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SERENITY: THE FUTURE OF COGNITIVE MODULATION FOR THE HYPER ENABLED OPERATOR

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SERENITY: THE FUTURE OF COGNITIVE MODULATION FOR THE HYPER ENABLED OPERATOR

by

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In the Special Operations community, cognitive enhancement and resilience is at the forefront of the 2035 Hyper Enabled Operator Program (HEO). The United States Special Operations Command's vision is to combine cutting-edge communications and data capabilities into a next generation tactical system for the end user. Using algorithms and autonomous systems to enhance the ability to make rational decisions faster can ultimately determine life or death on the battlefield. Over the past several years, cognitive enhancement with the introduction of brain computer interface (BCI) technology has had major breakthroughs in the medical and science fields. This thesis looks to analyze BCI technology for future cognitive dominance and cognitive overmatch in the Hyper Enabled Operator. Machine-assisted cognitive enhancement is not beyond reach for special operations; throughout the research and after multiple interviews with subject matter experts, it has been concluded that interfaces using transcranial alternating current stimulation (tACS), median nerve stimulation (MNS), or several other exploratory procedures have been successful with enhancing cognition and reducing cognitive load. Special Operations should not shy away from transformational innovative technology or wait for commercial or lab-tested solutions. To start, Special Operations should foster avant-garde theories that provide solutions and evolve ideas into unsophisticated prototypes that can be fielded immediately.

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SERENITY: THE FUTURE OF COGNITIVE MODULATION FOR THE HYPER ENABLED OPERATOR

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ABSTRACT

In the Special Operations community, cognitive enhancement and resilience is at the forefront of the 2035 Hyper Enabled Operator Program (HEO). The United States Special Operations Command's vision is to combine cutting-edge communications and data capabilities into a next generation tactical system for the end user. Using algorithms and autonomous systems to enhance the ability to make rational decisions faster can ultimately determine life or death on the battlefield. Over the past several years, cognitive enhancement with the introduction of brain computer interface (BCI) technology has had major breakthroughs in the medical and science fields. This thesis looks to analyze BCI technology for future cognitive dominance and cognitive overmatch in the Hyper Enabled Operator. Machine-assisted cognitive enhancement is not beyond reach for special operations; throughout the research and after multiple interviews with subject matter experts, it has been concluded that interfaces using transcranial alternating current stimulation (tACS), median nerve stimulation (MNS), or several other exploratory procedures have been successful with enhancing cognition and reducing cognitive load. Special Operations should not shy away from transformational innovative technology or wait for commercial or lab-tested solutions. To start, Special Operations should foster avant-garde theories that provide solutions and evolve ideas into unsophisticated prototypes that can be fielded immediately.

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LIST OF ACRONYMS AND ABBREVIATIONS

AAR	after action review
ARL	Army Research Lab
AFRL	Airforce Research Lab
BCI	brain computer interface
CW	continuous wave
DARPA	Defense Advance Research Project Agency
EEG	electroencephalogram
HEO	hyper enabled operator
IARPA	Intelligence Advance Research Project Agency
ISR	intelligence, surveillance and reconnaissance
IVAS	Integrated Visual Augmentation System
MEnTs	magnetoelectric signals
NRL	Naval Research Lab
N3	Next-Generation Nonsurgical Neurotechnology
R&D	research and development
SOCEP	Special Operations Cognitive Enhancement and Performance
SOCOM	Special Operations Command
SRM	Sustainable Readiness Model
NRL	Naval Research Lab
tACS	transcranial alternating current
TD-fNIRS	time-domain functional near-infrared spectroscopy
OODA	observe, orient, decide, act

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EXECUTIVE SUMMARY

Artificial intelligence, human machine teaming, cortical coupling, virtual reality, augmented reality, and brain computer interface technologies (BCI) are all ways in which exploratory science and medical fields are rapidly revolutionizing a way to harness the power of the human brain. This thesis argues that rapidly fielding breakthrough neuroscience technology can help answer the question, How can the use of cognitive enchantment technology help a Hyper Enabled Operator mitigate distractions and gain cognitive supremacy on the battlefield?

In military operations, especially special operations, "cognitive dominance—the ability to consistently process and rapidly make critical decisions faster than an adversary — ensures" special operators can effectively and expeditiously dictate how the battle unfolds and conclusively ends in their favor.[1] Historically, U.S. Special Operation units have maintained a technological advantage in multiple domains of conflict and that advantage has been eroded by the proliferation of cheap, commercially produced technologies. As a result of this, the United States' allies, adversaries, and competitors are confronting our advantage in every domain.

One way to preserve U.S. cognitive advantages is to pursue innovations in BCI in support of special operations. The United States Special Operations Command (USSOCOM) defines a Hyper Enabled Operator (HEO) as a Special Operations Forces (SOF) professional franchised by breakthrough technology that enhances the operator's cognition on any battlefield environment. Creating advantages "by increasing situational awareness, reducing cognitive load, and accelerating decision making."[2]

Conceptionally, the basis of manipulating or artificially coupling a person's brain for superhuman capabilities is more fitting for movies in Hollywood than utilized by

[1] Chris Balcik, "For Hyper-Enabled Operators, Cognitive Dominance Is Built on Mobility," White Paper, May 13, 2020, https://insights.samsung.com/2020/05/13/for-hyper-enabled-operators-cognitive-dominance-is-built-on-mobility/.

[2] Alex MacCalman, Alex, Jeff Grubb, Joe Register, and Mike McGuire, "The Hyper-Enabled Operator," Small Wars Journal, June 6, 2019. https://smallwarsjournal.com/jrnl/art/hyper-enabled-operator

warfighters. However, the advancement of technology, specifically brain computer interface technology, proves operational feasibility is closer than ever before. BCI provides a mechanism for amalgamating human strengths and computer advantage, and much of the ongoing work aims to link these two sets of capabilities and yield synergistic outcomes. The efficiency of the interface between computers and humans—whether providing communication avenues by text, screen, audio or other forms—is a significant factor in the capability of humans to manage heightened complex systems, information, and data sets. BCI can directly improve such efficiency.

Cognitive enhancement for the end user involving neurotechnology is not a new concept in the neuroscience and psychology fields. In 1929, work with the first human electroencephalogram (EEG)—a medical device for analyzing, tracking, and recording brain wave patterns—was first published by German psychiatrist Hans Berger. Fast-forward to 2022 and cognitive enhancement and neurotechnology have become a multibillion-dollar industry invested by universities, think tanks, state-sponsored institutions, hospitals, and big tech corporations.

Literature to date in multidisciplinary fields of cognitive enhancement and enablement technologies provide an abundance of medical, technological, and scientific information relevant to the advancement of neurotechnology. However, an opportunity for SOF to adapt and research the dual use application of neurotechnology and how it can be applied in special operations has been identified and discussed within the thesis research. Particularly, concentrating on the categories of wearables, non-invasive technology, and invasive technology.

Ethical concerns are inherent when considering who or what entity will be controlling access, sharing human data points, selling of data and distribution equality of cognitive enhancement technologies. Ethics is covered extensively through a systematic review of published articles, journals, and intimate interviews with subject matter experts across differing disciplines. Highlighting privacy, effects on humanity and how SOF as an institution has to take a different approach to ethics than a society does, due to the nature of the institution in of itself.

To maintain the technological advantage over our adversaries, since World War II, I recommend the following:

- Concentrate funding and resources in noninvasive technology that has potential to maximize cognition outside of a controlled laboratory setting.
- Introduce policy now on neurotechnology. The commercial industry is further ahead than the Department of Defense. Off-the-shelf products like Thync are already being utilized in high-stress work environments to maximize cognition or reduce stress at a touch of a phone application. It will not take long before forward-leaning warfighters start adding it to their gear and kits.
- Promote an open campaign of safety and consent for testing emerging technology that has the potential to disrupt cultural and societal norms.
- Establish and communicate clear ethical stances and guidelines on research and development, implementation, operational use and after care.
- Conduct an annual review or detail a DOD scientist to participate in international neuroscience conferences to keep a pulse on commercial applications, emerging technologies and how the other nations are fostering development and experimentation.
- When considering cognitive enhancement usage with augmented reality and virtual reality, operational needs must be aligned with the training and not the newest "shiny object" being pitched by developers.

There will be a number of challenges to the adoption of BCI by SOCOM. Freedom and privacy versus security is a continues debate in the United States and in every aspect of the American life. The approach to new technological advances, specifically when it comes to commercial and or military use of cognitive enhancement technologies must be based on consent. Educating an individual on the potential risks and benefits regardless of

how social norms impact society's voice will ultimately create trust in the system. Some members will be the first to raise their hands; "some service members may not want to provide the government with access to the inner workings of their brains."

In the end, to maintain our competitive advantage, a special operator must have the tools and technology to dominate the virtual, physical, and cognitive domains against our adversaries. Albeit the current function of neurotechnology is to provide medical or scientific aid to the physically or mentally debilitated, its potentials are unlimited. The competitors of the United States acknowledge this hypothesis and are already investing in neurotechnology for military modernization; the side that controls cognitive overmatch through rapid informed decision making will become the victor. Immediately fielding noninvasive BCI technology has the potential to enhance a Hyper Enabled Operator's cognition at the edge, and ultimately evolve U.S. warfighter capabilities to counter all future threats.

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I. INTRODUCTION

The United States Special Operations Command (USSOCOM) defines a Hyper Enabled Operator (HEO) as a Special Operations Forces (SOF) professional franchised by breakthrough technology that enhances the operator's cognition on any battlefield environment. Thus creating advantages for U.S. SOF "by increasing situational awareness, reducing cognitive load, and accelerating decision making" in multiple domains.[1] In the Special Operations community, cognitive enhancement and resilience is at the forefront of the Sustainable Readiness Model (SRM) to organize, man, train, equip and deploy its operators:[2] principally, acquiring the capability to achieve cognitive supremacy over our competitors and adversaries in future Special Operations Forces global campaigns. Colonel Ryan Barnes, director of the Joint Acquisition Task Force at USSOCOM recently stated that "The Hyper Enabled Operator program is designed to combine existing communications and data analytics technology into a tactical system that allows isolated special operations teams to gather and analyze battlefield intelligence to help them make decisions faster than ever before."[3] The ability to think faster, react sooner and become steadfast during a time of heightened noise, complex problems, or the fog of war during an engagement, will give us the advantage over our competition.

Artificial intelligence, human machine teaming, cortical coupling, virtual reality, augmented reality, and brain computer interface technologies (BCI) are all ways in which exploratory science and medical fields are rapidly revolutionizing a way to harness the power of the human brain. My research focuses on *How can the use of cognitive enchantment technology help a Hyper Enabled Operator mitigate distractions and gain cognitive supremacy on the battlefield?*

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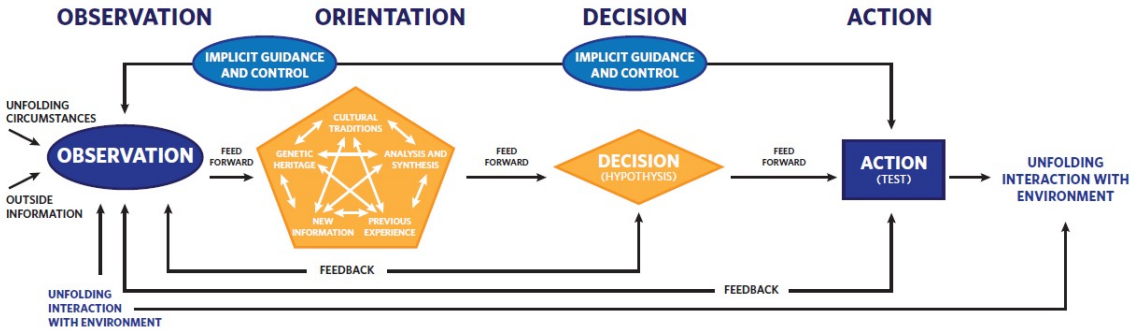
[1] Alex MacCalman, Alex, Jeff Grubb, Joe Register, and Mike McGuire, "The Hyper-Enabled Operator," *Small Wars Journal*, June 6, 2019. https://smallwarsjournal.com/jrnl/art/hyper-enabled-operator

[2] "ARN9412_AR525_29_FINAL.Pdf," accessed October 24, 2022, https://armypubs.army.mil/epubs/DR_pubs/DR_a/pdf/web/ARN9412_AR525_29_FINAL.pdf.

[3] Matthew Cox, "This Smart-Soldier Gear May Succeed Where SOCOM's 'Iron Man' Suit Failed," Task & Purpose, May 14, 2020, https://taskandpurpose.com/news/special-operations-hyper-enabled-operator-program/.

The military already trains cognitive enhancement through repetition exercises, breathing and decision-making programs like the OODA loop (Observe, Orient, Decide, Act) visually depicted in Figure 1. However, these practices are reaching max capacity to the trained operator, and the introduction of technology in the cognitive realm now becomes a force multiplier.



The OODA Loop model currently used in military training models.

Figure 1. John Boyd's OODA Loop Sketch[4]

Using algorithms and autonomous systems to enhance the ability to make rational decisions faster can ultimately determine life or death on the battlefield. The capacity to speed up judgement not only helps us on the battlefield, but the same applications can apply to the commander in the control center, or the businessman on Wallstreet. SOF's advantage will come from the ability to have expedited access to new data at the decision point, more effective and efficient means of exploitation, and the obscuration of digital footprints while operating in smart cities around the world.

Conceptionally, the basis of manipulating or artificially coupling a person's brain for superhuman capabilities is more fitting for movies in Hollywood than operations either in the ISIS occupied central and north-eastern regions of Syria or smart cities like Shanghai and Moscow. However, the advancement of technology, specifically brain computer

[4] Mark Phillips, "Revisiting John Boyd and the OODA Loop in Our Time of Transformation," Defense Aquistion University, October 4, 2021, https://www.dau.edu:443/library/defense-atl/blog?TermStoreId=dce24bd1-67d5-449a-a845-034b26f02d5e&TermSetId=8f7816db-bdf4-4718-9235-765b669106cc&TermId=14ebb14e-a7d6-4156-8c1d-baac16c70f63&UrlSuffix=revisiting-john-boyd.

interface technology, proves operational feasibility is closer than ever before. BCI provides a mechanism for amalgamating human strengths and computer advantage, and much of the ongoing work aims to link these two sets of capabilities and yield synergistic outcomes. The efficiency of the interface between computers and humans–whether providing communication avenues by text, screen, audio or other forms-is a significant factor in the capability of humans to manage heightened complex systems, information, and data sets. BCI can directly improve such efficiency.[5]

Cognitive enhancement for the end user involving neurotechnology is not a new concept in the neuroscience and psychology fields. In 1929, work with the first human electroencephalogram (EEG)—a medical device for analyzing, tracking, and recording brain wave patterns-was first published by German psychiatrist Hans Berger.[6] Fast forward to 2022, Over 400 universities globally offer advanced degrees in Neuroscience and Behavior, programs led by Harvard, UC SF, MIT, Stanford, and John Hopkins.[7] Due to the nature of possibilities it can produce neuro modulation is not siloed into education alone; massive think tanks like RAND corporation are conducting experiments and studies on these emerging technologies. Government research institutes including: the Defense Advanced Research Projects Agency (DARPA),[8] DEVCOM Army Research Lab (ARL),[9] Air Force Research Lab (AFRL),[10] Naval Research Lab (NRL),[11] Intelligence Advanced Research Projects Activity (IARPA),[12] SOFWERX[13] all have programs dedicated to cognitive enhancement. Completing the trifecta of the enablement ecosystem, billion

[5] Binnendijk, Marler, and Bartels, "Brain-Computer Interfaces."

