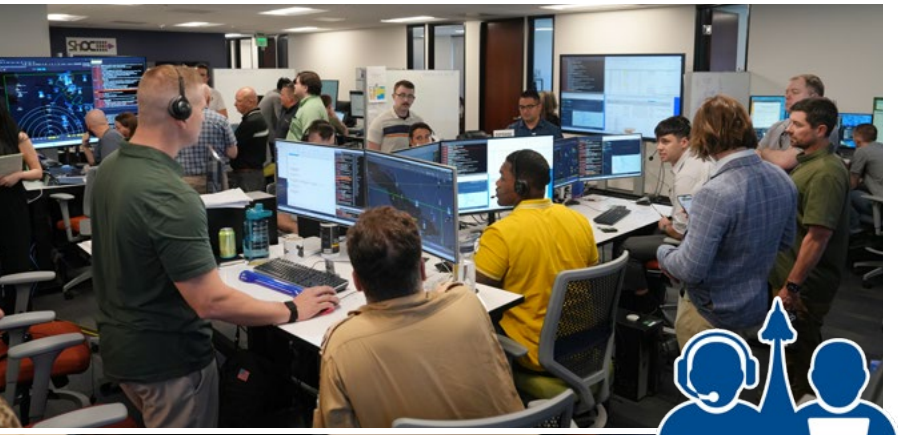


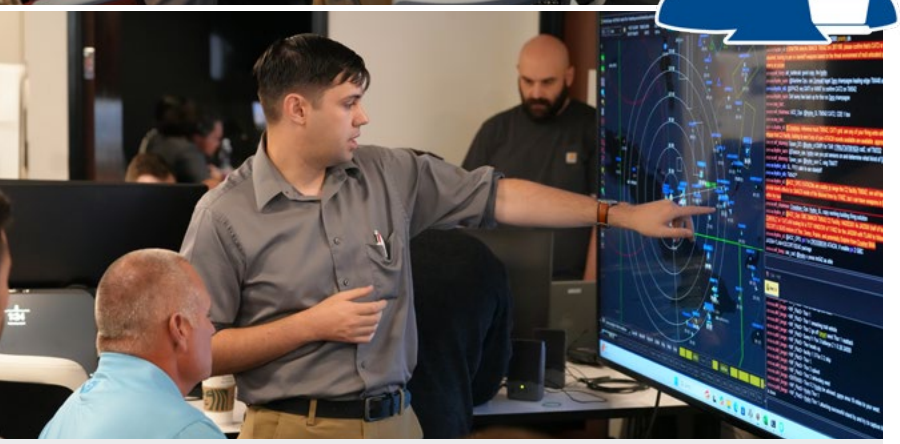
60th Security Forces Squadron drone operator pilots operate a drone during a BOAR demonstration at Travis Air Force Base, California, March 22, 2024.

U.S. Air Force photo by Kenneth Abbate

E-7A MQ-28 Flight Test team

Photos (top) by Royal Australian Air Force and (bottom) Kristen "Cuda" Barrera





The Transformational Model-framed DASH events help build machine teammates that arm the C2 enterprise with decision advantage capabilities.

U.S. Air Force photos by Deborah Henley

PL OVERVIEW

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

The MOBIUS team has maintained an exhausting schedule, supporting flight tests performed by Australian partners from the Defence Science & Technology Group (DSTG), the Royal Australian Air Force (RAAF) and Boeing Defence Australia (BDA) to demonstrate ground and airborne C2 of Collaborative Combat Aircraft (CCA). Software co-developed by 711HPW/RH, DSTG, and BDA demonstrated C2 of multiple MQ-28 Ghost Bats by taking custody of those vehicles and executing a number of operational behaviors related to mission payloads also under test. This demonstration provides evidence of the feasibility of the CCA concept to bring greater mass to the fight. The team, led by Kristen 'Cuda' Barrera is instrumental to the success of these flight tests.

Last but not least, the JADPACT (Joint All Domain Persistent with Adaptive Collaborative/Control Technologies) team has supported three productive DASH (Decision Advantage Sprint for Human Machine Teaming) events. Dr. Elizabeth Frost and her team have collaborated with the Advanced Battle Management Cross Functional Team (ABMS CFT), 805th Combat Training Squadron (CTS), operational warfighters, and industry software developers to focus on decision functions from the Transformational Model of Decision Advantage (TM-DA). The DASH experiments showed how machine support can dramatically reduce decision time and improve decision quality for air battle managers working in complex operational environments, accelerating data and decisions. Based on the JADPACT team's expertise and accomplishments, the ABMS CFT, warfighters, and the Shadow Operations Center - Nellis (ShOC-N) specifically requested for the Air Force Research Laboratory's (AFRL) team to lead future DASH events.

As my career comes to a close, I leave knowing that these teams will continue to achieve cutting edge technology and provide essential capabilities to the warfighter. They will keep fighting the fight, bringing knowledge and passion to the Air Force. Fly-Fight-Win! ☆

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

Dr. Jerred Holt
Intelligence Analytics & Sensemaking PL Lead, 711 HPW/RHW

INTELLIGENCE ANALYTICS & SENSEMAKING

PRODUCT LINE

The Intelligence, Analysis and Sensemaking (IAS) Product Line continues to accelerate multiple science and technology (S&T) efforts and has already demonstrated solid operational mission impact. With a strong baseline in traditional Intelligence, Surveillance, and Reconnaissance (ISR) process augmentation through the LEGION program, our focus has been on increasing involvement in the Space and Cognitive Warfare domains as well as building better interconnectivity between research and development (R&D) systems.

PL OVERVIEW

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

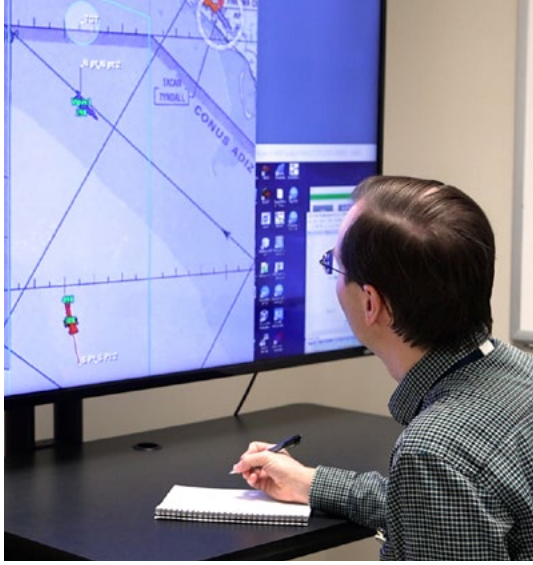
The primary goal of IAS is to provide decision superiority to the AF and Joint intel community through tools, systems and process that augment the operator's ability to make timely, effective decisions in an increasingly organic and distributed battlespace. The diversity of expertise, responsibility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

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

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

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

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



Photos by Mr. Will Graver (SierTek, Ltd)

MODELING AND SIMULATION INTEGRATION LAB (MSIL)

Human-in-the-Loop Technology Integration and Mission Engineering

The MSIL provides a unique, government-owned ecosystem supporting technology integration in a virtual simulation environment that permits experimentation in high-fidelity scenarios to bring the future faster for the Department of the Air Force (DAF). The mission emphasizes 3 goals:

1. **Interoperability**. The critical foundation for MSIL includes the Flexible Architecture for Synthetic Training and Test (FASTT), which provides agility for technology integration at multiple levels of fidelity, classification, and scale. To maximize value for the DAF, FASTT emphasizes integration and interoperability across Distributed Mission Operations (DMO), the Joint Simulation Environment (JSE), and the Advanced Framework for Simulation, Integration, and Modeling (AFSIM).

2. **Human-in-the-Loop Technology Assessment**. Capitalizing on decades of experience in virtual simulation, human performance measurement, and metrics development, MSIL focuses on the intersection between technology and human performance. This includes consideration of human system integration, human-machine teaming, decision making, and training to support exploration of concepts of operations, tactics, and mission engineering.

3. **Increase Transition Speed**. At the end of the day, increasing the pace of technology maturation is a fundamental need for present-day research and development. The primary measure of success for MSIL is the ability to accelerate tech transition with mechanisms and processes that support rapid research execution and delivery of results and capabilities to program offices and end users.

MSIL was created to establish an infrastructure to help the DAF bring the future faster with agile modeling and simulation (M&S) technologies that connect the Air Force Research Laboratory's (AFRL's) science and technology (S&T) to the DAF's Operational Training and Test Infrastructure (OTTI) through human-in-the-loop M&S. We are achieving this objective by leveraging a partnership with the DAF's Chief Modeling & Simulation Office (CMSO), Air Force Major Commands including Air Combat Command (ACC), program offices in the Air Force Life Cycle Management Center (AFLCMC), and the Defense Advanced Research Projects Agency (DARPA). Continuous evolution to speed technology transition positions MSIL to help the DAF fly, fight, and win again... and again... and again. ☆

Dr. Glenn Gunzelmann, Principal Research Psychologist, 711 HPW/RHW

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

HUMAN LEARNING & COGNITION

CORE TECHNICAL COMPETENCY (CTC)

Comprehensive operational readiness remains one of the greatest challenges facing the US Air and Space Forces today. Success in the future fight will require solutions and training that evolve as quickly as the threats we will face, and as technological parity has become a reality for our adversaries, our ability to prevail will be determined by the complete, and dominant, readiness of the *Human Warfighter*. The Human Learning and Cognition Core Technical Competency (HLC CTC) provides the tools and capabilities to support warfighter readiness through a program of research focused on developing and integrating computational models of human information processing and advanced training technologies into a comprehensive readiness ecosystem.

Future warfighters will need technologies and training solutions that can adapt as quickly as the adversaries and challenges they confront. This requires the creation of an advanced, extensible, multi-domain training ecosystem capable of replicating the operational complexities anticipated in future Joint All-Domain mission environments – that is, we must be able to *train as we fight*. Critical to this vision is the ability to create personalized training tools that can support rapid skill acquisition and retention as well as ensure warfighter proficiency and availability. We must develop advanced training architectures and data management systems that allow for the collection of contextualized, purposeful data to address metrics identified as critical in all phases of learning and yield analytics for developmental training intervention. We must also create the technologies that support human/Artificial Intelligence (AI) teams that can rapidly and effectively learn from, and with, each other in real time for adaptive learning that may be required during critical mission operations.

Train as we fight also means that we must effectively recreate *all* aspects of a mission space – most critically, the human element – in order to

Continued on next page

> **Our Airmen must fly, fix, and train with purpose, realism, and discipline to ensure we are ready any time our nation calls."**
>
> **— General Kenneth S. Wilsbach**
> Chief of Staff, United States Air Force

CTC OVERVIEW

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

Graphic by Mr. Will Graver (SierTek, Ltd)

Human Learning & Cognition CTC

Digital Models of Cognition CRA

Learning & Operational Training CRA

reach complete operational fidelity, and integrate that human element into a larger synthetic modeling and simulation training architecture. The implementation of high-fidelity representations of human teammates and adversaries depends on the development of scalable models of perceptual and cognitive processes that mediate decision-making. These processes are impacted by the many stressors present in operational environments, including cognitive load and fatigue; physical factors such as operating at altitude, in noise, constrained by personal protective equipment; uncertainty; and the challenges associated with team coordination and, importantly, the realities of skill decay.

The HLC CTC addresses the above challenges by organizing our research portfolio into two focused Core Research Areas (CRAs), each of which has identified a set of goals in response to demand signals from DoW leadership:

1. **Digital Models of Cognition**: This CRA addresses the DoD's emphasis on a digital transformation, enabling this team to rapidly and effectively support elite operational training and assess weapons systems with human models in place in order to predict performance and mission success.

2. **Learning and Operational Training**: This CRA represents the Air Force Research Laboratory's (AFRL) historical expertise in research for elite operational training supporting Warfighters in air, space, and cyberspace, addressing leadership's demand for persistent readiness that can only be achieved through large-scale, Joint All-Domain operational training exercises at a frequent cadence.

The Human Learning and Cognition CTC research portfolio addresses the most challenging, and time-critical, issues identified by USAF and USSF leadership. The following sections provide a more detailed description of our efforts and demonstrate how we will continue to deliver capabilities to the warfighter in order to position the DoD to be the strongest fighting force in the world. ☆

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

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

DIGITAL MODELS OF COGNITION

CORE RESEARCH AREA

Strategic competition with our adversaries demands our warfighters to be agile, swift, resilient, and decisive. To prepare our warfighters and to ensure unbeatable decision-making during missions, we must develop informative, real-time models that simulate cognitive and social influence processes at different abstraction levels and generalize across domains with realistic internal and environmental stressors. The Digital Models of Cognition (DMC) Core Research Area (CRA) addresses this need by developing and advancing computational and mathematical modeling capabilities that represent human perception, cognitive-social information processing, and behavior in warfighter decision-making in operational contexts.

CRA OVERVIEW

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

We have three technical challenge areas (Lines of Effort) that drive our CRA work:

1. The first challenge area is Holistic Models for Decision-Making (HMDM) which focuses on addressing warfighter cognitive overload by developing software that can detect and predict cognitive workload and inform mitigation strategies to enhance decision-making performance.
2. The second is Multi-Sensory Human System Modeling and Evaluation (MSHSME), an externally funded LOE that supports requests from customers focused on evaluating the physical characteristics of technologies and human systems to address evaluation gaps and enhance human performance and safety in complex operational environments.
3. The third 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.

The CRA is made up of a unique, technically diverse team, and further embraces a multidisciplinary approach by collaborating with several teams across the Air Force Research Laboratory (AFRL) and within other services, industry, and academia. Over the last year we have pivoted are foci within the LOEs to meet customer needs and align with AFRL leadership expectations for quickly delivering tools that can enhance warfighter decision-making. In the following articles, you will learn more about our LOEs and we will highlight some specific efforts for a deeper dive. ☆

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

Digital Models of Cognition
CRA

Holistic Models for Decision-Making
LOE

Multi-Sensory Human System Modeling and Evaluation
LOE

Information Mastery for Cognitive Warfare
LOE

Graphic by Mr. Will Graver (SierTek, Ltd)

HOLISTIC MODELS FOR DECISION-MAKING

LINE OF EFFORT

The Holistic Models for Decision-Making (HMDM) Line of Effort (LOE) continues to address research and technology gaps in monitoring and augmenting human cognitive capabilities for improved human decision-making performance in warfighters. The cognitive demands of the current and future fight necessitate that we develop better predictive models of human decision-making under the influence of stressors, fatigue, and information overload and, as a result, develop tools that mitigate or compensate for the negative effects of these factors. The LOE brings together a multi-disciplinary team to consider a wide range of human mental activities that feed decision-making, including visual processing, auditory processing, attention, and language processing.

This research line considers how the acoustic environment impacts a warfighter's ability to understand spoken communication (DETHSCAR) and provides predictions for how well a warfighter can maintain situation awareness while monitoring an overwhelming number of communication channels (Language Comprehension). We are also assessing how varying the properties of autonomous platforms impacts decision-making during a simulated mission (Multi-Cue Decision-Making). The project Enhancing Cognitive Human Operability (ECHOES) aims to provide a common framework for digital models of human cognition to facilitate collaboration and transition of the analytics to customers, while Hybrid-Cognitive Models focuses on developing an adaptive, multi-model approach to predicting a learner's knowledge acquisition during training.

Program Leads

LOE LEAD
Current: Dr. Sarah Bibyk
Former: Dr. Frank Mobley

PROGRAM MANAGERS
Current: 2d Lt Anastasia Stuart
Former: Maj Shinae Wagner

Finally, we will take a deeper dive into some of the specific gaps we are addressing in the articles that follow. In Modeling Visual Search Fatigue, we discuss research addressing how fatigue affects the ability to process visual information. In Environment, Noise Demands, Utilization of Cognitive Resources, and Extended Mission Time for Mobility Crews (ENDURE-MC), we discuss methods for assessing how cognitive workload is affected by noise exposure and time-on-task. We'll also get a deeper dive into an external effort under the LOE that focuses on individualizing predictive modeling for cognitive fatigue. Finally, in Analytic Ensemble for Automated Interference (AE4A1) – a cross-LOE effort – our researchers discuss the ongoing development of analytical tools that will support decision-making and inference over data. ☆

Dr. Sarah Bibyk, Holistic Models for Decision-Making LOE Lead, 711 HPW/RHWEO

Photo by Mr. Rick Eldridge, 711 HPW CAG

Modeling Visual Search Fatigue

In maximum endurance operations, warfighters must perform at a high level during tasks that involve visual stimuli and decision-making. This is challenging as human performance declines to a degree over time, especially when doing tasks that have a low rate of critical events (e.g., cruise), known as time-on-task fatigue or the vigilance decrement. Some research has addressed time-on-task fatigue in simple tasks. However, in dynamic environments the underlying mechanisms, precursors, and specific effects of time-on-task fatigue remains unclear. To address these scientific gaps, researchers in the Holistic Models of Decision-Making LOE developed experiments and models to identify methods to measure and detect the onset of fatigue and explain how it affects performance to inform long duration performance predictions, fatigue mitigation, and mission simulations.

