AFRL FIGHT'S ON!

THE AIR FORCE RESEARCH LABORATORY

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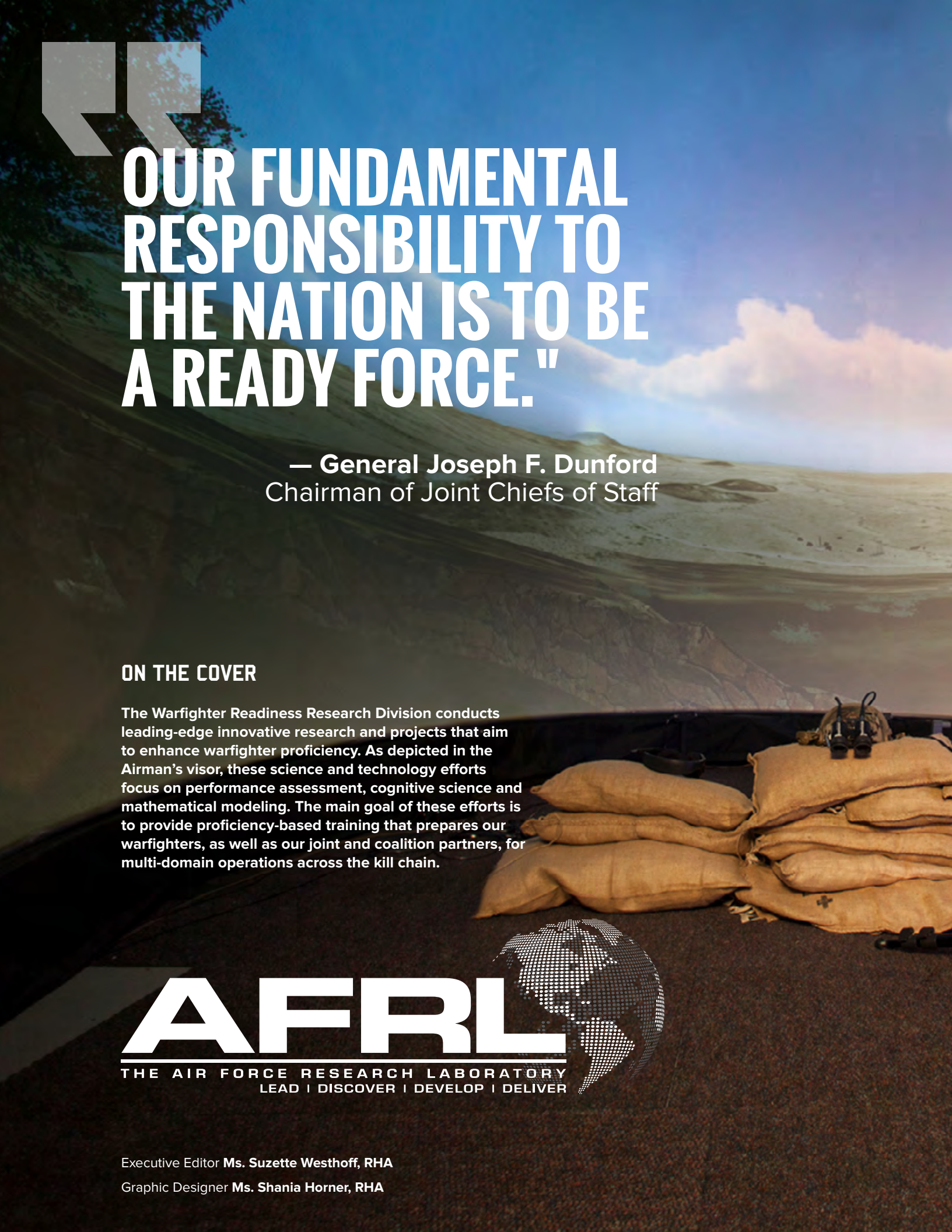
FALL 2019

OPTIMIZING WARFIGHTER PROFICIENCY

Transformative Readiness Across the Kill Chain

I/ITSEC Edition



"OUR FUNDAMENTAL RESPONSIBILITY TO THE NATION IS TO BE A READY FORCE."

— General Joseph F. Dunford
Chairman of Joint Chiefs of Staff

ON THE COVER

The Warfighter Readiness Research Division conducts leading-edge innovative research and projects that aim to enhance warfighter proficiency. As depicted in the Airman's visor, these science and technology efforts focus on performance assessment, cognitive science and mathematical modeling. The main goal of these efforts is to provide proficiency-based training that prepares our warfighters, as well as our joint and coalition partners, for multi-domain operations across the kill chain.

AFRL
THE AIR FORCE RESEARCH LABORATORY
LEAD | DISCOVER | DEVELOP | DELIVER

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Photo by Mr. Will Graver

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Photo by Mr. Will Graver

RHA

WARFIGHTER READINESS RESEARCH DIVISION

The Warfighter Readiness Research Division is one of five divisions that comprise the Air Force Research Laboratory's Airman Systems Directorate, a key component of the 711th Human Performance Wing.

The Division supports our nation's warfighters by creating and validating training research methods, models and technologies for learning and readiness across Air Force missions. Teams of researchers, engineers and subject matter experts conduct the work required to provide our warfighters affordable, adaptable and personalized training.

The Division's branches are:

Continuous Learning and Performance Assessment (RHAS)

Cognitive Science Models and Agents (RHAC)

Warfighter Readiness Research Operations Support (RHAO)

TRAINING SYSTEMS PRODUCT GROUP

The Training Systems Product Group is the name assigned to the collective relationship between the 711th Human Performance Wing, Airman Systems Directorate, Warfighter Readiness Research Division and the Air Force Life Cycle Management Center, Agile Combat Support Directorate and Simulators Division. The Group works closely with the Air Force for modeling and simulation (the Air Force advocate for Modeling and Simulation policy). The group's mission includes the following exciting challenges.

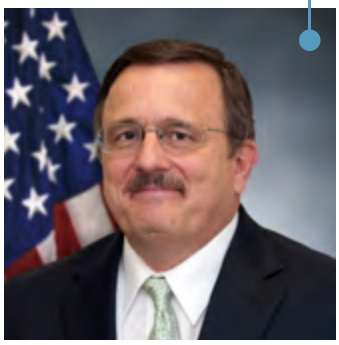
- Advancing the state-of-the-art in simulation technology
- Keeping current trainers fully capable and concurrent with aircraft
- Delivering new systems to meet emerging training needs
- Promulgating Distributed Mission Operations throughout the Air Force

The Training Systems Product Group dedicates its efforts to superior training systems that maximize the mission effectiveness of our Airmen!

THESE LEADERS HELP MAKE OUR MISSION SUCCESS POSSIBLE

Col Danny “Floyd” Slifer
Division Chief, RHA

Dr. Winston "Wink" Bennett
Readiness Product Line Lead, RHA



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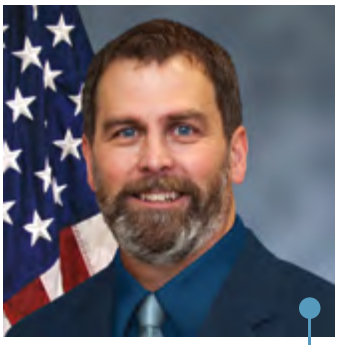
Deputy Division Chief, RHA

Dr. Glenn Gunzelmann
Core Technical Competency Lead, RHA

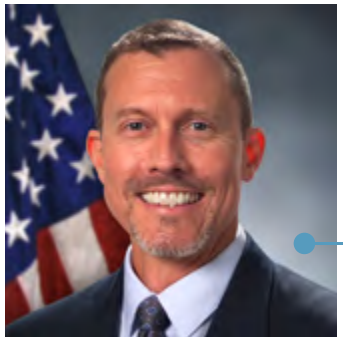
Mr. Phil Peppler
Branch Chief, RHAC

Lt. Col José Fadul
Deputy Branch Chief, RHAC



Mr. Jeffrey "Sam" Griffith
Branch Chief, RHAO

Dr. Christopher Myers
Core Research Area Lead for Cognitive Modeling, RHAC



Dr. Kevin Gluck
Core Research Area Lead and Principal Cognitive Scientist, RHAC

Maj Eric Wolf
Branch Chief, RHAS

Dr. Leah Rowe
Branch Technical Advisor, RHAS

CORE TECHNICAL COMPETENCY LEAD

Transformative Science and Technology to Enable the Future of Readiness

Dr. Glenn Gunzelmann
Core Technical Competency Lead, RHA

> **The only constant is change."**
>
> **—Heraclitus**

OUR DIVISION EMPHASIZES

Research in the blending of Live-Virtual-Constructive (LVC) technologies

Performance measurement and assessment

Cognitive Science

Computational and mathematical modeling

Welcome to the 2019 fall edition of "Fights ON!" for the Interservice/Industry Training, Simulation and Education Conference (I/ITSEC). During the last year and a half, our parent organization, the Airman Systems Directorate, has undergone significant change. One result is that about a year ago, I became the Core Technical Competency Lead for Training, which was formerly held by Dr. Winston “Wink” Bennett. Fortunately, he remains within the Warfighter Readiness Research Division (RHA) as the Airman Systems Directorate’s Readiness Product Line Lead. Roughly speaking, that means that Wink is focused on more mature research and capabilities (late 6.2 and 6.3), while I emphasize foundational and earlier applied science and technology research (6.1 and 6.2).

Even with these changes in responsibility, however, our mission remains intact. The Division conducts research on learning and cognitive science methods, models and technologies for personalized, career-long proficiency-based training and readiness management to provide Airmen the knowledge, skills and experiences to maximize mission effectiveness across the full range of operations and environments. Our Division emphasizes research in the appropriate blending of Live-Virtual-Constructive (LVC) technologies, as well as in performance measurement and assessment, cognitive science, and computational and mathematical modeling.

At the same time our organization is changing, so is our thinking about warfare. Air Force Chief of Staff General David Goldfein remarked in 2017 that, “We are transitioning from wars of attrition to wars of cognition.” Intense focus and attention has been placed on artificial intelligence and autonomy in this evolution. However, it is clear that the ongoing revolution in artificial intelligence and its applications across the technological landscape will unfold similarly to previous technological revolutions. The roles that humans play are likely to change, but the need for trained, ready and equipped warfighters to make effective use of the technology will only increase.

To support the future of readiness means RHA is changing as well. We are expanding research into technologies to support adaptive personalization technologies for more effective and efficient learning, knowledge and skill retention, as well as robust and agile mission readiness. At the same time, we are redoubling our efforts to mature and transition technologies derived from research to understand the computational capacities and limitations of human cognition to create teammates, adversaries and coaches for training systems that have sufficient cognitive fidelity to provide meaningfully realistic training experiences for human counterparts. The focus of all of this research is to ensure our Airmen have the knowledge, skills and abilities to meet mission objectives in every operation.

You can read about the Division’s impressive array of research efforts in the remainder of this issue. As you do, I hope you will recognize that we are not only researching how to adapt training practices to the evolving operational environment, but we are also changing readiness for the future of the United States Air Force. I look forward to you stopping by the Air Force side of the Quad Services Booth 1533 to see some of the things we have been working on and the advances we have made! We welcome your comments on our work, and I invite you to contact me, or any of our team members, to explore opportunities for collaboration and partnership.☆

Dr. Glenn Gunzelmann, Training Core Technical Competency Lead, RHA

READINESS PRODUCT LINE LEAD

A hearty welcome to the 2019 "Fights ON!" I am excited to share some of our work and great successes. 2019 was an incredible year of change in our Airman Systems Directorate with a reorganization that affected two science and technology divisions and provided new opportunities for collaboration and support.

This year we closed out our 10-year research collaboration with the 31st Fighter Wing at Aviano Air Force Base (AFB), Italy. The work led to novel advances in our field-evaluation regimen while it provided regular simulation-based training opportunities as the Wing anticipated the stand up of their full-fidelity mission training center. The feedback received and the technological advancements made enabled us to field technology that supports the Commander Air Combat Command's (COMACC) Future Training Concept. A huge shout out to the 31st Fighter Wing and the 510th, 5th and 555th Fighter Squadrons for their tremendous support and collaboration!

Additionally, working with Air Combat Command operations personnel at Langley AFB, we completed top-line coordination for the Future Training Concept and are pressing ahead with pathfinder efforts aimed at placing our performance measurement, tracking and feedback technologies in the field for evaluation.

We also continued a great partnership with the Warrior Preparation Center at Ramstein, Germany. There we have a four-ship of our new Mission Adaptive Tactical Training Immersive Environment and our performance measurement and tracking and debrief technologies, which support their mission sets. Our four-ship complements our Joint Theater Air Ground Simulation System (our new Air Support Operations Center trainer being fielded in partnership with the Simulators Program office) and our Next Generation, Multirole Fighter Instruction and Rehearsal Environment (our low-cost, flexible F-35 training environment).

Also this year, we continue our comprehensive Joint Service training and rehearsal events at our Dayton, Ohio facilities. The quantity and diversity of the training data we continue to harvest has led us to explore innovations and best practices in "big data" analytics. Very soon, we want to standardize how we capture, store, retrieve and package our research data for a variety of applications, such as machine learning, mathematical modeling and longitudinal trend analyses of training and readiness effects.

In close partnership with our United States Air Force customers at Air Education and Training Command and Air Combat Command as well as our Simulators Program Office colleagues, our Division is creating and transitioning proof-of-concept developments in learning management and performance measurement technologies, game-based applications for aircraft maintenance and medical training and low-cost options for realistic fifth-generation tactical training.

We continue to advance the state-of-the-art with industry leaders to create more rapid agent and teammate models using operational mission data. This year's work progressed to much more tactically rich and operationally relevant contexts. You'll see some of our "Wink's Not So Grand Challenge Partners" on the floor identified by their booth signs!

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Dr. Winston "Wink" Bennett
Readiness Product Line Lead, RHA

Our academic, industrial and the international partners continue to grow their interest and involvement in collaborations with us. We have a number of new agreements, partnerships and contract activities underway. Our Division is growing its already strong support of our international standards development and involvement in multinational research and technical groups. I invite you to contact me or any of our team members to explore opportunities for collaboration and partnership.☆

Dr. Winston "Wink" Bennett, Readiness Product Line Lead, RHA

OUR WORK

Advances the state-of-the art in learning, performance and modeling

Drives "innovation at the speed of Ops"

Develops solutions and capabilities (informing Air Force vision and investment)

Aligns with academia, acquisition and industry to transition effective and efficient methods and technologies

Contributes to the operational readiness of our Airmen

COGNITIVE MODELS CORE RESEARCH AREA

Cognitive modeling is a set of formal, mathematical or computational approaches that contribute to an understanding of the human mind and or facilitate the development of models capable of operating as intelligent teammates, adversaries, coaches or cognitive performance prediction systems. The key objective of the Cognitive Models Core Research Area is to conduct leading-edge foundational research on invariant human cognitive capacities and novel integrations with AI (artificial intelligence) approaches to develop synthetic teammates and effective cognitive performance and prediction systems.

There are three research foci.

Multiscale Models of Cognitive of Performance focuses on development of models that can predict cognitive performance given the exposure to environmental stressors (i.e., toxins, oxygen deprivation, fatigue, workload etc.) across different levels of analysis, from the biological to the cognitive.

Machine and Social Interaction focuses on research involving computational approaches to contextually sensitive, situationally aware models that facilitate natural communication and coordination in team-based tasks and paradigms.

Teachable Training Agents focuses on novel approaches to developing cognitive models rapidly through the development and leveraging of foundational cognitive capacities, such as skill acquisition and retention, reading comprehension, instruction taking, common-sense reasoning, context or situation awareness and metacognition, including the use of machine learning and planning techniques across large, existing datasets. ☆

Dr. Christopher Myers, Core Research Area Lead and Senior Cognitive Scientist, RHAC

Dr. Christopher Myers
Core Research Area Lead for
Cognitive Modeling, RHAC

Human effectiveness research in cognitive science, data presentation and human-machine interfaces is vital to optimize human-machine teaming performance."

—"United States Air Force Science and Technology Strategy: Strengthening USAF Science and Technologies for 2030 and Beyond"

PERSONALIZED LEARNING AND READINESS SCIENCES CORE RESEARCH AREA

Dr. Kevin Gluck
Core Research Area Lead and
Principal Cognitive Scientist, RHAC

ONE-SHOT LEARNING VS. FEW-SHOT LEARNING

One-shot learning occurs from a single training event, sample or image

Few-shot learning occurs from very small amounts of training data

How can we maximize the effectiveness, efficiency and durability of education and training for all Air Force personnel in order to ensure our people are ready? To answer this question, we are taking a multi-disciplinary approach to improving our fundamental understanding of human readiness and to developing novel personalization technologies that are useful in complex, uncertain and dynamic environments. We need to invest in this area because the Air Force identifies readiness as a key objective and has called for innovative new ways to ensure it. Personalized learning and readiness sciences are the pillars on which we will create a future force that is ready to "fly, fight and win!"

The Personalized Learning and Readiness Sciences (PLRS [pronounced "pillars"]) Core Research Area (CRA) focuses on scientific discovery regarding the fundamental nature of readiness and on exploratory application of personalization technologies. The objective is to improve learning and performance for robust mission readiness. Research and development in this CRA occur in the following two primary clusters.

Applied Proficiency Technologies

Focus: Maturing emerging technologies for the Readiness Product Line by advancing proficiency-based training innovations

Research and development in this cluster addresses the challenges of adaptive instruction at individual, team and unit levels of analysis.

Activities include:

- Persistent, high-resolution human and system measurement
- Proficiency-centric readiness evaluation and prediction
- Novel methods for multi-objective optimization of personalization across content selection, delivery media and scheduling

Interactive Task Learning

Focus: Establishing the technical foundation for bi-directional human-machine teaching and learning of entirely new content on demand

Research and development in this cluster addresses the challenges of joint human and machine understanding to improve pace, persistence and partnering.

Activities include:

- One-shot and few-shot learning for interactive machine intelligence
- Task- and mission-relevant content parsing, processing and constraint representation
- Continuously running computational intelligence adapting to and supporting human intent
- Effective measures, methods and models for improved human and machine understanding ☆

Dr. Kevin Gluck, Core Research Area Lead and Principal Cognitive Scientist, RHAC

DIVISION CHIEF, RHA

COL DANNY "FLOYD" SLIFER

711 HPW RHA

The Warfighter Readiness Research Division (RHA) welcomes its new Chief, Colonel Danny "Floyd" Slifer. As Chief, he leads government, civilian, military and contracted employees in the Division's mission to lead innovation in human performance methods, models and technologies that optimize warfighter proficiency by delivering the knowledge and skills required by our Airmen to achieve operational effectiveness in all domains and operations. In addition, Colonel Slifer serves as the Air Force Research Laboratory's (AFRL) Flight Operations Authority (FOA). In this capacity, he oversees all the flight test and operations for the AFRL enterprise.

The following responses from Colonel Slifer to interview questions provide insight to his experience and his vision for the Division and its mission.

Q: How has your academic background and 22+ years of service prepared you for the Division's work?

A: My academic background is in mechanical and flight-test engineering, which I know is not quite like the folks here [Division] with software engineering, psychology or computer science backgrounds—but, it's enough of a technical background that I get what's going on and can add to the discussion. And, I can call "BS" when I see it.

I think more importantly, what I bring to this position is my background from the ops community. As an Air Force aviator, I understand warfighters. I've been in their shoes and speak their language, so I have a good sense of what works and what doesn't. Let's say some of our bench-level scientists are working on a good idea, but don't completely have it right. As an operator, I might be able to point out that if they tweaked something a bit, it would work better for the warfighter or the operational environment.

Q: How would you describe your leadership philosophy?

A: I tend to keep things simple: provide a vision and then take care of the people who accomplish the mission [science and technology (S&T)]. First, I align with leaderships' vision—from Dr. Geiss to Major General Cooley to the President—and provide that vision to RHA. Then, I support our personnel in taking ownership in setting the goals and objectives to fulfill that vision. In addition, I help provide the resources needed and help remove obstacles impeding our accomplishments. I want to motivate people and take care of them by letting them know I have their back, but will also hold them accountable.

Q: As a warfighter, what is your most memorable experience and why?

A: As an operational warfighter with eight deployments, five of which were B-1 bomber combat deployments in Iraq and Afghanistan, there are many individual memorable experiences of supporting our ground forces. One particular nighttime mission in Afghanistan in 2005 involved providing close air support to a group of U.S. Marines taking heavy enemy fire. As I talked with their JTAC [Joint Terminal Attack Controller], I could hear in his voice that the group was in trouble. They were traveling through a valley and due to the darkness and terrain could not tell exactly where the enemy fire was originating. Under normal doctrine, we would have exact coordinates or radar identification before dropping a bomb. However in this circumstance, that was not going to work, so we had to improvise. I had the JTAC give me his coordinates as well as the direction and estimated distance to where he thought the enemy was located. We dropped the bomb and he said that it was close, but we needed to target a hundred meters to the northwest. We continued that recalibration process until he reported the enemy was no longer shooting. The next day, the JTAC reiterated his thanks and said that their reconnaissance confirmed we had hit our targets successfully.

Q: As a developmental flight-test expert, what lessons learned transfer to the Division's readiness training research?

A: I think testing is testing, whether for big acquisition research and development or science and technology. The basics of how we develop a test are similar, whether it's doing developmental flight test on a B-1 bomber or trying to develop and mature technologies for training and readiness.