[6] Hans Berger, "Über Das Elektrenkephalogramm Des Menschen," Archiv f. Psychiatrie, 87 (1929): 527–70, https://doi.org/10.1007/BF01797193.

[7] "Top Neuroscience and Behavior Schools in the World - U.S. News Education," accessed October 25, 2022, https://www.usnews.com/education/best-global-universities/neuroscience-behavior.

[8] "Defense Advanced Research Projects Agency," accessed October 25, 2022, https://www.darpa.mil/.

[9] U.S. Army CDCC Staff, "U.S. Army CCDC Army Research Laboratory," accessed October 25, 2022, https://www.arl.army.mil/.

[10] "Air Force Research Laboratory," accessed October 25, 2022, https://afresearchlab.com/.

[11] "NRL," accessed October 25, 2022, https://www.nrl.navy.mil/.

[12] "IARPA - Home," accessed October 25, 2022, https://www.iarpa.gov/.

[13] "SOFWERX," accessed October 25, 2022, https://www.sofwerx.org/.

dollar tech corporations including: Microsoft,[14] Nueralink,[15] Synchron,[16] Kernel,[17] Blackrock Neurotech[18] and even Meta[19] have committed departments for BCI and cognitive enhancement technologies.

Both America's adversaries and competitors have also acuminated on the potential to harness and enhance the power of the human brain through strategic latency. The definition of strategic latency for this thesis is "the inherent potential for technologies to bring about significant shifts in the military or economic power."[20] Understanding the foundation of strategic latency, China's targeted efforts are (1) encouraging policy that factors greater government agency, (2) harnessing global academic potential, (3) creating loopholes for opportunity at which point intellectual property can be homogenized for state utilization.[21] These efforts can be targeted as the dominant archetypal enterprise for effecting their military modernization policy. China's engagement in such activity, especially in the biotechnology, cognitive enhancement, and neurosciences sectors, positions Beijing to authorize research and development (R&D) endeavors and results capable of positioning political, economic, military power, and brain science and the multifarious uses away from the U.S. and even the entire Western Hemisphere.[22]

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[14] Deborah Bach, "U.S. Army to Use HoloLens Technology in High-Tech Headsets for Soldiers," Transform, June 8, 2021, https://news.microsoft.com/transform/u-s-army-to-use-hololens-technology-in-high-tech-headsets-for-soldiers/.

[15] Play Studio, "Home," Nueralink, accessed October 27, 2022, https://neuralink.com/.

[16] "Synchron | Unlocking the Natural Highways of the Brain.," accessed October 27, 2022, https://synchron.com/.

[17] "About Kernel," 2022, https://www.kernel.com/about.

[18] "Blackrock Neurotech," Blackrock Neurotech, accessed October 27, 2022, https://blackrockneurotech.com/.

[19] "Meta | Social Metaverse Company," Meta | Social Metaverse Company, accessed October 27, 2022, https://about.meta.com/.

[20] Zachary Davis, Ronald Lehman, and Michael Nacht, "Strategic Latency and World Power: How Technology Is Changing Our Concepts of Security," *Livermore (EUA): Lawrence Livermore National Laboratory (LLNL)*, 2014.

[21] Davis, Lehman, and Nacht.

[22] Celeste Chen, Jacob Andriola, and James Giordano, "Biotechnology, Commercial Veiling, and Implications for Strategic Latency: The Exemplar of Neuroscience and Neurotechnology Research and Development in China," *Strategic Latency: Red, White, and Blue. Managing National and International Security Consequences of Disruptive Technologies* (Lawrence Livermore Press: Livermore, CA, 2018).

II. LITERATURE REVIEW

A. LITERATURE REVIEW INTRODUCTION:

Literature to date in multidisciplinary fields of cognitive enhancement and enablement technologies, provide an abundance of medical, technological, and scientific information relevant to the advancement of neurotechnology. This literature review will discuss themes of cognitive enhancement and special operations, neuro-stimulation techniques and for the purpose of this research, three current technological groupings or bins that researchers, scientist, and engineers utilize to revolutionize the cognitive process: (1) Wearables (2) noninvasive procedures and outer cranial devices and (3) Invasive procedures and inner-cranial devices. Importantly, a gap in research for the application of neurotechnology and its use in special operations will be discussed.

B. COGNITIVE ENHANCEMENT AND SPECIAL OPERATIONS

Outside of decision-making programs like the OODA loop (Observe, Orient, Decide, Act) U.S. Special Operations Command trains cognitive enhancement through several innovative approaches. One of the primary methods of cognitive enhancement training is SOCOM's human performance program, noted "as the Tactical Human Optimization, Rapid Rehabilitation and Reconditioning program," or to the operators involved in it as THOR3.[23] The intent of THOR3 is to build specialized programs for SOF focused missions by utilizing highly specialized staff to implement coaching in physical therapy, dietetics, strength and conditioning, and cognitive enhancement. Creating Cognitive resilience and understanding workloads "is a formal part of the program, which seeks to furnish a systematic way to build mental and emotional strength."[24] Another

[23] Daniel Wyatt, "Program Boosts Special Forces Members' Physical, Mental Capabilities," U.S. Department of Defense, accessed October 26, 2022, https://www.defense.gov/News/News-Stories/Article/Article/1389545/program-boosts-special-forces-members-physical-mental-capabilities/https%3A%2F%2Fwww.defense.gov%2FNews%2FNews-Stories%2FArticle%2FArticle%2F1389545%2Fprogram-boosts-special-forces-members-physical-mental-capabilities%2F.

[24] Wyatt.

program falls under the "Preservation of the Force and Family" (POTFF) banner.[25] POTFF integrates holistic human performance programs to support brain enhancement, monitor exposure, and protect brain health.[26] categorical descriptions of the cognitive performance model are highlighted in Table 1:

Table 1. POTFF Domain Priority.[27]

Enhance	Optimize cognitive performance, capacity, agility, and resilience through training.
Monitor	Monitor brain health to keep warfighters lethal longer.
Advance	Leverage innovation in AT&L-ST to further cognitive function and protection.
Protect	Synchronize all efforts to implement protection measures of SOF cognition.

Lastly, SOCOM uses the Special Operations Cognitive Enhancement and Performance (SOCEP) program.[28] SOCEP uses evidence-based psychological, neurocognitive, and psychophysiological tests to assess and enhance various aspects of cognitive/psychological performance especially through the application of neurofeedback and biofeedback.[29]

Arizona State University's Human-Oriented Robotics and Control Lab led by Dr. Panagiotis Artemiadis have created and fielded technology that allows a user to control 100 robotic drones or more with their mind. While fielding their technology, Dr. Panagiotis

[25] POTFF, "About USSOCOM Preservation of the Force and Family (POTFF)," SOCOM.MIL, Special Operations Command, April 20, 2021, https://www.socom.mil/POTFF/Pages/About-POTFF.aspx.

[26] POTFF.

[27] Adapted from POTFF.

[28] "Special Operations Cognitive Enhancement Practitioner (AFSOC/Fort Bragg, NC) in Fort Bragg, North Carolina | ClearedJobs.Net," accessed October 26, 2022, https://clearedjobs.net/job/special-operations-cognitive-enhancement-practitioner-afsoc-fort-bragg-nc-fort-bragg-north-carolina-1205611.

[29] Randall Baucom, "Military Intelligence Soldiers Receive Cognitive Enhancement," www.army.mil, August 18, 2017, https://www.army.mil/article/192624/military_intelligence_soldiers_receive_cognitive_enhancement.

stated that "when pilots picture different formations, it triggers certain areas of their brain. That activity is measured by electrodes on a skull cap, decoded, and sent via Bluetooth to the drones. Picture a circle and the drones will form a circle. Picture an expanding circle, and the drones will spread out."[30] Autonomous unmanned aerial system are already a vital technology used by special operations globally. The combined effects of autonomous unmanned aerial systems (UAV), artificial intelligence, and smart sensors, and how special operation warfighters interface with these systems are advancing the prospects of hyper enablement. A critical research focus should couple the implications of advanced neurological technology in prosthetics—which have the technology to control robotic limbs by stimulating latent cells within the brain, just by thinking about them—with the Hyper Enabled Operator program.[31]

Our capacity to interact and communicate with the human brain has rapidly evolved since the twentieth century when Hans Berger created the electroencephalography (EEG) however, the fascination and advancement of purposeful applications of neuro and nanotechnology has been continual.[32] Technological advances have provided insights on the expanded range of conditions involving sensory, communication, and motor deterioration in humans. The need for innovative brain interfaces that can read, write, modulate, or "even bypass compromised neurological pathways" is an upmost priority for the medical and science fields.[33] The evolution of neurotechnology and brain computer interfaces is transforming the near future application of cognitive enhancement and enablement in multiple disciplines. The convergence of human machine teaming, neuro-

[30] Derek Staahl, "ASU Researcher Controls Multiple Drones with His Mind," AZFamily, November 7, 2018, https://www.azfamily.com/archives/asu-researcher-controls-multiple-drones-with-his-mind/article_7ec5c97b-f643-52c1-8b92-e6f65abf30bb.html.

[31] Nicole Casai Moore, "'It's like You Have a Hand Again': An Ultra-Precise Mind-Controlled Prosthetic," University of Michigan News, March 10, 2020, https://news.umich.edu/its-like-you-have-a-hand-again-an-ultra-precise-mind-controlled-prosthetic/.

[32] Mario Tudor, Lorainne Tudor, and Katrina Tudor, "Hans Berger (1873-1941)--the History of Electroencephalography," *National Library of Medicine*, 2005, https://pubmed.ncbi.nlm.nih.gov/16334737/.

[33] Elizabeth Fernandez, "Benefits Of 'Deepfaking' The Mind In Creating Brain-Computer Interfaces," Forbes, November 30, 2021, https://www.forbes.com/sites/fernandezelizabeth/2021/11/30/benefits-of-deepfaking-the-mind-in-creating-brain-computer-interfaces/.

enhancement technologies, and an increased understanding of the central and peripheral nervous systems will factor into breakthrough technological advancements and applications in cognitive enhancement. Human computer interfaces do not rely on muscle or eye movements, rather "the user is trained to manipulate an object using the power of thought alone. BCIs can allow a fully paralyzed person to operate a wheelchair by just thinking, to move a cursor on a computer screen, or even play pinball by moving the paddles with their mind."[34] The potential is seemingly only limited by the technology itself and even that is advancing daily.[35] The electronic neuroengineering breakthroughs that are being developed, implemented, and analyzed in medicine, to include military medical practices to diagnose and treat psychiatric and neurological aftereffects of war, can additionally be employed through dual-use initiatives to augment, and advance special operator capabilities.[36]

C. TYPES OF ENHANCEMENT TECHNIQUES AND DEVICES

1. Neuro Stimulation Techniques

The current comprehensively cited physical procedures for cognitive enhancement include several innovative brain stimulation techniques and technological devices that could evolve the current state of cognitive enhancement today. Deep brain stimulation—an invasive procedure—are clinically proven to produce cognition enhancing effects are restricted to highly controlled labs where subjects are diagnosed with pathological conditions.[37] Currently, there are multiple forms of noninvasive electrical stimulation procedures being used on healthy subjects, among them are the following: "transcranial

[34] Elizabeth Fernandez, "Benefits of 'Deepfaking' the Mind in Creating Brain-Computer Interfaces," Forbes (Forbes Magazine, November 30, 2021), https://www.forbes.com/sites/fernandezelizabeth/2021/11/30/benefits-of-deepfaking-the-mind-in-creating-brain-computer-interfaces/.

[35] Fernandez.

[36] Jonathan D. Moreno, Michael N. Tennison, and James Giordano, "Security Threat versus Aggregated Truths: Ethical Issues in the Use of Neuroscience and Neurotechnology for National Security," in *Neuroethics: Anticipating the Future*, ed. Judy Illes (Oxford University Press, 2017), 0, https://doi.org/10.1093/oso/9780198786832.003.0027.

[37] Nanthia Suthana et al., "Memory Enhancement and Deep-Brain Stimulation of the Entorhinal Area," *New England Journal of Medicine* 366, no. 6 (February 9, 2012): 502–10, https://doi.org/10.1056/NEJMoa1107212.

direct current stimulation (tDCS),"[38] "transcranial alternating current stimulation (tACS),"[39] "median nerve stimulation (MNS),"[40] "transcranial random noise stimulation (tRNS),"[41] "transcranial pulsed current stimulation (tPCS),"[42] and "transcutaneous vagus nerve stimulation (tVNS)."[43] Transport nanotechnology like the magnetoelectric nano transducers (MEnTs) are also currently being tested to infiltrate the brain and cross the blood-brain barrier.[44]

2. Wearables

The first method or BIN is utilizing wearable technology to enhance the user interface through augmented reality, virtual reality, or a combination of both. Companies like Facebook and Google are creating wearable glasses to eventually replace the cellphone while other companies like brain scientific[45] and FUVI are creating "innovative cognitive products to help and assist people in learning, thinking, communicating, and making decisions effectively." [46] Microsoft has created a unique partnership with the Department of Defense (DOD) after being awarded a lucrative augmented reality and virtual reality

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[38] Brian A. Coffman, Vincent P. Clark, and Raja Parasuraman, "Battery Powered Thought: Enhancement of Attention, Learning, and Memory in Healthy Adults Using Transcranial Direct Current Stimulation," *NeuroImage*, Neuro-enhancement, 85 (January 15, 2014): 895–908, https://doi.org/10.1016/j.neuroimage.2013.07.083.

[39] Emiliano Santarnecchi et al., "Frequency-Dependent Enhancement of Fluid Intelligence Induced by Transcranial Oscillatory Potentials," *Current Biology* 23, no. 15 (August 5, 2013): 1449–53, https://doi.org/10.1016/j.cub.2013.06.022.

[40] Sandra Carvalho et al., "Median Nerve Stimulation Induced Motor Learning in Healthy Adults: A Study of Timing of Stimulation and Type of Learning," *European Journal of Neuroscience* 48, no. 1 (2018): 1667–79, https://doi.org/10.1111/ejn.13990.

[41] Albert Snowball et al., "Long-Term Enhancement of Brain Function and Cognition Using Cognitive Training and Brain Stimulation," *Current Biology* 23, no. 11 (June 3, 2013): 987–92, https://doi.org/10.1016/j.cub.2013.04.045.

[42] Camila Cosmo and Leon Morales-Quezada, "Cognitive Effects and Autonomic Responses to Transcranial Pulsed Current Stimulation," *Experimental Brain Research |SpringerLink* 233 (n.d.): 701–9.

