# Reshaping the Ocean Battlespace with Naval Mining

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# Acknowledgements

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- Expert review and commentary, with your insights also welcome

Dedicated today to

Rear Admiral John D. Pearson USN, 1939-2026

Former Mine Warfare Commander (COMMINEWARCOM)
President of the Mine Warfare Association (MINWARA)
Faculty Chair for Mine Warfare, NPS USW Academic Group

# Topics

- Summary, Problem and Goal
- Background
- Operationalizing Mine Warfare
- Exploitable Advantages
- Enabler for future work: minefield simulation and analysis
- Conclusions and Recommendations

# Summary, Problem and Goal

*Summary*

- Considering future minefields as a **system of *distributed robots,*** made up of split ***sensor suites*** plus controllable ***munition sets***. Splitting sensors from effectors can enable potent, low-cost, repeatable solutions.

*Problem*

- USA and allies do not have a sharable active mining strategy.

*Goal of this paper*

- Show many ways to operationalize active mining for Mine Warfare.
- Build modeling, simulation and analysis tool for precise quantitative understanding of tactics, costs, risks, potential influence and impact.

# National Imperatives

- U.S. is maritime nation dependent on Freedom of Navigation (FON)
- Fundamental imperatives relevant since Alfred Thayer Mahan
- Multinational partnerships and alliances are essential to ongoing economic stability, especially given prominence of global trade

Key references

- Mahan, *Influence of Sea Power upon History*
- Tangredi, *Anti-Access Warfare*
- Vandenengel, *Considering the Carrier*

# Sweep of History

- Restrictions and permissions on ocean mining have been codified for centuries by international law
- Eight of nine global conflicts with USA have been **dominated or determined by mine warfare**

References


- Mason, Operation Starvation
- O'Hara, Innovating Victory
- Price, "Expeditionary mining.,."
- Marlatt, Mine Warfare bibliography


Global Conflicts involving United States of America

- ✓ 1905 Russo-Japanese War
- ✓ 1914 World War I
- ✓ 1939 World War II
- ✓ 1950 Korean War
- ✓ 1965 Vietnam War
- ○ 1947-1991 Cold War
- ✓ 1990 Gulf War
- ✓ 2022 Russo-Ukrainian War
- ✓ 2026 US-Iran War

# Mining is still not a U.S. Navy capability

*"Our most advanced mines are no more capable than those used in World War II, except some can be delivered more accurately using precision-guided capability. They still have primitive fusing devices and are only effective in shallow water. We should bring these mines into the twenty-first century using technology that would enable them to be positively controlled, be frequently updated, act as a sensor, use machine learning for acoustic discrimination, and be lethal in deeper water. The ability to selectively seal off Chinese naval assets or commercial shipping from leaving or entering port would be truly disruptive, presenting a new dilemma to Chinese ambitions in its neighborhood. Sadly, this capability has no constituency."* (Winnefeld Sailing Upwind 2023)

# National capabilities for mobilization

- Long-term naval operations are dominated by tandem logistics and maneuver for preparation and concentration of power
- Embodies Hughes' precept to "attack effectively first"
- Mobilizing industrial base proved to be critical in World War II
- Similar strategic framework today might impose asymmetric costs on opponent to **deter** conflict, **deescalate** hostilities, and **defeat** if necessary

Mining to **reshape the ocean battlespace** for reliable stability of ocean commerce

References:


- Cares, Fighting the Fleet
- Hughes, Fleet Tactics and Naval Operations
- Herman, Freedom's Forge: How American Business Produced Victory in World War II

# Strategic insight via computational analysis

- Fresh look at active mining based on **first principles of warfighting**, along with a broader strategic perspective for peacetime protection of allied commerce, is needed and missing.
- **Shared understanding** of theater-scale mining relationships provides further deterrent influence on opponents while simultaneously strengthening allied resolve.
- Theater-wide reconsiderations for naval mining include options for **sea lines of commerce and communications (SLOCs), harbors, choke points, safety lanes (i.e. Q routes), safe havens**, **and expeditionary operations** that can reveal multiple new opportunities for coalition stability through subsea mining defenses.