The team designed experiments leveraging established visual search research with target prevalence (i.e., frequency that a target is present vs absent) and integrated physiological measurements to identify and quantify changes in eye movements (i.e., eye tracking), brain activity (electroencephalogram; EEG), and performance (i.e., accuracy and response time) over time. They are also collecting individual data (e.g., caffeine intake and sleep) and related cognitive skills (e.g., working memory capacity, vigilance, and attention control) to assess whether these relate to performance or fatigue resistance. Initial results for the first experiment showed lower performance when there were less target present trials, changes over time in visual search behavior and more errors related to fixating on but failing to identify the target, and a relationship between visual working memory and performance.

A second experiment addressed low light conditions using night vision goggles (i.e., NVGs) in a newly developed testbed where dynamic visual stimuli are presented via a calibrated organic light-emitting diode (OLED) television. The main focus was comparing performance in normal light (i.e., first experiment) to performance in low light using two different types of NVGs (high performance green and white phosphor). This comparison provides novel data about performance and time-on-task fatigue with and without NVGs and serves to address anecdotal evidence and preferences for the two types of NVGs. Initial results suggest performance differences between light conditions and NVG type over time, which will inform model and simulation, performance predictions, and best mission conditions and equipment for operations.

Overall, this research effort addresses performance in long duration missions, provides methods for fatigue detection, novel data to develop and validate prediction/simulation models, and informs how to mitigate negative effects of time-on-task fatigue based on individual qualities, fatigue detection, and potentially adaptive automation of interface enhancements. ☆

Dr. Alex Hough, Research Psychologist, 711 HPW/RHWEO

Photo (top) by Tech. Sgt. Benjamin Sutton
Photo (bottom) by Dr. Elizabeth Fox, 711 HPW/RHWEM

Environment, Noise Demands, Utilization of Cognitive Resources, and Extended Mission Time for Mobility Crews (ENDURE-MC)

One of our primary studies we will be conducting in FY26 for the Holistic Models for Decision-Making Line of Effort focuses on the assessment of cognitive workload and effects of noise exposure and time-on-task. Crew members on the MC-130 J endure long operations to deliver and retrieve troops and cargo in challenging airfields. Within a crew, the Combat Systems Operator (CSO) plays a critical role in mission planning, tactical navigation, defensive countermeasures, communication, refueling and airdrops, and coordination of the aircraft's specialized systems during mission execution. The CSO must maintain situation awareness, manage demanding task requirements, and sustain proficient and flexible cognitive functioning for extended durations and amid physiologically stressful environments. Importantly, the MC-130 J was recently equipped with an additional electronic warfare system (i.e., Radio Frequency Countermeasure; RFCM) that adds substantial acoustic noise to the internal aircraft and crew exposure levels – hence, RHWE received a demand signal to characterize noise emissions in the MC-130 J under various contexts and assess its impact on crew (i.e., CSO) performance.

Researchers in 711 HPW/RHWEM partnered with AF Life Cycle Management Center (AFLCMC; MC-130 J Program Office) and U.S. Special Operations Command (USSOCOM; Detachment 1) to both capture the key task characteristics and cognitive demands of CSOs and collect in-flight acoustic recordings at the CSO workstation. They are using existing, and building new, simulation capabilities at Wright-Patterson Air Force Base to conduct a research study that quantitatively measures the effects of 1) time-on-task [fatigue], 2) operational noise, and 3) their interaction on people to quickly and accurately complete CSO-specific and mission essential tasks, maintain situation awareness (measured through behavior), manage workload (measured through brain activity [electroencephalogram; EEG], behavior [response time, accuracy], and survey [modified Bedford Workload Scale; mBWS]) and maintain proficient cognitive processing such as working memory, reasoning, visual learning, visual search, and vigilance. The results of this work will inform healthy Airmen protocol and guidelines and the design of support systems with a focused effort to enhance CSO performance. Continued collaboration with AFLCMC and AFSOC is planned for FY2026, and the current laboratory study is groundwork for future field studies regarding assessment of crew member workload and physiology during extended mission execution and crew resource management (CRM). ☆

Dr. Elizabeth Fox, Research Psychologist, 711 HPW/RHWEM

Monitoring and Modeling Fatigue in Joint Operational Environments

As mentioned in the ENDURE-MC and Modeling Visual Perception Fatigue efforts, fatigue from maximum endurance operations will exacerbate warfighter cognitive load, leading to degraded mission performance and increased safety risk. The warfighter needs tools that can predict cognitive fatigue and enhance fatigue risk management. This cross-service collaborative effort, funded by the Joint Program Committee-5/ Military Operational Medicine Research Program Working Group: Fatigue Mechanisms and Countermeasures, focused on developing a cognitive modeling capability that generalizes across multiple military domains and predicts individualized operational performance degradations due to fatigue and workload – a feature lacking from present fatigue modeling capabilities. The effort consisted of two separate studies, one involving operational US Air Mobility Command C-17 mobility pilots and the other involving US Navy Surface Warfare Officer (SWO) trainees.

The C-17 mobility pilot study included a simulated long-duration 24-hr mobility mission where volunteer pilots completed various mission tasks of different complexity levels in augmented crews and practiced realistic crew rest. Pilots wore an actigraph watch during the study to estimate sleep and also completed questionnaires regarding self-reported sleep, fatigue perceptions, and individual differences. Throughout the simulated mission after key mission tasks, pilots completed questionnaires on self-reported fatigue and workload and completed a cognitive task suite that measured attention, working memory, and executive functioning. Results from the study suggested that fatigue increased across the 24-hr simulated mission, despite the presence of crew rest, degrading attention, working memory, and executive functioning performance. Computational cognitive models of the cognitive tasks captured changes in performance with fatigue. When integrating individual differences questionnaire data into the models, we found that one's subjective typical sleep and sleep need can be leveraged to inform how much sleep deprivation impacts performance.

Although the effort originally targeted operational Naval officers for the second study, due to operational demands, we focused on SWO trainees during a training course that involved simulator sessions. As a result, the study protocol was different and did not have the exacerbated fatigue effects that were present in the C-17 mobility pilot study. Trainees wore an actigraph watch and completed the same questionnaires and cognitive tasks as the C-17 pilots but had fewer data collection bouts. Despite the different context, significant fatigue effects were observed for attention and working memory, while executive functioning performance remained stable. The computational cognitive models showed overall good alignment with the trainee data. To enhance model sensitivity in this context, subjective workload (captured via the NASA Task Load Index) was integrated as a modulatory factor in the fatigue model. This adjustment improved model fit for the attention and working memory tasks in the US Navy dataset with minimal detriment to model fit in the C-17 dataset, supporting the cognitive modeling capability's generalizability to different military domains.

Junior officers maneuver a simulated destroyer at the Mariner Skills Training Center Pacific (MSTCPAC) (top) and an operator pilots a C-17 flight simulator at Joint Base Charleston (bottom).

Photos by Seaman Tyler Miles and James M. Bowman

We published four conference proceedings based on the overall effort presented at Human Factors and Ergonomics Society ASPIRE (2024 and 2025) and the Aerospace Medical Association Annual Scientific Meeting (2025). Once the associated technical reports are finalized, we will out brief stakeholders and work toward modular software solutions for this cognitive modeling capability to enhance fatigue risk management tools. ☆

Dr. Megan Morris, Senior Research Psychologist, 711 HPW/RHWE

Dr. Christopher Stevens, Senior Research Psychologist, 711 HPW/RHWO

MULTI-SENSORY HUMAN SYSTEM MODELING AND EVALUATION

LINE OF EFFORT

The Multi-Sensory Human System Modeling and Evaluation (MSHSME) Line of Effort (LOE) is made up of three primary research areas that support technology and human system evaluations for performance and safety, as well as provide datasets to the Holistic Models for Decision-Making LOE for cognitive load software development, validation, and verification. The first area focuses on F-35 noise data and impact assessment on Warfighter personnel with the F-35 Joint Program Office as the primary stakeholder, international partners/FMS participants as secondary stakeholders, and international collaborators. The second area focuses on noise exposure/impacts of missiles and space vehicles on the surrounding environment with primary stakeholders, Japanese Self Defense Forces, USSF Space Launch Deltas 30 and 45, and Air Force Civil Engineering Center, as well as several other stakeholders and collaborators in the Federal Aviation Administration, NASA, and the Department of Transportation. The third area focuses on evaluation of technology and perceptual factors that describe/affect night vision goggle performance. The following article is a deeper dive into the Night Vision Goggle laboratory. ☆

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Dr. Hilary Gallagher, MSHSME PI, 711 HPW/RHWEM
Dr. Alan Wall, MSHSME PI, 711 HPW/RHWEO
Ms. Sharon Ellis, MSHSME PI, 711 HPW/RHWEO

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PROGRAM MANAGERS
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Night Vision Goggle Laboratory

The RHWE Night Vision Goggle (NVG) laboratory is a base-wide resource for optical metrology to optimize the use of sensors and displays for aviation in low light environments. RHWE researchers provide highly specialized lab testing to create/validate specification requirements, critical substantiating documentation to support fielding, and visual performance validation for system upgrades. In addition to validating system visual performance, the team developed a testbed and innovative measures of NVG visual performance The testbed includes a calibrated organic light-emitting diode (OLED) television screen enabling the presentation of dynamic visual stimuli to an individual wearing NVGs. The team is collecting data on a visual search task to simulate target detection and replicate real-time decision-making in complex environments. The results from these studies provide novel data to develop models of the factors that describe/affect NVG performance and facilitate a better understanding of the interplay between perception, cognition, and NVG use. Augmenting traditional system performance measures with more operationally relevant, cognitively demanding task performance measures help provide a more well-rounded understanding of the myriad of perceptual issues inherent with the night ops mission due to low light/degraded visual environments. This understanding can then inform aircrew equipment upgrades, integration, training, command level

Photo by Mr. Rick Eldridge, 711 HPW CAG

mission planning, and aircrew readiness. RHWE has supported over 31 different AFLCMC Program Offices and AETC 342nd Training Readiness Squadron's (TRS) NVG Academic Instructor Course (NVAIC) with quarterly briefings that have become an integral component of NVAIC. ☆

Ms. Sharon Ellis, Engineering Research Psychologist, 711 HPW/RHWEO

Graphic by Mr. Will Graver (SierTek, Ltd)

INFORMATION MASTERY IN COGNITIVE WARFARE

LINE OF EFFORT

The Information Mastery for Cognitive Warfare (IMCW) Line of Effort (LOE) is conducting research and developing solutions to support Information Operations missions. This diverse group is working to provide improved capabilities for operators within the information environment through research and development by delivering practical tools and techniques that will enhance readiness and mission effectiveness. Outputs from this LOE will feed into our new MORRIGAN project, an AI-powered tool suite that will assist in influence operations analysis, planning, and assessment.

One project within this LOE is the development of a simulation of the operational Information Environment in collaboration with the 39th Information Operations Squadron. This project is intended to create a representation of the critical aspects of the information environment for training, exercises, and wargaming. The simulation will allow teams to practice and refine their methods in a controlled environment that can model various information-based scenarios, generating appropriate responses by simulations of target audiences, providing a valuable resource for preparing for the complexities of actual operations. In addition to the simulation, the IMCW LOE is creating tools to improve the assessment of Information Operations in collaboration with the Joint Military Information Support Operations (MISO) WebOps Center at the Special Operations Command (SOCOM). These tools will leverage the AE4AI toolkit (see article in this issue) and large language models, and are being designed for use during the planning, execution, and assessment phases of an operation. The objective is to give commanders and planners a clearer understanding of the effects of their actions. By providing more accurate and timely feedback, these tools will help personnel evaluate the impact of their work and make more informed decisions.

A third effort focuses on bolstering the cognitive security of airmen. The LOE is conducting research on the cognitive and social science aspects of social engineering to develop training programs, educational resources, and models that enhance the force's ability to recognize and resist adversary influence operations, such as disinformation and propaganda with new models generating weaponized hyper-personalized content at speeds unimaginable just a few years ago. The project seeks to provide software and digital tools and methods to reduce the vulnerability of military personnel to hostile information activities, thereby strengthening the overall resilience of the force. The following article will focus on one of these cognitive security efforts. ☆

Dr. Eric Thompson, IMCW LOE Lead, 711 HPW/RHWE

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Former: Dr. Katie Larson

PROGRAM MANAGERS
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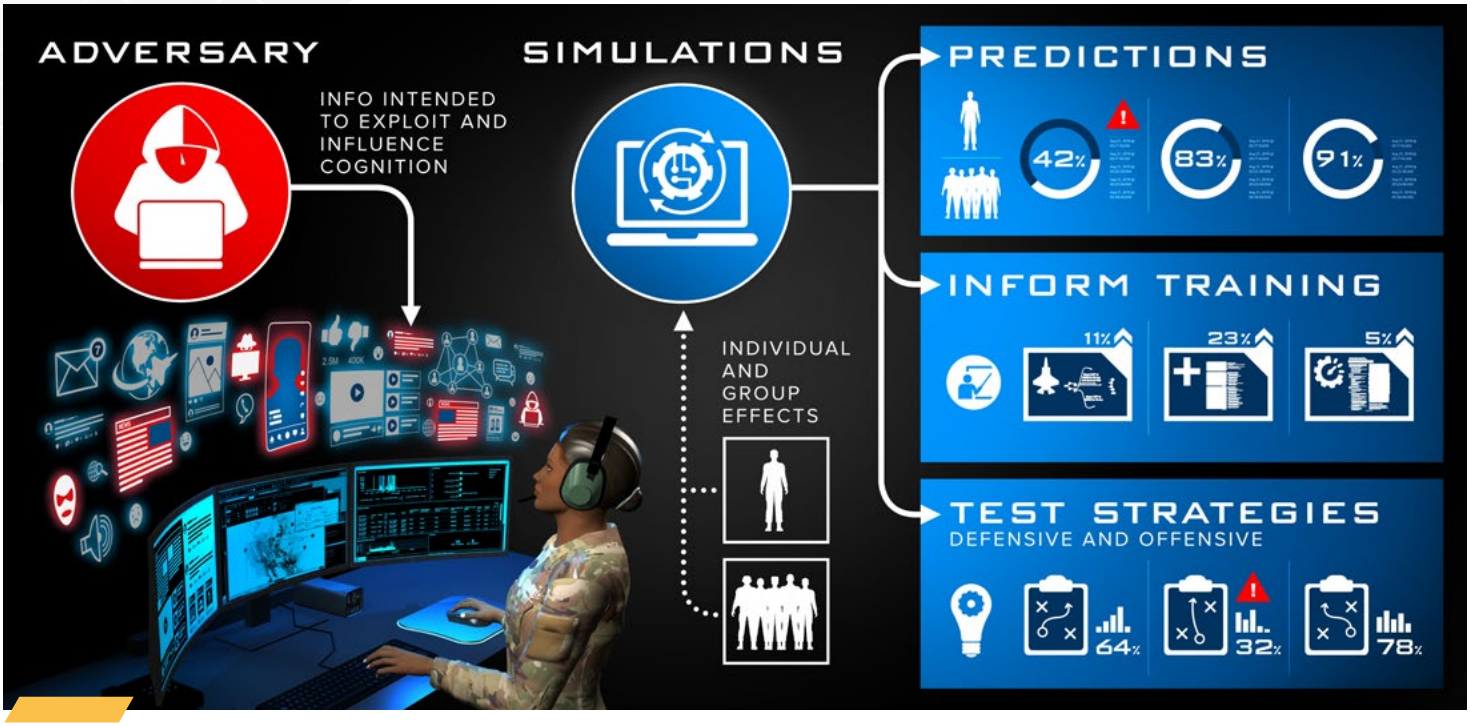


Graphic by Mr. Will Graver (SierTek, Ltd)

Scalable Models for Cognitive Warfare

Information operations are an important component for kinetic and non-kinetic missions, but are time consuming, require significant manpower, and there are no available tools for explaining, predicting, or simulating various effects. Academic research documented robust effects, but mixed findings, artificial tasks, and lack of computational cognitive models have hindered our ability to leverage the research. To address information operations and research gaps, the Information Mastery in Cognitive Warfare Line of Effort is developing and integrating models of decision-making and social dynamics.