We have a phrase in flight test that summarizes the scientific method: theory[1], plan[2], fly[3], reduce[4] [the data], deduce[5], report[6]. The work done here [Division] correlates closely, we hypothesize[1], plan[2], implement research[3], manage results[4], evaluate results[5] and report what was learned[6].

Q: According to the United States Air Force's Science and Technology Strategy for 2030 and beyond, "... the Air Force Research Laboratory [AFRL] plays a vital role in translating and transitioning innovation fostered by ... partnerships into Air Force capabilities." In what ways would you like to see the Division foster collaborations with our allies, other agencies, industry and academia?

A: As the former Chief of AFRL's Partnering Division, my short answer is that we absolutely should partner with everybody we can. In reality, I understand that we're limited by staff bandwidth, so we should collaborate with our known top-tier partners. For instance, we need to collaborate with our Five Eyes allies [United Kingdom, Australia, Canada, New Zealand] for two reasons. First, we fight alongside them. Second, they also conduct cutting-edge research, they just have smaller teams. Likewise, other government agencies, military labs and academic institutions have experts researching the same things we are studying. Why would we not want to benefit from each other's innovation and discovery?

Ultimately, if we did partnering perfectly, we would invest and divest in different technology areas based on requirements and fellow partners' expertise. As an example, within the military, one Service may take the lead on a specific tech focus area while the other Services work on related supporting areas. In a different tech area, the leading and supporting roles may change. Together, as DoD [Department of Defense], we should work at leveraging resources: the people and money required to complete the work we need done.

Q: In addition, the Air Force Science and Technology Strategy states, "The Air Force aims to attract, develop and retain exceptional talent and create a culture of innovation and risk-taking conducive to driving research from basic science to transformational military capability." As the Division's new Chief, what do you see as the biggest obstacle in supporting this goal? How do you foresee guiding the Division to overcome this obstacle?

A: The short answer is processes, specifically Air Force internal processes are the biggest obstacle. Although well intentioned, policies and regulations can hamper hiring and maintaining a talented workforce as well as enabling that workforce to innovate. Sometimes the big picture is lost because the focus is on following the regulations and procedures, not on the value-added efforts. I am a proponent of only following processes that add value and make sense for what we are doing. I believe in hiring really good people and empowering them to take risks, then covering for them if it doesn't work out.

Q: Air Force Lieutenant General Brian T. Kelly, Deputy Chief of Staff for Manpower, Personnel and Services, in his presentation to the Subcommittee on Personnel for the Committee on Armed Services United States Senate stated, "The National Military Strategy directs a balanced 'boxer's stance' of military readiness..." How do you envision the Division supporting a posture of offensive and defensive readiness?

A: To adapt to an ever-changing boxer's stance, we need warfighters to tell us their requirements and gaps in capabilities for their operations. Once we know the prioritization of those needs and gaps, we work on devising innovative methods, models and technologies to enhance warfighters' proficiency and performance. Through our human performance, training and readiness efforts, we support one of the most important precursors to anything the Air Force does. It doesn't matter how nice an airplane or weapon technology is built, the Air Force needs properly trained and prepared individuals who are proficient in their mission.

Q: Is there any additional information that you would like to share with our readers?

A: Yeah, first, I am proud and appreciative of all the folks here in the Division who have committed to these training and readiness S&T [science and technology] efforts and serve as part of our team. I know that sometimes it's hard to see where S&T translates to the warfighter, but I assure you that what we do is important. Second, I encourage our passionate hard-working personnel to maintain a good work-life balance, to enjoy life and have fun. What we do here is important, but let's keep some perspective and ensure that we remain well-rounded. ☆

Ms. Suzette Westhoff, RHA

SIMULATORS DIVISION

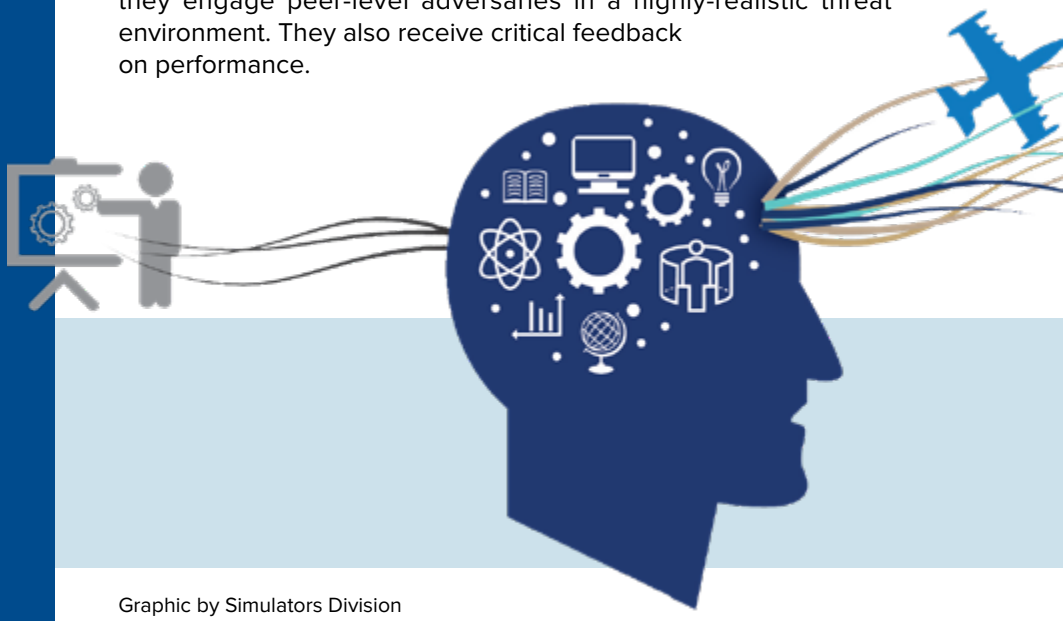
COL PHILIP CARPENTER
AFLCMC/WNS

PREPARING FOR THE WAR OF COGNITION

Without doubt, America's military is the absolute best in the world, and many would-be challengers around the globe are constantly trying to figure out the ingredients in our secret sauce. Most focus on our incredible materiel capability, which makes sense since it's on display for the world to see. However, this focus causes onlookers to adopt a myopic view, where they often lose the forest for the trees. If one were only to take a step back and look at the bigger picture, I think the conclusion reached would be much different. Yes, our materiel capability is truly awesome, but America's real strength and competitive advantage lie in its phenomenal warfighters.

In building its warfighters, America begins with great raw material: A highly motivated, all-volunteer force who come from all walks of life. From there, it invests heavily in training in an attempt to boost warfighter cognition, which the Oxford Dictionary defines as, "The mental action or process of acquiring knowledge and understanding through thought, experience, and the senses." By practicing in a controlled environment, America's warfighters gain valuable knowledge and experience. Moreover, they're constantly pushing lethality boundaries without fearing the consequences of a mistake. Since most training is highly iterative, learning is reinforced, and the outcome is a more effective and capable warfighter.

If you need an example of the power of training, look no further than Red Flag: The United States Air Force's premier air-to-air combat training exercise. Lessons from Vietnam showed less experienced pilots did not fare very well; however, it was discovered if a pilot survived 10 combat missions, the probability for long-term survival increased substantially. Hence, Red Flag was initiated in 1975 in an effort to provide the needed combat experience so forces better understood the rigors of war. When warfighters arrive at Nellis Air Force Base for the semi-annual training, they engage peer-level adversaries in a highly-realistic threat environment. They also receive critical feedback on performance.



Graphic by Simulators Division

Photo by Staff Sgt. Sergio Gamboa

Through a crawl-walk-run approach and through a constant feedback loop, participants come away from the exercise with a greater appreciation of the challenges of combat and a mental fortitude that allows them to out think an adversary in war.

Training is vitally important, and it has a direct impact on warfighter readiness and lethality. While most potential aggressors are preparing for a war of attrition via technology and materiel advancement, our nation's military has a tremendous advantage by prioritizing training. As great power competitions continue across the globe, the United States military must continue to amp up its investment in training systems and find ways to expand the training continuum, so our warfighters are always prepared for both wars of attrition as well as cognition. ☆

Colonel Philip E. Carpenter, Senior Materiel Leader, Simulators Program Office

"AMERICA'S REAL STRENGTH AND COMPETITIVE ADVANTAGE LIE IN ITS PHENOMENAL WARFIGHTERS."

— Col Philip E. Carpenter
Senior Materiel Leader,
Simulators Program Office

RHAS

CONTINUOUS LEARNING AND PERFORMANCE ASSESSMENT BRANCH

Maj Eric Wolf
Branch Chief, RHAS

Dr. Leah Rowe
Branch Technical Advisor, RHAS

Collage by Mr. Will Graver

By 2035, evolution in the way the Service achieves readiness and required performance levels will change the organization, training and equipping of Airmen."

—Concept for Future Air Force Operations
A View of the Air Force in 2035

MISSION

To develop methods, techniques and technology that improve learning, mission performance and decision making across military operations

The Continuous Learning and Performance Assessment Branch focuses on improving training for our current and future force to maximize readiness and lethality. We collaborate with Air Force, Joint Service and coalition forces to uncover critical training gaps and deliver processes and products to fill those gaps. Our blend of research psychologists, engineers, program managers and subject matter experts work as a team to develop effective and efficient products in response to warfighter needs. These teams use instructional design theory and industry best practices to research, develop and deliver quality materiel leading to direct training enhancements. Transitioned products vary widely from knowledge products, (i.e., Mission Essential Competencies®) to exercises support (i.e., training scenarios or debriefing software) to full simulator systems. This wide array of items is evidence of the agile and tailorable nature of our Branch.

While we deliver solutions to fill today's warfighter needs, we constantly look to the future to help navigate our research and development. Three areas of development are (1) constructing an architecture and validation method for proficiency-based learning, (2) incorporating virtual and augmented reality into training and (3) integrating digital agents into our training systems.

Proficiency-based training is the desire of Air Combat Command. The goal is to maximize training effectiveness and minimize the time for Airmen to achieve readiness standards. Our research efforts have allowed us to understand how to better move training design away from the current, complete-the-task and check-the-box system to a future performance, proficiency-based system. We will use the data we have collected in our testbeds to create a baseline-training database. This database will serve as the basis for future analytics and lay the foundation for data standards for future proficiency training.

In addition, in recent years virtual- and augmented-reality systems have exploded in their availability and use. The Air Force has begun using virtual-reality systems in their Pilot Training Next efforts, but we need to conduct research to understand the effects of training that uses virtual tools. Considerations include how to optimize the blend of virtual and physical training and how individuals' responses differ between the physical and virtual worlds. Virtual environments offer the potential for a drastic cost savings when compared to legacy training, but we need to explore the full potential and ramifications of those environments.

Finally, training events and exercises have historically used "white force" participants to play the role of other team members. The work force requirement for a white force is very costly and resource intensive. Simulated personnel or "digital agents" have the potential to reduce the human resources need as white force members. Our work seeks to learn how to best incorporate these agents into existing systems and to study the efficacy of the agents in training.

The following five Branch teams accomplish our activities. Each team has a distinct but complimentary mission set, which strives to improve readiness across the range of military operations. They are able to integrate operational domains to create a unique team-of-teams training experience for our warfighters of today and tomorrow. ☆

Maj Eric T. Wolf, Branch Chief, RHAS

Dr. Leah Rowe, Branch Technical Advisor, RHAS

THE FIVE RHAS BRANCH TEAMS

Gaming Research Integration for Learning Laboratory®

Medical Readiness and Personnel Recovery

Tactical Fastjet

Integrated Combat Operations Training Research Testbed

Command and Control Computers and Communications Intelligence, Surveillance and Reconnaissance (C4ISR)

TOOLS AND MEASURES

> **It [United States Air Force] needs to harvest the potential offered by technologies like virtual reality and augmented reality to train better."**
>
> **—Gen James M. "Mike" Holmes**
> **Commander, Air Combat Command**

FUTURE TRAINING CONCEPT AND VISION MOVES FORWARD

The Future Training Concept is a vision document spearheaded by Headquarters Air Combat Command's Future Operations Division and the Air Force Research Laboratory's Flight Operations Division and Test and Training Division with support from the Warfighter Readiness Research Division. The goal of the document is to provide a pathway to more objective future readiness assessments data and to better quantify gaps in readiness that need to be addressed.

The Commander Air Combat Command identified the need to capture more specific performance and proficiency data as a means of improving and targeting training and readiness resources into the 2030 timeframe. Based on this identified need, our first and foremost priority is combat employment in support of the joint mission. Adequate training enables our warfighters to meet combatant commanders' mission-proficiency expectations and helps ensure they are prepared for the challenges in those respective theaters of operations. Because the current training framework inherently contains some limitations, our team has developed a multi-faceted rationale for modifying the training framework. This framework includes clarification of training requirements and integration of relevant training warfighting systems ("train as we fight"). It also ensures training remains as agile and adaptable as the future fight will require.

Central to the 2030 readiness target is the shift from event-based to proficiency-based training. Developing and maintaining proficiencies will be the framework that defines individual competency and shapes readiness assessments and reporting, when aggregated at the unit level. Proficiency-based training will not replace the Ready Aircrew Program (RAP), but will be a hybrid of the two, such that identified proficiency deficiencies will influence subsequent RAP training events.

A shift to a proficiency-based system for readiness will enable assessment of performance (via objective and subjective measures) rather than counting the number of training events. The goal is to maximize the efficient use of resources to attain greater proficiency.

Our team will develop, validate, field and track appropriate assessment metrics to proactively refine proficiency levels and address emerging mission requirements. In addition, these metrics will facilitate mission debriefs by enabling tailorable reviews that target critical training aspects and real-time performance indicators for all participants.

Identifying current desirable training practices, which should continue and expand to appropriate training audiences, will capitalize on efficiencies and enable a common training

strategy. In addition, addressing modifications to the learning and training infrastructure can occur simultaneously. Implementing modifications to the training framework, such as those detailed, will improve training readiness that is required to meet mission-proficiency expectations for our warfighters now and for the decades to come.

The Warfighter Readiness Research Division created a method and a set of technologies that track specific subjective and objective mission-performance indicators; facilitate visualizing those indicators for after-action reviews and data warehousing; and quantify and monitor the quality and fidelity of training environments—both live and virtual. The interplay of these key methods and tools is depicted in Figure 1.

Several of these technologies are also highlighted in the "Fight's ON!" IITSEC (Interservice/Industry Training, Simulation and Education Conference) edition. They include the Division's Performance Evaluation and Tracking System™ (PETS™), the LVC [Live-Virtual-Constructive] Network Control Suite™ (LNCS™), the Knowledge Management System for Distributed Mission Operations and the LVC Ops™. These technologies along with the Mission Essential Competency® (MEC®) methodology, the Division's metrics specification process and Environment Effectiveness Assessment Tool (E2AT) will work hand-in-hand with current readiness tracking operations tools to enable the shift to Proficiency-Based Training and the Future Training Concept. ☆

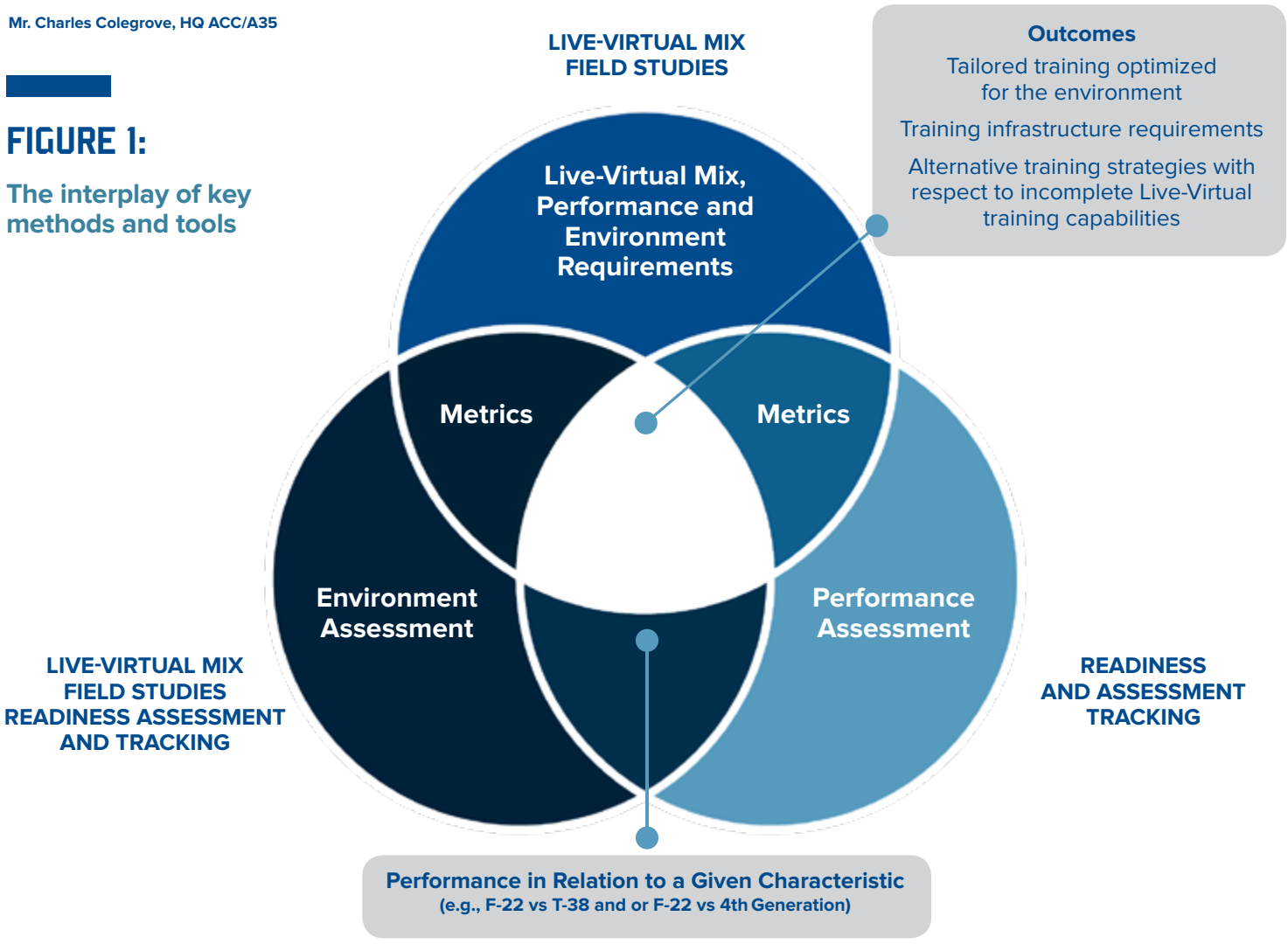
Dr. Winston "Wink" Bennett, Readiness Product Line Lead, RHA

Mr. David Cienski, HQ ACC/A35I

Mr. Charles Colegrove, HQ ACC/A35

FIGURE 1:

The interplay of key methods and tools



ADVANCES IN TRAINING DATA TRACKING AND VISUALIZATION

Tracking, analyzing, warehousing and visualizing human-performance data are key enabling components of proficiency-based training. Under the direction of Air Combat Command, the Command is fielding a Combat Air Forces (CAF)-wide Proficiency-Based Training (PBT) program to operational units throughout the CAF, with the first selected Mission Design Series units being F-16, F-15E Strike Eagle and the Airborne Warning and Control System.

This article introduces the Performance Evaluation and Tracking System™ (PETS™), a performance-measurement system, and the Live, Virtual and Constructive Network Control Suite™ (LNCS™), a multi-domain Instructor Operator Station. The article also discusses the role of these tools in supporting a proficiency-based training program at operational sites. Dr. Winston "Wink" Bennett, Warfighter Readiness Research Division Readiness Product Line Lead, has led the development and fielding of these technologies.

The Air Force Research Laboratory's (AFRL) engineering and research teams have had the capability to execute advanced capture, processing, tagging and visualization of training-research data for some time. However, the operational nature of the upcoming Air Combat Command PBT initiative generated a critical need for PETS and LNCS to be accredited software packages.

Throughout fiscal year 2019, the PETS and LNCS engineering teams worked together with local cybersecurity experts to prepare, submit and guide accreditation packages for these technologies through the Air Force Evaluated Products List. Both PETS and LNCS received three-year accreditation approval on this list, enabling easier transitions of the technology into the field and illustrating the high technology-readiness level and operational readiness of these systems.

The United States Air Force has used PETS for quite some time as an intelligent data human-performance analysis tool for the Division's training and readiness research efforts in the Laboratory's F-16 Distributed Mission Operations testbed and has fielded it to numerous national, international and coalition-partner training sites.

The PETS technology contains subject matter expert vetted-measurement algorithms for many Combat Air Force Mission Design Series platforms. To support a data-driven approach, such as PBT, the PETS team leveraged system-level native data inputs, along with the measurement algorithm outputs, to develop and refine a series of output "products" or proficiency dashboards that support PBT.The engineering and research teams designed these dashboards to provide feedback to learners and enhance after-action reviews. At the instructor level, the tool shows local mission and fleet-wide readiness and capability at any point-in-time at the operational decision-making level.

