

Twenty-First-Century Aerial Mining

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On 23 September 2014, a B-52H bomber at high altitude north of Guam accomplished an aviation first—the release of a winged, precision aerial mine (fig. 1). The inert, orange and white GBU-62B(v-1)/B Quickstrike-ER (extended range) separated cleanly from the B-52, rolled, and three seconds after release, the BSU-104 wings deployed, transforming a free-fall munition into a medium-range weapon. Under command from the attached Joint Direct Attack Munition (JDAM) tail kit, the weapon flew around 40 nautical miles (nm) and impacted the water. Had the weapon been a live system dropped in shallow water, it would have settled to the bottom to lie in wait for a target. This effort marked the first advance in aerial mine-delivery techniques since 1943 and demonstrated a capability that substantially changes the potential of aerial mining in a threat environment. Using off-the-shelf components and operational aircraft, aerial mining quietly entered the twenty-first century.

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US Air Force photo

Figure 1. The first-ever release of a Quickstrike-ER, 23 September 2014

Historical Background

The use of mines in naval warfare is extensive, dating from the American Civil War.¹ The Luftwaffe mined the Thames Estuary in November 1939, marking the first use of aerial mines. By 1940 the Royal Air Force (RAF) was laying an average of 1,000 each month for the entire duration of the war. For some areas, such as inland waterways and the Danube, mine laying by aircraft was the only option.² Aerial mines, placed in the harbor approaches and training areas used by U-boats, sank 16 of the 26 German submarines destroyed by mines during the entire war.³

The US Navy's offensive mine laying began in late 1942, when the USS *Thresher* mined the Gulf of Siam. In December *Trigger* laid mines near Tokyo and witnessed the first sinking before leaving visual range. Nevertheless, the number of submarine-laid mines was small, and risk to the boats was high. Avenger torpedo bombers laid mines effectively

against Japanese island bases in conjunction with antishipping strikes, but no such attempt took place against the home islands. In total, naval aviation was responsible for only 3 percent of the aerial mines laid in the Pacific.⁴

Fifth Air Force relied on the RAF and Royal Australian Air Force (RAAF) for its mine-laying capabilities.⁵ Tenth Air Force, though, embraced aerial mining more enthusiastically and closed the Rangoon River for the duration by using British mines from early 1943. Fourteenth Air Force laid airlifted mines in China's rivers, including the Yangtze. Twentieth Air Force conducted its first aerial mine-laying mission off Sumatra in August 1944, later mining Singapore, Saigon, and Cam Ranh Bay.⁶

In March 1945, the 313th Bombardment Wing (B-29) began mine-laying operations in Japanese home waters.⁷ Referred to as "Starvation" missions, the mining effort was directed at the Shimonoseki Strait, the key remaining choke point in the Japanese maritime supply network, along with Tokyo, Nagoya, and smaller Japanese and Korean ports.⁸ Despite the short duration, aerial mining effectively stopped maritime traffic, racked up almost as many ships damaged as all US Army Air Forces (USAAF) land-based air during the entire war, and accounted for half of all of the ships sunk or damaged during the aerial mining period. According to Wesley Frank Craven and James Lee Cate,

The 313th Wing got into the game late, operating with mines for only four and one-half months and at a period when the enemy's merchant fleet had contracted in size and in scope of its activities. During that short period, mines planted by the wing were more destructive than any other weapon, accounting for about half of the total tonnage disposed of. To accomplish this task, the 313th sent out 1,528 sorties and planted 12,053 mines, a much heavier effort than had been suggested by the Navy in the negotiations of 1944 and, indeed, the heaviest aerial mining campaign ever waged.⁹

The United States again conducted large-scale aerial-mining efforts in Vietnam. President Johnson authorized mining of the Song Ca, Giang Song Ma, Kien, and Cua Sot Rivers in 1967.¹⁰ Throughout the

later days of Operation Rolling Thunder, carrier aircraft were mining inland roads and waterways.¹¹

Aircraft from the *Coral Sea* mined Haiphong Harbor on 8 May 1972, dropping 36 Mk-52 mines and giving the harbor the dubious distinction of being the only foreign port mined by the United States in two wars.¹² The mining of Hon Gai and Cam Pha followed, along with the approaches to Haiphong. All were periodically reseeded. The mines shut down Haiphong until Operation End Sweep in 1973, which cleared Vietnamese harbors (but not rivers).

Aerial mining remained a Cold War mission conducted by US Air Force bombers and carrier air, primarily with the intention of constraining the Soviet fleet—especially submarines. Two days into Operation Desert Storm, A-6 aircraft from the USS *Ranger* dropped 42 mines in the Khawr Az Zubayr River to no known effect, marking the most recent combat drop of aerial mines.¹³ With the exception of this sortie, which resulted in the loss of Jackal 404 and its crew, aerial mining has proven highly effective in enforcing a maritime blockade against both warships and submarines.