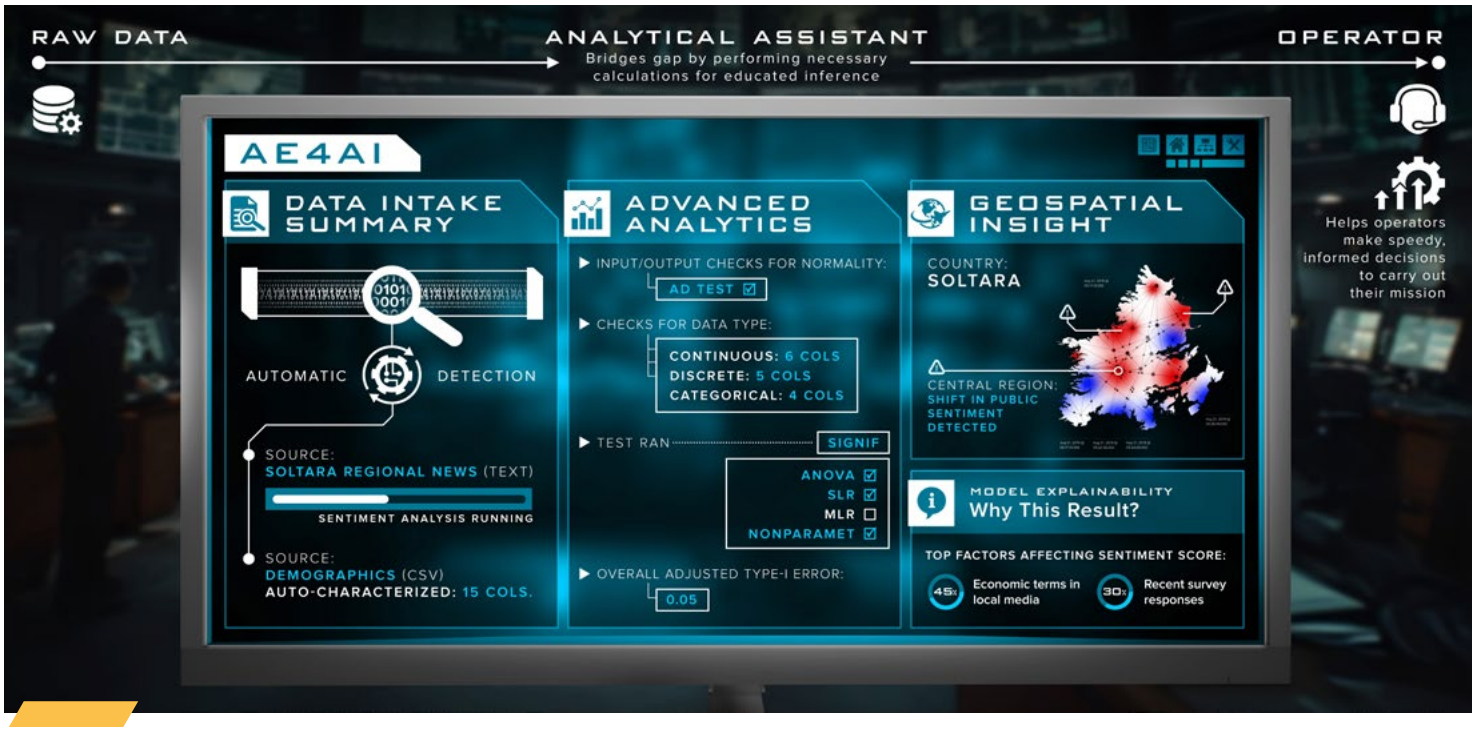
To model human decision-making, the team leveraged an extensively validated cognitive architecture (e.g., Control of Thought-Rational; ACT-R) to implement human declarative memory (i.e., facts or knowledge) and individual cognitive processes that represent thinking patterns, responses, and decision-making heuristics. An information pipeline was established to enable the model to take in and form new knowledge representations from text (e.g., news narratives) that interact with existing knowledge and preferences (e.g., existing beliefs). This enables the ability to simulate and explain how information affects cognitive processes leading to patterns of thinking (e.g., biases) and both internal (e.g., beliefs) and external (i.e., behavior) changes. Successful demonstrations validated memory activation, emotional reactions to content and information sources, and related cognitive processes can explain several effects documented in the literature. Ongoing work involves prediction and simulation of effects in real-world scenarios and a simpler code implementation (i.e., python) to enable the complete pipeline to plug and play with other models.

To help contextualize the decisions that individuals make, the team is also addressing social interactions and group dynamics using agent-based modeling (ABM) simulations. ABMs allow researchers to model societal dynamics while also imbuing individual agents with specific decision-making behaviors. To best examine knowledge gaps with respect to information and influence operations, the team has developed several ABMs that demonstrate how theories of individual cognition (e.g., ACT-R) are compatible with those of social influence (e.g., Social Sampling Theory; SST), showing a strong relationship between individual beliefs and long-term memory dynamics during social interactions. Additionally, the team has used ABMs to demonstrate the sensitivity of event-based social media platforms, such as prediction markets, to disinformation. This line of research will continue to examine the important interplay between societal environments and individual-level behaviors and simulate important emergent behaviors in large-scale networks.

The research team is also making progress to develop a complete framework to enable the ability to focus in on dynamics at a specific level (e.g., person, group, or population). In an initial demonstration, the team integrated features from individual level and group dynamics modeling to replicate how an individual level effect (e.g., false information continuing to affect decisions after it is corrected) propagates in a group because a majority of individuals (i.e., agents) share false information and a minority try to eliminate the effect by sharing the correction.

We have presented the results of these studies to academic conferences (International Conference for Cognitive Modeling and SBP-BRiMS) and journals (Computational and Mathematical Organization Theory), NATO technical groups (MSG-222 and HFM-377), and the Air Force Research Laboratory (AFRL) briefs (tours, AFRL discover). ☆

Dr. Alex Hough, Research Psychologist, 711 HPW/RHWEO



Graphic by Mr. Will Graver (SierTek, Ltd)

Analytic Ensemble for Automated Inference (AE4AI)

The most critical battlefield is not the physical space—it is the human mind. Presently, even the most experienced operators are at risk of being overwhelmed by the volume and velocity of information presented to them. Accurate and swift decision-making is critical to winning the fight, but this capability gap will only grow with the rapid advancement of artificial intelligence. The Analytic Ensemble for Automated Inference (AE4AI) aims to reduce that gap by providing an analytical assistant to perform the necessary calculations for educated inference that feeds into an operator's decision process.

Analytical and statistical tools are essential for various applications, including characterization, system monitoring, estimation, and prediction. However, selecting the appropriate tool often requires significant background knowledge that may not be readily available to every analyst. Building on previous work in collaboration with the Air Force Institute of Technology (AFIT) through a RH Chief Scientist seedling, this research focuses on enhancing automated statistical analysis and modeling capabilities. The partnership with AFIT will be leveraged to develop a framework for a statistical analysis microservice, with an initial focus on providing bench-level analytical service for both Holistic Models for Decision-Making (HMDM) and Information Mastery for Cognitive Warfare (IMCW) Lines of Efforts. Ultimately, it will be integrated into the MORRIGAN system as part of the Intelligent Analytics & Sensemaking product line. AFIT's expertise will be instrumental in refining the algorithms, validating the outcome-agnostic approach, and ensuring the framework's robustness for diverse data scenarios relevant to Air Force operations.

Specifically, AE4AI will streamline data analysis, integrate diverse and often conflicting information, and expedite findings within experiment results such as the Multi-Cue Decision-Making (MCDM)'s dataset, which focuses on multi-asset unmanned aircraft management decision-making characterized as "noisy." This will significantly enhance the evaluation and ranking of analytical methods for complete data scenarios. The integration with MORRIGAN aims to support 14F operations planning by applying social science theories and findings, and analyzing aggregated data from demographic, survey, and other publicly available information. This will help operators make speedy, informed decisions to carry out their mission.

This work directly supports Air Force and the Air Force Research Laboratory (AFRL) priorities and enhances MORRIGAN by delivering enhanced information warfare analysis capabilities. AE4AI will feed product line efforts by providing the automated sentiment analysis module for programs that aim to optimize the process of developing and executing intelligence requirements. By automating robust statistical analysis, AE4AI enhances responsiveness, situational awareness, and decision-making for Counter-Targeting and Space Protection and Defense. This project lays the groundwork for future exploration of integration with AF systems, recognizing the potential for long-term impact across multiple domains. ☆

Dr. Fairul Mohd-Zaid, Mathematical Statistician, 711 HPW/RHWEM

Dr. Christopher Stevens
Learning & Operational Training
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LEARNING & OPERATIONAL TRAINING

CORE RESEARCH AREA

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

Warfighters must be prepared to fight and win in increasingly complex, multidomain operations. This presents scientific and technical challenges for training. What are the indicators of elite performance in individuals, teams, and teams of teams? How can training be adapted in real-time to maximize Warfighter effectiveness? How can we most effectively train the unique combinations of skills that emerging capabilities will require? To address these challenges, Warfighter Learning Technologies applies cognitive and learning science to develop analytics and interventions that enable robust Warfighter proficiency measurement and acquisition. This includes model-based assessments and analytics to track proficiency in pilot training, team communication, and information analysis. These tools rapidly identify knowledge gaps and recommend personalized training regimens. Additionally, Warfighter Learning Technologies analyzes emerging technology, such as Autonomous Collaborative Platforms (ACPs) and AI, to identify unique skillsets required to execute tomorrow's missions and create training environments to support those skillsets.

Continued on next page

CRA OVERVIEW

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

Graphic by Mr. Will Graver (SierTek, Ltd.)

The unique learning dynamics of human and machine teammates present novel challenges in training research and application. These challenges include establishing common ground and shared mental models among teammates, developing metrics for human, AI, and team learning in complex, uncertain domains, and identifying knowledge gaps in team members to apply just-in-time tutoring. Addressing these questions requires a paradigm shift in the way we think about training. The Co-Learning for Adaptive Human and Machine Teams LOE lays the foundation for this new paradigm by elucidating the ways in which humans and AI learn *with* and *from* each other. This work will culminate in novel training environments like the Just-In-Time Tactical Tutor (JINTTACT). JINTTACT will leverage AI to monitor the knowledge of human and AI teammates and recommend training to fill gaps in team competencies. Additionally, the team is developing tools to adapt AI teammates and tools in real-time based on human input, making AI much more robust in dynamic operational environments. Planned use cases for this work include improved training and decision support tools for Space Domain Awareness, Cislunar Operations, and AF/SF/Joint wargaming.

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

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

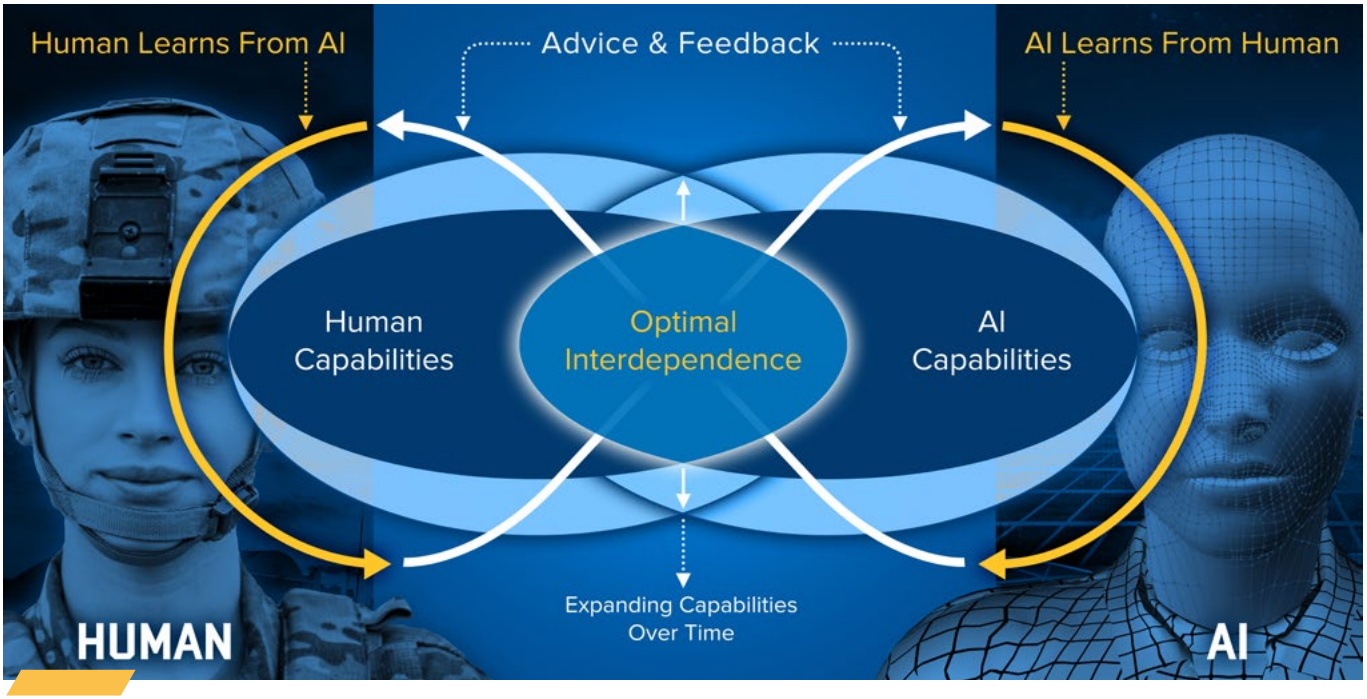
Learning and Operational Training CRA

Co-Learning for Adaptive Human-Machine Teams
LOE

Warfighter Learning Technologies
LOE

Gaming Research Integration for Learning Laboratory®
GRILL®

Graphic (above) by Capt Raymart de Asis, 711 HPW/RHWOH



CO-LEARNING FOR ADAPTIVE HUMAN-MACHINE TEAMS

LINE OF EFFORT

The Co-learning for Adaptive Human-Machine Teams LOE develops the agile, collaborative partnerships between humans and intelligent machines essential for maintaining decision superiority against technologically sophisticated adversaries in today's rapidly evolving battlespace. The program innovates technologies that enable humans and machines to co-evolve through real-time mutual learning, adapting dynamically to mission complexity. This approach leverages the concept of interdependence by integrating superior human capabilities—analogical reasoning, theory of mind, and heuristics—with superior machine capabilities like large-scale data analysis, high-speed computation, and consistent execution without fatigue. Interdependence drives both decision-support systems and warfighter readiness technologies while advancing breakthrough methodologies for real-time machine learning updates, solving a critical challenge facing contemporary artificial intelligence and machine learning (AI/ML) systems.

Current decision-support research develops human-informed machine learning (HIML) models that merge human expertise with AI capabilities. *PI-GRU* combines multi-phenomenology data-based time series forecasting with human reasoning over intelligence products to predict orbital transfers in the notoriously chaotic cislunar environment. *Intent-X* creates an adaptable modular architecture that integrates human ability to estimate adversary intent with Large Language Models (LLM) multimodal data fusion and reasoning, generating real-time, quantifiable courses of action (COAs) for operator assessment and selection.

Warfighter readiness systems leverage AI-enabled interactive technologies to foster deep operational knowledge, critical thinking, and a more intuitive understanding of rapidly emerging dilemmas and opportunities. *AI-enabled Deterrence Theory* research develops a reinforcement learning-based wargaming decision-aid to assist Warfighters in making faster, more informed, and more effective decisions when facing complex dilemmas. The *Strategic Foresight Planner* harnesses LLMs' vast knowledge base to prompt DOD leaders' creativity in strategic foresight to identify future disruptive technologies and increase USAF/USSF element of surprise. *Just-in-time-tactical-tutor (JINTTACT)* is an adaptive intelligent tutoring system that personalizes continuous learning for individuals and teams. The *Cislunar Adaptative Tutor* uses intelligent tutor technology to build a principled understanding of non-intuitive cislunar dynamics in both planners and Warfighters.

