DEFENSE, EMERGING TECHNOLOGY, AND STRATEGY PROGRAM

Augmentation Nation

Strategic, Operational, and Governance Implications of Human Enhancement Technologies for the U.S.

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HARVARD Kennedy School BELFER CENTER | 50 YEARS OF RESEARCH, POLICY, AND LEADERSHIP

OCTOBER 2025

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Sarah recently worked on emerging technology legislation on the U.S. House Foreign Affairs Committee (Indo-Pacific Sub-Committee) and is an Adjunct Fellow at the Center for Strategic and International Studies (CSIS) in Washington DC, and a Fellow in the Emerging Technology, Scientific Advancement, and Global Policy Project at the Belfer Center. Sarah also holds a Bachelor of Advanced Science with First Class Honours and a Bachelors of Arts from the University of New South Wales.

Abbreviations

AR: Augmented Reality

BCI: Brain-Computer Interface

BTO: Biological Technologies Office

C2: Command and Control

DARPA: Defense Advanced Research Projects Agency

DASA: Defence and Security Accelerator (UK)

IDF: Israel Defense Forces

IVAS: Integrated Visual Augmentation System

N3: Next-Generation Nonsurgical Neurotechnology Program

NIH: National Institute of Health

SOCOM: United States Special Operations Command

TRL: Technology Readiness Level

VR: Virtual Reality

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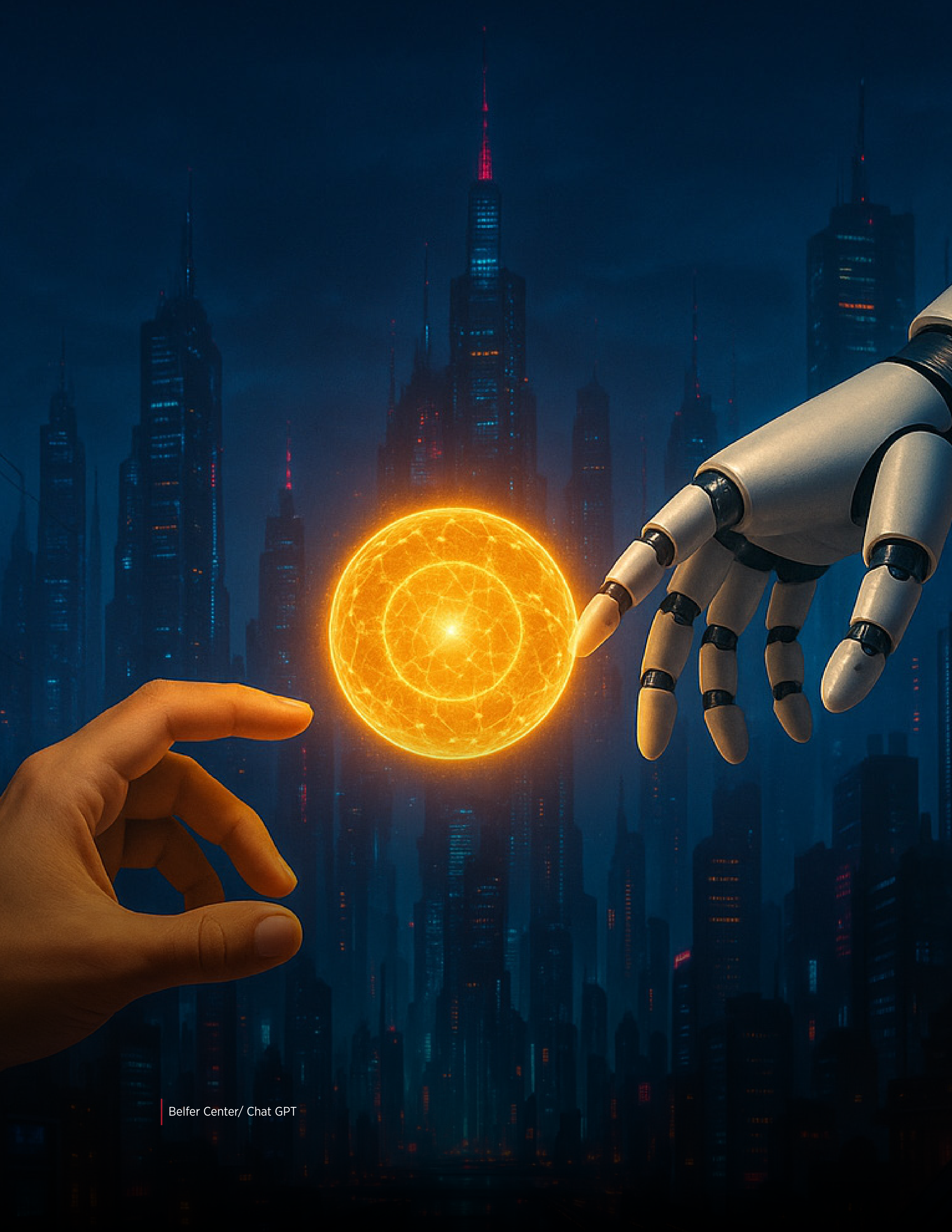

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Executive Summary

Human augmentation technologies, from brain-computer interfaces to gene-modulated endurance and wearable neuroprosthetics, are rapidly evolving from experimental concepts to field-ready tools. As global competition intensifies, adversaries like China and Russia are accelerating development through state-integrated, ethically permissive approaches that threaten to erode U.S. technological and normative leadership.

While the United States leads in core scientific research and innovation, its human augmentation efforts remain fragmented across civilian and defense institutions. There is currently no unified strategy, command authority, or operational framework guiding the transition of these technologies from lab to field. This institutional disconnection risks strategic delay and vulnerability, even as authoritarian competitors push forward with integrated, militarized programs.

This policy brief argues that the U.S. must treat human augmentation as a critical defense domain on par with cyber or space, and act swiftly to consolidate its programs, define ethical and legal red lines, and lead in shaping international governance norms. Without decisive action, the U.S. risks ceding both battlefield advantage and moral authority in a domain that will define the next generation of warfare. Delay is not neutrality; delay is decline.

What follows is a comparative analysis of global approaches, a synthesis of operational and strategic challenges, and a set of six targeted policy proposals to reassert U.S. leadership in the bio-digital era.

Recommendation 1: DARPA & Threat Review Board - Continue investing in DARPA-led human augmentation research to maintain U.S. technological dominance. Establish a cross-branch review board with cybersecurity experts, intelligence analysts, and private contractors to assess vulnerabilities and prevent misuse. This ensures innovation is paired with proactive threat mitigation.

Recommendation 2: Invest in Key R&D - Scale federal investment in critical technologies like neural interfaces, exoskeletons, and gene therapies. Coordinate efforts across DARPA, NIH, and ARPA-H to accelerate breakthroughs and counter adversary advances. Transition discoveries to defense use and allied collaboration to maintain global leadership.

Recommendation 3: Interagency Coordination Task Force - Create a National Human Augmentation Initiative led by the White House to unify efforts across defense, health, energy, and tech agencies. This ensures military needs guide civilian research and civilian breakthroughs are rapidly adapted for national security. Better coordination also enhances regulation, resilience, and messaging.

Recommendation 4: Public-Private Innovation Partnerships - Forge deeper partnerships with startups, universities, and biotech firms to tap into non-traditional innovation pipelines. Launch prize challenges, co-research centers, and rapid contracting models to scale promising technologies. Broad collaboration enables agile development and industrial resilience against foreign dominance.

Recommendation 5: Build a Talent Pipeline - Develop a national bio-digital talent strategy through scholarships, fellowships, and military career tracks in human augmentation. Train scientists, engineers, and warfighters with specialized skills to implement and manage emerging technologies. A strong, diverse talent pool ensures U.S. leadership and resilience in the field.

Recommendation 6: Allied Ethical Red Lines - Lead efforts with NATO, Five Eyes, and Quad partners to define shared ethical boundaries such as banning non-consensual enhancement or inheritable gene edits. Use multilateral platforms to coordinate positions and launch workshops to build consensus. Link violations to diplomatic tools like sanctions and export controls.

Recommendation 7: Ethics-by-Design Advantage - Embed transparency, reversibility, and consent into augmentation systems from the start. Leverage existing ethical review frameworks and align with allied values to build trust and legitimacy. Ethics becomes a strategic edge that reinforces democratic innovation over authoritarian coercion.

Recommendation 8: Lead on Global Norms - Launch diplomatic initiatives to shape global rules on human enhancement before rivals do. Start with allies to build coalitions and eventually engage adversaries on transparency and restraint. Setting norms early aligns security interests with democratic values and prevents destabilizing arms races.

Overview of Human Augmentation

Human augmentation is the application of science and technologies to temporarily or permanently improve human performance[1]. The goal of human augmentation is typically to optimize or extend performance, leading to incremental improvements as well as radical enhancements that could reshape what humans can do.

Human augmentation can be further categorized into two categories: human performance optimization and human performance enhancement. Human performance optimization is the use of science and technologies that improve human performance "up to the limit of biological potential without adding new capabilities."[2] Human performance enhancement is the use of science and technologies to enhance human performance "beyond the limit of biological potential and can include additional capabilities beyond those innate to humans."[3]

The focus of this policy brief is on human performance enhancement. More specifically, what are the opportunities, risks and dilemmas emanating for the U.S from the emerging technologies within the human performance enhancement domain? In addition, human performance enhancement technologies span civilian, military, and dual-use applications ranging from neural-controlled prosthetics for amputees, to cognitive enhancers used by students and professionals, to exoskeletons being tested by soldiers in combat simulations.

While these innovations increasingly blur sectoral boundaries, this brief focuses specifically on military and dual-use applications of human performance enhancement because these categories pose the most immediate strategic implications for national security, technological competitiveness, and force readiness. Investments and decisions made today in these areas will directly shape America's ability to deter conflict, project power, and lead responsibly in a contested future.

Human Performance Enhancement (HPE) technologies are typically categorized by what they enhance: physical, sensory, cognitive, or biological.

- **Physical Augmentation:** Enhances human strength, mobility, and endurance through external or internal support systems
- **Sensory Augmentation:** Expands or restores sensory perception to improve situational awareness and response.
- **Cognitive Augmentation:** Improves brain function by increasing alertness, processing speed, and decision-making capacity.
- **Biological Augmentation:** Alters internal biology to enhance resilience, adaptability, and overall human performance.

