CALL SIGNS

USN AEP SOCIETY

AUGUST / **2020**

HUMAN-MACHINE TEAMING

Learning together, working together, succeeding together

The science behind teamwork, and how the future of the DoD will be shaped by the need for cooperation with machines.

A bi-annual publication of the US Naval Aerospace Experimental Psychology Society

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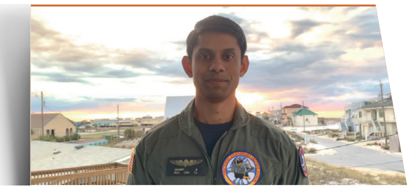

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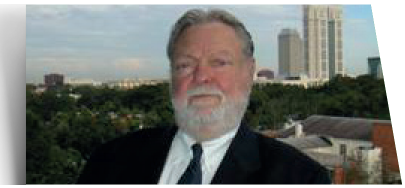

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CALL SIGNS is a bi-annual publication of the US Navy Aerospace Experimental Psychology Society (USNAEPS).

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LT ERIC S. VORM / LAYOUT EDITOR AND GRAPHIC ARTIST

FROM THE PRESIDENT

Friends, on behalf of the United States Aerospace Experimental Psychology Society (USNAEPS) Executive Committee (EXCOM), welcome to another issue of Call Signs. This issue focuses on research questions, ongoing programs, and applied work in the area of Human-Machine Teaming. This area of practice is aligned with our AEP mission areas, and is more important than ever with the increased prevalence of unmanned and autonomous systems across warfare domains.

I am delighted to report the ongoing success of the USNAEPS-driven recruiting efforts championed by Vice-President LT Eric Vorm and our Recruitment Team Coordinator (RTC), LT Aditya Prasad. Since our last issue, the recruitment team has developed 3 promotional videos and 3 static photo advertisements, all promoted on multiple social media platforms, significantly improving visibility for the AEP community among prospective AEPs and graduate students, as well as driving traffic to the navyaep.com website. Our RTC has established contact with four new downstream contacts as of this writing, in addition to the 10 active prospects our LCDR Lee Sciarini, our Assistant Specialty Leader (ASL), is maintaining contact with. We have also been invited to provide updates to a navy.com AEP community brochure being produced by Navy Recruiting Command. ASL LCDR Sciarini has also challenged members of the AEP community to visit their alma maters to build awareness of AEP employment opportunities and offer job talks about the exciting work we do.

One of the USNAEPS videos has already been featured on the USN Medical Service Corps Facebook page, and potentially most important of all, other MSC community members are telling me they are jealous of the videos and recruitment products the team is producing. This initiative is really achieving the best of both worlds for the AEPs.

If you haven't seen it lately, please be sure to visit our website at www.navyaep.com. It has received a significant overhaul to better reflect its alignment with our recruiting goals. You can find expanded information about the nature of the work AEPs do, complete with summaries of applied examples, and the opportunity to learn more about individual AEPs, including their backgrounds, interests, and applied work. The site also includes critical information about AEP billet locations, eligibility requirements, and an overview of our training pipeline.

Finally, because I was honored to accept appointment as AEP Specialty Leader (SL) in March 2020, I have stepped down as USNAEPS President, and am proud to welcome CDR Brent Olde as the incoming President. The AEP Community and Society are grateful for the leadership he will provide, and for his continued championship of the USNAEPS recruiting efforts. Thank you, Brent, for stepping up!

On behalf of the USNAEPS EXCOM, I hope you enjoy this issue of *Call Signs*. Thank you for your continued support of the Society!

DO YOU TRUST YOUR PARACHUTE?

A call to study human-machine teaming in uncontrolled environments

Nathan L. Tenhundfeld, Department of Psychology, University of Alabama in Huntsville

Mustafa Demir, Human Systems Engineering, Arizona State University

Recent research suggests that jumping out of a plane without a parachute makes one no more susceptible to death than jumping out *with* a parachute (Yeh et al., 2018). In this first-of-its-kind, randomized, controlled study, participants who jumped out of the plane with just a backpack were as likely to survive the fall (and as likely to emerge unscathed) as were those who jumped out of the plane with a parachute. However, the authors acknowledge that certain conditions of the study were not ecologically valid: namely, the plane was parked on the ground at the time of the jump. Despite this one detail, everything else in the study was ecologically valid and of sound methodology.

Clearly, the aforementioned parachute study represents an obvious discrepancy between the real world and an 'ecologically valid' testing environment.

U.S. Marine Corps Sgt. Cory Kim, an explosive ordnance disposal technician with Combat Logistics Battalion 11, 11th Marine Expeditionary Unit (MEU), operates an Endeavor Robotics First Look Robot during chemical, biological, radiological and nuclear response training at Marine Corps Base Camp Pendleton, Calif., Jan. 22, 2020. The Marines participated in the exercise to retain the skills necessary to safely identify and dispose of contaminated, unexploded ordnance. (U.S. Marine Corps photo by Cpl. Dalton S. Swanbeck)

However, could a similar claim be made in regard to research on human-machine teaming (HMT)? Take, for example, research on human interactions with automation. Considerable research has been done with self-driving vehicles to show the interactions between automation, situation awareness, trust, and human performance (Endsley, 2017; Petersen et al., 2019; Young & Stanton, 2007). However, many of these have been inherently reliant on simulators or real-world vehicles in highly controlled testing environments (Boelhouwer et al., 2019; Li et al., 2019; Tenhundfeld, de Visser, Ries, et al., 2019; Walch et al., 2015) the system has to de-escalate (e.g. emergency braking). This is not to say there is not benefit for simulator and highly controlled studies, as there absolutely is, including easier International Review Board approval, greater experimental control, and facilitation of theory development.

In HMT, one solution to achieve the aforementioned is to insert a simple and task specific research framework. The living lab (LL) framework is a holistic, cognitively based research approach that attempts to understand psychological and sociological aspects (e.g., cognition, teamwork, situation awareness, transparency) in context, further understand it in the lab, and then develop technologies to improve performance in real-world contexts (McNeese, 1996). LL focuses on transactions between team members and their environments. In order to understand these transactions ecologically, the LL framework combines ethnographic observations of teams within their task environments with unique knowledge from each team member's perspective (McNeese et al., 2017). The LL framework focuses on the following outcomes (McNeese, Perusich, and Rentsch 2000; Hall et al. 2008): (1) ethnographic studies, which focus on understanding the issues related to a particular domain or application; (2) cognitive systems engineering in which knowledge elicitation methods are used to understand the problem domain; (3) scaled world simulations wherein researchers can create a high level fidelity environment to evaluate the evolving concepts, scenarios, and test sets; and (4) design of support tools that are developed based on the results of scaled world simulations (McNeese et al., 2017). However, the LL framework and some of the constructs we study, as well as the ways we study them, are inextricably linked to risk. Trust is one of these constructs. To study trust in the absence of evaluations of risk is somewhat self-defeating.


U.S. Marines with Combat Logistics Battalion 11, 11th Marine Expeditionary Unit (MEU), operate an Endeavor Robotics First Look Robot during chemical, biological, radiological and nuclear response training at Marine Corps Base Camp Pendleton, Calif., Jan. 22, 2020. The Marines participated in the exercise to retain the skills necessary to safely identify and dispose of contaminated, unexploded ordnance. (U.S. Marine Corps photo by Cpl. Dalton S. Swanbeck)

The most classically used definition states that trust is "...the attitude that an agent will help achieve an individual's goal in a situation characterized by uncertainty and ***vulnerability***" (emphasis added; Hoff & Bashir, 2015; Lee & See, 2004). Trust influences reliance on automation. In particular, trust guides reliance when complexity and unanticipated situations make a complete understanding of the automation impractical. This review considers trust from the organizational, sociological, interpersonal, psychological, and neurological perspectives. It considers how the context, automation characteristics, and cognitive processes affect the appropriateness of trust. The context in which the automation is used influences automation performance and provides a goal-oriented perspective to assess automation characteristics along a dimension of attributional abstraction. These characteristics can influence trust through analytic, analogical, and affective processes. The challenges of extrapolating the concept of trust in people to trust in automation are discussed. A conceptual model integrates research regarding trust in automation and describes the dynamics of trust, the role of context, and the influence of display characteristics. Actual or potential applications of this research include improved designs of systems that require people to manage "imperfect automation." Beyond a subjective self-report, many studies have sought to examine levels of trust through behavioral measures (Banks et al., 2018; Muir & Moray, 1996; Tenhundfeld, de Visser, Haring, et al., 2019; Tenhundfeld, de Visser, Ries, et al., 2019).

Because one of the largest influences on trust in automation is the familiarity with the system, we sought to examine the effects of familiarity on driver interventions while using the autoparking feature of a Tesla Model X. Participants were either told or shown how the autoparking feature worked. Results showed a significantly higher initial driver intervention rate when the participants were only told how to employ the autoparking feature, than when shown. However, the intervention rate quickly leveled off, and differences between conditions disappeared. Even for those who believe that trust can exist independent of some appraisal of risk, it seems difficult to argue that measures of changes in behavior (such as driver interventions in a self-driving vehicle) are not susceptible to changes in the driver's perception of risk (Ghazizadeh et al., 2012; Hoff & Bashir, 2015; Lee & See, 2004). Trust influences reliance on automation. In particular, trust guides reliance when complexity and unanticipated situations make a complete understanding of the automation impractical. This review considers trust from the organizational, sociological, interpersonal, psychological, and neurological perspectives. It considers how the context, automation characteristics, and cognitive processes affect the appropriateness of trust. The context in which the automation is used influences automation performance and provides a goal-oriented perspective to assess automation characteristics along a dimension of attributional abstraction. These characteristics can influence trust through analytic, analogical, and affective processes. The challenges of extrapolating the concept of trust in people to trust in automation are discussed. A conceptual model integrates research regarding trust in automation and describes the dynamics of trust, the role of context, and the influence of display characteristics. Actual or potential applications of this research include improved designs of systems that require people to manage imperfect automation.

Often joint human-automation performance depends on the factors influencing the operator's tendency to rely on and comply with automation.

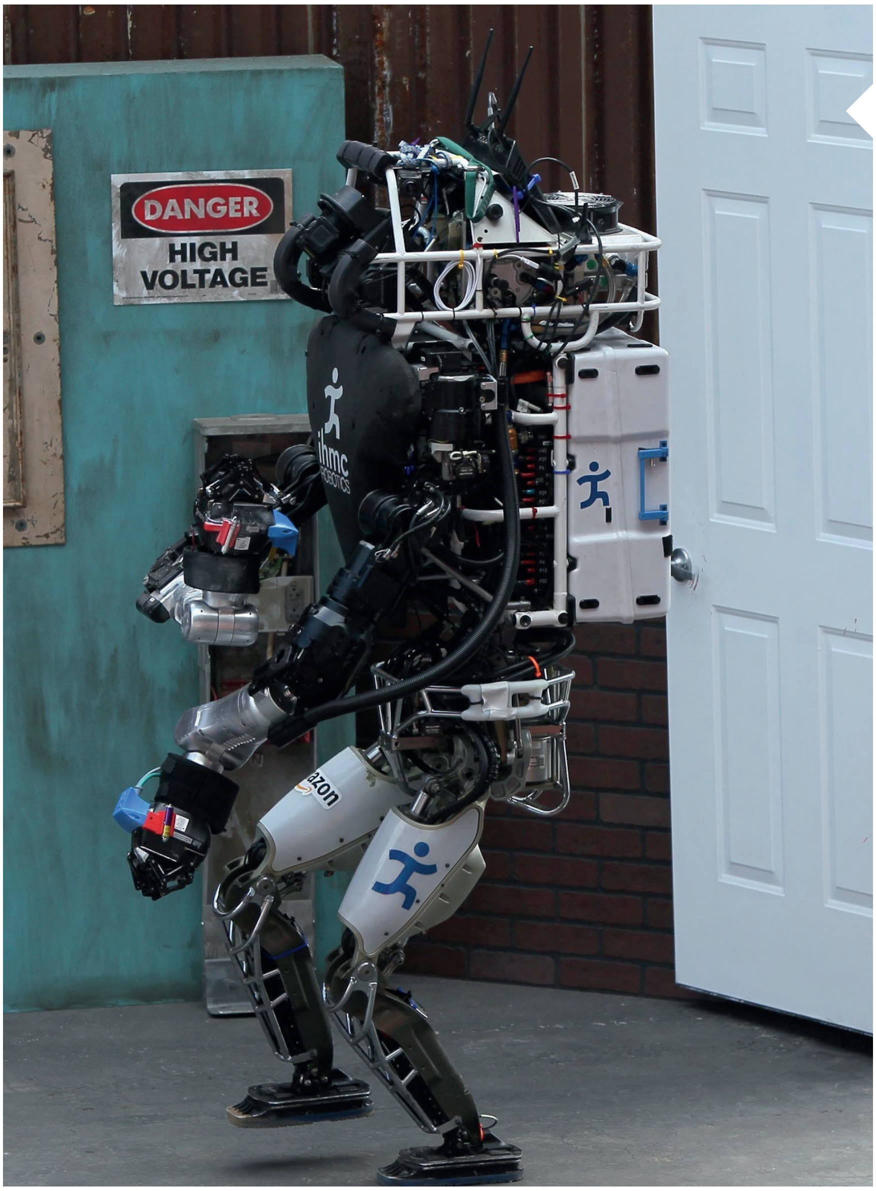
It is therefore illogical to say that changes in behavior, independent of *direct* measurements of perceived risk, are indicative of changes in level of trust. Perhaps I allow Tesla's "Autopark" feature to park my vehicle, not because I trust it, but because my appraisal of the risk has changed over time (Tomzcak et al., 2019). This seems particularly likely as the use of repeated exposures is an effective method of therapeutic reduction of expected risk in anxiety disorders (Craske et al., 2008). Additionally, given that individuals perceive risk differently, it is also insufficient to simply attempt to experimentally control for objective risk levels (Sjöberg, 2000). It therefore seems somewhat ill-advised to study trust in the absence of quantifying the user's perceived risk.

All of this remains independent of the reality that as risk changes, so too does an individual's reliance strategy (Hoff & Bashir, 2015). Therefore, understanding an individual's likelihood of relying on a system at a fixed level of trust, does not help with the extrapolation of their likelihood of use at higher (or lower) levels of perceived risk. For those of us interested in understanding the warfighter, the ability to project reliance on a system into the most high-risk operational environments seems of paramount importance.