[43] Lorenza S. Colzato, Simone M. Ritter, and Laura Steenbergen, "Transcutaneous Vagus Nerve Stimulation (TVNS) Enhances Divergent Thinking," *Neuropsychologia* 111 (March 1, 2018): 72–76, https://doi.org/10.1016/j.neuropsychologia.2018.01.003.

[44] Rakesh Guduru et al., "Magnetoelectric 'Spin' on Stimulating the Brain," *Nanomedicine* 10, no. 13 (July 2015): 2051–61, https://doi.org/10.2217/nnm.15.52.

[45] https://brainscientific.com

[46] https://www.fuvi.us/technology

technology contract based on its revolutionary HoloLens design.[47] The headsets use innovative technology called the Integrated Visual Augmentation System (IVAS). Currently IVAS allows operators "to see through smoke and around corners," use augmented reality generated holograms for training in different environments and generate three-dimensional "terrain maps projected onto their field of vision at the click of a button."[48]

The HoloLens 2 system which is available for Commercial Off the Shelf (COTS) acquisition.

Figure 2. Microsoft HoloLens 2[49]

[47] Stephan Nellis and Dave Paresh, "Microsoft Wins $21.9 Billion Contract with U.S. Army to Supply Augmented Reality Headsets," *Reuters*, March 31, 2021, sec. Retail, https://www.reuters.com/article/us-microsoft-army-idUSKBN2BN36B.

[48] Bach, "U.S. Army to Use HoloLens Technology in High-Tech Headsets for Soldiers."

[49] Source: "HoloLens 2—Overview, Features, and Specs | Microsoft HoloLens," accessed October 27, 2022, https://www.microsoft.com/en-us/hololens/hardware.

A Soldier orients his compass to his heads-up display at Fort Bragg, NC. Microsoft coders and Soldiers stayed in the field together to work and improve the HUD system. Adding features like automatic target identification, live drone feed and surveillance videos.

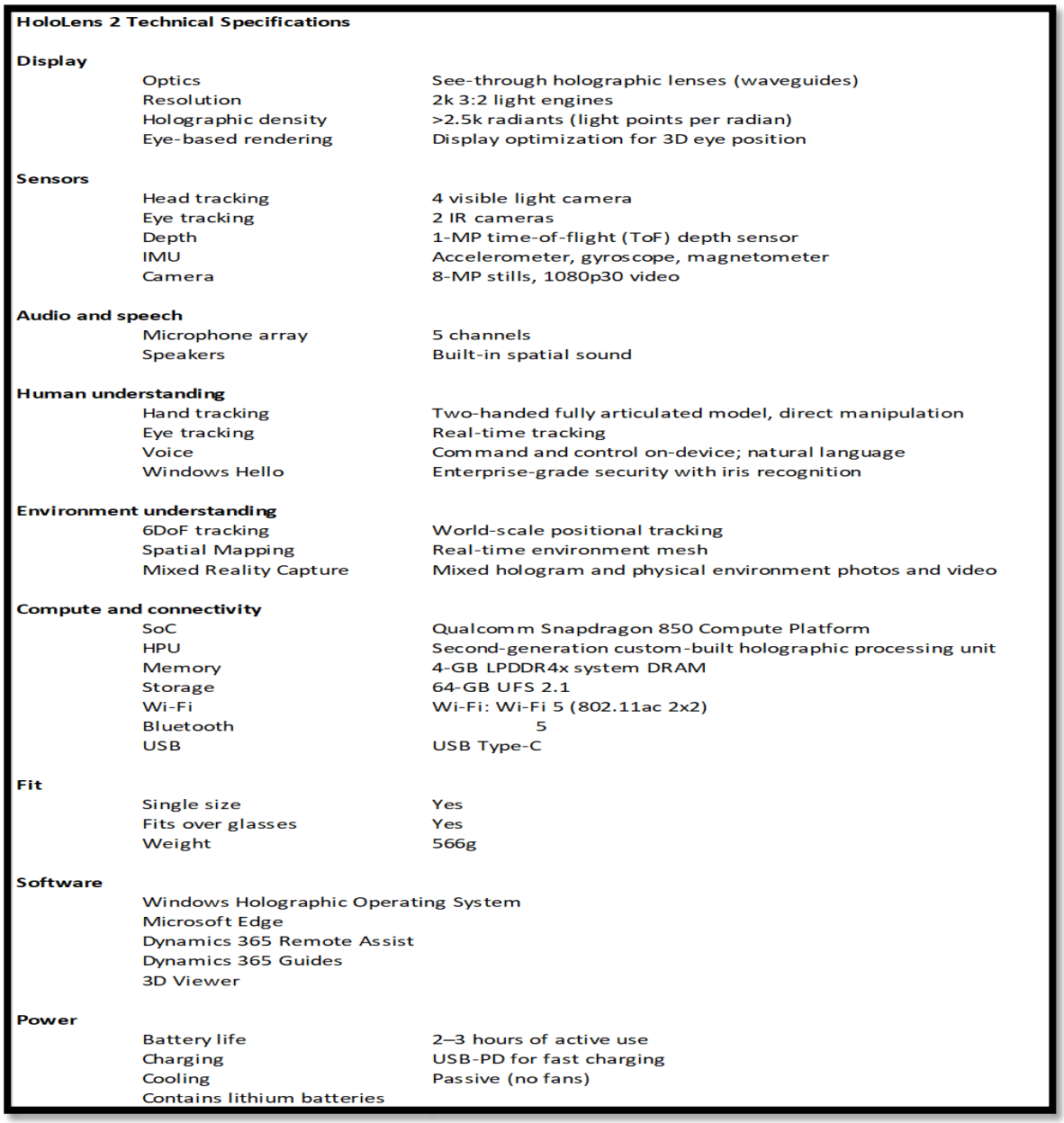
Figure 3. HoloLens Field Test with 82nd Airborne[50]

[50] Source: Sydney J. Freedberg Jr, "Soldiers, Coders Surprise Army Brass by Changing IVAS Goggles," *Breaking Defense* (blog), December 13, 2019, https://breakingdefense.com/2019/12/soldiers-coders-surprise-army-brass-changing-ivas-goggles/.

Included in the IVAS is a heads-up display (HUD), body-worn computer (puck), networked radio, and three conformal batteries for each soldier. This system includes several advanced battery chargers and a tactical cloud computing capability, known as Bloodhound, for each company.

Figure 4. Microsoft IVAS Integrated with Protective Gear[51]

[51] Source: "Integrated Visual Augmentation System (IVAS) After Action Report," accessed October 27, 2022, https://www.dote.osd.mil/Portals/97/pub/reports/FY2020/army/2020ivas.pdf?ver=d0z6Z47TQU0PDSJ8zmwgtw%3D%3D.



HoloLens 2 Technical Specifications		
Display		
	Optics	See-through holographic lenses (waveguides)
	Resolution	2k 3:2 light engines
	Holographic density	>2.5k radiants (light points per radian)
	Eye-based rendering	Display optimization for 3D eye position
Sensors		
	Head tracking	4 visible light camera
	Eye tracking	2 IR cameras
	Depth	1-MP time-of-flight (ToF) depth sensor
	IMU	Accelerometer, gyroscope, magnetometer
	Camera	8-MP stills, 1080p30 video
Audio and speech		
	Microphone array	5 channels
	Speakers	Built-in spatial sound
Human understanding		
	Hand tracking	Two-handed fully articulated model, direct manipulation
	Eye tracking	Real-time tracking
	Voice	Command and control on-device; natural language
	Windows Hello	Enterprise-grade security with iris recognition
Environment understanding		
	6DoF tracking	World-scale positional tracking
	Spatial Mapping	Real-time environment mesh
	Mixed Reality Capture	Mixed hologram and physical environment photos and video
Compute and connectivity		
	SoC	Qualcomm Snapdragon 850 Compute Platform
	HPU	Second-generation custom-built holographic processing unit
	Memory	4-GB LPDDR4x system DRAM
	Storage	64-GB UFS 2.1
	Wi-Fi	Wi-Fi: Wi-Fi 5 (802.11ac 2x2)
	Bluetooth	5
	USB	USB Type-C
Fit		
	Single size	Yes
	Fits over glasses	Yes
	Weight	566g
Software		
	Windows Holographic Operating System	
	Microsoft Edge	
	Dynamics 365 Remote Assist	
	Dynamics 365 Guides	
	3D Viewer	
Power		
	Battery life	2–3 hours of active use
	Charging	USB-PD for fast charging
	Cooling	Passive (no fans)
	Contains lithium batteries	

Technical specification courtesy of Microsoft.

Figure 5. HoloLens 2 Technical Specifications[52]

Microsoft is just one of hundreds of companies investing in wearable technology for neuro-enablement. Augmented reality and virtual reality headsets to enhance end user capabilities are beginning to flood the commercial market as competition between startups

[52] Adapted from: "HoloLens 2—Overview, Features, and Specs | Microsoft HoloLens."

and tech conglomerates heat up in Silicon Valley.[53] Magic Leap technology led by CEO Peggy Johnson is one such breakout company that has shown promise in leading the field of cognitive enhancement through AR. Magic Leap 2, which gives people the ability to use their senses to interact with digital information and translates the world around them (and their interaction with it) into expedited data at their fingertips.[54] By changing the way humans relate to technology, data, and their work environments, magic leap technology can create new possibilities and opportunities for the end user.[55] According to the developers the "Magic Leap 2 integrates new innovations to address the historical barriers that have prevented the widespread adoption of AR technology and are critical to making AR a valuable tool for daily use in the healthcare, manufacturing/light industrial, retail, and defense sectors."[56] The use of Magic Leap, Microsoft or other mixed reality technologies can provide the Hyper Enabled Operator the capability to manipulate holographic screens that could display Intelligence, Surveillance, and Reconnaissance (ISR) video, geographical maps and mission oriented communication text.[57]

3. Noninvasive Procedures and Outer Cranial Devices

The second method is utilizing noninvasive outer cranial devices (which differ from wearables by controlled environments and medical device technology) to directly interpret brain functions to enhance cognitive abilities. Noninvasive technologies often "use sensors applied on or near the head to track and record brain activity."[58] These technologies can be donned and doffed easily on an end user however, the reading and writing signal may

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[53] "Augmented Reality Startups in United States," accessed November 2, 2022, https://tracxn.com/explore/Augmented-Reality-Startups-in-United-States/.

[54] Magic Leap, "About Magic Leap Technology," Magic Leap, accessed October 27, 2022, https://www.magicleap.com/about.

[55] Magic Leap.

[56] Scott Stein, "Magic Leap 2 Hands-On: AR Glasses That Can Dim the Real World," CNET, accessed November 2, 2022, https://www.cnet.com/tech/computing/features/magic-leap-2-hands-on-ar-glasses-that-can-dim-the-real-world/; "Magic Leap 2 Now Available to Customers as the Most Immersive Augmented Reality Headset for Enterprise," MagicLeap, September 30, 2022, https://www.magicleap.com/news/magic-leap-2-now-available-to-customers-as-the-most-immersive-augmented-reality-headset-for-enterprise.

[57] MacCalman et al., "The Hyper-Enabled Operator | Small Wars Journal."

[58] Millan, Ferrez, and buttfield, "Non Invasive Brain-Machine Interfaces Final Report."

be imprecise and muted due to trying to pass or monitor electrodes and activity on top of skin and bone.

Kernel has emerged as one of the leading developers of non-invasive technologies being used in a vast array of trails and research.[59] Founded in 2016 by CEO Bryan Johnson, Kernel was built on the foundation of making neuroimaging mainstream after realizing most noninvasive technologies avail record brain signals by measuring electromagnetic fields generated by formations of neurons or assessing neural activity correlation through small changes in blood oxygenation.[60] Both methods as indicated by Kernel engineers and scientist are "rife with drawbacks, limitations or shortcomings."[61] Kernel has developed a wearable, Time-domain functional near-infrared spectroscopy (TD-fNIRS) helmet that continues current TD-fNIRs benchtop performance and has showcased several instances of exceling current standards. According to multiple scientific sources, Time-domain functional near-infrared spectroscopy is referred as "the gold standard for optical brain imaging systems given their elevated information content over continuous wave (CW) systems."[62] In Time-domain functional near-infrared spectroscopy devices, "picosecond pulses of light are emitted into tissue, and arrival times of single photons are measured at detectors, the distribution of photon arrival times can be parameterized to estimate tissue optical properties, such as absorption and reduced scattering ($\mu's$) coefficients."[63] In addition to, the photon arrival data points have the potential to pinpoint alterations in deeper

[59] SPIE--International Society for Optics and Photonics, "Kernel Flow: A Wearable Device for Noninvasive Optical Brain Imaging: A New Wearable Helmet-Shaped Device Monitors Brain Activity," ScienceDaily, January 18, 2022, https://www.sciencedaily.com/releases/2022/01/220118154852.htm.

[60] "About Kernel."

[61] "About Kernel."

[62] Alessandro Torricelli et al., "Time Domain Functional NIRS Imaging for Human Brain Mapping," *NeuroImage*, Celebrating 20 Years of Functional Near Infrared Spectroscopy (fNIRS), 85 (January 15, 2014): 28–50, https://doi.org/10.1016/j.neuroimage.2013.05.106; Stanislaw Wojtkiewicz et al., "Self-Calibrating Time-Resolved near Infrared Spectroscopy," *Biomedical Optics Express* 10, no. 5 (May 1, 2019): 2657–69, https://doi.org/10.1364/BOE.10.002657.

[63] "About Kernel."

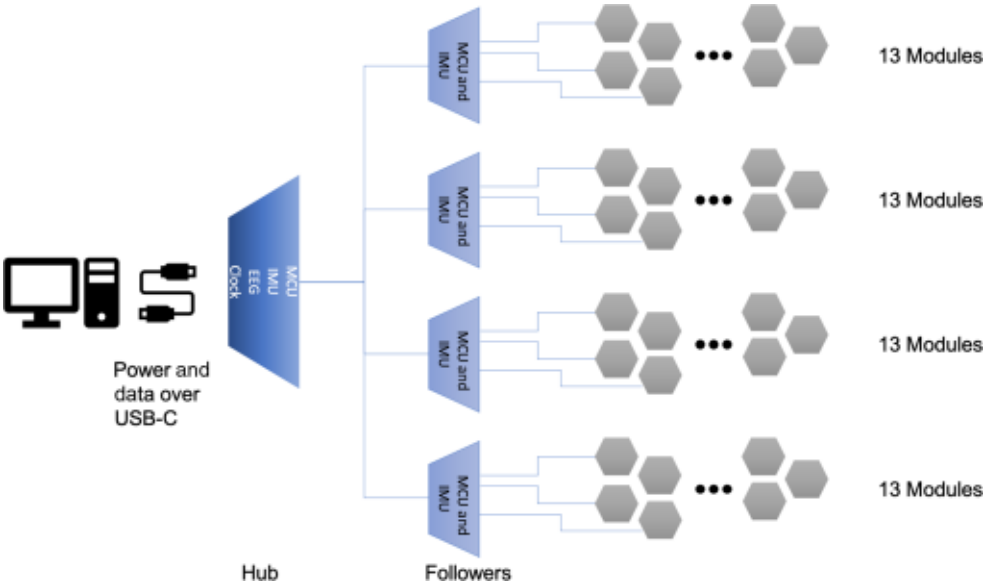
brain tissue by analyzing the gating photons or "investigating moments of the time of flight (ToF) distribution".[64]

The Kernel Flow system is made up of structural plates and modules. The structural plates are designed to adjust to the end user, allowing maximum coverage of the desired regions of the head for neural detection and imagery.