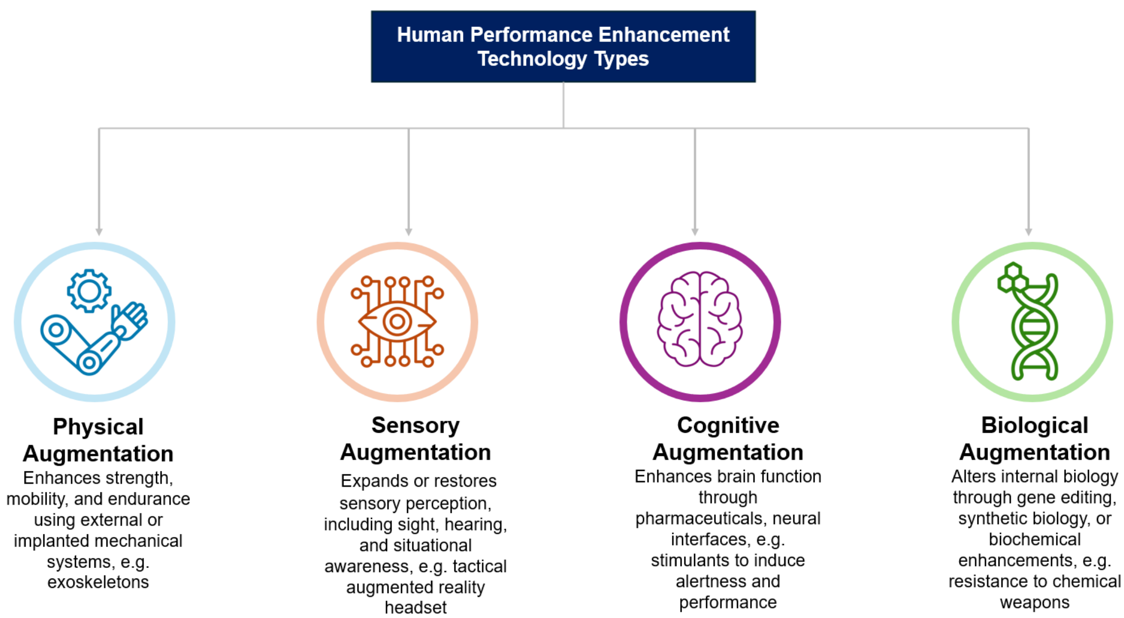

Fig 1: Military and dual-use-relevant Human Performance Enhancement technologies

The readiness of these four different types of HPE technologies is typically assessed via the Technology Readiness Level (TRL) framework, which ranges from 1-9, with TRL 1 being basic research and TRL 9 being proven, deployed systems that are commercialised and in the market. An assessment of the TRL levels of emerging HPE technologies for military and dual-use purposes is outlined below.

Table 1: Human Augmentation Technologies and Readiness Levels

Augmentation Category	Technology	Technology Readiness Level: 1-3 Basic Research	4-6 Field Prototype	7-9 Deployable Systems
Physical Augmentation	Powered exoskeleton suits		■	
	Advanced prosthetic limbs			■
	Full-body combat exoskeleton		■	
	Synthetic muscle fibers or implants	■		
Sensory Augmentation	Cochlear implants			■
	Retinal prosthesis (e.g., Argus II)			■
	Augmented Reality (AR) HUDs			■
	Brain-linked visual implants	■		
	Sensory modalities (ultrasonic hearing)	■		
Cognitive Augmentation	Nootropic drugs (e.g., modafinil)			■
	Brain-computer interfaces		■	
	AI decision-support systems			■
	High-bandwidth neural implants	■		
	Brain-to-brain comms via neural signals	■		
	Enhancement via gene editing	■		
Genetic Augmentation	Gene therapy to improve physical traits	■		
	Hormonal or metabolic enhancers	■		
	Bio-monitoring implants		■	
	Anti-aging genetic tweaks	■		
	Organ bioengineering	■		
	Germline genetic enhancements	■		

The Global HPE Landscape: Strategic Divergence in Capability and Ethics

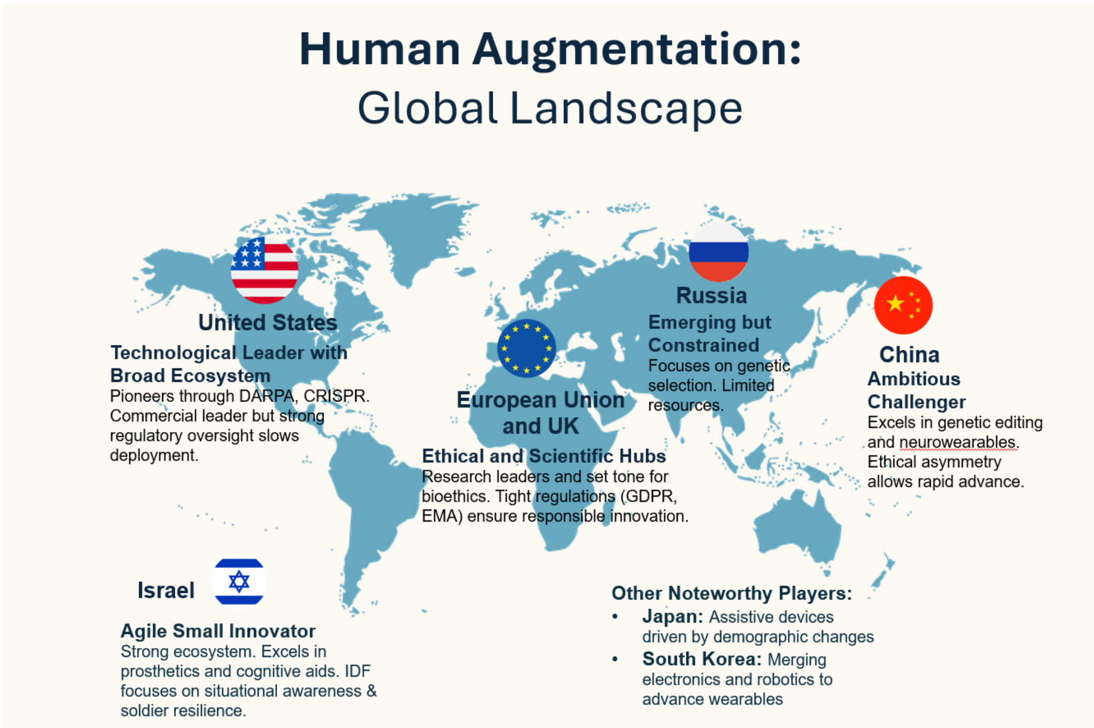

Fig 2: Global Landscape of HPE capability

Human augmentation is emerging as a key axis of military-technological competition, and a strategic divergence is becoming evident in how the United States, China, and Russia approach the development and governance of human enhancement technologies (see **Fig 2**). While the United States maintains global leadership in foundational research and biotechnology innovation, its progress is constrained by ethical guardrails, interagency fragmentation, and a lack of coordinated doctrine. In contrast, China and Russia are advancing rapidly with more centralized, strategically integrated programs and a demonstrably higher tolerance for ethically ambiguous practices. Other nations are racing to develop HPE technologies that will allow them to remain competitive on the battlefield or choosing to optimise within the HPE supply chain by playing key roles in its research and development. **Table 6** in the Annex outlines the major components of each nation's HPE program under development currently.

U.S., China, and Russia: Capability Pathways and Ethical Fault Lines

While many nations are investing in elements of human performance enhancement, China and Russia stand out as the United States' most consequential competitors in the military application of these technologies. Both possess the political will, institutional capacity, and strategic intent to integrate human augmentation into their force development, yet they do so under markedly different ethical and governance frameworks from those of the U.S. (see **Fig 3**). China's vertically integrated civil–military fusion model and tolerance for ethically contentious experimentation enable rapid fielding of capabilities that might be slowed or prohibited under U.S. norms. Russia, though less technologically advanced, has a history of seeking asymmetric advantages through coercive or high-risk enhancement methods, making it an unpredictable actor in this domain. Understanding these divergent approaches is essential to assessing the balance of capabilities and the potential risks of an ethical overmatch in future conflict.

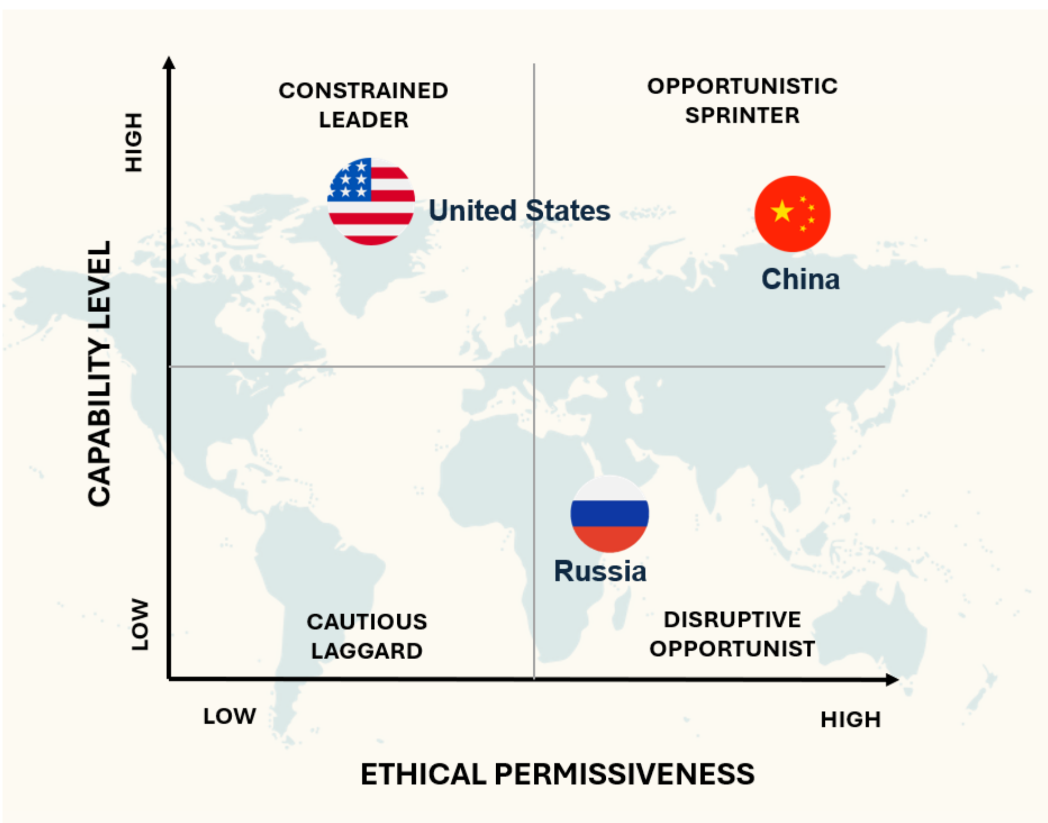

Fig 3: United States risks falling behind in its development of HPEs due to a piecemeal development approach and constrained regulatory environment

China: Integrated Biotechnological Ambition with Ethical Flexibility

China has clearly identified biotechnology and human performance enhancement as strategic priorities in both its civil and military domains. The People's Liberation Army (PLA) integrates biological research directly into its broader military modernization agenda, consistent with its doctrine of "intelligentized warfare."[4] Institutions such as the Academy of Military Medical Sciences (AMMS), Beijing Genomics Institute (BGI), and defense research centers are reportedly pursuing gene editing (e.g., CRISPR), brain-computer interfaces (BCIs), and EEG-based neurocognitive monitoring for warfighters.[5] Reports indicate that the PLA views human enhancement as essential to achieving overmatch against technologically superior adversaries.[6] China's concept of civil-military fusion means that breakthroughs in gene editing or BCIs in the civilian sector are quickly assessed for military utility.