The Mines

In Operation Starvation, the B-29s employed Mk-25 (2,000-pound) and Mk-26/36 (1,000-pound) aerial mines. Blunt-nosed and parachute-retarded, these weapons had magnetic fuzes with either pressure or acoustic sensors, variable sensitivity settings, randomly set arming delays, and ship counters between one and nine, allowing some mines to ignore a certain number of ships before they triggered. None had any kind of deactivation device, and all were bottom mines.¹⁴

Mines used in Vietnam were mostly variations of general-purpose (GP) bombs with high drag tails. Called Destructors, the Mk-36 (500 pounds), Mk-40 (1,000 pounds), and Mk-41 (2,000 pounds) incorporated arming delay and self-destruct features. Fuzes were magnetic, seismic, contact, or a combination, and the system could be used on

land or in shallow water. Destructor mines and GP bombs differ only in fuzing and (sometimes) in the tail kit attached to the bomb body. This design feature continued in the Quickstrike, the successor to the Destructor series.

The Quickstrikes (Mk-62/-63/-64/-65) are the current US air-delivered bottom mines, intended for shallow water at depths from 40 to 200 feet.¹⁵ The weapon consists of a GP bomb body, safe/arming device, tail kit, battery, adapters, and a target detection device (TDD). The Mk-65 is the only weapon in the series not derived from a GP bomb. The legacy Mk-57 TDD is magnetic-seismic, and the Mk-58 is magnetic-seismic-acoustic. The newest TDD, intended to replace both of the older TDDs, is the microprocessor-driven, programmable Mk-71.

Mine Delivery

Typically, mine delivery has been a low-altitude operation, largely because of the drift of a parachute-retarded weapon. Aircraft typically laid Starvation minefields at night, under radar navigation and at altitudes ranging from 200 to 30,000 feet. Bombers would drop mines in a straight line in a planned location, sometimes with individual mines landing ashore.¹⁶ About 50 percent of the emplaced mines were dropped within a half mile of their intended location.¹⁷

The same techniques are used today, often requiring multiple passes with inaccurate, parachute-retarded mines. A B-52 mine-laying pass occurs at 500 feet and 320 knots—too slow to be safe in fighters or the B-1B. The F-18 and P-3 employ similar profiles, leaving the laying aircraft low, slow, and predictable—a contributor to the loss of one aircraft and crew in Desert Storm's only mine-laying attempt.

The Twenty-First-Century Aerial Mine

Aerial mining techniques have not advanced since the Second World War, but the demonstration of Quickstrike-ER changed the picture en-

tirely, mixing a modern mine with both precision and standoff. The Mk-82/-83/-84-series bomb bodies can be fitted with JDAM kits, which convert the weapon into a GBU-38/-32/-31, respectively.

The short range of the JDAM provides little standoff, but the addition of a wing kit corrects that deficiency. The GBU-62B(V-1)/B Quickstrike-ER is Pacific Air Forces' nomenclature for an Mk-62 Quickstrike configured with a BSU-104 JDAM-ER wing and the GBU-38's guidance kit. The range of the system is in excess of 40 nm when launched from 35,000 feet.

These kits, applied to the Mk-62 Quickstrike, allow both precision delivery and "one-pass" standoff mine laying from either medium or high altitude.¹⁸ A bomber aircraft with a full load of guided Quickstrike-ERs can lay an effective minefield with a single release sequence. Mines with guidance kits can be laid in an unpredictable pattern, making mine clearance that much more difficult; furthermore, they can be tailored to the characteristics of specific waterways.

The Twenty-First-Century Aerial Minelayer

The implications for the Quickstrike-ER (fig. 2) go beyond precision, allowing aircraft to emplace mines from range. Today, only F-18, P-3, B-1, and B-52 crews train for mining. JDAM training, on the other hand, is ubiquitous. There is no practical difference between JDAM employment against a fixed ground target or a fixed location under shallow water; no additional training for basic mine laying is required.



US Air Force photo

Figure 2. Airmen from the 36th Munitions Squadron load a recently assembled Quickstrike-ER onto a munitions trailer.

The addition of low observable aircraft to the stable of potential standoff minelayers introduces two new capabilities to the mix. The first is the possibility of laying minefields within the outer limits of a target country's air defenses. The second is the potential to air-deliver a minefield covertly.

Mine Warfare

Typically, aerial delivery of mines is offensive mine warfare because mines are emplaced in a country's home waters. This technique is effective for maritime interdiction (Starvation, 1945), port closure (Hanoi, 1972), or even antisurface warfare (Palau, 1944). Offensive mining of inland waterways interdicts local traffic, a technique used extensively in Germany, Burma, China, and Vietnam. Unlike the RAF, the US Air Force has never used aerial mining for defensive purposes.

The collateral effect of mining extends beyond simple target destruction. Fear of mines is likely to interdict more shipping than actual mine detonation, and the requirement under the Hague Convention of 1907 to declare minefield danger zones actually increases the effect. All Eastern Bloc vessels in Hanoi remained for the duration—even though the United States gave 72 hours' notice of minefield activation. During mining of the Hanoi harbor, no ship challenged the minefield or made an attempt to clear it. For commercial vessels, the increase in insurance rates in a declared danger zone can be prohibitive, causing ships to avoid mined or potentially mined areas entirely. Ambiguity is key; a mined zone must be declared, but not all declared zones must be mined.

Introduction of the TDD has improved the specificity of mines. The new Mk-71 Mod 1 TDD is software programmable and has different algorithms for various classes, including submarines, minisubs, air-cushion vehicles (hovercraft), and fast patrol boats, allowing the mine to classify and select the desired target. The Mk-71 can distinguish between actual targets and decoys or countermeasure devices. This capability might allow for tailored mining, intended to interdict one kind of vessel but not another.

