Echoes of War: Integrating Acoustics into the Operational Doctrine

Unmanned aerial systems challenge conventional defenses, cyber campaigns erode traditional boundaries, and now acoustics—long overshadowed by electromagnetic spectrum operations is emerging as a critical factor in modern warfare.

This once peripheral domain now demands reconsideration as an integral element of multidomain operations. The proliferation of low-signature platforms, increasing urban warfare scenarios, and the growing sophistication of peer adversaries necessitate an expanded understanding of the battlespace. One that includes acoustic sensing, disruption, and deception.

The joint force recognizes warfighting functions: mission command, movement and maneuver, intelligence, fires, sustainment, and protection—as foundational pillars guiding operational success.[1] These functions give us a system for which to evaluate acoustics on the battlefield and demonstrate how acoustics capabilities align. This offers a contemporary layer of situational awareness and non-kinetic effect to commander and warfighter. Whether through passive surveillance of mechanical noise, detection of underwater threats, or leveraging directed acoustic energy, the possibilities present commanders with novel ways to detect, disrupt, and defend.[2]

Moreover, the inclusion of acoustics in doctrine offers planners a more comprehensive view of the invisible battlespace, enabling improved synchronization across domains. The ability to monitor and manipulate the acoustic environment enhances decision advantage, situational awareness, and operational tempo. As our adversaries invest in counter-acoustic and sound-based technologies, the United States must critically assess its own approach to this emergent field.

This article posits that the time is right to formally consider acoustics as a doctrinal element of joint operations. Doing so may unlock strategic advantages across all warfighting functions which have become apparent in the increasing rise of acoustics by our allies and foes.

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[1] Joint Chiefs of Staff, *Joint Publication 3-0: Joint Operations*, October 2022.

[2] Jonas Kjellén, *Russian Electronic Warfare – The Role of Electronic Warfare in the Russian Armed Forces* (FOI, 2018), 14–15.

The Rise of Acoustic Battlespace

Acoustic technologies are rapidly shifting from niche applications to pivotal enablers in modern warfare. Though historically rooted in earlier military applications, acoustic operations are now actively shaping missions and altering the ways militaries complete kill chains and protect themselves.[3] This shift occurs along the continued primacy of the electromagnetic spectrum outside the aquatic medium, the longitudinal wave spectrum—or acoustic spectrum—has emerged at the forefront, with advanced sound-based systems offering new ways to detect troop movements, mask vehicle signatures, intercept, sense or obscure covert communications, and provide kinetic and psychological effects across the battlespace.[4] *In some cases, the acoustic spectrum can even be used to enable covert communications through low-probability-of-detection (LPD) modulation techniques, such as direct-sequence spread spectrum (DSSS) for underwater communications*.[5] Often operating in conjunction with cyber and electromagnetic methods, such developments empower commanders with enhanced situational awareness, allowing them to adapt tactics and exploit opportunities. Yet the doctrinal gap surrounding acoustic technologies persists. While current electromagnetic and electronic warfare concepts acknowledge emerging domains, formal guidance remains limited, constraining the full operational potential of acoustics.

In practice, this shortfall can lead to underutilized capabilities and missed opportunities to surprise or outmaneuver an adversary. Furthermore, a lack of standardized doctrine complicates interoperability—not only within the joint force, but also among allied partners—leading each service and ally to develop its own acoustic strategies in isolation. This fragmented approach creates exploitable seams, which adversaries can use to disrupt cohesion and gain advantage. To close these seams and unlock the full potential of emerging acoustic capabilities, codifying acoustic-related doctrine is essential. Unification provides a foundation from which commanders, tacticians, and innovators can develop capabilities to surprise both friend and foe. As advanced acoustic systems continue to evolve, their integration with existing electromagnetic and cyber capabilities, techniques, and tactics requires a well-defined operational framework to maximize utility. Without unified doctrine, acoustic sensing, targeting, and protection will remain underutilized—resulting in disjointed implementation across the force and undermining interoperability. Acoustics have shaped battles for centuries—now it's doctrine's turn to catch up.