Ethically, China's leadership views Western norms as impediments they don't necessarily share. China's more flexible standards act as an enabler for faster development, especially in biological enhancement, potentially making China the world's leading innovator in biological HPET and its military applications by 2030. The 2018 case of CRISPR-edited embryos, which provoked global outrage, underscored China's readiness to push the boundaries of biological experimentation.[7] Although the Chinese government condemned the scientist involved, the episode revealed systemic gaps in oversight and a broader permissiveness within its R&D environment. Chinese sources themselves frame biotech as a strategic high ground.[8] If China succeeds in fielding enhanced units (even in small numbers, like special forces with gene tweaks for night vision or endurance), it could challenge U.S. technological superiority in a domain traditionally dominated by the West. This enables accelerated testing cycles and potential military applications that would face intense ethical and legal scrutiny in liberal democracies.[9]

Russia: Cognitive Focus and Coercive Legacy Systems

Russia presents a more complex picture. While Russia is less advanced than China in these technologies (and even lags the U.S. in many areas), it has a history of seeking asymmetric advantages to compensate for conventional shortfalls.[10] President Putin's public remarks on genetic super-soldiers suggest Russia is keenly aware of the disruptive potential and may prefer global rules to constrain a race, though it does operate its own programs on human enhancements.[11] The reported Russian BCI chip project is one example of Moscow trying to keep a hand in the game. Russian military medicine has traditionally been willing to use pharmacological enhancers (e.g., pain inhibitors and stimulants) in ways more constrained militaries might not. Facing a protracted war in Ukraine, if Russian commanders believe certain drugs can make their soldiers fight harder or withstand stress, they might deploy them regardless of longer-term consequences.[12] In terms of high-tech enhancements like exoskeletons or gene editing, Russia's economic constraints and declining science base mean it is unlikely to pioneer breakthroughs, but it could acquire tech from others or repurpose civilian science. For instance, Russia could potentially collaborate with China or tap illicit biotech markets if desperate for an edge.

While it lacks the biomedical R&D depth of China or the U.S., Russia compensates by focusing on cognitive and pharmacological enhancement, drawing on longstanding state-sponsored practices of performance optimization. Research into neurostimulation, stress adaptation, and cognitive load reduction is ongoing within Russian military institutions, and public statements from Russian military scientists have described future soldiers capable of "controlling combat equipment through neural signals."[13] Russia's history of using performance-enhancing drugs in state-run sports programs, coupled with the opaque structure of its military R&D, suggests a higher tolerance for coercive or ethically dubious practices. Reports indicate that Russia continues to explore biochemical enhancers and neuropsychological tools for both individual performance and psychological operations.[14] Regulatory transparency is minimal, and oversight mechanisms are largely internal to the state.

United States: Technological Edge, Institutional Fragmentation

The U.S. leads in HPE innovation through a distributed ecosystem of **federal agencies, service branches, elite research labs, and venture-backed startups**. Key funders and players include:

- **DARPA** (e.g., Safe Genes, N3, ADAPTER, Warrior Web)
- **ARPA-H** (medical R&D with dual-use potential)
- **NIH / BRAIN Initiative** (brain mapping, BCIs, mental health augmentation)
- **DIU / SOCOM** (mission-specific prototyping, exosuits, stress inoculation tech)
- **Private Sector** (Synchron, Paradromics, Ekso Bionics, Neuralink)

However, the U.S. effort is **fragmented across civilian and defense agencies**, with no centralized national program for military human augmentation. However, most programs are still siloed. A 2024 white paper highlighted the lack of integration across these initiatives, and Congress has not consistently funded biotechnology as a strategic category.[15] While DARPA has pioneered many of these programs, its 2024 budget for biotechnology R&D was under 4% of its total funding.[16] Regulatory bodies such as the FDA, while critical for safety, also slow deployment and complicate integration with military acquisition pathways. There is currently no unified augmentation strategy under the Department of Defense, and interagency collaboration remains inconsistent. In contrast to China's civil-military fusion model, the U.S. faces challenges in translating cutting-edge science into field-ready capabilities. In short, ethical frameworks are appropriately emphasized but also impose constraints that adversaries can bypass.

Strategic Competition and the Risk of Ethical Overmatch

For the U.S., China's trajectory suggests actively monitoring and matching their advances in HPE closely over the next decade. If China is seen to be leaping ahead (for instance, widespread reports of PLA units using performance-enhancing drugs or brain-controlled drone swarms in exercises), the U.S. may face pressure to close the gap to avoid a perceived military disadvantage. Scholars warn that this competition could become a classic security dilemma where each side feels compelled to outdo the other's enhancements and both sides are in a race where falling behind is not an option either is willing to accept.[17]

The adversarial competition raises the question: Should the U.S. consider international agreements or norms to limit a hazardous arms race in human enhancement? If China and Russia were receptive, talks could theoretically cover bans on inheritable genetic modification of soldiers, or rules for informed consent in military medical research. However, given verification difficulties (it's hard to monitor what a state does to its soldiers in labs) and mutual distrust, formal arms control here will be challenging. More realistically, the U.S. might develop informal norms with allies, for example, a NATO statement on ethical human augmentation to set itself apart from adversaries.[18] This could strengthen alliances and also serve as a soft-power contrast, showing the world that U.S. enhancements are conducted responsibly. As of now, states such as China are perceived as unencumbered by ethical concerns that the U.S. and its allies consider fundamental.[19] This ethical divergence is itself becoming a competitive factor as the U.S. faces the dual challenge of protecting its values while preventing an authoritarian adversary from gaining a decisive lead through unethical experiments.

Visualizing the Divide: Centralized vs. Fragmented HPE Architectures

Unlike China's vertically integrated PLA system, where universities, biotech firms, military research institutes, and operational commands are coordinated under a single national mission, the U.S. system resembles a decentralized network. NIH and the BRAIN Initiative focus on non-military neuroscience; ARPA-H funds biomedical breakthroughs with limited coordination with DoD; DARPA drives disruptive innovation but with uncertain service uptake; the VA remains disconnected from warfighter augmentation planning; and oversight regimes (FDA, IRBs) operate under peacetime public health models, not battlefield realities. The absence of a central coordinating office means promising technologies often stall between demonstration and deployment.

This divergence is best illustrated by comparing China's vertically integrated augmentation pipeline with the United States' decentralized architecture. In

China, the PLA's augmentation ecosystem flows top-down from national strategy through military research and university labs to field testing and deployment, all within a unified command structure. Ethical concerns are managed internally and subordinate to the state's strategic objectives.

By contrast, the U.S. system features multiple powerful but siloed actors: DARPA, ARPA-H, NIH, DIU, the military services, FDA, and the VA. Each conducts valuable work, but with limited interoperability and without a central mission coordinator. Promising technologies languish in transition because no one actor owns both development and deployment. Regulatory hurdles designed for civilian healthcare often impede operational testing. Meanwhile, service-specific pilots rarely feed into joint doctrine or long-term sustainment.

Fig 4 clearly illustrates the stark contrast between the state architectures: China's model is a vertical stack with command integration, while the U.S. model resembles a wheel of disconnected spokes, with no central hub to synchronize efforts. Without reform, this fragmentation risks turning U.S. technical leadership into strategic vulnerability.[20]

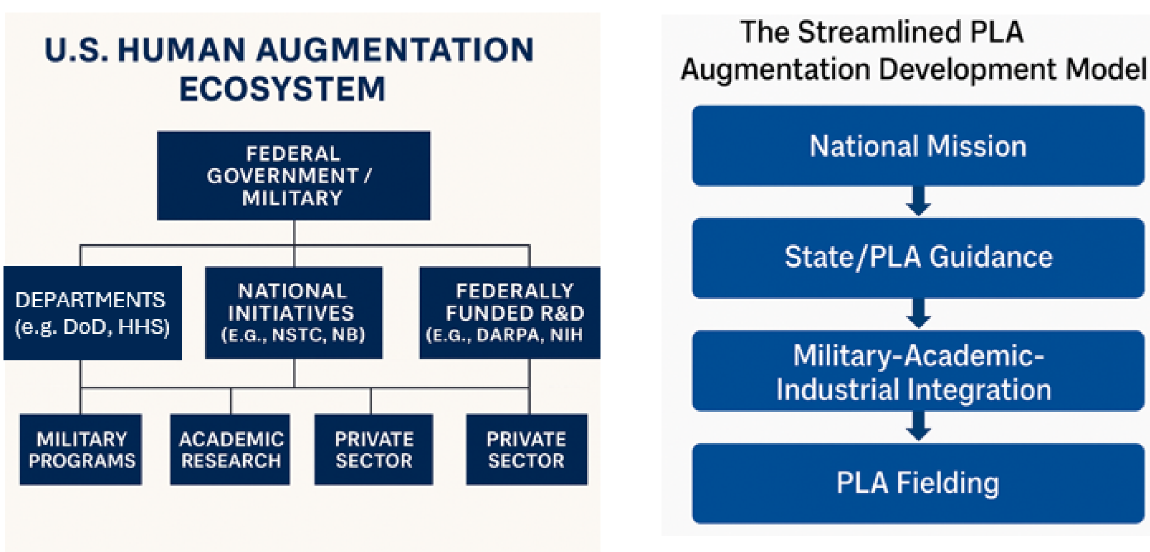

Fig 4: United States and China's HPE ecosystem architecture

This ethical and organizational asymmetry has profound implications for the future of warfare. China's centralized and ethically permissive approach allows rapid scaling and integration of novel capabilities that would face years of delay or outright rejection under U.S. norms. Russia, while technologically behind, may seek disruptive or coercive uses of augmentation in gray-zone conflict scenarios.

If the U.S. does not move to streamline its internal augmentation architecture and proactively shape international norms, it risks a future where authoritarian actors define the rules of human enhancement in war. Without clear red lines, doctrine, and investment strategies, the U.S. could lose both technological and moral leadership in a domain that is rapidly moving from speculative to strategic.

While this comparative analysis highlights the strategic pressures shaping U.S. decisions, operationalizing HPE within the U.S. military presents its own set of doctrinal, legal, and command challenges. Understanding these global dynamics is essential before examining how U.S. forces would operationally integrate HPE.

