

2025 LtCol Earl “Pete” Ellis Essay Contest: First Place

Drone-Delivered Minefields

Precision obstacles for future Marine operations

by Capt Andrew Trossen

As a Chinese amphibious task force advances toward a narrow chokepoint in the Western Pacific, a Marine littoral regiment positions itself to deny access. Traditionally, combat engineers relied on labor-intensive minefield emplacement. Alternatively, they used scatterable systems such as the Family of Scatterable Mines, which often had unreliable timers. Both methods left hazards that outlived their purpose and slowed friendly maneuver.¹

Instead, a coordinated operation unfolds. A swarm of drones—ranging from small first-person-view (FPV) platforms to larger attritable aerial and ground vehicles—launches from cover. Carrying anti-tank (AT) and anti-personnel (AP) charges, they create a precise, reversible minefield in minutes. Command and control of the operation is meticulously structured; commanders authorize deployments after thorough assessments and monitor drone movements through secure communication channels. Support drones sustain concealment and command links, ensuring continuous oversight. Commanders maintain the ability to reseed or recover mines as the fight evolves, adjusting operations dynamically in response to battlefield developments. The enemy halts long enough for fires and maneuver to destroy the force.²

What once required days is now achieved with tempo and accountability, setting the stage for new operational approaches. Drone-delivered

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minefields—leveraging commercial swarms, quantum navigation in GPS-denied environments, and human-in-the-loop autonomy—transform mines into adaptive tools for distributed operations.³ By imposing disproportionate costs at minimal expense to Marines, they embody asymmetric warfare and deliver the “unfair fight” envisioned by *Force Design 2030*.⁴

Background

Minefields have long shaped combat. In World War I, belts of barbed wire and mines slowed offensives across no man’s land, forcing attackers into corridors exploitable by machineguns and artillery.⁵ During World War II, vast mine belts were used in North Africa, where both British and German forces emplaced hundreds of thousands of mines to control maneuver across the open desert.⁶ These examples demonstrate how obstacles amplify combat power by channeling an adversary into predetermined kill zones.

Legacy systems carried significant costs. During the Gulf War, scatterable mines produced high dud rates—over 1,900 unexploded mines were recorded at Al Jabar Airbase sector alone, with

similar patterns across six other sectors in Kuwait—leaving hazards that risked civilians’ safety and delayed reconstruction.⁷ In Kosovo and Iraq, unexploded ordnance likewise undermined legitimacy and fueled political backlash. To mitigate such risks, the International Committee of the Red Cross codified restrictions in Amended Protocol II of the Convention on Certain Conventional Weapons.⁸ As Marines consider innovations in mine deployment, it is essential to anticipate how humanitarian backlash could shape future rules of engagement. Building reversibility and accountability into mine warfare ensures operational effectiveness while preserving political credibility.

Recent U.S. policy shifts provide an opening. *Executive Order 14307*, Secretary of Defense guidance, and the revocation of National Security Memorandum 17 collectively restored authorities for drone integration and limited landmine employment.⁹ Together, these measures provide Marines with both the legal authority and strategic mandate to reinvent mine warfare. The challenge is to adapt these restored authorities responsibly, balancing combat effectiveness with humanitarian considerations.

Adversaries never stopped innovating. Russian doctrine emphasizes “reflexive control”—shaping enemy perceptions with deception, mines, and electronic warfare.¹⁰ Chinese military writings on systems warfare envision integrated denial across domains, supported by precision fires. Their public drone displays, forming three-dimensional dragons, illustrate swarm precision that could be repurposed for deception or terrain denial.¹¹ These developments underscore that near-peer competitors are experimenting aggressively while the U.S. risks stagnation.

Recent allied experimentation suggests that terrain shaping is evolving rather than becoming obsolete. The Army’s 2025 Multi-Service Prototyping Exercise (MSPIX) demonstrated that combat engineers can mass low-cost drones to create “three-dimensional obstacles” that delay, deter, and deny enemy formations.¹² The Army Applications Laboratory’s Engineer Operations initiative likewise prototyped stacked drones, radio-frequency (RF) decoys, and autonomous unmanned ground vehicles for breaching and countermobility.¹³ These experiments validate autonomous terrain shaping as a feasible engineering capability and highlight opportunities for Marine adoption.