As such, this article proposes a 4-tiered strategy to address the aforementioned concerns. ***Tier 1*** involves no changes to the field's current approach. This will still allow the field to understand effects of changes in transparency on operator use/disuse/misuse, but will prevent the field from being able to isolate trust as a cognitive construct. ***Tier 2*** involves the inclusion of measures of perceived risk into pre-existing paradigms. This will allow for perceived risk to be an included covariate in analyses in an effort to better isolate trust. A Tier-2 approach would involve nothing more than the inclusion of perception of risk scales (e.g. Hulse et al., 2018).

Next, a ***Tier-3*** approach would involve the direct manipulation (and evaluations of users' perception) of risk within a controlled environment. This would allow for greater understanding of the interactions between trust and risk on reliance, as well as changing levels of trust in the face of changing levels of risk. This approach would still allow for the high levels of control necessary to advance the theory, and to collect data in a timely manner. However, every precaution should be taken to avoid giving the illusion of changes in risk, in the absence of real changes, as an obvious experimental risk, manipulation (with or without actual changes in risk) could

Staff Sgt. David Cain and Sgt. Maximilian Musick lift the tracks of the Mark II Talon explosive ordnance disposal robot during charge employment training Aug. 2, 2018 at Camp Hansen, Okinawa, Japan. The training taught EOD technicians to effectively neutralize IED threats with unmanned robotic platforms by safely finding and removing any hazards. Cain, a native of Fredericksburg, Virginia and Musick, a native of Phoenix, Arizona are EOD technicians with EOD Company, 9th Engineer Support Battalion, 3rd Marine Logistics Group. (U.S. Marine Corps photo by Pfc. Terry Wong)



Running Man robot of Team IHMC Robotics from Pensacola, Fla., clears a doorway during Defense Advanced Research Projects Agency (DARPA) Robotics Challenge. Twenty-five teams from around the world competed for $3.5 million in prizes as they navigated a simulated disaster-response course. Naval Surface Warfare Center (NSWC), Corona Division's display of Seaperch Remotely Operated Vehicles (ROV) supports the Navy's strategy to inspire, engage and educate the next generation of scientists and engineers. (U.S. Navy photo by Greg Vojtko/Released)

lead to experimental demands influencing participant responses on perception-of-risk measures (Orne, 1962).

Finally, ***Tier 4*** would involve the collection of data in real-world, operational, high-risk environments. While this involves the least control of the four tiers, it provides the greatest degree of ecological validity which is ignored in the LL framework. What is more, a Tier-4 approach would help guard against the false sense of security associated with obvious manipulations of risk which are independent of true changes in risk. To put it another way, this approach would help guard against having a participant jump from 10 feet without a parachute and extrapolating those results to what would happen if one were to jump from 10,000 feet. While this approach can be used, it does not necessitate formal data collection by researchers. Instead, researchers can seek to leverage existing data provided publicly, or available privately through collaborations with government/industry partners.

For a great example of real world data available to all, see the California "Autonomous Vehicle" testing reports (*Testing of Autonomous Vehicles with a Driver*, n.d.). By looking at the existing data from those unfortunate souls whose parachute never deployed, we can get a fairly good understanding of the impacts of jumping without a parachute. Importantly, a Tier-4 approach does not replace the benefits conferred by a lower tier approach. In fact, a Tier-4 approach would be significantly lacking in sufficient control to advance much of the field's understanding. However, data derived from a Tier-4 approach can be an invaluable tool to enhance understanding derived from a 'lower' tier approach. In conclusion, there may be theoretical reason to believe that, as a field, our approach to studying trust in human-machine teams, may be insufficient. This article has attempted to briefly outline the logic behind that idea, and lay out a potential tiered structure within an LL frame, to address these concerns. We need not throw the baby out with the bath water. There should be substantial considerations and discussions in regard to the field's research approaches moving forward. This article attempts to initiate that dialogue.

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*Cartoons written by LT E.S. Vorm; original artwork by LT Zach Morris, creator of "**The Landing Strip**" comic*

COMPUTER-CENTERED HUMANS

What can the game of chess teach us about the future of cooperative synergy between humans and technology?

LT E.S. Vorm, PhD, US Naval Research Laboratory

The dynamics of teamwork have been a subject of fascination by social scientists for many years. Even Aristotle, who is commonly considered the father of western philosophy, devoted study to this curious human behavior. He is famously credited with developing the definition of synergy: "the whole is greater than the sum of its parts."

He observed that when human beings determine to work together, their synergistic effects can produce remarkable accomplishments. Ancient examples of these feats abound, such as the Great Wall of China, which began in 770BC and took almost 900 years to complete, yet still stands robust and sturdy today.

Scientists have long been interested in ways to take what they have observed from human teamwork, and create that same effect between computers and their users. It seems almost every generation since the introduction of the first computer has had a vision for the potential of human performance to be improved by computer technology. As early as the 1950's, great scientists like Allen Turing were describing a future where humans would work symbiotically with robot companions, aided in every way by intelligent systems [1]. Turing, and many others after him, described human-machine systems that would combine the best characteristics of humans, such as ingenuity, intuition, and the ability to generalize learning with the best characteristics of computers, such as their raw speed, accuracy, and computational power. This hybrid system of humans and computers working together is the central characteristic of the field of inquiry known as human-machine teaming (HMT). ***The vision at the heart of HMT research is the development of technologies that can successfully augment human performance so that a superior combination of both human and machine should be able to outperform either the best human or the best machine.*** It isn't about machines replacing humans, or machines working autonomously. It is about machines that join with humans in synergy, each side contributing strengths and mitigating weaknesses.

What can Chess teach us about human-machine teaming?

A fascinating example of HMT in modern times is the world of Freestyle Chess. Freestyle chess, also known as "cyborg chess," is a style of gameplay whereby humans and computers can join as teams called Centaurs. Games are run using the same turn-based rules as regular chess. Humans can leverage computers for strategy and analysis, but only humans can move the game pieces. In this way, computers serve humans in a decision support role. Intelligent algorithms analyze the game board, predict future moves and strategies, and advise their human teammates on things like what strategies the opponent team seems to be using and which move has the highest probability of being successful. Interestingly enough, there isn't a limit on how many computers and algorithms a human can use. Human players can literally surround themselves with laptops in a game if they want, and they sometimes do. The reason for this is simple: No matter how superior the tool, its ultimate usefulness still depends on how the craftsman uses it. In the case of Freestyle Chess, it often comes down to how humans decide to use their computers to gain an advantage. In other words, success is determined not by the expertise of the human or the processing power of computers, but primarily through the intelligent interaction and integration of them together. Perhaps the most striking successful example of the potential of human-machine teaming is the story of ZachS.

In 2005, an amateur Centaur team by the name of ZachS, made up of a database administrator and high school soccer coach from New Hampshire, entered the competition and proceeded to sweep its way all the way to the final match. Merely making it to the final match of the competition defied all odds. ZachS's rankings predicted that they would probably be eliminated in the first round of serious competition, yet they were able to beat their way to the final competition where they won a decisive victory against a team of professional chess players, including one world Grand Champion.

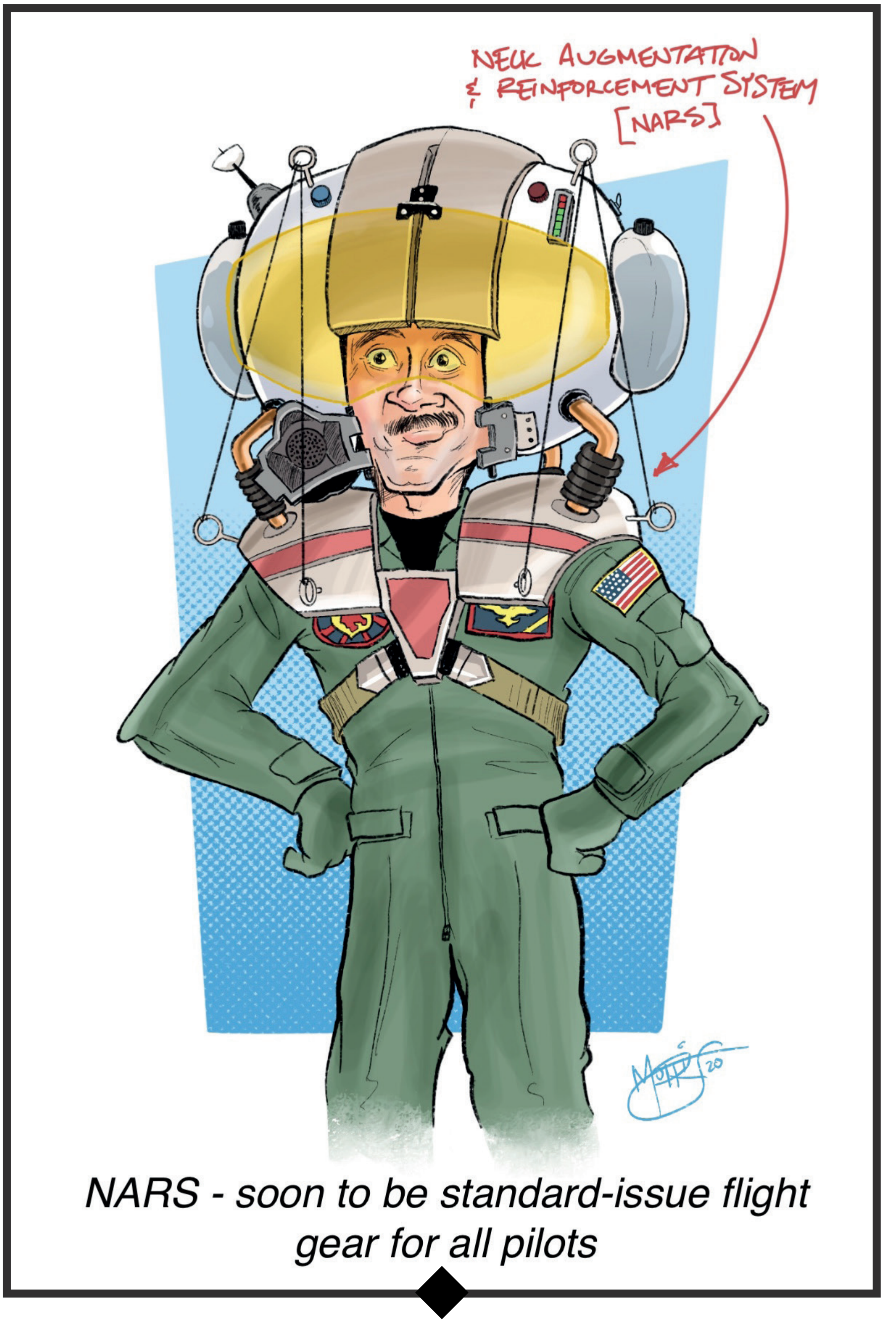
When ZachS shocked the world with its accomplishment, the world once again caught a vision of a future where human and computer intelligence in concert could rule supreme. But what can we attribute to the surprising success of ZachS? Most scientists agree that what ZachS did well was to develop a superior process, which they used consistently throughout the competition. This process has since become the principal focus of HMT. The goal is to afford the right kinds of interactions that enable the strengths of both humans and computers to be leveraged in a complementary fashion in order to produce a superior outcome. The future of defense envisions computers that control missiles, jam signals, aim lasers, read sensors, and aggregate immense amounts of data into an intuitive interface that humans can read, understand, and use to command the mission.

Unfortunately, there is more to achieving this vision balance than meets the eye. Simply pairing expert humans with advanced technologies to accomplish some cooperative task seldom results in superior performance. In fact, somewhat paradoxically, the opposite is often true; pairings of expert humans and advanced technologies often result in lower overall performance on cooperative tasks that require deliberate communication and cooperation [2]-[4]. Where the problems occur is also somewhat paradoxical. Contrary to popular opinion, problems in team performance between humans and advanced technologies are seldom the result of technological failures. Instead, these conflicts and subsequent failures tend to originate in a far more variable and lesser understood system— the user's brain.

As it turns out, how humans use and react to complex technologies is a delicate dance between perception, sense making, decision making, and acting (with sticky ingredients such as trust thrown in for extra measure). And while the speed of research in the technology of artificial intelligence in the DoD is clearly increasing, research in human-AI interaction and human-machine teaming does not appear to be keeping pace. Issues such as usability, interaction modalities, visualization knowledge representation techniques and others are all vital parts of a coherent technology integration strategy, but these are seldom the principal focus of large-scale research projects in the DoD. Instead, large-scale research projects tend to focus on things like algorithm and software development, machine learning model advancements, and the various hardware-based enablers of advanced AI such as remote sensing. So, while there are significant investments being made to build algorithms and hardware, the historical record of past tech booms would suggest that unless equal focus is placed on user modeling and human-centered design, then the dream of super-human performance like that of ZachS is unlikely to be achieved.