Challenges to HPE Adoption in U.S. Defense

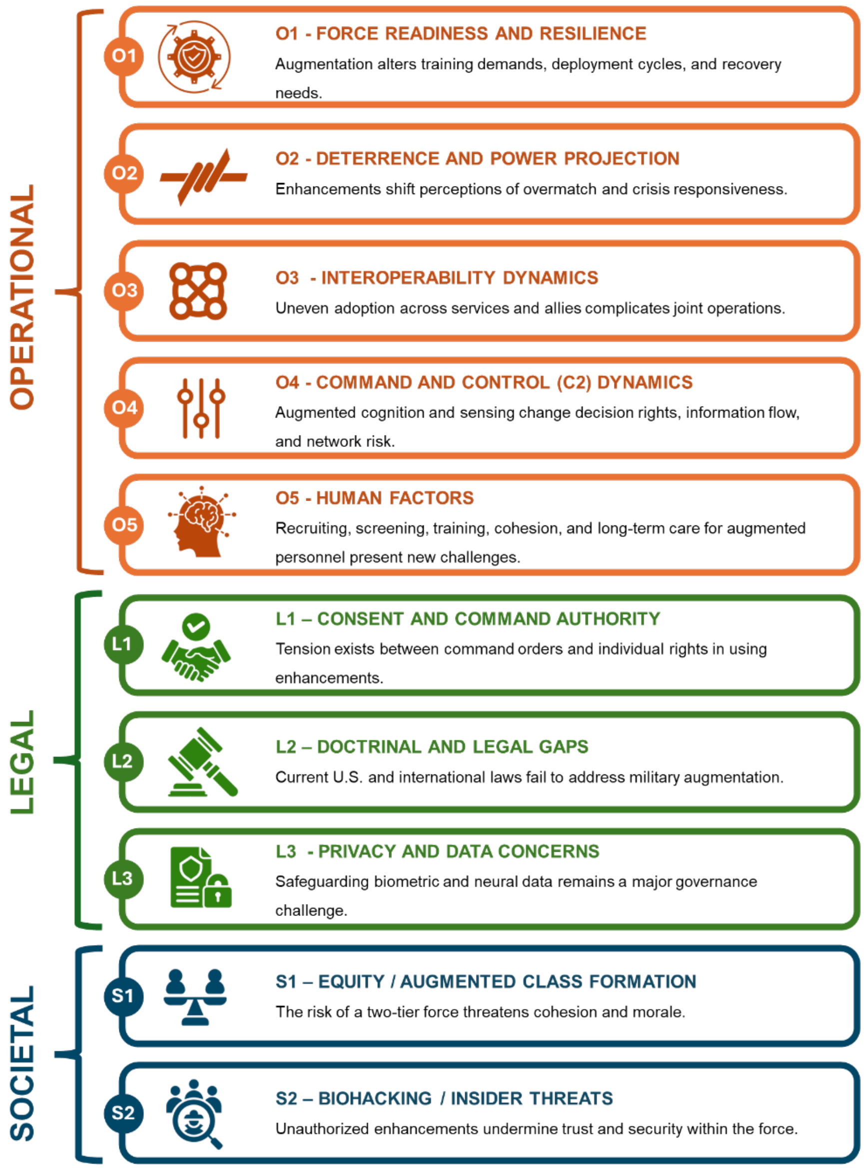

Table 2: The United States faces a number of operational, legal and societal implementation challenges to widespread HPE uptake by the United States Defense forces

Taken together, the challenges outlined in this report, spanning the global competitive landscape, the internal operational barriers, and the external legal and societal constraints, define the environment in which the United States must pursue human performance enhancement (HPE) adoption (**Table 2**). From the global analysis, it is clear that key competitors such as China and

Russia are advancing HPE capabilities under markedly different ethical and governance standards, creating the risk of a capability and "ethical overmatch" gap.

Domestically, the U.S. faces its own operational hurdles: safeguarding force readiness and resilience, managing human factors that affect cohesion, adapting command-and-control structures, ensuring interoperability, and sustaining strategic deterrence. Externally, it must navigate the legal guardrails and societal acceptance issues that will shape legitimacy: from consent and equity, to doctrinal clarity, biosecurity, and the protection of neural and biometric data. Together, these global, operational, and societal-legal dimensions underscore that HPE adoption is not a singular technical challenge but a systemic transformation requiring coordination across doctrine, law, culture, and technology. With this challenge landscape already established, the following section sets out targeted policy recommendations to address these risks while safeguarding warfighter welfare, sustaining public trust, and preserving the U.S. competitive edge.

Operational Challenges

The accelerating pace of human performance enhancement development worldwide presents the U.S. military with a dual imperative: to preserve force readiness in the near term and to adapt its structures, policies, and training for a future in which such technologies may be integrated into daily operations. While competitor nations pursue centralized, rapid adoption strategies, the U.S. must reconcile its innovation strengths with a complex defense bureaucracy, stringent ethical oversight, and a dispersed research ecosystem. As the global landscape analysis has shown, the United States faces mounting pressure to keep pace with competitors like China and Russia in the development and deployment of human performance enhancement (HPE) technologies. Yet even if the U.S. were to accelerate its R&D and acquisition pipelines, adoption would not be a simple matter of fielding new capabilities. The realities of the U.S. defense ecosystem and its force structure, alliance commitments, and ethical constraints mean that integration will surface complex operational challenges.

This section examines **five interrelated Operational Challenge areas** that will shape the U.S. military's ability to adopt HPE effectively.

01 – Force readiness and resilience

Human enhancement technologies promise to boost force readiness by maximizing the physical and mental potential of personnel and by reducing the traditional toll of military operations.[21] Physically enhanced soldiers – whether through exoskeleton support or biochemical aids – can endure longer missions with less downtime. For example, exoskeletons that mitigate fatigue and injury mean fewer soldiers sidelined by musculoskeletal issues and a faster recovery after strenuous tasks such as loading ammunition or carrying loads.[22] If troops can take a performance pill to stay alert for 48 hours, a unit can maintain a higher operations tempo without rotating out personnel for rest, thus staying "ready" longer. Enhanced immune systems or genetic resistance to diseases could also keep troops available in bio-threat or endemic disease regions (a critical advantage for readiness during deployments to areas with malaria or other illnesses).[23] Cognitive enhancements likewise improve readiness by speeding up training and decision-making. AR and VR training systems allow soldiers to gain experience in varied scenarios more rapidly, while neurostimulation or BCIs might one day accelerate learning (for instance, using neurofeedback to optimize marksmanship training).[24] The result is a force that reaches proficiency faster and retains skills better.

Enhancements can also increase resilience under stress. Biochemical interventions might enable soldiers to function in extreme environments such as high altitude, extreme cold/heat with fewer ill effects, expanding the range of conditions under which U.S. forces can sustain operations. Genetic tweaks or biochemical prophylactics could strengthen tolerance to G-forces (for pilots), resistance to sleep deprivation, or psychological resilience against trauma. All these contribute to a more robust and deployable force: if future genetic enhancements made troops immune to certain chemical or biological agents, the force could be ready to operate in contaminated environments with less protective gear, thus maintaining effectiveness in scenarios that previously would degrade readiness.

There are also risks to readiness if these technologies are not managed properly. Dependence on enhancements could backfire: troops whose effectiveness relies on a device or drug might be mission-capable only as long as those aids are present. If an exoskeleton battery dies mid-mission or an AR system malfunctions, an otherwise heavily burdened soldier might be worse off than if they had trained to carry the load unaided.[25] There is also the issue of long-term health: some enhancements (particularly experimental drugs or gene edits) might have delayed adverse effects that could medically discharge soldiers later, hurting overall readiness.[26] The military must rigorously test and evaluate health impacts – a lesson from past experiences, such as the use of amphetamines in past wars which boosted short-term performance but carried addiction and health risks. Ensuring enhancements are reversible is also part of maintaining force readiness; for instance, designing policies so that if a soldier leaves service, they can taper off any enhancement drugs safely, or remove implants without permanent damage.

On balance, appropriate use of human enhancement tech should improve readiness: fewer injuries, better fitness, sharper minds, and the ability to "train hard, fight easy" with high-tech simulation. But the U.S. will need to implement these technologies in ways that include health monitoring, backup systems for gear, and ethical guidelines, so that in pursuit of a ready force we do not inadvertently degrade the long-term health of our warriors or create brittle dependencies.[27]

Gains in readiness are not just internal efficiencies: they shape how adversaries read U.S. resolve and capability. We next examine how augmentation could influence deterrence credibility and power projection.

02 – Deterrence and Power Projection

If the United States harnesses human enhancement technologies effectively, it could bolster deterrence by demonstrating a qualitative edge in military capabilities. Deterrence relies on convincing adversaries they cannot win, and enhanced soldiers could contribute to that perception. For instance, a relatively small U.S. force equipped with AR targeting, exoskeletons, and cognitive enhancements might overmatch a much larger conventional force. This force multiplication effect could mean that the U.S. could project power with fewer troops in certain scenarios, a valuable deterrent when facing numerically superior adversaries.[28] Visibly augmented units (e.g., troops with advanced HUDs and robotic exosuits) also have a psychological impact, potentially dissuading hostile actions due to fear of high-tech overmatch. In essence, fielding elite units at the cutting edge of human performance could reinforce the U.S. military's reputation for technological supremacy, adding another layer to conventional deterrence alongside hardware like stealth aircraft and precision weapons.[29]

As always, there is a flip side: if the U.S. hesitates for ethical reasons and rivals leap ahead, adversary enhancements could erode U.S. deterrence.[30] A scenario where, say, China widely deploys gene-edited, drug-augmented troops while the U.S. has not, might embolden China's aggressive behavior if they believe their soldiers have a warfighting advantage. The U.S. must therefore carefully watch competitors' human enhancement developments to avoid any perception of a capability gap. If another nation achieves effective BCIs or other augmentations first, the U.S. could be at a disadvantage.[31] Thus, maintaining a competitive parity or lead in human enhancement even in the face of ethical asymmetry is part of sustaining deterrence in the long term.

Human enhancements can also extend the global reach and endurance of U.S. forces. Enhanced soldiers require potentially lighter logistical footprints. For example, if troops need less sleep and carry more supplies themselves, deployments can be leaner with fewer support units. Special operations forces could operate deeper behind enemy lines or in hostile environments if their physiology is bio-augmented to handle stressors (e.g., a commando team engineered for high altitude could operate in mountainous terrain without acclimation delays, projecting power into areas previously off-limits or requiring large support). Exoskeletons could enable rapid air-deployable units with heavy weaponry (since troops can carry heavy weapons off a transport without vehicles). Cognitive enhancements and BCIs may allow forces to control dispersed assets (drones, cyber effects) far from traditional command and control hubs projecting influence without always needing physical presence.[32]

At the strategic level, if the U.S. can reliably field forces that are exponentiated through mechanical tools, such as a soldier effectively commanding a swarm of drones via BC, it magnifies U.S. power projection in any theater. This could reduce the number of troops needed in forward bases or allow quicker surge responses to crises with smaller, yet potent, units.[33] In theory, it strengthens conventional deterrence by lowering the threshold for the U.S. to respond – if fewer troops can accomplish the mission due to being enhanced, deploying them might be more politically and logistically feasible, thereby making U.S. deterrent deployments more credible.

It's worth noting that the introduction of augmented troops might also spark new forms of arms racing that influence deterrence stability. Just as introducing a new weapon can upset an adversary's sense of security, showcasing human enhancements might push rivals to respond asymmetrically – possibly by developing counter-technologies (like directed-energy weapons to disable electronics on exoskeletons or neural jamming devices to confuse BCI-equipped troops). In extreme cases, adversaries could double down on autonomous systems and AI to target and counter U.S. enhanced humans. This interplay will shape the overall deterrence equation: the U.S. must consider not just direct effects (our soldiers get stronger) but also second-order effects (adversaries react by shifting strategies).

Projecting augmented power rarely happens alone. The operational value, and political signaling, of these capabilities will depend on how well they mesh with joint forces and allies. That raises the question of interoperability.

03 – Interoperability Dynamics

As the U.S. introduces human enhancement technologies, a critical consideration is interoperability, both among U.S. forces of different types and with allied militaries. Not all nations will adopt enhancements at the same pace or extent. This uneven adoption could create capability gaps that complicate joint operations.[34] For example, if U.S. soldiers have advanced AR communications and data links via BCIs, but allied troops do not, there's a risk that the Americans operate on a different situational awareness plane than their partners. Information might flow so quickly among augmented U.S. units that unenhanced allies struggle to keep up or even to be included in the loop – something that is already an issue with classic military technology such as aircraft.[35] To mitigate this, the U.S. will need to develop interface solutions such as simplified data feeds or translation layers through APIs so that allies can plug into augmented networks with their existing equipment.