# Hedge Strategy

- Design pillars: ***small and low cost***, ***unmanned***, ***many***, and ***smarter***.
- These attributes *exactly match* the potential of massing low-cost smart mines assembled using modern unmanned system.
- Adaptation, innovation, and ingenuity are essential for success.
- Failure to adapt leads to irrelevancy.

References


- Selby, Revisiting the Hedge Strategy with Renewed Urgency, video
- Caudle, CNO Unveils Fighting Instructions at U.S. Naval War College

# Urgent need for complementary Hedge Strategy

CNO's Fighting Instructions public release:

*"We find ourselves operating in an era with other great powers, an era in which the speed of decision ruthlessly punishes delay. The requirement for a strong, resilient, and globally present Navy has never been more important to our Nation's defense. […]*

*Our Navy's approach to combat can no longer be based on capability overmatch and winning by mass dominance alone. The Nation needs a Navy that can hedge lethal effects aggressively, innovate continuously, fight [with] distributivity, and command with clarity across a global network of battlespaces."* (Caudle 2026)

# Deployment with Minimal Risk

- Ability to avoid placing human operators (and major ship assets) in harm's way offers compelling motivation for remote delivery.
- Surreptitious deployment of ocean assets across (and delivery into) any Weapon Engagement Zone (WEZ) is a particular challenge.
  - LPV Low Profile Vessels (also known as "narco subs") can do it
  - Expensive platforms are not scalable, not worthy of risk, busy elsewhere
- Once deployed, naval mines effectively become a complementary weapons inventory for forward-operating submarines, surface ships and aircraft that do not need to be carried onboard.

Sierra, Unmanned Low-Profile Vessels: "Narco Subs" For Contested Logistics

# Sensor suites for precise target identification

- Minefield sonar devices/buoys can act individually or as a sonar array
- Such systems can support larger sensor constellations, contributing (and utilizing) overall capabilities for theater-scale data collection by Maritime Domain Awareness (MDA) and ocean surveillance systems
- Long-term presence in situ permits AI/ML training on “signs of life” and abilities for **Identification Friend Foe Neutral Unknown (IFFNU)**
- Training of AI neural nets produces low-cost simple detection filters
- Mines can thus avoid unintended attacks and protect friendly assets

Reference: Winnefeld, AI Surprise in Black Ditch

# Command and Control (C2)

- Untapped capability becomes possible by treating minefields as a robotic system that includes sensor suites and munition sets
- Simplest form: **on/off (enable/disable) authorization** for minefield
- National command authorities can gradually ratchet up or reduce level of threat provided by minefields, thus reshaping the battlespace
- Provides theater commander options to deter, de-escalate, defeat
- Reduces difficulty of later, arduous MCM neutralization, clearance
- Similarly reduces reluctance to deploy minefields

# … with Communications (C3)

- **Network-Optional Warfare (NOW).** Naval forces do not have to be engaged in constant centralized communication.
- Since they can operate unattended, minimum-essential communication needs are exceedingly simple for minefields
- Overt capabilities greatly reduce (and practically eliminate) the need for real-time tactical communications.
- Ordering minefield on/off is relatively simple if delivery of short messages is reliable, with multiple means of delivery available.
- "Long" time delays (even on order of days) to command a tactical shift in minefield modes are operationally advantageous, actually faster than expectations, historical capabilities, or international law requirements.

References: Brutzman NOW including IMWTS 2024 presentation

# Minefield munitions and mine placement

- Many weapons options are possible, since separation of sensor suites from munition sets allows a mix of both simple and sophisticated hardware devices.
- Careful early geographic placement of triggerable munitions is key factor for these potentially first-fired weapons – i.e. classic minefield planning.
- When positioned carefully, even with some spatial randomness, munition placement epitomizes “fire effectively first” imperatives.
- Propulsion disablers (PDs) as mine effectors can offer a nonlethal “mission kill” alternative against opponent vessels
- Stranded damaged vessels offer stark warning, possible retargeting also
- How many mines are needed to close a harbor or international passage?