Figure 6. The Kernel Flow System[65]

[64] Heidrun Wabnitz et al., "Depth-Selective Data Analysis for Time-Domain FNIRS: Moments vs. Time Windows," *Biomedical Optics Express* 11, no. 8 (August 1, 2020): 4224–43, https://doi.org/10.1364/BOE.396585.

[65] Source: Han Y. Ban et al., "Kernel Flow: A High Channel Count Scalable Time-Domain Functional near-Infrared Spectroscopy System," *Journal of Biomedical Optics* 27, no. 7 (January 2022): 074710, https://doi.org/10.1117/1.JBO.27.7.074710.



In total, the Flow helmet system supports connection of up to 52 time-domain optical modules and includes five nine-axis IMUs, six EEG channels, and self-contained power management and distribution. In the human studies the entire headset was populated to clearly show regions of activation/deactivation throughout the whole brain during the task. This provides higher confidence in the measured results because artifacts due to systemic physiology and/or motion would be common to all modules.

Figure 7. Overall Architecture of the Flow Hardware.[66]

[66] Source: Ban et al.

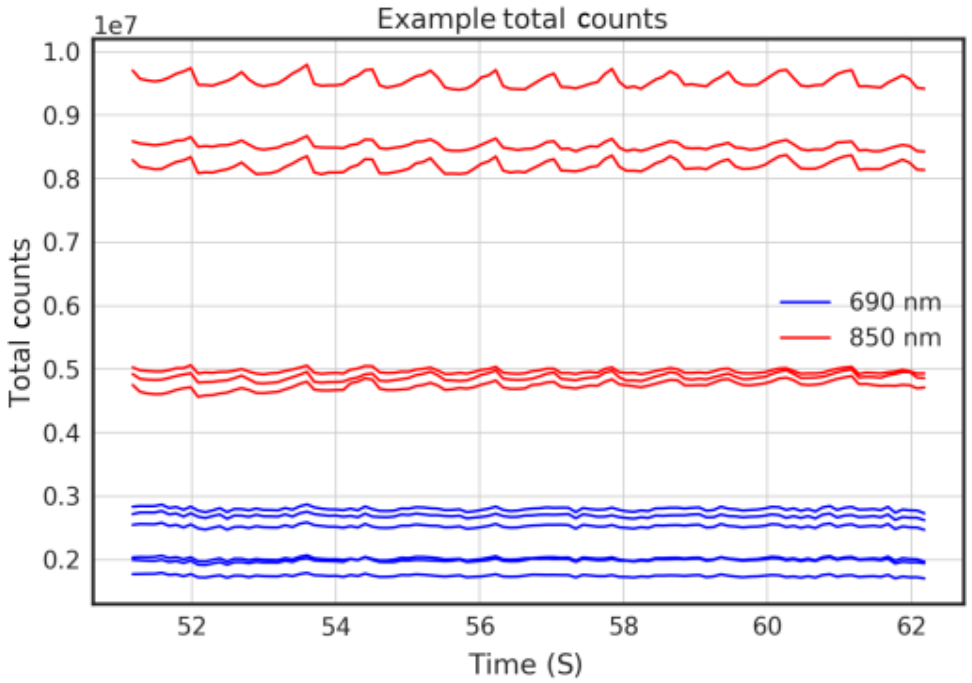


Chart 2 shows an excerpt from a recording from one module on the forehead of a participant. Traces are total counts summed over the histogram. The total counts metric shows an oscillation at a frequency consistent with a heartbeat with a higher magnitude in the 850-nm signal as compared with the 690-nm signal. The ability to measure a heartbeat oscillation with a time domain system is unique and enabled by the 200-Hz sampling rate of our detectors.

Figure 8. Histogram of Oscillation Frequency in a Human Participant[67]

DARPA with its Next-Generation Nonsurgical Neurotechnology (N^3) program is the lead research institute for cognitive enhancement in the DOD. The program partners with top university research labs in the United States to create or innovate wearable interfaces that potentially enable divergent SOF solutions at rapid speeds. DARPA is focusing on providing individual neurotechnology that can control "active cyber defense systems, swarms of unmanned aerial vehicles," or simply enhance cognitive responses by utilizing human machine teaming to reduce cognitive loads during complex operations.[68] Noninvasive neurotechnology however, has significant challenges due to the tradeoff between signal clarity and the ability to target specific neurons due to the human skull and

[67] Source: Ban et al.

[68] "Six Paths to the Nonsurgical Future of Brain-Machine Interfaces," DARPA RSS, May 20, 2019, https://www.darpa.mil/news-events/2019-05-20.

the blood brain barrier acting as a natural distorter. Here is where the N3 program is seeking to rectify these challenges by developing a portable system with the capability of an invasive system.[69]

DARPA's N3 program also funds outside projects like Rice University's magnetic, optical, and acoustic neural access program also known as MOANA. The proof of principle technology uses "light to decode neural activity in one brain and magnetic fields to encode that activity in another brain, all in less than one-twentieth of a second."[70] The main goal of the MOANA Project is to "create a dual-function, wireless headset" that coincidingly "reads" and "writes" neural activity without a need for invasive surgery.[71] The N3 program is also collaborating with Airforce Research Labs and the Battelle Memorial Institute to create an interface employing what researchers have titled "Brain System to Transmit Or Receive Magnetoelectric Signals" or for short, BrainSTORMS.[72] BrainSTORMS "employs magnetoelectric nanotransducers (MEnTs) localized in neural tissue for BCI applications, one of the key MEnT attributes are their incredibly tiny; thousands of MEnTs can fit across the width of a human hair. The MEnTs are injected into the circulatory system and then placed in position with a magnet to the targeted area of the brain," which eliminates the need to surgically position the MEnTs.[73]

4. Invasive Procedures and Inner-Cranial Devices

The third and most controversial method is intercranial or surgically implanted devices which allow for a greater interconnectivity between technology and the human brain. Invasive BCI requires invasive surgery. Currently, an electronic chip or network of sensors is required to be implanted beneath the skull, directly onto the brain, to target

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[69] Binnendijk, Marler, and Bartels, "Brain-Computer Interfaces."

[70] Rice University "Brain-to-Brain Communication Demo Receives DARPA Funding | Electrical and Computer Engineering | Rice University," Rice University Electrical and Computer Engineering, February 26, 2021, https://eceweb.rice.edu/news/brain-brain-communication-demo-receives-darpa-funding.

[71] Rice University.

[72] "Battelle Neuro Team Advances to Phase II of DARPA N3 Program| Battelle Press Release," Default, December 15, 2020, https://www.battelle.org/insights/newsroom/press-release-details/battelle-neuro-team-advances-to-phase-ii-of-darpa-n3-program.

[73] "Battelle Neuro Team Advances to Phase II of DARPA N3 Program| Battelle Press Release."

specific sets of neurons and have the greatest capacity to sync with the technology.[74] Current BCI implants under development are extremely small however, they have the capability to communicate and monitor up to a million neurons simultaneously. For instance, a research team out of Berkeley, has created implantable sensors that are "roughly the size of a grain of sand, they call these sensors neural dust."[75] Companies on the cutting-edge of intimate brain interface systems like Elon Musk's Neuralink are transforming how a human can interface with future AI.[76] Currently Neuralink is being tested in a pig and a monkey but has applied to conduct human testing in 2022 through the FDA's IPB process. The interface being created will allow people to control phones or computers with their mind, but in the future, they aim for what is coined as "superhuman cognition" in part to combat artificial intelligence that becomes too powerful.[77]

Blackrock Neurotech has powered an array of "firsts" when it comes to human BCI applications and innovation: The tech company was the premier lab in providing tetraplegic subjects with the capability to control robotic prosthetics directly using their minds; and the pioneer for ALS communication utilizing auditory spelling devices—even within patients locked out—by simply using their mind.[78]

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[74] Marissa Norris, "Brain-Computer Interfaces Are Coming. Will We Be Ready?," August 27, 2020, https://www.rand.org/blog/articles/2020/08/brain-computer-interfaces-are-coming-will-we-be-ready.html.

[75] Norris.

[76] "Approach," Neuralink, accessed March 16, 2022, https://neuralink.com/approach/.

[77] "Neuralink: Elon Musk Unveils Pig with Chip in Its Brain," BBC News (BBC, August 29, 2020), https://www.bbc.com/news/world-us-canada-53956683.

[78] Karen Neurotech, "Blackrock Neurotech Closes $10M Financing Round To Advance Development Of Its World-Leading Brain-Computer Interface (BCI) Technology," May 19, 2021, https://www.prnewswire.com/news-releases/blackrock-neurotech-closes-10m-financing-round-to-advance-development-of-its-world-leading-brain-computer-interface-bci-technology-301295002.html.

The Slant array has been approved for the use in humans under the FDA's investigational Device Exemption (IDE) regulation.

Figure 9. Black Rock's Slant Array[79]

At present development of invasive brain interface technology is rapid both on the hardware modernization, where multielectrode recordings of more than 400 electrodes permanently implanted in a human brain are currently state-of-the art, and in software inventiveness, where computers and artificial intelligence learn to interpret high-quality signals from the ensembles of single neurons.[80]

D. GAP

Evolving decision making processes to outcompete competition or aide in conflict areas is not a new idea. However, with the advancement of Artificial Intelligence, human machine interfacing and neurotechnology; we are starting to see a new evolution on the

[79] "Blackrock Neurotech Products" (Blackrock Neurotech), accessed October 27, 2022, https://blackrockneurotech.com/research/products/.

[80] Lebedev, Crist, and Nicolelis, "Building Brain–Machine Interfaces to Restore Neurological Functions."

way individuals make rational decisions,[81] mitigate distractions,[82] and manipulate emerging technologies and robotics.[83] However, most articles and publications in the BCI ecosphere specifically reference medical, clinical or science application with a potential of commercial implications in the future. The gap therefore lies in the application of neuro-technology for military application specifically, addressing Special Operations. Kernel's flow is a good example of this; by creating an exploratorily system that can measure a person's heartbeat oscillation with a time domain system through the brain, has the potential to study and potentially enhance the cognition of Soldiers at the onset of a kinetic engagement or during a survival situation. Current literature and published findings showcase that visceral information is continually deciphered by the brain, potentially enhancing human cognition. "One index of such process is the heartbeat evoked potential (HEP), an ERP component related to the cortical processing of the heartbeat."[84]

Secondly, transcranial alternating current stimulation has been proven in trials with animals and humans to produce a clear frequency-specific effect, as cognitive performance was significantly affected only by γ-tACS. Notedly, "the time required to produce responses was affected by γ-tACS in a trial-type-specific manner, pointing to a specific improvement of the conditional reasoning abilities required to solve logic trials."[85]Recent studies prove that "healthy participants receiving rhythmic imperceptible currents at gamma band on the left prefrontal cortex became about 15% faster in correctly solving

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[81] Tshilidzi Marwala, *Artificial Intelligence Techniques for Rational Decision Making*, Advanced Information and Knowledge Processing (Cham: Springer International Publishing, 2014), https://doi.org/10.1007/978-3-319-11424-8.

[82] Aaron Trafton, "How We Tune out Distractions," MIT News | Massachusetts Institute of Technology, accessed November 3, 2022, https://news.mit.edu/2019/how-brain-ignores-distractions-0612.

[83] Joe Burton and Simona R. Soare, "Understanding the Strategic Implications of the Weaponization of Artificial Intelligence," in *2019 11th International Conference on Cyber Conflict (CyCon)* (2019 11th International Conference on Cyber Conflict (CyCon), Tallinn, Estonia: IEEE, 2019), 1–17, https://doi.org/10.23919/CYCON.2019.8756866.

[84] Caroline Di Bernardi Luft and Joydeep Bhattacharya, "Aroused with Heart: Modulation of Heartbeat Evoked Potential by Arousal Induction and Its Oscillatory Correlates," *Scientific Reports* 5, no. 1 (October 27, 2015): 15717, https://doi.org/10.1038/srep15717.

[85] Santarnecchi et al., "Frequency-Dependent Enhancement of Fluid Intelligence Induced by Transcranial Oscillatory Potentials."

complex Raven's matrices, a widely used neuropsychological instrument indexing fluid reasoning."[86]

Special Operations Forces are known for being detail oriented, highly trained, and are equipped with state-of-the-art technology that provides a distinct advantage in multiple domains over adversaries. The SOF model goes over and beyond just being prepared. It is a conscious succession of strategies and tactics to eclipse the decision making model of the opposition. "Each element is designed to more effectively observe the situation, orient oneself or unit appropriately, decide how best to maneuver, and take effective Action."[87] Not applying this growing phenomenon to our field will give our adversaries an advantage in this space.

E. LITERATURE REVIEW CONCLUSION

This literature review discussed the themes of cognitive enhancement and special operations, neuro-stimulation techniques and for the purpose of this research, three current technological groupings or bins that researchers, scientist, and engineers utilize to revolutionize the cognitive process: (1) Wearables (2) noninvasive procedures and outer cranial devices and (3) Invasive procedures and inner-cranial devices. Lastly, a gap in research for the application of neurotechnology and its use in special operations has been identified.

[86] Santarnecchi et al.

[87] Mark Bonchek and Chris Fussell, "Decision Making, Top Gun Style," Harvard Business Review, August 7, 2014, https://hbr.org/2013/09/decision-making-top-gun-style.

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III. RESEARCH APPROACH AND METHODOLOGY

My research looks to answer the question "How can the use of cognitive enchantment technology help a Hyper Enabled Operator mitigate distractions and gain cognitive supremacy on the battlefield?" the foundation of qualitative data was gathered through multiple academic journal articles in science, medicine, technology, and defense. Due to the pace and state of technological advances in neuroscience and cognitive enhancement devices, correspondence with experts in all fields was utmost important, as quantitative data has rarely been published. Technological projections based on a probability, possibility, and plausibility models; provided a feasibility model for the Hyper Enabled Operator program 2030 and future technology that USSOCOM should invest in beyond 2035.[88] Based off the sensitivity and objective circumstances surrounding the research of inner cranial brain interface technologies in general, the qualitative data was collected and analyzed as a systematic review to protect individuals and patented technologies. Supplemental information will utilize data through IRB-approved interview questions intended for subject matter experts within the identified networks and ecosystems.

Research will also incorporate the following: Ethics of military use surrounding cognitive enhancement technologies, innovation adaptation of medical devices, and great power competition (what our competitors are using BTI for).

A. IRB-APPROVED QUESTIONNAIRE

Not all questions listed below were asked, answered, or even acknowledge during personal communication or coordinated interview sessions:

[88] Ruud Van der Helm, "Towards a Clarification of Probability, Possibility and Plausibility: How Semantics Could Help Futures Practice to Improve," The Consortium for Science, Policy & Outcomes (Arizona State University, 2006), https://cspo.org/wp-content/uploads/2014/11/read_van-der-Helm-Towards-a-Clarification-of-Probability.pdf.