Discussion

Drone-delivered minefields offer Marines decisive advantages over legacy systems. First, they provide precision and accountability. Using realtime kinematics Global Positioning System or quantum-enabled navigation, aerial and ground drones can emplace mines exactly where doctrine requires while producing digital logs that ensure accountability.¹⁴ Human operators play a critical role throughout this precision workflow, ensuring oversight and control. During deployment operations, human authorization occurs at key decision nodes, such as the initial activation of the system, confirmation of target coordinates, and upon any reseeding or retrieval of mines. This human-in-the-loop approach aligns with the emerging Department of War autonomy policy, providing reassurance to those skeptical of fully autonomous operations. In

Europe, Marines supporting NATO could seed a river crossing in under an hour, delaying adversary armor long enough for fires to strike.¹⁵

Second, these minefields deliver dynamic control. Unlike fire-and-forget scatterables, drone-delivered obstacles can be armed, disarmed, and redeployed in minutes.¹⁶ This allows commanders to deny an avenue, reopen it for maneuver, and then reseed it as the fight evolves. Such reversibility ensures Marines preserve tempo while denying it to the enemy.

Third, drones enable doctrinal versatility. They can mass mines across a chokepoint to block reinforcements or cluster AT and AP mines to disrupt breaching efforts.¹⁷ This flexibility provides commanders with a scalable toolset for shaping enemy movement.

Fourth, drones create opportunities for deception and camouflage. Spray drones can obscure emplacements with terrain-colored coatings, while decoy mines generate false signatures.¹⁸ In practice, false fields force hesitation at critical moments and complicate adversary decision making.

Finally, drone-delivered minefields integrate seamlessly into the MAGTF and Joint Force. Obstacles become dynamic elements that complement fires, maneuver, and electronic warfare. Small FPV drones, such as the Neros Archer, offer an affordable near-term option for testing terrain-shaping tactics at the company level.¹⁹ By employing FPVs today, Marines can validate doctrine and reinforce the engineer community’s role as the Marine Corps’ countermobility specialists.

Technology Enablers

Civilian industries already demonstrate the feasibility of drone-delivered minefields. Drone swarms, such as those by companies like Verge Aero, synchronize hundreds of aircraft with centimeter accuracy during public light shows.²⁰ These algorithms can be adapted for military use, enabling engineers to deploy mines with doctrinal precision. Proven swarm techniques provide Marines with an immediate advantage, eliminating the need for lengthy research cycles.

Commercial logistics proves scalability. Companies such as Zipline operate fleets of drones that navigate complex airspace and deliver payloads with precision and accuracy.²¹ These operations show drones can reliably carry ordnance-sized weights, providing confidence that swarms can sustain repetitive sorties in contested environments.

Artificial intelligence (AI) further enhances swarming potential. Vision-based AI allows drones to recognize terrain and optimize mine placement, while machine learning enables swarms to adapt mid-mission.²² This autonomy allows commanders to designate intent—“fix armor here” or “block this pass”—while swarms execute with minimal supervision.

Command-and-control resilience remains a decisive challenge. Army experimentation during MSPIX 2025 revealed that stacked drone swarms and RF decoys generated significant communication demands and integration challenges.²³ Marines must learn from these lessons by prioritizing mesh networks, relay drones, and training in degraded environments. Building trust in autonomy and resilient communications will ensure these systems function under electronic warfare pressure. To mitigate electronic warfare threats, Marines will implement advanced electronic warfare training programs that simulate electronic attacks, equipping personnel with the skills to rapidly adapt and sustain operations. Regular drills will integrate electronic warfare scenarios with standard procedures, ensuring that Marines are adept at maintaining operational capability and communication integrity even when contested by adversarial electronic tactics.