The LNCS multi-domain Instructor Operation Station provides a single point of visualization, recording and environmental control for LVC (Live-Virtual-Constructive) exercises. Like PETS, LNCS received Air Force Evaluated Products List operational certification, enabling its use as the primary training feedback tool across AFRL testbeds and at local and international Air Force sites. The Air Force has used the AFRL-developed LNCS since 2008. Its initial mission using the technology was in providing F-16 testbed exercise control. The LNCS system has become one of several operational brief-debrief systems of choice.

As an Instructor Operation Station, LNCS provides operators and trainees with industry-leading visualization capabilities during and after exercises and contains a robust set of plug-ins that enhance the core software's capabilities as well as supports third-party development. The overlay of key-mission events onto the LNCS visualization screen provides feedback to instructors during a mission and provides additional learning opportunities during an after-action review. Together, LNCS and PETS enable enhanced feedback for instructors and trainees by visualizing a mission's key elements and situations thus enabling decisions that affect mission outcomes. In tandem, LNCS and PETS work to support PBT efforts, with LNCS providing the visualization capabilities and PETS the computing measures of performance. ☆

Mr. Jeremy May, PETS Software Engineer, RHAS

Mr. Peter Neubauer, PETS Software Engineer, RHAS

Mr. Brad Pfefferle, LNCS and PETS Software Engineer, RHAS

Mr. Robert Theimer, LNCS software engineer, RHAS

Mr. Eric Watz, Program Manager, RHAS

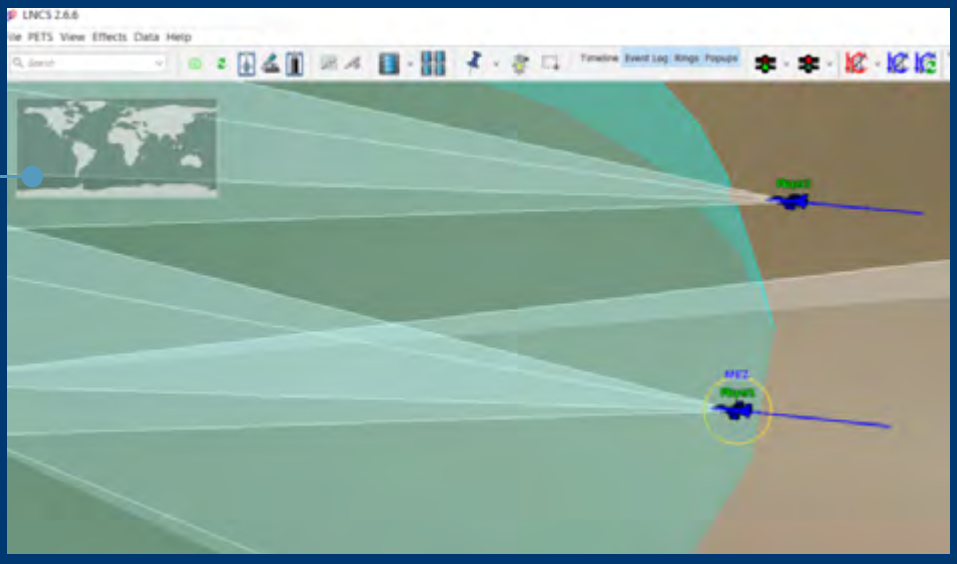
Dr. Winston "Wink" Bennett, Readiness Product Line Lead, RHA

TOGETHER, LNCS AND PETS ENABLE ENHANCED FEEDBACK FOR INSTRUCTORS AND TRAINEES BY VISUALIZING A MISSION'S KEY ELEMENTS AND SITUATIONS THUS ENABLING DECISIONS THAT AFFECT MISSION OUTCOMES."

— Dr. Winston Bennett
Readiness Product Line Lead, RHA

LNCS DISPLAY

Depicted is a screen shot of LNCS enhanced mission display with performance-measurement overlay.



PETS DASHBOARD

Depicted is a screen shot of the PETS proficiency dashboard during mission execution.

Screenshots by 711 HPW/RHA

GAMING RESEARCH INTEGRATION FOR LEARNING LABORATORY®

MISSION

To evaluate and exploit commercial off-the-shelf technology to fill Air Force gaps and requirements while simultaneously conducting STEM (science, technology, engineering, mathematics) outreach on behalf of Air Force Research Laboratory and the United States Air Force

The Gaming Research Integration for Learning Laboratory (GRILL®)—under the Air Force Research Laboratory, 711th Human Performance Wing, Airman Systems Directorate, Warfighter Readiness Research Division—leverages low-cost high-fidelity commercial-off-the-shelf technology solutions for a variety of Department of Defense customers.

Since the GRILL's inception in 2007, our team has worked successfully on achieving near- and long-term objectives. These objectives include the following.

- Create and validate a new and flexible generation of synthetic task environments for research
- Use game-based technologies to develop STEM (science, technology, engineering, mathematics) modeling and simulation content and exemplars
- Develop and evaluate virtual-reality and autonomous technologies and ad-hoc networks
- Create methods and tools to demonstrate and evaluate a "family of complimentary trainers" that can share content (i.e., interfaces, databases, models, metrics) via virtual-reality, part-task trainers, high-fidelity simulations and live operational systems
- Conduct university and operational collaborative research

In pursuing these objectives, our team evaluates and exploits commercial-off-the-shelf gaming technology to fill Air Force gaps and requirements and also conducts STEM outreach (on behalf of the Air Force Research Laboratory and the United States Air Force). Our team's vision is to serve as an authoritative resource for the integration and application of game-based technology to address United States Air Force education and training requirements. Together with our local, regional and national partners, our team supports the development of a highly qualified technical and scientific workforce for the future.

In 2019, our team led the development of a wide variety of projects, some of which are highlighted in the following pages.

Lt Dave Clement, Program Manager, RHAS

Mr. Jon Diemunsch, Software Engineer, RHAS

Mr. Quintin Oliver, Development Engineer, RHAS

Dr. Winston "Wink" Bennett, Readiness Product Line Lead and GRILL Team Lead, RHA

WANT TO COLLABORATE?

If you are interested in opportunities to collaborate, we invite you to contact us at:

http://gamingresearchintegrationforlearninglab.com/contact-us/

WHAT'S HAPPENING AT THE GRILL?

The Gaming Research Integration for Learning Laboratory® (GRILL®) evaluates, innovates and conducts science, technology, engineering and mathematics (STEM) outreach through a variety of projects.

The following are samplings of their ongoing work.

My most rewarding experience at the GRILL is watching students' excitement over solving a problem as a team and their eventual completion of the problem that they are given."

—Ms. Gretchen Capogna
STEM Outreach Coordinator

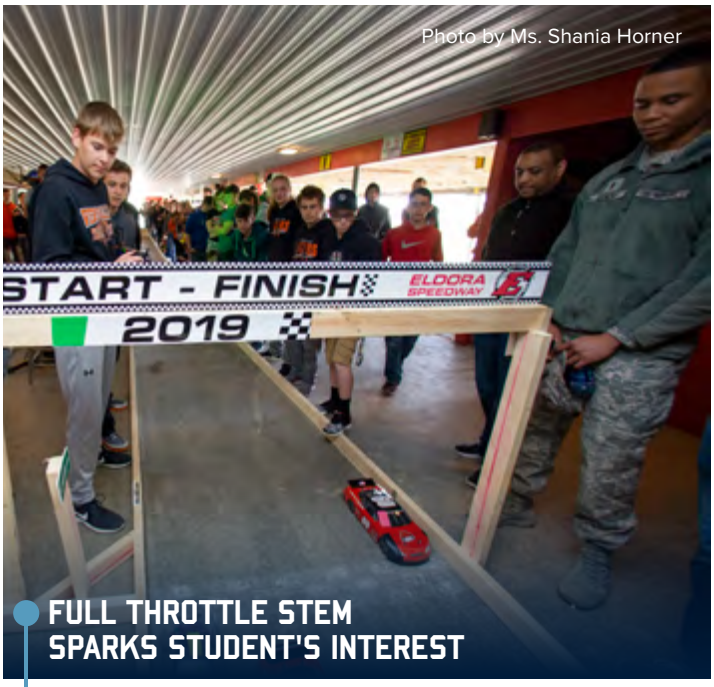


Photo by Ms. Shania Horner

FULL THROTTLE STEM SPARKS STUDENT'S INTEREST

Students and teachers who participated in this year's Full Throttle STEM program used a series of GRILL-created project-based STEM learning materials throughout the academic semester. The students applied skills, such as physics, graphic design and marketing to design and develop their own radio-controlled vehicles and autonomous rover projects. This spring at Eldora Speedway, the students demonstrated their modeling and simulation-based projects as well as competed in live-drag and autonomous-rover races.

Photo by Mr. Will Graver

JOINT TERMINAL ATTACK CONTROLLERS TRAINING PROTOTYPE

A team of four high-school students spent nine weeks working alongside former Joint Terminal Attack Controllers (JTAC) to create a virtual-reality JTAC training prototype. Current JTAC training solutions use a projection dome to provide immersive realistic training, but suffer from a lack of portability, high-licensing cost, complex setup and dated graphics. The prototype built by the students is fully immersive, portable, has no licensing cost and uses a single computer and non-proprietary off-the-shelf gaming technology. The prototype even provides trainees the ability to interact with real-world equipment, such as a laser-range finder while being fully immersed in virtual reality.

IMPROVING AIRCRAFT MAINTENANCE THROUGH COLLABORATION

In an effort to enhance aircraft-maintenance training capabilities, the GRILL® Team collaborated with Air Force Research Laboratory (AFRL) government affiliates (i.e., Virtual, Augmented and Mix Reality for Aircraft Maintenance [VAMRAM] and the Maintenance Training Next [MXN]) and the Air Education and Training Command. One project the team constructed for this effort is the changing of an F-16 fighter aircraft tire. The team gathered three-dimensional modeled assets from the other groups and leveraged those assets to create the simulation, which immerses the user in a virtual-reality environment where the trainee uses simulated tools to change the tire.

WRIGHT SCHOLAR RESEARCH ASSISTANT PROGRAM UNDERWAY AT NEW LOCATION

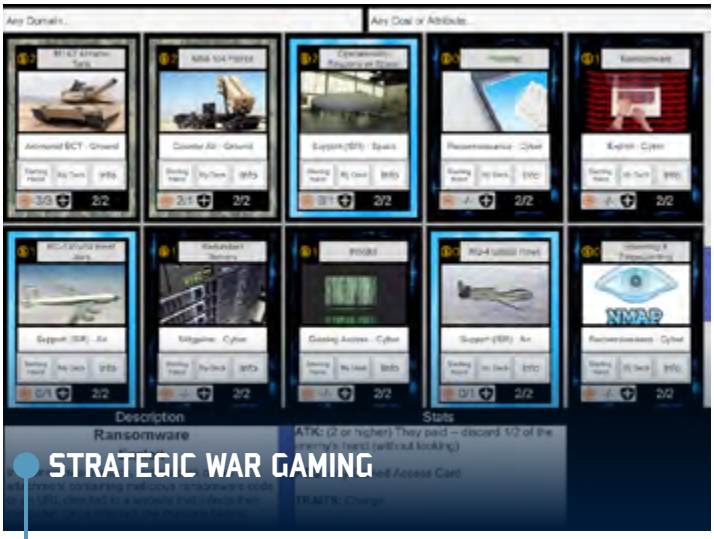
The GRILL held this summer's Wright Scholar Research Assistant program in a new facility at the Dayton Regional STEM (science, technology, engineering, mathematics) School. The program is a nine-week summer internship for exceptionally talented students with a strong interest in future engineering or science careers. The students along with local teachers and AFRL scientists and engineers focused on real-world research challenge problems such as autonomy, Live-Virtual-Constructive and high-fidelity simulation.

SNOWCAT ANTARCTIC SEARCH AND RESCUE GAME

In collaboration with the University of South Florida, the GRILL Team is creating a serious game that observes dynamic team processes and measures the outcomes of cooperative task performance. In the immersive game, players drive snowcats through a three-dimensional Antarctic terrain in order to accomplish a search-and-rescue mission. Players work together to develop strategies and discover mission-related clues via seismic monitors, physical traces and satellite communications.

VIRTUAL-REALITY GAME-BASED HELICOPTER TRAINER

Current Air Education and Training Command schoolhouse virtual-reality helicopter trainers are expensive to develop and maintain, are not portable and many do not address identified training gaps. In an effort to mitigate these shortcomings, the GRILL Team constructed the low-cost, portable and easy-to-maintain helicopter-training simulator using government and commercial gaming software and hardware. The simulator's three-dimensional software offers trainees a variety of virtual helicopters and landscapes, which allows development of different scenarios and testing of a wider range of flight skills. The simulator enables trainees to develop, refine and retain proficiency of required skills when aircraft are unavailable.



STRATEGIC WAR GAMING

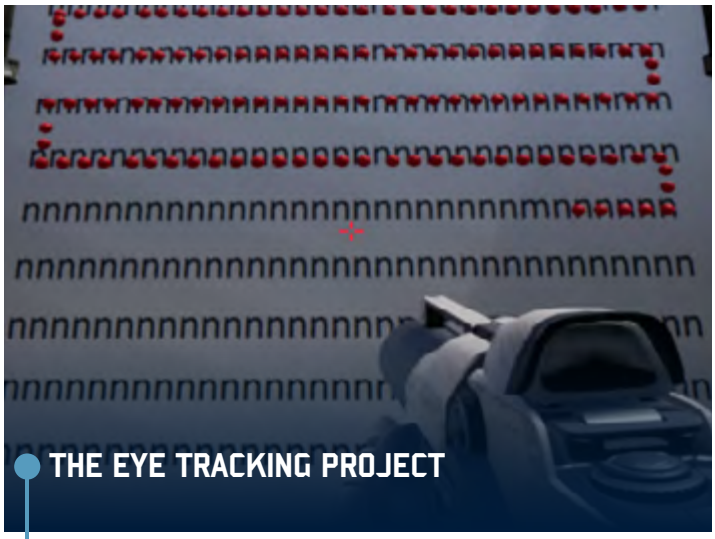
The GRILL® Wright Scholar Team's summer challenge involved exploring strategic war-gaming using desktop applications, including the Deck Builder game. The Deck Builder features detailed cards of Air Force aerial and ground weapons and vehicles. Through partnership with the Air Force Institute of Technology, students enhanced their war game, called BattleSpace Next, which provided the game's players the opportunity to learn about military assets.

UNMANNED ARIAL VEHICLE SIMULATOR

Together with the Florida Institute of Technology's ATLAS Lab, the GRILL Team developed the Unmanned Aerial Vehicle Simulator (UAVsim) for the dual-purpose of training and evaluating UAV systems for emergency and mission applications. By developing an immersive computer-based environment, researchers and UAV trainers can build scenarios to mimic real-life situations that would be difficult or costly to replicate otherwise. The simulator will provide a realistic flight experience that allows operators to practice UAV free-flight and mission planning and strategy for scenarios, such as search-and-rescue or inspection tasks.

PARACHUTE SIMULATOR

The GRILL is constructing a prototype virtual-reality harness and simulator for the 336th Training Group SERE (Survival, Evasion, Resistance, Escape) School. By using off-the-shelf gaming technology in conjunction with the existing hanging harnesses, the simulator immerses students in an emergency parachute experience that incorporates weather, wind, terrain, time of day and realistic physics. The system, which synchronizes multiple jumpers' actions in advance of live airborne operations, seeks to increase knowledge retention, permits identification of malfunctions, allows for corrective actions, scores jumps and provides user feedback.



THE EYE TRACKING PROJECT

The GRILL Legacy team's challenge for the Eye Tracking project involved exploring the tracking of eye-movement patterns and the feasibility of applying the knowledge gained to virtual-reality training. The team investigated eye-movement patterns using a specialized data search used to locate images. They also looked at ways to use eye-tracker technology to set waypoints and to assist with the aim of the first-person viewer. By understanding the eye-tracking technology, the team can record eye-movement patterns and use the information to train people on how to move their eyes.

Photos and screen shots (pg. 22–23) by Mr. Will Graver and 711 HPW/RHA

MEDICAL READINESS AND PERSONNEL RECOVERY

MISSION

To develop methods, techniques and technologies that improve the learning, decision-making and mission performance of our nation's warfighters. The mission comprises two training research areas:

(1) Medical Readiness

- **Tactical combat-casualty care training**
- **Point-of-injury**
- **Medical tasks**
- **Training environment**

(2) The Personnel Recovery Core function and Combat Search and Rescue mission set

Mission-related training has a very large "field-based" component that is outside of instrumented training ranges. Consequently, the our team implements Live-Virtual-Constructive concepts to the training, at times in very harsh environments. In addition, our team develops performance metrics and measurements that support proficiency-based training and the corresponding validation and verification of the training. Our team's efforts focus on increasing the readiness of today's force and ensuring the ability of our warfighters to surpass tomorrow's challenges.

Under our Medical Readiness portfolio, we are conducting studies to support the Department of Defense Instruction 1322.24, which looks for ways to innovate and increase training efficacy and efficiency with the use of new human-patient simulators and other advanced training models to map capabilities to training tasks and evaluate the training for maximum learning.

Our team collaborates with multiple Air Force Research Laboratory teams and with industries via Cooperative Research and Development Agreements (CRADAs). Currently, we have CRADAs with TraumaFX Solutions, Inc. and CAE Healthcare, Inc. to integrate human-patient simulators with the Battlefield Assisted Trauma Distribution Observation Kit called BATDOK. The goal of the project is to bolster the "train-like-you-fight" concept with program-of-record medical tools. Our team's collaborations also include work on the SHARK (SERE [Survival, Evasion, Resistance, Escape] Health Awareness Responder's Kit), which researchers use to track the health status of warfighters during training that is physically demanding and conducted in harsh environments. The SHARK project aims to prevent safety mishaps.

Our personnel recovery work supports developing lightweight operational training technologies that provide "instrumented" capabilities for training that happens outside primary ranges. This work is leading the team to explore augmented- and mixed-reality technologies for a variety of applications, including combat search-and-rescue and the instrumentation of battlefield effects. The goal of our team's investigation is to reduce training overhead and "man-in-the-loop" data dissemination during complex integrated training events. The data gained will provide us with the ability to validate performance metrics, understand scenario complexities and deploy proficiency-based metrics and analysis capabilities. ☆

Mr. Ted Harmer, Team Lead, RHASR

Capt Stephen Bell, Research Engineer, RHASR

Ms. Cayley Dymond, Research Engineer, RHASR

Ms. Kaylee Eakins, Biomedical and Human Factors Engineer, RHASR

Ms. Katelyn Kay, Research Psychologist, RHASR

Ms. Jennifer Winner, Research Psychologist, RHASR

DEPLOYABLE LIVE-VIRTUAL-CONSTRUCTIVE ADVANCEMENTS

Deployable Live-Virtual-Constructive (DLVC) is the concept of applying LVC to field-based training to reduce costs of large-scale events, while increasing the efficacy and support of training events when assets are limited due to availability and schedules.

Many difficult technical challenges arise in supporting fast-paced distributed training in very austere environments. To address these technical challenges, the Medical Readiness and Personnel Recovery Team is working to reduce the size, weight and power of LVC equipment and infrastructure requirements, while increasing sensor and threat systems access. In an effort to make these reductions and lessen the complexity of using and operating DLVC capabilities, the team has begun implementing Amazon Web Services GovCloud for the capability's required tools. This implementation has reduced the on-site footprint by roughly 6000%, while enabling immense scalability and access to modern big and distributed data frameworks. These endeavors provide essential support to operational training and research objectives.

The team is also exploring the creation of synthetic training environments from live player full-motion video captures to save time in developing realistic training scenarios. Currently, the team creates maps derived from full-motion video and unmanned aerial system feeds in less than four hours versus the months it takes to build new environments manually.

In addition, the team has also produced a proof-of-concept capability that integrates battlespace effects simulators with Distributed Interactive Simulation networks to provide real-time engagement notifications from small arms against live and constructive vertical lift and slow-moving platforms during Air Combat Command large-force exercises. The team executed this effort in direct response to Air Combat Command's Red Flag exercise request for real-time kill-removal capabilities to validate participants' actions in near real time versus post-mission data-compilation hours later.

With the technological advances in augmented and mixed-reality systems, the team is looking forward to helping tackle the integration of these systems to benefit warfighters using the next generation of LVC and operational training infrastructure capabilities. ☆

Ted Harmer, Team Lead, RHASR

The initial implementation of the Deployable Live-Virtual-Constructive concept, while successful, carried a large footprint that precluded access to inhospitable training environments. The size, weight and training implementation costs (i.e., transportation, personnel) were prohibitive.

PAST

PRESENT

Current capabilities in tactical communications allow for small form factor networking stacks, as pictured with Cubic™ DTECH Labs' M3C4G. The smaller size, weight and power consumption reductions integrated with GovCloud applications enable training in environments that may be challenging or hard-to-access. In addition, smaller, lighter weight and more powerful network stacks reduce operational and maintenance requirements.

The use of tactical mobile ad hoc networks (MANET) as pictured with Silvus Technologies' Streamcaster 4200, Commercial Solutions for Classified Program (CSfC) and fifth-generation wireless (5G) capabilities will allow greater connectivity to remote sensors, increase edge computing capabilities and transport data with very low latency. This enables more realistic training and enables greater awareness of training effects, outcomes and effectiveness in near-real time.

FUTURE

Photos by Mr. Will Graver

Photo by Mr. Will Graver

The Battlefield Airman Trauma Distributed Observation Kit, known as BATDOK, provides real-time status of an "injured" human-patient simulator's vital signs via phone.