1. Technological and Adaptation Questions

1. What is the standard philosophy on neurological technology in the 21st century?
2. Based on current literature and data, is it likely that the military will adapt medical neuro-technology to advance the warfighter?
3. How does current neuro-technologies advance cognitive enhancement compared to historical technologies?
4. Describe the advantages of using human machine teaming versus traditional training techniques?
5. Does this research community have standards defined? If so, can you explain some of the advantages and disadvantages of each category of technology (Wearable, Outer-Cranial, Inner-Cranial)?
6. What technology should the Special Operations Community concentrate on based on those standards?
7. What other countries are currently invested in Neuro-technology to scale?
8. What biological benchmarks or areas have you seen the greatest improvements on utilizing neurotechnology?
9. What is the current state of technological capabilities, today? In 2025? in 2035?
10. Describe some informational data highlights from current research or technological fielding assessments?
11. What does the future look like for Neuro-weaponry?

2. Ethics Questions

1. Is a neuroethical dilemma defined and accepted among experts when introducing brain interface technology to military application?
2. What would be the biggest concern or contention point?

3. Is this concern different than ethical issues for commercial application?

4. Who controls the coding of brain interface technology? (For example, with private companies like Nueralink, Is there concern with subliminal marketing exploitation?) Have any concerns been documented?

5. Are there ethical considerations for when an end user "unplugs" or no longer receives the Artificial Intelligence (AI) or machine advantage?

6. What type of social risks come with Neuro-enablement technologies?

7. This technology has the potential to change all aspects of human life… how has the industry prepared for these changes?

8. Describe what, if any, potential physiological, psychological, or behavioral impacts with adapting brain interface technologies are established. If so, what in…?

B. DATA COLLECTION CRITERIA

The primary source of data collection for this research came in the form of a systematic review of existing data, analysis of published biometric and biomarker quantitative data, interpreting projections of phasal data and correspondence with Subject Matter Experts (SME) in the science, medical and technological fields. Data feasibility was assessed on the following criteria:

- Is the research coming from a reputable source?
- Was the research focused on one of the three Bins (Outer Cranial, Inner Cranial, Wearables)
- Which phase is the technology currently in (TRL)?
- Does the research incorporate ethical considerations?
- Does the research utilize humans or animals?
- If so, is it FDA approved?

- Does the research provide acute data and metrics?
- Does the research provide long-term data and metrics?

C. DATA ANALYSIS

Quantitative data analysis compilation was to be assessed on the research that meets the identified criteria above. Particularly in, results that reflected the capacity and capability at which these technologies enhance the brain's cognitive modulation ability. However, through extensive research, interviews with subject matter experts and industry professionals, the authorization to access quantitative data sets were generally denied or ignored. Biomarkers, lab results, patents, proprietary technology, and statistics for emerging technology are held true to the idiom "play one's cards close to one's chest" due to the ever-growing threat of intellectual property theft domestically by other tech companies or internationally by U.S. competitors.

The Chinese Communist Party (CCP) has sought to gain innovative and breakthrough technologies by any means, legitimate or illegitimate since 1978, when Deng Xiaoping introduced the Open Door Policy to the country.[89] Such tactics as state sponsored espionage, bribes, and piracy were authorized. Conducting business in and/or with the PRC forced corporations into mandatory tech trap agreements. China's rapid advancement in the automobile, locomotive, aircraft, cyber, medical technology, and defense modernization all prospered from espionage.[90] Domestically there are over 188 new neurotechnology startups created between 2020 and 2022, all vying for breakthrough technology or software and a piece of the multi-billion-dollar prize, no wonder why these industry leaders won't share their data.[91]

[89] James Lewis, "How Much Have the Chinese Actually Taken?," Center for Strategic & International Studies, March 22, 2018, https://www.csis.org/analysis/how-much-have-chinese-actually-taken.

[90] Lewis.

[91] StartUs Insights, "5 Top Emerging Neurotechnology Startups Impacting Healthcare," StartUs Insights, August 27, 2020, https://www.startus-insights.com/innovators-guide/5-top-emerging-neurotechnology-startups/.

Qualitative data from the systematic review and correspondence with subject matter experts and white papers, was analyzed using thematic analysis to structure themes, topics, and patterns. An inductive approach was taken in my research to provide a clear systematic assortment of procedures for assessing accumulated information in which produced reliable and valid findings on cognitive enhancement. A deductive approach was utilized when identifying themes in which the technology would fall into (Wearable, Noninvasive, Invasive) for interpretation through a special operations lens.

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IV. NEURO-ETHICS

A. ETHICAL CONCERNS

Ethical concerns are inherent when considering who or what entity will be controlling access, sharing human data points, selling of data and distribution equality of cognitive enhancement technologies. Scientist and medical professionals are not the only ones raising a red flag when it comes to the evolution of neurotechnology. A 2016 Pew Research Poll stated that 69% of Americans had either very or somewhat worrisome opinions on the prospects of invasive brain technology that could offer improved cognitive and information processing abilities. This opposition was led by the fear of losing human control.[92]

The rapid advancements of brain interface and neuro technology do not come without skepticism. For instance, Dr. Nita Farahany of Duke University School of Law stated that "Our brain is our last bastion of freedom, our last place for privacy," echoing the same sentiment many other scientists have, skepticism of the intent of corporations like Nueralink.[93]

Dr. L. Syd Johnson of the Center for Bioethics and Humanities at SUNY Upstate Medical University echoed the same concerns as many other professionals about the evolutionary state of neurotechnology. Dr. Johnson has openly expressed that:

> These are very niche products—if we're only talking about developing them for paralyzed individuals—the market is small, the devices are expensive. If the goal is to use the acquired brain data for other devices, or use these devices for other things—say, to drive cars, to drive Tesla—then there might be a much, much bigger market," she said. "But then all those human

[92] Antonio Regalado, "Brain Implants Could Be the next Computer Mouse," MIT Technology Review, October 27, 2021, https://www.technologyreview.com/2021/10/27/1036821/brain-computer-interface-implant-mouse/.

[93] Santosh Chandrasekaran et al., "Historical Perspectives, Challenges, and Future Directions of Implantable Brain-Computer Interfaces for Sensorimotor Applications - Bioelectronic Medicine," SpringerLink (BioMed Central, September 22, 2021), https://link.springer.com/article/10.1186/s42234-021-00076-6.

research subjects—people with genuine needs—are being exploited and used in risky research for someone else's commercial gain.[94]

B. INTERVIEWS WITH SUBJECT MATTER EXPERTS

In this research, I found it incredibly important to talk with subject matter experts in various disciplines, due to the pace in which technology is advancing compared to scholastic articles being written specifically, in regard to ethics. Through several personal communications and recorded interviews with industry professionals I did get a chance on a few occasions to ask the question: What type of social risks come with Neuro-enablement technologies? These are the aggregated responses to the question.

1. Dr. Eric A. Pohlmeyer, Assistant Director DARPA N3 Program, Senior Professional Staff in the Intelligent Systems Group at John Hopkins APL

Pohlmeyer:[95] When it comes to social risks associated with Neuro-enablement technologies, the topic of privacy and data is generally at the pinnacle of conversations. Take for example Kernel, a fantastic company doing some innovative things with their "flow" technology. However, all data gathered by their headgear most be stored in the Kernel cloud, and once the data is stored then Kernel owns that data. This information can be used to identify participants, cultural groups, ethnicities... This new phenomenon did not happen with EEG headsets of the past. As Neurotech continues to improve, will this proprietary data collation become an industry standard? If the scientist and medical doctors performing the procedures and studies don't own the data, then there is a possibility of conflict between all parties.

Of note, Kernels website does reinforce Dr. Pohlmeyer's discussion on current practices of the data control. According to the Services Privacy Policy the following is included:[96]

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94 "Historical Perspectives, Challenges and Future Directions"

95 Eric A. Pohlmeyer, personal communication, October 13, 2022.

96 "Services Privacy Policy - Policies," accessed October 28, 2022, https://docs.kernel.com/docs/services-privacy-policy.

> When you wear a Kernel Product, we collect data about your brain. That data is uploaded to the Kernel Cloud and may include, without limitation, information relating to brain activity and information about the position, orientation, and movement of the Kernel Product while it is in operation. We keep Personal Data for as long as reasonably necessary for the purposes described in this Privacy Policy or for facilitating research in which you participate, while we have a business need to do so, or as required by law (e.g., for tax, legal, accounting, or other purposes), whichever is longer. We may also collect information relating to the activities you are engaged in and your response to stimuli. We may collect information from Product sensors such as your heartrate and eye movement. In certain circumstances, we may share your Personal Data with the following categories of third parties, without further notice to you, unless required or permitted by the law, as set forth below: Vendors and Service Providers, Business Transfers, Legal Requirements, Researchers, Third Parties, Affiliates and With Your Organization.[97]

It was particularly interesting to note that within Kernels privacy policy, no matter the circumstance of the user—direct consumer, patient or research participant—Kernel owned the rights of the data collected.[98]Not the patient, or the doctor performing the medical assessment or the scientist conducting the trial.

2. Dr. Patrick Taylor Smith, Resident Fellow, United States Naval Academy, Stockdale Center for Ethical Leadership

Smith:[99] The main concern beyond safety and reliability, is that these technologies may override or dilute human agency or autonomy, undermining the freedom of those subject to the intervention. Concerning "unplugging," I think the main ethical issue is whether the intervention will create psychological dependency. Will individuals feel coerced into remaining in the military in order to retain the enhancement or will the lack of access to the enhancement make demobilized warfighters feel psychological pain, disorientation, or discomfort?

97 "Services Privacy Policy - Policies."

98 "Services Privacy Policy - Policies."

99 Patrick Smith, personal communication, October 5, 2022.

3. Dr. Tim Marler, Senior Research Engineer at RAND Corporation, Professor at Pardee RAND

Marler:[100] The topic of data is always relevant in the use case of brain or cognitive enhancement. For example, when you don a device that reads, writes, or stimulates the brain, data is produced. Who owns that data and who has access to that dossier is always a concern. Imagine as a SOF professional you utilize some of this technology and record data points during training or during an operation. You may even record the entire training and the after-action review (AAR) as standard practice in the military. Say that training or AAR includes specialized training or tradecraft. Does a company like Kernel have access to classified tactics and techniques because you utilized their technology while doing so?

Marler: A second topic to consider for social risk is when using either augmented or virtual reality in your training or operations. The virtual environment that you operate in, will the creation of the content have inclusivity? Are all bad guys brown or is it diverse? Will it have other natural biases based on the developer? Is there a mechanism to vet the dynamic environments as they change with the mission and security needs? There are myriad of ways you can enhance cognition through augmented or virtual reality, but you must also know the risks that are associated with it.

4. Dr. James Giordano, Chief of Neuroethics Georgetown University and Co-Director O'Neill-Pellegrino Program in Brain Science and Global Health Law and Policy

Giordano:[101] There are three systems you must take into consideration when looking at ethics and social risks of neuro-enablement technologies. Ethicists will argue about idiosyncratic risks. Okay, these are risks that are posed to an individual and the reason for that is very simple, because in the main right the primacy of the western philosophy, the primacy of the person, is fundamental right. All the western ethical constructs that are predicated upon long standing ethical philosophical grounds put tremendous importance upon the value of the individual right. The United States as a

[100] Timothy Marler, personal communication, October 12, 2022.

[101] James Giordano, personal communication, October 11, 2022.

whole, doesn't operate as a collectivist sort of mindset. Respect for autonomy, the idea of doing good, the primacy of the individual's best interest in any way being as non-malevolent as possible towards the individual right. that's the whole issue to date with approaching cognitive enhancement for the military is the fact that the argument is built upon the Nuremberg code, which speaks to the primacy of the individual versus the primacy of "the state." However, it is critically important when it comes to the military right, why? because now what you're doing is you're having to balance idiosyncratic risk with systemic risk. It is relative and relevant to be able to ask what system within the military intra systemically. One has to ask, what are the benefits, what are the burdens and the risks? One way to look at that is, what are the factors within that system whereby benefit is maintained, or benefit is mitigated.

a. System one

Giordano: What is going to be the effect given the non-homogeneity within the system of the military, more narrowly what is going to be the systemic effect within Special Operations? Is everybody in SOF going to get cognitive enhancement devices or are only a few select units going to get them? How do we determine what units or operators in SOF get them and what others don't, if there's some implicit benefit for those who've gotten these devices turn into a "super operator"? right will then realistically you know as well as I do that everybody wants to be that person if for nothing else because they come home and get recognition or a badge or ribbon. So, here again if recognition begins to come to those individuals with the devices, at some point there is going to be directionality. Operators might cast off the burdens for the benefits of becoming a super operator. Once this transpires, the issues arise with what happens when they can't do that job anymore, and they lose their superpower? Does the loss of their superpower then engender something that our research group called post enhancement distress syndrome PDS so under the words now I'm just Clark Kent I'm not Superman anymore?

b. System two

Giordano: Next you must think about the argument for the civilian system. If I make somebody a "super operator" and let's just say that these represent predictable qualities

that you the individual says I don't want to shut them off or the science and technology is such that the military can't shut them off. What happens when the person comes to Expiration Term of Service (ETS) gets discharged or retires? OK you're out, now you must get into your law enforcement or be a mercenary or become an intelligence operator and work on the contract side because being a cognitive enhanced operator your options are very limited in the scope of work your able to do now. The question now becomes, are there civic institutions that would be ready for that kind of enablement or enhancements? I can tell you from my research my colleague John shook the answer to that latter question is no.

c. System three

Giordano: One more system and that is the system in which the military participates what is the role of the military the role of the military in an open democracy. The system of the military must be able to engage with other military systems in those ways that at least remain apace with their scientific and technological capability, if not by design and intent to remain one step ahead. So, what are the systemic risks? The inter systemic risks is intra systemic latent failure and non-computability.

Giordano: The argument here is that ethics has to be about the enterprise I mean if I'm using business ethics for medicine ethicist would make a very true argument against me. So, in that context I can't use civilian ethics for the military. Critics will argue that you have to because in an open society in an open liberal and democratic society the military serves the polis. The polis represents the determining factor and therefore transparency is necessary.

Giordano: That rebuttal is a fallacy because if the military is to serve the polis and protect the polis then absolute transparency to a polis that is impregnable by foreign actors, represents a counter thesis to the effectiveness of the military. So, there have to be things in the military that remain classified and not completely transparent which means the military ethos cannot be identical to the civilian ethos which it strives to protect, because the military ethos must do those things that guarantee its genuine authenticity in terms of what it does to be ethically sound. This inevitably means that military ethics have to be

different. If one of the goals of the military is to remain competitive, as to be able to in some ways negate viable burden, risk, and threat from a foreign competitor, combatant, or adversary then they must be aware of what's going on internationally and they should be aware to remain at pace or ahead of those developments. Multiple systemic risks.

Giordano: Failure to appreciate the inter systemic dynamics then renders any ethical approach to sustaining the viability of the system as effective. Ethics must understand not only idiosyncratic risks but systemic risks in and across all levels of intra and inter systemic engagement.