# Mining limitations and maritime context

- Mines are not a superweapon, but…
- During era dominated by missile warfare, the primary limitation of minefields for friendly shipping is no direct protection from missiles.
- Controlled denial of ocean access to missile-capable warships, but providing Q-route safety lanes for merchant shipping, reduces risk.
- Thus *transit access for friendly shipping offers* ***sea control****, while blocked transit for hostile shipping offers* ***sea denial****, simultaneously*
- Q-route length might be tens or hundreds of miles
- Powerful capabilities useful as part of larger theater-wide efforts

# Operational considerations by pacing threat

Translated from Chinese, republished (CMSI 2026, original 2013)

1. *"they are difficult to detect, and their attacks are invisible and sudden;*
2. *they are capable of autonomously biding time, waiting for the right opportunity to strike; they are a weapon of sea control; they can remain in place for long periods of time, presenting an enduring threat;*
3. *they are easy to deploy: naval ships, fishing vessels, merchant ships, aircraft, and submarines can all lay mines;*
4. *they possess comparatively strong offensive capabilities, and have the ability to serve both offensive and defensive functions;*
5. *they are difficult to remove/sweep; at present there is no MCM approach that can completely eliminate the threat of sea mines."*

# Split sensor suites and munition sets

- Separating sensors from munitions helps independent co-development over long term, co-evolution helps acquisition, evolution, tactics, etc.
- Split design also allows complementary sensors, different munitions. Best mix of both worlds over time further exemplifies Hedge Strategy.
- Embedding impressive computation in sensors or mines is no longer a limiting factor. NPS student capstone work showed that cellphones (i.e. simple small computers) have computational capability for both LPV and mine task requirements, operating for long periods of time if needed.
- Essential design principle for robotics is that when a necessary capability cannot be easily engineered into a robot, then it might be possible to "engineer the environment" instead. Shaping the robotic battlespace with mine sensors/munitions also shapes the operational environment.

# Treat friends differently than foes

- Current Naval mines are typically dumbest robots on the planet, computationally less capable than mobile home vacuum cleaner.
- Simply adding remote “on/off” (enable/disable) controllability is sufficient to throttle lethality for mission requirements during conflict, also meeting legal requirements for Rules of Engagement (ROE) in the maritime commons.
- Similarly, adding simple IFFNU discernment allows friendly commerce to continue with confidence while placing opponent assets at risk.
- All of these factors enable support internationally agreed-upon Laws of Armed Conflict (LOAC) and powerful alliances.

# Put time on our side…

- Mines are “weapons that wait” - naval mining is “long game” enabler.
- Minefields are a hidden threat, always difficult to detect and clear, thus impacts from a small set of mines can be similar to a large set.
- Longer time frames for transit and delivery of weapon assets are not an impediment for sustained emplacement.
- Such delays might even be irrelevant if mine assets are already staged forward with allied partners.
- “Reshaping the battlespace” requires nontrivial planning, preparation

Reference: Hartman, Truver, *Weapons that Wait*, new edition planned

# … to play the “long game”

- Using a split design for sensor suites and mission sets, a distributed minefield operating with loosely coupled communications has significantly greater operational usefulness than a classic minefield.
- Over long periods of time it can act either as a sensing system, a weapons system, or both.
- Preprogrammed sensor abilities can share simple lines of bearing and proximity information that creates a “spiders web” to entrap moving targets, whose own motion actually creates high-probability targeting opportunities and reduces the need for weapon travel.
- Note similarity to swarm robotics, substituting time for distance. Minefields lay in wait for the right opportunity to “fire effectively first.”

# Outsized effect on adversaries and allies

- Minefield operational influences and impacts are profound.
- For example, detonation of single covert mine can cause “hard kill.”
- Then, the overt potential presence of additional covert mines can cause a “mission kill” for opponents by
  - deterring port egress/ingress,
  - depleting multiple adversary resources, and even
  - imposing strategic uncertainty as potential psychological warfare.
  - Uncertainty is amplified by coincidental unrelated events, misinformation.
- Variations are further multiplied by (covert) IFFNU discrimination and (overt) safe transit of friendly forces.

# Force Design Considerations: Navy

- Fundamental refactorings of future force design for effective fleet composition of ships, aircraft, submarines, and robots continue.
- When preparing for conflict, emphasis on weapons production, logistics, deployment and delivery are primary drivers.
- Mine warfare has potentially profound influence on multiple-year efforts to achieve a balanced, effective, and dominant posture for U.S. and allied Naval forces.
- Significant robot impact has already been observed in wargames, especially when force-on-force engagements might persist, shifting from short-lived local weapons exchanges to sustained wars of attrition.