Never before has aerial mining been conducted with either precision or standoff. The emergence of this kind of capability not only will enable more effective and easier offensive mining but also will allow for short-notice defensive mining and a new category—reactive mining.

Offensive Mining

Offensive mining can affect harbors and shipping channels, river mouths, canals and interior waterways, choke points, and straits or coastal waters. It might even be possible to introduce reactive offensive mining—quick-reaction minefields designed to interdict surface combatants in littoral waters.

Harbor Mining

Harbor mining interdicts vessels at the source, preventing effective use of the harbor. For navies that lack an underway replenishment capability, preventing naval combatants from returning to refuel and rearm may effectively neuter them without a direct attack. With no port available, most adversaries have little ability to project naval power. This mission is nonlethal—at least until attempts are made to clear or pass the minefield. The effect extends to merchant ships, warships, and auxiliaries—if the harbor exit is closed, it can be closed to everybody.

Harbor mining can trap vessels inside, prevent them from entering, or sink vessels to deny access to channels, piers, or off-load facilities. Naval bases, more concentrated than commercial ports, are even easier to close. Headquarters People's Liberation Army Navy fleet at Zhanjiang, Ningbo (Zhoushan), and Qingdao are all susceptible to interdiction, with Zhoushan the easiest to isolate and Ningbo the most difficult. The fleet's submarine pens on Hainan Island have limited approaches and might be bottled up from standoff range. A sunken ship in a shipping channel can prove brutally effective.

Mine laying in the Hanoi harbor occurred in the face of significant opposition. Aircraft placed strings of mines released at a specified interval, some of them actually landing in locations where they were not useful. A minefield laid using precision guidance would create a precisely defined pattern optimized for the particular body of water. Quickstrike-ER standoff capabilities would have enabled the mining of Vietnamese harbors from outside the range of surface-to-air missiles (SAM).

Westward, the dual-use port at Bandar Abbas would be a prime candidate for mining. We have long-standing concerns about Iranian navy submarines—Russian-built *Kilo*-class diesel-electrics. Bandar Abbas hosts the Iranian Revolutionary Guard Corps navy as well, including minisubmarines and the ubiquitous small speedboats. The anchorage is 30–35 feet deep with an entrance only 800 feet wide fronted by a

breakwater with a gap of 1,300 feet, making it an ideal candidate for closure.

Not all port facilities offer as lucrative a target. Commercial ports are likely to be more spread out but will still rely on dredged shipping channels for large traffic. Boston Harbor, though no longer a naval facility, has been a busy port since the 1680s and has a long history of blockade (fig. 3).¹⁹ It has two parallel inbound and outbound shipping channels, each 1,200 feet wide with a dredged depth averaging 40 feet. East of Deer Island, the approaches open up into three deepwater channels and then into unrestricted waters. Using traditional aerial mine-laying techniques outside the harbor's anti-aircraft artillery defenses is feasible but munition-intensive; employing Quickstrike-ERs to close the twin channels between Logan Airport and Fort Independence would require roughly only 10 percent of the mines necessary to mine the harbor approaches.

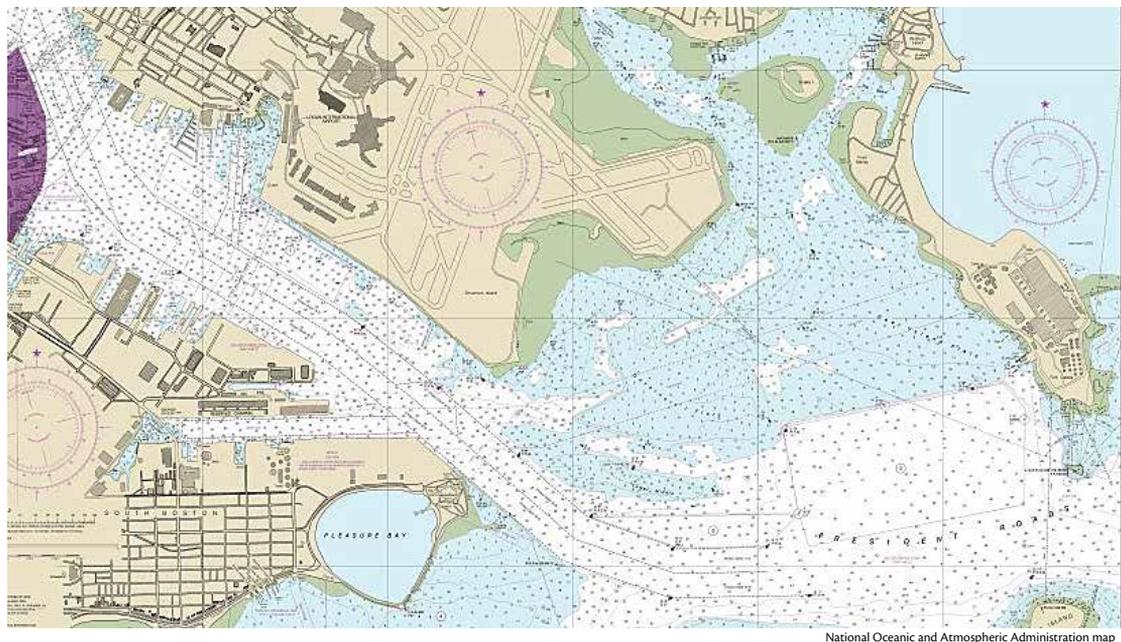


Figure 3. Boston's inner harbor, showing two lucrative choke points—the channels south of Logan International or the Deer Island channel in the lower right. Areas in blue are too shallow for larger vessels, including naval ships.