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[3] Gerald Kidd Jr. and Christopher Conroy, "Auditory Informational Masking," *Acoustics Today* 19, no. 1 (2023): 29–37.

[4] Brian G. Ferguson, "Defense Applications of Acoustic Signal Processing," *Acoustics Today* 15, no. 4 (2019): 10–12.

[5] T. C. Yang and Wen-Bin Yang, "Low Probability of Detection Underwater Acoustic Communications Using Direct-Sequence Spread Spectrum," *Journal of the Acoustical Society of America* 124, no. 6 (2008): 3632–3647.

The Historic Role

The role of acoustics in warfare has been part of warfare since at least antiquity. Harkening in such texts as the bible with Jericho's use of trumpets and even by Alexander the Great's employment of swine and brass against enemy war elephants. A tactic later repeated by the Romans against Pyrrhus in 202 BC. Such weaponization and psychological use of acoustics resulted in physical effects, and often changing the tide of battle. Preceding the industrialization of warfare, most acoustic tactics target animals or manipulated the enemy's perception. However, with the onset of the World Wars acoustic methods evolved and began prioritizing the information advantage of intelligence and situational awareness that acoustics provided.[6]

World War II marked a turning point for acoustic warfare with the British Dowding System, the world's first truly integrated air defense network. Electromagnetic systems, such as the Chain Home RADAR, were synchronized with listening posts and sound mirrors into a centralized node. Resulting in the Royal Air Force and Air Defenses to rapidly concentrate fires against invading Luftwaffe aircraft. Arguably the decisive advantage that led to the allied victory during the Battle of Britain and paving the later victory over Nazi Germany.[7] As the enemy shifted and the cold war begin to chill, acoustics utility was not lost and became increasing prevalent in the naval environment. With NATO and Warsaw Pact alliances prioritizing acoustic surveillance to overcome the submarine, especially the nuclear submarine threat. The United States developing the sound surveillance system (SOSUS) in the 1950's. A system that evolved into the integrated undersea surveillance system (IUSS) and is still utilized to counter the prevailing submarine threat to the homeland. These global acoustic arrays are deployed world-wide and provide, to great effect, the capability to find, fix and track underwater weapon systems.[8] Eventually acoustic sensing technology began to be further developed for land use.

Originally used in archaeology, electrical resistivity tomography (ERT) and similar methods are now used to detect subterranean military infrastructure. Most recently the Israel Defense Force began employing acoustic sensors to map and destroy Hamas tunnel networks in Gaza, striking at a key operational center of gravity of Hamas.[9]

In addition to being sources of intelligence and protection, acoustics systems also are **offensive tools.** During the Cold War, as psychological warfare tool. From Huey missions flying propaganda missions, to sonic boom runs and false "Magnum calls" to suppress enemy air defenses the use of sound and human voice was utilized to cause hesitation in our enemy, resulting in a decisive advantage for the American Warfighter. This was later retooled and reused in various American conflicts to include the most recent Afghanistan and Iraqi conflicts, when low-fly passes of aircraft, typically fighter jets, and acting as a force multiplier for coalition forces. Even during the withdrawal of Afghanistan fighter jets flew low to medium altitudes shaking the buildings and nerves of the enemy forces. A warning to the enemy that engaging

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[6] Adrienne Mayor, "Battle Cries: How Ancient Soldiers Used Sound to Frighten and Confuse Their Enemies," *Big Think*, August 23, 2022, https://bigthink.com/the-past/battle-cries/, accessed March 31, 2025.

[7] Andrew Grantham, *Sound Mirrors*, accessed April 13, 2025, https://www.andrewgrantham.co.uk/soundmirrors/.

[8] Discovery of Sound in the Sea, "The Cold War: History of the Sound Surveillance System (SOSUS)," accessed March 20, 2025, https://dosits.org/people-and-sound/history-of-underwater-acoustics/the-cold-war-history-of-the-sound-surveillance-system-sosus/.