Another interoperability issue is more procedural. Enhanced capabilities might lead the U.S. to tactics that allies aren't trained or equipped for. If U.S. squads can fight effectively at night without rest (due to night-vision AR and anti-fatigue enhancements), an allied unit used to diurnal cycles might not be prepared for 24-hour continuous operations. Aligning expectations and doctrines will be important. The U.S. might need to share lessons learned from enhancement usage with close partners (like NATO allies, Australia, and Japan) to help them adapt and overcome. In some cases, allies may choose to acquire or develop their own human enhancements influenced by U.S. success.

Within U.S. joint forces, interoperability means ensuring various branches integrate enhancements in a complementary way. If the Army leads in exoskeleton infantry suits, the Marines might adopt similar gear to operate alongside, whereas the Air Force might focus on cognitive enhancements for pilots. Coordination is needed so that, for instance, an Army JTAC (Joint Terminal Attack Controller) with an advanced BCI can effectively interface with an Air Force pilot who might not have a BCI but has other augmented reality aids.[36] The Pentagon should consider joint standards for data and connectivity akin to how radios have common frequencies. Augmented systems should have interoperable architectures to ensure maximization of utility in the tools.

Affecting interoperability is in the domestic conversation around ethics. Differing ethical stances among allies could affect coalition willingness. Some nations might be uncomfortable if U.S. forces deploy with certain enhancements (imagine a partner nation uneasy about fighting alongside gene-edited soldiers due to public opinion at home).[37] This could strain alliances if not addressed diplomatically. The U.S. may need to be transparent with allies about what technologies are being fielded and possibly even seek their input on guidelines, to maintain trust. Conversely, allies who lag technologically might specifically seek out U.S. enhanced units for tough tasks, leveraging the capability disparity (like requesting a U.S. augmented platoon for a high-risk mission where their own troops would fare worse).[38] Either way, clear communication and joint planning will be key, so that human enhancements become a force multiplier for the entire coalition, not a point of friction.

Making mixed augmented/unaugmented formations work is ultimately a C2 problem: who sees what, who decides when, and how fragile the network becomes. The next section turns to those command and control dynamics.

04 – Command and Control (C2) Dynamics

Human enhancement technologies will have profound implications for command and control dynamics across the board. On one hand, enhancements can empower lower-level decision-making by providing individuals with more information and capabilities; on the other hand, they can enable higher ranks to exert more direct oversight on the actions of individuals in the field.[39] Finding the right balance will be crucial to effective C2. With AR and BCIs giving soldiers unprecedented situational awareness and connectivity, junior leaders on the ground could have a real-time operational picture that previously only a battalion or brigade commander might have had. This potentially enables more decentralized command. Small-unit leaders can make informed decisions rapidly without waiting for instructions, in line with mission command principles.[40] For example, a squad leader with live drone feeds via AR might identify an opportunity on the flank and act on it immediately. Cognitive enhancements that improve multitasking or memory could make leaders more adept at handling complex engagements without constant higher guidance.[41] In this sense, human enhancement could push decision authority downward, making frontline units more autonomous and agile.

These technologies also allow higher commanders to reach down further into the tactical space. If every soldier is feeding data back to a network (visual, biometric, positional data), commanders at an operations center might see detailed ground truth in real time. In extreme cases, a commander with a BCI link might even be able to directly interface with a soldier's sensory feed or communications, blurring lines between levels of command. There is a risk of information overload at the top and the temptation for micromanagement.[42] Striking a balance will require updated doctrine on information flow: deciding what data is filtered upward and what decisions are delegated.

C2 networks themselves will need upgrades to handle the influx of data from enhanced warfighters, far beyond the current state. Bandwidth and security become even more critical. A compromised BCI deployment could not only disrupt comms but potentially manipulate a soldier's perceptions. The specter of an enemy hacking into an AR feed or a brain implant introduces new command vulnerabilities.[43] Protecting the integrity of orders and information is even more paramount. Enhanced command links will likely be hardened with encryption and fail-safes (for instance, a quick way to disconnect implants or shut off certain feeds if hacking is suspected). Another C2 consideration is ethical command responsibility. If commanders are ordering the use of enhancements (like issuing drugs to troops before a mission to suppress fear or pain), those commanders carry a new kind of responsibility for their soldiers' well-being. Military law and regulations might evolve to cover misuse of enhancement, for example making it a punishable offense to compel subordinates to undergo risky enhancements without proper authorization or to override a soldier's right to refuse in certain cases. Commanders will need training on the legal and ethical aspects of deploying enhanced capabilities, ensuring they respect the boundaries of soldiers' autonomy as much as possible in a military setting.[44]

Any change in C2 lands on people: who we recruit, how we train, what risks we ask them to carry, and how units cohere under stress. We conclude with the human factors that will determine whether augmentation helps or hurts the force.

05 – Human Factors

The advent of human enhancement technologies will influence who is recruited into the military, how they are trained, and how they are managed throughout their careers. Personnel selection might broaden in some ways and narrow in others. On one hand, certain physical requirements might become less stringent if technology can compensate. A recruit who lacks in strength might still be viable for a mission if an exoskeleton will provide lifting power. This could open the door to talented individuals who previously might have been excluded by strict physical standards.[45] On the other hand, some enhancements may require screening for compatibility; for example, not everyone may neurologically tolerate a BCI implant or the side effects of a cognitive enhancer. The military might screen for traits like neural resilience or genomic markers if planning to apply gene therapy (raising sensitive questions about genetic selection). Psychological robustness will also be key – those who receive enhancements might need the mental fortitude to handle changes to their body or new sensory inputs. Recruiting could involve aptitude for augmentation as a factor, potentially assessed through advanced testing.

Training would evolve dramatically with these technologies. Current state VR training can immerse recruits in realistic scenarios from day one, accelerating skill acquisition. Complex tasks could be taught through AR overlays. If BCIs advance, there is the prospect of downloadable knowledge – perhaps using neurostimulation to reinforce certain training or simulate experiences. Even without that, enhanced cognitive function from nootropics might help trainees absorb and retain information faster. The result could be shorter training pipelines or higher proficiency at graduation. Training will also be needed for the enhancements themselves: soldiers must learn to use exoskeletons tactically (not just wear them, but leverage them in movement and combat drills), learn to fight with AR (avoiding distraction, trusting the data), and practice operating in both enhanced mode and without. This dual-training approach ensures baseline warfighter skills remain if the gadgets go down. For instance, an infantry unit might train clearing a building with IVAS AR cues, then repeat the drill with IVAS off to ensure they're not wholly dependent.

Introducing human enhancement technologies will also affect soldier identity and teamwork. For some, being augmented might be a source of pride. It could boost morale if handled as an elite capability. However, if mishandled, it could create resentments or divisions. Those with enhancements might be seen as different by those without. The military will have to guard against a tiered force of augmented vs "regular" troops that undermines unity. This might be addressed by equitably distributing enhancements when practical, or rotating personnel through augmentation programs, so it's not a permanent class system.[46] Another morale factor is trust in equipment. Incremental introduction with plenty of feedback loops following current standards for assessing quality and reliability of equipment should be maintained, soliciting warfighter feedback and evolving programs through data gathered.[47] Continuing that practice, the military should incorporate soldier input on comfort, usability, and even ethical comfort.

Taken together, these operational realities intersect with, and are bounded by, ethical, legal, and strategic considerations. The following section addresses those constraints and the policy choices they imply.

Legal Challenges

The rapid emergence of human performance enhancement technologies exposes deep cracks in the legal frameworks that govern military conduct. Neither U.S. statutes nor international law were designed to anticipate soldiers equipped with neural implants, genetic modifications, or bio-integrated systems. As a result, militaries face a widening legal vacuum in which traditional doctrines offer little guidance on command authority, liability, or the permissible use of enhancements in conflict. Competitor nations may exploit this ambiguity to advance capabilities without constraint, while the United States must balance its adherence to rule of law with the strategic imperative to innovate. This tension underscores the urgent need for doctrinal clarity, updated treaties, and interoperable standards with allies.

This section examines **three key Legal Challenge areas** that complicate the governance of military augmentation.

L1 – Consent and Command Authority

The advent of human augmentation in the military raises difficult questions about soldiers' autonomy and the limits of command authority. Unlike acquiring a new weapon or armor, augmentations blur the line between equipment and the soldier's own body and mind. International law provides some baseline: for instance, Additional Protocol I to the Geneva Conventions prohibits medical procedures not indicated by a person's health "regardless of the consent of the person concerned."[48] In other words, even voluntary enhancements may breach the law if they are not medically necessary and consistent with accepted standards. This underscores the need for genuine informed consent in any augmentation program. Yet true voluntariness can be problematic in hierarchical military structures, especially if declining an enhancement might sideline a soldier's career. As legal scholars Dinniss and Kleffner observe in the seminal *Soldier 2.0* report, modern volunteer forces (like that of the United States) are under extra pressure to respect their members' human rights in order to attract and retain talent.[49] This implies U.S. military leadership must be cautious that orders to undergo augmentation do not amount to coercion.

Some allied defense ethicists have gone so far as to recommend forbidding any cognitive enhancements that could impair a soldier's freedom of conscience in carrying out orders, emphasizing the primacy of free will.[50] Guidelines G13 and G14 of the "Opinion on the Augmented Soldier" report released by the French Ministry of Armed Forces Defence Ethics Committee stipulated that the French military must "prohibit any cognitive augmentation of soldiers that would affect the free will they must have in firing action" and "prohibit any augmentation which could lead a soldier to overstep the bounds of their disciplinary obligations."[51]

Commanders will also need to consider how augmentations might affect a soldier's mental privacy and agency. Brain-computer interfaces or neuro-enhancing drugs could theoretically enable monitoring or even manipulation of soldiers' thoughts and moods. A compelling scenario is described by Denisa Damian: imagine a thought-controlled neural implant that is hacked by an adversary – the augmented soldier could be "coerced into performing actions against their will" effectively becoming a puppet of the hacker.[52] This is not just a cyber-security vulnerability but a profound threat to personal autonomy and lawful command. The U.S. military will need robust safeguards (both technical and legal) to ensure that augmented personnel remain in control of their actions and that superiors cannot exploit enhancements in ways that violate privacy or human dignity. In sum, maintaining informed consent, bodily autonomy, and mental integrity of warfighters is essential if human enhancement is to align with American legal values and the military's ethical standards.

While questions of consent determine whether and how individuals can be subjected to enhancement, the distribution of those enhancements across the force raises a second challenge: the risk of creating structural inequities. Even fully voluntary programs could unintentionally divide the military into augmented and unaugmented classes, with long-term implications for cohesion and morale.