The LOE also builds modeling and simulation frameworks to test co-learning technologies in realistic, dynamic scenarios, preparing warfighters for rapidly changing operational environments. The *Oko* framework provides high-fidelity simulations of space situational awareness tasks to assess space-based interactive co-learning models and architectures. Complementary metrics are also being developed. *Mental Modal Alignment* enables high-performing human-machine teams by aligning individual mental models and facilitating a shared understanding of the complex and evolving battlespace. *Joint Activity Testing* evaluates co-learning human-machine teams under diverse levels of stress and uncertainty to aid further development or, if deployed, foster appropriately calibrated and context-specific trust in the system. ☆

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

Lt Tim Davis, Co-learning Program Manager 711 HPW/RHWOH

Wargaming Decision Aid

The Co-learning for Adaptive Human-Machine Teams line of effort is developing an artificial intelligence (AI)-powered decision aid for wargaming scenarios. This tool is designed to act as an intelligent partner to assist operators in making faster, more informed, and more effective decisions when facing complex dilemmas. By training alongside this AI in wargames across the Air Force and Space Force, warfighters can sharpen their skills and develop a deeper, more intuitive understanding of deterrence and escalation. This effort directly addresses the need for better-prepared warfighters, as skills honed with this tool are designed to increase decision efficiency and effectiveness in live environments.

Wargames provide the ideal landscape for the development of this type of decision aid. In these interactive scenarios, participants must make high-stakes decisions based on ambiguous information under immense pressure. For example, adversaries that act aggressively could be testing defenses, bluffing to gauge a response, or preparing for genuine escalation. Participants must decipher this hidden intent and navigate acts of deception, relying solely on their training and available information to make timely decisions. This intense cognitive challenge is where the AI partner contributes to the decision-making process, by assisting operators in analyzing an adversary's behaviors and developing Courses of Action (COAs) with assessed risks and benefits. By augmenting the human operator with these capabilities, the tool allows them to better explore the complexities of deterrence and escalation within the wargame.

The AI agent is trained and informed on a wide range of data, including contextual information such as current events, military doctrine, historical data on an adversary's behavior, and foundational deterrence theory derived from simulations of human-subjects research. This diverse knowledge base provides context for the AI agent to help inform its decision-making process. When a human operator observes an adversary's action, the observation can be given to the decision aid for future consideration. The AI partner analyzes this move against its knowledge base to provide an estimate of the adversary's probable intent. Based on this assessment, potential COAs are then generated, each with clearly articulated risks and potential short and long-term outcomes for the operator to consider. The fundamental methods can be applied to a wide variety of wargames, including domains like Intelligence, Surveillance, and Reconnaissance (ISR), the space domain like Rendezvous Proximity Operations (RPO), operations research, and military strategy. ☆

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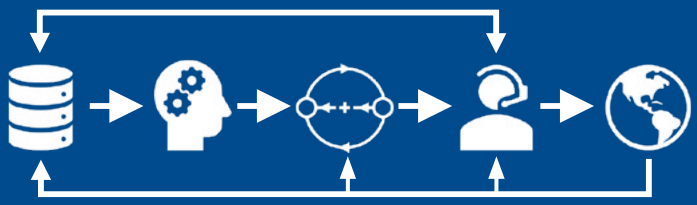
Dr. Daniel Sazhin, National Research Council (NRC) Postdoctoral Fellow

US Space Force photo

TECHNICAL APPROACH



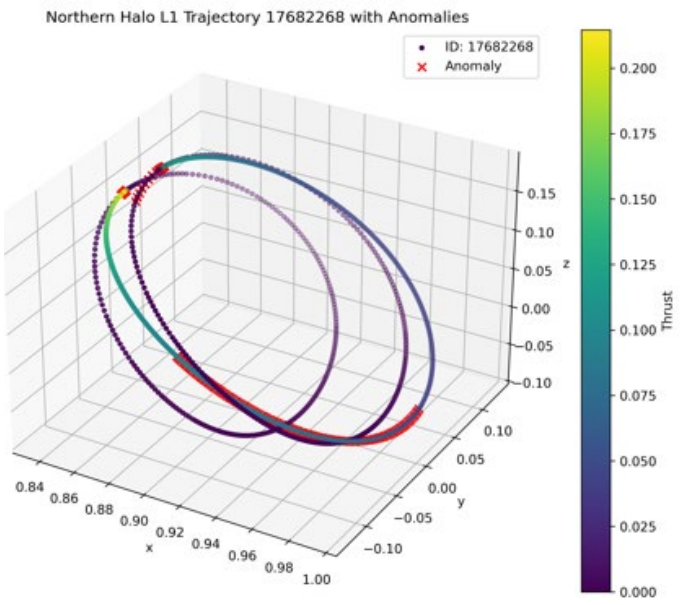
Use contextual information to build Reinforcement Learning policies for the operator to consider when making deterrent decisions.

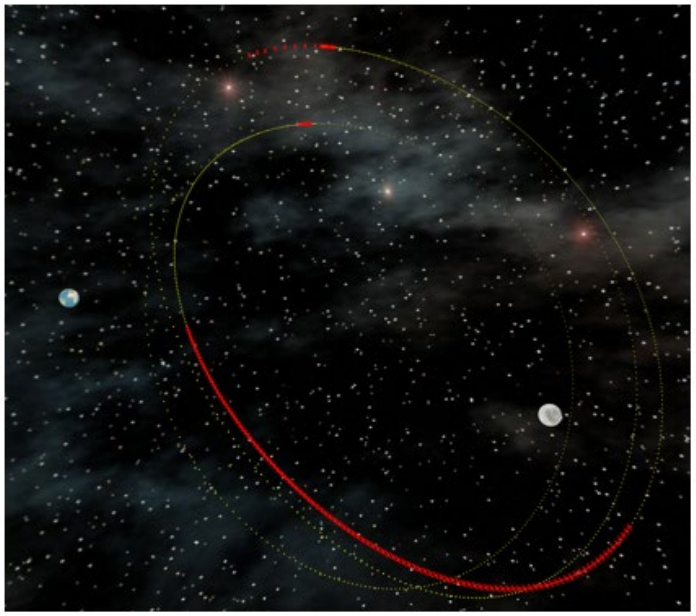
- **Situational Awareness**
- **Increased Efficiency**
- **Understood Adversarial Intent**
- **Improved Decision-Making**

CAPABILITIES

The Wargaming Decision Aid suggests near real-time Courses of Action through incorporating adversarial behavior for intent estimation for deterrent strategies.

- Adversarial Intent Estimation
- Human Machine Teaming
- Strategic & Tactical Decision-Making
- Applicable to Training and Field Operations





Graphics by 711 HPW/RHWOH

Anomaly Detection and Intent Inference in Cislunar Space

Figure 1. **These plots show a transition between two cislunar orbits. The purple points represent the start and destination orbits, the color-coded transition path shows thrust magnitudes, and the red markings highlight predicted anomalies. The model captures both large thrust events and subtle deviations, but unflagged (non-red) portions resemble natural dynamics and may require further tuning to capture. Both plots show the same data; the right uses our in-house tool, Oko, developed by Mr. Allen Dukes.**

The Co-Learning for Adaptive Human-Machine Teams Line of Effort (LOE) has been hard at work developing artificial intelligence (AI)-powered solutions designed to improve efficiency, capability, and decision-making in complex domains. The space domain has historically underutilized artificial intelligence/machine learning (AI/ML) techniques for satellite trajectory forecasting and anomaly detection, relying instead on computationally intensive physics models. This challenge is particularly acute in the cislunar environment, where complex gravitational dynamics and other forces drive satellites into unstable, quasi-periodic orbits. Observational challenges further compound this problem, as satellites can be unobservable for days due to lighting and signal noise conditions. These observational gaps, combined with chaotic environmental dynamics, make it difficult to distinguish natural orbital drift of a satellite from deliberate, low-thrust maneuvers. Such subtle, long-term transitions can signal a change in a satellite operator's intent, yet may go undetected until the new objective is achieved, leaving a critical gap in space situational awareness (SSA) capabilities.

To address this gap, we introduce a novel approach for the early detection of anomalous satellite behaviors using a physics-informed ML framework. At the core of this framework is a Physics-Informed Gated Recurrent Unit (PI-GRU) model, which employs a time-series forecasting approach to learn historic satellite motion patterns. The PI-GRU also embeds the Circular Restricted Three-Body Problem (CR3BP) equations of motion into its learning process to penalize deviations from known physics in its predictions. This structure enables the model to capture historical satellite behavior while ensuring physical consistency, improving the timeliness and accuracy of anomaly detection. The resulting approach is both efficient and scalable for long-term prediction while remaining generalizable to previously unseen orbital behaviors. To supplement available real-world operational data, we also developed a custom CR3BP simulation environment to generate physically-grounded training data for orbit-to-orbit transitions.

Our preliminary results demonstrate that this hybrid methodology can effectively distinguish irregular, intent-driven orbital transitions from naturally degrading orbits well before they become kinematically apparent. However, to maintain SSA, operators must know not only *if* a satellite is behaving abnormally but also *why*. Future work will focus on expanding this framework into a full intent recognition pipeline. This pipeline will provide possible intents based on a satellite's position, capabilities, and behavior. Operators can then consider these predictions alongside their own contextual knowledge and any provided intelligence reports to determine the most likely course of action. Feedback from these operators will be used to refine and improve the system's future predictions of satellite behavior. By incorporating human insights, the system will correlate detected orbital deviations with potential target orbits to classify mission objectives and provide operators with enhanced foresight through an intuitive visualization interface. This system will provide a deployable tool that significantly enhances decision support, offering a critical operational advantage in the increasingly strategic cislunar domain. ☆

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

2d Lt Michael Dillon, Computer Engineer 711 HPW/RHWOH

Oko: A Framework for Advancing the Understanding of Co-learning

In the rapidly evolving fields of artificial intelligence and machine learning (AI/ML), the pursuit of co-learning between humans and machines is reshaping the landscape of technological development and military operations. A cornerstone of this transformation is the framework designed for research purposes to model the uncertainty, complexity, and dynamics inherent in co-learning processes.

Driving Factors

The modernization of our defense competencies, driven by DoD directives, emphasizes the integration of advanced AI/ML concepts into warfighter operations. Existing virtual and Synthetic Task Environments (STEs) often offer limited capabilities for integrating comprehensive methods to collect human and machine performance data. These data are critical for quantifying and qualifying co-learning processes. A significant challenge in understanding co-learning lies in effectively controlling, capturing, and communicating the progressive interactions between humans and machines.

With Oko as a green-field developed system, our team can instrument and capture the human and machine telemetry data for each permutation of learning between the two entities. This quantitative telemetry data can then drive the qualitative insights to define new measures for co-learning. The necessity for sophisticated solutions is clear as we seek to emulate the intricate interactions between humans and machines in various domains.

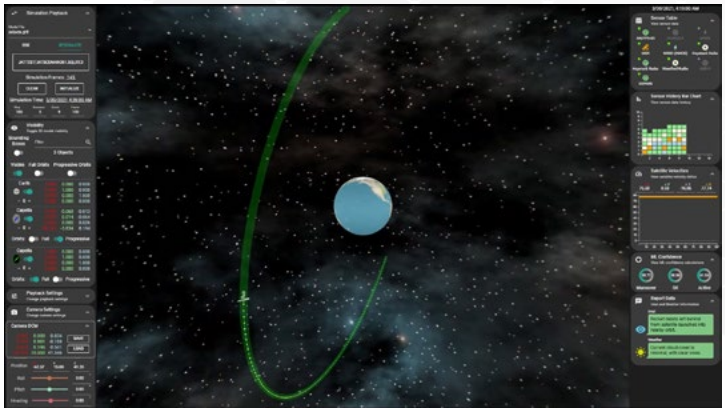
Key objectives driving Oko's development include:

- **Develop an AI/ML-driven Human-Machine Team (HMT) framework to support testing and evaluating co-learning**
- **Simulate real-world scenarios to evaluate HMT interactions.**
- **Quantify those interactions to provide metrics of co-learning.**

Oko provides a STE focused on simulating space situational awareness tasks which drive participants and machine learning models to categorize spacecraft orbits as active or station-keeping. This behavioral task provides an initial design for evaluating co-learning. Integrating these AI/ML concepts in a single architecture facilitates human interaction with various machine learning technologies, ensuring that data from both humans and machines is ingested and available for later analysis to foster that understanding.

Development Progress

Over the past twelve months, the Co-learning LOE has made significant progress in building the Oko framework. To start, orbital propagation software from academic collaborators has enabled synthetic data generation necessary for scenario development. Given these orbital propagation data, custom in-house developed interface software presents an interactive



Screen Capture by Mr. Allen Dukes, 711 HPW/RHWOH

view, allowing the user to pan, tilt, zoom, and rotate, which aids in understanding the relationships between orbital bodies. Alongside this interactive view, the presentation of additional synthetic data supports designing tasks to understand the decision-making processes of satellite sensor operators. These additional data types include sensor availability (current and historical), visualizations of magnitude changes in position and velocity for a spacecraft, Intel and Weather communication injects, and the outputs of a ML orbital classification model.

Experimental Progress

The first human-performance evaluation testing occurred in March 2025 with Ohio State University using the Joint Activity Testing (JAT) methodology as a co-learning metric. In the summer of 2025, a Repperger intern developed heuristic evaluations to enhance user experience and align with interface standards. A second JAT experiment occurred in February 2026 that combined real-time human inputs to machine learning models to understand the how machine learning adapts when given human inputs.

Future Research Directions

Understanding co-learning requires modular, robust, and adaptable architectural frameworks for data capture. This allows the development of innovative metrics for evaluating and accelerating warfighter decision-making processes. Additionally, the Oko framework enables the evaluation of interfaces in various modalities, with APIs facilitating each permutation of human-machine interactions.

For the USAF and USSF, creating Geostationary Earth Orbit (GEO)/Cislunar-specific metrics for operator adoption and performance remains an empirical challenge. The focus on operator performance within these unique domains is pivotal. By leveraging existing techniques and expanding on them, the Co-learning team is poised to gain insights into this emergent field.

Conclusion

The journey towards a symbiotic co-learning framework between humans and machines is marked by significant strides in research, evaluation, and collaboration. By addressing technical challenges and focusing on domain-specific needs, we are paving the way for a future where advanced AI/ML-driven systems enhance and accelerate human decision-making processes, ultimately leading to more effective and resilient defense operations. ☆

Mr. Allen Dukes, Computer Scientist, 711 HPW/RHWOH

Graphic by Mr. Will Graver (SierTek, Ltd.)

WARFIGHTER LEARNING TECHNOLOGIES

LINE OF EFFORT

As peer adversaries rapidly develop advanced capabilities and augment both the size and sophistication of their military capabilities, Airmen and Guardians face unprecedented readiness challenges including the need to work effectively and efficiently with force multiplying artificial intelligence (AI)-driven technologies and the need to serve in multiple roles as needs arise in contested environments. It is critical as we face emerging challenges that we improve how the Air Force trains for the integrated complexities of the joint all-domain command and control (JADC2) operating paradigm by pivoting to proficiency-based training (PBT) and optimizing our training pipelines through personalized education to accelerate acquisition of knowledge and skills and reduce washout. The Warfighter Learning Technologies (WLT) line of effort directly supports these critical readiness needs by rapidly developing and validating innovative training solutions that ensure our forces are not only prepared for the future fight, but possess a decisive capability advantage against peer adversaries.

Our work is guided by 4 interconnected aims:

- To **anticipate** future training needs by understanding the unique challenges new paradigms and capabilities pose to training.
- To **design** immersive training environments that ensure maximum training transfer to operational environments.
- To **track** individual and team proficiency with high granularity, temporal fidelity, and explainability for actionable insights.
- To **adapt** training pedagogy, individual regimens, and immersive training experiences.