[9] Sales, Ben. "Using Seismic Vibrations, Israeli Firm Aims to Detect Gaza Tunnels." *The Times of Israel*, August 27, 2014. https://www.timesofisrael.com/using-seismic-vibrations-israeli-firm-aims-to-detect-gaza-tunnels/.

with U.S. forces during the withdrawal would come with consequences.[10] Though we controlled our enemies tactically with such minor acoustic bouts, this broad technology began being adapted against western forces in subtle ways.

Reports of Havana Syndrome, potentially linked to directed sonic-energy attacks, have raised concerns about acoustic threats to personnel. Though the U.S. government has not publicly confirmed hostile attribution, the persistence of these incidents demands attention, as it poses a threat to force protection. [11] Such auditory system attacks, like that used to disrupt the March 2025 anti-corruption protests in Belgrade, Serbia, could be escalated and wielded against massing forces in garrison or deployed.[12]

Evident upon further analysis, acoustic and electromagnetic system integration has been a consistent feature of 20th and 21st-century warfare. With the explosion of new technology, capabilities are emerging, and gaps are being highlighted that are driving the spectrum to be further integrated. Resulting in the necessity to understand and refine the merging of electromagnetic, cyber, and acoustic operations into one holistic spectrum approach to warfare in the invisible battlespace—one synchronized from the national, service, and operational level. Focusing on "...managing and operating within the information, acoustic, electronic, electromagnetic and cyber…" so that both the visible and invisible battlespaces may be synchronized to provide effective maneuver in the offense and defense. [13]

Across all domains of the physical, logical and invisible battlespaces of the spectrum, the joint force finds itself presented with many dilemmas and threats. However, none currently more so than force protection against the air threat presented by small and medium UAS. These UAS are widely distributed, low-cost, quickly mastered, survivable against traditional means, and heavily modifiable, which has resulted in the democratization of low intensity airpower to smaller units. This democratization and large quantity (mass) can further be employed asymmetrically, making them a threat to any modern military. Worsley—once mass drone swarm technology takes hold, it will present an increasingly difficult threat to intercept. [14]

To tackle the threat, synchroneity of operations in the physical, logical, and nonmaterial spectrum is a must. Small UAS (sUAS), for instance, can be kinetically destroyed with traditional air defense fires, but often this is not timely enough to coordinate or too costly to use on such a low-cost asset. Therefore, many forces have begun turning to electromagnetic warfare.

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[10] Kyle Mizokami, "In a Warning to the Taliban, U.S. Fighter Jets Are Buzzing Kabul," *Popular Mechanics*, August 19, 2021, https://www.popularmechanics.com/military/aviation/a37340603/us-fighter-jets-flyby-kabul-taliban-warning/.Popular

[11] U.S. Government Accountability Office, "Havana Syndrome—Americans Affected by Mysterious Symptoms May Struggle to Get Care," *WatchBlog*, July 29, 2024, https://www.gao.gov/blog/havana-syndrome-americans-affected-mysterious-symptoms-may-struggle-get-care

[12] Aleksandar Vasovic and Milan Pavicic, "Mystery Sound at Serbia Protest Sparks Sonic Weapon Allegations," *Reuters*, April 2, 2025, https://www.reuters.com/world/europe/mystery-sound-serbia-protest-sparks-sonic-weapon-allegations-2025-04-02/

[13] Zev McCarty, "On Spectrum Warfare," *Æther: A Journal of Strategic Airpower & Spacepower*, 2025

[14] Shaan Shaikh, Tom Karako, and Michelle McLoughlin, *Countering Small Uncrewed Aerial Systems: Air Defense by and for the Joint Force* (Washington, DC: Center for Strategic and International Studies, 2023), 12–16, https://www.jstor.org/stable/resrep54525.5.ra

However, this can be thwarted with advances in electronic protection, countermeasures, tactics, or simply altering the connection to a physical one, such as fiber optic cable—as seen in Ukraine. [15] This only increases the demand to layer more defenses to ensure force protection. In this reality**,** enters acoustics, tasked with enhancing situational awareness and defeat capacity of the commander**.** With systems such as those provided by Edge Sources: Dowding and Wind-talker acoustic systems—which utilize acoustic sensors to detect the distinct acoustic sounds of various sUAS. Sounds that have been collected or exploited from acoustic, cyber, and electronic means. Ultimately resulting in tracks displayed to air defenders and updated to the common operating picture. [16] A picture that allows for quick battle management and engagement (attack) from any means available—including acoustic. Acoustic attacks can disrupt the micro-electromechanical systems and rotor assemblies with focused resonance frequencies, causing inertial navigation systems and rotors to become unstable and leading to the targeted unmanned aerial systems' departure from coordinated flight**.** [17]