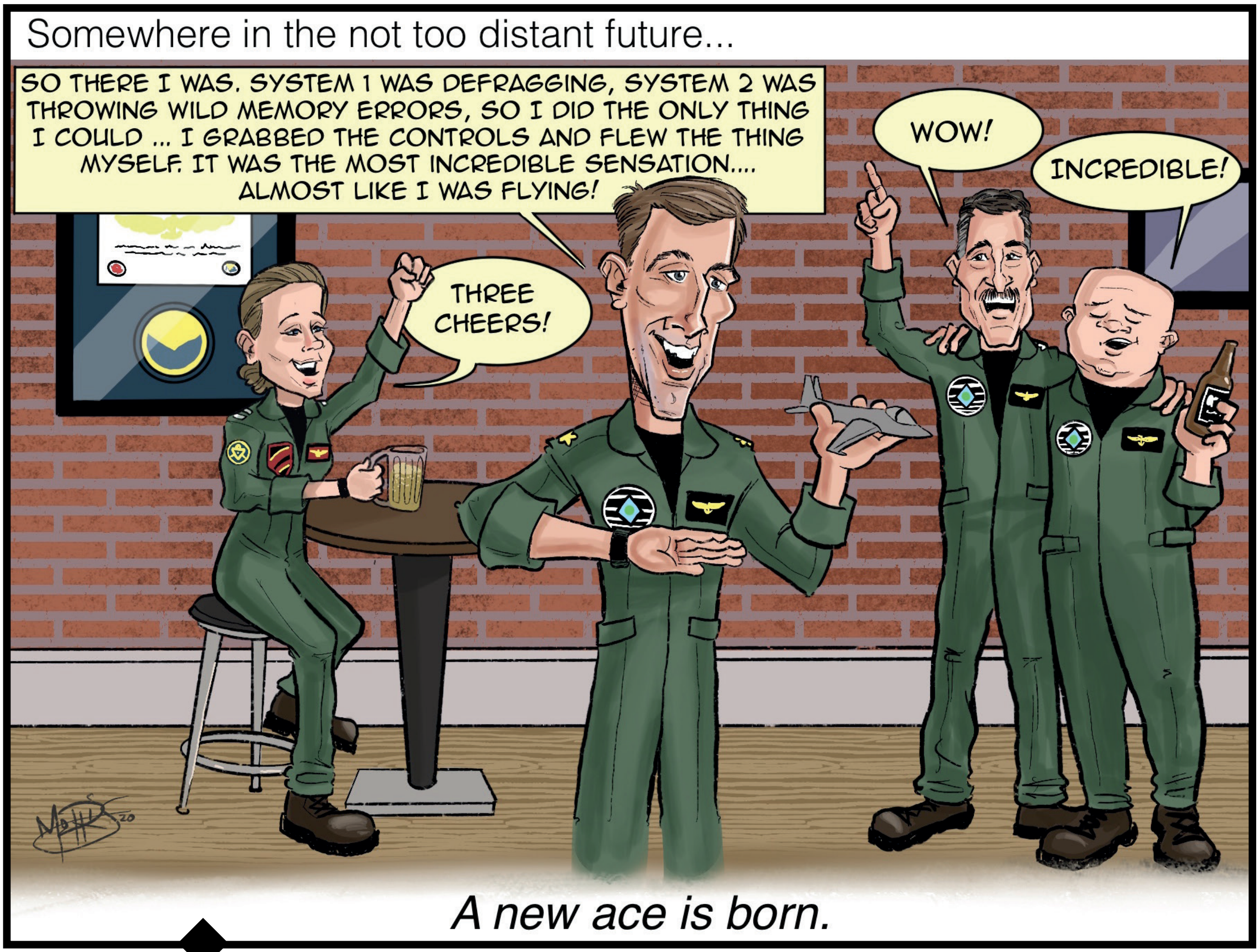
The need for human-centered design in a techno-centered landscape

Many past system development efforts that have resulted in clumsy, ill-fitting, difficult-to-use, or often dangerous systems can be traced back to strategies that relied too heavily on technology development and largely ignored the user and their needs. Undergraduate engineering students often learn of famous examples where decisions about the placement of buttons or the routing of electricity forced design decisions which put ergonomics in the backseat [5]. As future technologies are developed and tested, it will become increasingly important that they be developed FOR the user, and not as something the user must accept and fit into. Scientists working these concerns often discuss the concept of human-centered design, especially in the context of artificial intelligence, as "cognitive orthoses" [6]. For example, eyeglasses, which are a kind of



NARS - soon to be standard-issue flight gear for all pilots

An abundance of technology can lead to systems that are ill-fitting, uncomfortable to use, and sometimes dangerous. To achieve the synergistic effects envisioned in human-machine teaming, research and development will need to keep the user and their needs as a top priority.



De-skilling is a serious concern for commercial aviation, as well as other domains. Tomorrow's technologies will need to be developed using the principals of human-centered design in order to avoid this fictionalized future.

orthotic for our eyes, need to be fitted to our face in order for their benefit to be realized. Similarly, AI systems will need to be developed in ways that leverage and extend human cognition, or else risk the equivalent of being stuck with someone else's prescription.

Another concern over the lack of human-centered design focus is the fear that the ever-expanding scope of technologies may result in a loss of human capabilities (a concern known as de-skilling). Over the past several decades, for example, commercial aviation has made significant advancements in automation. Today's airplanes are capable of taking off, navigating waypoints, lining up on approach, and landing— all without any direct human intervention. This has led to generations of pilots who spend the majority of their time interfacing with automated systems, and very little time actually controlling the aircraft. Dozens of studies and surveys, and many unfortunate mishap reports have yielded ample evidence that when the unexpected occurs and pilots must resume control of the aircraft from their automated counterparts, they are uncomfortable, unfamiliar, and in some cases, unsuited to do so appropriately (for example, the recent 737MAX accidents, see [7], [8]).

De-skilling is not only a concern for commercial aviation. One could even argue that the introduction of search engines such as Google has fundamentally changed how scientists conduct research also. Today, the speed and ease with which a person can access thousands of articles from across multiple domains has revolutionized how we scientists conduct literature reviews, on which we base our ideas and plan our research. In gaining that speed and ease of use, however, many critical research skills, one can argue, have been lost. If the DoD embraces a strategy that prioritizes technology over user-centered development in areas such as combat patrolling, search and rescue, route planning and execution, and reconnaissance, then this could similarly lead to future soldiers and Marines who are overly dependent on these technologies. In circumstances where they must do their jobs without them (for instance, when the batteries go dead, or the networks go down), we may find that critical skills such as land navigation, systematic surveillance, and military planning have atrophied beyond useful levels.

Conclusion

Studying how human beings perceive, comprehend and make decisions while interacting with artificial intelligence, therefore, remains an absolutely necessary component of the DoD's AI integration strategy, and is vital to achieving the kinds of synergistic effects between humans and computers that most of these advanced technologies promise to provide. The need for more research in human-AI interaction and human-machine teaming today is greater than ever if we are to consider seriously how best to capitalize on AI in the DoD in ways that improve mission success. Failing to do so only perpetuates a strategy that asks humans to fit into uncomfortable and ill-fitting technology, and further impedes the accomplishment of the decades-old promise of human-machine teaming. While the need to stay ahead of advanced disruptive technologies, we need to also ensure that we do not adopt a strategy that results in disrupting only ourselves.

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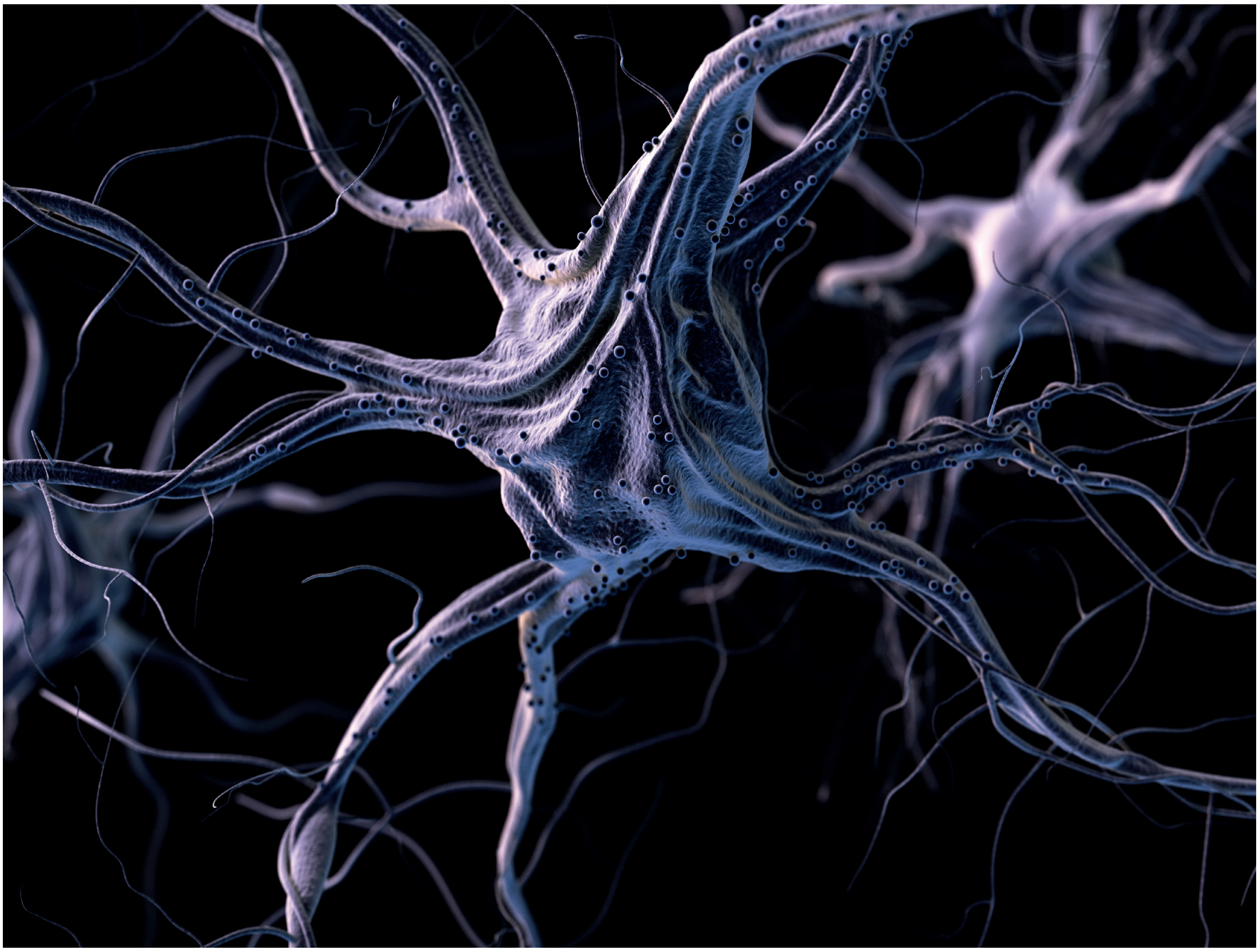


NEUROCOGNITIVE PATTERNS

An architecture for inferring actionable human intent

CAPT Joseph V Cohn, PhD Chief, Research Program Administration Division, Defense Health Agency; Webb Stacy, Ph.D., Corporate Fellow, Aptima, Inc; Danielle Ward, Ph.D., Senior Research Engineer, Aptima, Inc; Peter Squire, PhD, Office Naval Research Portfolio Manager for Decision Tools; and Program Officer - Human Performance, Training, & Education Code 34 - Warfighter Performance

Brain Computer Interfaces (BCIs) offer the promise of effective and natural human system interactions. While the vision for such interfaces includes a way of directly sharing a user's goals with a machine that could then act to satisfy these goals, significant challenges with realizing this vision remain. They present a central exemplar of human-computer teams: Using signals from physiological and environmental sensors, the computer infers the human's goals without requiring human effort or attention, then acts to help the human accomplish those goals. The net result is a human-computer team with high-quality, specialized, and shared mental models. One critical challenge is to develop BCIs that will allow for direct interpretation of users' intent from neural data gathered through noninvasive means. Noninvasive brain sensors such as EEG and fNIRS are able to probabilistically detect when a human intends to do something, but do not currently provide enough information to infer what they intend to do.

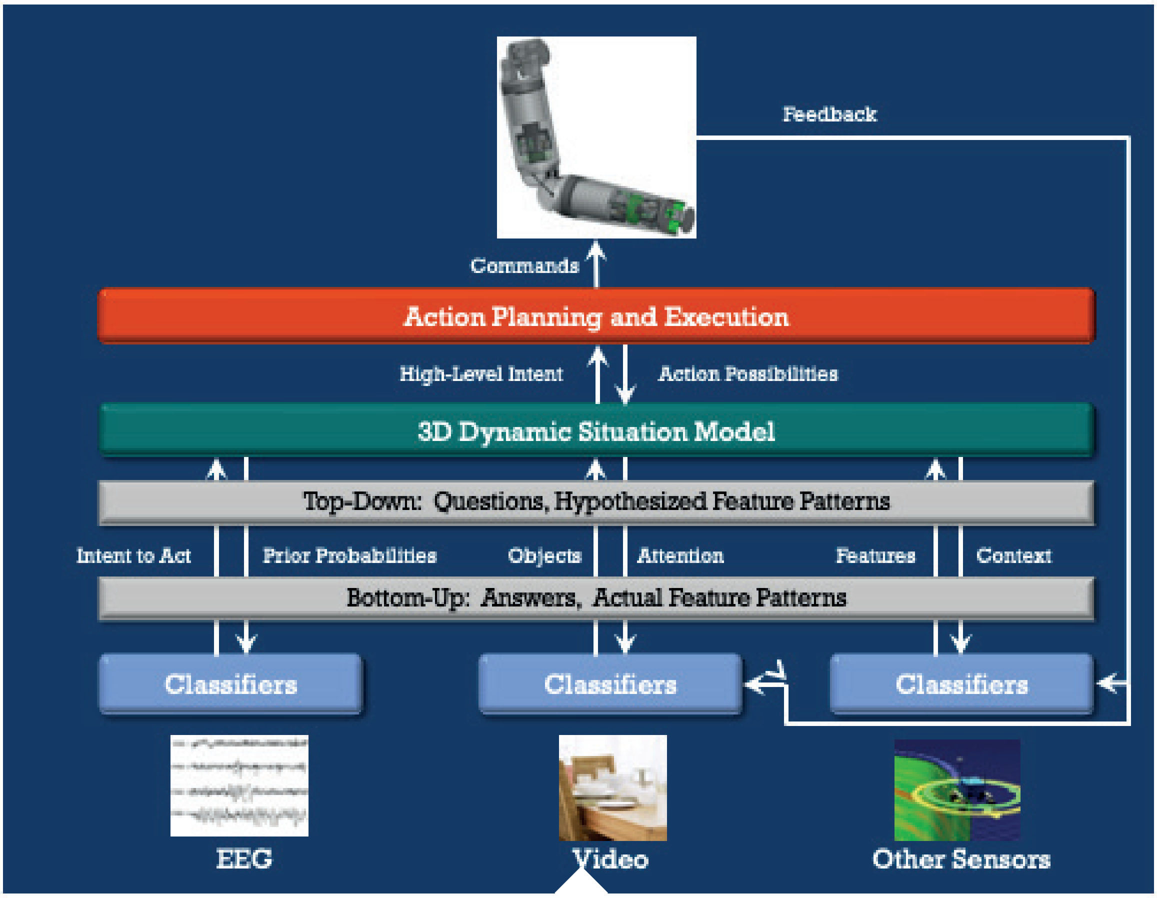


Figure 1: (a) The general NCP architecture for integrating environmental context with neurocognitive information for robust inference of actionable user intent.

It is an open question whether this is a problem with sensor resolution and analysis or whether the sensor signals simply do not contain enough information. However, when those analyzed signals are supplemented with appropriate contextual information from the environment, it turns out to be possible to perform inferences. To provide that contextual information, we developed innovative models for event understanding and object detection and classification. As a result, the BCI effectively acts on user intent. When fully developed, this will result in a new generation of BCIs that will free the operator to attend to other mission-important tasks. In work sponsored by the Office of Naval Research and the Office of the Secretary of Defense, we developed a new architecture for BCIs called Neurocognitive Patterns (NCP) containing both neural and environmental information (Figure 1.)