SAVING LIVES WITH SIMULATORS AND SENSORS

Tactical field medicine takes place in dangerous environments where military medical personnel are taking care of multiple patients. Unlike a clinical setting, patients are not strapped to pieces of equipment that alert the medical staff when the patient is crashing.

To improve care of those injured in the field, the Battlefield Air Targeting Man-Aided kNowledge (BATMAN) team has adapted sensors to communicate with an end-user device called the Battlefield Airmen Trauma Distributed Observation Kit (BATDOK). This kit enables pararescuemen to monitor several patients' vitals on their phone or tablet.

The Warfighter Readiness Division is collaborating with BATMAN to integrate their technology into training capabilities for fielded medical personnel. Our approach is to implement the human-patient simulators used during Tactical Combat Casualty Care training to communicate with BATDOK directly.

Using a Cooperative Research and Development Agreement, the Division and TraumaFX Solutions, Inc. successfully developed a BATDOK plug-in for the TraumaFX critical response human-patient simulator. The plug-in enables the simulator's vitals to display on the BATDOK application alongside live patient actors during training. Just like the homeostatic system of a human being, the patient simulator's vitals change when simulated injuries occur and medical personnel perform treatments. By placing sensors on patients, pararescuemen have a simple way to track and monitor vitals of those they treated. During a training exercise, BATDOK's simulated vitals enable pararescuemen to experience care of multiple patient simulators, including triage decisions and treatment of declining vital signs.

The collaboration between TraumaFX, the BATMAN team, and the Warfighter Readiness Division enables training that matches field conditions by using human-patient simulators. During training, these simulators allow medical personnel to perform repetitive, intrusive interventions that otherwise are not possible on humans or donated anatomical gifts. New technologies, such as BATDOK, are reducing the technological leap from simulation to real life for our military medical professionals preparing for tactical field medicine. ☆

Ms. Kaylee Eakins, Associate Biomedical Engineer, RHAS

HUMAN-PATIENT SIMULATOR FIDELITY AND TRAINING EFFECTIVENESS

The Warfighter Readiness Research Division's Continuous Learning and Performance Assessment Branch is focused on extending our common tools for training effectiveness and fidelity assessment to medical training environments. Current Department of Defense guidance for medical-readiness training specifies that instruction should rely increasingly on training alternatives to live tissue (e.g., commercial training simulation, manikins and cadavers), where applicable. The continued growth in the usage of commercial training simulators and manikins underscores the need to understand the fidelity and its impact on the training effectiveness of medical-simulation training devices.

Most recently, the 711th Human Performance Wing, Continuous Learning and Performance Assessment Branch outlined a systematic approach for evaluating human-patient simulation. This approach involves mapping fidelity assessment to training objectives, representing patient assessment cues, representing variations in injuries and pathologies and using converging measures of trainee performance. Research focus areas include the relationship between fidelity, performance and learning. Overconfidence and the factors contributing to learners' ability to reflect upon and appropriately rediagnose their learning needs are also central for this work.

Collaboration with industry partners such as CAE Healthcare, Inc. and TraumaFX Solutions, Inc. enables our Branch to participate in an open dialogue with industry regarding fidelity and training needs for combat medical-readiness training. These collaborations are helping result in an approach to improve the empirical assessment and therefore design of human-patient simulation for maximal training effectiveness. Our Branch's work in this area is applicable to not just to combat medics, but is broadly applicable across medical training audiences.

Ms. Jennifer Winner, Research Scientist, RHAS

Ms. Katelyn Kay, Research Psychologist, RHAS

APPROACH FOR EVALUATING HUMAN-PATIENT SIMULATION

- Mapping fidelity assessment to training objectives
- Representing patient assessment cues
- Representing variations in injuries and pathologies
- Using converging measures of trainee performance

A pararescueman writes down patient notes during an in-flight medical transport mission.

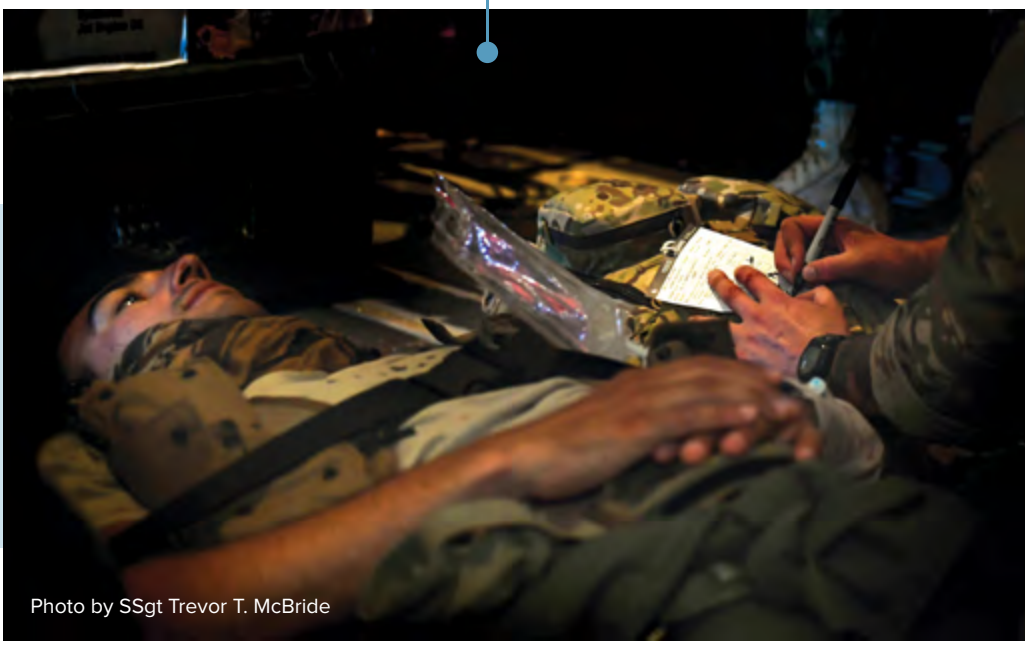


Photo by SSgt Trevor T. McBride

INTEGRATING PHYSIOLOGICAL SENSING AND SIMULATION GAMING TO IMPROVE TRAINING

Due to budget constraints and increasing technological advances, simulation and gaming are often becoming more advantageous for training than physical environments. Virtual and constructive environments allow for faster, more cost-effective training. The Air Force Research Laboratory's (AFRL) Warfighter Readiness Research Division, Gaming Research Integration for Learning Laboratory® (GRILL®) uses gaming technologies for education and training solutions.

Due to lower technology costs, it is becoming easier than ever to obtain data, including human physiology information. As a result, research into topics like heart-rate variability, physiological stress and vital signs is booming. Many of these research teams use physiologic sensing technologies to correlate variables that are not physiological (i.e., stress or performance) to data points omitted by the sensors.

Recently, our Division attempted to mitigate this incongruity by combining two worlds of technology. The Airman Bioengineering Division (another AFRL division) assisted our Division with the integration of a Zephyr Bioharness into the Unity Game Engine using their own trademarked technology. This enabled the sensors to communicate with the game engine.

With this integration, our team hopes to implement this technological pairing into a simulation. Once implemented, research studies can use the application to analyze the Zephyr Bioharness's parameters, such as respiration rate, heart rate and heart rate variability to parameters within the simulation. This collaborative effort between the GRILL and the Airman Bioengineering Division not only keeps our Division on the cutting edge of technology, it also provides a means to gather quantifiable data during training simulations. The more training data our Division gathers, the more opportunities we have to develop effective training techniques that will require fewer repetitions to improve warfighters' knowledge, proficiency and readiness. ☆

Ms. Kaylee Eakins, Associate Biomedical Engineer, RHAS
Mr. Jon Diemunsch, Software Engineer, RHAS

ZEPHYR™ BIOHARNESS™

Wearable technology, such as the Zephyr Bioharness, provide physiological and biomechanical data that researchers can use to better understand performance to improving training.

"THIS COLLABORATIVE EFFORT... NOT ONLY KEEPS OUR DIVISION ON THE CUTTING EDGE OF TECHNOLOGY, IT ALSO PROVIDES A MEANS TO GATHER QUANTIFIABLE DATA..."

— Ms. Kaylee Eakins
Associate Biomedical Engineer, RHAS

Graphic by Mr. Will Graver

TACTICAL FASTJET

MISSION

To enhance the efficiency of training across the United States Air Force, including Air Combat Command (ACC), Air Mobility Command, Air Force Special Operations Command, United States Air Forces in Europe Air Forces Africa (USAFE), Pacific Air Forces and our coalition partners

The Tactical Fastjet Team has led the way in Department of Defense LVC (Live-Virtual-Constructive) training research to enhance readiness and decrease training costs by developing innovative technology options, methods and content. The objective is to enable the Air Force to augment the Ready Aircrew Program with more readiness-focused quantitative metrics to enable individualized proficiency-based training.

The Fastjet Team is developing capabilities that

- Provide scalable scenario-based training content and environments
- Track experiences and performance
- Adapt and tailor additional training events based on individual's or team's current competency level
- Provide a range of more personalized experiences for individual, team and team-of-teams training

The team recently completed the landmark, highly successful, SLATE (Secure LVC [Live-Virtual-Constructive] Advanced Training Environment) Advanced Technology Demonstration.

Now, the team focuses on optimizing warfighter proficiency by

- Bringing LVC-enabled training to the warfighter by assisting the Air Force Life Cycle Management Center, Joint Program Office and ACC staffs in understanding efficient deployment of these technologies through more agile paths than the standard acquisition pipeline
- Integrating and expanding these LVC lessons learned throughout the research conducted in our Division testbeds, including expanding our assistance to the USAFE Warrior Preparation Center in Germany

The team is also working with coalition partners to develop common and secure distributed mission training events as well as measures and metrics of performance applicable to multinational training events. The eventual goal is to establish common content and context of language, metrics and tools that will enable readiness discussions across international boundaries. ☆

Mr. Dave "Moses" Noah, Fastjet Team Lead, RHAS

Maj Thomas "Flash" Adams, LVC Program Manager, RHAS

Maj Jason "FLIR" Lingle, Current, Combat Operations Program Manager, RHAS

Lt Julian Barriga, Multi-Domain Training System Program Manager, RHAS

Photo by Mr. Will Graver

> **Training realism shall be maximized through use of the live training domain supplemented by integrated virtual and constructive capabilities."**
>
> **—Department of Defense Directive 1322.188**

SLATE IS BUILDING ON SUCCESS

The Tactical Fastjet Warfighter Readiness Research Team recently completed the landmark, highly successful, SLATE (Secure LVC [Live-Virtual-Constructive] Advanced Training Environment) Advanced Technology Demonstration. This 40-month demonstration concluded on 31 December 2019, with a 435-page Unclassified/For Official Use Only Final Report published in late February 2019.

Currently, our team focuses on two primary goals. First, getting LVC-enabled training to warfighters. The team is accomplishing this goal by assisting the Air Force Life Cycle Management Center, Joint Program Office and Air Combat Command staffs in understanding efficient deployment of these technologies through more agile paths than the standard acquisition pipeline. Second, the team is integrating and expanding these LVC lessons learned throughout our Division's testbeds for warfighter research.

In addition, Air Combat Command and the F-35 Joint Program Office are working to fund our Division's proposed look at SLATE capabilities' integration with the F-35. We have also established a strong working collaboration and testbed presence with our sister Air Force Research Laboratory Information Directorate in Rome, New York. This collaboration will continue to advance and extend the capabilities of the Fifth-Generation Advanced Training Waveform (5G-ATW) and relevant radio technologies for the future of LVC. Additionally, we are standing up a SLATE and future LVC software integration laboratory at our former Mesa research site. This site will support on-going interests and applications (i.e., encrypted ACMI [Air Combat Maneuvering Instrumentation]). It also manages range operations at different levels of classification as well as data services and bandwidth needs for future test and training capabilities that might leverage LVC concepts. ☆

Mr. Dave "Moses" Noah, FastJet Team Lead, RHAS
Maj Thomas "Flash" Adams, LVC Program Manager, RHAS
Maj Jason "FLIR" Lingle, Current Combat Operations Program Manager, RHAS

Photo by Senior Airman Joshua Hoskins

Photo by Staff Sgt Andrew Lee

Photo by Staff Sgt Ashley Taylor

Photo by Sgt Brandi Hansen

FIGHTER INTEGRATION TRAINING RESEARCH

The mission of the Fighter Integration Research Team is to develop an environment that can host United States Air Force (USAF) fifth- and fourth-generation fighter aircrews for training research in current and future integrated combat operations using secure networked testbed and operations locations. The aircrew include Air Combat Command, United States Air Forces in Europe, Pacific Air Forces and potentially our coalition partners.

The team has led the way in Department of Defense LVC (Live-Virtual-Constructive) training research to enhance readiness, better optimize resources for training and subsequently decrease training costs. We are leveraging these lessons learned and technologies specifically aimed at optimizing warfighter proficiency through focused research and technology development and training for fighter integration—the coordinated employment of multi-generation fastjet assets for maximum efficacy in military operations. Our Division has the engineering expertise, the operational experience and a facility designed to support specifically such research activities.

Given the breadth of the research testbeds representing a variety of USAF mission sets, we can develop and validate novel tactics, techniques and procedures and concepts of operation for specific mission sets as well as bringing those mission sets into a fuller “kill chain” operational context.

EXAMPLES:

UNITED STATES AIR FORCE MISSION SET PLAYERS

- Fastjet (fourth- and fifth-generation)
- Remotely Piloted Aircraft
- Air Battle Manager
- Joint Terminal Attack Controller
- Air Support Operations Center
- Combined Air Operations Center

The team will also be able to help the Air Force Research Laboratory and Air Force Materiel Command lead the way towards USAF, interservice and coalition combat operations through our research and training activities, keeping the focus of research at the speed of operations. ☆

Mr. Dave “Moses” Noah, Fastjet Team Lead, RHAS
Maj Jason “FLIR” Lingle, Current Combat Operations Program Manager, RHAS

SOLVING F-35 PILOT TRAINING GAPS WHILE INCREASING INTEROPERABILITY AND PROFICIENCY ACROSS NATO WARFIGHTERS

The Warfighter Readiness Research Division, working with Charles River Analytics, Inc., has developed a medium-fidelity Next Generation, Multi-role Fighter Instruction and Rehearsal Environment (GeMFIRE) for F-35 fighter pilot training research. The GeMFIRE offers a scalable display and control-device framework, while integrating commercial off-the-shelf and government-off-the-shelf software as well as flight-simulator technologies. The system's capabilities include customized multi-touch panoramic cockpit display, multi-function in-cockpit interfaces, helmet-mounted displays and realistic controls. GeMFIRE accomplishes all of this in a low-cost, medium-fidelity, Live-Virtual-Constructive mission training and rehearsal environment tailored for fifth-generation fighter mission and pilot training.

In 2019, the GeMFIRE program achieved a successful transition to an operational unit, highlighting the importance of using the Small Business Innovative Research program to fulfill Department of Defense critical warfighting gaps. The Division delivered two training cockpits to the Warrior Preparation Center (WPC) to adapt, extend, test and integrate the system at their U.S. Air Forces in Europe-Air Forces Africa location in Germany. The WPC's goal is to advance the F-35 fighter training during coalition readiness exercises and events with NATO countries and other U.S. allies.

The Center's mission objective is to prepare NATO, Partner Nations and joint warfighters to conduct full-spectrum operations against near-peer threats through strategic, operational and tactical training exercises. To achieve this mission requires detailed tailoring of GeMFIRE's capabilities and additional development of critical new interfaces and system framework. The Division will continue researching and developing GeMFIRE to ensure the system will integrate to networked exercises that support WPC's mission.

The successful execution of GeMFIRE within WPC's training events will enhance U.S. alliances with foreign nations in the European Area of Responsibility and fortify training objectives across a joint battlefield with NATO countries and other allies. GeMFIRE is providing the U.S. Air Force a key training technology that when shared with our allies helps ensure warfighters are interoperable during training as they are expected to be during mission execution.

To optimize warfighter readiness, the Division is also guiding the GeMFIRE program to explore, research and develop fighter integration across fourth- and fifth-generation aircraft to support major training events. This effort aims to enable warfighters to "train as they fight" in a controlled environment where they leverage the latest weapon-system technology to achieve mission success. ☆

Photo by Mr. Will Graver

Lt Julián Barriga, Multi-Domain Training System Program Manager, RHAS

INTEGRATED COMBAT OPERATIONS TRAINING-RESEARCH TESTBED

MISSION

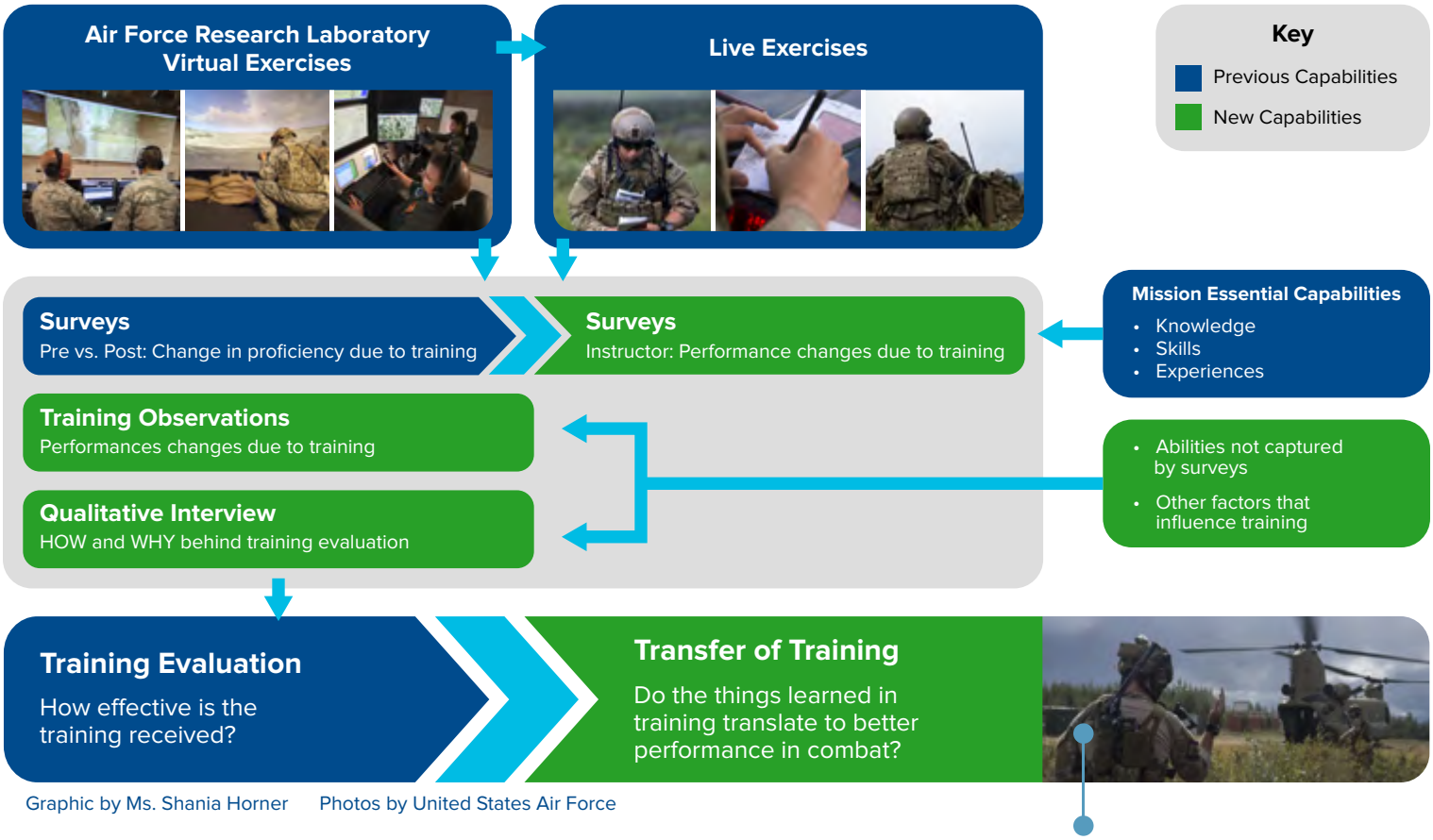
To develop strategies, methods, technologies and competency-based tools that promote learning and enhance individual, team (flight or crew) and team-of-teams (collective) proficiency-based training for the Joint Terminal Attack Controller, Air Support Operations Center, Joint Operations Center and MQ-9 remotely piloted aircraft in support of multi-domain operations

The Integrated Combat Operations Training-Research Testbed (ICOTT) Team's top research goals are to restore readiness through problem-based learning and content delivery; facilitate the rapid development and validation of tactics, techniques and procedures; and to capitalize on team-of-teams transfer of training research opportunities.

During 2019, the ICOTT Team hosted 20 team-of-teams training events in a unique setting where more than 1400 joint warfighters were able to collectively plan, execute, debrief and capture lessons learned while executing realistic combat-training scenarios in a distributed, networked simulation environment. These training research events allowed joint warfighters to refine and validate tactics, techniques and procedures prior to deploying for real-world combat operations. Additionally, the ICOTT Team was able to leverage these opportunities to collect an unprecedented amount of human-performance training-research data in a very short period of time. The following articles will cover the Joint Theater Air Ground Simulation System and Network Integrated Tactical Exercise Testbed. ☆

Mr. Lon Hopson, Team Lead, RHAS
Ms. Rachel Vickhouse, Research Scientist, RHAS
Lt Julian Barriga, Program Manager, RHAS
Lt Kyle Bucklew, Program Manager, RHAS

Photo by Mr. Will Graver



Graphic by Ms. Shania Horner Photos by United States Air Force

The methods used to collect data for evaluating NITE testbed training effectiveness and the transfer of the training include surveys, observations and interviews.