It has become evident that acoustic technologies have converged with electromagnetic, and cyber technologies to provide significant operational advantages. From intelligence gathering and battlespace preparation to real-time sensing, situational awareness, and kill chain completion, acoustics, cyber, and electromagnetic operations are intertwined from the start**.** Acoustics expands the commander's toolkit to shape the fight and is not an inhibitor, but a key enabler for the joint force. Thus, requiring a new approach to its integration in doctrine alongside cyber and electromagnetic warfare.

The current joint doctrine predominately incorporates acoustics within the *maritime domain* (e.g., sonar) or as part of a broader set of sensors. Less emphasis has been given to how acoustic technology can integrate or support other joint operations. Preventing synergy with electromagnetic or cyber methods, resulting in fragmented efforts or missed opportunities rather than a cohesive, unified spectrum approach.

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[15] Ukraine Discloses New Method to Defeat Russian Fiber-Optic-Controlled FPV Drones," TWZ, accessed March 20, 2025, https://www.twz.com/news-features/ukraine-discloses-new-method-to-defeat-russian-fiber-optic-controlled-fpv-drones.

[16] https://www.edgesource.com/wp-content/uploads/2023/09/Edgesource-Dowding.pdf

[17] Nielsen, P. E. (2012). *Effects of Directed Energy Weapons.* Middletown, DE: CreateSpace Independent Publishing Platform.

Joint Warfighting Function	Description	Acoustics in Doctrine
Command and Control (C2)	Direction and coordination of military forces to achieve mission objectives.	Acoustic data supports real-time situational awareness, but its use is incidental rather than systemic.
Intelligence	Collection, analysis, and dissemination of information about adversaries and operational environments.	Acoustic sensors are used for intelligence collection in anti-submarine warfare, artillery detection, etc.
Fires	Integration of weapons systems to deliver effects supporting operational goals.	Acoustic tools assist in fire support targeting, but focus remains on kinetic or electronic assets.
Movement and Maneuver	Positioning and mobility of forces for tactical or strategic advantages.	Not explicitly detailed in the context of acoustics within the current doctrine.
Protection	Safeguarding forces and assets from threats.	Acoustic applications include maritime protection (sonar) and crowd control devices, though less emphasized.
Sustainment	Logistical support to maintain combat power and operational endurance.	Acoustics are not commonly highlighted in sustainment efforts within the doctrine.
Information	Managing and leveraging information to influence operations and outcomes.	Acoustic technology's integration with information operations remains limited and fragmented.

Due to the lack of a unified approach acoustic technologies struggle to find a home in the various doctrine publications, both conceptually and in consistent terminology. While recognized for maritime applications, occasionally discussed in force protection and counterbattery operations, acoustics overwhelmingly remains underrepresented in joint doctrine[18]. In Command and Control (C2), acoustic data is sporadically mentioned for situational awareness. Lacking in a sustained doctrinal emphasis. Further in intelligence the use of acoustic sensors to support collection, notably in anti-submarine, artillery detection and cyber, is scarcely conferred. Thought as peripheral or supplemental to electronic warfare and cyber operations.[19] This also runs true in Fires doctrine in which acoustic sensors are considered for targeting but the doctrine

