*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?

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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.

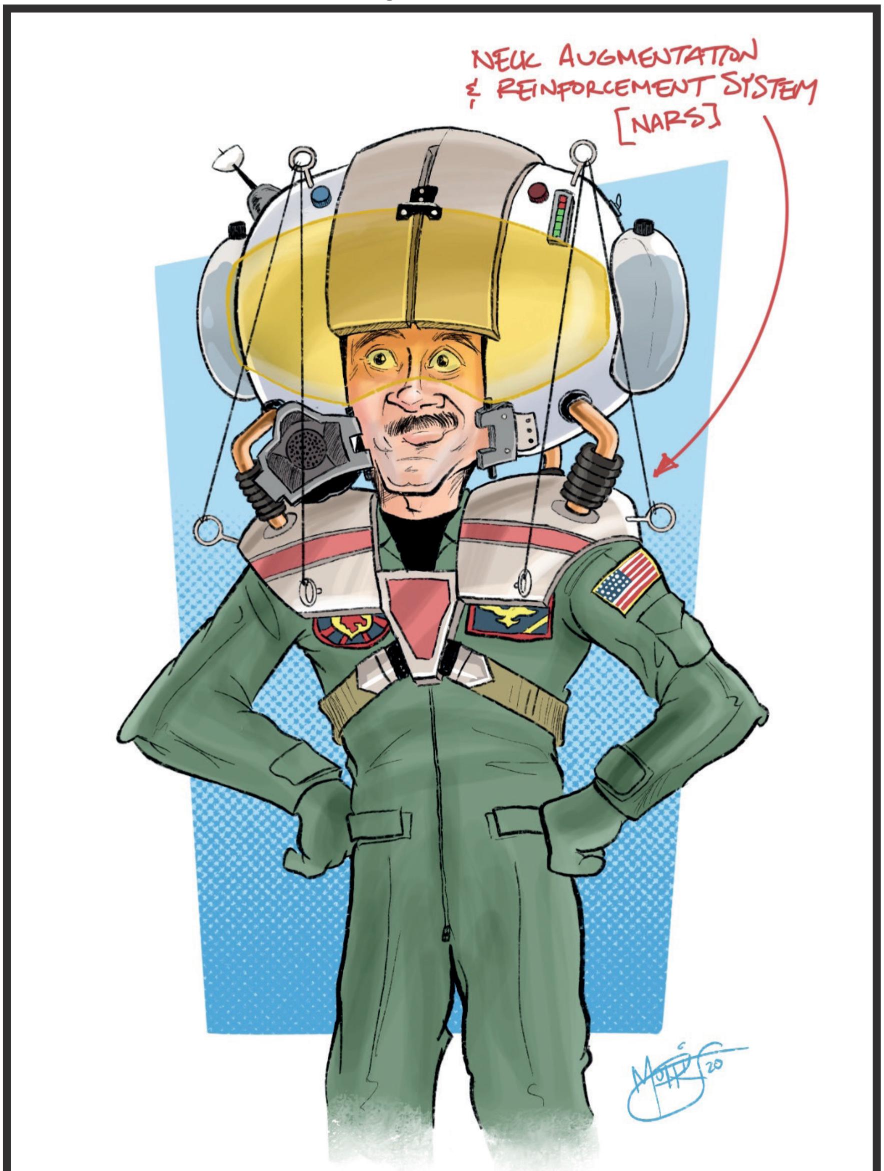
When ZachS shocked the world with its accomplishment, the world once again caught a vision of a future where human and computer intelligence in concert could rule supreme. But what can we attribute to the surprising success of ZachS? Most scientists agree that what ZachS did well was to develop a superior 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.

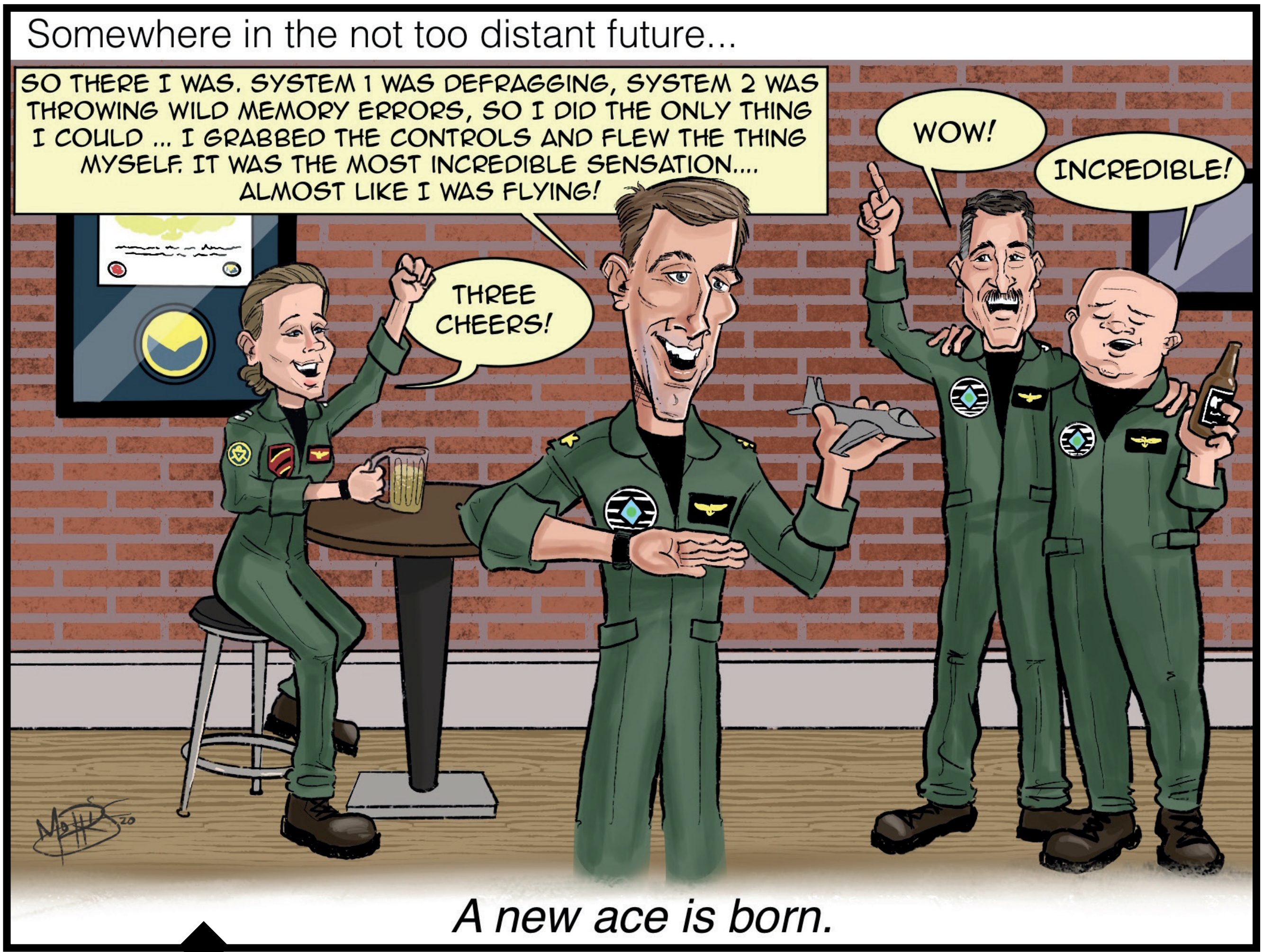
The need for human-centered design in a techno-centered landscape

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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