L2 – Doctrinal and Legal Gaps

Introducing transformative human enhancements could outpace current military doctrine and legal frameworks, creating dangerous gaps. U.S. and NATO military doctrine will need revision to account for soldiers who might fight longer, learn faster, or even interface directly with autonomous systems. Indeed, a U.K.-led study on human augmentation warns it "may lead to fundamentally new concepts of warfare," potentially altering force structure and doctrine significantly.[53] For example, if certain troops no longer require sleep or can communicate telepathically via brain links, traditional concepts of unit rotation, command-and-control, and even esprit de corps might be upended. The U.S. Armed Forces will have to update training and operational planning to integrate augmented and non-augmented soldiers smoothly. Without doctrinal adaptation, augmentation could cause confusion in the field ("doctrinal breakdown"), as old tactics may not fit new human capabilities. There is also the prospect of adversaries developing "counter-human augmentation" measures – for instance, weapons or electronic warfare aimed specifically at crippling augmented functions – which U.S. doctrine must be ready to anticipate.[54]

Legal norms are similarly playing catch-up. At present, no arms control treaty directly addresses human enhancement technology, yet these tools could challenge the spirit of existing laws of war. The law of armed conflict (LOAC) traditionally regulates weapons and tactics to ensure humanity and distinction; the question is how, if at all, enhancements should be classified under these rules. Any nation which is a party to the Additional Protocol I (AP I) of LOAC is "under an affirmative obligation to determine whether the study, development, acquisition or adoption of a new weapon or means and methods of warfare would be prohibited under the Protocol or any other rule of international law applicable to that State." Despite not being a party to AP I, the United States has a very similar review process for all new weapons or means and methods of warfare. Dinniss & Kleffner's *Soldier 2.0* legal review argues that the augmentation technology itself may be considered a new weapon but it is unlikely that the person with it would be considered a new weapon and be required for review.[55] In other words, if human enhancement technologies were to emerge as organizational features of, and techniques for, weapons and military units to deliver force against opposing armed forces and military objectives, they will trigger the review obligations under Article 36 of AP I and/or under domestic regulations.

It is currently unclear how augmented humans in a military context would be treated under either International Humanitarian Law or Human Rights Law. Would a biologically enhanced human be considered a biological or biochemical weapon in a military context under the Biological Weapons Convention (ratified by the United States in 1975 under President Ford)? It is likely that these new enhancements may need to be defined as weapons or a means or a method of warfare amidst much debate in academia. For enhancements that do not themselves apply force (such as sensory or cognitive augmentation) many commentators treat these as personal equipment, not as a weapon or a method of warfare: the causal agent of harm remains the combatant using separate weapons.[56] By contrast, technologies that directly apply or amplify force or that integrate decision-making into technical systems (such as powered exoskeletons or brain–computer interfaces that control weapon functions) are more plausibly characterized as means of warfare, triggering states' Article 36 review obligations and the general prohibitions on weapons that are indiscriminate or cause superfluous injury or unnecessary suffering. However this becomes more complex and ill-defined in the event of more recent enhancement technologies such as exoskeletons and brain-computer interfaces: if an augmented soldier inflicts excessive suffering (due to, say, a strength enhancement used in close combat), is the technology to blame or the individual?[57] Such hypotheticals expose grey areas in accountability.

Nevertheless, current legal opinion suggests that existing accountability mechanisms "are unchanged with respect to deaths that involve" enhanced soldiers.[58] In practice, this means an unlawful killing by an augmented fighter is still prosecuted as a war crime; augmentation is no excuse for breaches of discipline or law. But assigning responsibility can get murky if a device malfunction or remote hack was a contributing factor. Who is liable if a neural implant glitch leads a U.S. soldier to mistakenly fire on civilians – the soldier, the commander, the device manufacturer? These accountability asymmetries between human and machine actors are not yet resolved in law or policy.

Domestic law and military regulations must also evolve. Consider the ownership and personhood issues associated with permanent augmentations. U.S. service members receive government-issued gear, but if that gear is fused with their body (e.g., a cybernetic arm or a brain implant), does it remain government property or become part of the person?[59] Jurisdictions differ on the ownership of implanted medical devices and even the data they collect. The implications are significant: upon separation from service, can the military order an ex-soldier to return or disable an augmentation? Or would forced removal violate that veteran's bodily integrity and health rights?[60] Dinniss and Kleffner highlight that there may be a distinction between explantable prosthetics (which might be retrieved) and truly integrative enhancements that effectively become an inseparable aspect of the individual.[61] The U.S. has yet to articulate clear policy here.[62] Additionally, if enhanced personnel are to re-enter civilian life, laws against discrimination will need updating to protect these individuals – akin to protections for people with disabilities, but in this case for people with *augmented* abilities.[63] Leading U.K. bioethicists have even recommended amending human-rights laws to explicitly include the rights of augmented persons.[64]

These doctrinal and legal blind spots also open the door to vulnerabilities that adversaries or malicious insiders could exploit. Without clear rules and secure systems, the same technologies designed to enhance capability could be subverted through biohacking or other insider threats.

L3 – Privacy and Data Concerns

As human augmentation technologies integrate deeper into the cognitive and neurological systems of U.S. warfighters, questions of privacy and mental sovereignty emerge as critical yet underdeveloped dimensions of military ethics and law. Unlike traditional data privacy, which concerns external behaviors or communications, augmentation introduces the possibility of extracting, interpreting, or even manipulating an individual's internal mental states.[65] Brain-computer interfaces (BCIs), biometric wearables, and neural feedback loops can collect vast streams of data, ranging from stress levels to decision-making patterns, that were previously inaccessible. These systems may record not only *what* a soldier does, but *how* they think and feel in the moment of action. This shift challenges longstanding American legal and constitutional assumptions about the boundary between the self and the state.

The United States currently lacks legal doctrines that explicitly address the privacy of thought or emotional inference. While the Fourth Amendment protects against unreasonable searches and seizures, its application to real-time neurodata collected during combat or training is unclear.[66] If a BCI embedded in a U.S. soldier detects signs of hesitation before a lethal decision, who owns that data? Can commanders use it in performance evaluations or to preemptively remove someone from duty? These are not theoretical questions. Indeed, Damian notes that once militaries deploy neural augmentation at scale, "mental privacy" becomes a strategic vulnerability as well as a personal right.[67] In the absence of statutory protections or established jurisprudence, augmented personnel could be subject to intrusive forms of surveillance that exceed both ethical norms and public expectations of bodily integrity.

Beyond voluntary military applications, there are implications for how augmented individuals might be surveilled or profiled by state and private actors after service. The U.K. Neurotechnology Innovation Network notes that augmentation data is not merely medical – it can become behavioral, emotional, and political.[68] If private employers gain access to performance-enhancement data or stress-resilience metrics from veterans' implants, the result may be a new form of algorithmic discrimination. This mirrors debates already seen in the commercial wearable space, where biometric tracking has prompted lawsuits over consent and employer overreach.[69] The same risks are magnified in the case of invasive or long-duration military augmentations.

In the military context, commanders and medical personnel may have legitimate reasons to monitor augmentation outputs such as ensuring implant safety, detecting fatigue, or preventing psychological breakdown. Yet the absence of clear limits on that monitoring opens the door to abuse. Consider the potential for predictive models based on neural data: a commander might receive a real-time alert that a soldier's cognitive state resembles that of someone who previously disobeyed orders. Would acting on that alert be a justified precaution or a violation of due process? Even in extraordinary, wartime scenarios, military necessity must be balanced against the individual rights of service members.[70] The more granular and predictive augmentation data becomes, the greater the risk that mental privacy will erode in practice, even if not in doctrine.

From a national security standpoint, the protection of neural and biometric data is not only an ethical imperative but a counterintelligence priority. If adversaries gain access to U.S. warfighters' cognitive profiles, emotional baselines, or decision-making patterns, they may be able to craft disinformation, social engineering attacks, or targeted coercion strategies. This is not far-fetched: as the *Soldier 2.0* report notes, the increasing connectivity of augmented systems introduces "a new plane of vulnerability."[71] Commanders and policymakers must recognize that the mind, once networked and integrated, becomes part of the battlespace. Unlike physical wounds, breaches of mental integrity may not be visible but can still be operationally catastrophic.

Societal Challenges

Beyond doctrine and operations, the integration of human performance enhancement technologies raises profound societal questions about identity, equity, and legitimacy. Military use of augmentation will inevitably spill over into civilian life, shaping public trust in institutions and altering perceptions of what it means to serve or even to be human. In democratic societies, skepticism toward invasive technologies is amplified by fears of coercion, inequitable access, and erosion of personal autonomy. These concerns can influence recruitment, retention, and the social contract between the armed forces and the populations they protect. In contrast, authoritarian regimes may face fewer domestic constraints but risk global backlash. For the United States, navigating societal expectations will be as critical as managing battlefield advantage.

This section explores the **two principal Societal Challenge areas** that will define the long-term acceptability and legitimacy of military augmentation.

S1 – Equity / Augmented Class Formation

Human augmentation technology also prompts concerns about equity, both within the military ranks and in society at large. If only select elite units or richer militaries can afford cutting-edge enhancements, it may create a two-tier force of augmented "super-soldiers" and unaugmented troops. This could undermine unit cohesion and morale, as well as raise difficult questions about fairness in promotions and assignments. Back in civilian life, Dinniss and Kleffner note that if enhanced veterans appear to threaten the employment prospects of unaugmented civilian workers, a societal tendency to marginalize or discriminate against them may emerge if their abilities are viewed as unfair or destabilizing in competitive labor markets.[72] This risk is compounded by uncertainty over whether enhancement-based discrimination would qualify for legal protection under existing human rights instruments, which generally do not name "augmentation status" as a protected category.[73] Conversely, we must also consider the flip side: augmented individuals might form an advantaged class with better access to jobs or benefits, exacerbating social inequalities.

Globally, unequal access to human augmentation could widen power disparities between nations.[74] Advanced militaries investing heavily in bio-enhancements and brain-machine integration could gain a significant edge, potentially leaving others behind. Some analysts even foresee a new form of inequality on the world stage where victory is determined less by army size than by the technological quality of soldiers.[75] Wealthy states (or factions) able to produce augmented personnel might attain what we might call "bio-supremacy," or a superior class of warfighters that creates pressure on others to respond in kind.[76] Such a scenario risks fueling arms-race dynamics (akin to nuclear or AI races) but centered on human enhancements.[77] To prevent a bifurcation of humanity into the augmented and the rest, international norms or agreements may be needed. The United States, with its diverse all-volunteer force, has an interest in promoting equity in augmentation access and avoiding any perception that enhanced soldiers are a separate, privileged caste. This includes carefully managing how veterans with permanent augmentations are treated in the long term (in healthcare, employment, etc.), so that embracing new technology does not unintentionally harm the very people it is meant to help.

Addressing equity concerns is only part of the equation. Many of the most consequential issues such as how augmented personnel fit into existing rules of engagement, or how international law treats their use fall into areas where doctrine and legal precedent have yet to catch up with technological reality.