[18] JP 3-0
[19] JP 2-0

prioritizes more traditional kinetic or electronic assets.[20] Protection doctrine primarily focuses on maritime threat detection (sonar) and nonlethal crowd control tools, overshadowing broader land and air applications like that of counter-drone (UAS). Acoustics, though not a direct user of the EMS, its functions—detection, identification, targeting, and potential denial—share conceptual parallels with electronic and cyber warfare. For instance, in communications we should consider acoustics, cyber, and electromagnetic, as well as medium and domain into are planning, creating a plan that is constructed with frequency, usage, security, emission and domain (FUSED) into the traditional primary, alternate, contingency, and emergency (PACE) plan, detailed in figure 1.2. Or in intelligence we could interpret and plan the use of the spectrum with a hybrid, acoustic, cyber, and electromagnetic (HACE) that considers the FUSED matrix, see figure 1.3. Allowing for more seamless coordination and fusion cross various shops in the operation center. Though such methods could be adapted or explored they are not because understanding is not in place. A result of the fact that because official publications do not single out acoustics as a standalone capability that requires unique frameworks, nor do they explore the potential for harmonizing cyber, electronic and acoustic operations.

Consequently, several gaps have emerged. Firstly, a definitional gap wherein there is no unified doctrine-wide term or category for acoustic operations comparable to electromagnetic or cyber warfare. Second, acoustics remains largely confined to maritime contexts, limiting cross-domain integration, particularly in land and air environments.[21] Third, interoperability guidance for integrating acoustic data across multiple services or coalition settings is minimal. Fourth, while some references appear in training materials, there is insufficient detail on joint or large-scale planning and execution of acoustic operations. Finally, there is no detailed guidance or integration of acoustic with cyber or electronic warfare leaving each to operate as their own independent fiefdom rather than one synchronized system.

Counter to the perspective of unifying acoustic operations across the warfighting doctrine and ultimately operations, is the notion that acoustics is adequately encapsulated within existing intelligence, surveillance, and reconnaissance (ISR) frameworks and tradecraft. Further specialized attempts to alter doctrine and establish an acoustic category, wholly or embedded with electromagnetic and cyber operations, is unnecessary. Arguing that acoustic sensors, whether used in for detection or protection, operate under the same fundamental processes—detection, collection, analysis, and dissemination—as other sensor technologies and within Fires is no different than any other non-kinetic or kinetic measure.[22] Thus, rather than complicating doctrine with an additional “acoustic operations” segment, it is contended that refining the integration of acoustic data into current ISR and Fires doctrine and manuals is more effective, as well as resource-efficient. Supported by the fact that JP-3-0 already calls for joint interdependence and sensor fusion across domains. This argument implies that acoustic sensors inherently align within broader capabilities without the need for distinct categorization or doctrinal expansion.[23] However, the North Atlantic Treaty Organization’s (NATO), our closest and largest alliance, approach paints a contrasting picture.

Acoustic operations and the electromagnetic spectrum share a conceptual thread within NATOs’ Allied Joint doctrine. Both explicitly described as contributing to detection, identification, and targeting across the five recognized domains: maritime, land, air, space, and

[20] Jp 3-09
[21] JP 3-31
[22] JP 3-02
[23] JP 3-0

cyberspace. Though described acoustic operations are still relegated to an ancillary role, overshadowed by the emphasis on electromagnetic and cyber effects.[24] NATO doctrine acknowledges the interconnectedness of electromagnetic and acoustic 'spectra' within its doctrine. However, it draws a distinction between the 'spectra,' electromagnetic and acoustics, and that of cyberspace. The latter classified as an operational domain and thus critical to deter and defend against adversaries.[25] Contrarily the entire alliance doesn't agree with the United Kingdom which combines cyber and electromagnetic as a unified domain. [26]

"Information is not a domain. However, information activities use operational domain capabilities to specifically affect the cognitive elements of the engagement space. Although the electromagnetic and acoustic spectra could be viewed as distinctive spheres of capabilities and activities, they do not constitute an operational domain. Both spectra are strongly interconnected with the five recognized operational domains. The ability to use these spectra is crucial to conducting activities effectively in all operational domains."

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The lack of a unified approach creates friction within the alliance, especially when it begins at the top and will develop into operational requirements as set by the commanders of each nation's perspective. Ultimately limiting the full power of Allied forces throughout multi-domain operations against adversaries of the alliance, to include the most prevailing European threat Russia, who, in contrast, has clearly defined acoustic operations into their electromagnetic and cyber operations doctrine.