Program Leads

LOE LEAD
Dr. Ryan Wohleber

PROGRAM MANAGER
Lt Alexandra Weisenburger

WLT currently achieves each of these aims through four core projects:

STRIKE

The aim of the *Strategic Training for Reasoning and Information Knowledge Extraction* project is to build an advanced AI-based training capability to make operators more effective users of the advanced AI-driven technologies they will rely on in the future fight. To achieve this, we are defining the role and job/task model for operators of autonomy across specialization, identifying and specifying competencies for this role, and using these competencies to drive development of experiential training content and pedagogy to achieve rapid AI fluency. Through this AI-based experiential training solution, STRIKE aims to reduce operators' time to proficiency when teaming with any advanced capability and maximize operators' understanding of tool functions, capabilities, limitations, and biases. STRIKE training will enhance operators' critical thinking about system outputs, recognition of patterns in autonomy behavior, adaptation of utilization or teaming strategies in real time, and will improve operator trust in systems they did not build and cannot fully control.

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Graphic by Mr. Will Graver (SierTek, Ltd.)

CICLOPS

As collaborative combat aircraft (CCA) capabilities near integration with 5th generation aircraft, the goal of the *Competency In CCA and Lethal Operations for Pilot Superiority* project is to **anticipate** training requirements, developing state and competency-based analytics in a live-virtual-constructive (LVC) environment. CAA operation requires unique tactics, techniques, and procedures (TTPs) for maximal lethality and thus requires careful calibration of the learning experience. CICLOPS-developed state analytics will ensure training experiences avoid over-saturation in the learning process while maintaining the level of challenge necessary to accelerate training and build resilience. CICLOPS-developed proficiency tracking via competency model analytics will ensure that content delivered and tasking practiced are within the learner's zone of proximal development (i.e., the set of tasks the learner cannot do independently but can accomplished with instruction). CICLOPS efforts will culminate in a software-based analytics package integrated into a blended environment that demonstrates the efficacy of model-based state detection and proficiency tracking for calibrating the CCA operator learning experience.

MAP

The aim of the *Model-based Assessment for Pilots* project is to develop personalized, PBT tools for pilots. The first phase of the project will produce an empirically-based cognitive skills assessment and training tool for undergraduate pilot training (UPT) as part of Air Education and Training Command's CRAFT program. This product is designed to broadly bolster development of cognitive skills necessary for pilot tasking across platforms. This initial deliverable will serve as an independent assessment and training battery. In the second phase of the project, MAP will adapt and extend it to an experiential pilot training environment thereby improving training transfer. The final phase of MAP will involve integrating predictive analytics to deliver personalized, proficiency-driven training recommendations, and model-based competency tracing to improve granularity of pilot proficiency estimations. Together these solutions will increase pilot throughput by mitigating washout and washback through targeted remediation and augmentation training and enhance retention and resilience of skill execution under stress and across time.

STS

The *Scalable Training Solutions* project develops an analytics tool designed for rapid, objective proficiency estimation in complex, large scale experiential training. While proficiency estimation and quantitative competency modeling have been achieved at smaller scales – typically for individuals and small teams, there is difficulty in scaling these analytics up from relatively well defined and constrained small team training contexts to large loosely structured teams of teams. However, this is a critical need that must be addressed to support simulated JADC2 operations where context is difficult to neatly define, team structure can be fluid, and rigid models struggle to consistently provide valid insights due to high degrees of freedom. Beyond the challenges in scaling up certain analytics are the practical constraints for large scale exercises including lack of lead time to inform, build, tailor, implement, and validate analytics, and lack of control over exercise structure. To improve support for instructors orchestrating large scale exercises and their work to generate after action reviews, STS will implement methods that operationalize subject matter expert (SME) knowledge to support online monitoring, sensemaking, and judgement of decision-making performance and other skill execution. These tools will provide objectivity and improve awareness during exercises and support rapid understanding of mission events post-exercise to support after-action review (AAR). While supporting instructor proficiency estimates these methods will also generate training data for more structured, data driven analytics approaches. The initial focus of this effort will be identifying and understanding information network errors. This work will leverage relationships with the Air Force Research Laboratory (AFRL) assets and collaborations such as the Gaming Research Integration for Learning Lab (GRILL) and Calamityville (Wright State University CRADA) to implement, test, and demonstrate this emerging capability.

While addressing their individual aims, each project supports ongoing development of a training ecosystem that will allow more targeted and efficient training through better proficiency estimates and theory-driven predictions. By thinking holistically about the solutions we develop in WLT, we aim to "pull all the capability out of every single Airmen that we put into harm's way, and…un-constrain them from the functional stovepipes that we grow them in today." (Chief Master Sergeant of the Air Force David A. Flosi; Air & Space Forces Magazine, 2024) creating a lasting readiness advantage over our peer adversaries. ☆

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

THE GAMING RESEARCH INTEGRATION FOR LEARNING LABORATORY®

GRILL® Vision

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

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

Wargaming Projects

The GRILL is enhancing warfighter training by developing advanced wargaming projects that leverage gamification. One key project, the Wargaming Toolkit, is designed to teach tactical and operational knowledge by simulating crucial decision-making scenarios, such as fuel management and air-to-air combat, in an engaging, game-based environment. Another significant effort is the digital replication of a tabletop Indo-Pacific Wargame, which allows players to explore military capabilities and limitations. This digitized wargame facilitates on-demand training and strategic learning outside the traditional classroom through rapid setup and gameplay. ☆

Photos by Mr. Will Graver (SierTek, Ltd.) / Screen Capture by The GRILL

Program Leads

GRILL TEAM LEAD
Mr. Stephen McGee

PROGRAM MANAGER
Lt Aathi Anandan

For additional information, visit the GRILL's website:

WWW.AF-GRILL.COM

Summer at the GRILL

During the summer of 2025 the GRILL hosted numerous Wright Scholars, teachers, United States Air Force Academy (USAFA) cadets, and interns. These participants worked collaboratively on community-driven challenge problems and developed free educational science, technology, engineering, and mathematics (STEM) content for teachers to use in the classroom.

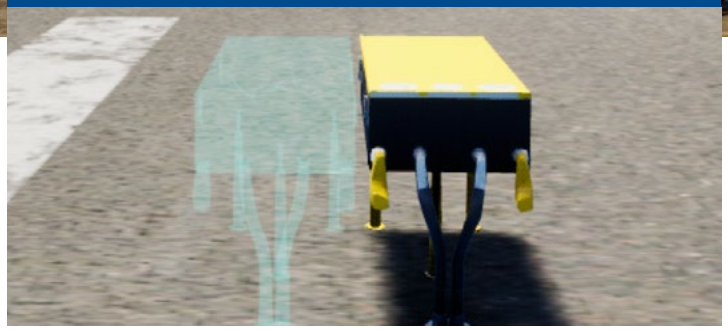
The Wright Scholar program is enhanced by experienced engineers, real-world customers, and team-based learning, impacting their future STEM career opportunities and the broader community.

1 Virtual Instruction in Surveying and Terrain Assessment (VISTA)

The Department of the Air Force (DAF) GeoBase program works with civil engineers to conduct geodetic and geometric surveys. One of the instruments that are used is the total station, a $38K device that is used for the surveys and requires a high level of accuracy and calibration to set up properly. The accessibility to this instrument for training is very scarce and its fragile nature makes it very difficult to train with. VISTA provides a realistic total station model in a virtual reality (VR) environment for personnel to learn how to safely and efficiently assemble the instrument, while tracking their performance and giving real-time feedback to the user.

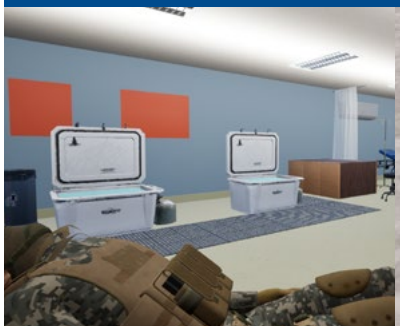
Screen Captures by the GRILL

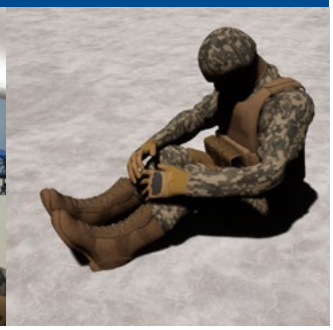
2 Rapid Airfield Post-Attack Training for Operational Restoration (RAPTOR)



RAPTOR is a VR training simulation for the DAF GeoBase program that trains airmen on rapid airfield restoration after an attack. It places users on a virtual, damaged runway where they must determine the Minimum Airfield Operation Strip distance and accurately position Precision Approach Path Indicator (PAPI) lights, critical for safe landings. The simulation focuses on the proper location and orientation of PAPI lights to ensure correct vertical glide path indication for pilots. By providing a cost-effective, realistic training environment, RAPTOR equips airmen to quickly and effectively restore airfield landing capabilities in real-world emergency situations.

3 Heat Casualty Response Training





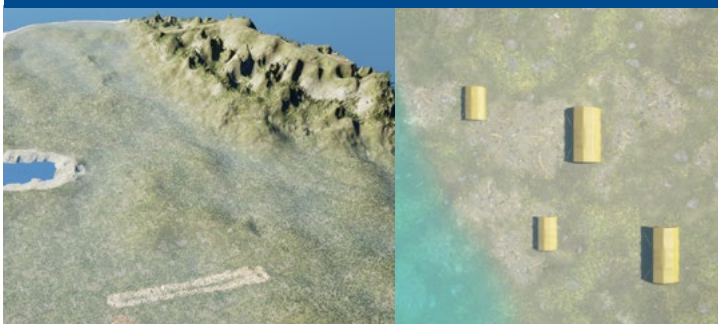
Heat casualties are a concern during large exercises like Basic Military Training. To address limited medical responders, the 37th Human Performance Squadron developed a virtual training simulation. This accessible simulation trains airmen on quick response procedures for heat casualties anytime, anywhere. Users engage in interactive gameplay with realistic equipment, treating virtual patients while being evaluated on their adherence to proper procedures. Real-time feedback on performance ensures effective learning and prepares all personnel to provide crucial medical assistance during heat-related emergencies.

Summer Challenge Problems

4 C-130 Laser Dazzle Flight Simulator

The C-130 aircrew are highly prone to laser dazzlement in-flight, impairing their vision and making them rely on instruments for flight. The team developed an interactive flight simulator with instruments that display the flights' motion. This is a step up from what is currently available in VR laser dazzle simulators where the instruments are static. This training simulator was created for the Radiofrequency and Optical Radiation Bioeffects (RHDO) of the 711th Human Performance Wing. This virtual training reality combined with other warfighting simulations will train warfighters and pilots to combat laser dazzlement in flight, and safely maneuver the C-130 aircraft.

5 Sight Assessment for Base Layout Establishment (SABLE)



SABLE is a touch-screen application that utilizes Unreal Engine and Android Studio to enable students in U.S Air Force School of Air Force Medicine (USAFSAM) Force Development Division (OED) to learn how to perform Occupational and Environmental Health Safety Assessments. This application allows users to explore and interact with landscapes, assess hazards, determine optimal locations for structure placement, and practice creating layouts for airfields with basic infrastructure that is safe and functional for operations. This application packages onto Samsung tablets and makes training easier, cost effective and available to more students in the virtual environment.

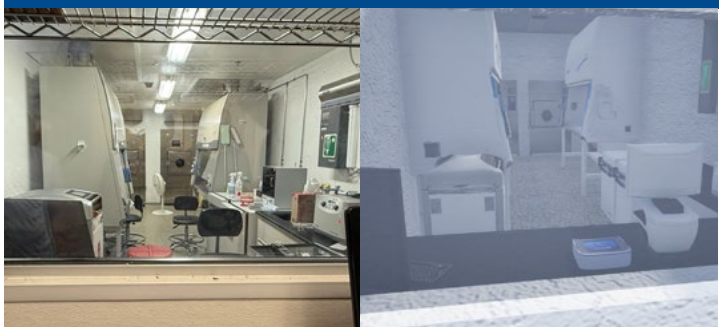
Screen Captures by the GRILL / Photo by Mr. Will Graver (SierTek, Ltd.)

USAFA Project

Land Engagement Adjudication Platform (LEAP)

The third year United States Air Force Academy (USAFA) cadets came to the GRILL for their Cadet Summer Research Program, a five-week research internship. Over their time at the GRILL, they continued working on the Land Engagement Adjudication Platform (LEAP), a critical tool from their Multi-Domain Laboratory. They focused on integrating the Distributed Interactive Simulation (DIS) protocol into LEAP allowing students to simulate land-based engagements and receive real-time feedback on their online platform to provide cadets with a joint warfighting environment.

6 Biosafety Level 3 Virtual Twin Lab



The Biosafety Level 3 Virtual Twin Lab is a virtual replica of the USAFSAM's Biosafety Level 3 Lab (BSL-3) that captures the exact setting down to all the model equipment in its precise locations. This project enables the Applied Technology and Genomics Division (PHT) to train students in a virtual reality (VR) setting which allows more personnel to train in the BSL-3, of which there are only two in the Air Force Research Laboratory (AFRL). This training simulation significantly reduces training cost and the risk of personnel getting exposed to infectious agents, providing a safe transition for students to train before working in the actual lab.

Full Throttle STEM®

The 11th annual Full Throttle STEM® (FTS) event, now hosted at both the Eldora Speedway in Darke County, OH, and in its fourth year at the National Museum of the United States Air Force, continues to be a fun-filled STEM experience. Drawing students primarily from Darke County, Montgomery County, and Cincinnati, the event showcased many science exhibits designed by students from several schools. The drone challenge this year required precise finite maneuvering skills with students to go through specific color based obstacles. 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 13 schools and close to 300 students, was a roaring success, celebrating STEM in a hands-on, engaging manner.

STEM Education

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

Several educators made notable contributions at the individual level. Jennifer Corder expanded her expertise in coding and mentored a FIRST® LEGO® League team. Macy Timmerman made the resources available on TeachersPayTeachers, a platform for educators nationwide to share their teaching programs and activities and strengthen collaborations with teachers across the country. Lisa Galpin worked on resources and knowledge sharing for teachers to share each other's work in STEM and enrich their skills to provide a wholistic teaching environment for students. Jill Weaver worked towards getting grants approved for underprivileged and rural school district students equal opportunities and took students to visit the Indianapolis Speedway track where they got to see autonomous race cars and interact with the racers. Jack Hu created a semester's curriculum for a game design class as well as four hours of workshop presentation content for the GRILL that will be presented at I/ITSEC. Finally, Bridgett Williams created in-depth projects and engaging activities for a 7th grade engineering course including an introduction to hydraulics, circuit and soldering activities, and an innovative elevator design project. ☆

Dr. Mark Draper
Warfighter Interfaces & Teaming
CTC Lead, 711 HPW/RHW

WARFIGHTER INTERFACES & TEAMING

CORE TECHNICAL COMPETENCY (CTC)

Operator interfaces are ubiquitous 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 while under constant threats of complexity, 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. Therefore optimized human-machine teaming (HMT) is required to win the next fight.

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, autonomous and intelligent machines, thus creating maximally effective and resilient HMT teams. WIT CTC research focuses on discovering, developing, evaluating, and transitioning adaptive warfighter interface technology, mission-optimized distributed team performance enhancements, communication management, and context-tailored intelligent decision aids/analytics in order to achieve and maintain decision advantage in complex environments. This CTC consists of two core research areas: 1) advanced human-machine interfaces (with emphasis on artificial intelligence (AI) and autonomy), and 2) distributed teaming and communications.

Warfighter Interfaces & Teaming CTC

Distributed Teaming & Communication CRA

Human-Machine Interactions CRA

Automation and AI technology can be exceptionally powerful when operating within defined situations/environments. However, they can become unreliable and unpredictable when operating outside of their competency envelopes. Current system design processes often strive to maximize machine capabilities across all fronts, which relegates the human role to handling any and all functions that the machine algorithms failed to accomplish. Thus, when contingencies inevitably arise, an out-of-the-loop warfighter is expected to suddenly intervene and 'save the day' with little time and resources available to properly assess, understand and act on the situation. This dilemma is often exacerbated by automation/AI designed with little-to-no explanatory ability as to its underlying functioning and reasoning (i.e., the 'black box' syndrome). A much preferred approach to system design is to consider the human and machine as a joint-cognitive system from the very beginning, where human and machine capabilities can be dynamically and smartly interleaved to continually maximize performance across a range of realistic operating conditions and contingencies. WIT research aligns with this preferred approach to HMT design.