S2 – Biohacking / Insider Threats

As militaries integrate advanced neurotechnologies, implants, and wearable interfaces into human performance enhancement, the battlefield increasingly includes not just physical domains but also the biological and cognitive integrity of the soldier. One of the most pressing and under examined risks in this context is biohacking: the malicious manipulation or unauthorized modification of augmented human systems. Prominent scholars in the field warn that augmentation makes the human body "hackable," transforming soldiers into targets not only of kinetic attacks but of cyber-infiltration, social engineering, and neurological compromise.[78]

The technical feasibility of hacking brain-computer interfaces (BCIs) and other networked augmentations is not purely speculative. Military-grade neurotechnology, such as cognitive enhancers, sensory augmenters, or neuromodulatory implants, will inevitably rely on wireless data transmission, firmware updates, and interaction with battlefield networks. Each of these interfaces presents a potential vulnerability. A successful breach could allow a hostile actor to manipulate behavior, access mission data, or even induce physiological changes.[79] This could lead to the U.S. needing to grapple with tricky ethical questions such as: if the BCI of a U.S. soldier were hacked and used to coerce that individual into unlawful or destructive acts, would the state be prepared to kill one of its own?[80] The ethical stakes are compounded by the strategic ones: such a breach could not only jeopardize operational success but also undermine public trust in augmentation programs themselves.

The threat of biohacking also magnifies insider risk. Soldiers, contractors, or private-sector technicians with advanced knowledge of neural or bio-enhancement systems could modify or repurpose those systems without authorization. In an era when "do-it-yourself" biohacking communities already exist outside the military, it is conceivable that warfighters or specialists might augment themselves in ways that exceed, evade, or compromise official oversight.[81] This creates a novel insider threat vector: personnel whose bodies or minds have been modified outside chain-of-command authorization, potentially introducing uncontrolled variables into operations.[82] As noted by the U.K. Government, countries do not have a comprehensive framework to monitor augmentation after deployment, raising concerns about how off-duty or ex-service individuals might repurpose residual enhancements in unpredictable ways.[83]

The civilian domain presents parallel vulnerabilities. If neurostimulation implants designed for mental health treatment were co-opted by adversarial actors, it could open a new front of digital warfare targeting civilian populations.[84] In such a scenario, the distinction between military and civilian targets would blur, as neural implants become conduits for coercion, propaganda, or psychological destabilization.[85] Moreover, there is currently no robust infrastructure of surveillance, criminal law, or cybersecurity tailored specifically to the protection of augmented humans.[86] While the Food and Drug Administration provides some guidance on the cybersecurity of medical devices, these protocols were not designed for adversarial military environments or for high-intensity conflict zones where hostile state actors may directly target cognitive hardware.[87]

The legal frameworks surrounding biohacking in this context are deeply underdeveloped. It remains unclear how international humanitarian law (IHL) would treat the hacking of an augmented soldier – for instance, whether it would constitute a prohibited form of perfidy or an indirect attack on command and control structures.[88] The Geneva Conventions are largely silent on the neuro-cyber domain.[89] Domestically, U.S. law does not yet define what legal protections apply to "mental privacy" or what liability the Department of Defense would incur if a compromised augmentation system led to wrongful harm.[90]

Equally troubling is the absence of a "kill switch" or standardized containment mechanism in current augmentation concepts.[91] Unlike a malfunctioning drone or corrupted software system, an augmented human cannot simply be rebooted or wiped without breaching fundamental ethical and legal boundaries.[92] Once integrated into the warfighter's neurology, certain technologies may be irreversible – making prevention and anticipatory regulation the only ethically defensible approach.

For the U.S. military, addressing this challenge will require a multi-layered strategy. This includes not only hardening the cybersecurity of augmentation systems but also extending insider threat protocols to cover unauthorized physiological modifications.[93] DoD should explore parallel legal regimes akin to export controls or controlled substances for regulating access to powerful augmentation technologies, especially within special operations and contractor communities.[94] Additionally, there is a compelling need to define new norms for mental sovereignty and augmented cognition under both U.S. constitutional law and the law of armed conflict.[95]

Biohacking is not just a technical glitch: it is a strategic vulnerability, an ethical frontier, and a test of whether the United States can protect its most advanced capabilities when those capabilities are fused with the human body.[96] Preventing unauthorized modifications is only one facet of safeguarding augmented forces. Even authorized systems will collect unprecedented volumes of biometric, neurological, and performance data, creating new privacy and mental sovereignty concerns that must be addressed before such technologies can be trusted in operational environments.

The operational challenges outlined in the previous section highlight the internal frictions the U.S. military will face when integrating human performance enhancement (HPE) technologies. Equally important are the *external guardrails*:

the legal boundaries, policy frameworks, and public acceptance factors that will determine whether these capabilities can be fielded at all, and under what conditions. Even the most technically mature or tactically promising enhancement may be rendered unusable if it conflicts with existing law, violates alliance commitments, or erodes domestic legitimacy. In this respect, the adoption of HPE is as much a question of governance and societal consent as it is of military innovation.

Policy Recommendations

The priority, as with any technology dealing with human bodily autonomy, must be to ensure that these technologies are secure, protecting both the individuals who use them and the systems they interact with from potential cyberattacks. We propose **eight major policy reforms** to address the coming challenges with human augmentation for military purposes.

Table 3: Overview of policy recommendations

1. Double down DARPA-led augmentation research paired with threat assessment, mitigation review board
2. Surge Investment in Priority Augmentation R&D
3. Establish an Integrated Interagency Augmentation Initiative
4. Forge Public-Private Partnerships for Innovation
5. Build a Talent Pipeline for the Bio-Digital Force of the Future
6. Establish and Promote Ethical Red Lines Through Allied Frameworks
7. Integrate Ethics as a Battlefield Advantage in Augmentation Design
8. Establish a Leadership Position in International Norms and Governance

The challenges identified in the preceding chapters make clear that successful adoption of human performance enhancement (HPE) technologies in U.S. defense will require more than acquiring the right tools; it will demand a coordinated strategy that integrates technology, doctrine, law, and public engagement.

Operational hurdles must be met with targeted capability development and training reforms; legal and societal constraints must be addressed through clear governance frameworks and transparent communication. The following recommendations are designed to bridge these domains, sequencing immediate actions to enable safe pilot programs while laying the groundwork for longer-term institutional, legal, and cultural adaptation. Taken together, they chart a pathway for the United States to lead in HPE adoption in a manner that safeguards warfighter welfare, maintains public trust, and preserves strategic advantage over competitors.

Table 4: Mapping of policy recommendations with the addressing of operational, legal and social challenges

	O1 - Readiness	O2 - Deterrence	O3 - Interoperability	O4 – C2 Dynamics	O5 – Human Factors	L1 - Consent	L2 – Legal Gaps	L3 – Privacy	S1 - Equity	S2 – Insider Threats
Recommendation 1 - DARPA-led Research	✓	✓		✓						
Recommendation 2 - Augmentation R&D Investment	✓	✓			✓		✓			
Recommendation 3 - Augmentation Initiative			✓	✓		✓				
Recommendation 4 - Innovation PPPs	✓				✓					
Recommendation 5 - Build a Talent Pipeline					✓				✓	
Recommendation 6 - Ethical Frameworks						✓		✓		✓
Recommendation 7 - Ethics in Augmentation Design								✓	✓	✓
Recommendation 8 - International Norms and Governance							✓	✓		

Recommendation 1 - Double down on DARPA-led augmentation research but pair it with a cross-branch threat assessment and mitigation review board

The Trump administration should continue to fund next-gen human enhancement research as a major security arena for geotechnological competition and dominance via DARPA, DIU and private-sector primes (discussed earlier). There is a growing need for a review body to ensure prevention of augmentation development misuse, select for reliability and identify augmented-adversary countermeasures. This body should be drawn from across the different branches and comprise the following:

- Representatives from ARPA-H
- Joint Strategic Operations Command
- Cyber warfare experts from NSA and CYBERCOM, tasked with identifying digital vulnerabilities in BCIs, implants, and augmented behavioral systems, as well as mapping adversarial capabilities in offensive neurocyber warfare.
- Private-sector augmentation contractors (for example, Synchron or Paradromics for BCIs), invited under NDA, to expose potential exploit paths and reliability failures in proprietary systems
- Strategic foresight analysts drawn from the intelligence community to test scenario vulnerabilities, adversary mimicry potential, and counter-augmentation doctrine development.

Recommendation 2 - Surge Investment in Priority Augmentation R&D

To maintain U.S. leadership in human augmentation and counter rapidly advancing efforts by strategic competitors, the federal government must significantly scale investment in priority research and development areas. This includes high-impact technologies such as neural interfaces, advanced prosthetics, genetic resilience tools, and exoskeletons.

- **Action:** Accelerate research and development in key human augmentation technologies to maintain a competitive edge. This includes significantly increased funding for programs in brain-computer interfaces, neurotechnology, genetics and biotech, advanced prosthetics, and exoskeletons.

- Agencies like DARPA, NIH, and the new ARPA-H should coordinate to target breakthroughs (for example, DARPA's work on neural interfaces and prosthetics can synergize with ARPA-H medical research).
- Budgetarily, this is viable with moderate increases; Congress has shown willingness to fund cutting-edge defense tech, especially if framed as part of the China competition (e.g., DARPA's budget could be bolstered, and ARPA-H's mandate broadened to include warfighter health enhancements).
- Federally funded breakthroughs can be transitioned to the Services (for operational prototyping) and shared with allies (through NATO cooperation in science and technology. Note: NATO's new €1B innovation fund cites human enhancement as a focus).[97]
- This investment directly counters adversaries' strides – if China is racing ahead on CRISPR for soldiers, the U.S. should fund safe-genetics research (e.g., gene therapies to enhance soldier health or counter enemy bio-augments) to avoid a tech gap.
- It will spur American innovation and help set standards (the U.S. leading in patents and intellectual property).

Recommendation 3 - Establish an Integrated Interagency Augmentation Initiative

Because human augmentation spans health, defense, tech, and ethics, a whole-of-government approach is needed. We recommend establishing a National Human Augmentation Initiative (or task force) led by the White House (NSC/OSTP) that brings together DoD, Department of Health and Human Services (including NIH and FDA), the Department of Energy (which oversees national labs on biotech), and others (NASA, VA, etc.) to coordinate efforts.

- **Action:** Sign an executive action – building on the 2022 National Biotechnology Initiative which already called for NSC coordination and leveraging of diverse stakeholders.[98] Once a framework is in place domestically, it can be extended to allies – for instance, a U.S.-NATO working group on human performance or a Quad (U.S.-Japan-Australia-India) dialogue on biotech security.

- A unified approach means military needs (say for an endurance drug) inform NIH research priorities, and civilian breakthroughs (like a new brain implant) can be quickly evaluated for defense use. It avoids siloed efforts and duplicative spending. Better interagency coordination will also strengthen regulatory preparedness – the FDA and DoD can jointly plan how to fast-track safe augmentation tech for troops, avoiding delays. Importantly, an interagency body can formulate cohesive policy and messaging to the public and international forums, ensuring the U.S. speaks with one voice on contentious topics.
- This coordination directly addresses issues like dual-use oversight (linking DoD intelligence with Commerce export control to monitor foreign attempts to acquire U.S. tech). It also improves resilience: for example, if an adversary fielded a novel enhancement, a coordinated U.S. team (with DoD, intelligence, CDC, etc. under one roof) could rapidly respond – be it a countermeasure or an acceleration of our own program.

Recommendation 4 - Forge Public-Private Partnerships for Innovation

Many of the breakthroughs in human augmentation will come from outside the traditional defense establishment – academia, startups, biotech firms, and tech giants. The U.S. government should actively partner with the private sector to harness this innovation and keep it onshore.