Our research was aimed at inferring the motion intent of prosthetic users as they go about their daily activities. To collect neural signals we collected data from four project team members using a 64-channel electroencephalogram (EEG) system and a Kinect sensor for video and depth signals. To make the domain of potential activities manageable, we focused on making coffee and making toast in a single kitchen-like environment. Figure 2(a) shows a sample of the EEG data we collected and identifies those portions of the signals used to develop a classifier that could tell us whether the person intended to make a movement, and Figure 2(b) shows a sample of the algorithm that predicts whether or not the person intends to move, given the EEG signals. Figure 3 shows a sample of the video generated by the object detection and tracking system that used the Kinect signals.

The event understanding system was based on the system of human event understanding developed by Prof. Jeff Zacks at Washington University of St. Louis, Event Segmentation Theory (EST). As Figure 4(a) shows, the idea is that, given an ongoing event, the brain

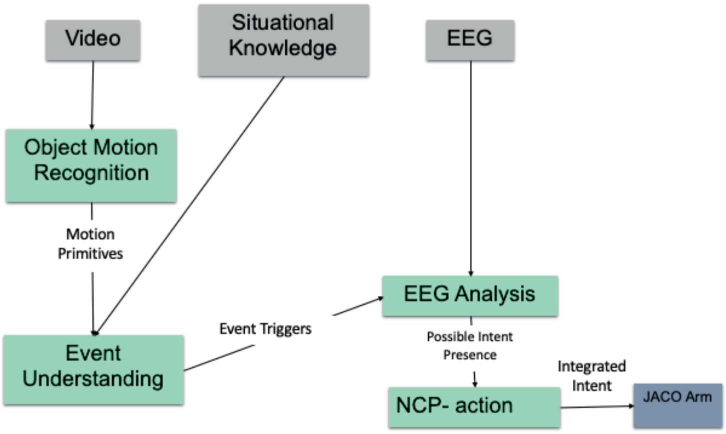
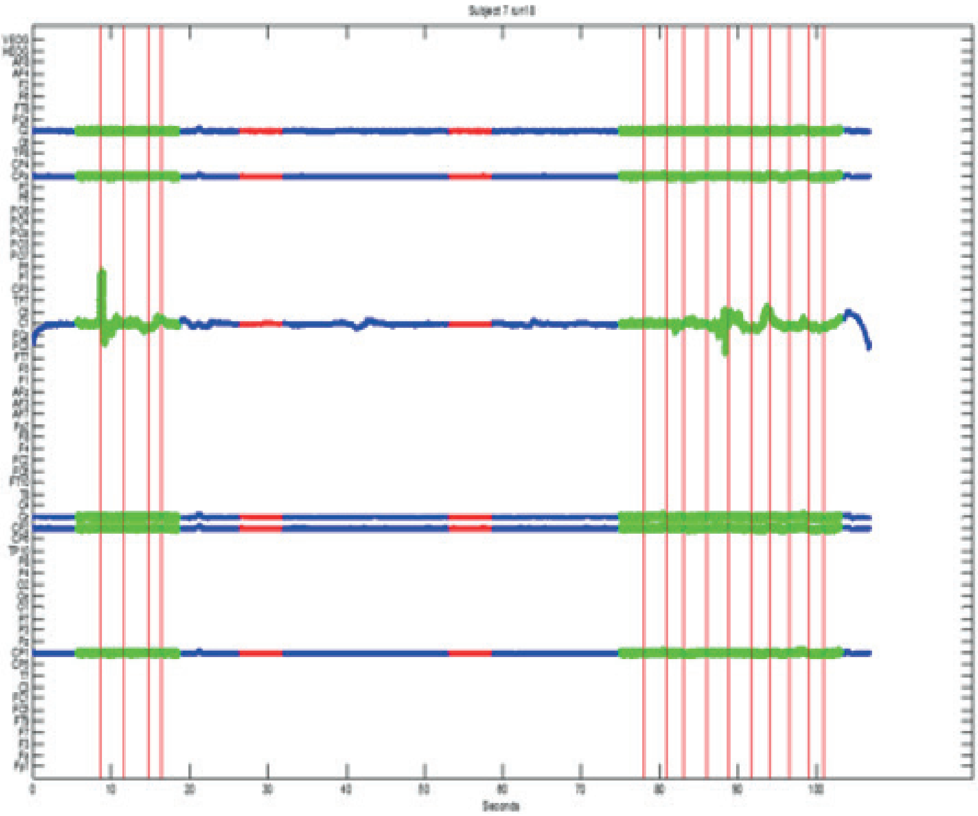


Figure 1:(b) The NCP demo system component diagram with the data coming from the gray boxes, analysis in the green boxes, and action in the blue box.



(Above) Figure 2: (a) Training data for one run of data collection. The red vertical lines are the places where movement was started in the video. The green segments indicate the training data for the intent signal, while the red segments are the training data for the no-intent signal.

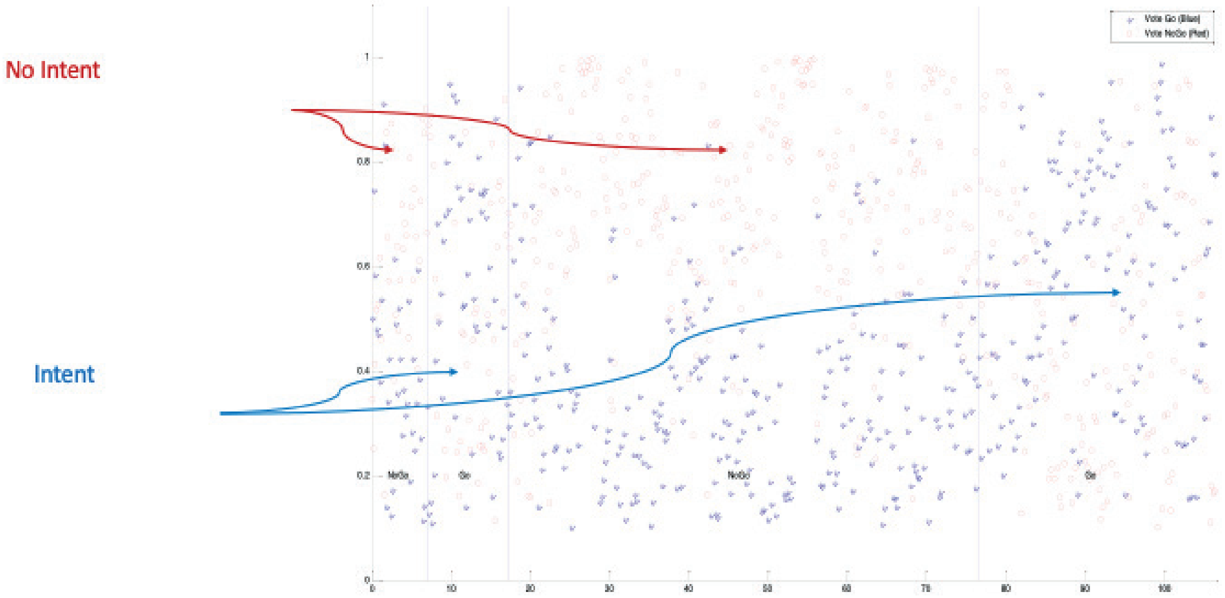


Figure 2: (b) The output of the Linear Discriminant Analysis (LDA) classifier where red dots indicate the probability of no-intent, and blue crosses are the probability of intent.

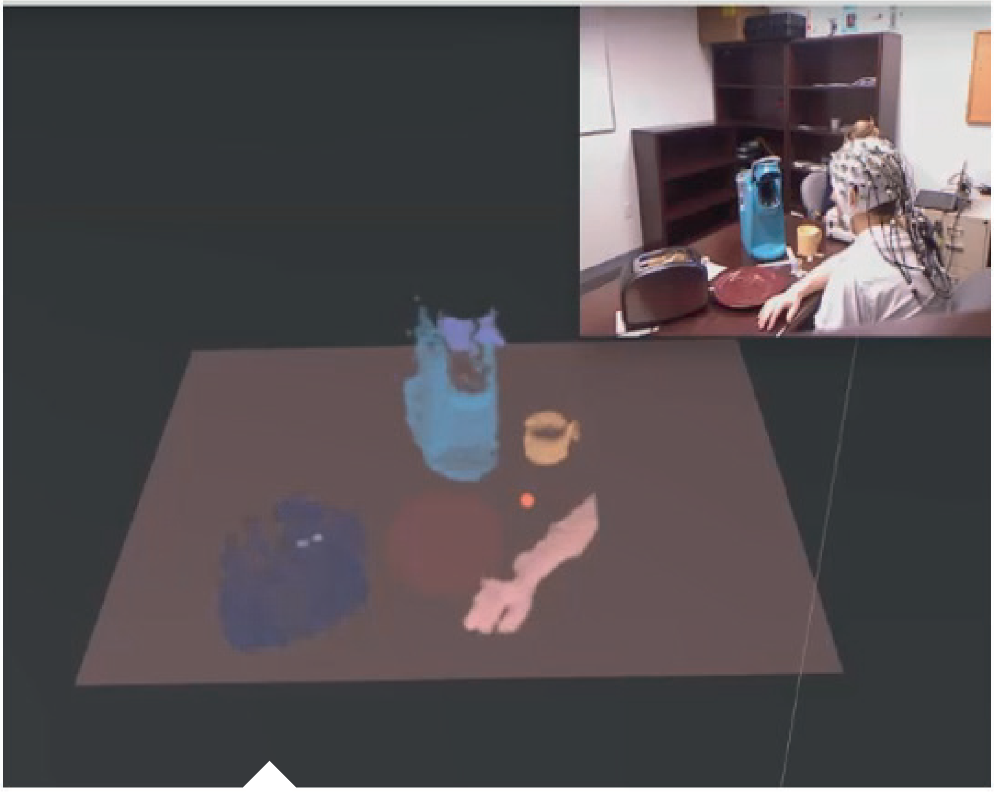
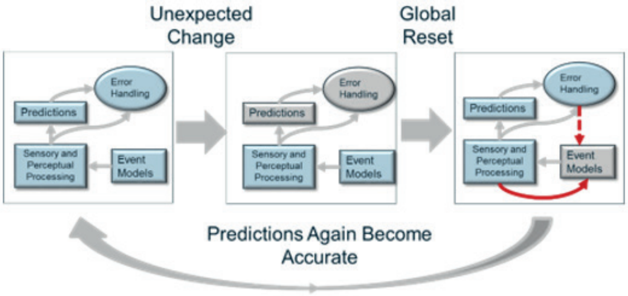


Figure 3: Output of Object Clustering where the different pixels are clustered together into distinct objects and then colored on the screen. In this image, we can see the toaster as a dark blue cluster on the left, the Keurig machine in turquoise on the top of the screen, the coffee cup in yellow in the top right, the plate in red in the middle, the K-cup as an orange dot in the center right, and our participant's arm in pink on the bottom right.



From Zacks, J.M. & Kurby, C.A. (2008). Segmentation in the perception and memory of events. *Trends in Cognitive Science*, **12**(2), 72-29.

(Above) Figure 4. (a) Diagram of Zacks' Event Segmentation Theory. Lines in red indicate activities aimed at identifying a new model when the current model generates too many errors.

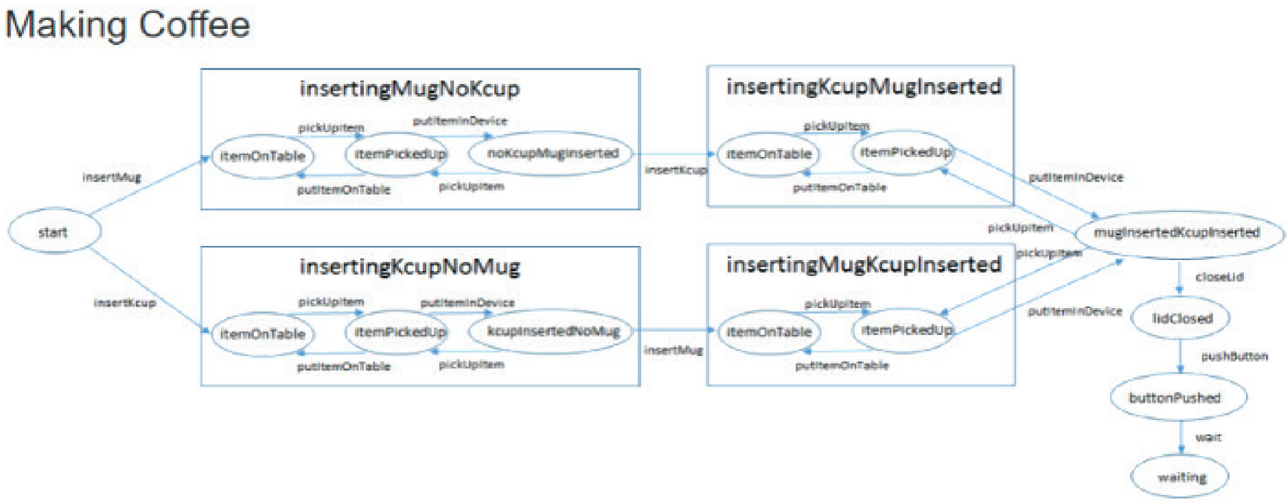
makes predictions about what comes next in a given event, and when those predictions fail, it identifies a new event to track. NCP used models of coffee- and toast-making events, and Figure 4(b) shows a diagram of the coffee-making event.

We analyzed the EEG data to detect the presence of a motion intent, and we used the video and depth information to detect, identify, and track objects in the environment. To supplement this information, the event models for coffee making and toast making were combined with object tracks to identify the human's current position in those models and the actions that were feasible given that position.

Given the early developmental nature of the research, it was not feasible to recruit a prosthetic-wearing human, so instead we recorded EEG signals and Kinect video and depth information from several humans as they made coffee and toast in the small kitchen, and then used those signals, together with the event models, to control a robot arm. We were able to demonstrate robot toast- and coffee-making using this setup.

It proved challenging to find a robot arm with the precision required to make toast and coffee in our setup, and in the end, in consultation with Dr. Kapil Katyal of the Johns Hopkins Applied Physics Laboratory, we settled on a Kinova JACO robot arm. The arm can be mounted to a wheelchair, but for our demonstration, it was mounted to the "kitchen" table. Figure 5 shows the arm inserting a K-Cup into a Keurig machine during the demonstration of the working system.