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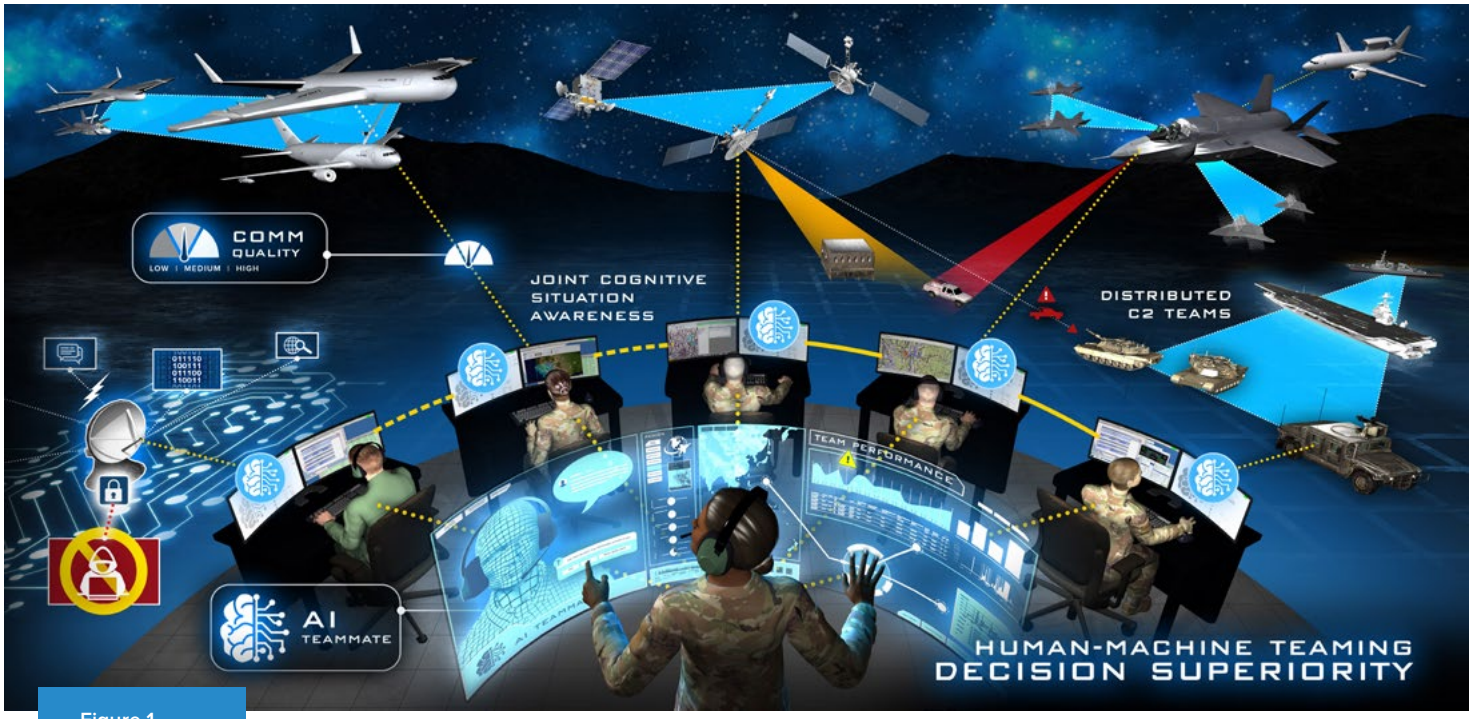

Figure 1

Graphic by Mr. Will Graver (SierTek, Ltd.)

In addition to the rapid expansion of machine capabilities, future fights will also be characterized by the need to 1) dynamically fuse information across different warfighting domains and 2) operate as increasingly agile distributed forces 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 multi-domain mission planning and execution activities across distributed heterogenous teams of warfighters and machines, and across C2 echelons (see Figure 1). Aggregating information across domains will create new information challenges (and opportunities) for the warfighter. In addition, communications between distributed forces will often be contested, degraded, or denied. 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 JADC2 environments.

CTC OVERVIEW

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

The WIT CTC is dedicated to conducting research 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 for the coming year include JADC2 battle management, base defense, and a variety of adaptive crewed-uncrewed operations.

So, what does the WIT CTC contribute to the fight? We provide contextually optimized HMT interaction and teaming solutions that empower warfighters 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. In the past year we have had multiple projects graduate to the next level of development, including those related to C2 Battle management (JADPACT), team assessment (FLARE), and agentic agent decision aiding (BoBCAT).

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), Intelligence, Surveillance, and Reconnaissance (ISR), Cyber, and JADC2 environments, FY26 looks to be another exciting and productive year! ☆

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

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

DISTRIBUTED TEAMING & COMMUNICATION

CORE RESEARCH AREA

Future wars will be waged 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 that result in missing, incomplete, or incorrect information; delayed information; potential misinformation; information saturation and information bottlenecks; and fog of war.

To overcome these challenges, 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. In response to 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 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 (LOEs): Dynamic Team Performance Assessment and Team Optimization and Recovery.

CRA OVERVIEW

Enhance the rapid formation, real-time assessment, and dynamically optimized performance of distributed, heterogeneous human-human and human-autonomy teams of warfighters for resilient mission operations through the creation of novel distributed communication and collaboration tools, technologies, and teaming management methods.

Distributed Teaming & Communication
CRA

Dynamic Team Performance Assessment
LOE

Team Optimization and Recovery (TOR)
LOE

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Graphic by Mr. Will Graver (SierTek, Ltd)

Dynamic Team Performance Assessment (DPTA) LOE

The Dynamic Team Performance Assessment (DTPA) LOE is working to enable the rapid formation, real-time assessment, and dynamically optimized performance of distributed heterogeneous teams of warfighters as well as human-machine teams to promote rapid, agile, and robust mission operations. Simply put, the DTPA LOE is focused on quantifying and modeling team processes and performance. Research areas include factors that influence the formation of mission-effective heterogeneous teams (Teamwork Fundamentals, POC Ali Momen), dynamic monitoring of team performance via optimal assemblage of novel and existing metrics (Novel Team Performance Metrics, POC Gregory Funke), multimodal information processing for contextualized sensemaking (Contextualized Communication Machine Learning, POC Jeremy Gwinnup), and real-time contextual aids from team communication (Agile Communications, POC Michael Tolston).

Team Optimization and Recovery (TOR) LOE

To complement DTPA's measurement and modeling of teams, the Team Optimization and Recovery (TOR) LOE focuses on developing tools for distributed heterogeneous team coordination, collaboration, and agility to maximize team performance. The TOR LOE is focused on optimizing teams with intelligent aids, adaptive displays, and informed teaming interventions. Research areas in this LOE include designing, developing, and evaluating team optimization and recovery technologies to enhance communication, coordination, and decision making among distributed teams (Team Collaboration and Resilience, POC Jessica Bartik), developing interfaces to support joint tasking and team shared awareness (SA) across multiple domains (Multi-domain Team Integration, POC Peter Venero), and conversational artificial intelligence (AI) technologies to enable high bandwidth natural communications with agent teammates (Tailored Expressive Dialog Systems, POC Emily Conway; Synthetic Agent Voice Analysis Generation and Exploitation, POC Grant Erdman).

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/RHWT

DYNAMIC TEAM PERFORMANCE ASSESSMENT

LINE OF EFFORT

Program Leads

LOE LEAD
Dr. Gregory Funk

PROGRAM MANAGER
Capt Mathew Kinneer

Harnessing AI for Creative Military Solutions: Insights from a USAFA Capstone

Joint distributed operations demand rapid and creative solution generation in human-machine teams. This project examined a central research question: *How should Airmen combine artificial intelligence (AI) assistance and team composition to generate ideas that are both inventive and fieldable?*

A team of five U.S. Air Force Academy cadets, mentored by RHW, explored this question using a set of military-relevant scenarios that required creative problem-solving. These scenarios tasked participants with developing concepts for new technologies, such as a system for covert non-verbal communication or a ruggedized wearable for climate control. Participants alternated between conditions: working alone or in pairs, with or without access to an AI assistant. Subject matter experts evaluated the final concepts on three established dimensions of creativity: originality, effectiveness, and implementability. This design enabled the team to systematically assess how AI and teaming influence creative problem solving.

A clear pattern emerged. First, access to AI expanded the solution space: concepts generated with AI support tended to be more original. However, those same ideas were less immediately implementable, highlighting the need for human judgment to translate novel suggestions into practical designs.

For operators and planners, the implication is straightforward: use AI to diverge and humans to converge. AI is best employed early in ideation to surface unconventional options. Human review and team refinement should follow, emphasizing feasibility, Concept of Operations (CONOPS) alignment, and mission timelines. An effective workflow involves personnel first generating ideas individually, then converging as a team to integrate and down-select—balancing novelty with practicality.

The project also produced tangible deliverables and professional outcomes. The cadet team completed the full research cycle, including design, data collection, analysis, and communication, and presented their results at the 2025 NDIA conference in Arlington, VA. The collaboration strengthened the Air Force Research Laboratory (AFRL)-USAFA ties and provided evidence-based guidance for integrating AI into distributed human-machine teaming. ☆

Dr. Ali Momen, Research Psychologist, 711 HPW/RHWTE

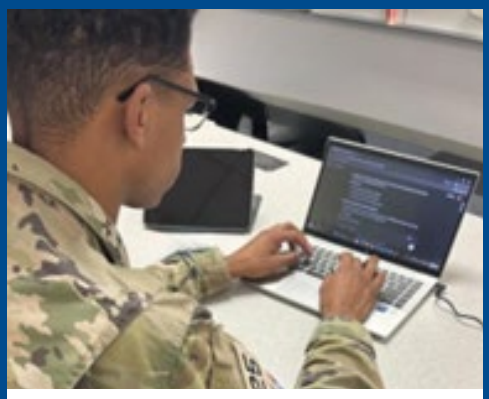
Dr. Gregory Funke, Senior Research Psychologist, 711 HPW/RHWTE

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

Photos by 711 HPW/RHWT

Participant interacting with CHATGPT 4.0

Participants collaborating without use of AI



Participant consolidating ideas

Preliminary findings suggest AI access broadens the originality solution sets but may come at the cost of implementability. Human evaluation is recommended to enhance the feasibility of ideas.

TEAM OPTIMIZATION AND RECOVERY
LINE OF EFFORT

Program Leads

LOE LEAD
Ms. Jessica Bartik

PROGRAM MANAGER
Ms. Lauren Morse

Interdependent Task Management Interfaces for Distributed Multi-Domain Teaming Operations

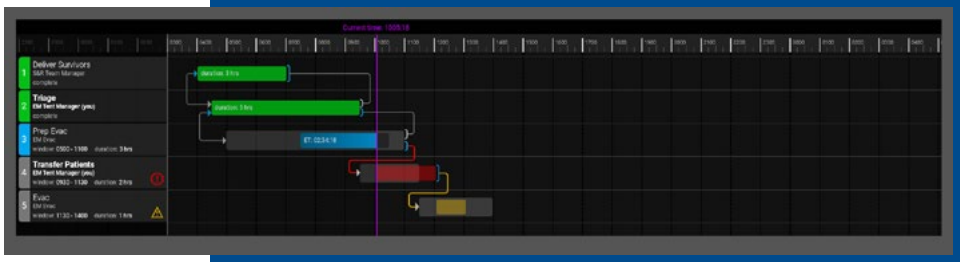
Within military research and development, the need for Mission Planning and Execution in Joint All-Domain Command and Control Systems is clear, and utilization of artificial intelligence (AI) to support joint planning to process data for human decision makers is critical to the efficacy of these systems. However, there is also a need to design a means for human interpretation of data such that joint missions can be optimally synchronized and executed. The Air Force Research Lab has begun to investigate this challenge via the Team Collaboration and Resilience project. A recent study (*N = 24*) evaluated candidate concepts (1. Timeline 2. Checklist 3. Combination) for interdependent task management utilizing Emergency Medical Services scenarios.

ANOVA results indicated that there was a significant interaction effect of Display Type with Question Type for response accuracy ($F(6,138) = 4.194$, $p = .001$, $\eta_p^2 = .154$). Specifically, the use of the Timeline Display resulted in higher accuracy for Dependency Questions, and the only Question Type it was not at least as accurate as the other Display Types was the Status Questions. This points to the efficacy of basing the Timeline Display's design on Kilgore's logical relationship visualizations between temporal intervals.

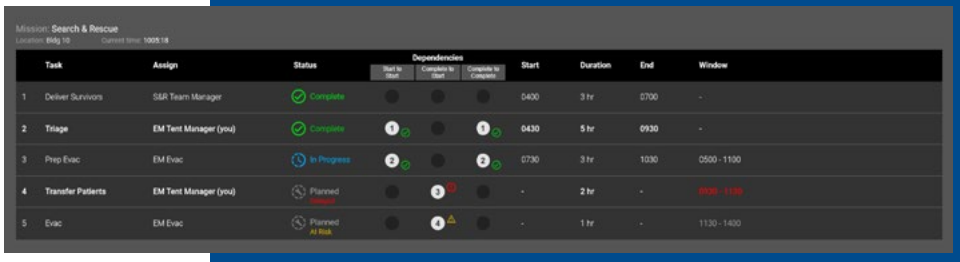
The results of this initial study will be used to inform the design of a high-fidelity, fully interactive, aggregate Task Management Interface that can support highly effective Joint All-Domain operations whereby domain management operators can quickly recognize alerts/issues, gravity of an alert, and impact to other team members. This research will support greater shared awareness which, along with properly calibrated intelligent decision aids, will allow the team as a whole to adapt to issues and replan mission elements without compromising entire mission parameters. ☆

Ms. Jessica Bartik, Research Psychologist, 711 HPW/RHWT
Dr. Hunter Oldham, Research General Engineer, 711 HPW/RHWTC

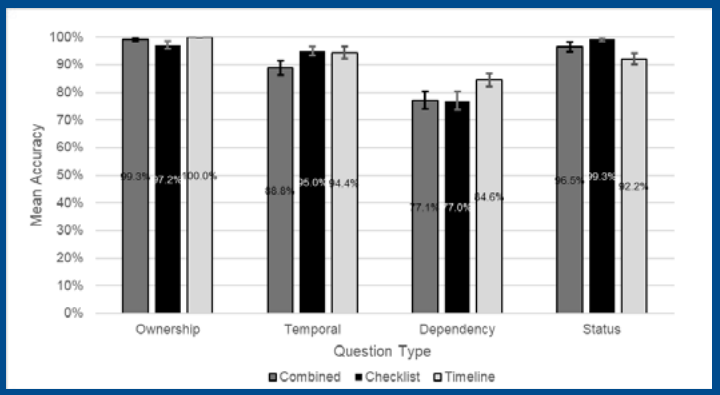
Timeline Display



Checklist Display



Mean Accuracy of Display Type by Question Type



Screen Captures and Graph by 711 HPW/RHWT

CITATIONS

Oldham, H., Ruff, H., Bartik, J., Frost, E.,Behymer, K., Eckert, A. & Schoening, S. (2024) Interdependent Task Management Interfaces for Distributed Multi-Domain Teaming Operations. In Proceedings of the NATO HFM-377 Symposium. Amsterdam, NL. Doi: 10.14339/STO-MP-HFM-377

CROSS-LOE COLLABORATION

TEAM OPTIMIZATION AND RECOVERY AND DYNAMIC TEAM PERFORMANCE ASSESSMENT

Domain Adapted Automatic Speech Recognition from CCML/SAVAGE for the DASH

711 HPW/RHWTE members have been leading efforts to support Decision Advantage Sprints for Human-machine teaming (DASH) throughout the summer of 2025 held at the Shadow Operations Center (ShOC) H2O Facility in Las Vegas NV. These events bring Government, Industry, and Academia together to test and evaluate new technology in support of the command and control (C2) enterprise with a focus on Battle Management scenarios.