Finally, quantum navigation and sensing offer a breakthrough. Recent demonstrations using magnetometers and gravimeters achieved centimeter-level accuracy without satellites, proving navigation without GPS is no longer theoretical.²⁴ Russia and China have already been jamming and spoofing GPS in Ukraine and the Pacific, but ruggedized systems from companies such as SandboxAQ, Q-CTRL, and

Inflection are being accelerated by DARPA and allied militaries.²⁵ For Marines, quantum-enabled navigation ensures drone-delivered minefields remain accurate and accountable even under electronic attack.

Employment Options

Drone-delivered minefields enable doctrinally precise obstacle deployment. Using realtime kinematics Global Positioning System or quantum-enabled navigation, unmanned aerial system swarms can seed mines in fixing, turning, blocking, or disrupting patterns with each emplacement digitally logged for accountability.²⁶ A commander could seed a river crossing in under an hour, delaying an adversary long enough for long-range fires to attrit the lead elements. Such speed and precision impose dilemmas without committing large forces.

Separate or clustered mines expand tactical flexibility. The AT mines delay armored formations, while AP mines deter dismounted infantry and breaching engineers. When clustered, these systems magnify effects, as engineers clearing AT lanes are disrupted by nearby AP threats.²⁷ This layered approach forces adversaries to expend time and resources while Marines preserve tempo.

Reversibility provides commanders with dynamic control. Drone-emplaced mines can be armed, disarmed, and re-deployed in just minutes rather than days.²⁸ For instance, commanders have historically faced delays stretching up to 48 hours to reposition traditional mine systems. This rapid redeployment enables Marines to close a corridor to delay an advance, reopen it for friendly maneuver, and reseed it to deny pursuit. Such flexibility directly addresses long-standing criticisms of minefields as static liabilities by significantly reducing response times and enhancing operational tempo.

Drones also enable deception and counterattack facilitation. False minefields and decoys can create uncertainty across the battlespace, while commanders can pre-designate corridors to allow counterattacks and then reseed behind them.²⁹ These techniques transform ob-

stacles from static hazards into adaptive enablers of maneuver.

Combat engineers must remain the primary operators of these systems. Countermobility, demolition, and terrain shaping are core engineer tasks and already own the training and readiness standards and demolition authorities.³⁰ Anchoring these systems in the engineer community ensures doctrinal integrity and synchronization with fires. If the capability scales, a dedicated military occupational specialty for unmanned aerial system obstacles may be explored, but initial investment must remain engineer-led.

Lessons from Current Conflicts

Ukraine highlights both the utility and costs of legacy mines. Russian scatterable mines disrupted maneuver but left farmland contaminated for decades.³¹ Dud rates and the absence of digital control created hazards that

experiments show that adversaries are already exploring the same technologies Marines must adopt, and delaying risks ceding initiative in countermobility.

Coalition partners also highlight the importance of accountability. NATO allies in Eastern Europe and humanitarian groups in post-conflict zones face heavy clearance burdens from unexploded ordnance.³⁵ Drone-delivered minefields, equipped with digital emplacement records and remote disarmament capabilities, could alleviate these challenges, reducing political costs while enhancing alliance interoperability.

Doctrine

The Marine Corps should update *MCWP 3-17, Engineer Operations*, and *MCWP 3-12, Combined Arms Countermobility*, to codify precision, reversibility, and deception as core tenets of mine warfare. Engineer units must add scalable “drone obstacle pla-

A commander could seed a river crossing in under an hour, delaying an adversary long enough for long-range fires to attrit the lead elements.

slowled civilians and friendly forces long after combat. By contrast, Ukrainian forces adapted commercial drones to deliver precision charges against armored vehicles, demonstrating the potential of adaptive drone-enabled obstacles.³²

Nagorno-Karabakh in 2020 underscored the vulnerability of static defenses. Armenian mine belts slowed Azerbaijani advances, but swarms of Turkish-supplied drones systematically destroyed armor and artillery supporting the defense.³³ The lesson for Marines is clear: without adaptability and synchronization with fires, modern reconnaissance-strike complexes will render fixed minefields ineffective.