The result of this research was that we were able to create a system that used object recognition to feed a model which segmented the world into events which helped to predict user intent when the EEG signals indicated that they intended to move. The system built on the NCP architecture allows a user to control an intelligent mechanical arm through a brain computer interface. This outcome, while still preliminary, does show that there is promise for context driven neural control of human-machine dyads. Research will be needed to determine how a system like NCP can be extended



(Above) Figure 4. (b) NCP model for coffee making.

Figure 5. The JACO arm making coffee during the NCP demonstration.

to larger teams, but we are confident that this is a solid beginning. This line of research can usher in a new generation of automation that will require dramatically less attention from the operator(s), freeing them to attend to other mission-important tasks.

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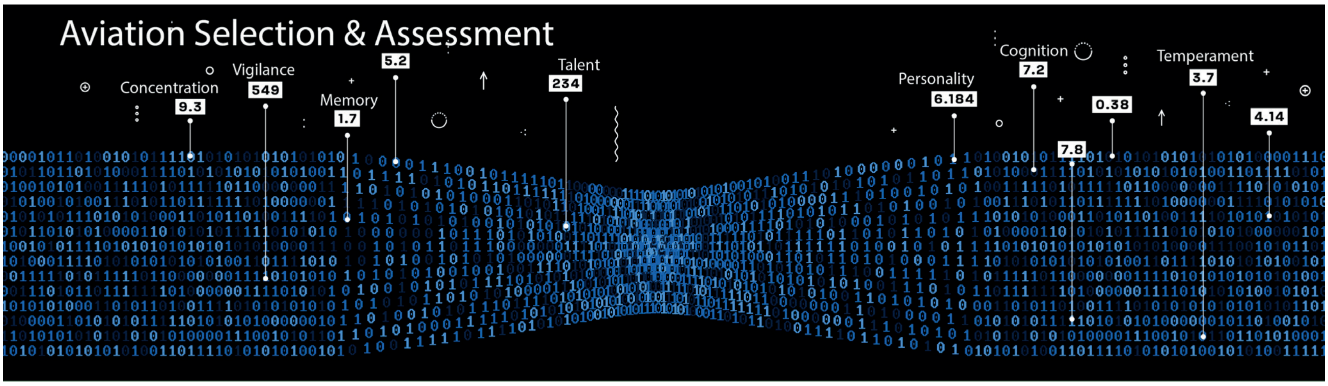


INTEGRATING AI WITH AVIATION TRAINING

A preview of the Virtual Instructor Pilot Referee (VIPER)

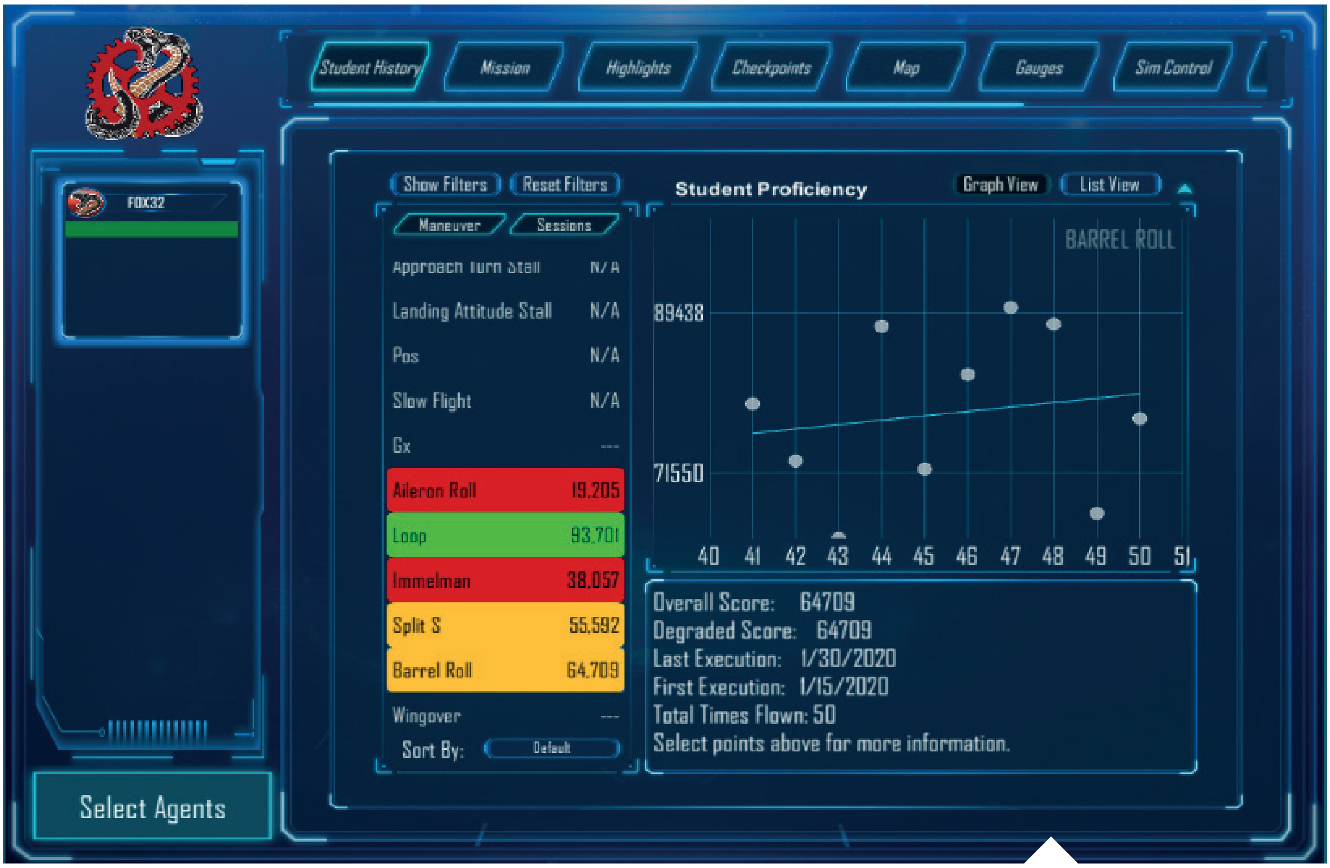
Authors: LT Mike "Tinder" Natali, LT Joe "Sway" Mercado, and CDR Chris Foster

Significant advancements in technology over the past decade are providing society with the opportunity to leverage innovative methods and solutions to enhance the human experience via the ever-more complex integration and interaction with machines. These advancements are not limited to hardware getting smaller and more powerful, but rely heavily on the intricate software and programming that fuel our computers and devices. One of the largest explosions in science and technology influencing human-machine integration and interaction has been in the field Machine Learning (ML) and Artificial Intelligence (AI). As computers have become powerful enough to handle the processing required to run ML algorithms, people have begun applying those techniques in attempts to model all types of human behavior from predicting outcomes to mapping individual learning.

The Aerospace Experimental Psychology (AEP) community has taken great interest in the application of ML and AI to Naval aviation training and has begun several projects to research what deficiencies they can address and what benefits they can provide. One of the major projects in this area is the Virtual Instructor Pilot Referee (VIPER) for T-6B student instruction developed by Discovery Machines, Inc (DMI). AEPs at the Naval Aviation Training Systems and Training Ranges program office (PMA-205), Naval Air Warfare Center Training Systems Division (NAWCTSD), and Chief of Naval Air Training (CNATRA) are working together to integrate and evaluate VIPER to determine the training impact of an AI-enabled tutor that will guide and provide feedback to students in practice sessions using Virtual Reality (VR) devices.

One of the best ways to learn is from a private tutor or instructor who works one-on-one with a student, allowing them to identify student strengths and weaknesses and adapt teaching to target specific learning needs and the Knowledge, Skills, and Abilities (KSAs) of each student (Ireson, 2004). Historically, this has been practiced via apprenticeships where a master artisan or expert trains a student "on the job," in which the student learns the necessary knowledge and techniques by observing and performing under the tutelage of the expert. After years of guidance, the apprentice then becomes a master in his or her own right. In such an environment, it is easier for both the student and instructor to: ask and answer questions, provide and receive feedback on performance, and discuss or coach techniques and methods on how to improve performance. Although evidence supports this method of education to optimize learning, it is difficult to leverage on a large scale due to time, money, and personnel constraints.

Despite these constraints, the need for individualized instruction remains, especially for highly complex jobs such as those in aviation. Due to the high-risk nature of flight, Naval aviation requires students to fly with a qualified aviator with access to flight controls to provide not only instruction, but additional safety until the student reaches a proficiency level safe enough to fly alone. This allows Naval aviation to capitalize on aspects of the apprentice-master dynamic during training where each simulator and flight event consists of a single instructor and student pair. Though the pairing varies based on scheduling, it exposes the students to the one-on-one instruction and experience most likely to speed and enhance learning. Additionally, each student is assigned an



Approach Turn Stall	N/A
Landing Attitude Stall	N/A
Pos	N/A
Slow Flight	N/A
Gx	---
Aileron Roll	19.205
Loop	93.701
Immelman	38.057
Split S	55.592
Barrel Roll	64.709
Wingover	---

Sort By: Default

Overall Score: 64709
Degraded Score: 64709
Last Execution: 1/30/2020
First Execution: 1/15/2020
Total Times Flown: 50
Select points above for more information.

The VIPER Interface, designed to streamline Naval Aviation Training, and inform future manning and training pipeline decisions.

“On-wing” instructor who instructs on the majority of beginning flights prior to the determination of “safe to solo” in an effort to develop better familiarization and aid instructors deliver lessons tailored to student KSAs and training progression.

However, outside of safety restrictions and structured use of one-on-one instruction and learning, two major issues for increasing student learning and optimizing training pervade Naval aviation: the first is an Instructor Pilot (IP) shortage; the second is that outside of scheduled syllabus events, students do not receive feedback or practice guidance.

Feedback is in integral part of training and essential to improving performance – it is how students learn to address and mitigate their mistakes. With an IP shortage and limited feedback opportunities during training, finding alternate or virtual means for students to receive guidance in their training may improve student learning and progression through training while not relying on limited personnel resources. Research has consistently shown the value of deliberate practice in the development of expertise (Ericsson & Charness, 1994) as well as the value of specific feedback on performance (Kluger & DeNisi, 1996). Finding additional and alternative means for delivering quality performance feedback could aid student preparation for higher intensity, graded events in the simulator and aircraft. This has led the Navy to investigate the feasibility and utility of providing student aviators AI tutors to provide performance feedback on non-syllabus practice in VR.

Recently, PMA-205, NAWCTSD, and CNATRA began work with the commercial AI company Discovery Machine incorporated (DMI) to develop a method to deliver tailored feedback to students during study and practice through the use of VR devices. The initial focus is on Primary flight training and utilizing the T-6B VR Pilot Training Next (PTN) flight trainers. Utilizing both adaptive training and Artificial Intelligence (AI), DMI is developing the VIPER system to mimic human instructor feedback based on the performance of the student. Specifically, VIPER will: be trained to recognize a plethora of flight maneuvers and deviations from the optimal performance of those maneuvers; evaluate student performance against objective Course Training Standards (CTS) that students need to meet on those maneuvers (i.e., level of performance necessary); monitor and track trainees attempts and progress over time; assess trainee state and performance in real-time; identify when and how to intervene; and conduct an After-Action Review (AAR).

VIPER integrates the science of real-time adaptive training for the Navy by creating a unique approach to guide and evaluate Student Naval Aviator (SNA) performance outside of normal training events. Partnering with the CNATRA IP Subject Matter Experts (SME), the innovative VIPER mental models are developed based on optimal task performance across a variety of maneuvers and sequences to allow it to simultaneously track and evaluate multiple potential task sequences at varying threshold levels for a given individual. As more students utilize the program and data is collected, the underlying machine learning algorithms allow not only for identifying, tracking, and assessing complex tasks where optimal performance may be represented by two or more tasks, but will also allow for evaluation and feedback based on individual SNA experience level. For example, novices may be allowed larger tolerances and more comprehensive feedback early in the learning process to afford experiential learning. As experience is gained, VIPER will recognize any improvements to performance and automatically adjust the feedback and training parameters to provide continued challenges – more difficult scenarios and/or tighter thresholds which require more precise and timely decisions and actions. The resultant human-machine teaming and instruction will provide individualized training that enhances and reinforces SNA learning and skill acquisition by providing AI-tailored guidance beyond the traditional student-IP relationship.

Examining the technical side of the human-machine teaming effort, VIPER leverages multiple technologies to create an environment where an SNA can receive effective one-on-one feedback virtually, reducing the demand for human IP instruction. First, DMI has developed a unique approach to the problem of transferring SME expertise into digital information with powerful knowledge enabling software: the Knowledge Service Modeler. The Modeler allows SMEs to digitally capture, encode, and leverage their own specific strategies for solving complex problems, thus enabling SMEs to develop model parameters to: 1) Quickly capture and encode trainee behaviors; 2) Display, share, and manipulate that knowledge; and 3) Effectively analyze knowledge bases, using their own expertise.

Second, leveraging previous development on a Defense Advanced Research Project Agency's (DARPA) "AI Next" sponsored project, DMI built the capability to enable SMEs to encode "critic" models where the "critic" looks at other models and logs of their results in order to contrast the other models for monitoring, assessing, intervening, and injecting. VIPER provides this capability to monitor a trainee's actions and compare those actions to expert specified hierarchical models as well as other students using the program. Thus, VIPER has the capability to compare SNA performance against both IPs and SNA peers to provide a more accurate model of KSA progression as assessed by the program. Beyond monitoring the trainee, the critic model also briefs the trainee on his or her performance after the scenario or maneuver is completed. This After Action Review (AAR) builds a dialog with the SNA by comparing the log of the trainee's action to the desired expert behavior developed from CTS and IP SME input. The critic capability is similar to that of IBM's AI question-answering computer system, Watson, and is integrated across the VIPER program. Serving as the interactive-basis for the AI instructor guiding the student, the VIPER's critic model has the ability to prioritize based on training objectives, criticality, and student ability.

As DMI develops the VIPER AI tutor and underlying critic model, it is imperative to collect data from SNAs and IP SMEs utilizing the program to give the machine learning algorithms the information to develop trends and accurate models of learning and skill acquisition. To assist with data collection and program refinement, DMI is providing incremental developments of the program to CNATRA for student use and practice. This will give VIPER the necessary data to build and refine appropriate models. Further, CNATRA will also provide SNA feedback to DMI on the system as a whole in order to enable DMI to improve the human-machine interfacing and application. For initial deployment and evaluation, DMI is developing 22 T-6B flight maneuvers from Primary flight training for VIPER, including but not limited to: takeoff, power-on-stall, barrel roll, Cuban, and Split-S.