As a final note, the RAF and US Air Force attacked and destroyed most of the Libyan navy, sinking ships in port to prevent their use. Had precision mines been available, those ships might have been successfully bottled up in the harbor, retaining them for a successor government.

River Mining

The Second World War saw extensive river operations, including effective mining of the German canal system as well as the Yangtze and Rangoon rivers. By late 1944, mines routinely sank shipping at the mouth of the Yangtze.²⁰ In the Vietnam War, inland waterways were extensively mined in both North and South Vietnam to interfere with the North Vietnamese army's supply and infiltration routes, often forcing men and materiel back onto jungle roadways. In Vietnam, as in China during the Second World War, aerial mining of rivers was effectively unopposed.

The Yangtze is a lucrative target. Navigable for at least 1,000 miles from the river mouth, it carries a full 40 percent of China's inland waterborne freight and more inland freight than any other river.²¹ Shanghai is the world's busiest port, making the Yangtze a viable candidate for standoff mining both at the river mouth and along its length. Shanghai's air defenses make standoff mining—even with Quickstrike-ER—a dicey proposition, achievable only with low observable aircraft. Similarly, mining the interior reaches of the waterway would involve some penetration into the country, if only to avoid Shanghai. Mining, of course, is by no means the only way to block a waterway.

North Atlantic Treaty Organization operations in Allied Force included the destruction of a number of Danube River bridges, including all of those in Novi Sad, Serbia. Several took five years to clear and rebuild, and one, the Žeželj Bridge, took more than a decade to replace. Almost 1,000 ships were trapped in the river network, unable to pass Novi Sad, and four years went by before clearing of the debris.²² A need for rapid clearing and the seeding of the approaches to the bridge with aerial mines at the same time it was attacked would have made

the task immeasurably worse.²³ As for cases in which engineers might rapidly construct a pontoon bridge or in which underwater bridges are feasible, mining efforts might very well prevent completion of those structures.

Mining of Choke Points

Aerial mines might successfully interdict narrow choke points in numerous places worldwide. Straits often have no reliable alternative route, and closure may have a major economic and military impact. Candidates must be narrow but shallow with significant traffic. The Dardanelles strait, 35 nm long with an average depth of 180 feet, is only 4,500 feet wide at the narrowest point and was closed to surface ships in the First World War by 370 moored mines, laid in 10 strings.²⁴

The Gulf of Finland, approaching Helsinki and Saint Petersburg (Leningrad), was mined extensively by the Russians in the First World War and the Germans in the Second World War. In Asia, the Strait of Malacca, Sunda Strait, and Lombok Strait are critical choke points, especially for oil tankers. Malacca, which narrows to only 1.6 nm with a minimum depth of 82 feet in the Phillips Channel, sees 60,000 ship transits per year.²⁵ The Singapore Strait, which abuts the Strait of Malacca, was mined by the Royal Navy during the Second World War. The Strait of Hormuz is shallow, and the vast majority of the Persian Gulf (average depth of 150 feet) can be affected by Quickstrike. The selective capability of the Mk-71 TDD might allow closure of the straits or portions of the Persian Gulf to diesel-electric submarines yet leave commercial shipping unaffected. Some straits, such as Gibraltar, Lombok, or the Bab el Mandeb (Red Sea) are too deep for bottom mines.

Coastal Mining

Coastal mining, which attempts to interdict shipping in between the origin and destination, depends heavily on maritime topography. Intra-coastal waterways increase the feasibility immensely. In the Second World War, B-29s conducted mining along the Korean coast, pushing

ships out further from shore where they were more easily detected and attacked. The key disadvantage of mining in coastal waters is the requirement for area mining rather than point application used in the vicinity of a harbor, river mouth, or choke point—making avoidance much easier. Notably, mines in coastal waters are impossible to sweep if the adversary cannot determine where mines were laid.

In 1940 the RAF began extensive coastal mining (“gardening”) in areas of high shipping density, with aerial mines considered more effective than those laid by ships. Coastal mining included defensive minefields laid off Britain as well as mines placed off the coasts of Germany, Denmark, France, Holland, and Belgium. A series of operations targeted iron-carrying vessels off the coast of Norway between 1942 and 1944; mine-laying operations off France were constant even past D-day.²⁶ Northern European waters were lucrative mine targets since coastal traffic could not stray far from friendly coastlines before being attacked by other means. The RAF also conducted aerial mining in the Mediterranean, with waters around Sicily attracting particular attention prior to the Allied landings. Similarly, after mid-1941, almost every Axis port in the Mediterranean received some attention from RAF aerial minelayers, often in conjunction with bombing raids.