Adversaries are rapidly innovating with unmanned deception. Russia has combined decoy drones with live systems to saturate defenses, while China’s precision drones demonstrate the potential for swarm deception at scale.³⁴ These

toons” capable of supporting MLRs and MEUs. *MARADMIN 416/25*, which announced the fielding of the Neros Archer FPV drone, illustrates both the opportunity and the challenge of integration—momentum toward low-cost drone employment, but also the risks of dependency and doctrine lagging behind capability.³⁶

Organization

The pioneer battalion provides the ideal structure for experimenting with drone-delivered minefields. Its littoral engineer reconnaissance teams and littoral explosive ordnance neutralization sections are already tasked with countermobility and terrain shaping.³⁷ Embedding drone-enabled obstacle platoons within this formation would align with its campaign of learning mandate and validate swarming minefields in littoral terrain.

Doctrine and Concept Alignment

The *Maritime Terrain Shaping and Area Denial (MTS-AD) Functional Concept* emphasizes that the Marine Corps is not currently organized, trained, or equipped for scalable terrain shaping.³⁸ Drone-delivered minefields directly fulfill these requirements by providing reversible, deception-enabled, and recoverable obstacles that assure friendly maneuver.

Joint Integration

The Army is investing heavily in terrain-shaping prototypes through the Army Applications Laboratory and MSPIX. Experiments have shown that stacked drone swarms, RF decoys, and autonomous unmanned ground vehicles are viable engineering tools.³⁹ Marines should observe and shape these efforts while avoiding redundant costs—“let the Army spend, Marines adopt”—and focus resources on doctrine, naval integration, and operational tactics, techniques, and procedures.

FPV Options

The FPV drones, such as the Neros Archer, provide a near-term, affordable method to validate terrain-shaping tactics. They can deliver explosive charges, reinforce countermobility lanes, and be integrated into Service-level training exercises. By employing FPVs now, Marines can refine doctrine, build trust in autonomy, and accelerate field adoption without waiting for larger programs of record.⁴⁰

Operator Ownership

Combat engineers must remain the primary operators of drone-delivered minefields. Countermobility and demolition are core engineer tasks, and the community already owns the training standards and authorities required for safe and effective obstacle employment.⁴¹ Anchoring these systems in the engineer community ensures doctrinal integrity and synchronization with fires. If the capability scales, a dedicated unmanned aerial system obstacle military occupational specialty may be explored, but initial investment must remain engineer-led.

Training

The Engineer School curriculum should incorporate swarming, digital accountability, and AI-enabled planning. Training must include degraded communications scenarios and integration into Service-level and coalition training exercises. Reserve units, drawing on civilian drone expertise, are particularly suited to accelerate adoption.

Materiel

Attritable drones with modular mine kits should be prioritized, supported by 3D-printed components to reduce logistics burdens. A pilot program fielded in both an active-duty and a reserve engineer unit within 24 months would validate the concept and refine tactics, techniques, and procedures.⁴²

Facilities and Policy

The Marine Corps should establish ranges for inertly emplaced drone minefields. Current executive guidance permits experimentation, but accountability and coalition releasability must remain central. Early NATO integration will ease interoperability and strengthen legitimacy.⁴³

Roadmap

Implementation should follow a phased approach. Year 1: demonstrate commercial swarming, Year 2: equip pilot units, Year 3: integrate into exercises, Year 4: establish a program of record. Future systems must incorporate resilient command and control, deception, and reversibility as mandatory features while framing employment as compliant and humanitarian focused.

Conclusion

In the 1950s, basketball slowed until the introduction of the shot clock forced tempo and creativity back into the game. Legacy scatterable mines have created a similar problem in maneuver warfare. They are static, unreliable, and strategically costly—slowing friendly operations, creating enduring hazards, and undermining legitimacy.⁴⁴ Without reform, the Marine Corps’ countermobility capability risks irrelevance in an era defined by tempo and adaptability.