The VIPER program also offers student profiles that track performance across attempted maneuvers: as the student gets closer to "expert" performance (i.e., meeting CTS), the highlighted maneuver name shifts from Red to Yellow to Green. For example, in image 2 below the SNA has met CTS for the "Loop" maneuver, is progressing on "Split S" and "Barrel Roll," and has significant work to do on "Aileron Roll" and "Immelman" maneuvers. DMI has also created a "Profile Builder" tool to allow instructors or SNAs to construct complex events by stringing multiple maneuvers together to mimic syllabus simulator or flight events. Though only starting with a limited number

KINGSVILLE, Texas (July 17, 2020) Lt. j.g. Madeline G. Swegle, the U.S. Navy's first Black female tactical jet aviator stands in front of a T-45C Goshawk jet trainer aircraft on the Training Air Wing 2 flight line at Naval Air Station Kingsville, Texas, July 17, 2020. Swegle completed her final training flight with the "Redhawks" of Training Squadron 21 (TW-2). TW-2 is one of five air wings under the Chief of Naval Air Training and conducts intermediate and advanced jet training for the Navy, Marine Corps, and international military partners. VIPER, and other AI technologies, may play a large role in U.S. Navy aviation training in the near future. (U.S. Navy photo by Lt. Michelle Tucker/Released) of events, DMI will continue work on expanding the maneuver list and refinement of how the program works with additional maneuvers scheduled for delivery by the end of Fiscal Year 2020.

Ensuring that the VIPER system is effectively integrated and fully transitioned into Naval aviation training requires that a comprehensive training evaluation be conducted in order to demonstrate program utility and effectiveness and to inform how best to build VIPER into the CNATRA curriculum. PMA-205 and NAWCTSD in partnership with CNATRA will evaluate the impact it has on student performance. AEPs CDR Chris Foster (PMA-205), LT Joseph "Sway" Mercado (PMA-205 and NAWCTSD), and LT Mike "Tinder" Natali (CNATRA) will be leading an in-depth study and evaluation of the VIPER program and student training outcomes. This study will examine usability, frequency and purpose of use, scenario development, skill progression within VIPER, and impact on syllabus training events (i.e., grades):

Usability

Throughout the evaluation, SNAs will be asked questions about their experiences with VIPER, such as how well they thought VIPER worked. This qualitative feedback will provide insights into design improvements to facilitate human-machine integration for training.

Frequency and Purpose of Use

Student use of the VIPER program will be tracked to capture data such as frequency and duration of use (how often and how much) as well as the SNA's objective or purpose for each use (e.g., event preparation, maneuver practice, event remediation). Understanding frequency, duration, and purpose of use provides a better understanding of how to incorporate the program appropriately into a training syllabus.

Skill Progression within VIPER

SNA progression and performance on programmed maneuvers will be tracked within VIPER. This data will be matched with SNA training records to see how different progression or performance on the various maneuvers relates to performance in graded simulator and flight events. Results will inform decisions on how best to incorporate potential VIPER syllabus events into training.

Impact on Syllabus Training Events

SNA frequency, duration, and performance utilizing VIPER will be evaluated against performance in training via grades on simulator and flight events during the Contacts and Instruments stages of Primary Flight Training. Data will be compared to those who went through training without VIPER access to determine whether the AI tutor provided beneficial guidance, i.e., SNAs utilizing VIPER performed better than those who did not use it.

The evaluation of VIPER is set to begin in 2020 at Naval Air Station Corpus Christi, Texas and last up to a year to collect the necessary data. Following the evaluation, the research team will publish a Technical Report detailing all relevant findings and provide recommendations to guide future integration and development of VIPER. If the results of the evaluation show VIPER significantly improves SNA training, developing VIPER for both the T-45 and TH-57 are the next logical paths forward as well as extending VIPER into more challenging graded items or mission sets.

Funded by the NAVAIR Small Business Innovation Research Office and PMA-205, the VIPER development and evaluation will inform how to optimally incorporate Virtual Reality into aviation training and leverage new technology to better integrate humans and machines with the purpose of improving learning outcomes.

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MANAGING UNCERTAINTY

How lessons learned from the recent world-wide push to work from home reinforce the critical need for human-machine teaming principals

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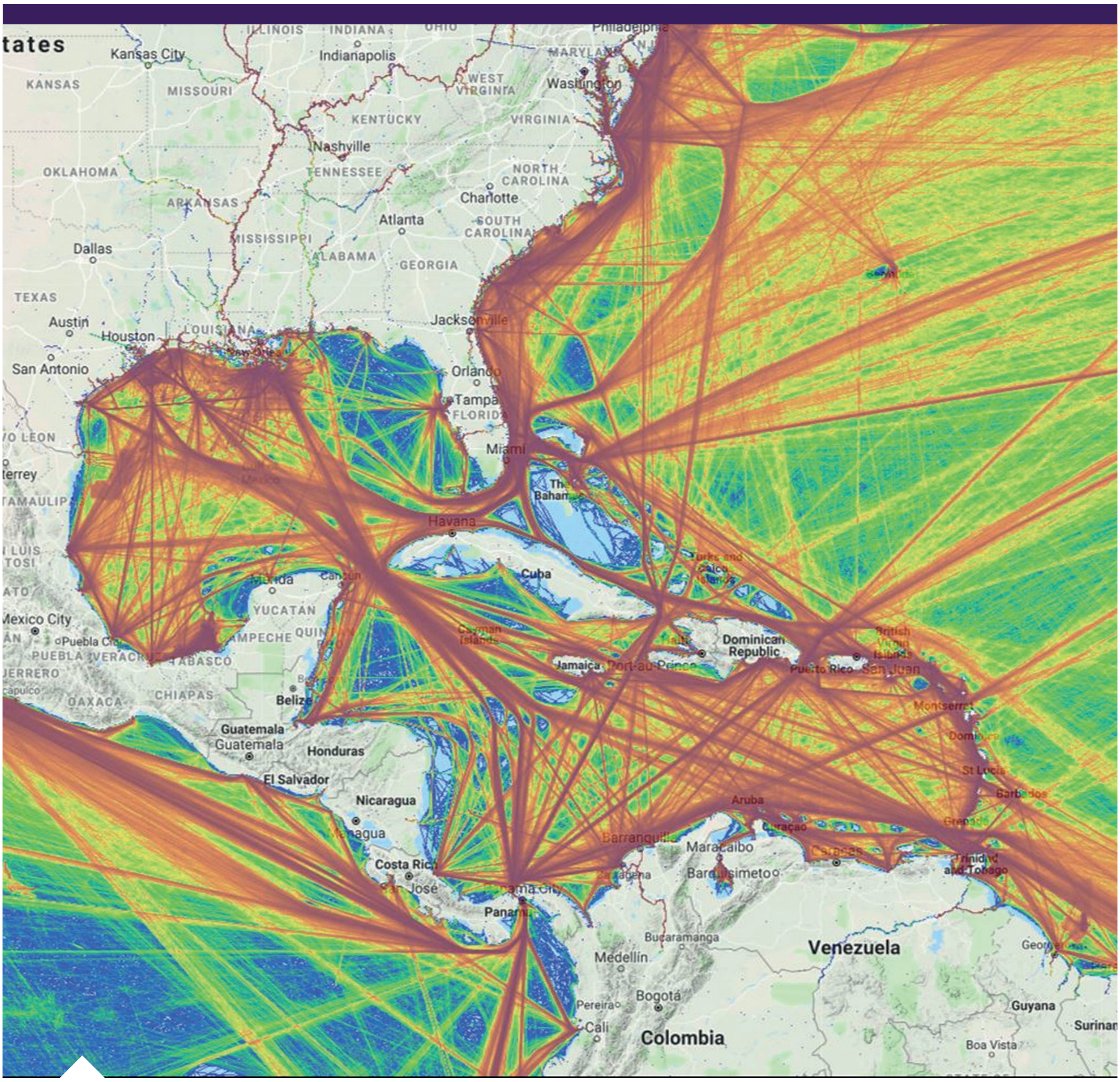
Naval Postgraduate School, Monterey CA

As I write this article, we are several weeks into the shelter-in-place response to COVID-19. Like many, I'm now juggling telework and homeschooling duties (*I get to ~~relive~~ teach 2nd and 5th grade, the joys!*). When I'm not videoconferencing or remotely managing projects, my kids and I are co-reading Harry Potter (for Language Arts) and repurposing old Lego sets (for our STEM needs). Interestingly enough, the details of this scenario provide context for discussing human machine teaming (HMT), which I will do herein by referencing principles of macroergonomics (Hendrick, 2002) and systems integration (Siemieniuch & Sinclair, 2006).

Macroergonomics is the study of *sociotechnical* work systems. Within this framework, the *social* subsystem corresponds to our "human" element of HMT. It refers not only to the individuals who carryout work-related tasks, but also to how personnel interact in terms of collaboration, competition, and power relations. The *technical* subsystem maps onto the "machine" element of HMT, including the design and availability of tools and technologies, as well as the frequency, difficulty, importance, and sequencing of their use. The "teaming" nature of HMT, as you might expect, corresponds to how these social and technical subsystems interact within the operational environment, which itself is characterized by physical and cultural subsystems.

Hal Hendrick, the father of macroergonomics, provides insight into how sociotechnical systems operate and guidance on how to maximize their effectiveness (2002). The social and technical subsystems, he writes, are inherently *interdependent*, such that changes to one will likely affect change in the other. It is important, therefore, to consider how different personnel might interact with the same technology in unique ways (which can happen with staff turnover), or how even small changes to a tech-



MarineTraffic's Density Map format showing vessel trajectories from billions of data points from 2017. The 'cool' colored lines signify that a route has not been taken often, the 'warm' colored lines signify where routes are often utilized. The result is a global dataset of ship tracking density. Operations to identify, track, and interrupt illegal trafficking across international shipping routes are examples of domains that the U.S. Navy is seeking to leverage decision support systems built on a platform of Machine Learning. Photo by Victor Chen, US Naval Research Laboratory.

nical component could influence how it is interpreted or used by the human operator (as with system updates). This interdependence has implications for system design and engineering, as well as user training, if the goal is to achieve consistent and acceptable performance in HMT events.

Hendrick also observes that social and technical subsystems operate under *joint causation*; that is, they are similarly open and responsive to internal and external influences (e.g., policy change, OPTEMPO, budget constraints…a pandemic). Because these subsystems respond jointly to causal events, optimizing one subsystem (e.g., acquiring a state-of-the-art technology) and then forcing the other to adapt to it (e.g., training the uninformed operator on its use) will lead to suboptimal integration and performance. A preferred approach, Hendrick advises, is to pursue *joint optimization*; that is, shared and synchronized consideration of the characteristics, requirements, and objectives of the human and the machine. This joint optimization, by necessity, will require attention to the overarching work system as well, as the organization's structure, resources, and related processes must be compatible in order to support the human-machine interaction.

When COVID-19 mandated school closures and shelter-in-place orders disrupted the social and technical subsystems of my household (let alone the world), "Just use Zoom," was the immediate recommendation to millions of workers and students forced to work from home, many with little to no preparation. In this case, a technology-driven solution was pushed upon a user population as part of "the new normal." The tool (or modality) for conducting operations was prioritized, with less concern given to the psychosocial characteristics of the users and the limitations of their work environment (e.g., not enough home computers for simultaneous use; insufficient bandwidth for streaming). As I explained to my kids, not all witches and wizards return to magical households when school ends; some, like Harry Potter, leave the comforts of Hogwarts, where they're encouraged to use wands, flying brooms, and potions, to living with the disgruntled Durselys in the cupboard under the stairs.

Hendrick would advocate for a different approach. Among macroergonomic practices to avoid, he cautions against: (1) technology-centered designs [designing technology without considering human limitations, interests, etc.]; (2) a "leftover" approach to function and task allocation [assigning machines to do the work, leaving humans to supervise the technology]; and (3) failure to consider the organization's sociotechnical characteristics when integrating systems. The preferred strategy should instead strive for (a) joint design [simultaneous consideration of the social and technical subsystems]; (b) a human-centered approach to function and task allocation and task design [making full use of human skills and compensating for human limitations, with leftover functions allocated to the machine]; and (c) integration with the organization's sociotechnical characteristics.

In their cross-departmental collaborative, Carys Siemieniuch (Dept. Systems Engineering) and Murray Sinclair (Dept. Human Sciences) of Loughborough University offer additional insights on systems integration applicable to HMT (2006). They begin by making a distinction between *complicated* and *complex* systems. Like a Lego set, complicated systems may be difficult to understand, yet they consistently behave according to their design and can even be deconstructed and reassembled to understand their inner workings. Out of the box, like a piece of Ikea furniture, users need only to follow the step-by-step pictures to assemble even the most daunting of Lego creations. Some Lego sets are even powered, with motorized parts and blinking lights. Nevertheless, they can be taken apart and put back together, again and again, so long as no pieces are lost, damaged, or repurposed. They are complicated, but not complex.

Complex systems are far less predictable. In many cases, this complexity erupts from the introduction of the human-in-the-loop. Unlike traditional engineered systems, human systems learn, adapt, and behave in unexpected ways. These complex systems have intelligence. They behave with autonomy. Their parts become highly interconnected, with each interconnection having its own goal or agenda. Complex systems evolve, and they're capable of operating an evolving environment. These properties, most if not all of which apply to HMT, create a pathway for system entropy, coping mechanisms, chaos, and ultimately, darkness.