Defensive Mining

The RAF and Luftwaffe conducted defensive aerial mining, but the USAAF did not. The British effort sought to interfere with U-boats and a potential invasion fleet (fig. 4).²⁷

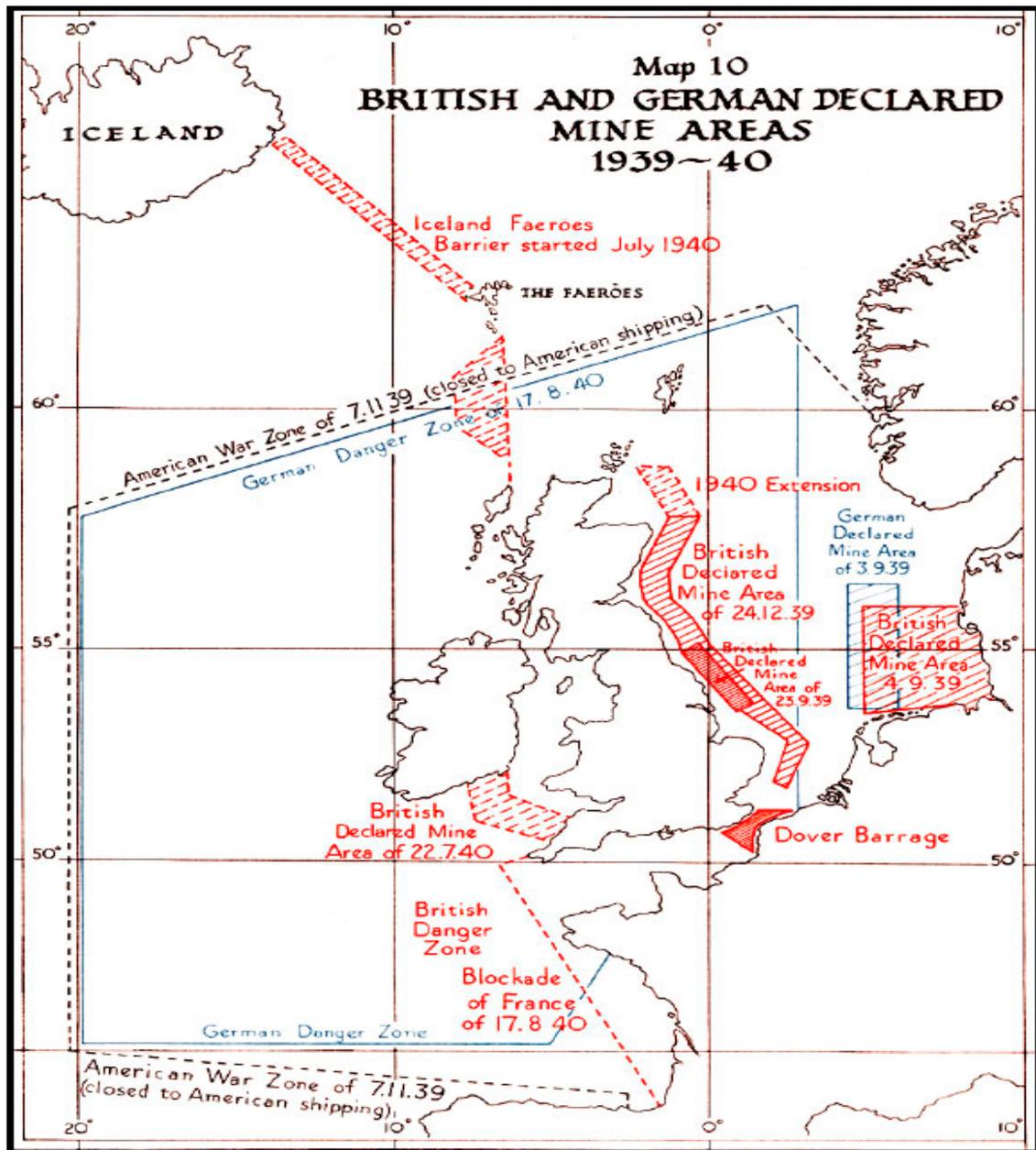


Figure 4. British and German declared mine areas, 1939–1940. (Reprinted from S. W. Roskill, *The War at Sea, 1939-1945*, vol. 1, *The Defensive*, History of the Second World War, United Kingdom Military Series [London: Her Majesty's Stationery Office, 1954], 97, <http://ibiblio.org/hyperwar/UN/UK/UK-RN-I/index.html>.)

Defensive mining to counter amphibious assault remains relevant. The number of countries facing an amphibious threat is low, and no country is willing to maintain a permanent emplaced minefield in peacetime. In effect, this reluctance has resulted in a de facto disarmament with respect to defensive mine laying, which demands a sustained effort and specialized forces. Furthermore, trying to protect against an assault when the offense gets to choose the time and place after long preparation means that defensive mining efforts are likely to be ineffective in practice.

That calculation might change with Quickstrike-ER. With very little strategic warning and some timely intelligence, it should be possible to emplace a defensive minefield to impede the establishment of a beachhead. In reality, one cannot count on timely intelligence and strategic warning, and the first wave of any amphibious assault will probably make it ashore. In this case, the applicability of a modern aerial minefield becomes apparent.