Of note, Dr. Giordano and Dr. Michael Tennison elaborate more on the difference in military versus civilian ethics in implantable technologies, bio integrated BMIs and neurofeedback-equipped helmets in their research. The ethics of civilian enhancement may be extrapolated and extended to address the implications of warfighter enhancement. When approaching these ethical issues, it becomes important to evaluate actual capabilities and limitation of the training and technology at hand and the state of national security at that time.[102]

C. ETHICS CONCLUSION

Ethics in of itself needs to be a discussion when it comes to utilizing breakthrough technology that could potentially disrupt collective behavior, alter informal societal understandings, or transform human value within a civilization Guidelines should be established for the use of invasive and potential alteration of the human brain. The subject matter expert interviewees implied a central theme that humanity and privacy are of utmost importance when it comes to the ethical and social costs that may be incurred during the technological evolution that is currently taking place. Cognitive enhancement may also represent a deeper transgression against what some view as humanity, by providing advantages to those who are financially able or militarily capable of acquisition; computer enhanced individuals could be seen as an attempt at "playing God."[103]

[102] Moreno, Tennison, and Giordano, "Security Threat versus Aggregated Truths."

[103] Moreno, Tennison, and Giordano.

However, the ethics in regard to special operations and cognitive enhancement and enablement technologies have to be about fighting for right and freedom while attempting to keep your honor clean, as you define cleanliness to mean honor. As highlighted in the interview with Dr. James Giordano and in his chapter of *Security Threat Versus Aggregated Truths,* the individual ethics of a society cannot be singularly applied across the spectrum of the military.[104] The U.S. military must place the security of our nation at the forefront of its mission set by all advantages possible. This has been evident since 1945, when then-U.S. presidential advisor Vannevar Bush briefed President Truman that "science represented an essential component to U.S. national defense, one that the government must support as it is essential to national security."[105]

Freedom and privacy versus security is a continues debate in the United States and in every aspect of the American life. The approach to new technological advances, specifically when it comes to commercial and or military use of cognitive enhancement technologies must be based on consent. Educating an individual on the potential risks and benefits regardless of how social norms impact society's voice will ultimately create trust in the system. Some members will be the first to raise their hands; "some service members may not want to provide the government with access to the inner workings of their brains."[106]

104 Moreno, Tennison, and Giordano.

105 Vannevar Bush, *Science The Endless Frontier*, 75th Annniversary (National Science Foundation, 1945).

106 Norris, "Brain-Computer Interfaces Are Coming. Will We Be Ready?"

V. IMPLICATION AND APPLICATION FOR DUAL USE

A. INTRODUCTION

In this chapter we discuss the dual use case for brain interface technology for cognitive enhancement In particular, we consider how, based on the research illustrated throughout this thesis on how the use of cognitive enhancement and neuro-enablement technology can be applied to USSOCOM's Hyper Enabled Operator Program. Discussion of relevance in SOF modernization, vulnerabilities, and benefits to the end user, and ending with how the United States' global competitors may be exploiting breakthrough neurotechnology for future warfare application.

B. SPECIAL OPERATIONS FORCE MODERNIZATION

The United States Military has enjoyed a long-standing technological edge over our adversaries.[107] In the past 20 years, we have seen this technological evolution have far reaching effects in multiple domains in which conflict occurs. For example, the Islamic States' ability to influence tens of thousands over social media networks created a massive influx in international fighters and sympathizers.[108] Russia's modern-day use of Iranian-made drones—also known as kamikaze or suicide drones—continues to terrorize the population centers in Ukraine from hundreds of miles away.[109] In the United States, Task Force Pineapple, an ad hoc group of active and veteran special operators, intelligence officers, aid workers, and other specialties utilized cutting-edge technology to thwart Taliban hunter teams, and recover over 800 interpreters and their families during the Kabul

[107] Department of Defense, "2022 National Defense Strategy of the United States of America," October 27, 2022.

[108] Brendan Koerner, "Why ISIS Is Winning the Social Media War," *Wired Magaine*, April 2016, https://www.wired.com/2016/03/isis-winning-social-media-war-heres-beat/.

[109] Wynne Davis, "What Are the Suicide Drones Bombarding Ukraine, and Where Did Russia Get Them?," *NPR*, October 18, 2022, sec. Ukraine invasion — explained, https://www.npr.org/2022/10/18/1129576360/suicide-drones-ukraine-russia-iran-shahed-kamikaze.

withdrawal.[110]These few examples illustrate how technology continues to matter significantly. It will change how we fight, where we adapt and how we win future military conflicts.

In military operations, especially special operations, "cognitive dominance—the ability to consistently process and rapidly make critical decisions faster than an adversary—ensures" special operators can effectively and expeditiously dictate how the battle unfolds and conclusively ends in their favor.[111] Historically, U.S. Special Operation units have maintained a technological advantage in multiple domains of conflict, that advantage is now unpredictable, as breakthrough technologies and software are more affordable and accessible globally. As a result of this, the United States' allies, adversaries, and competitors are confronting our advantage in every domain.[112]

Over the past several years cognitive enhancement, in particular cognitive dominance and cognitive overmatch at the edge, is highly sought after by USSOCOM. The "edge" specifically references a small unit or individual operator conducting special operations in a remote, austere environment or in a cyber capacity.[113] These cognitive enhancement capabilities are designed to provide operators overmatch on the battlefield. The advancement for neurotechnology through non-invasive and invasive techniques, has the potential to provide overmatch in any conflict environment.

The Pentagon predicts the battlefield of tomorrow to be "an interconnected web of sensors that pass data to special operators, combined with a myriad of cutting-edge technologies" including artificial intelligence coupled with machine learning, advanced waveforms, mesh networks, and enhanced software tools that allow leadership to rapidly

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110 James Gordon Meek, "US Special Operations Vets Carry out Daring Mission to Save Afghan Allies," ABC News, accessed November 14, 2022, https://abcnews.go.com/Politics/us-special-operations-vets-carry-daring-mission-save/story?id=79670236.

111 Chris Balcik, "For Hyper-Enabled Operators, Cognitive Dominance Is Built on Mobility," White Paper, May 13, 2020, https://insights.samsung.com/2020/05/13/for-hyper-enabled-operators-cognitive-dominance-is-built-on-mobility/.

112 Balcik.

113 Yasmin Tadjdeh, "SOCOM Moving Forward with Hyper-Enabled Operator Concept," National Defense Magazine, accessed November 10, 2022, https://www.nationaldefensemagazine.org/articles/2020/5/12/socom-moving-forward-with-hyper-enabled-operator-concept.

assess the battlefield.[114] The Department of Defense (DOD) believes outfitting warfighters with access to cognitive overmatch technology in austere environments to improve decision-making will be key against near peer adversaries and the modernization of their militaries.[115]

Currently in 2022, The military operation in Ukraine reinforces the hypothesis that the tempo in which future armed conflict is conducted will be expeditiously higher than historical engagements. "Enablement technologies that will remove cognitive load off commanders (and tacticians) will be required as events unfold rapidly."[116] Lisa Sanders, SOCOM science and technology director stated "Reducing that cognitive burden will allow those decisions to be better and more impactful … Because things are happening so fast, and new mistakes are known immediately."[117]

SOCOM has already dedicated the Hyper Enabled Operator program and the Future Soldier 2040 program to enhance cognitive overmatch and dominance through technology and innovative training techniques. Funding is following trend. In fiscal year 2020, the Hyper Enabled Operator project had a $16 million budget.[118] In 2022 the SOCOM Science and Technology department currently has a budget of $146.5 million. Figure 10 below delineates FY2022 funding for cognitive enhancement technologies and other S&T focus areas.

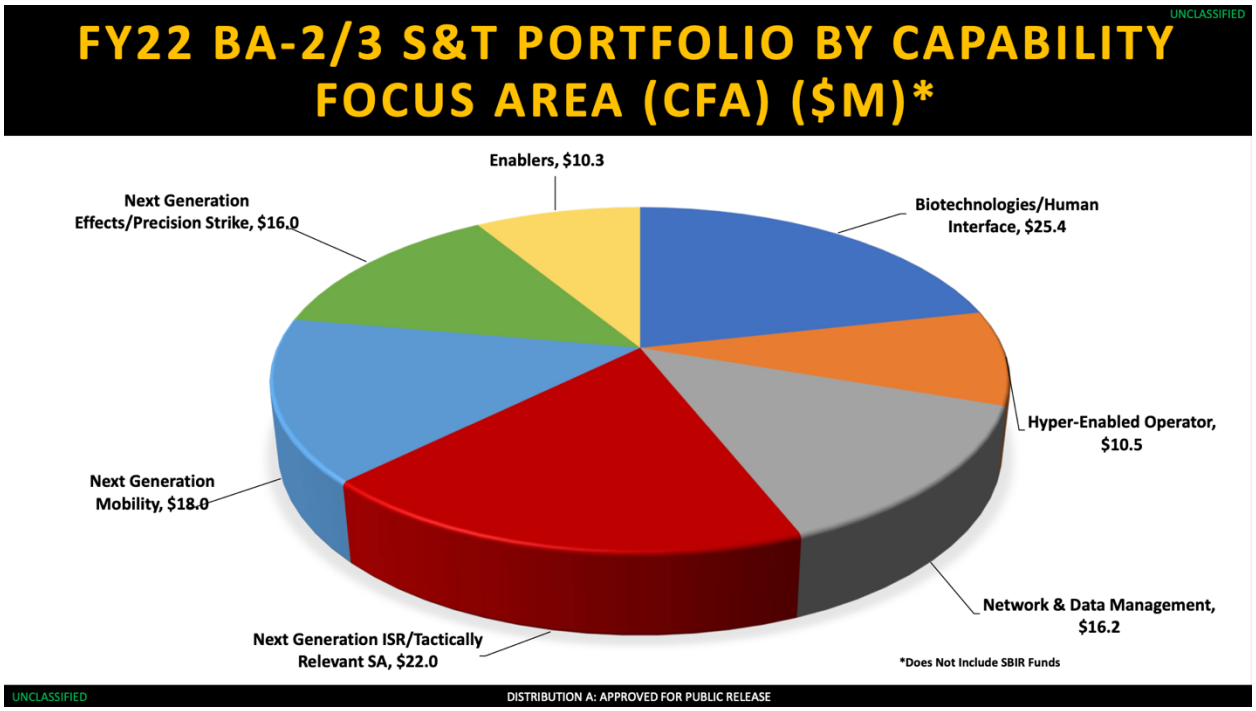
[114] Andrew Eversden, "SOCOM Investing in New Capabilities to Address Technology Shortfalls," C4ISRNet, May 19, 2021, https://www.c4isrnet.com/battlefield-tech/it-networks/2021/05/18/socom-investing-in-new-capabilities-to-address-technology-shortfalls/.

[115] Department of Defense, "2022 National Defense Strategy of the United States of America."

[116] Steve Magnuson, "Special Ops Tech Pulled in Different Directions," National Defense Magazine, June 28, 2022, https://www.nationaldefensemagazine.org/articles/2022/6/28/special-ops-tech-pulled-in-different-directions.

[117] Lisa Sanders, "Special Operations Forces Industry Conference (SOFIC)" (Tampa, FL), accessed November 14, 2022, https://ndia.dtic.mil/2022/2022sofic.html.

[118] Eversden, "SOCOM Investing in New Capabilities to Address Technology Shortfalls."



Biotechnologies/Human Interface has the highest budget within the $164-million-dollar investment profile in SOCOM's S&T department.

Figure 10. USSOCOM S&T Portfolio 2022.[119]

USSOCOM's investment in enablement technology does not include the Biden administration's plan for a $50 billion investment in the National Science Foundation, to "collaborate with and build on existing programs across the government."[120] The directorate would focus on semiconductors, advanced computing, advanced energy technologies and biotechnologies for homeland security and the department of defense.[121]

C. END USER VULNERABILITIES FROM EMERGING TECHNOLOGY

With every new technological innovation that SOF uses, we also may create a new vulnerability for our adversaries and competitors to exploit. Brain-computer interfaces and

119 Source: Lisa Sanders, "Campaigning with Partners for Integrated Deterrence" (Tampa, FL, May 17, 2022).

120 Andrew Eversden, "Biden's Infrastructure Plan Includes Billions to Develop Emerging Tech the Military Needs," C4ISRNet, March 31, 2021, https://www.c4isrnet.com/artificial-intelligence/2021/03/31/bidens-infrastructure-plan-includes-billions-to-develop-emerging-tech-the-military-needs/.

121 Eversden.

cognitive enhancement devices are no exception. What we tend to imagine is an offense-minded advantage, an offense dominance, but of course it is more complicated than that. The defender can design their own terrain. This virtual geography then does not always work in the favor of the offense.

When it comes to the communication between a BCI and the human brain, the interface device through which the SOF operator communicates with "provides a layer of separation between what the user wants the machine to do and then what the machine actually does."[122] This partition can create an unwanted cognitive load on the operator if/ when technical difficulties are encountered. A reoccurring issue with current technology is "interfacing the human motor and sensory channels in a reliable, durable, effective, bidirectional package."[123] Increasing cognitive load of an operator in an austere environment could potentially nullify the intended effects of the device.

Through the use of Artificial Intelligence hacking techniques, hackers have the ability to learn what people are looking at in any given moment.[124] By dint of neuromuscular signals, a hacker has the potential to receive untold PINs, passwords, and high accuracy digit recognition by gaining access to the human machine teaming device. The consequences of these privacy leakages may be conceivably devastating, in the application of ISR or launching targeted attacks against users in a conflict environment.[125]

The data collection and collation dictated by end user agreements could directly contribute to the phenomena of big data leaks that is already ongoing globally.[126] Potentially exposing end user lifestyle preferences, daily routines and social behaviors is

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122 Kevin Warwick, "The Disappearing Human-Machine Divide," *Approaching Religion* 3 (November 1, 2013): 3–15, https://doi.org/10.1007/978-3-319-09668-1_1.

123 Warwick.

124 Anuradha Mandal and Nitesh Saxena, "SoK: Your Mind Tells a Lot About You: On the Privacy Leakage via Brainwave Devices," *Undefined*, 2022, https://www.semanticscholar.org/paper/SoK%3A-Your-Mind-Tells-a-Lot-About-You%3A-On-the-via-Mandal-Saxena/6a40eb354f71e0dbfc0c3c4aeef47f638191a00a.

125 Mandal and Saxena.

126 Jonna Brenninkmeijer and Hub Zwart, "From 'Hard' Neuro-Tools to 'Soft' Neuro-Toys? Refocussing the Neuro-Enhancement Debate," April 1, 2016, https://www.researchgate.net/publication/309611029_From_%27Hard%27_Neuro-Tools_to_%27Soft%27_Neuro-Toys_Refocussing_the_Neuro-Enhancement_Debate.

not only concerning to the SOF operator but also the unit, higher command structure, and potentially violates operational security (OPSEC).