Drone-delivered minefields are the shot clock for maneuver warfare. They enable Marines to emplace, camouflage, arm, disarm, and redeploy obstacles in minutes. The opening scenario illustrates the point: a Chinese amphibious force was delayed for 36 hours, then destroyed in a withdrawal kill zone. The same logic applies globally: NATO shaping Russian maneuver in Europe, FPVs denying approaches in the Middle East, or drones rapidly seeding chokepoints in the Arctic.⁴⁵

The Marine Corps cannot afford to lag behind adversaries already experimenting with swarms and deception. Maintaining tempo and adaptability will determine whether Marines impose costs or suffer them. Drone-delivered minefields impose disproportionate costs on adversaries at minimal expense, embodying the essence of asymmetric warfare.⁴⁶ Just as the shot clock revitalized basketball, these systems will revitalize Marine Corps obstacle warfare—ensuring engineers deliver the unfair fight envisioned by *Force Design 2030*.

Notes

1. U.S. Government Accountability Office, *Military Operations: Information on U.S. Use of Land Mines in the Persian Gulf War*, GAO-02-1003 (Washington, DC: GPO, 2002).
2. David Hambling, “Mine Craft: Ukrainian Drones Add a New Dimension to Mine Warfare,” *Forbes*, April 3, 2025, <https://www.forbes.com/sites/davidhambling/2025/04/03/mine-craft-ukrainian-drones-add-a-new-dimension-to-mine-warfare>.
3. Army Applications Laboratory, *Engineer Operations: Autonomy Cohorts and Terrain Shaping Experimentation* (Austin: May 2025); and Headquarters Marine Corps, *MARADMIN 416/25, Guidance for the Fielding of the Neros Archer* (Washington, DC: September 2025).
4. Headquarters Marine Corps, *Force Design 2030* (Washington, DC: 2020).
5. Gary Sheffield, *The First World War in 100 Objects* (London: Imperial War Museum, 2017).
6. Ian Gooderson, *A Hard Way to Make a War: British and German Minefields in North Africa, 1941–43* (London: Routledge, 2001).