The key to any amphibious landing is not the original assault but the follow-up waves. At Tarawa, had follow-on waves been successfully interdicted on the first day, the assault might have failed. At Omaha Beach, the first wave likely would have never made it past the seawall without follow-on waves to support. Even in cases in which landings occurred with little opposition (Anzio, Inchon, and Suez), the follow-up delivery of reinforcements and materiel is essential. In an environment where Overlord-scale invasion fleets are not feasible, the ability to interdict follow-on waves may prove an effective counter to amphibious assault.

Prior to the arrival of an invasion force, the actual landing location remains unknown. After the first wave arrives, the arrival location of follow-on forces becomes known, and the port facilities necessary to support disembarked assault troops are easily derived. Similarly, the origin points of amphibious transports are known, and it may be possible to successfully isolate both the landing beaches and the ports where follow-on waves must embark and disembark. A modern replay

of Operation Husky—the Allied Invasion of Sicily (fig. 5)—clearly reveals the potential for rapidly emplaced defensive minefields.

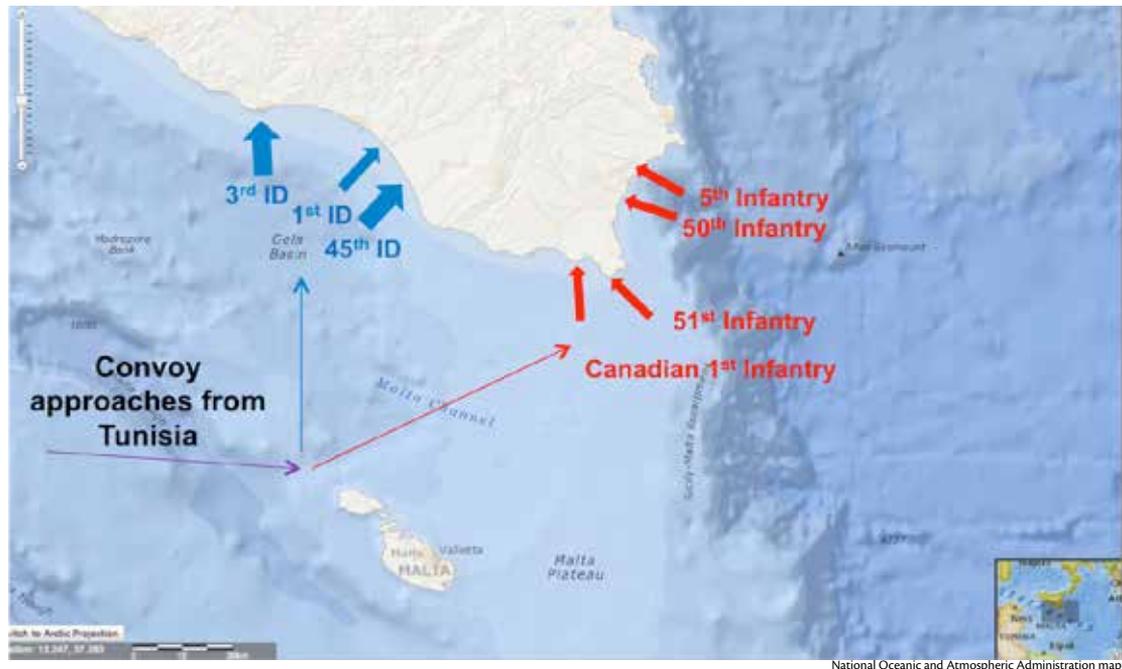


Figure 5. US (blue) and Commonwealth (red) landing beaches on Sicily. Shading contours, from light to dark, are 50-meter depth lines.

The landing fleet approached from Bizerte and Tunis, some 350 miles distant and almost due west of the landing beaches. For deception purposes, the convoy headings tended southeast toward Malta, turning north at a point 5 nm due west of the Gozo light at Malta. Follow-on waves were scheduled for D + 1 (one day after D-day), D + 3, and D + 4; empty landing craft had to return to Tunisia.²⁸ All of the Commonwealth landing craft crossed the Malta Channel, an area of shallow water (less than 300 feet) extending all the way to Malta, while the American divisions crossed the deeper Gela Basin. Potentially, the US forces were in easily mined waters for the last 10 nm of travel; the Commonwealth forces, for at least 50.

US forces landed and established 3 beachheads. The unloading of the first wave of support ships was not completed for 60–88 hours. The total offload for the first 3 days amounted to 22,554 personnel; 2,179 vehicles; and 7,801 tons of materiel. The port at Palermo did not open until D + 18 and even then was at 30 percent of capacity due to combat damage. In the next 6 weeks, a total of 736 voyages supported US forces ashore, the vast majority of which were landing ships.²⁹

Fortunately, no mines were laid to interdict the transport areas because minesweeping assets were in short supply and had not trained for night operations. Had the Luftwaffe been able to mine the invasion beaches or captured ports, Allied soldiers fighting well-equipped Wehrmacht forces in the interior might have found themselves with inadequate rations, fuel, and ammunition—a supply situation that became tenuous at times as it was. Within hours of the landings, the beachheads were known to Axis forces, and the ports that the Allies would have to use were easily identified by proximity. Palermo, heavily damaged prior to the landings, might have been rendered entirely unusable with aerial mines.