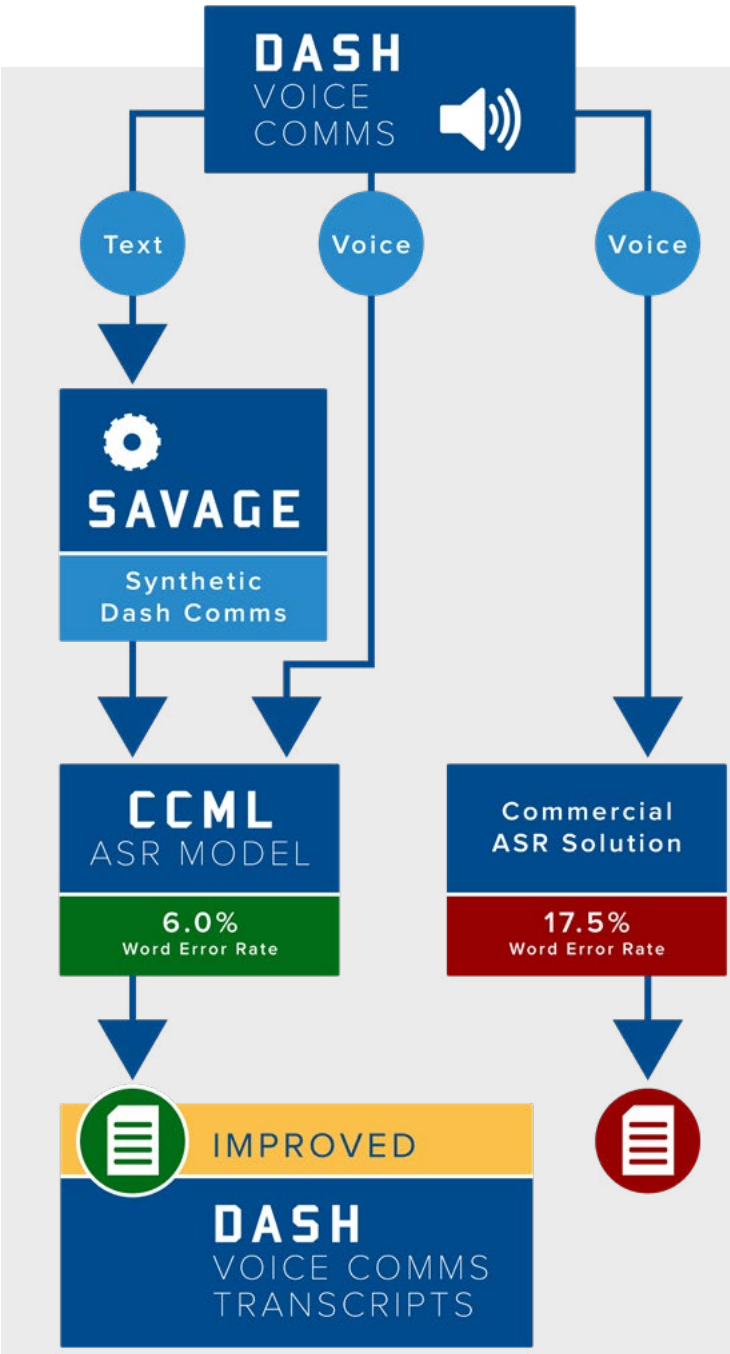
The first DASH event in June of 2025 employed commercial automatic speech recognition (ASR) technology for real-time transcription of operator communications that were then pushed into downstream analytics for the goal of delivering decision advantage to the team. The commercial ASR did not provide adequate accuracy and the resulting transcripts were never used due to the amount of errors they contained. 711 HPW/RHWTE stepped in and leveraged existing work through the Contextualized Communication Machine Learning (CCML) project and the Synthetic Agent Voice Analysis Generation and Exploitation (SAVAGE) project to build a better ASR system for this use case. First, it was determined that the commercial ASR system was delivering 17.5% Word Error Rate (WER) and that this value was unacceptable for the downstream microservices to use. Next, 711 HPW/RHWTE evaluated custom military trained ASR systems developed under CCML and determined the WER could be reduced to 9.3% when evaluated on the communications generated at the DASH. Noting the structure of the communications used during the DASH events, 711 HPW/RHWTE generated thousands of sample text sentences mimicking those call outs with multiple Callsigns, and Bearing, Range and Altitude values, and used this text to drive Text-To-Speech models being developed under SAVAGE. Over 10 hours of synthesized DASH specific speech was generated. This DASH specific synthetic speech was then used to fine-tune a new ASR model which was then measured to have a WER of 6.0%, a significant 11.5% WER reduction over the original commercial system. This solution was then delivered to ShOC-N and utilized in the July DASH event enabling the industry partners to utilize the operator communications in near real-time. The speed and the accuracy of this tuned ASR model was so successful that it will be used in all future DASH events. ☆

Mr. Brian Ore, Electronics Engineer, 711 HPW/RHWTE

Dr. Grant Erdmann, Senior Research Mathematician 711 HPW/RHWTE

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

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



Graphic by 711 HPW/RHWTE

Mr. Peter Venero
Human-Machine Interactions
CRA Lead, 711 HPW/RHWI

HUMAN-MACHINE INTERACTIONS
CORE RESEARCH AREA

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

Mr. Peter Venero
Human-Machine Interactions CRA Lead, 711 HPW/RHWI

CRA OVERVIEW

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

Human-Machine Interactions
CRA

HMI-enabled Decision Superiority
LOE

Rapid Joint Cognitive Awareness
LOE

HMI-ENABLED DECISION SUPERIORITY
LINE OF EFFORT

Program Leads

LOE LEAD
Former: Dr. Jordan Haggit

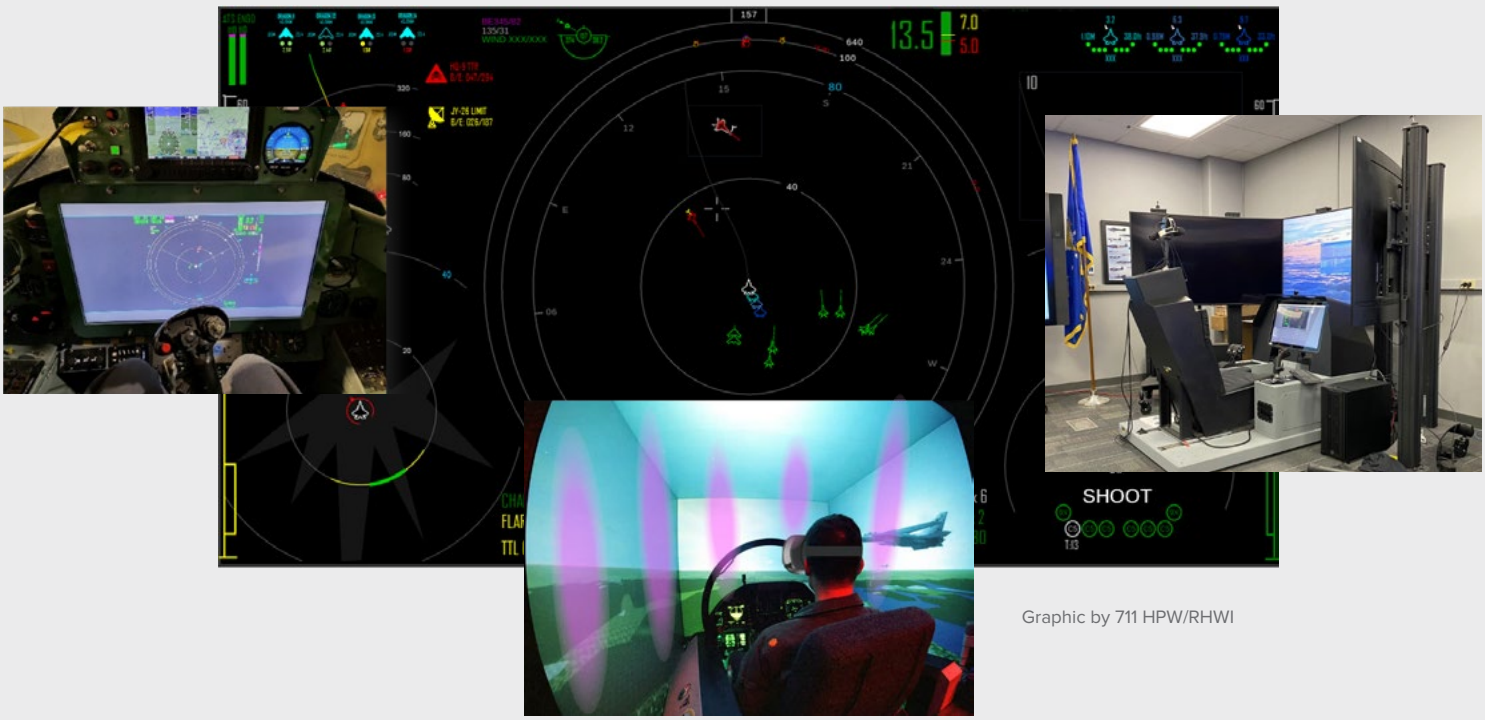
PROGRAM MANAGER
Lt Arianna Martinez

Next-Generation Human/Machine Interface Research (NG-HMI)

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

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

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



Graphic by 711 HPW/RHWI

Continuous Command and Control (C2)

The future battlespace requires a fundamental shift towards adaptive, continuous planning, to effectively navigate constant change, exponentially increasing data volumes, and increasingly sophisticated adversaries. Future planning must involve the constant re-evaluation of plans based on real-time data and changing circumstances, requiring a flexible and responsive approach to decision-making. Although necessary, planning beyond legacy capabilities places a greater demand on the cognitive work and collaboration of warfighters such as intelligence analysts. Analysts must more rapidly distill meaningful insights from vast quantities of ambiguous data, assess its relevance, and discern critical relationships, all while operating under strict time constraints dictated by mission objectives. The sheer volume of data threatens to overwhelm human cognitive capabilities, underscoring the urgent need for advanced decision support solutions.

One promising strategy is to leverage artificial intelligence's (AI) ability to rapidly process and analyze vast amounts of data, identify patterns, and detect anomalies. These AI capabilities will help analysts to overcome these challenges and enable them to focus on higher-level reasoning and decision-making. However, key questions persist regarding its impact on highly complex, dynamic, and ambiguous situations such as planning under uncertainty. This 6.2 research program aims to better understand how best to implement AI into analyst workflows to aid in such situations where human judgment and sensemaking are necessary, but the sheer amount of information and pace of the battlespace demands AI support. As such, we are looking at how best to optimize the human-AI system for critical tasks such as anomaly detection. AI development must align with operator needs and seamlessly integrate into existing workflows to be truly effective. Rather than a standalone solution, AI should serve as a tool to augment human decision-makers, providing valuable inputs for judgment while recognizing that it cannot function independently or engage in meaningful sensemaking. Therefore, it is crucial to empirically determine optimal AI implementation strategies, identify areas where it provides the greatest value, and understand how it best supports individual and team decision superiority.

With an initial focus on anomaly detection as a key function that often triggers plan re-evaluation and adaptation, we initiated the first in a series of experiments to investigate how individuals utilize Large Language Models (LLMs) in intelligence analysis tasks. We focused specifically on understanding how the timing and accuracy of AI-provided anomaly detection and subsequent Course of Action (COA) recommendations affect analyst accuracy, trust, and reliance in time-constrained intelligence analysis tasks. The task required participants to determine whether a single anomaly was present and whether that anomaly was critical enough to change COA from the current plan. AI assistance was given in the form of a recommendation that included information about the presence of an anomaly (or not) and whether that anomaly was critical. The AI correctly detected anomalies on approximately 83% of trials and provided the correct interpretation in 50% of trials. Participants were told beforehand that the AI was not 100% accurate and to validate its recommendation. Participants were not given AI accuracy feedback during the trials. In total there were 4 conditions administered between subjects that included:

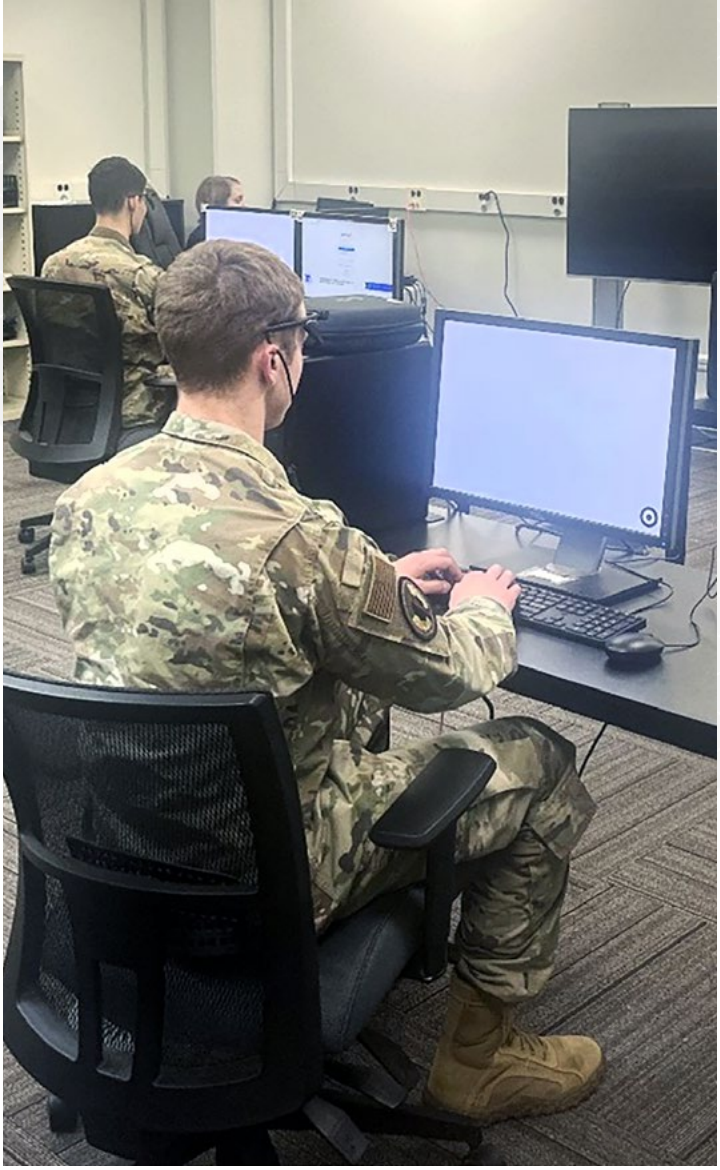


Photo by 711 HPW/RHWI

1. No-AI assistance.
2. AI assistance available during the entire scenario with the AI presenting either a correct or incorrect COA recommendation.
3. AI assistance available during the entire scenario with the AI presenting the opposite recommendation. For example, if anomaly A was interpreted as benign in condition 2, anomaly A was interpreted as critical in condition 3.
4. AI assistance was provided at the end of a scenario only after participants reviewed the information beforehand.

Continued on next page

MISSION: Critical Route

Mission Pre-Brief / Commander Intent:

This compound sits along a key convoy route previously assessed as low-risk. The position justifies active monitoring to protect movement along the corridor. A convoy is currently headed down this route and needs to know immediately if the route is safe.

Current Pattern of Life

Comms (Typical)	Imagery / GEOINT (Typical)	HUMINT (Typical)
• Low, sporadic radio activity: short calls, check-ins, and handheld FM chatter • No encrypted signals, high-bandwidth traffic, or satellite phone use detected • Signal strength terrain-dependent; no jamming or abnormal bursts near compound	• Occupants engaged in routine agriculture, livestock care, and tool use • Foot traffic limited to fields and compound; consistent daily patterns. No unusual activity like digging or loitering along roadside. • Single vehicle present; no signs of defense, patrols, or concealment	• Residents describe compound as long-standing family farm with no complaints • Neighbors note routine fieldwork, food prep, and occasional family visits • No reports of strangers, disputes, or unusual gatherings

MISSION CRITICAL LEVEL: HIGH

Charts by 711 HPW/RHWI

Figure 1

Figure 2

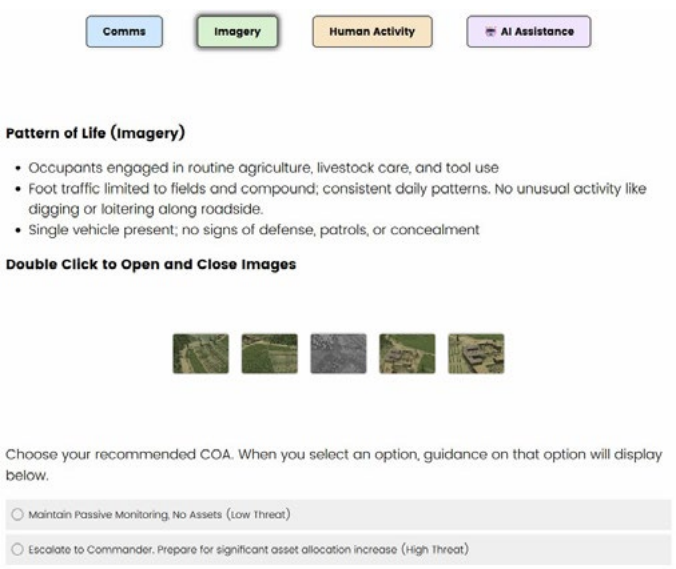


Figure 1 (above) displays a single trial. Page 1 provided a short mission pre-brief to understand the mission objectives and established pattern of life (PoL). PoL served as the basis to distinguish anomalies from normal activity. Page 2, displayed in Figure 2 (left), provided all raw intel and AI assessment accessible through toggle buttons. Participants chose to either maintain passive surveillance or escalate an anomaly to their commander.