7. Government Accountability Office, *Military Operations: Information on U.S. Use of Land Mines in the Persian Gulf War*.
8. International Committee of the Red Cross, *Protocol on Prohibitions or Restrictions on the Use of Mines, Booby-Traps and Other Devices* (Amended Protocol II to the CCW) (Geneva: October 1996).
9. The White House, “Executive Order 14307: Expanding Drone Integration to Increase Efficiency and Productivity,” June 6, 2025; Secretary of Defense, “Unleashing U.S. Military Drone Dominance,” (Washington, DC: July 2025); and The White House, “Revocation of National Security Memorandum 17 on Anti-Personnel Landmine Policy,” (Washington, DC: July 2025).
10. Timothy L. Thomas, “Russia’s Reflexive Control Theory and the Military,” *Journal of Slavic Military Studies* 17, No. 2 (2004).
11. Staff, “China Celebrates Lunar New Year with 3D Dragon Drone Display,” *South China Morning Post*, February 2021.
12. U.S. Army, *Final Report–MSPIX 2025: Deep Terrain Shaping and Remote Breaching of Obstacles* (Fort Leonard Wood: Army Applications Laboratory, May 2025).
13. *Engineer Operations: Autonomy Cohorts and Terrain Shaping Experimentation*.
14. *Military Operations: Information on U.S. Use of Land Mines in the Persian Gulf War*.
15. David C. Isby and Charles Kamps, *Armies of NATO’s Central Front* (London: Jane’s, 1985).
16. Emma Dodd and Caitlin Welsh, “Demining Ukraine’s Farmland: Progress, Adaptation, and Challenges,” *CSIS*, December 5, 2024, <https://www.csis.org/analysis/demining-ukraines-farmland-progress-adaptation-and-needs>.
17. Headquarters Marine Corps, *Force Design 2030* (Washington, DC: 2020).
18. Staff, “Operation False Target: How Russia Plotted to Mix a Deadly New Weapon among Decoy Drones in Ukraine,” *Associated Press*, November 2024, <https://apnews.com/video/ukraine-drones-russia-aerospace-and-defense-industry-war-and-unrest-76742f121c4d-4081a87b504b1a48afc7>.
19. *Force Design 2030*.
20. Staff, “Flight Control System,” *Verge Aero*, n.d., <https://verge.aero>.
21. Staff, “About Zipline: Drone Delivery Service,” *Zipline*, n.d., <https://flyzipline.com>.
22. Paul Scharre, *Army of None: Autonomous Weapons and the Future of War* (New York: W.W. Norton, 2018).
23. U.S. Army, *Final Report–MSPIX 2025: Deep Terrain Shaping and Remote Breaching of Obstacles* (Fort Leonard Wood: Army Applications Laboratory, May 2025).
24. David Hambling, “GPS Just Became Optional for Military Navigation. Quantum Sensors Are Why,” *Forbes*, September 2025, <https://www.forbes.com>.
25. U.S. Department of Defense, “DARPA’s Robust Quantum Sensing Program,” *Defense.gov*, 2025, <https://www.darpa.mil/research/programs/roqs-robust-quantum-sensors>.
26. *Military Operations: Information on U.S. Use of Land Mines in the Persian Gulf War*.
27. International Committee of the Red Cross, *Anti-Personnel Landmines: Friend or Foe?* (Geneva: ICRC, 1996).
28. Emma Dodd and Caitlin Welsh, “Demining Ukraine’s Farmland: Progress, Adaptation, and Challenges,” *CSIS*, December 5, 2024, <https://www.csis.org/analysis/demining-ukraines-farmland-progress-adaptation-and-needs>.
29. “Operation False Target: How Russia Plotted to Mix a Deadly New Weapon among Decoy Drones in Ukraine.”
30. U.S. Marine Corps, *Marine Corps Task List (MCTL), Engineer Section* (Washington, DC: 2023).
31. *Anti-Personnel Landmines: Friend or Foe?*
32. “Mine Craft: Ukrainian Drones Add a New Dimension to Mine Warfare.”
33. Michael Kofman and Leonid Nersisyan, “The Second Nagorno-Karabakh War: Lessons for Future Conflict,” *War on the Rocks*, December 2020.
34. “Operation False Target: How Russia Plotted to Mix a Deadly New Weapon among Decoy Drones in Ukraine;” and “China Celebrates Lunar New Year with 3D Dragon Drone Display.”
35. International Committee of the Red Cross, *Amended Protocol II to the CCW* (Geneva: October 1996).
36. Headquarters Marine Corps, *MARADMIN 416/25, Guidance for the Fielding of the Neros Archer* (Washington, DC: September 2025).
37. U.S. Marine Corps, *Pioneer Battalion Concept of Employment* (Quantico, VA: Capabilities Development Directorate, February 2024).
38. U.S. Marine Corps, *Marine Corps Functional Concept: Maritime Terrain Shaping and Area Denial* (Quantico, VA: Deputy Commandant for Combat Development and Integration, July 2022).
39. *Final Report–MSPIX 2025: Deep Terrain Shaping and Remote Breaching of Obstacles*.
40. *MARADMIN 416/25*.
41. *Marine Corps Task List (MCTL), Engineer Section*.
42. U.S. Department of Defense, “Drone Operator Career Field Development,” *Defense.gov*, 2025.
43. “Executive Order 14307: Expanding Drone Integration to Increase Efficiency and Productivity”; Secretary of Defense, *Unleashing U.S. Military Drone Dominance* (Washington, DC: July 2025); and *Revocation of National Security Memorandum 17 on Anti-Personnel Landmine Policy*.
44. *Military Operations: Information on U.S. Use of Land Mines in the Persian Gulf War*.
45. *Force Design 2030*.
46. “Operation False Target: How Russia Plotted to Mix a Deadly New Weapon among Decoy Drones in Ukraine;” and “China Celebrates Lunar New Year with 3D Dragon Drone Display.”



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