Because Sicily is a large island, Operation Husky required a staggering logistical effort. Even had substantial losses occurred, Allied forces possessed sufficient excess capability to accept a grinding war of attrition in the island interior. The duration and cost of an operation might well have been increased and might have looked like Anzio did later—with enough sealift capability available to support a toehold but not enough to contemplate a major offensive. For smaller islands, aerial mining might be capable of providing an ad hoc defense (for friendly islands) or a method of isolating island garrisons after an island seizure. Aerial mining as a response to a provocative action (such as the de facto seizure of Mischief Reef in 1994) might offer an option for incremental escalation short of direct counterattack.

Reactive Mining

An untried concept, reactive mining relies on the ability to emplace “instant” minefields from standoff. Precision allows for emplacement patterns that can be changed prior to launch—just like any other JDAM release. Interdicting beachheads offers an obvious application. In restricted littorals, instant minefields could target task forces by mining a probable route. Antiship missile attacks must penetrate a warship’s air defenses, but a mine bracket dropped 30 or 50 nm in front of a task force will not be intercepted and may not even be recognized. If the mines are directed against a ship, the captain may have to use scarce missiles for defense. For navies that cannot reload at sea, this situation amounts to a resource-allocation challenge. Unlike a Harpoon or other cruise missile, *Quickstrikes do not stop being dangerous when they are shot down*. Shooting down a mine probably would not affect the TDD (in the tail well) or the bomb body itself—a forged steel casing half an inch thick. A bomb that splashes into the water short of a target ship is still likely to arm and constitute a threat.

Additional measures might be feasible with reactive mining. The naval equivalent of “delousing” a friendly vessel being pursued might involve laying a minefield across the path of the pursuing ship or submarine. It may also be possible to use this technique deliberately when an unmanned underwater vehicle mimics a friendly submarine, inviting pursuit that is drawn into a reactive minefield.

Powered Standoff

Quickstrike-ERs are launched from medium to high altitude and glide to their destination. With this weapon, mine laying in the vicinity of long-range SAM systems can be conducted only by low observable aircraft or at some distance from the threat. Adding an engine to Quickstrike-ER expands the employment envelope, especially in defended airspace. Raytheon demonstrated the feasibility of doing so by fitting a TJ-150 turbojet from the miniature air-launched decoy into an

AGM-154C1 joint standoff weapon, extending the range from 70 to 260 nm.³⁰ Similarly, Boeing has performed a wind tunnel test of a powered JDAM-ER using a compact turbojet. Called a powered JDAM (P-JDAM), the proposed system is expected to have a range of well over 100 nm when launched from medium altitude. With this kind of distance, a powered Quickstrike (Quickstrike-P) could be launched from beyond the limits of most long-range SAM systems.

Increased standoff is not the only benefit of a powered mine. An engine allowing the weapon to maintain level flight makes a 40 nm low-to-low shot possible, permitting the shooter and the weapon to remain below the radar horizon up to release, even over water. Assuming a mast-mounted radar (such as a Type 381 Sea Eagle) at a height of 80 feet, an ingressing aircraft at 500 feet remains below the radar horizon until 38 nm. For the weapon itself, if it can fly at an altitude of 50 feet above the water, it will not break that same radar horizon until 20 nm.³¹ For a surface-mounted radar, the horizon closes in to 12 nm or less. This low-flight capability would allow a Quickstrike-P to come very close to defended targets without risk of intercept—and in some cases, without risk of detection from a surface threat.

Wrap-Up

Aerial mining has been dramatically effective in the Pacific, reaching its height in the Second World War as part of Operation Starvation against Japan. The value of this low-cost, persistent weapons system has been enhanced over time with increased specificity of the mines, which can be programmed to function against specific targets. The addition of an off-the-shelf precision guidance kit (JDAM) with a brand-new wing kit offers an innovative application for aerial mining, further enhancing the value of airpower against maritime nations.

The development of precision, standoff aerial mining capabilities should serve to restore the impact of aerial mining, particularly in defended airspace. Given the fact that potential adversaries are dependent

or partially dependent on maritime logistics for trade and support to military operations, the renewed capability to deploy mines while maintaining platform survivability will allow the laying of aerial mines in locations practically off-limits for decades. Maritime interdiction, antisubmarine warfare, and counteramphibious operations will all be enhanced by the option to lay custom-tailored minefields in high-traffic waterways. The long-overdue matching of precision-delivery capability to advanced undersea weapons will grant US air and naval forces a low-cost, asymmetric warfare capability unmatched by any other country and will provide the president and secretary of defense with additional strategy options for a large variety of operations. ✪