NETWORK INTEGRATED TACTICAL ENVIRONMENT TESTBED

The Networked Integrated Tactical Environment (NITE) testbed, at the Air Force Research Laboratory (AFRL) in Dayton, Ohio, is a system of interconnected simulation devices networked together to train warfighters for operational missions. Typical missions involve finding and tracking an enemy while simultaneously minimizing the possibility of incurring collateral damage. Common participants in the exercises include one or more of the following personnel: Remotely Piloted Aircraft; manned Intelligence, Surveillance, Reconnaissance; Joint Terminal Aircraft Controllers; Joint Operations Center; and white force operators who control the overall exercise as well as red and neutral forces.

Until 2015, a simulated capability to train warfighters for these missions never existed; warfighters only had "on-the-job training," typically in actual combat missions. Today, the NITE testbed enables the AFRL research team to focus on the amount of learning gained from the training and the transfer of the resulting skills into combat. Measures of learning consist of data collection from expert and self-ratings of performance, readiness and learning.

To keep pace with the training requirements of today's mission sets, the NITE testbed leverages the unique laboratory infrastructure to model current and future capabilities using government owned and commercial off-the-shelf technologies such as (i.e. Modern Air Combat Environment [MACE], Virtual Reality Scene Generator™ [VRSG™] and X-Plane®). High-fidelity simulation capabilities developed in the testbed include the Predator Reaper Integrated Networked Combat Environment (PRINCE). The PRINCE is a modular mission rehearsal and reconstruction system that provides a Distributed Mission Operations and Live-Virtual-Constructive capability. The team validated the training system, which provides more than 92% of the task experiences required for pilot training.

Due to the effectiveness of this capability, PRINCE is a staple in our large-scale, team-of-teams exercises. This capability allows AFRL to collect invaluable data to understand problem-based learning and eventually the ability to prescribe individualized or team training recommendations. The methods used to assess training effectiveness and the transfer of that training is shown in the methods matrix graphic. The triangulation of data across multi-faceted efforts supports the most scientifically rigorous studies in an applied research environment. ☆

Ms. Rachel Vickhouse, Research Scientist, RHAS

Mr. Brian Schreiber, Aptima, Inc.

JOINT THEATER AIR GROUND SIMULATION SYSTEM

The Joint Theater Air Ground Simulation System, also known as JTAGSS, is an Air Support Operations Center (ASOC) simulation trainer developed by the Air Force Research Laboratory (AFRL) that provides air and ground command and control primary battlefield-management training and rehearsal for ASOC personnel. This Live-Virtual-Constructive simulation system consists of four Instructor Operator Stations, 13 trainee positions and is capable of participating in distributed mission operations with other virtual simulators and training systems. The system uses both government-off-the-shelf and commercial-off-the-shelf software and is capable of integrating with United States Army tactical mission command systems.

Engineers from AFRL's Integrated Combat Operation Training-Research Testbed team recently integrated the Advanced Field Artillery Tactical Data System (AFATDS) and Tactical Airspace Integration System (TAIS) with JTAGSS at Wright-Patterson Air Force Base. The integration of these mission command systems give ASOC personnel the ability to train with Army staff and refine tactics, techniques and procedures used for joint fires synchronization and rapid airspace de-confliction during multi-domain operations. It also reinforces the concepts of joint operational environment and "train like we fight."

Air Force and Army personnel assigned to the Joint Air Ground Integration Center perform duties to coordinate, integrate and control joint air-ground assets to maneuver and achieve the commander's objectives and intent. The integration of AFATDS and TAIS into JTAGSS enables the establishment of a training technology and environment where Air Force and Army warfighters can train and execute mission rehearsal jointly. These technological advances will help shape the delivery of training and enhance mission readiness and interoperability across the Services.

As a one-of-a-kind program, AFRL fielded the JTAGSS trainer to 15 Air Force operational units covering Areas of Responsibilities within the United States, Europe and the Pacific. This approach allows Air Combat Command to procure a warfighter-focused training system that uses software and tools employed in the field as well as new lab-developed technologies to improve training delivery and reduce white-force requirements.

Currently, the Warfighter Readiness Research Division is working with the Air Force Life Cycle Management Center's Simulator Program Office to transition the JTAGSS program into their portfolio of training devices in 2021. This transition establishes two key milestones for the JTAGSS program:

- It becomes an Air Force Program of Record as well as the ACC approved training system for the ASOC community
- The system begins the sustainment phase in its acquisition lifecycle

The transition of JTAGSS to a Program of Record represents the AFRL's, the Division's and the JTAGSS Team's commitment to addressing warfighters' readiness and performance through hard work, innovation and technical expertise. ☆

Mr. Lon Hopson, Team Lead, RHAS

Lt Julián Barriga, Multi-Domain Training System Program Manager, RHAS

JTAGSS ROOM

As a system-of-systems simulation, JTAGSS provides command and control training in a theater-immersive synthetic battlespace environment using technologies such as intelligent agents.

"[JTAGSS] REINFORCES THE CONCEPTS OF JOINT OPERATIONAL ENVIRONMENT AND 'TRAIN LIKE WE FIGHT'."

— Mr. Lon Hopson
Team Lead, RHAS

Graphic by Mr. Will Graver

COMMAND, CONTROL, COMMUNICATIONS, COMPUTERS, INTELLIGENCE, SURVEILLANCE AND RECONNAISSANCE

NITE-REX represents a quantum leap in ISR training capability."

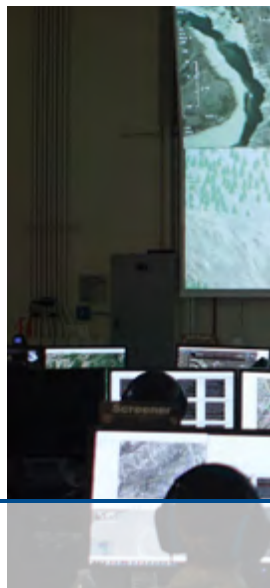
—Col Hugh Ragland
USAF Warfare Center A2 and 365th ISR Group Commander

The Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance Training Research Team, referred to as C4ISR, works across the Command and Control (C2), Intelligence Surveillance and Reconnaissance (ISR), space and cyber domains to provide robust, efficient and effective training and readiness assessments to American warfighters.

Currently, the team is focused on developing a modular testbed infrastructure wherein customers can integrate operational tools and data sources into a high-fidelity integrated networked training environment. Movement towards an open-architecture training system enables warfighters to adapt and integrate rapidly to a wide variety of C2, ISR, space and cyber training capabilities for current and future problem sets.

Leveraging the Branch's legacy of training and learning science, the team also delivers a diverse set of knowledge products, including performance-based training metrics; readiness assessments; validated tactics, techniques and procedures; and requirements for the operational training infrastructure. Additionally, this testbed provides a venue for the experimentation with and validation of emerging technology and procedures, to include advances in automation and machine learning. Guided by the “National Defense Strategy” and United States Air Force’s ISR “Flight Plan,” the C4ISR Team is poised to provide the warfighter with a training advantage in near-peer contested environments while still retaining relevance for traditional operations. ☆

Capt Nicholas Attillo, C4ISR Team Lead, RHAS
Mr. Nicholas Oyler, Associate Psychologist, RHAS
Lt Noah Scott, Engineering Lead, RHAS
SSgt Kacper Sovinski, Program Manager, RHAS



INTELLIGENCE TRAINING EXERCISE INTEGRATES MULTI-DOMAIN AIR FORCE OPERATIONS

On 24–28 September 2018, the Air Force Research Laboratory's Warfighter Readiness Research Division conducted the Networked Integrated Tactical Environment Research Exercise, known as NITE-REX 18-2. Forty-six Airmen from more than a dozen units, representing the core functions of globally integrated ISR (intelligence, surveillance and reconnaissance); global strike; air superiority; and command and control (C2), attended the multi-domain training exercise.

The focus of NITE-REX 18-2 was to study the integration of Air Force personnel in a team-of-teams environment using realistic, operationally relevant scenarios that incorporated anti-access, area-denial challenges. As the largest and most diverse Live-Virtual-Constructive intelligence-focused exercise to date, NITE-REX 18-2 spanned the operational to the tactical levels of war.

NITE-REX 18-2 featured a new open-infrastructure and modular ISR testbed designed to enhance exercise management and scenario realism. This system, which operators can rapidly configure for more than ten different crew positions, is designed specifically to generate stimuli necessary for intelligence analysts to participate in a dynamic, multi-domain training scenario with other distributed players. This emerging capability also provides a unique venue for testing and validating new cutting-edge human-centered ISR operational tools.

Based on the Combined Air Component Commander's guidance, the Laboratory's team designed a scenario that tasked MQ-9 and F-16 aircrews to plan and execute realistic missions against a near-peer competitor using intelligence derived from a unified training environment and delivered by squadron and wing-level analysts with real-time support from the Distributed Common Ground System and Air Operations Center. Distributed Common Ground System members from three separate sites, conducting analysis in different areas-of-responsibility, came together and delivered timely and accurate products to satisfy the commander's intent for good effects in the battle space.

Division researchers developed comprehensive research objectives for each of the five iterations of the exercise to measure readiness, scenario relevance and training effectiveness. Additionally, the Laboratory's team validated methods required to conduct multi-domain C2ISR training, including the integration of operational and exercise management tools during the exercise.

Researchers gave exercise participants pre- and post-exercise surveys to self-evaluate readiness for duty-specific tasks. The surveys' purposes were to validate scenario complexity as well as the participants' perception of their learning, performance and the training's effectiveness for tasks they do not typically complete in their daily duties. During the exercise and in parallel with the surveys, researchers collected objective measures using software designed to evaluate individual and team performance. Researchers collected the data via chat, simulator and intelligence products. Simultaneously, subject matter experts oversaw the software to evaluate real-time performance for debrief purposes.

In conjunction with the individual surveys, each participating team had imbedded subject matter experts that evaluated the team's performance on team tasks. Researchers also gave participants daily surveys to identify (1) what training components they cannot get at their home stations and (2) the most and least effective components of each day.

Although NITE-REX 18-2 provided challenging scenarios for the participants, the results showed a general increase in self-perceived individual readiness throughout all duty positions. Participants' comments emphasized the ability to mission plan and debrief face-to-face helped them during the complex scenarios. In addition, subject matter experts' reports indicated an increase in team performance throughout the exercise. ☆

Capt Nicholas Attillo, C4ISR Team Lead, RHAS
Mr. Nicholas Oyler, Associate Psychologist, RHAS

As a part of the open infrastructure and modular design, members of the Distributed Common Ground System work out of the Joint Operation Center normally used in close-air-support training research.

To obtain a full technical report of NITE-REX 18-2, please contact Mr. Nicholas Oyler at **nicholas.oyler.1@us.af.mil.**

Photo by Mr. Will Graver

Photo by Mr. Will Graver

Realistic intelligence exercises are hard to find, let alone duplicate. T-REX 19-3 is the closest I've seen. It is invaluable to increasing the readiness and lethality of our Airmen."

—Lt Col Aaron "Splash" Wilson
Commander, 118th Intelligence, Surveillance and Reconnaissance Group, Tennessee Air National Guard

TRAINING RESEARCH EXERCISE

Training Research Exercise (T-REX) 19-3 trained Air Force targeting teams effectively in Battle Damage Assessment (BDA) and re-attack recommendations as part of the Air Force and Joint Targeting Cycle. The five-day exercise simulated the 2011 Operation Odyssey Dawn from the Libyan conflict. T-REX 19-3 provided four Air National Guard (ANG) participating units with a high-fidelity and threat-representative simulated environment to train and assess task proficiency within relevant operational timelines. The T-REX Team developed and executed two Air Tasking Order days through a combination of real-world products and constructive computer-generated forces. Internally developed Air Force Research Laboratory (AFRL) software parsed data automatically from the virtual-mission execution and dynamically delivered realistic intelligence to targeting analysts for exploitation in a simulated scenario.

One of the primary training research objectives of the exercise was the validation of the Plan-Brief-Execute-Debrief methodology. This methodology is a commonly used tactics, techniques and procedures in flying units and the United States Air Force Weapons School. Air Force Research Laboratory subject matter experts tailored the methodology for the BDA targeting process and provided analysts with a deliberate set of methods and guidance to improve communication and employ continuous process improvement. In order to validate the methodology, participants were split into two teams that exercised concurrently. The experimental group received the additional tactics-techniques-procedures training during the academics portion of the exercise, and their proficiency was compared to the control group, who received the training after exercise execution.

In the months preceding the exercise, AFRL researchers worked closely with targeting subject matter experts from the participating ANG units in Iowa, Tennessee, North Dakota and Washington to determine the essential tasks and performance criteria required to evaluate proficiency in BDA. During execution, researchers used subject matter expert assessors, participant surveys and unobtrusive data-collection software to gather relevant research data on participant performance, individually and as a team.

The Air Force Research Laboratory's ability to tackle and accomplish the complex problem set of providing relevant stimuli in a timely manner to intelligence analysts showcased its unique capability to provide high-fidelity training research. ☆

SSgt Kacper Sovinski, Program Manager, RHAS

RAMPAGE SAVES TIME AND ELIMINATES ERRORS

In every exercise, there are two sides of the operation. The first side involves the participants, those working to improve their skills and complete the assigned tasks effectively. On the other side exists the personnel (white forces) working to setup and execute exercise logistics. Many exercises leverage intelligence materials, such as Mission Reports (MISREPs), which the white forces spend hours hand creating based on the correct format and task execution details. This is where the Remote Access MISREP Population And GEneration (RAMPAGE) tool comes into play.

RAMPAGE is software that runs on the network during a pre-exercise simulation, gathering data in the background while the aircrew executes the flight. The air tasking order is also loaded on to the network, allowing the software to know what each of the aircraft is expected to do, in addition to grouping the aircraft. Then the software formats the exact simulation information (i.e., coordinates and drop time for each strike) into proper field locations and produces a MISREP. The automated fill-in-the-blanks completion of the MISREP saves white forces time figuring out where and when to drop the weapons.

In addition, by allowing RAMPAGE to do the formatting and calculating, white forces are able to spend more time ensuring a higher level of readiness and exercise fidelity for the training participants. The software reduces mission report writing from several hours to a just a few and eliminates human errors, such as mistyping a field. RAMPAGE is the ideal tool for cutting down on exercise preparation hours and ensuring a more accurate MISREP output.

Lt Noah Scott, C4ISR Engineering Lead, RHAS

WHAT IS RAMPAGE?

RAMPAGE is software that runs on the network during a pre-exercise simulation, gathering data in the background while the aircrew executes the flight.

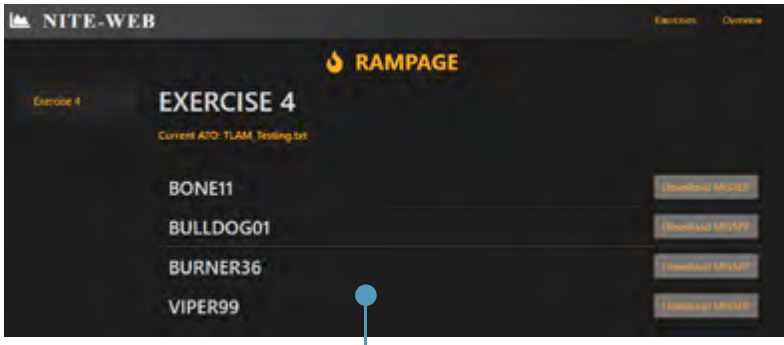


Photo and screen shot by Mr. Will Graver and 711 HPW/RHA

A GLIMPSE OF LIFE AT THE LAB

On a daily basis, a wide variety of subject matter experts, including scientists, engineers and programmers, work on developing technologies, techniques and methodologies needed to assess and improve warfighter readiness and performance. In addition to the Warfighter Readiness Research Division's efforts highlighted in this publication, the Division's professionals collaborate with other Air Force Research Laboratory divisions, Services, industries, academic institutions and agencies on innovative science and technology projects that are transforming readiness.

The images featured here provide a glimpse into the variety of activities that are driving the scientific and technological advancements that will enable "... a more lethal, resilient and rapidly innovating Joint Force[1]."

[1] "National Defense Strategy"

Kaylee Eakins (right), Biomedical and Human Factors Engineer, demonstrates performing a tracheotomy on a human-patient simulator manikin at the National Center for Medical Readiness at Calamityville. Wright State University's Calamityville routinely collaborates with the Division on medical readiness and personnel recovery research.

Program Manager, Lt Julian Barriga and support personnel (Tom Knapp [left] and Dustin Hofer [right]) coordinate the integration and control of technological advances, such as the Joint Theater Air Ground Simulation System. Joint air-ground assets enable warfighters to train for operational missions.

The Division's team-of-teams training events are helping transform warfighting capabilities by providing a unique setting for joint warfighters to debrief the lessons learned.

Division researchers track and analyze the medical training of Air Force personnel in order to predict how knowledge and skills are acquired and decay. The Division's research efforts strengthen alliances and attract new partners through Joint Service collaboration.

Lt Dave Clement, Gaming Research Integration for Learning Laboratory® (GRILL®) Program Manager, instructs students on the Unreal Engine. The GRILL's programs are one way the Division is engaging the future workforce.

Jimmy Cline (center right), software engineer, demonstrates new testbed capabilities to military personnel. The Division's development of the testbed and other innovative operational science and technology solutions are improving mission-relevant warfighter performance and proficiency.

Photos by Mr. Will Graver

RHAC

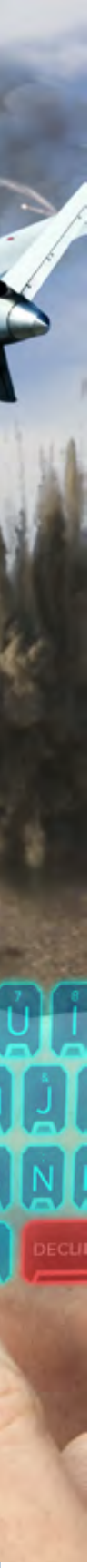
COGNITIVE SCIENCE, MODELS AND AGENTS BRANCH

Mr. Phil Peppler
Branch Chief, RHAC

Graphic by Ms. Shania Horner

Human effectiveness research in cognitive science, data presentation and human-machine interfaces is vital to optimize human-machine teaming performance."

—"United States Air Force Science and Technology Strategy: Strengthening USAF Science and Technology for 2030 and Beyond"



MISSION

We conduct research to advance the state-of-the-art in the computational and cognitive sciences to create technologies for personalized training, continuous readiness monitoring and real-time operational support.

The Cognitive Science, Models and Agents Branch is the leading organization for the science and application of computational and mathematical models of the human mind. Our Branch has an extensive history of contributions to basic research, which has developed the necessary scientific foundation for many of the applied technologies we are pursuing. Our research has successfully matured to applied demonstrations in many of our project areas.

An area that is maturing and has significant potential to bring machine intelligence to a variety of applications is the development of Synthetic Teammates and software-based agents that can assume required roles in training and aiding events. We are putting together a new rapid agent-development project to improve machine intelligence, reduce agent development time and create a computer architecture to train and verify agents rapidly. This effort will improve machine intelligence significantly and make the technology more widely available to military applications.

We are also leveraging our understanding of human memory to schedule personalized training events in a way that maximizes long-term retention. Our Branch has developed a tool, called the Predictive Performance Optimizer (PPO), which uses algorithms to predict when an individual needs training to maintain proficiency. We are using PPO in medical-, language-, resiliency- and pilot-training development projects. The PPO tool and its applications are examples of cognitive science making considerable improvement to training and readiness of highly skilled professionals.

At this year's Interservice/Industry Training, Simulation and Education Conference (I/ITSEC), we are demonstrating a new autonomous Mission Prep and Debrief capability that utilizes software agents to aid planning, monitor mission progression and tag critical debrief elements for after-action review. By leveraging capabilities grounded in computational cognitive science, we are aiming to increase the speed of the mission planning process, thus enabling operators to focus more of their time and attention on tactical planning to enhance mission effectiveness.

The Branch has a number of research efforts underway that are exploring how we can combine our understanding of biological and neural processes to better assess and predict cognitive performance in operational settings. We use the term Multiscale Modeling to describe models that bridge different scales of human activity—from biological, to neural, to cognitive. Areas of application of Multiscale Modeling are fatigue, chemical exposure and workload assessment and reduction.

Our Branch is also supporting the Defense Advance Research Project Agency (DARPA) with their Aircrew Labor In-cockpit Automation System (ALIAS) and eXplainable Artificial Intelligence (XAI) projects. As it has developed, ALIAS has demonstrated an extensible automation architecture for existing manned aircraft to enable safe, reduced and unmanned crew operations. Developers have demonstrated ALIAS in various air vehicles, including helicopters. Currently, the Air National Guard is integrating ALIAS into its F-16 Block-30 aircraft. Recently, the XAI project began to develop explainable technology to communicate with data analytics and autonomy AI (artificial intelligence) paths by using several neural net and cognitive modeling approaches. Currently, we are studying text and visual explanations in a wide array of software agents.