# Force Design Considerations: Marine Corps

*"Strategic guidance calls for a Marine Corps able to survive and thrive inside contested spaces. Developed concepts are tested through experimentation and wargaming. Integrated planning teams study and analyze the concepts for validation and refinement."*

- Baseline USMC force-design system inventories already include multiple robots such as Autonomous Low-Profile Vessel (ALPV), the semiautonomous LRUSV, seven unmanned air systems (UAS), and three different mobile anti-air missile launchers. (USMC 2024)
- USMC minefields can feasibly create expeditionary havens that reshape the battlespace and strengthen lethality.

# Consider OODA loops at every level

- Perfect comprehensive systems are not needed in advance when sensor suites and munition sets can be augmented in tandem.
- OODA loops apply to tactical, operation, strategic levels of thinking.
- As John Boyd repeatedly demonstrated, apparent “failures” actually offer lessons learned and potentially rapid improvement when responsive Observe Orient Decide Act (OODA) loops are achieved.
- When minefield is initially revealed (or triggered), the individual weapons in minefield nevertheless remain clandestine. Thus, scope of minefield effectiveness limited only by opponent’s imagination and uncertainty.
- Also offers further opportunities for US, allied partners working together.

Reference: Coram, Boyd: The Fighter Pilot Who Changed the Art of War

# Minefield detonations as combat sensors

- Explosions from active mines detonating due to opponent activity provide immediate sensor alertment to friendly forces in theater, without requiring explicit communication links.
- Such events are underwater “bell ringers” that an operational flank or back-door barrier is being breached.
- Remote mine detonation can also be accompanied by minefield’s sensor suite overtly transmitting a notification message that provides classification details about the attacked target, without loss of covertness for other nearby systems.
- Minefield detonations thus add to theater battlespace awareness.

# Information Operations (IO)

- Existence, boundaries, density, and likely lethality of any minefield together provoke great uncertainty among adversaries, neutral shipping, economic markets, and even friendly forces.
- Naval mining emphatically reshapes the information battlespace as well as the ocean battlespace.
- Information Operations include public or private sharing of ***valid information***, sharing misleading mistaken ***misinformation***, and disseminating deliberately deceptive ***disinformation***.
- Information Operations based on minefield operations offer major new lines of for both attack and defense.

# Clearing minefield promptly, on command

- **Self-destruct** is useful third command for minefield C2 repertoire. Implementation is technically similar to **enable/disable** commands.
- Given simple autonomy capabilities, all mines in minefield can be required to individually report time of message receipt, confirming time for expected self-detonation. Failure to respond is good info.
- Later “fail-safe” fallback reporting of failure to self-destruct is also possible, building confidence in full minefield clearance and alerting allied forces if follow-up actions are needed. Timeouts can help.
- Simple design yields controllable destruction, eliminating need for costly arduous time-consuming MCM to remove “friendly” minefields.

Proposed Future Work

# Minefield modeling, simulation, analysis

- Important to realize: **missiles, mines, drones, satellites** are ***robots***
- Different ways of thinking are needed, grounded by shared tools
- Open-source open-standards software is possible
- Unclassified software can be separate from sensitive data
- Multinational efforts can lead to Decision Advantage
- Design characteristics provided in paper:
  - Facing forward: discouraging opponents
  - Analytic enablers as intellectual advantages
  - Reinforce continuing research with Naval imperatives (and vice versa)
- Resulting process can be considered **analytic campaigning**

Boom!

# Conclusions and Recommendations

- “Weapons that wait” with split sensors and munition sets, plus minefield-wide C2 commands for on/off/disarm, can **reshape the future ocean battlespace** to “attack effectively first”
- Treating **mines as robots, and minefields as systems**, provides new options
- Elevating active mine warfare exactly matches **Hedge Strategy** objectives, namely **small and low cost, unmanned, many,** and **smarter** designs.
- **Simulation-driven analytics** for quantitative study of maritime mining can propel greater understanding that also grows Navy and allied armaments.
- Reshaping battlespace to dynamically rebalance **sea control** and **sea denial** through mine warfare amplifies all other Naval capabilities.
- Active naval mining supports perennial global challenges facing allied nations for **great-power conflict resolution** and **unrestricted maritime commerce**.

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