- **Action:** Expand DoD programs that engage non-traditional vendors (such as DARPA's open challenges, DIU's commercial solutions, and In-Q-Tel investments) specifically in augmentation technologies. Create innovation incentives – for example, a prize competition for a lightweight exosuit that meets military requirements, or grants for companies developing dual-use neurotech. Enhance information-sharing and joint R&D: DoD could establish cooperative research centers (perhaps a "Human Augmentation Research Center of Excellence") where military researchers work alongside industry and university experts on government-funded projects.

- Organizationally, this builds on existing models (the Army's xTech competitions, AFWERX, etc.). Funding can come from small reallocations within RDT&E budgets to pilot these partnerships. The political environment is supportive of public-private collaboration, especially to out-innovate China.

- Success in pilot projects can lead to larger programs – e.g., if a startup develops a promising brain-interface helmet, the Army can scale it via rapid contracting. Alliances matter here too: incorporate allied high-tech firms and researchers into these efforts (for instance, a joint U.S.-Israel program on prosthetics, leveraging Israel's biotech sector, or involving European labs that are world-class in neuroengineering).

- This strategy injects Silicon Valley agility into military modernization. It helps the U.S. field cutting-edge augmentation tools faster than a purely internal effort. A recent example is telling: After Microsoft's faltering development of AR combat goggles, the Army turned to defense-tech startup Anduril, whose founder announced a "new path in human augmentation" to deliver an improved IVAS and integrate it with autonomous systems.[99] Tapping such entrepreneurial energy is crucial. Public-private partnerships also shore up our industrial base – they ensure American companies lead in the production of critical augmentation hardware and software, rather than ceding that to foreign competitors.

- If the U.S. detects an adversary breakthrough, we can rapidly mobilize the private sector's ingenuity to respond (similar to how private pharma raced to produce vaccines). On the opportunity side, many civilian tech advances (AR/VR for the metaverse, wearable health trackers, AI assistants) can be spun into military applications with minimal adaptation if lines of collaboration are open. By partnering widely, the U.S. military essentially swarms the problem, leveraging the force of American innovation ecosystems to stay ahead in the augmentation race.

Recommendation 5 - Build a Talent Pipeline for the Bio-Digital Force of the Future

Winning in human augmentation requires not only technology but also skilled people – scientists, engineers, doctors, and warfighters – who understand and can implement these advances. The U.S. should enact policies to educate, recruit, and retain the necessary talent.

- **Action:** Expand scholarships, internships, and ROTC-like programs in fields related to augmentation (biomedical engineering, neuroscience, cybernetics). For example, a "Bioengineering for Security" fellowship could fund graduate students in biotech with a service commitment in defense labs or the Uniformed Services University.

- Enhance DoD's ability to attract top scientists: offer competitive grants and establish distinguished researcher positions focusing on human performance enhancement. Within the military, develop a career field or additional skill identifier for augmented operations – troops specially trained to use and maintain augmentation gear.

- The White House's 2022 Bioeconomy Executive Order already mandates expanding biotech training for Americans, providing a policy foundation and initial funding to build on. Congress and DoD could incorporate defense-specific talent initiatives under that umbrella (ensuring some of those trainees flow into national security roles).[100]

- A well-designed program can scale nationally – partnering with universities and technical schools across the country to create pipelines of tens of thousands of skilled workers in relevant disciplines. It can also prioritize diversity and inclusion to tap the widest pool of talent (as the EO suggests – outreach to underrepresented communities can grow the talent base).

- Talent is perhaps the most decisive factor in sustaining U.S. technology leadership. If we build a generation of American experts at the intersection of biology and defense, we not only out-innovate adversaries, we also insulate ourselves from their talent poaching. (It's worth noting that China's success in biotech is aided by aggressively recruiting global talent; we must outperform that by making the U.S. the premier destination for cutting-edge bio-tech work.)

Recommendation 6 - Establish and Promote Ethical Red Lines Through Allied Frameworks

The U.S. should take a leadership role to drive efforts with NATO, the Quad, and Five Eyes partners to define and adopt a shared set of *ethical red lines* on military human enhancement such as banning non-consensual experimentation, inheritable genetic modifications, and permanent augmentations without reversal protocols.

- **Action:** Direct the Department of Defense and Department of State to co-lead a multilateral ethics initiative under NATO's Emerging and Disruptive Technologies framework, leveraging the Defense Innovation Accelerator for the North Atlantic (DIANA) and NATO's S&T Board to begin drafting augmentation-specific ethical guidelines.
- Through the National Security Council and the Office of Science and Technology Policy, initiate a Five Eyes and Quad bioethics coordination mechanism to align ethical positions on military human enhancement and explore joint declarations or addenda to strategic documents (e.g., the NATO Strategic Concept or Indo-Pacific Quad statements).
- Task U.S. defense attachés and embassy science advisers to convene allied workshops on augmentation ethics, using France and the U.K.'s existing bioethics frameworks as starting points for consensus on red lines such as prohibitions on non-consensual enhancement.
- Use these allied commitments as the basis for naming and shaming adversaries that violate human rights in augmentation research, and link violations to diplomatic tools such as Magnitsky-style sanctions, multilateral export controls, or joint intelligence designations of unethical foreign programs.

Recommendation 7 - Integrate Ethics as a Battlefield Advantage in Augmentation Design

Rather than treating ethics as a constraint, the U.S. should design augmentation systems that embed transparency, consent, and reversibility from the outset. This "ethics-by-design" approach strengthens operator trust, interoperability with allies, and legitimacy in the eyes of the international community. It also counters adversary narratives that only authoritarian regimes can innovate at speed.

- **Action:** Institutionalize ethics-by-design principles such as reversibility, informed consent, and long-term accountability across all U.S. military human augmentation R&D programs.

- The Department of Defense already incorporates ethical review in emerging tech (e.g., AI and autonomy), providing a governance foundation that can be adapted to bio-enhancement.
- FDA medical device regulations and HIPAA-informed health data protections offer regulatory scaffolding for embedding reversibility and mental privacy safeguards.
- DARPA's history of operationalizing responsible innovation (such as in Safe Genes and N3 programs) shows that ethics and speed are not mutually exclusive.
- Allies such as the U.K. and France explicitly center ethics in their national human enhancement policies; embedding ethics early improves allied interoperability.
- By showcasing ethical safeguards in public R&D programs and international forums, the U.S. can reframe democratic values as a *strategic asset*, not a liability, undercutting the narrative that coercion is required to compete in warfighting innovation.

Recommendation 8 - Establish a Leadership Position in International Norms and Governance

The U.S. should proactively shape global norms, standards, and perhaps formal agreements on human augmentation to reflect democratic values and reduce risks of destabilizing arms races.

- **Action:** Launch a diplomatic initiative – possibly under the P5 at the U.N. or through NATO – to begin crafting guidelines on military human enhancements. This could echo past arms control efforts: for example, exploring an agreement to prohibit certain inhumane augmentations (akin to how chemical/biological weapons are banned) or at least a transparency regime for biomedical enhancements.
- While a full treaty may be premature, U.S. leadership in convening discussions is feasible and sends a strong signal. Allies like the U.K., France, and Germany are likely partners, since their own studies emphasize aligning augmentation with international law and ethics.

- Starting with like-minded nations (NATO/EU, Australia, Japan), the U.S. can build a coalition to later engage Russia and China in dialogue. Even if rivals won't agree to strict rules now, establishing normative red lines – e.g., no genetic modifications that are inheritable, no non-consensual experimentation – creates moral pressure.
- By leading on norms, the U.S. can blunt adversary propaganda about its programs. The U.S. should also push for updating relevant laws: ensure the laws of armed conflict evolve to cover augmented soldiers (to clarify status and protections), and update export control regimes to address augmentation tech as a category (multilateral export controls on critical biotech could slow rogue state progress).
- Setting norms now prepares us for future scenarios – e.g., if brain-to-brain communication progresses through to proliferation, we might need protocols akin to how we treat POWs or novel weapons. Leading the conversation early means the U.S. can embed its security interests (preventing horrific abuses or first-use of dangerous enhancements) into the global framework before others do.

Annexure

Table 5: Major Government HPE Programs

Nation	HPE Program	Description
United States	DARPA-led Military R&D	DOD requested $1.3 billion for biotechnology efforts in FY2023; the department did not provide a topline breakout of its request for biotechnology in FY2024.[101] DARPA's BTO funds NESD, N3, Safe Genes, ADAPTER; 3% of DARPA projects neurotech; FY2024 focus on survivability
	NIH/BRAIN Initiative	NIH and BRAIN Initiative fund BCIs, genomics, aging research; therapeutic advances applicable to augmentation
	Service Programs & ARPA-H	Army (Soldier Lethality), SOCOM (exoskeletons), Air Force (fatigue countermeasures), ARPA-H (resilience-focused health R&D)
China	State-Backed National R&D	Brain Science mega-project ($0.5B-$7B), Made in China 2025 promotes biotech and AI, major public genomics funding
	Civil-Military Fusion	PLA's Academy and Tianjin University conduct augmentation research; pharmacological trials in PLA medical universities
	Industry & Provincial Support	Firms like Tencent, Alibaba invest in neurotech; provincial incubators support startups in prosthetics, wearables
Russia	Ratnik-3 Combat Suit & Soldier Gear	Ratnik-3 exosuit in armament plan; limited funding and sanctions slow progress; focus on future soldier gear
European Union	EU Funding Programs	EU supports robotics, BCIs, exoskeletons (e.g., HAL-5, neurorehab BCIs) via ICT, health, and security programs
	EDF Defense Research	EDF includes AR helmets, biomedical defense R&D; supports situational awareness and resilience tools
	National & Industry Initiatives	France (Hercule exo), Germany fund military R&D; Airbus, Thales lead dual-use AR and wearables via consortia
United Kingdom	DASA Competitions	DASA launched safe, ethical augmentation prototype competitions for U.K. military in 2021
	Academic R&D	ARIA and UKRI fund bioengineering, AI for augmentation and advanced R&D
Israel	Defense Ministry	MAFAT supports rehab and defense tech; ReWalk, BrainQ among startups with U.S. and global backing
Japan	Targeted Robotics & Brain R&D	METI funds robotic care suits, JST funds brain science; targeted rather than large-scale investment
South Korea	Wearable Robotics	Govt supports exosuits via Hyundai under 4th Industrial Revolution; strong robotics/AI backing

Private Investment figures are in Table 3 in the Annexure

Table 6: Private Sector Investment Categories in Human Enhancement Technologies

Sector	Key Players / Examples	Focus / Contribution
Venture Capital	Neuralink ($373M), Synchron ($70M+), Kernel, Neurable, Emotiv, NextMind	Investment surge in neurotech and BCI startups, enabling brain-reading and enhancing devices
Big Tech and Augmentation	Meta (CTRL-Labs), Google (smart contact lenses), Apple (health sensors)	Integration of digital augmentation tools for AR/VR, health monitoring, and cognitive interfaces
Exoskeleton Companies	Ekso Bionics, ReWalk, Sarcos Robotics, Toyota, Honda, Hyundai	Development of wearable exoskeletons for medical, industrial, and military applications
Biotech and Pharma	CRISPR Therapeutics, Editas, Intellia, pharma firms developing stimulants and gene therapies	Gene editing, cognitive enhancers, and muscle-strengthening drugs with enhancement potential

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