In addition, this past year, our Branch stood up an operating location at Carnegie Mellon University (CMU)—a renowned leader in cognitive science for more than 50 years. Our resident researcher is identifying research opportunities to fill gaps in Air Force applications. Our efforts at CMU have already led to national and international collaborations focused on artificial intelligence and autonomy strategy relevant to the United States Air Force. This effort is just underway, but we are expecting significant results in the future.

These advanced research efforts use cognitive science and computational models of human cognition to support the education and training of our warfighters, monitor their performance to ensure they are prepared to execute their missions and provide adaptive support to maximize mission effectiveness. These efforts highlight the continual cycle of research that uses applied problems to drive basic research investments and capability development, which feed transition opportunities and further research questions. ☆

Mr. Phil Peppler, Branch Chief

Lt. Col José Fadul, Deputy Branch Chief

MULTISCALE MODELING

MISSION

To develop simulations that describe and predict factors that influence an aviator's performance at the cognitive, biological and chemical levels of analysis

Subtle changes in physiological state, such as fatigue, oxygen levels or chemical exposure can have significant effects on an aviator's readiness. The goal of the Multiscale Modeling Team is to develop simulations that describe and predict factors that influence an aviator's performance at the cognitive, biological and chemical levels of analysis. Our approach links dynamic biomathematical models of human physiology with cognitive models that describe how people process information and complete tasks. This linkage enables us to predict how changes in one level will affect another. Our models will help monitor the physiological state of the Airman and detect changes that may lead to cognitive performance impairment. Specific areas of emphasis include models that predict effects of chemical absorption (e.g., toluene, isopropyl alcohol or caffeine), fatigue and circadian rhythms and cognitive workload on operational performance.

In the past year, our team:

- Developed technology for simulating workload conditions in Intelligence, Surveillance and Reconnaissance (ISR) and unmanned vehicle-control settings
- Collected physiological and movement data to support fatigue risk-management systems
- Conducted an analysis on the contribution of fatigue to aviation mishaps
- Collected behavioral and physiological data for workload monitoring in C-17 pilots. ☆

Dr. Christopher Stevens, Research Psychologist, RHAC

Dr. Megan Morris, Research Psychologist, RHAC

Dr. Christopher Myers, Core Research Area Lead and Senior Cognitive Scientist, RHAC

Dr. Glenn Gunzelmann, Core Technical Competency Lead and Senior Cognitive Scientist, RHA

UNDERSTANDING AIRMAN WORKLOAD WITH COGNITIVE METRICS PROFILING

Many operational environments can tax an aviator's cognitive resources. When this workload is too high, it results in an increased risk of accidents and errors. In this work, we apply a method known as Cognitive Metrics Profiling to understand the sources of workload in a task before they create a problem. We create cognitive models of task performance that simulate the various resources (i.e., memory, visual processing, motor planning, time management, etc.) required by a task. Then we use this profile to identify moments in a planned task that could lead to overtaxing cognitive resources. By identifying the specific type of overload that will result (e.g., memory), we can recommend potential remediation methods. We have applied this approach to various operational task environments, including unmanned vehicle control and aerial refueling in C-17s.

Recently, we collaborated with scientists and engineers in the Human-Centered Intelligence, Surveillance and Reconnaissance Division and the Airman Bioengineering Division to develop a novel task environment that represents basic cognitive capacities required of Intelligence, Surveillance and Reconnaissance analysts. In this environment, analysts must complete a set of interrelated subtasks to arrive at a final decision. We aim to develop models that can predict the workload associated with individual subtasks and different combinations of those subtasks. We will combine predictions from these models with neural metrics of workload to inform the decisions of an autonomous manager that can re-assign tasks between human and machine teammates, as needed to achieve optimal workflow. ☆

Dr. Christopher Stevens, Research Psychologist, RHAC

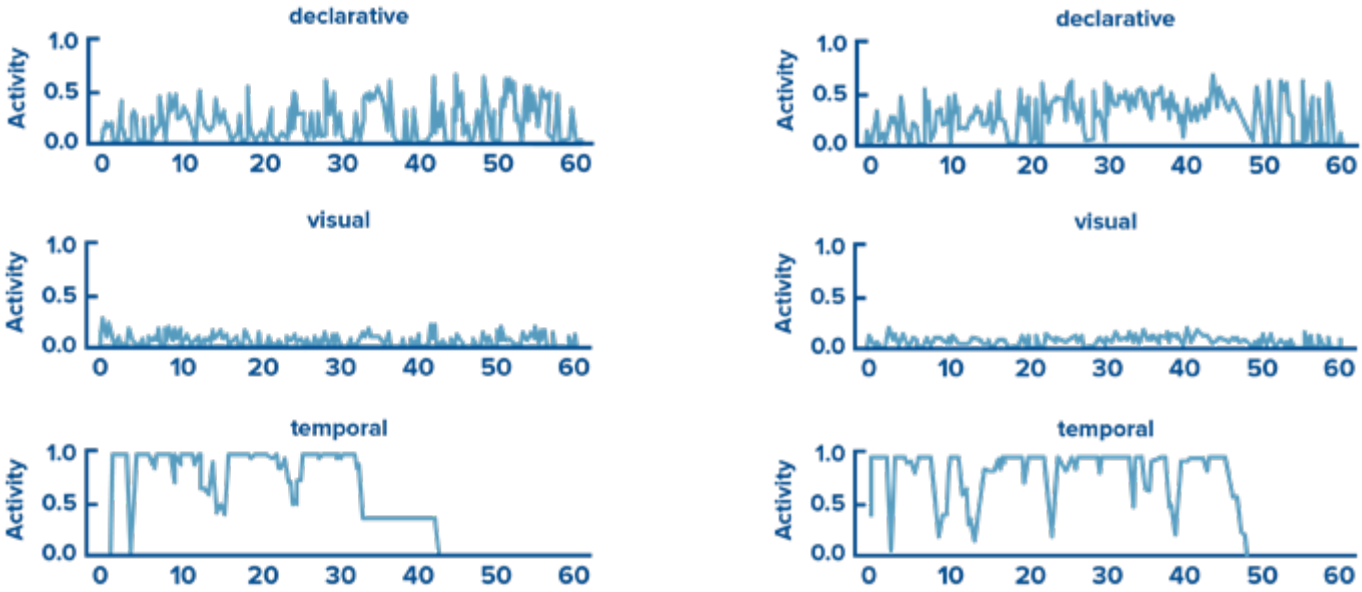
Dr. Megan Morris, Research Psychologist, RHAC

Dr. Christopher Myers, Senior Cognitive Scientist and Core Research Area Lead, RHAC

COGNITIVE METRICS PROFILE

Unmanned Vehicle-Control Task

The below graphs illustrate a cognitive metrics profile of an unmanned vehicle-control task. The graph's lines depict the timeframe of activation for various cognitive resources, including memory, vision and timekeeping. Our research team use these profiles to predict how demanding the operator feels the task is to perform and how well that task will integrate with other possible concurrent tasks. On the left is a condition with low-task load, on the right is a more difficult condition with more tasks to perform.



COMPARISON STUDY OF WATCHES AND SLEEP ESTIMATES

In collaboration with the Air Mobility Command, researchers from the Cognitive Science, Models and Agents Branch conducted a study comparing a commercial fitness smartwatch to a research-grade actigraph watch to determine if the fitness watch could provide comparable use in an operational context. Specifically, the team was interested in comparing sleep period estimates, including total sleep minutes, total wake minutes, and start and end times. An important component of this comparison was the investigation of the fitness watch's ability to estimate nap and sleep periods outside of normal sleep hours, common occurrences in an aircrew's operational environment.

Thirty-six members from the 437th Airlift Wing at Joint Base Charleston volunteered to wear their fitness watch (Garmin fēnix® 5x) and a research-grade actigraph watch (Ambulatory Monitoring Inc. Micro Motionlogger®) for two weeks and complete an activity log. Volunteers self-reported sleep and nap start and end times, sleep quality and watch off-wrist periods in their activity logs. Team researchers scored the actigraph watch data to produce sleep estimates and compared them to sleep estimates generated by the fitness watch's proprietary algorithm based on activity and heart-rate metrics from the fitness watch.

Compared to the actigraph watch, the fitness watch tended to moderately overestimate sleep minutes and very slightly underestimate wake minutes in regard to sleep periods. The fitness watch tended to have very slightly earlier start times and later end times for sleep periods compared to the actigraph watch. Importantly, several nap periods and some primary sleep periods outside of normal sleep times were self-reported and identified by the actigraph watch, but were not identified by the fitness watch application. This suggests that the fitness watch sleep estimates are not currently optimal for research or application in the mobility environment.

As this research progresses, researchers will explore approaches to improving the fitness watch sleep and nap estimates. In real-world settings, fitness watches have a number of strengths relative to research-grade watches (e.g., smart applications, additional physiological measurement capabilities, ruggedness, automatic processing, etc.). ☆

Dr. Glenn Gunzelmann, Core Technical Competency Lead and Senior Cognitive Scientist, RHA

Dr. Megan Morris, Research Psychologist, RHAC

ACTIGRAPH VS.FITNESS SMARTWATCHES

An Air Wing volunteer wears an actigraph watch as part of the comparison study of actigraph and fitness smartwatches and how well they track participants' sleep.

"ONE OF THE MOST BENEFICIAL WAYS TO ENSURE A HEALTHY LIFESTYLE IS TO PRIORITIZE YOUR SLEEP."

— Maj Jaime Harvey
Chief of Human Factors and Operational Safety Issues
Headquarters Air Force Safety Center

Photo by Mr. Will Graver

SYNTHETIC TEAMMATE RESEARCH

MISSION

To enhance the effectiveness and efficiency of training through the research and development of cognitive models that can play the role of team members, white forces and adversaries during training exercises

The Synthetic Research Team has conducted a first-of-its-kind empirical evaluation of a synthetic teammate operating with human team members and compared their performance to all-human teams. The results indicated that there was no statistically distinguishable difference between teams with the synthetic teammate and all-human teams. Currently, our team is researching how closely synthetic teammates need to approximate human-level cognitive processes for adequate human training experiences. Further, our team is conducting research to enable rapidly developed models for synthetic teammates.

In 2019, our team is executing a second evaluation study testing a new approach to computational models of situation awareness that generalize the integration of text-based communications. In addition, the second evaluation study will test the synthetic teammate's ability to adapt to failures depicted in its task display through communications with its team members. The IEEE [Institute of Electrical and Electronics Engineers] Intelligent Systems awarded our team the journal's cover based on the related paper "Autonomous Intelligent Agents for Team Training: Making the Case for Synthetic Teammates." ☆

Dr. Christopher Myers, Core Research Area Lead and Senior Cognitive Scientist, RHAC

Dr. Christopher Stevens, Research Psychologist, RHAC

IEEE Intelligent Systems serves users, managers, developers, researchers and purchasers who are interested in intelligent systems and artificial intelligence, with an emphasis on application.

Myers, C., Ball, J., Freiman, M., Caisse, M., Rodgers, S., ... McNeese, N. (2019). Autonomous intelligent agents for team training: Making the case for systhetic teammates. *IEEE Intelligent Systems, 34*(2), 3–14.

UNDIFFERENTIATED COGNITIVE AGENTS FOR TEAM TRAINING

Autonomous systems are a new frontier for pushing sociotechnical advancement. Such systems will eventually become pervasive, participating in everything from manufacturing, healthcare, defense and even research itself. However, the high-development costs and the resulting inflexibility of the produced systems stifle their proliferation. The current state-of-the-art in the development and integration of computational cognitive agents that operate as team members in complex situations requires a 3–15 year development period, often requiring humans to adapt to the limitations in the autonomous systems. This past spring, we kicked-off a new basic (6.1) collaborative research effort with Kansas State University and Drexel University to research and develop a cognitive system capable of independently acquiring task knowledge and skill.

Our approach begins with a foundational and generalizable system that transforms into a specialized cognitive agent through written instruction, direct interactions with its trainers and experience with the task. We are working toward an undifferentiated agent (uAgent) that is a set of general-purpose computational cognitive capacities enabling it to read task instructions, iteratively interact with trainers to disambiguate instructions, generate the requisite task knowledge from the instructions and specialize to different levels of task proficiency. We will use the generalized method of iterative, closed-loop experimentation performed by the Autonomous Research System to tailor uAgent training scenarios to provide the appropriate task experiences to transform the uAgent into a specialized agent that performs at a desired level of task proficiency.

Dr. Christopher Myers, Team Lead and Core Research Area Lead for Cognitive Modeling

Dr. Pascal Hitzler, Wright-State University

Dr. Benji Maruyama, AFRL/Materials & Manufacturing

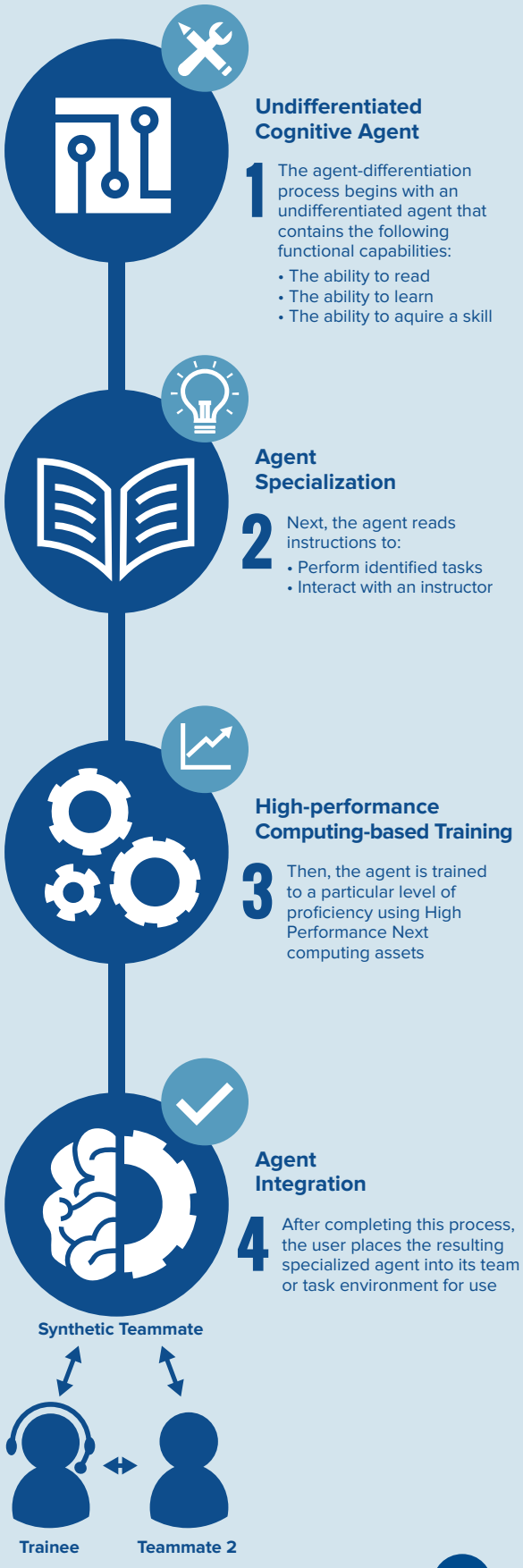
Dr. Dario Salvucci, Drexel University

Dr. Christopher Stevens, Cognitive Scientist, RHAC

> **"We are working toward an undifferentiated agent that is a set of general-purpose computational cognitive capacities..."**
>
> **—Dr. Christopher Myers**
> **Team Lead and Core Research Area Lead for Cognitive Modeling**

THE PROCESS OF DIFFERENTIATING GENERAL AGENT

Concept by Dr. Christopher Myers, RHA



PREDICTED PERFORMANCE OPTIMIZER

VISION

Our ultimate vision is to apply this technology to military readiness training across the spectrum of operations, in order to produce higher performance readiness and lower training costs.

Researchers at the United States Air Force Research Laboratory's Airman Systems Directorate, Cognitive Science, Models and Agents Branch, have developed an innovative technique designed to personalize and optimize learning based on a patented cognitive technology known as the Predictive Performance Optimizer (PPO).

This technology functions by using a cognitive modeling methodological approach to quantitatively and validly track and predict knowledge or skill acquisition and decay. It uses individual student historical-performance data to estimate learning and forgetting and prescribes optimal future training times to help students acquire and sustain that knowledge or skill most efficiently and effectively. Our team has forged collaborative efforts with distinct communities in medicine, language learning, total-force training, aviation and sharp shooting. In addition, the validation of this personalized learning approach is underway in each of these application areas. Our ultimate vision is to apply this technology to military readiness training across the spectrum of operations, in order to produce higher performance readiness and lower training costs.

In 2018, this research won Outstanding Research awards from the United States Air Force School of Aerospace Medicine's Independent Review Team and the Air Force Research Laboratory's Scientific Advisory Board. In addition, commercialization plans are in place with the American Heart Association to roll this personalized learning technology into state-of-the-art cardiopulmonary resuscitation training systems. ☆

Dr. Tiffany Jastrzembski, Team Lead and Senior Cognitive Scientist, RHAC

Dr. Leslie Blaha, Senior Research Psychologist and Lead for Carnegie Mellon University Operation Location, RHAC

Dr. Kevin Gluck, Core Research Area Lead and Principal Cognitive Scientist, RHAC

Dr. Glenn Gunzelmann, Core Technical Competency Lead, RHA

Mr. Michael Krusmark, Research Scientist, RHAC

Dr. Florian Sense, Cognitive Scientist, University of Groningen

Dr. Hedderik van Rijn, Cognitive Scientist, University of Groningen

OPTIMIZED LEARNING FOR LINGUISTS

Researchers in the Cognitive Science, Models and Agents Branch (RHAC) are collaborating with researchers in the Mission Analytics Branch to integrate the Predictive Performance Optimizer's (PPO) personalized learning capabilities with the automated translation capability of Haystack Technologies' foreign media. This integrated capability will be a component of the Air Education Training Command's (AETC) Linguist Next project and has a transition path to the Defense Language Institute (DLI).

The goals for an integrated technology capability are twofold. First, the technology will provide linguist instructors real-time performance assessments and remediation instructional materials for small group classrooms assessed by PPO. The PPO technology will identify group weaknesses and provide pointers to Haystack's technology to deliver optimal materials for instructors to use to remediate students' subject-matter content deficiency. Second, students will use DLI's NetProf, an integrated distributed learning platform, to study and pronounce vocabulary words. NetProf assesses pronunciation of words on a scale of 0–100, based on how closely the student sounds compared to a native speaker. Those assessments provide fodder for PPO to determine what phonemes need additional practice. The PPO technology then provides pointers to Haystack's technology to provide a library of additional targeted words or phonemes that the student in need of remediation can to listen to in order to improve their weaknesses.