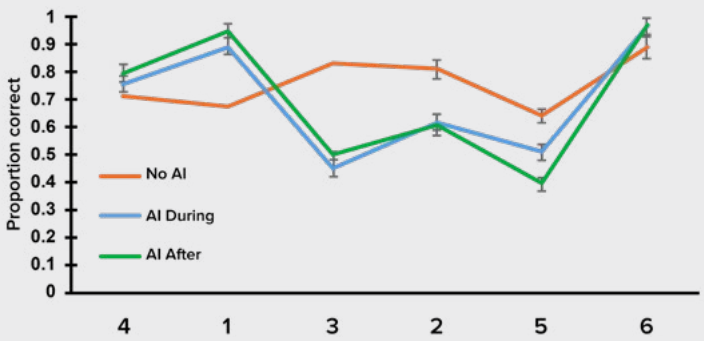
The differences in conditions were intended to better understand whether participants relied on the AI assistance regardless of correctness, and whether performance was dependent on when the AI assistance was given (available throughout the scenario, or only available at the end of the scenario).

Initial results are presented in Figure 3 (below). The main findings represented in the figure suggest that when AI correctly identifies an anomaly (left two data points) performance is better than when there is no AI support. On the other hand, if the AI recommendation is incorrect (middle two data points), performance is much worse than when there is no AI support. We believe this indicates a heavy reliance on the AI recommendation for this task. Surprisingly, performance was not dependent on whether AI support was given from the very beginning of a trial or only at the end, after participants reviewed the material independently. It will be important to continue to analyze the results and conduct future studies that help provide insight into how AI can be best integrated into critical ISR tasks. ☆

Dr. Jordan Haggit, Continuous C2 Research Lead, 711 HPW/RHWID

Figure 3

Group x AI Behavior Interaction



1. The AI correctly detects a significant anomoly and correctly recommends escalation
2. The AI correctly detects a significant anomaly but incorrectly recommends no escalation (AI misinterpretation)
3. The AI correctly detects an insigificant anomaly but incorrectly urges escalation (AI misinterpretation)
4. The AI corretly detects an insignificant anomaly and corretly recommends to stay passive
5. The AI fails to detect a real anomaly, requiring the participant to identify the issue independently (AI missed detection)
6. The AI correctly detects no anomaly and correctly recommends to stay passive

RAPID JOINT COGNITIVE AWARENESS
LINE OF EFFORT

Program Leads

LOE LEAD
Dr. Jim Bliss

PROGRAM MANAGER
Lt Arianna Martinez

Multilevel Transparency for Human-Autonomy Interaction

Transparency is a psychological construct describing the degree to which users can perceive and ascribe meaning to machine systems, guiding their trust and reliance (Chiou & Lee, 2023). Given the opacity in emerging complex machine systems, there are calls for methods to promote system transparency (AFDN 1-24, *Artificial Intelligence*). As transparency in human-autonomy interaction will act as a force multiplier in the Future Fight, research explicating when, why, and for whom transparency is relevant in human-machine interactions becomes increasingly necessary.

The Multilevel Transparency for Human-Autonomy Interaction Project (MTHAI) is identifying ways to promote artificial intelligence (AI) / machine learning (ML)-enabled system transparency through systematic, human-centered experimentation with the goal of facilitating calibrated trust toward and effective use of complex machine systems.

In FY 25, MTHAI investigated the influence of ML-enabled explainability affordances in decision support systems for non-image-based data classifications in both in-person and online experiments. These findings were delivered to a 6.3 Program partner in RHWT, and future iterations with a multi-pronged approach investigating large language models (LLM) with varying transparency and capabilities have been planned for 6.2 Applied Research in FY 26 and beyond.

MTHAI has successfully capitalized on the advancements of LLMs and other forms of Conversational Artificial Intelligence systems, positioning the DoD at the cutting edge of human-centered interaction with next-generation technology, shaping the future of battlefield strategy and operational capabilities. For example, through a 2-year 711 HPW/CL funded effort, MTHAI partnered with the Information Directorate (RI) and RHWTE to examine how tailoring these systems to a user's expertise might both accelerate workflows of expert intelligence analysts while also providing instructional on-the-job training for novice analysts.

In addition, MTHAI continues their 6.1 Basic Research efforts identifying foundational transparency guidance for human-AI/ML interactions and methods of promoting eXplainable AI (XAI) for effective human-machine teaming. MTHAI also successfully completed their 2-year cross-organization collaboration (RHB, 59th Medical Wing) investigating decision support applications for aeromedical evacuation, the outcome of which offered transparency guidelines for decision support systems and a candidate clinical validation automation system vetted by end-user warfighters in emergency aeromedical evacuation. MTHAI also continues their international collaboration with NATO partnering nations on human-centered design promoting successful human-robotic swarm interactions.

> **"With the increasing ubiquity of opaque AI/ML-enabled systems, guidelines which increase system transparency for users must be identified and leveraged to promote Decision Superiority in Human-Machine Teaming."**
>
> — Multilevel Transparency for Human-Autonomy Interaction Team

Deliverables include transparency guidelines for Advanced Technology Development programs, as well as inputs for inter-Division (RHB) candidate products and cross-Directorate stakeholders (RI). Some identified interface concepts promoting transparency include: a) needs from emergency aeromedical medical professionals, which were instantiated in a candidate decision support system by RHB for an end-user evaluation; b) coupling accurate algorithms with XAI software for non-image-based data classification; and c) users' preferences of XAI features and modality of a decision support assistant's explanation. Collectively, MTHAI explicates effective human-AI/ML/XAI interactions, an emerging human-machine teaming context, to promote the 711 HPW Decision Superiority Operational Concept. ☆

Dr. Gene Alarcon, Senior Research Psychologist, 711 HPW/RHWID
Dr. August Capiola, Research Psychologist, 711 HPW/RHWID
Mr. Dexter Johnson, Research Computer Engineer, 711 HPW/RHWID
Ms. Sasha Willis, Associate Research Psychologist, 711 HPW/RHWID

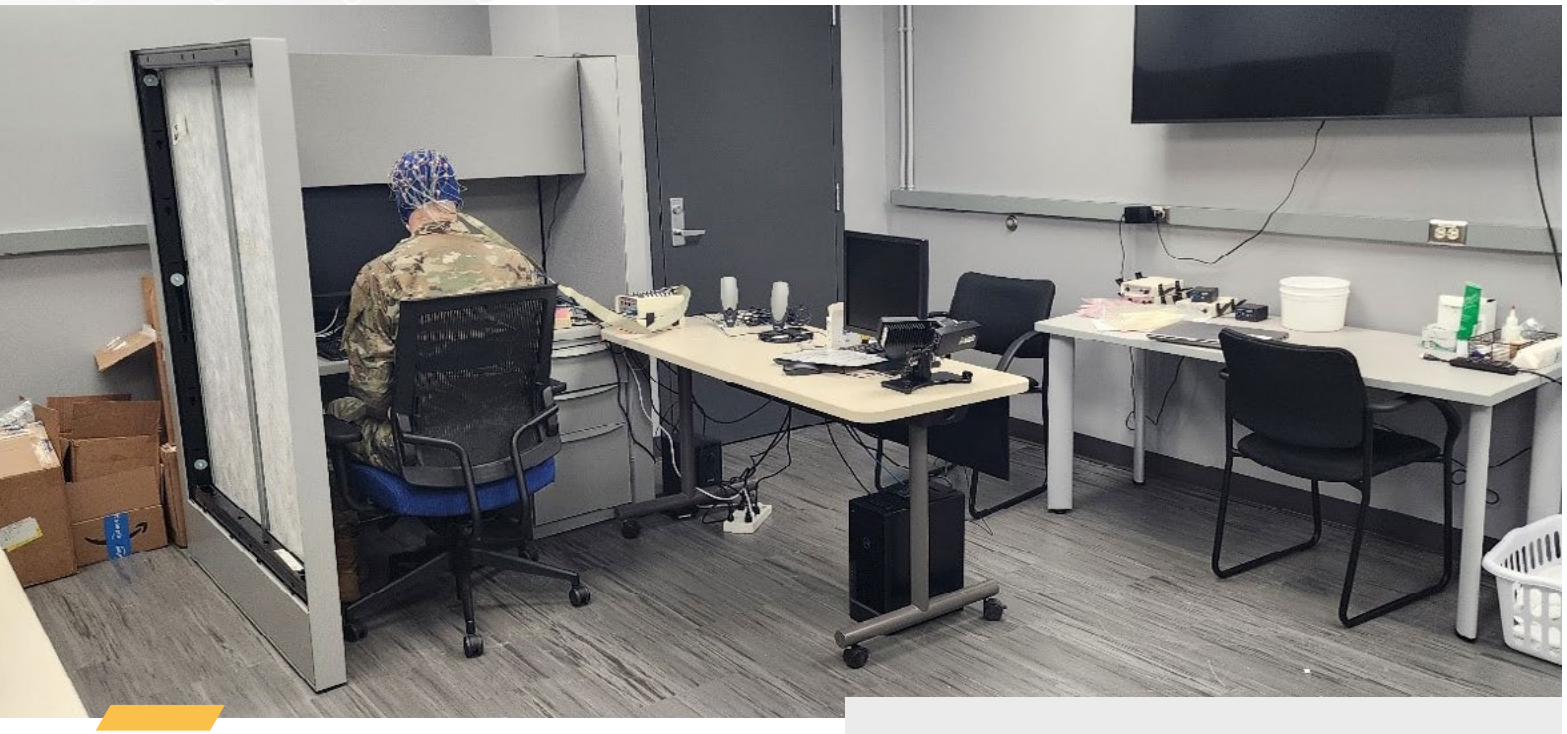


Fig. 1. Military participant seated at the primary task workstation.

Photo by Erica Christoffers (Parallax)

Closed-Loop Human-Automation Interaction (CLHA)

Given the importance of human-machine teaming in future conflicts, the interdependence between human operators and automated systems remains a critical focus of Air Force researchers. Many Air Force systems feature a role for dynamic artificial intelligence and machine learning (AI/ML) coordination (MOBIUS, JADPACT, LEGION, BoBCAT). As such, it is increasingly important that human operators remain cognizant about automated operations and that sharing and delegation of responsibilities occurs seamlessly in real time.

Many researchers and task developers have focused on "task shedding" or delegation of entire tasks to automation (and back to the human). Given the particular need for human Intelligence, Surveillance, and Reconnaissance (ISR) operators to stay in the loop, perceptually and cognitively, recent efforts have begun to concentrate on ISR-relevant use cases that feature joint task completion between human and automated partners. Successfully achieving such sharing would likely ensure a more effective balance of workload and situation awareness while allowing human operators to demonstrate improved resilience when resuming responsibility of task execution.

The Closed-Loop Human-Automation Interaction Adaptation (CLHA) project is part of the Rapid Joint Cognitive Awareness Line of Effort within the Air Force Research Laboratory's (AFRL) Warfighter Interfaces and Teaming Core Technical Area. CLHA has acknowledged the complexity of human-automation task sharing and created a new laboratory by which to further explore this area (see Fig. 1). CLHA researchers have teamed with researchers from the Bioeffects Core Technical Competency to collect data focused on six questions: WHO should initiate task transfer, WHEN transfer should occur relative to mission demands, HOW transfer should be signaled to the operator, WHERE on the operator's screen indications should occur, WHY transfer is occurring based on operator state, and WHAT elements of the task should transfer during a mission.

A central focus of the CLHA research plan is the conceptualization and development of a modular executive tool to balance task responsibilities in real time. The ACME (Automation Coordination Management Engine) is anticipated to function as middleware that leverages available information about operator state and bandwidth, mission priorities, past tactical and strategic successes and failures, and adversary intelligence to direct task responsibilities. This ACME tool is anticipated to enhance the adaptive capabilities of many projects including BoBCAT. To accomplish this, the team anticipates leveraging standalone agentic AI functionality.

To date, data have been collected from 200 participants across four experimental testing sessions. Results have addressed questions about who should initiate task transfer, when human operators should be notified about transfer, and whether feedback should be provided to operators. Progress has also been made toward development of an ML-based algorithm for integrating physiological data with performance data, and toward the development of an agentic AI application. Upcoming data collection sessions will focus on non-intrusive strategies for informing operators of impending task transfers and refinements to a ML algorithm for assessing physiological states. ☆

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

RHW FY25 SUCCESSES

Digital Models of Cognition CRA

- Transitioned human modeling government reference architecture, Enhancing Cognitive Human Operability (ECHOES), candidate product V1.0 and Advanced Framework for Simulation, Integration, and Modeling (AFSIM) Air-to-Air Combat simulation use case to Bioeffects Product Line.
- Transitioned Safe-to-Fly documentation to support Night Vision Imaging Systems (NVIS) compatibility test requirements including specialized laboratory testing for AFLCMC/WISM (C-130J), WNB (T-7), WN/ROU (Aeromedical Equipment), Crew Systems (B-21), and WNY (LAIRCM) Program Offices.
- Developed progressive web application version of Fatigue Optimized Cognition Under Stress (FOCUS) Mission Readiness App and transitioned to AMC HQ/A3TO to accelerate testing and validation.
- Enhanced COMBAT-AFRL/711 wargaming digital gameboard with new personnel fatigue risk metric to inform ops decision-making and transitioned to Booz Allen Hamilton and Air Force Futures.

Intel Accomplishments

- Air Force Intelligence, Surveillance, and Reconnaissance (ISR) Awards Program wins at the AFRL level, 1 July 2024 – 30 June 2025: SNCO – MSgt Ryan Swindlehurst, FGO – Maj Matthew Fagan, and ISR Unit (RegAF) – 711 HPW Intelligence Team.
- Legion suite Intel Research and Development (R&D) team traveled to Joint Base Pearl Harbor-Hickam to observe ISR operations in the 613th AOC with the ISR Division (ISRD) and SIDO (Senior Intel Duty Officer) team. They provided Kraken tool (part of Legion suite) training to over 14 AOC/ISRD ISR Operations and SIDO personnel and collected 39 additional user stories from teams within ISR operations, improving the suite's future operational integration and participation in exercises.

Warfighter-Machine Integration PL

- Enhanced Intelligent Multi-UxV Planner w/Adaptive Collaborative Control Technologies (IMPACT) executed final demo for Medusa Command & Control Counter sUAS technology transition.
- Machine-Operator Blending for Integrated Uncrewed Systems (MOBIUS) human machine interface controlled multiple MQ-28s for 10+ hours across four flights, providing crucial evidence that the Collaborative Combat Aircraft (CCA) concept is feasible for bringing increased combat mass to future operational scenarios.
- Joint All-Domain Persistent with Adaptive Collaborative Technologies (JADPACT) project collaborated with Advanced Battle Management Cross Functional Team (ABMS CFT), 805th Combat Training Squadron (CTS), operational warfighters, and industry software developers to execute Decision Advantage Sprints for Human-machine teaming (DASH) multi-week events that enhance Decision Advantage capabilities for the warfighter.

Modeling & Simulation Integration Lab

- Demonstrated initial capabilities leveraging the Joint Simulation Environment to the DAF Modeling and Simulation Council's General Officer Sterring Group, including:
  - Data sharing across multiple common operating picture (COP) systems linking research, test and training, and operations
  - Integration and execution of autonomous aircraft technology
  - Demonstration of human-machine interfaces for shared control of autonomous aircraft
- Accelerated Defense Advanced Research Projects Agency's (DARPA) Artificial Intelligence Reinforcements (AIR) program by hosting 2v2 experimentation.
- Transferred MQ-9 simulator unit to Air National Guard at Springfield, OH to support training needs, including participation in exercises and events hosted by Joint Forces Readiness Center (JFRC).

EST. 2001

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Cleared / Case # AFRL-2026-0704

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