Behavior addiction to cognitive enhancement technologies is a possibility when introducing superhuman traits to the end user by the push of a button or an app.[127]

> The term "Internet Addiction Disorder," recognizes the dependence of the "network" as a pathology, an obsessive / compulsive disorder, which drives a person to overuse of this technology and includes a wide variety of behaviors and problems with impulse control.[128]

A robust study of Internet Addiction Disorder would need to be addressed at both active and veteran health care facilities and units with the introduction of cognitive enchantment abilities to operators.

D. BENEFITS TO THE OPERATOR AND MISSION

When looking at exploratory technology such as brain computer interfaces or human computer interfaces the benefits on cognition highlighted in the literature review are key to maximizing cognitive dominance over our competition. Specifically, when conducting operations against a modernized enemy. To maintain the technological advantage the U.S. currently holds, "the continued research and development of human performance modifications is critical for maintaining and enhancing the U.S. military's operational effectiveness and dominance."[129] Table 2 below provides a brief overview of existing technology and the relevance that had been established during use.

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[127] Martin Dresler et al., "Hacking the Brain: Dimensions of Cognitive Enhancement," *ACS Chemical Neuroscience* 10, no. 3 (March 20, 2019): 1137–48, https://doi.org/10.1021/acschemneuro.8b00571.

[128] Francesca Salicetia, "Internet Addiction Disorder (IAD)," *Procedia - Social and Behavioral Sciences*, The Proceedings of 6th World Conference on educational Sciences, 191 (June 2, 2015): 1372–76, https://doi.org/10.1016/j.sbspro.2015.04.292; Kathryn Yung et al., "Internet Addiction Disorder and Problematic Use of Google Glass™ in Patient Treated at a Residential Substance Abuse Treatment Program," *Addictive Behaviors* 41 (February 2015): 58–60, https://doi.org/10.1016/j.addbeh.2014.09.024.

[129] Magney, "The Benefits and Risks of Human Performance Modification for the U.S. Military."

Table 2. Existing BCI Types by Function with Relevant Military Application and Significance.[130]

Type	Function	Relevant Military Applications	Overall Operational Significance
Type 1	Interaction with Sensory Cortices	Shared sensory data. Human or other organism sensory data incorporated into sensor fusion. New senses and expansion of natural sensory perception beyond natural limits. Enhanced data management and ability to data-mine. Ability to record innate sensory data. Augmented reality applications. Enhanced operator training / computer system programming.	Heighten situational awareness. Provide advanced capacity to quickly resolve battlespace problems. Improve data and trend-analysis ability.
Type 2	Interaction with Motor Cortex	Enhanced autonomous system management/operation. Exoskeleton/supernumerary limb operation. Augmented response. Enhance operator's task performance and expand range of manual tasks that the operator may be considered competent to perform. Enhanced operator training / computer system programming.	Increase operator's scope of control in quality and quantity of systems. Reduce number of personnel required to achieve desired effects. Reduce casualty rates.
Type 3	Interaction with Cognition	Cognitive enhancement beyond natural ability. Synthetic Telepathy / Shared Consciousness Recover impaired cognitive ability and maintain operator's cognitive performance levels despite adverse conditions. Improved ability to allocate human or computer oversight (Scalable autonomy/consciousness). Communication of complex concepts such as operator's intent to autonomous system.	Achieve Cognitive Dominance. Enhance communication.
Type 4	Interaction with Autonomous Nervous System plus Medical Intervention	Mimic physiological states typically associated with pharmaceuticals. Regulate awake-sleep states. Induce meditative cycles. Improve operator's sensitivity to BCI methods. Monitoring operator's medical condition. Neural tissue sustainment / improved medical outcomes.	Extend operator peak performance time. Maintain operator's performance levels despite adverse conditions. Improve casualty medical outcomes.

Currently, One of the largest benefits to the end user when introducing brain/human interfaces is potentially bypassing the diminished mental processing of the environment

130 Adapted from: Patrick A. Cutter, "The Shape of Things to Come: The Military Benefits of the Brain-Computer Interface in 2040," Technical Report, April 1, 2015, https://apps.dtic.mil/sti/citations/AD1012768.

and delayed physical performance during the initial period of the fog of war. Providing an operator an ability to rapidly enhance response times in both mental and motor applications is crucial.[131]Thus, allowing the operator to maximize and exploit any advantages put forth during the onset of kinetic engagements.

Utilizing a device, the directly interfaces with the nervous system has the potential to avoid sensorimotor bottle necking that may occur naturally. A warfighter coupled with an interface can directly gain the advantages of artificial intelligence; including advanced mathematical abilities for ballistic and breaching calculations, an instant, "almost infinite, internet-knowledge foundation," and acute enhanced memory.[132] Furthermore, human machine teaming offers modes of perception beyond normal senses that can exploit infrared, ultraviolet and ultrasonic signals, providing a deeper perception of the current battlefield atmospherics.[133]

One such example of heightened cognition through human-machine teaming was in the application of submerged target acquisition.[134] In the Human Perception and Automatic Target Recognition study, "specific strategies for cooperatively employing human operators and automated computer algorithms experimentally demonstrated that fusing the skills of human and artificial intelligence can significantly improve performance and recognition beyond that which is achievable with only a human—thanks to the diversity that is engendered when coupled."[135]

Also, since cognitive enhancement is intrinsically less noticeable than physical motor activity on the battlefield, BCI's could potentially be used during unconventional

131 Desney Tan and Anton Nijholt, "Brain-Computer Interfaces and Human-Computer Interaction," in *Brain-Computer Interfaces: Applying Our Minds to Human-Computer Interaction*, ed. Desney S. Tan and Anton Nijholt, Human-Computer Interaction Series (London: Springer, 2010), 3–19, https://doi.org/10.1007/978-1-84996-272-8_1.

132 Kevin Warwick, "The Cyborg Revolution," *NanoEthics* 8 (December 1, 2014), https://doi.org/10.1007/s11569-014-0212-z.

133 Warwick.

134 David P. Williams, Michel Couillard, and Samantha Dugelay, "On Human Perception and Automatic Target Recognition: Strategies for Human-Computer Cooperation," in *2014 22nd International Conference on Pattern Recognition* (2014 22nd International Conference on Pattern Recognition (ICPR), Stockholm, Sweden: IEEE, 2014), 4690–95, https://doi.org/10.1109/ICPR.2014.802.

135 Williams, Couillard, and Dugelay.

warfare and covert operations, similarly in command and control (C2) in a denied area or surveillance and reconnaissance applications during tactical operations.[136] For example in C2, an operator may be verbally overloaded in a given instance on the battlefield, a BCI could tailor information presentation to their spatial module to attain a larger communication bandwidth with the warfighter. This is only capable due to the fact that verbal and spatial endeavors "are processed by different areas of the brain, and each of these areas is largely independent of each other."[137]

Disruptive technology like Thync, has the capability to utilize transdermal electrical neurosignaling (TEN) to enhance the end users cognitive load through "delivering high frequency pulsed electrical currents to ophthalmic and maxillary divisions of the right trigeminal nerve and cervical spinal nerve afferents."[138] Figure 11 visually depicts the small size in which the stimulation can be conducted through.

[136] Tan and Nijholt, "Brain-Computer Interfaces and Human-Computer Interaction."

[137] Alan Baddeley, "Working Memory | Science," *Science*, NO. 5044, 255 (January 31, 1992): 556–59, https://doi.org/10.1126/science.1736359.

[138] Columbus Dispatch, "Thync Creates Wearable Tech to Alter Mind, Body," June 15, 2015, https://www.dispatch.com/story/business/2015/06/15/thync-creates-wearable-tech-to/23950525007/.

Thync's slim profile has the ability to fit underneath a Kevlar helmet or night watch cap.

Figure 11. Thync Cognitive Enhancement Device[139]

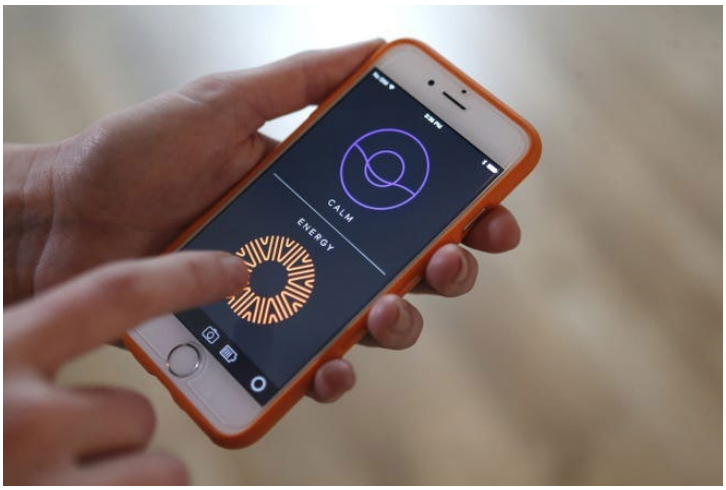
The device application has two modes, one of which is a "creative mode" which has been clinically proven to have a profound effect on learning, retention, and arousal—in some instances retention levels gained approximately 200% and lasted 90 days.[140] Just as important, Thync's "calm mode" (visually depicted in Figure 12) has been clinically proven to significantly suppress basal sympathetic tone, "lower levels of tension and anxiety, and produced a significant suppression of heart rate variability, galvanic skin conductance and salivary α-amylase levels."[141] Having a pseudo meditation effect at the

[139] Sourced: Heather Somerville, "Wearable Technology Aims to Alter Mind, Body," The Ledger, accessed November 21, 2022, https://www.theledger.com/story/business/2015/06/13/wearable-technology-aims-to-alter/8225227007/.

[140] Lindsey McIntire, Chuck Goodyear, and R. Mckinley, *Peripheral Nerve Stimulation to Augment Human Analyst Performance*, 2019, https://doi.org/10.1109/RAPID.2019.8864297.

[141] William Tyler et al., "Transdermal Neuromodulation of Noradrenergic Activity Suppresses Psychophysiological and Biochemical Stress Responses in Humans | Scientific Reports," *Nature*, 13865, Scientific Reports, no. 5 (2015), https://doi.org/10.1038/srep13865.

fingertip can provide clarity and defog the brain, especially after a high-stakes, high-stress environment. Increasing an operator's ability to conduct a thoroughly detailed after-action review or debriefing.



The Thync application allows the end user to choose between stimulation effects at the push of a button

Figure 12. Thync Phone Application[142]

Lastly, the digital parts of the implanted chip can in theory be connected to nearly any kind of software and through that, hardware. This would enable enhancing uses to virtually any code, technology or digital application that benefits the warfighter.[143] Brain computer interface technology allows for the brain and a computer interface apparatus to communicate, without the physical hinderances of the human body.[144] For example, there have been multiple successful instances of fleets of drones controlled simply by the end users mind and a BCI device since first being fielded in 2016 by Arizona State University.[145]

[142] Sourced: Somerville, "Wearable Technology Aims to Alter Mind, Body."

[143] Anders Sandberg and Nick Bostrom, "Cognitive Enhancement: A Review of Technology," November 8, 2022.

[144] Binnendijk, Marler, and Bartels, "Brain-Computer Interfaces."

[145] Michael Irving, "Brain Power Multiplied for Drone Swarm Control," New Atlas, July 19, 2016, https://newatlas.com/mind-controlled-drone-swarm/44417/.

E. GLOBAL COMPETITION IN NEUROTECHNOLOGY

1. The People's Republic of China

Beijing has positioned themselves to take advantage of disruptive neurotechnology like digital interfaces and nervous system coupling devices for both civilian and military use better than any other country in the world, due to the fact that China has fewer barriers for BCI adoption as a result of its party state capitalism, sociocultural climate, and a more cohesive neuroscience and technology ecosystem.[146]

The United States now must be prepared for the deployment of neurotechnology and cognitive enhancement in future tactical environments. In 2013, The U.S. created the BRAIN initiative under then-President Barack Obama.[147] Soon after, the PRC announced their own state sponsored Brain Project; placing a higher emphasis on human machine teaming and brain interface technology than any other country in the world.[148] The five major goals of the United States' BRAIN program concentrate on uncovering the complex links between brain function and behavior.[149] The PRC sponsored Brain Project's framework is proposed as "one body two wings" concept, with a main goal of understanding human brain functionality, and a proportionate accentuation of the subgoals which are referred to as the "two wings" concerning "treating brain disorders and developing brain-machine intelligence technologies."[150]

The People's Liberation Army (PLA) correctly asserts that advanced innovative and dual use technologies can hastily evolve the nature of conflict and competition. President Xi Jinping understands the importance of dual use technology and wants to modernize China's current force to have the capability to communication and assess

146 Margaret Pearson, Meg Rithmire, and Kellee S. Tsai, "Party-State Capitalism in China," *Current History* 120, no. 827 (September 1, 2021): 207–13, https://doi.org/10.1525/curh.2021.120.827.207.

147 "Mission," The BRAIN Initiative Alliance, accessed November 17, 2022, https://www.braininitiative.org/mission/.

148 Putney, "Neurotechnology for National Defense: The U.S. and China," The Cipher Brief, accessed November 10, 2022, https://www.thecipherbrief.com/column_article/neurotechnology-for-national-defense-the-u-s-and-china.

149 "Mission."

150 Putney, "Neurotechnology for National Defense."

information rapidly and fluently, interconnect digitally, all at the same time as integrating state-of-the-art neurotech to provide the PLA a cognitive advantage over its adversary.[151]In 2017 the Secretary of Defense presented the "National Artificial Intelligence Plan," describing how China is positioned to become the "world's major AI innovation center" within 15 years.[152] Secretary Mattis presents the case that the U.S. must "accelerate the integration of AI throughout the economy, society, and national defense."[153] The NAIP report affirmed that in 2020, the Chinese Communist Party (CCP) solidified its commitment to "intelligentization," of brain interface technology and AI by allocating $85 million dollars to fund their future warfare concept. That particular funding financially provides China a way in which to invest in emerging and disruptive technologies that support its modernization efforts, notably "identifying 22 research tasks including brain-inspired software and hardware, human-machine teaming, swarming, and decision making."[154]

The Academy of Military Science (AMS)—China's largest think tank—is entrusted with enterprising defense innovation and modernization, and providing the Chinese military a clear doctrinal path to cutting-edge advances in advanced robotics, artificial intelligence, quantum computing, nanotechnology, secure communications, virtual training environments and big data analysis.[155]With the establishment of the future warfare concept, the PLA is quickly benefiting from Beijing's willingness to deploy domestic scientific breakthrough technologies at a rapid and massive scale both operationally and tactically. Themes introduced by the AMS include "*Biotechnology*:

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[151] Stavros Atlamazoglou, "Warnings about 'brain-Control' Weapons Reflect Growing U.S. Concern about China's Military Research," Business Insider, accessed November 7, 2022, https://www.businessinsider.com/brain-control-weapon-warnings-show-concern-for-china-military-research-2022-2.

[152] Office of the Secretary of Defense, "MILITARY AND SECURITY DEVELOPMENTS INVOLVING THE PEOPLE'S REPUBLIC OF CHINA 2021," ANNUAL REPORT TO CONGRESS, 2021, https://media.defense.gov/2021/Nov/03/2002885874/-1/-1/0/2021-CMPR-FINAL.PDF.