Because AETC leadership, the Linguist Next project director and the DLI provost advocated for this research, our team is diligently working with DLI and Linguist Next subject matter experts to determine what a preliminary field assessment will look like. It is our hope that if positive evidence is attained, our team may integrate with additional DLI learning products to help create higher performing students without increasing training time. ☆

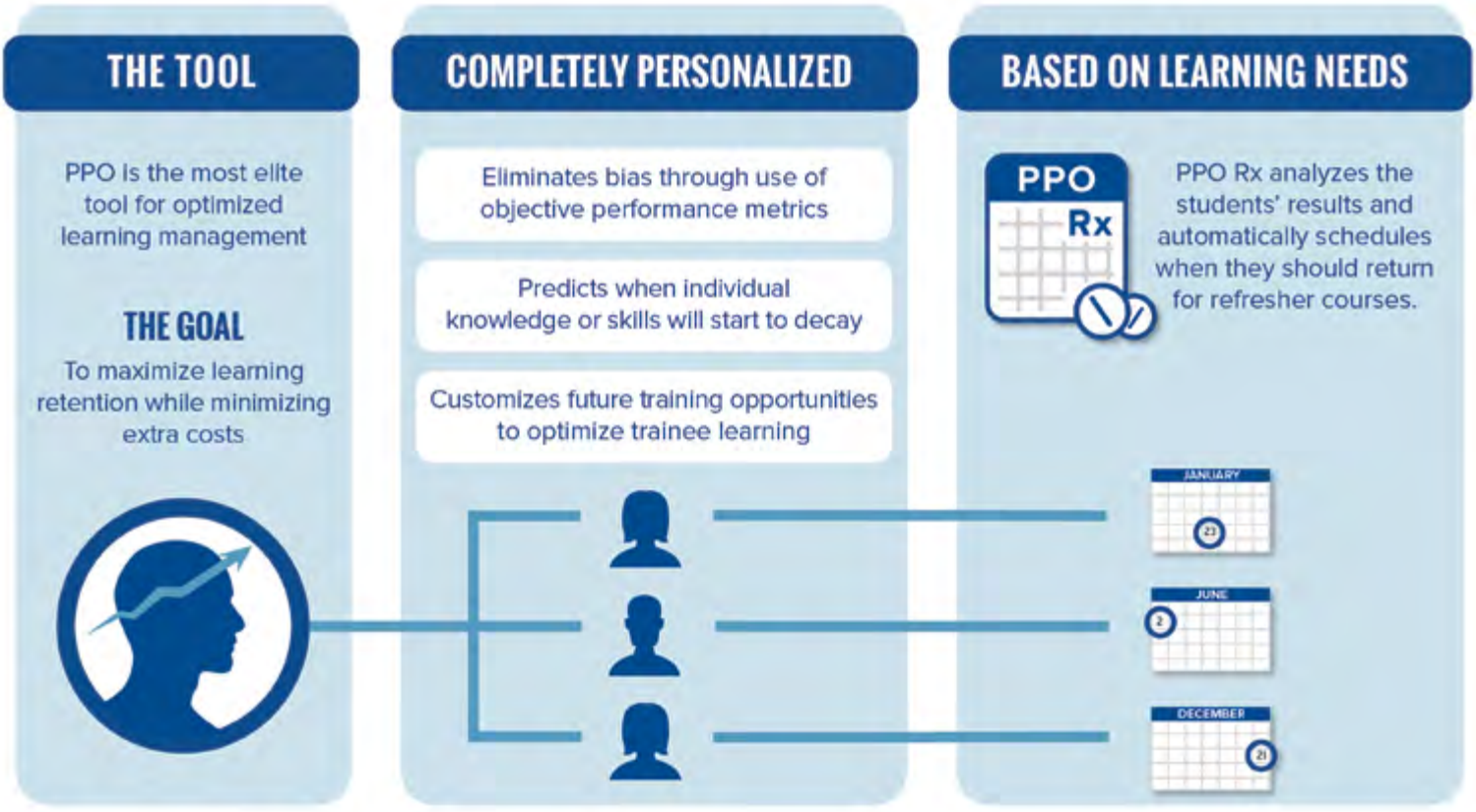
Dr. Tiffany Jastrzembski, Team Lead and Senior Cognitive Scientist, RHAC

Dr. Julie Cantwell, AETC Linguist Next Project Director

Dr. Jack Harris, Cognitive and Computer Scientist, Infinite Tactics

Mr. Michael Krusmark, Research Scientist, RHAC

Dr. Branka Sarac, Defense Language Institute



Graphic by Ms. Shania Horner

PERSONALIZED TRAINING FOR CARDIOPULMONARY RESUSCITATION SKILLS

Researchers from the 711th Human Performance Wing's Cognitive Science, Models and Agents Branch completed a large-field study in collaboration with the American Heart Association and Laerdal Medical. The study investigated the effectiveness and efficiency of prescriptively scheduling cardiopulmonary resuscitation, or CPR, training according to cognitively principled, individually personalized training schedules determined by the patented Predictive Performance Optimizer (PPO) technology, compared to performance levels in 3-month and 6-month fixed-calendar refresher training intervals. A key focus of this study was to assess the ability of PPO to help trainees better sustain CPR skills in order to reduce risks to patient safety, while simultaneously avoiding unnecessary and costly overtraining for trainees who have demonstrated high levels of sustained proficiency.

Results from the repeated measures in this 2-year longitudinal study indicate that across the nearly 400 nursing student participants, the use of PPO for personalized scheduling improves proficiency and mitigates risk simultaneously. Further, when extrapolated analytically over a longer timeframe (see Figure 1), PPO also reduces overall training time and costs, relative to any fixed-calendar refresher interval. Given the evidence for personalized scheduling benefits, the team is planning a follow-on exploratory hospital rollout to examine the feasibility of this approach for healthcare training in the civilian sector. These studies will investigate extensions to CPR, Advanced Cardiac Life Support, Neonatal Resuscitation Program training, trauma assessment and intracranial pressure monitoring skill sets. Negotiations are underway for additional validation studies to apply this technology to language learning, shooting, pilot and total-force training.

This work, combined with related research on the foundational mechanisms of human learning, retention and relearning, received Best Presentation Awards from the Scientific Advisory Board and the Independent Review Team in 2018. ☆

Dr. Tiffany Jastrzembski, Team Lead and Senior Cognitive Scientist, RHAC

Dr. Kevin Gluck, Core Research Area Lead and Principal Cognitive Scientist, RHAC

Dr. Russell Griffin, American Heart Association

Mr. Michael Krusmark, Research Scientist, RHAC

Dr. Lauren Sanderson, Research Psychologist, American Heart Association

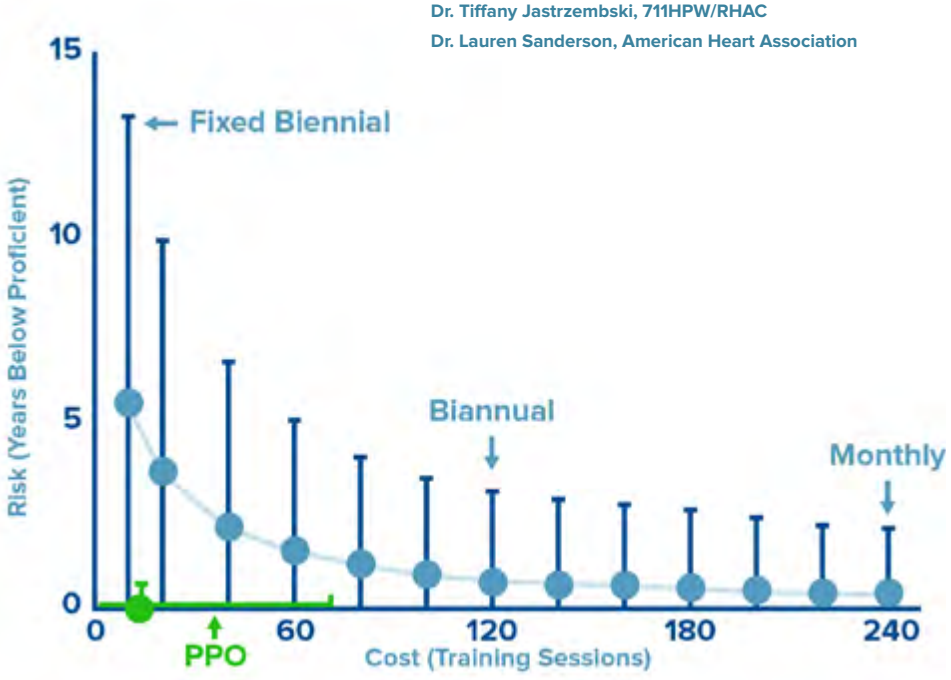
FIGURE 1: BENEFIT OF PERSONALIZED TRAINING

(Risk vs. Cost during the Span of 20 Years)

Data from nearly 400 trainees in the CPR field study demonstrate that PPO-based personalized learning schedules enhance performance effectiveness and reduce training time and costs

Dr. Tiffany Jastrzembski, 711HPW/RHAC

Dr. Lauren Sanderson, American Heart Association



Graphics by Ms. Shania Horner

BYSTANDER INTERVENTION AND RESILIENCE TRAINING

In order to develop a ready and able force, individual Airmen must possess skills that enable individual and unit resilience and have at-the-ready skills to prevent interpersonal violence and suicide. For learning to be maximally effective, it is imperative that training for these vital competencies be delivered in a way that meets individual learning needs. The current classroom one-size-fits-all annual training model falls short.

To optimize training efficacy, Airman skill proficiency and resource utilization, the Air Force Integrated Resilience Directorate (AF/A1Z) has partnered with the Air Force Research Laboratory's Cognitive Science, Models and Agents Branch to apply its patented, state-of-the-art cognitive modeling technique—the Predictive Performance Optimizer (PPO)—to deliver a precision learning capability. The collaborative effort's goal is to deliver the right training at the right time, based on principled identification of learning needs. This goal will require a shift towards proficiency-based learning through development and validation of objective performance metrics, so users may attain learning curves and personalized application of PPO may ensue.

The two-phase project will first apply the PPO to two key prevention and resilience skills; bystander intervention and cognitive restricting. The second phase will build a suite of foundational prevention and resilience skills for PPO application. Once fully implemented, the Air Force will establish a strong foundation of prevention and resilience skills early in an Airman's career and will reinforce these skills as needed, based on individualized learning needs and the optimal timing of refresher training to prevent skill loss. Development of objective metrics is currently underway and our team anticipates total-force implementation beginning in 2020. ☆

Dr. Tiffany Jastrzembski, Team Lead and Senior Cognitive Scientist, RHAC

Mr. Michael Krusmark, Cognitive Psychologist, RHAC

Dr. Andra Tharp, Air Force Integrated Resilience Office (AF/A1Z)

THE FACTS

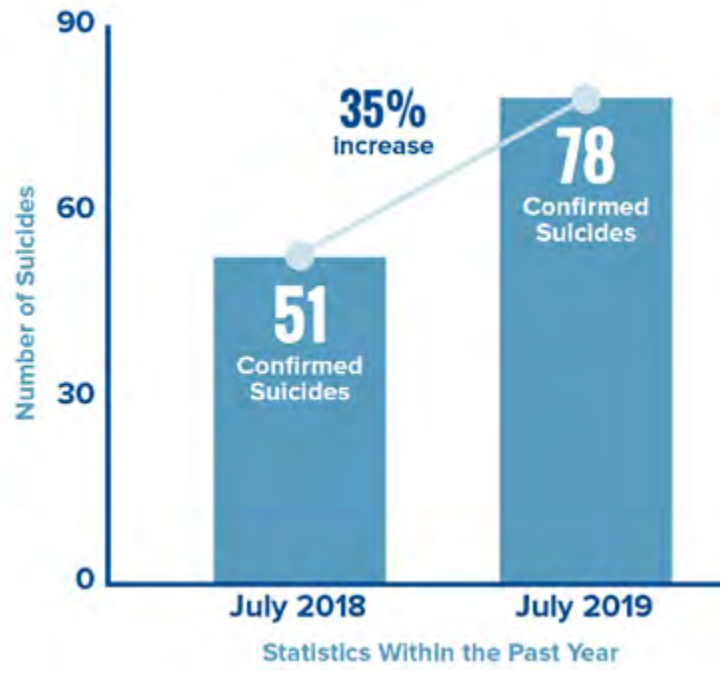
2019 is on pace to have the highest number of suicide deaths when compared to the past 11 years.

The graph below shows a 35% increase in suicide deaths during the past year.

Enlisted, married males ages 23–30 with relationship struggles are at heightened risk.

SUICIDES DURING THE PAST YEAR

(July 2018 to July 2019)



Facts and Chart Data Information: Resilience Tactical Pause Playbook

MISSION PLANNING AND DEBRIEF

OBJECTIVE

To accelerate processes and improve mission outcomes

OUR APPROACH

Involves a mix of new technologies that allow human-machine teams to engage jointly in iterative processes

EXAMPLES OF CURRENT INVESTMENTS

(1) Exploring the use of augmented reality for rapid visualization and preview of a digitally planned mission

(2) Planning and debrief as contexts for Interactive Task Learning, with humans and computer agents learning and teaching each other entirely new things on the fly

The pointy ends of our national defense spears involve some of the most sophisticated technologies in the world. Just behind these pointy ends, however, is a collection of planning and debriefing processes mired in decades-old technologies (e.g., chalkboards, whiteboards and laminated maps) that impede the operational ability to adapt, decide and execute. To address this our team is leading research, development and evaluation efforts for next generation mission planning and debrief.

The core of our in-house development is a web-based system we call Metis, after the ancient Greek goddess of wisdom, prudence and deep thought. Metis provides a web interface, an application programming interface for software agents and a database backend to serve both in real-time. Using this service-oriented architecture, our team has begun to develop and integrate an array of agent technologies.

These include the following initial capabilities.

- Air Tasking Order parser
- Reading agent that extracts constraints from mission planning guidance documents
- Mission plan generation and validation agent
- Planning product development agent that creates Coord Cards
- Automated Debrief Focus Point identification agent

Each of these agent technologies and their integration is in the prototype stage of development, but already we have begun formative evaluations. The evaluations indicate dramatic improvements in workflow and resulting decreases in process completion time. Early comparisons of machine-generated content to human-generated content show that they are comparable.

As part of our ongoing core applied research, the Mission Planning and Debrief testbed, along with the current implementation of associated agent technologies, provides a foundation on which to create the future. From a research program planning perspective, the concept is to use the testbed as a research and development platform as well as leverage its infrastructure for new investments. These investments span the continuum from fundamental research to advanced technology demonstrations, as time, attention and funding allow.

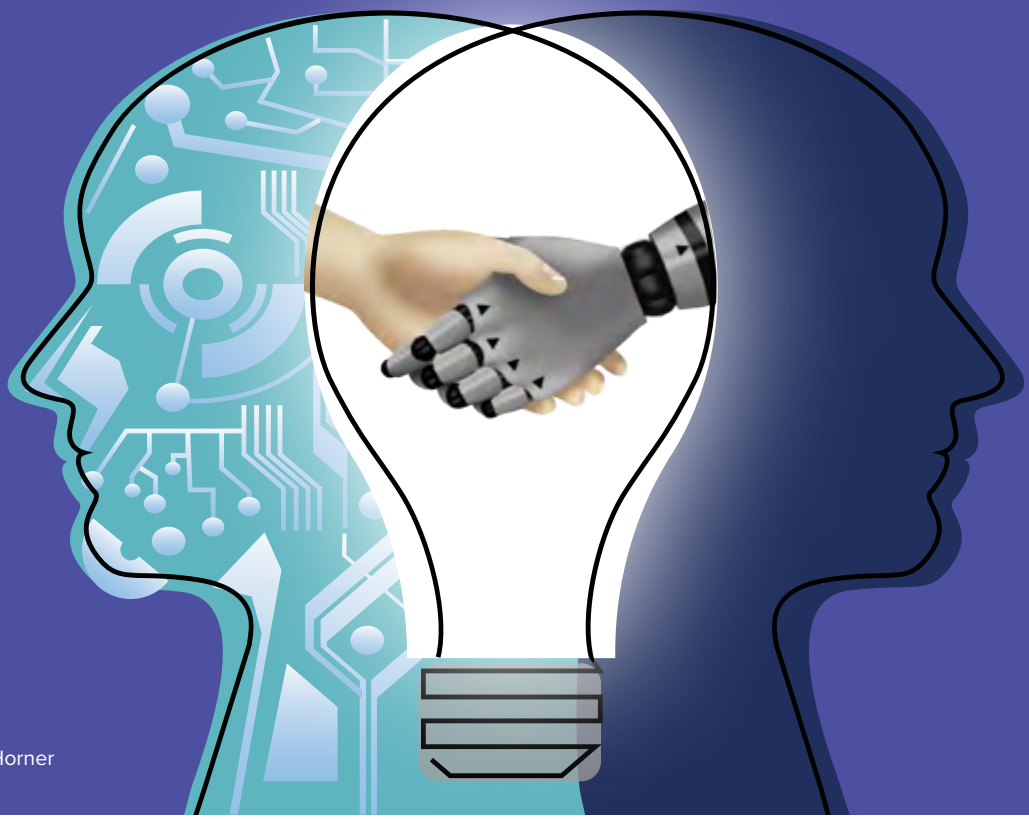
Preliminary results are encouraging, and we are enthusiastic about the possibility of near-term technology off-ramps that can benefit training at large-force exercises. However, the end goal really is to provide technology options that benefit operations and provide flexible force readiness more broadly. Our team is exploring extensions of the prototype capabilities described here. The goal is to move the technologies toward multi- and all-domain operations and a broader set of functional mission types and associated assets. ☆

Dr. Kevin Gluck, Core Research Area Lead and Principal Cognitive Scientist, RHAC

Dr. Leslie Blaha, Senior Research Psychologist and CMU Operating Location Lead, RHAC

Dr. Don Duckro, Program Manager, RHAC

Mr. Brandon Nolan, Associate Computer Scientist, RHAC



Graphic by Ms. Shania Horner

INTERACTIVE TASK LEARNING

People rapidly learn to do new things through interactions with others and with their environment. We both learn and instruct through these interactions. Historically, the artifacts we created (e.g., stone tablets, pieces of paper or whiteboards) have not had any means of participating proactively and intentionally in these learning and teaching processes. They have been tools we can use to support learning and teaching, but not capable of doing so themselves.

In recent years, some ideas have begun to emerge (Laird et al., 2017) around the topic of Interactive Task Learning (ITL). This involves breaking that historical mold in the implementation of our artifacts and taking advantage of new technologies for computational intelligence, in order to make progress on a vision of the future in which humans, robots and agents are able to rapidly learn and teach each other entirely new tasks through natural interaction.

The most complete treatment of these ideas is available in a book released earlier this year (Gluck & Laird, 2019) through MIT Press. The book is in the Strüngmann Forum Series and is an exploration of challenges, open questions and implications from multiple scientific disciplines for achieving scientific and technological progress in this direction. The introductory chapter emphasizes the issues of pace, persistence and partnering that emerged in the Forum discussions and writing of the book, as well as the deep challenge of understanding. Enduring challenges such as these are beginning to focus new research and development efforts in our Personalized Learning and Readiness Sciences Core Research Area. ☆

Dr. Kevin Gluck, Core Research Area Lead and Principal Cognitive Scientist, RHAC

In this 354-page book, "Experts from a range of disciplines explore how humans and artificial agents can quickly learn completely new tasks through natural interactions with each other."

Laird, J. E., Gluck, K. A., Anderson, J. R., Forbus, K., Jenkins, O., Lebiere, C., Salvucci, D., Scheutz, M., Thomaz, A., Trafton, G., Wray, R., Mohan, S., & Kirk, J. (2017). Interactive task learning. *IEEE Intelligent Systems*, 32(4), 6–21, (invited).

Gluck, K. A., & Laird, J. E. (Eds.) (2019). *Interactive task learning.* Strüngmann Forum Report, vol. 26, J. Lupp, series ed. Cambridge, MA: MIT Press.

Photo by Mr. Will Graver

PARTNERSHIP IS ADVANCING THE COGNITIVE SCIENCE OF HUMAN-AUTONOMY TEAMING

Solving the military challenges of tomorrow demands strong research partnerships today.

Members of the Cognitive Science, Models and Agents Branch (RHAC) are thinking outside the fence to develop deeper collaborations with academic partners at Carnegie Mellon University (CMU). In late 2018, RHAC established an operating location on the CMU main campus, ramping up research collaborations in 2019. This enables the Air Force Research Laboratory (AFRL) to embed personnel on campus, working directly alongside faculty, post-docs and students on a daily basis. Consistent, direct interaction expands AFRL's ability to push the cutting edge of research in human-machine teaming.

Carnegie Mellon has a long history pioneering artificial intelligence (AI), starting in 1955 with Herbert Simon and Allen Newell's "thinking machine." This tradition continues today with CMU advancing AI for human cognitive modeling, for robust autonomous systems, for machine-led engineering design and for human-robot interaction. Together, CMU's experts across the Departments of Psychology, Social & Decision Sciences, Machine Learning, Computer Science, Engineering and Robotics are working with AFRL to address knowledge gaps around the use of AI to augment humans and to improve AI-human collaborations in challenging, dynamic task environments.

Collaborative efforts between AFRL and CMU focus on three key areas.

1. **Cognitive Modeling:** Cognitive models are formalisms that characterize the mechanisms supporting measurable human behavior and predict future behaviors. Carnegie Mellon is home to leading experts in computational cognitive architectures, memory, perception and cognitive-neuroscience modeling. In support of personalized adaptive learning systems, one collaboration is examining the role that working-memory models might play in determining the selection of training-session items, to optimize the skill or knowledge gained within and between training sessions. Another collaborative effort is creating computational models of people performing complex, military-relevant tasks. This effort enables our team to make systematic inferences about the cognitive mechanisms supporting good task performance and to identify where we need new modeling theory to construct higher-fidelity cognitive models.

2. **Interactive Task Learning:** Interactive task learning comprises new paradigms for humans and machines to learn from each other through natural interactions. Under the Science of Understanding, our team is pursuing cognitive models that learn from experience in dynamic decision-making and policy-selection tasks, to enable machines to learn from and reason about human teammates.

3. **Human-Autonomy Systems Validation and Verification:** Researchers need new tools to evaluate intelligent technologies and autonomous systems that are capable of adapting and responding to unanticipated situations without pre-programming. These technologies include cognitive models learning in human-like ways and AI systems learning in machine-like ways. The AFRL is collaborating with CMU and other Defense researchers to develop new approaches and test harnesses for developmental test, evaluation, validation and verification of learning systems.

The CMU operating location provides a unique opportunity to develop future STEM (science, technology, engineering, mathematics) experts to work on Air Force relevant problems. On campus, we are working with students and post-docs to design experiments in language learning and dynamic decision making. In addition, we are creating opportunities for exchanges between CMU and AFRL scientists to bolster each other's research with new expertise and collaborations.

Carnegie Mellon University is a growing hub for mission-inspired research. The university currently boasts a University Center of Excellence in Trusted Human-Machine Teaming, funded by Air Force Office of Scientific Research and the 711th Human Performance Wing. In February 2019, the Army AI Task Force launched its research hub at CMU's National Robotics Engineering Center. Carnegie Mellon is home to the Software Engineering Institute, a Department of Defense federally funded research and development center, which supports transitioning research into application through AI engineering. ☆

Dr. Leslie Blaha, Senior Research Psychologist and CMU Operating Location Lead, RHAC

Dr. Kevin Gluck, Core Research Area Lead and Principal Cognitive Scientist, RHAC

ADVANCING A MUTUAL UNDERSTANDING BETWEEN HUMANS AND MACHINES

Future capabilities will rely heavily on teams of humans, artificial intelligence agents and autonomous systems. A fundamental assumption is that the team members, human and machine, will fluidly understand each other to predict each other's decisions, actions and future behaviors.