Russia has defined for many decades acoustic operations as an extension of electromagnetic warfare, tailored specifically to maritime conditions where hydroacoustic energy compensates for the limitations of electromagnetic spectrum (EMS) propagation in such mediums. To bridge historical practices with prevailing innovations, the Russian ground forces (SV) have restructured their electromagnetic forces, developing integrated technical control units and radio electromagnetic battle (REB) brigades consisting of four specialized battalions.[27] The function of KTK units of the brigade are tasked with self-monitoring forces for unintended emissions and exposures, expanding their scope beyond the EMS to include acoustic, hydroacoustic, optical, thermal, and chemical sources. Each of the four battalions have distinct focuses. The REB–N targets ground-based complexes; the REB–S focuses on aerial platforms; the REB–K addresses space complexes; and the REB–A specializes in operations against terrorists and unmanned aerial systems (UAS). Their use of a unified doctrine has shaped the organization of forces and permitted the land units to integrate advanced acoustic technologies, such as air defense acoustic systems for UAS detection, in coordination with EMS and cyber systems.[28]

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[24] AJP-01, Edition F, Version 1, Chapter 4, paragraph 4.43
[25] AJP-01 pg 21
[26] DP 0-01, *UK Defence Doctrine*.
[27] ATP 7-100.1 Russian tactics pg 4-45
[28] ATP 7-100.1 Russian tactics or some other reference needed

Acoustics has evolved far beyond its maritime and force-protection roots. Now, especially when combined with cyber and electromagnetic operations, has become a force-multiplier across multiple domains. Acoustics enhances situational awareness, disrupts adversaries, and aids in offensive operations. Despite the clear evidence and strategic importance, current doctrine continues to marginalize acoustic, often subsuming it within electronic warfare or intelligence, surveillance, and reconnaissance practices. The outdated framing treats acoustics as a peripheral concern rather than the critical capability it has become. The Joint Force can no longer afford fragmented spectrum operations. A unified approach –one that fully integrates acoustic, electromagnetic and cyber capabilities—is not just an innovation, it is a necessity. Our adversaries have already begun recognizing and implementing such integrated strategies. We must now transform our doctrinal framework—standardizing terminology, embedding acoustic capabilities across the alliance, enabling interoperability and innovation of non-kinetic systems. Because victory in future conflict may hinge not on what we see, but on what we hear –and how well we understand combined arms in the physical and non-physical battlespace.

Communication Layer	Primary	Alternate	Contingency	Emergency
Frequency	UHF SATCOM (protected)	EHF (AEHF)	HF ALE	Cellular/Iridium (if near civ grid)
Usage	Targeting/Strike C2	Tactical chat	Free-text burst data	Voice relayed via airborne/acoustic node
Security	Type 1 NSA encryption	IPsec VPN tunnel on SI	Manual one-time-pad burst	Unencrypted, with acoustic code words
Emissions	LPI/LPD directional antenna	Spread spectrum acoustic relay	Short acoustic burst signaling	High-risk omni/acoustic broadcasting
Domain	Space-based	Cyber/terrestrial relay	Airborne comm node	Local RF LOS/acoustic proximity-based comm

Communication FUSED_PACE method figure 1.2

Method	Frequency	Use	Security	Domain
Hybrid	Mixed (low to high)	Coordinated use of drones, signals, and on-ground scouts for real-time intelligence	Encryption of data streams; secure comms for troops	**Land-air coordination: UAV surveillance and ground patrols**
Acoustic	10 Hz–50 kHz	Detection of troop movements, counter-sniper operations, drone sound signatures, and explosives detection	Signal processing and sound masking to prevent exposure	**Land: Ground-based movement detection and counter-sniper systems**
Cyber	Variable (MHz to GHz)	Hacking into enemy C2 systems and data networks to disrupt and gather intelligence	Robust firewalls, real-time intrusion detection	**Land-based networks: Cyber recon and disruption of enemy communications**
Electromagnetic	300 MHz–300 GHz	Intercepting enemy radio communication and jamming signals to disrupt coordination	Secure spectrum encryption, frequency hopping	**Air-space: Signal interception and spectrum dominance**

HACE method for visualization figure 1.3