Systems entropy refers to the process by which a system (or system component), if left to itself, ultimately succumbs to environmental pressures, decays, and dies out. Adaptation, therefore, becomes necessary for complex systems to survive long-term. This adaptation may take the form of supervised maintenance or system upgrades, or it could be far less structured… unanticipated even. In response to external threats, complex systems turn to *coping mechanisms* –

A Marine with Company F, Headquarters Group with 2nd Battalion 5th Marine Regiment, relaxes against his pack as company commanders gather in the back of an Assault Amphibious Vehicle to plan their next movement during Integrated Training Exercises aboard Marine Corps Air-Ground Combat Center Twentynine Palms California. Training exercises that integrate the ground combat, air combat and logistics combat elements of the Marine Corps into one fully capable and lethal unit are logistically challenging, and require tremendous technical integration efforts. (U.S. Marine Corps photo by Cpl. Timothy Valero)

Lt. Aaron Van Driessche, a warfare tactics instructor at the Center for Surface Combat Systems (CSCS), Detachment San Diego, pilots the U.S. Navy's virtual combat curriculum with Sailors aboard USS Paul Hamilton (DDG 60) inside the newly launched portable simulator, the On Demand Trainer. Technologies such as this trainer enable highly complex, integrated operations to be taught in a fraction of the time it took using traditional methods. Tomorrow's military members will increasingly interact with hybrid intelligent systems designed to afford rapid decision making amidst highly complex, time-constrained, and high-risk scenarios. (U.S. Navy photo by Mass Communication Specialist 2nd Class Joseph Millar/Released)

conscious or unconscious strategies for resolving conflict and increasing (the perception of) control. Consider the "innovative" user who does not fully understand the system they're operating, and so they devise workarounds and shortcuts, reinterpret policy, and repurpose parts in order to get by.

As a result of system entropy, and the measures complex systems take to counteract its effects, long-term stability becomes an illusion and "normality" less defined. In some cases, new technologies are introduced to offset system decay, leading to mergers rather than subsystem replacements. This increases the number of interconnections, which provides a precursor to *chaos* (or chaos-like effects). According to Siemieniuch and Sinclair, as the number of variables in a complex system increases linearly, the workload to manage the system increases logarithmically. Furthermore, unaccounted for second and third order "ripple" effects may emerge and inhibit system stability. Complex systems are chaotic, and full of inherent surprises.

Which brings us to the *darkness principle*, which holds that no complex system can be known completely. Is this the case with all HMT events? Probably not. But as the conditions of HMT approach the criteria for complex systems outlined above, it is reasonable to assume our ability to predict HMT behavior erodes. Fortunately, there is a corollary to the darkness principle: although complex systems may never be completely known, they can be managed effectively (Lundgren-Cayrol, 2000). To do so, those working in systems integration (or HMT for that matter), should seek to:

- Devise a common framework and language for addressing issues of system complexity;
- Constrain the evolution of requirements and system configurations during design, maintenance, upgrades, and operation of the system over its lifecycle;
- Model the way complex systems self-organize, or co-evolve;
- Mitigate factors that influence the emergence of undesirable behaviors;
- Improve our ability to predict and/or detect and filter out such emergent behavior (Siemieniuch & Sinclair, 2006).

Although they do not mention it in their writing, an essential step to managing complex human systems integration is to follow the example of Siemieniuch and Sinclair, themselves, by building bridges between our systems engineering and human sciences departments. Members of the Aerospace Experimental Psychology community, along with our network of scientists, systems design/developers, operators, maintainers, and support personnel, are in a unique position to fulfill this critical requirement.

Whether we are dealing with sociotechnical systems, complex systems, HMT, or a worldwide pandemic, uncertainty is the only certainty.

But *we can* manage it.

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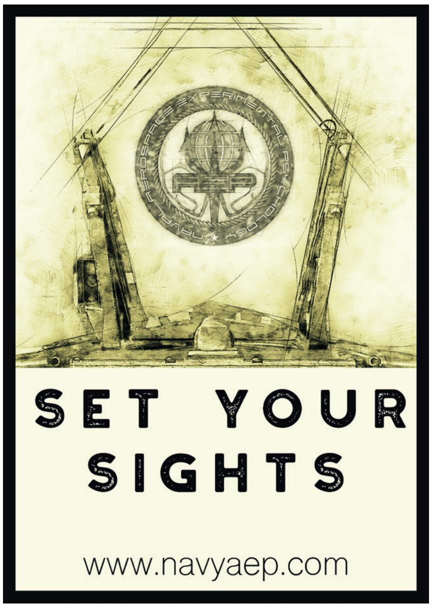


MEET AN AEP

LT Aditya Prasad, AEP #156, discusses his motivation for joining the AEP community and what drives his interests in his role at the Naval Air Warfare Center.

The decision to leave civilian life and join the military is one that involves a lot of personal choice and preferences. There is no "standard" servicemember, and there is certainly no standard uniformed scientist, despite what some movies or books may depict.

In this series, we spotlight individual AEPs to learn more about them in a one-on-one interview format in order to narrow that gap, and foster relationships and collaboration across our community.

In this issue we will meet LT Aditya Prasad. He just completed a three-year tour at the Naval Air Warfare Center, Aircraft Division at Naval Air Station Patuxent River, MD.

What is your academic background?

I attended the University of Southern California from 2005-2015. My original plan was just to complete a Bachelor's in Psychology, but when the opportunity presented itself, I chose to stay on and pursue my PhD in Cognitive Psychology, picking up my Master's along the way.

What made you decide to become an AEP?

After spending 10 years in an academic setting I was looking for a brand new path, one that would let me take the knowledge and skills I'd acquired and apply it to real-world situations.

Learning about the Navy's Aerospace Experimental Psychology community and the work AEPs do throughout the fleet, combined with the excellent experiences I had during face-to-face meetings with members of the community, convinced me that I'd found my path.

LT Prasad beside the USS Chaffee, a guided-missile destroyer, in Honolulu, Hawaii. LT Prasad spent three weeks underway on the Chaffee studying circadian rhythms of crew as part of a study for the Naval Post-Graduate School.

What was your most vivid memory of training?

There are actually several that spring to mind! The Helo Dunker – the helicopter water survival trainer in which you are submerged, inverted, wearing blackout goggles, was one of my favorite training events. Then there was camaraderie and sense of accomplishment I shared with my cohort on Flight Suit Friday, when you earn the right to wear your flight suit. Finally, the first time I was given the controls of the fixed wing and rotary wing training aircraft was an incredible sensation.

What has been your favorite project as an AEP and how will it impact the Navy?

I have been privileged to work on a pioneering effort focused on improving the readiness and lethality of our aviation assets through modernization of aircraft maintainers and support personnel. It is not immediately obvious, but generating a single flight hour on any given aircraft requires dozens of hours of maintenance and logistics, and a similar number of boots-on-ground personnel. As a result of several data collection efforts conducted throughout the fleet, the Design for Maintenance Engineering team in NAWCAD's Human Systems Engineering Department has been able to identify several personnel- and equipment-based inefficiencies in the complex process of producing ready-to-fly aircraft. These data formed the basis of a broad package of solutions—including tools, personal protective equipment, and processes—that received a five-year funding package to modernize and optimize the performance of aircraft maintenance and support personnel across the fleet.

LT Aditya Prasad, AEP #156 at the controls of an Army Beechcraft C-12 Huron conducting a courier mission for secret materials...

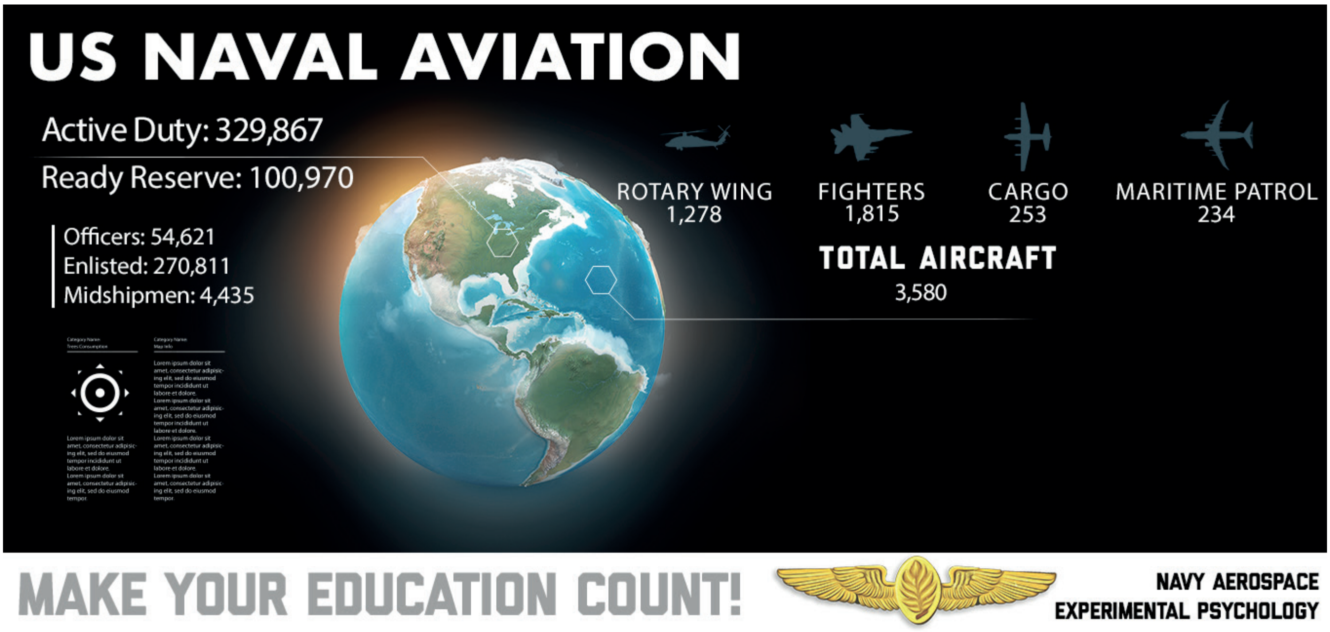
What are your career goals?

One of the reasons why I was so attracted to serving as an AEP was that it is a career that affords me great opportunities with lots of variety. When I finished grad school, I didn't really know whether or not I wanted to continue on in a post-doc position, or work in a lab environment, or continue on pursuing a career in academia. The AEP community has given me an opportunity to explore all of my options, while giving me great experience. I have found a great deal of enjoyment and fulfillment in advocating for seeking solutions to problems by focusing on the human as the centerpoint of a system—be that an information system, a weapons system, an aircraft, etc. I hope to continue to promote this view and am eager to see the many different roles and positions in which I can do so, through research, policy, and other avenues.

For those who are considering applying, what qualities make a great AEP?

From my experience, great AEPs demonstrate a strong dedication to the fleet, never losing sight of the fact that they serve the Sailors and Marines on the line. In addition, I feel it is important to be able and eager to problem solve in innovative and unconventional ways, thinking outside the box to find novel solutions. Finally, patience and humility are especially important. The Navy is a vast organization. In order for your skills and experience to make an impact you must first spend time learning about the culture, the processes, and the mission.

LT Prasad navigates his way through the USS Chafee. Visits to ships like the Chafee are unique opporunities that uniformed scientists like AEPs can afford, which take science out of the lab and into the wild.



We Remember

The AEP community says goodbye to one of its longtime and most influential members.

The AEP community is made up of a group of individuals, committed to a common goal, and united by a common passion- to apply scientific knowledge to help solve problems in the real world. Our group is small. At the time of this writing, we have 29 uniformed active duty members in a Navy comprised of just over 300,000 sailors. But it is not our size that defines us; it is our sense of community. A feature of our small, but tight-knit family is that each individual is afforded the opportunity to be known. In a community that numbers its members going back to World War II, each individual inevitably leaves a mark on the community. Perhaps no other AEP left as much of a mark as CDR Robert Samuel Kennedy, AEP #10.

Bob Kennedy, Ph.D was commissioned as an AEP on August 27th, 1959. These were the days of the early Cold War era, when the space race served as the collective focus of the United States. There were tremendous scientific hurdles that had to be cleared in order to achieve the stated mission of landing a man on the moon. This era also say a remarkable spike in growth in both military and commercial aviation. As systems grew in both complexity and scope, and new visions of the future grew into existence, new problems emerged that demanded new methods of inquiry, and new solutions. Bob was a pioneer in this era. He was a human factors engineer, which had only just recently became a professional discipline that was recognized by the greater engineering communities. The Human Factors and Ergonomics Society had only just been created in 1955. The US Navy was in the process of updating its aging fleet, retiring ships used in WWII, and updating them with newer, sleeker, more efficient models. This was the beginning of a new era in Naval Warfare, which saw the USS Enterprise (CVN-65) commissioned. It was the first nuclear-powered aircraft carrier the world had ever seen.

Bob joined in with other human factors scientists who were applying new forms of inquiry such as task analysis, and cognitive work analysis to better design aviation cockpits, screen displays, radar interfaces, and weapons systems. Bob led the way to investigating issues such as the origins of motion sickness, interface layouts and their effects on decision making, and developing imaging training methods for aircrew. Wherever Bob Kennedy went, he left his mark, and his notoriously astute and clever disposition added value to the work groups that he joined.

Bob served in the Navy for 22 years of active duty service as an AEP, before retiring, where he continued to work as a government scientist. All told, Bob gave the world over 60 years of industry-leading contributions in human factors and simulation sickness research. He was a pioneer and a legend within our community. When the US Navy AEP Society (USNAEPS) created its annual awards 10 years ago, there was only one AEP we seriously considered as the namesake for our ***excellence in research award***, as there has been no member of our community who has come close to the impact that CDR Bob Kennedy had on our field of practice, and likely no practitioner of human factors that hasn't cited his work. He pushed us forward, generating new insights, and producing a library of publications that changed how we design and use simulation. All AEPs, and all human factors practitioners, truly stand upon his shoulders.

CDR Bob Kennedy, AEP #10, rides the "vomit comet" to conduct human factors research in collaboration between the US Navy and NASA. Reduced Gravity aircraft such as this enable researchers to study the effects of low-G on humans.

Bob Kennedy passed away December 16, 2019 at the age of 83. He was a loving husband to Susan Lanham Kennedy, and a pillar of strength to his children Kathryn Chambers, Robert Kennedy (Dawn), Richard Kennedy (Rose Wenner), Kristyne Kennedy, and step children Elizabeth Patrie (Don), Mary Chappell (Scott) and Heather Fox (Matt). He was adored by 11 grandchildren and five great grandchildren.

Below are some remembrances from

other retired AEPs who worked with Bob Kennedy during and throughout their careers.

Mike Lilienthal, AEP #71 remembers Bob Kennedy

I first met Bob at a formal AEP get together meeting, but did not really get to know him until a few years later when I was stationed at the Naval Air Warfare Center, Training Systems Division (NAWC-TSD) in the 1980s. Bob had already retired from the Navy and was working with Norm Lane, a fellow AEP. Bob, Norm, and I worked together on the study of simulator sickness. The Google search application was not invented until 1998, but that was okay, because I had Dr. Kennedy via land line. He had information from books, presentations, journal publications, and firsthand knowledge at his mental fingertips, and was a wealth of knowledge.