This will require answers to two broad open questions:

1. What does it mean for humans to have an actionable understanding about machines?
2. What does it mean for intelligent machines to have an actionable understanding about humans?

These forms of understanding are likely not the same.

Researchers in the Cognitive Science, Models and Agents Branch, in collaboration with researchers at Carnegie Mellon University, are pioneering a new Science of Understanding. The objective of this basic research program is to lay a rigorous theoretical foundation around the concept of understanding, with attention to the fundamental similarities and asymmetries between humans and machine understanding each other. We are defining the critical tests and metrics to measure understanding, both in general and under mission-specific requirements.

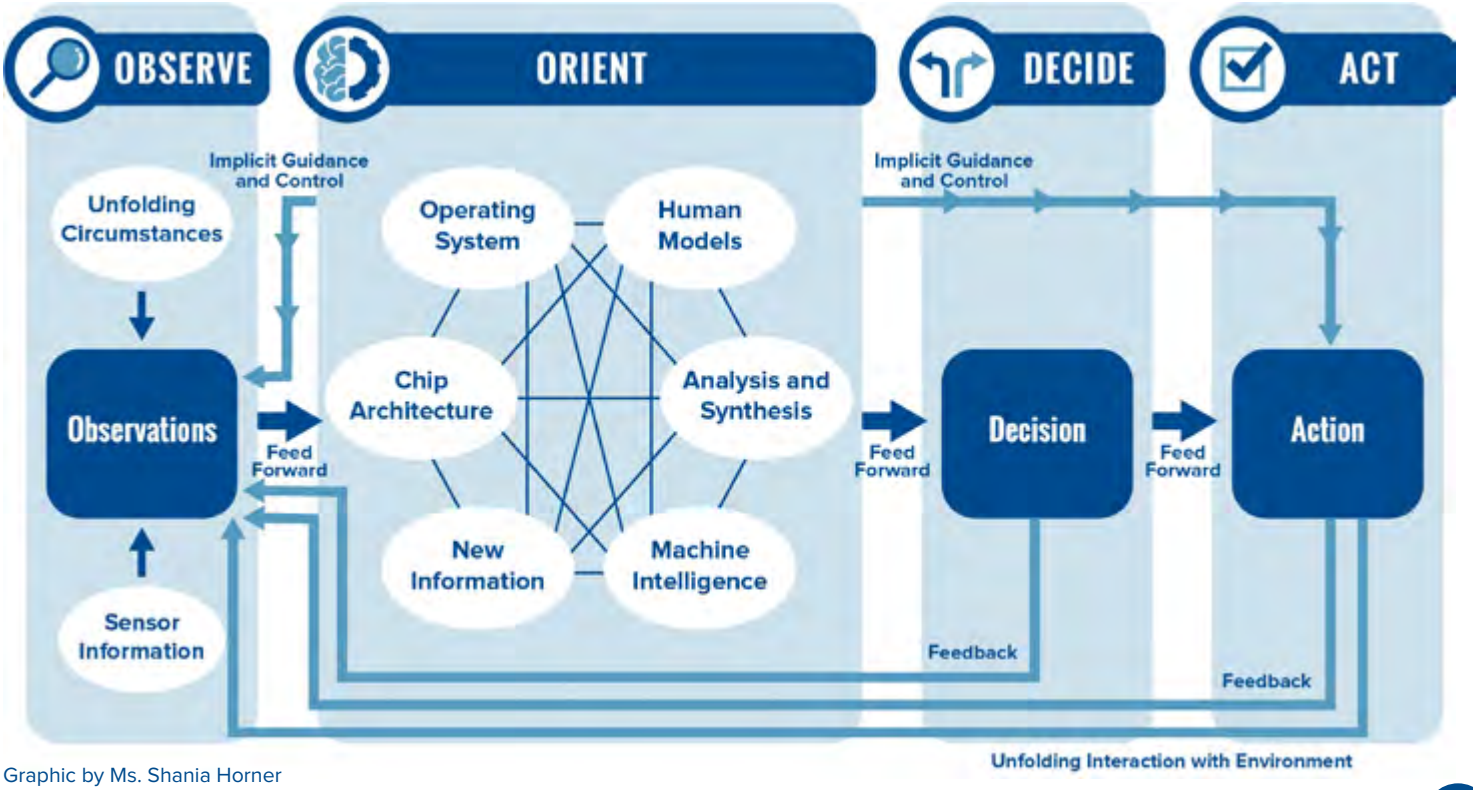
Our team adopts the perspective that cognitive models have a unique role to play in supporting machine understanding of human teammates. Cognitive models are the mathematical and computational formalisms that characterize and predict human behavior grounded in the principles and mechanisms of human information processing. These constitute a set of tools that can be incorporated directly into machine intelligence to enable it to reason about human behavior. The Science of Understanding is currently exploring the degree to which cognitive models enable intelligent meta-reasoning, inference and appropriate feedback by machines to indicate an understanding of their human teammates.

Because understanding should be mutual, we are also assessing the ways cognitive models can help us capture and characterize human's mental models of artificial intelligent agent behaviors. We are developing novel experiments to assess how human interactions with cognitive-model-based machine systems reflect and shape their mental models about their machine teammates. ☆

Dr. Leslie Blaha, Senior Research Psychologist and CMU Operating Location Lead, RHAC

Dr. Christian Lebiere, Research Professor, Carnegie Mellon University

Dr. Cleotilde Gonzalez, Research Professor, Carnegie Mellon University



Graphic by Ms. Shania Horner

MINDMODELING.ORG

WHAT IS MINDMODELING?

MindModeling is a tool for making the Cognitive Science, Models and Agents Branch's scientists and engineers more "effective" and "productive." Specifically, it provides an intuitive web interface for them to run cognitive models and agents as quickly as possible. It does this intelligently, distributing the work to volunteer computers and Department of Defense high-performance computers according to the job's requirements.

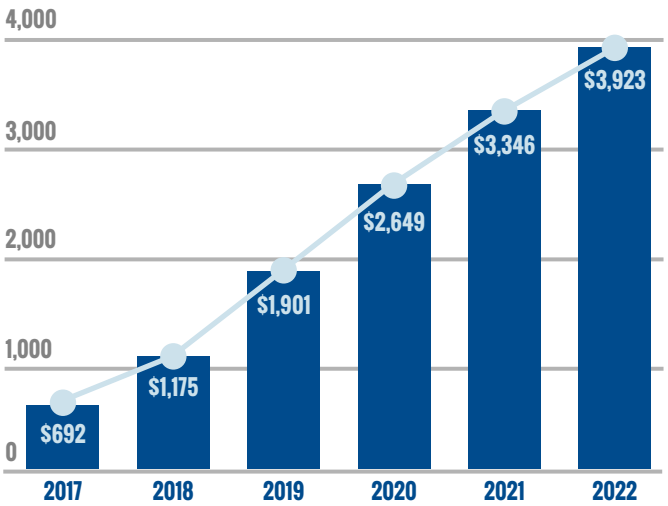
IT ALLOWS OUR SCIENTISTS AND ENGINEERS TO:

- Run bigger parameter sweeps
- Explore more model and agent approaches
- Enjoy faster development cycles and spend their time elsewhere


Photo by Mr. Will Graver

FORECAST OF GLOBAL ARTIFICIAL INTELLIGENCE DERIVED BUSINESS VALUE

(Billions of US Dollars)



Graphic by Ms. Shania Horner

MINDMODELING MODERNIZATION FOR AGENTS

Work to modernize MindModeling continues with two phases of work.

Phase I

Phase I (slated for completion by December 2019) involves a major overhaul of the system's internal workings. This modernization effort will increase the efficiency of the system, allowing for a larger number of jobs (i.e., agent training and or experimentation). It will also allow the team to iterate new features quickly, which is key to expanding MindModeling's capabilities and making it more useful for modern artificial intelligence (AI) development. Finally, the modernization is the last step before transitioning the code to an open-source model under the name "FTL Grid." Internally, the project will retain the name MindModeling.

Phase II

Phase II will focus on two major system features. The first feature includes user-defined, dynamic state-space exploration and agent packaging. This feature will allow scientists and engineers to define their own algorithms for choosing new "points" to explore in response to previous results. Currently, users can only define the state space to search and choose one of two algorithms to search with (1) full enumeration or (2) a generic algorithm based on a user-provided utility value. While these algorithms serve a large number of use cases, the new feature will allow users to obtain their desired data and or training and complete it in less time by guiding the search more intelligently. It will also enable dynamic agent training, based on prior results. The second major feature is agent packaging. This feature is necessary to support the Branch's development of increasingly complex, multi-language agents and models. Previous submissions to MindModeling required a single language or relied on out-of-band software dependencies (i.e., high-performance computing supplied).

Together, the two modernization phases will increase system efficiency and enhance the customization of model and agent development by the Branch's scientists and engineers. ☆

Mr. Josh Ziegler, Associate Computer Scientist and Team Lead, RHAC

Ms. Olivia Leung, Associate Computer Scientist, RHAC

RHAO
OPERATIONS SUPPORT BRANCH

Mr. Jeffrey "Sam" Griffith
Branch Chief, RHAO

Photo by Mr. Will Graver

Look for smarter, more effective ways to do business and empower your teams to innovate."

—Dr. Mark T. Esper
United States Secretary of Defense

MISSION

Provide the support necessary to keep the Division's research teams operating at their fullest capacity, while minimizing administrative burden

Although, the work performed by the members of the Operations Support Branch does not often garner the well-deserved lime light afforded to our research programs, their foundational efforts are essential to our Division's success. Our team is made up of seasoned experts in key areas that directly support and enable our researchers.

These key areas include:

- Acquisition Management
- Program Analysis
- Information Technology
- Information Security Systems Management
- Integration Management
- Business Management
- Financial Management
- Facilities Management

Our mission is to provide the "grease" to keep our research teams operating at their fullest capacity while minimizing administrative burden. Specifically, our team facilitates all aspects of a $.2 billion Warfighter Readiness Research contract and other related contracts, which directly support all of the Division's research efforts and testbeds. Near- and long-term budget management is provided by our team. We manage and prepare more than 100 active taskers originating from our Air Force chain-of-command each year and ensure timely and complete responses to each one. We coordinate more than 30 annual visits and tours of more than 400 personnel, including Flag Officers, Senior Executive Service officials, politicians and warfighters. These activities enhance our communications with our current and potential customers and other interested parties.

In order to meet our customers' requirements and remain on the cutting edge of technology, all renovations and upgrades to our testbeds are facilitated by the team as well. Our Information Security Systems Management personnel are in the process of securing Authorizations to Operate in all of our classified testbeds, as we transition from a research-based network to an operationally-based network in order to keep pace with our warfighter customers.

Our communications team ensures that our signature distributed Live-Virtual-Constructive efforts are optimized with the best information technology possible, whether that involves secure telephones or sophisticated data portals securely moving vast amounts of data throughout the world. Critical to our success is our ability to provide a meaningful framework for each of our research programs or work units by ensuring each is established and maintained correctly utilizing appropriate administrative guidance. In short, the Operations Support Branch is our organization's force enabler, and on a daily basis, its talented members facilitate the success of our world-class research efforts. ☆

Mr. Jeffrey "Sam" Griffith, Branch Chief, RHAO

WHAT WE DO

Facilitate all aspects of a $.2 billion Warfighter Readiness Research contract

Manage near- and long-term budgets

Prepare and manage more than 100 active taskers originating from our Air Force chain-of-command each year

Coordinate more than 30 annual visits and tours of more than 400 personnel

TESTBED RECONFIGURATIONS

Air Force Research Laboratory researchers acknowledge that agility is one of the key factors in meeting their customers' needs. Having flexible testbeds that reconfigure and are optimized easily are vital to responding to a new customer's, or an established customer's, emerging requirements. The Warfighter Readiness Research Division is fortunate to boast state-of-the-art testbeds that support the world's preeminent readiness research and address the requirements of Air Force warfighters and our other Department of Defense and coalition partners.

Approximately eight years ago, the Division constructed our current research lab with an eye towards incorporating the most flexible designs that would allow us to meet today's requirements and those that will inevitably emerge in the future.

Specifically, this design consists of features, such as:

- High ceilings to accommodate nearly any size of research fixture
- Vigorous heating, ventilating and air conditioning, which is designed for adjustability and upgrade ability to meet ever-increasing higher-heat loads
- Robust electrical capacity and accessibility to enable maximum upgradability for growing needs
- Raised flooring and floor troughs that route electrical, data and communications lines discreetly and safely to any point in the testbed
- Data portals and conduit that connect our testbeds internally as well as with other labs and operational units (contiguous and outside contiguous United States)
- State-of-the-art security systems with the ability to modify as the programs require

In an effort to respond to the requirements of future fights in multi-national, multi-domain environments, the Division is reconfiguring and updating several testbeds.

The following are examples of the reconfigurations efforts.

1. Integration and Development Test Bed for Secret Collateral Security-Level Research

The Division is currently standing up this testbed. Our plan is to have a representation of each of our testbeds in a single room. Doing so will simplify developing and integrating these capabilities in a single location. In addition, it will enable us to connect these representative testbeds with other testbeds throughout our lab in order to provide more realistic readiness research (i.e., Mission Tactic Trainer F-16s participating in an air-to-ground exercise in our Integrated Combat Operations Training Testbed). Furthermore, locating most of our lab's capabilities in a single testbed will enable us to provide one-stop tours to our customers and visitors, thereby maximizing efficiency and minimizing disruption to ongoing readiness research conducted in our regular testbeds.

2. Joint Theater Air Ground Simulation System Refit

This effort will allow for an expansion and repositioning of the instructor and operator stations to allow for more meaningful observation of and feedback to students. Plans include increasing training seats from 13 to 17 in order to accommodate new Army stations. The refitting of the Joint Theater Air Ground Simulation System testbed will facilitate the expansion of our cross-service cooperation and coordination.

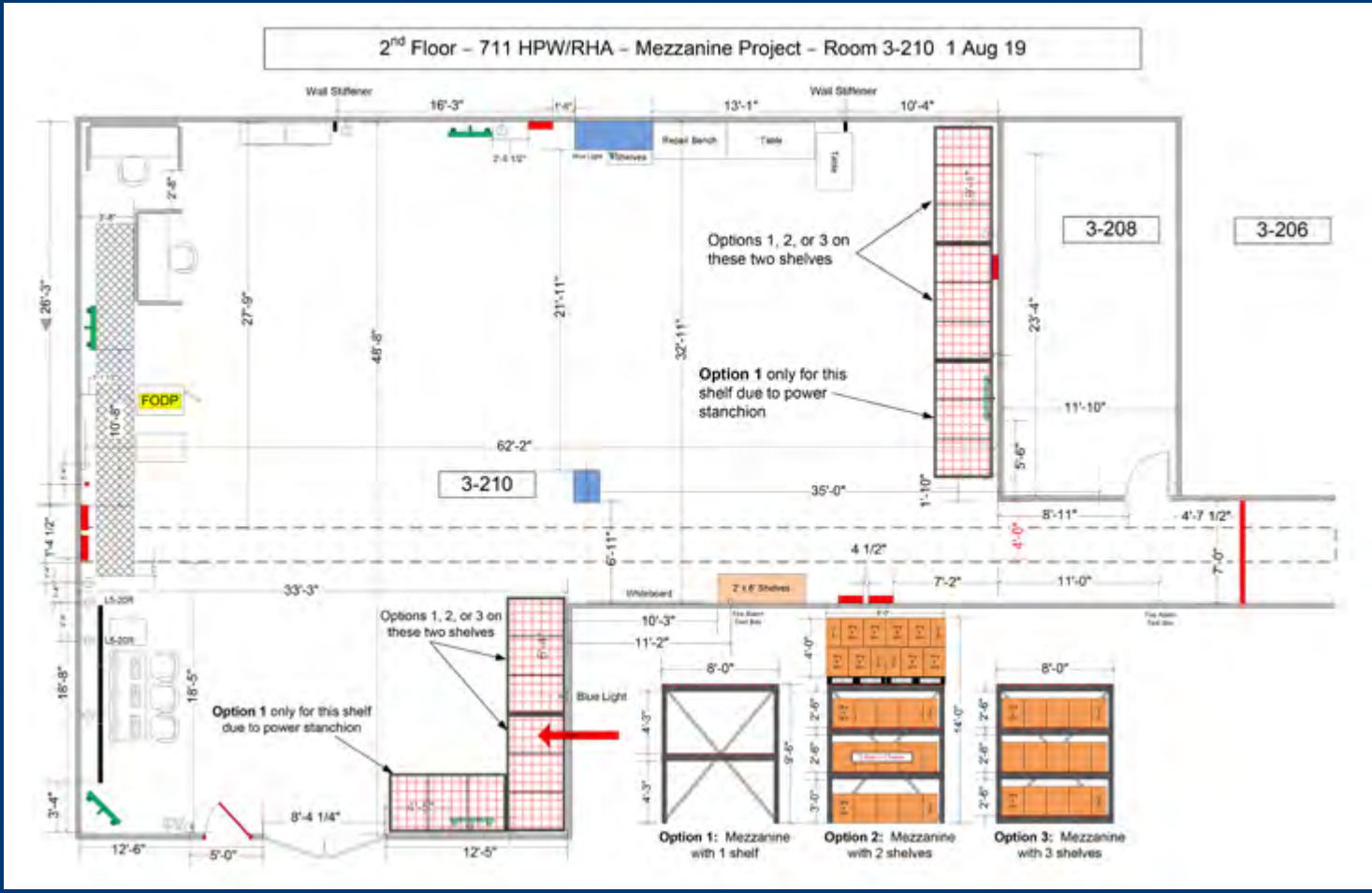
3. Joint Operations Center Moveable Wall

This project, slated to begin this fall, will in effect create two testbeds in a single room with the new movable partition. The room's front area will house the Joint Operations Center and the rear area will serve as a dedicated software-development testbed. With military construction becoming increasingly challenging to plan, this capability will allow the Division to maximize the space currently available. ☆

Mr. Jeffrey "Sam" Griffith, Branch Chief, RHAO

"THE WARFIGHTER READINESS RESEARCH DIVISION IS FORTUNATE TO BOAST STATE-OF-THE-ART TESTBEDS..."

— Mr. Jeffrey "Sam" Griffith
Branch Chief, RHAO



Graphic by Mr. David Greschke

CELEBRATING 50 YEARS OF COMMITMENT TO OUR WARFIGHTERS

Established as the Flying Training Division on 9 May 1969, the Warfighter Readiness Research Division has become recognized as a center of excellence in science and technology for education, training and readiness. Since its beginning at Williams Air Force Base, the Division has focused on creating and validating training research methods, models and innovative technologies that prepare warfighters for ever-changing missions.

As a driving force in pilot-training research, the Division's early work included curriculum design and engineering of technology that is central to today's modeling and simulation training. The Division led pioneering work in helmet-mounted displays, display and screen technology, motion cueing, simulator-flight ground models and mapping and run-time databases.

Researchers and engineers, as part of the Department of Defense, explored how to network simulators to interoperate. These collaborative efforts culminated in Distributed Interactive Simulation as a protocol and later an IEEE (Institute of Electrical and Electronics Engineers) standard. The Division was also a key innovator in the definition and implementation of high-level architecture (HLA) as another distributed simulation standard. In fact, the Division's F16 research testbed was among the first to be HLA accredited! Throughout the years, Division personnel were actively involved in standards working groups in which their expertise and testbeds were leveraged to derisk standards in development.

The Division has also maintained an active presence in joint and multinational collaborations for shared practices, common principles for learning and readiness assessment and NATO Standardization Agreement development. Division staff pioneered the Air Force's Distributed Mission Training concept as well as partnered with the Air Force Materiel Command Simulator System Program Office and then Colonel Ellen Pawlikowski and her team to field, evaluate and operationalize tactical training simulation. When Distributed Mission Training evolved into Distributed Mission Operations, the Division met the need to address additional integrated operations training with research studies, protocols, assessments and testbeds.

Today, the teams have research, engineering and transition work underway in and across a wide range of mission environments. A recent example of the Division's mission-relevant work was the Secure LVC [Live-Virtual-Constructive] Advanced Training Environment Advanced Technology Demonstration (SLATE ATD). This successful proof-of-concept prototype injected real-time virtual and constructive entities into live aircraft for advanced operational training—a game changer for future combat training!

As it has during the past fifty years, the Division will continue to collaborate with the other technical divisions; Service laboratories; academia; and joint, multinational, acquisition and industry partners to drive innovations in competency and proficiency-based learning and readiness science and technology. ☆

Dr. Winston "Wink" Bennett, Product Readiness Line Lead, RHA

THE DIVISION LED PIONEERING WORK IN:

- Helmet-mounted displays
- Display and screen technology
- Motion cueing
- Simulator-flight ground models and mapping
- Run-time databases

Photos by Mr. Will Graver and 711 HPW/RHA

FIFTY YEARS OF INNOVATIVE SCIENCE AND TECHNOLOGY ADVANCEMENTS

"WE MUST CONTINUE TO BUILD READINESS TO FIGHT TONIGHT SHOULD THE NATION CALL, WHILE MODERNIZING KEY CAPABILITIES FOR FUTURE CONFLICT."

—Dr. Mark T. Esper
Secretary of Defense

Published quarterly since 2001, Fight's ON! continues to serve as the Division publication for our partners and features innovative science and technology that is accelerating and revolutionizing readiness.

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