Notes

1. "Damn the torpedoes; full speed ahead!" This oft-misquoted comment by Adm David Farragut at Mobile Bay refers to mines, which at the time were referred to as torpedoes. Samuel Colt demonstrated the moored, command-detonated mine in 1844.
2. Maj John S. Chilstrom, *Mines Away! The Significance of US Army Air Forces Minelaying in World War II* (Maxwell AFB, AL: Air University Press, 1993), 13.
3. H. L. Thompson, *New Zealanders with the Royal Air Force*, vol. 2, *European Theatre, January 1943–May 1945* (Wellington, New Zealand: War History Branch, Department of Internal Affairs, 1956), chap. 5, <http://nzetc.victoria.ac.nz/tm/scholarly/tei-WH2-2RAF-c5.html>.
4. Chilstrom, *Mines Away!*, 25.
5. *Ibid.*, 21.
6. *Ibid.*, 22.
7. *Ibid.*, 29.
8. Wesley Frank Craven and James Lee Cate, eds., *The Army Air Forces in World War II*, vol. 5, *The Pacific: Matterhorn to Nagasaki, June 1944 to August 1945* (1953; new imprint, Washington, DC: Office of Air Force History, 1983), <http://www.ibiblio.org/hyperwar/AAF/V/AAF-V-21.html>; and CAPT Gerald A. Mason, USN, "Operation Starvation," AU /AWC/2002-02 (Maxwell AFB, AL: Air War College, 2002), 7, http://www.au.af.mil/au/awc/awcgate/awc/2002_mason.pdf.
9. Craven and Cate, *Pacific: Matterhorn to Nagasaki*, 674.
10. Chilstrom, *Mines Away!*, 43.
11. Edward J. Marolda, "U.S. Mining and Mine Clearance in North Vietnam," in *Encyclopedia of the Vietnam War: A Political, Social, and Military History*, ed. Spencer C. Tucker (Santa Barbara, CA: ABC-CLIO, 1998), <http://www.history.navy.mil/wars/vietnam/minenorviet.htm>.

12. Sabrina R. Edlow, *U.S. Employment of Naval Mines: A Chronology* (Alexandria, VA: Center for Naval Analyses, 1997), 7.

13. *Ibid.*, 11.

14. Mason, "Operation Starvation," 12.

15. Depths of 10–40 feet are considered very shallow, and less than 10 feet is considered the surf zone.

16. "Figure from XXI Bomber Command Tactical Mission Report, Field Order No. 16, Mission No. 47, 313th Bombardment Wing, May 19, 1945," in Mason, "Operation Starvation," 18.

17. Mason, "Operation Starvation," 14.

18. The stock GBU-38 tail kit will not fit on a Quickstrike mine with an Mk-71 TDD. An Mk-57 TDD might fit with a minor modification, but it is not a field modification.

19. To be fair, the USS *Constitution*, homeported on Boston, is still a commissioned vessel in US Navy service. Because she is a wooden sailing ship with no magnetic, acoustic, or seismic signature, she will be unaffected by bottom mines.

20. Joint Army-Navy Assessment Committee, *Japanese Naval and Merchant Shipping Losses during World War II by All Causes* (Washington, DC: Joint Army-Navy Assessment Committee, 1947), <http://www.history.navy.mil/library/online/japaneseshiploss1.htm>.

21. "The Strategic Importance of the Yangtze River" (video transcript), Stratfor, 29 March 2013, <http://www.stratfor.com/video/strategic-importance-yangtze-river>.

22. Edgar Martin, "International Waterway in Crisis: The Case of the River Danube" (paper presented at the International Association of Maritime Economists 2002 Conference Proceedings, Panama, 13–15 November 2002), http://www.cepal.org/transporte/perfil/iame_papers/proceedings/Martin.doc.

23. Strangely enough, during Operation Carolina Moon, the US Air Force attempted to destroy the Than Hoa bridge in 1966 using 3,750-pound parachute-retarded, magnetic floating mines dropped upriver by a C-130E. Four of five mines detonated on the bridge to no effect. The project was cancelled after the loss of a C-130 on the second attempt.

24. "Minefield in the Dardanelles (August 4, 1914–March 9, 1915)," Naval Operations in the Dardanelles, accessed 2 May 2014, <http://www.navyingallipoli.com/teksty/mines.pdf>.

25. US Energy Information Administration, *World Oil Transit Chokepoints* (Washington, DC: US Energy Information Administration, 10 November 2014), http://www.eia.gov/countries/analysisbriefs/World_Oil_Transit_Chokepoints/wotc.pdf.

26. LTCDR Geoffrey B. Mason, "Royal Navy Minelaying Operations, Part 1 of 2," World War II at Sea, accessed 2 May 2014, <http://www.naval-history.net/xGM-Ops-Minelaying.htm>.

27. See S. W. Roskill, *The War at Sea, 1939–1945*, vol. 1, *The Defensive*, History of the Second World War, United Kingdom Military Series (London: Her Majesty's Stationery Office, 1954), <http://ibiblio.org/hyperwar/UN/UK/UK-RN-I/index.html>.

28. Historical Section, Bureau of Naval Personnel, *The Sicilian Campaign: Operation "Husky," July–August, 1943*, Action Report, Western Naval Task Force (Washington, DC: Historical Section, Bureau of Naval Personnel, 1947), http://www.history.navy.mil/library/online/siciliancampaign_admhistry148c.htm. Document is now declassified.

29. *Ibid.*

30. "Raytheon Completes Free Flight of Joint Standoff Weapon Extended Range," Space War, 3 November 2009, http://www.spacewar.com/reports/Raytheon_Completes_Free_Flight_Of_Joint_Standoff_Weapon_Extended_Range_999.html.

31. The figure 50 feet was chosen because the BQM-167, a US Air Force target drone, is capable down to 50 feet above ground level, and this flight profile should be flyable with a jet-powered JDAM.



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