During technical discussions he would reel off citations and then have an assistant make a copy of the publications from his personal library. I would walk away with a thick folder of helpful reading material. Bob spent a lifetime learning and adding to the Navy's, as well as the world's, pool of knowledge about human exposure to accelerations and motion on different platforms. Bob was in his element collecting data, running subjects, and synthesizing information. He gave his knowledge freely to our community.

During his naval career you would find him on the vomit-comet experiencing weightlessness, in the Pensacola slow rotation room, which was used to expose subjects to up to 10 revolutions per minute for days; or on a ship in the North Atlantic in search of a storm. His sense of adventure permeated everything he did, and he was always on the move.

Bob always had a twinkle in his eye, and I am having trouble remembering a time when Bob had raised his voice or showed anger. I remember him as a man of patience who was eager to share his knowledge openly and freely. He loved his family and always enjoyed seeing them "growing like weeds." The AEP tribe is diminished by his loss, but it is also stronger because of his help and gentle mentoring.

CDR Bob Kennedy (Left) examines data from sensors on board NASA's reduced gravity KC-135A aircraft. Experiments on weightlessness gathered through flights like these helped scientists and engineers better design safety systems for high-velocity aircraft, including ejection seats in later-generation aviation.

CDR Bob Kennedy (third row from the front, second from the right) poses with his fellow Aerospace Experimental Psychologists in front of the Naval Aerospace Research Laboratory on board Naval Air Station Pensacola, circa 1970s.

Bill Moroney, AEP #46 remembers Bob Kennedy

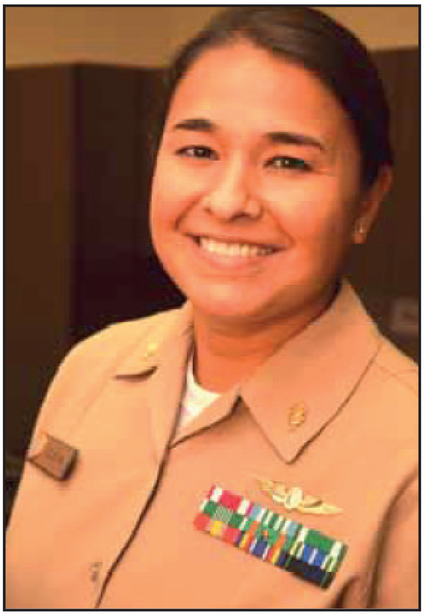
Bob was one-of-a-kind. Not only was he technically competent but he was always willing to share that competence. He saw real connections that most of us missed. I was always amazed by his ability to create testable hypotheses and to back them up with reference to the literature (which he often pulled off the shelf or out of a drawer). I expect, that now that he is safely home, he is still asking challenging questions. Bob was more than a "walking Wikipedia" in the areas of aviation. aerospace, human factors and psychology. He is a major node in an ever-expanding sociogram of researchers and practitioners.

Bob was an indefatigable mentor and I for one owe a lot to him and will miss him as a mentor and a friend. My thoughts at this time turn to Lincoln's memorialization of those who died at Gettysburg. He said, "It is for us, the living, rather, to be dedicated here to the unfinished work which they who fought here have thus far so nobly advanced." We owe it to Bob to serve as mentors in whatever way we can. Bob, enjoy your well-earned rest!

Bravo Zulu!

Some recent accomplishments from around the US Navy Aerospace Experimental Psychology community

Notable achievements:



Congratulations to **CDR Tatana Olson** (above) for being elected President of APA Division 19 Military Psychology in June 2020!

LCDR Lee Sciarini is the government PM for the On Demand Hypoxia Trainer (ODHT), now in acquisition contracting. CNAL and CNAF have both asked for Class 1 Aviator evaluation of the ODHT, representing the most senior interest in this tool to date. CNAF will soon make an acquisition decision about whether to provide ODHT units at all Air Wings.

Congratulations to CDR Mike Lowe and CDR Noel Corpus on their selections for FY21 promotion to the rank of Captain, as announced 13 May 2020!

CDR Chris Foster (above) coordinated the Strategic planning and Program Office Memorandum (POM) processes for Naval Aviation Training and Training Ranges to include $1.7B POM-22 portfolio; Science and Technology Level 1 for PMA-205 with direct oversight of 57 programs and $72M. He is spearheading the development of Mixed Reality training technologies for Aviation training applications and has delivered 22 VR trainers in 2019.

CDR Brent Olde (above) stood up a new NAVAIR Aeromedical Division, chartered to bridge the gap between medical experts and the acquisition process, thus ensuring critical medical requirements are integrated into naval aviation programs. He established two branches containing 30 subject matter experts and successfully added 1 MC and 5 MSC billets for future support through the POM process. An organizational change of this scope will have long-range impact on NAVAIR's ability to respond to human systems needs.

LCDR Rolanda Findlay (above) is part of the team standing up the Bureau of Medicine and Surgery's (BUMED) first Medical Capabilities Integration (MCI) Program Management Office (PMO). This effort is focused on adding organizational and acquisition management processes and structure to medical acquisition efforts, a critically necessary undertaking for ensuring BUMED maintains the organizational flexibility it needs in the modern environment.

LCDR Joe Geeseman (above) is the User Interface/User Experience (UI/UX) Lead for Next-Generation Navy Mission Planning System, leading a team of military, industry, and academia personnel to develop state-of-the-art mission planning software that will utilize modern user interaction capabilities including augmented reality and virtual reality to reduce mission planning time and improve mission success that will be used by all aircrew for all aircraft in the US Navy and Air Force by May 2021.

LCDR Ken King (above) is coordinating a team including members from academia and DoD research labs to further selection efforts using biomechanical and latent specific ability markers to find better aviation candidates, more quickly, cheaply, and reliably.

LCDR Pete Walker (above) has been named the Program Lead for Project Salus, which provides a Joint All-Domain Command and Control dashboard for NORTH-COM and National Guard focusing on shortages in supply chain and COVID-19 Disease Modeling. He was also hand-selected to lead the acquisition side of the Joint Artificial Intelligence Center (JAIC). He presented his team's work to Dr. Deborah Birx and the White House COVID-19 Task Force in July 2020.

LT Heidi Keiser (above) is conducting psychometric evaluation of current and proposed changes to test content and minimum scores for the Aviation Selection Test Battery (ASTB), including future attentional control measures, diversity implications for changes to minimum scores and retest policies, and updates to computer-adaptive test score calculations algorithms.

LT Joe Mercado (above) was hand-selected to manage the program directly supporting CNATRA 2020-2025 Vision for OPNAV N98. His efforts resulted in the delivery 22 trainers in under 10 months to operational/training commanders supporting more than 1300 pilot trainees per year and expected is to reduce training time by 3 months days with a cost avoidance of $105M/FY.

LT Mike Natali (above) serves as Lead scientist of Naval Aviation Training Next and Project Avenger for the Chief of Naval Aviation Training (CNATRA), developing new aviation training methodology, culture, and syllabi integrating Virtual Reality (VR) technologies to improve student quality and reduce time to train.

CDR Tatana Olson (above) led the NAMRU-D response to the physiological episode challenges facing Naval aviation, a program of research comprising 45 projects for $12M addressing a comprehensive range of potential contributing factors and mitigations including physiological sensor verification and validation, work of breathing and respiratory challenges, atelectasis, hypoxia, flight gear fit, brain-based monitoring, and oxygen and pressure fluctuations.

LT Sarah Sherwood (above) is leading independent testing and evaluation of the Otolith bone-conducted vibration headset for airsickness mitigation for USAF Air Education and Training Command to address a listed capabilities gap and to improve student pilot recruitment, performance, and retention.

LT Eric Vorm (above) has been named Evaluation Team Lead for the DARPA Explainable AI program, a $95M 3-year effort to study and develop techniques and technology to make artificial intelligence more transparent so that users can better understand and trust its outputs.

Four AEPs are serving on 2020 MSC Strategic Goal Groups (SGG): **CDR Hank Phillips (SGG Lead) and LT Joe Mercado** serve on the Transition Tracking SGG, evaluating the progress, impact, and most pressing needs associated with the transfer of Medical Treatment Facilities to Defense Health Agency Control

Assistant Specialty Leader **LCDR Lee Sciarini** and **LT Mike Natali** serve on the High Reliability Organization SGG, focused on practices to improve organizational efficiency and effectiveness within the Medical Service Corps.

Three AEPs are supporting the My Navy Coaching (MNC) Effort, a part of the larger Performance Transformation effort, and is an effort to transform the current mid-term counseling system. **CDR Tatana Olson** is leading the Research Testing, & Analysis group, relying on the expertise and contributions of **LT Heidi Keiser** and **LT Mike Natali** on lines of effort including development of a mid-term counseling survey, summaries of relevant research, and execution of a pilot effort planned for August 2020, which will include basic components of a coaching program and small group training to yield proof of concept for MNC training and an evaluation of program progress.

Awards and Recognition:

Congratulations to the winners of the 2019 USNAEPS Awards, presented on Tuesday 25 February at the US Naval Aeromedical Conference (USNAC) Awards Luncheon. This year's winners included:

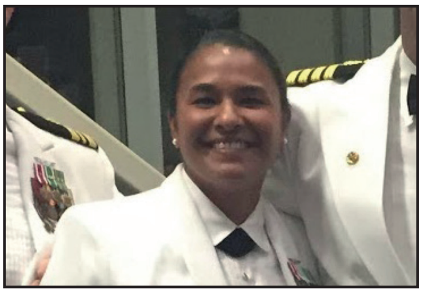
CDR Jeff Grubb (above) was named the 2019 recipient of the Michael G. Lilienthal Leadership Award.

LT Joe Mercado (above) was named the 2019 recipient of the Robert S. Kennedy Award for Excellence in Aviation Research.

CDR (Ret) Robert Kennedy was posthumously presented the Paul R. Chatelier Lifetime Achievement Award. This award was accepted by his son Dr. Robbie Kennedy, pictured above.

Pictured above is **LCDR Brennan Cox** being recognized for 3 years of outstanding service as AEP Assistant Specialty Leader.

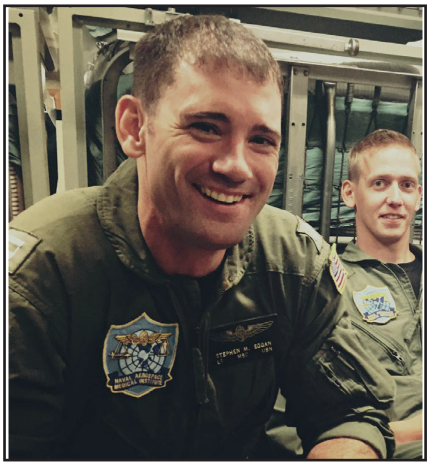
CDR Tatana Olson (below) was the sole military scientist invited to present at the 2019 SIOP Leading Edge Consortium on emerging technologies for selection personnel for high-risk occupations.



CDR Tatana Olson (above) was also the recipient of Society for Military Psychology 2019 Presidential Citation for advancing the field of military aviation psychology.

LCDR Brennan Cox (above) is the 2020 recipient of the Military Officers Association of America Joint Service Warfare Award. This award is given twice a year to an NPS military staff or faculty member who has contributed most significantly to the study, implementation, and spirit of joint service.

LT Todd Seech (above) was the first O-3 and first Naval officer to be awarded US Air Force Academy's General Robert F. McDermott Award for Research Excellence, in recognition of research focused on the development and validation of USAF's Pilot Training Next Program.



LCDR Stephen Eggan (above) was quoted in US Naval Institute News for his critical work supporting NHRC's mission to enable COVID-19 fleet and clinical testing. Unfortunately, in the article, he was identified as an "Infectious Disease Researcher."

Such is the burden of the AEP...

Notable assignments:

CAPT Joseph Cohn serves as Division Chief, Research Program Administration at the Defense Health Agency (DHA), as well as Program Manager for the DHA Small Business Innovative Research (SBIR)/Small Business Technology Transfer (STTR) Program.

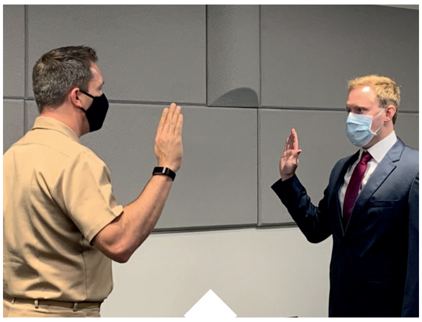
CAPT(S) Noel Corpus is reporting to US Naval Attache to the Philippines for the Defense Intelligence Agency.

CDR Jeff Alton serves as Chief of Staff for Deputy Director of Defense Research and Engineering (Research, Technology and Laboratories). He is the first Medical Corps or Medical Service Corps to hold this position.

CDR Jeff Grubb currently serves as Director for Operations, Capability Functional Area Lead, and Acting Director of the Joint Acquisition Task Force (JATF). He oversaw close-out of the $120M TALOS project and pivoted JATF to lead the Hyper Enabled Operator (HEO) concept, USSOCOM CDR's number one S&T priority. He is the first non-SOF officer to lead a SOCOM Joint Acquisition Task Force.

CDR Brent Olde serves as the Military Director, Human Systems Engineering Department and Naval Air Warfare Center Aircraft Division (NAWCAD) Product Director, Program Executive Office (PEO) for Common Systems (CS). Following a reorganization at Naval Air Systems Command (NAVAIR), CDR Olde was the only officer below O6 appointed as a Product Director, a key coordinating function between NAWCAD and PEO (CS).

LCDR Stephen Eggan is reporting for duty as the Science Director for Naval Medical Research Unit 3 Sigonella, an assignment for which he was by-name requested.



CDR Hank Phillips (above left), AEP Specialty Leader, administers the oath of office to Dr. Adam Braly, officially commissioning him into the US Navy as a student Aerospace Experimental Psychologist (SNAEP). LT Braly will now begin his aviation training to earn his wings, at which point he will become a designated Aerospace Experimental Psychologist (designator 2300/1844D) in the US Navy.

On 14 Aug 2020, **Dr. Adam Braly** (pictured above right) was commissioned as a Navy Lieutenant and the newest member of the AEP community by presiding officer CDR Hank Phillips.

LT Braly will report to Officer Development School in Newport RI on 30 Aug 2020 and is expected to earn his wings as AEP # 161 with NAMI Aeromedical Officer Class 2021-3 on 21 Jun 2021. LT Braly holds a PhD in Human Factors Psychology from Rice University and an MA in Experimental Psychology and Human Factors from Texas Tech University. Congratulations and Bravo Zulu LT Braly!

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Commander Hank Phillips, PhD
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