[153] Office of the Secretary of Defense.

[154] Office of the Secretary of Defense.

[155] James Wuthnow, "China's 'New' Academy of Military Science: A Revolution in Theoretical Affairs?," *Jamestown Foundation* 19, no. 2 (January 18, 2019), https://jamestown.org/program/chinas-new-academy-of-military-science-a-revolution-in-theoretical-affairs/.

precision medicine, biological warfare, enhanced soldier performance, human-machine teaming and *AI and Advanced Robotics*: enhanced data exploitation, decision support, manufacturing, unmanned systems, and C4ISR."[156]

Shortly after the Secretary of Defense confirmed the modernization and use of cognitive enhancement technologies by the PLA, The U.S. Commerce Department's Bureau of Industry and Security stated that the "Chinese Academy of Military Medical Sciences and 11 of its research institutions have been involved in the research and support of biotechnology, including brain-control weaponry, that the PLA intends to use for battlefield advantage."[157]

2. The Russian Federation

In setting the stage to modernize the Russian military, President Vladimir Putin proposed that "2021 will be the Year of Science and Technology in Russia" stating on national television, "artificial intelligence is the future, not only for Russia, but for all humankind" further suggesting that the country who leads in technology will dominate globally.[158] In particular, the modernization of the Russian military must capitalize on the advantages and opportunities associated with AI-based technologies to include cognitive enhancement and BCI. In recent years, artificial intelligence, robotics, military decision-making software applications and the rapid integration of automation and autonomous weapons systems on the battlefield have been identified as priorities for Russian special forces modernization.[159]

Advancement in neurotechnology and human-machine-teaming concepts dominates the Russian innovation market, especially since there is an abundance of support

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[156] Office of the Secretary of Defense, "MILITARY AND SECURITY DEVELOPMENTS INVOLVING THE PEOPLE'S REPUBLIC OF CHINA 2021."

[157] Atlamazoglou, "Warnings about 'brain-Control' Weapons Reflect Growing U.S. Concern about China's Military Research."

[158] Ministry of Science and Higher Education of the Russian Federation, "2021 Is Announced as the Year of Science and Technology in Russia," RBC, September 1, 2021, https://www.minobrnauki.gov.ru/god-nauki/.

[159] Anna Nadibaidze, "RUSSIAN PERCEPTIONS OF MILITARY AI, AUTOMATION, AND AUTONOMY," *Foreign Policy Research Institute*, no. Eurasia Program (January 2022): 36.

coming from Moscow's political elite to join the global technology race. Fledgling institutions supported by the Kremlin such as the Neuronet Industry Union, were created and funded to foster international neuroscience collaborations and develop a competitive neurotech market in Russia.[160] Table 3 below, highlights several key state sponsored startup companies that feed into the federations military modernization ecosphere.

Table 3. State Sponsored Neurotechnology Startups

Company	Location	Founded	Technology Focus
BiTronics Lab	Moscow	2015	Bioengineering and neurotechnology
Cosyma	Moscow	2017	BCI with advanced neural network algorithms
Exoatlet	Moscow	2013	Bionic exoskeletons and Human Machine Interface
I-Brain Technologies	Saint Petersburg	2017	Develops brain training solutions that use electrodes and artificial intelligence (AI) to improve athletes' performance
Impulse Neiry	Moscow	2018	Cognitive enhancement technology that blends brain-machine interfaces with virtual reality (VR)
Mdinc	Yaroslavl	2018	Augmented reality technology for remote rehabilitation of patients with upper limb motor dysfunction
Mybrainstorm	Saint Petersburg	2014	Focuses on improving cognitive abilities using non-invasive electrical stimulation to increase concentration, improving memory and reaction time.
Neurobotics	Moscow	2004	Device designed to evaluate mental activity, train self-control skills, and move virtual objects and robotic devices
Neurochat	Moscow	2016	Brain-computer interface capable of interpreting the brain reactions of the user, working with a brain wave called P300 that is involved in decision-making processes

[160] Carlos de Rojas, "Top Neurotech Startups Unlocking the Brain in Russia," Labiotech.eu, February 10, 2021, https://www.labiotech.eu/best-biotech/neurotech-startups-russia/.

One of the state sponsored startups from the list above, Impulse Neiry, publicly announced that their technology has the capability to "improve and restore human abilities and functions that were previously unattainable," and contribute to "the acceleration of computer-integrated human evolution."[161] Neiry has launched a non-invasive neurotechnology project in three public schools around Moscow, involving more than 100 children in the trial. The results of the trial suggest that the cognitive enhancement technology being fielded has improved the subject's "math performance by 16% on average while memory and other cognitive functions improved by 17% and 8%, respectively."[162]

The Russian Academy of Medical Sciences (AMS) was founded in 1944 and has become the country's most prestigious medical and science institution.[163] Recently the academy published numerous results in the last decade on how trial results showcased "EEG-EMG biofeedback training can be used for improving cognitive processes in healthy subjects, as well as for prognostic purposes in clinical practice and in the brain-computer interface technology."[164]

The Kremlin has direct access to the private sector and AMS technological breakthroughs for experimental use within its military modernization overhaul.[165] It can be assumed that they are fielding the same technology produced by the state-sponsored startups, currently in the invasion of Ukraine. In response to Putin's aggression, on June 11th, 2022, the White house announced that due to the unlawful invasion into Ukraine, the

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161 Adrien Henni, "Russian Neurotech Startup Raises $7.4 Million to 'Accelerate Computer-Integrated Human Evolution,'" May 24, 2021, https://www.ewdn.com/2021/05/24/russian-neurotech-startup-raises-7-4-million-to-accelerate-computer-integrated-human-evolution/.

162 Henni.

163 "Russian Academy of Medical Sciences - Brief History," World Health Summit, accessed November 17, 2022, https://www.worldhealthsummit.org/m8-alliance/members/russian-academy-of-medical-sciences.html.

164 M. V. Alexeeva et al., "Training for Voluntarily Increasing Individual Upper α Power as a Method for Cognitive Enhancement," *Human Physiology* 38, no. 1 (January 1, 2012): 40–48, https://doi.org/10.1134/S0362119711060028.

165 Markku Kivinen and Brendan Humphreys, *Russian Modernization: A New Paradigm* (Routledge), accessed November 17, 2022, https://www.routledge.com/Russian-Modernization-A-New-Paradigm/Kivinen-Humphreys/p/book/9780367567286.

United States In response to Putin's aggression, "has taken active measures to limit bilateral science and technology research cooperation with the Russian government" to include artificial intelligence and neurotechnology.[166]

According to the 2022 National Defense Strategy (NDS) both Russian Federation and the People's Republic of China are our biggest competitors in terms of global security.[167] However, when it comes to the use of disruptive technology it is just as important to understand our Allies' technological adaptation to scale. Israel has become a world leader in brain machine interfaces and neurostimulation and may offer use cases on how this technology can be adapted for military application.[168]The U.K., France, Germany, and Canada all have renown cognitive research and neuroscience ecospheres.

[166] White House Staff, "Guidance On Scientific and Technological Cooperation with the Russian Federation for U.S. Government and U.S. Government Affiliated Organizations | OSTP," The White House, accessed November 17, 2022, https://www.whitehouse.gov/ostp/news-updates/2022/06/11/guidance-on-scientific-and-technological-cooperation-with-the-russian-federation-for-u-s-government-and-u-s-government-affiliated-organizations/.

[167] Department of Defense, "2022 National Defense Strategy of the United States of America."

[168] Hillel Braude, "Enhancing Cognition in the 'Brain Nation': An Israeli Perspective," in *Cognitive Enhancement: Ethical and Policy Implications in International Perspectives*, ed. Fabrice Jotterand and Veljko Dubljevic (Oxford University Press, 2016), 0, https://doi.org/10.1093/acprof:oso/9780199396818.003.0009.

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VI. RECOMMENDATIONS AND CONCLUSION

A. RECOMMENDATIONS

Based on the research over the past 18 months, the following recommendations are for the Department of Defense, in particular the United States Special Operations Command on *how the use of cognitive enchantment technology can help a Hyper Enabled Operator mitigate distractions and gain cognitive supremacy on the battlefield.*

- Concentrate funding and resources in noninvasive technology that has potential to maximize cognition outside of a controlled laboratory setting. For example: "Current findings show that healthy participants receiving rhythmic imperceptible currents at gamma band on the left prefrontal cortex became about 15% faster in correctly solving complex Raven's matrices, a widely used neuropsychological instrument indexing fluid reasoning."[169]

- Introduce policy now on neurotechnology. The commercial industry is further ahead than the Department of Defense. Off-the-shelf products like Thync are already being utilized in high-stress work environments to maximize cognition or reduce stress at a touch of a phone application, it will not take long before forward-leaning warfighters start adding it to their gear and kits.

- Promote an open campaign of safety and consent for testing emerging technology that has the potential to disrupt cultural and societal norms.

- Establish and communicate clear ethical stances and guidelines on research and development, implementation, operational use and after care.

[169] Santarnecchi et al., "Frequency-Dependent Enhancement of Fluid Intelligence Induced by Transcranial Oscillatory Potentials."

- Conduct an annual review or sponsor a conference into dual use neurotechnology on an international level, to keep a pulse on commercial applications, emerging technologies and how the other nations are fostering development and experimentation.

- When considering cognitive enhancement usage with augmented reality and virtual reality, operational needs must be aligned with the training and not the newest "shiny object" being pitched by developers. The following questions must be answered.

a. Who is going to develop the training after the initial purchase?

b. If there is missing content within the program, how does this shoehorn training?

c. Does the contract provide a final validation of the efficacy of training, including a validation study?

B. CONCLUSION

Corporations, government institutions like the Department of Defense, and human beings as a race, routinely focus too heavily on changing particular actions or behaviors if it led to an undesired outcome or action. If more emphasis was placed on the decision-making methodology that led to that undesired outcome, decision, or action then the potential deduction of cognitive load could provide a powerful advantage. To possess true cognitive overmatch, a person most shift mindsets in the face of adversity and demand the brain to adopt a more critical thinking approach to the problem set. Therefore, a person must engage "System 2 thinking—the deliberate type of thinking involved in focus, deliberation, reasoning or analysis."[170] Dr. Daniel Kahneman, one of the leading experts on dual systems of the brain states that "System 2 thinking is contrasted by System 1 thinking, which is defined as the more intuitive reactions and instantaneous decisions that

[170] Grace Chang, "Shifting Mindsets to Engage System 2 Thinking - Sage Advice: Episode 22 - Training Films You'd Watch at Home: Video Production for L&D: Sage Media," Sage Media, July 21, 2020, https://sage.media/engage-system-2-thinking/.

govern most of our lives."[171] By taking Dr. Kahneman's theory of split systematic thinking for cognitive enhancement is relatively true, then the application of Brain interface technology complements this notion and revolutionizes the speed in which true cognitive dominance can be achieved. Human machine teaming and interface technologies can theoretically ameliorate SOF to rapidly make informed decisions in any domain, intimately control autonomous weapon systems, and engage with advanced robotics.[172]

The notion of human performance modifications for improved military application is not a new concept for the United States specifically, "enhancements or degradations to the human body to affect either physical or physiological performance—as it relates to U.S. military personnel's ability to wage war."[173] Cognitive enhancement is not beyond reach, throughout the research and after multiple interviews with subject matter experts, the technology presented will be involved in near-future conflicts in multiple domains. Augmented reality is already being utilized in multiple aspects of National Security and Special Operations.[174]

Albeit the current function of neurotechnology is to provide medical or scientific aide to the physically or mentally debilitated, its potentials are unlimited. Sooner or later technological advancements in neuroscience will produce interfaces that are "truly adaptive interactive systems that, on the one side, augment human capabilities by giving the brain the possibility to develop new skills and, on the other side, make computer systems fit the pace and individual features of their owners."[175] This is how the use of cognitive enchantment technology can help a Hyper Enabled Operator mitigate distractions and gain cognitive supremacy on the battlefield.

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[171] Daniel Kahneman, "Of 2 Minds: How Fast and Slow Thinking Shape Perception and Choice [Excerpt]," Scientific American (Scientific American, June 15, 2012), https://www.scientificamerican.com/article/kahneman-excerpt-thinking-fast-and-slow/.

[172] Binnendijk, Marler, and Bartels, "Brain-Computer Interfaces."

[173] Magney, "The Benefits and Risks of Human Performance Modification for the U.S. Military."

[174] Goldstein, "Special Operations Command Sees Potential in AR, VR for Soldiers"; "Snapshot: U.S. Border Patrol Agents Leverage Emerging S&T Tech to Ensure the Security of Our Nation's Borders | Homeland Security."

[175] Millan, Ferrez, and buttfield, "Non Invasive Brain-Machine Interfaces Final Report."

DARPA continues to have success in enhancing end user capabilities through their Neurotechnology for Intelligence Analysts program and the Cognitive Technology Threat Warning System program. Both programs utilize non-invasive procedures for "target detecting brain signals to improve the efficiency of imagery analysis and real-time threat detection, respectively."[176]

Not too far in the future, there will be fully implantable interface technologies that wirelessly transmit "multiple neuronal ensemble signals" to a BCI device that can decode "motor commands and cognitive characteristics of the action the subject intends to accomplish."[177] Aforementioned BCI devices "will analyze both high-order commands, derived from the brain activity and peripheral feedback signals involved in artificial reflex-like control loops."[178] A prevailing tendency for the design of closed-loop neurotechnology that provides the communication mentioned above is trending toward becoming less invasive.[179]

Special Operations should not shy from transformational innovative technology or wait for commercial, or lab-tested solutions. To start, foster avant-garde theories that provide solutions and evolve ideas into unsophisticated prototypes which can be fielded immediately. Only through experimenting with concepts and dual use technologies can we learn "whether these proposed solutions solve a clearly defined problem and inform our future investments in technology."[180]

However, consent and policy implementation should not be an afterthought. As USSOCOM prepares to incorporate neuro-enablement technologies into future SOF capabilities, it will require institutional innovations to address new ethical, operational and

176 Miranda et al., "DARPA-Funded Efforts in the Development of Novel Brain–Computer Interface Technologies."

177 Lebedev, Crist, and Nicolelis, "Building Brain–Machine Interfaces to Restore Neurological Functions."

178 Lebedev, Crist, and Nicolelis.

179 "FUTURE NEURAL THERAPEUTICS."

180 MacCalman et al., "The Hyper-Enabled Operator | Small Wars Journal."

policy issues at each stage of the implementation process-R&D, operations, and especially veteran care.[181]

In the end, to maintain our competitive advantage, a special operator must-have the tools and technology to dominate the virtual, physical, and cognitive domains against our adversaries.[182] The competitors of the United States are already investing in neurotechnology for military modernization; the side that controls cognitive overmatch through rapid informed decisions making will become the victor. Immediately fielding noninvasive BCI technology has the potential to enhance a Hyper Enabled Operator's cognition at the edge, and ultimately evolve U.S. warfighter capabilities to counter all future threats.

[181] Binnendijk, Marler, and Bartels, "Brain-Computer Interfaces."

[182] MacCalman et al., "The Hyper-Enabled Operator | Small Wars Journal."

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