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PING AND THE MATERIAL MEANINGS OF OCEAN SOUND

John Shiga

Emerging from early twentieth-century transportation catastrophes and military, political, and economic crises precipitated by submarine and nuclear warfare, sonar embodies a model of underwater sound conducive to military and commercial efforts to control movement in ocean space. As Matthew Axtell writes, while military officials and scientists involved in sonar research and development have tended to conceptualize the ocean environment as an expansive body of water containing various marine organisms and other "natural" entities and structures, the ocean has also been "mediated by transducers, battleships, hydrophones, and human science, making it a highly technological space . . . the world that Navy officers and marine scientists made . . . was both a natural habitat and a technical workshop."[1] The tension between the ocean as natural or wild space and the ocean as technical workshop in military, industrial, and commercial practices is particularly legible in the case of sonar.

This chapter suggests that acoustic knowledges, techniques, and discourses were key to rendering the ocean as highly technological space, and this process of intensive mediation was oriented toward institutional interests in long-distance communication and human-machine integration in underwater environments. The chapter sketches two stages in the production of the ocean as technical workshop. The first centers on the listening devices such as underwater trumpets, acoustic lenses, and hydrophones (underwater microphones), which initially linked the ocean environment to human ears by means of a nonelectric and largely human-powered assemblage. The second stage begins with the turn in anti-submarine research and development to "active acoustics" or pinging sonar to detect objects in the water. Active acoustics coincides with the broader process of the electrification of media and continues through computerization.

By contrasting hydrophone-based and ping-based technologies, I hope to bring into focus what Jacob Smith (2015) calls the "eco-sonic" dimensions of media, including the ways in which media enable aspects of the material environment to be captured, altered, and controlled and, just as important, the "strange agencies of the nonhuman world in modern media."[2] Through an eco-critical lens, the history of underwater acoustic techniques can be reappraised in light of their contributions to the contemporary eco-crisis. Long-forgotten technologies, practices, and discourses might also be revisited and reconsidered as a model for what might be called, borrowing from Smith, a more "convivial" underwater media infrastructure that aims for sustainability rather than the objectives that have guided sonar infrastructure development such as fidelity, clarity, accuracy, and ubiquity.

Toward an Eco-centric Analysis of Sonar History

Sonar contributes to the production of ocean space through its mobilization as a "logistical medium," which Judd Case defines as those media that

> intrude, almost imperceptibly, on our experiences of space and time, even as they represent them . . . they are devices of cognitive, social and political coordination . . . Lighthouses, clocks, global positioning systems, temples, maps, calendars, telescopes, and highways are just a few of them.[3]

As a logistical medium, sonar represents space and time by capturing and processing portions of the ocean's acoustic field and rendering them audible and/or visible to human operators. But as Case notes, logistical media do not produce neutral descriptions of the world; they also reshape experiences of, and coordinate thought and action in, space and time. Just as airspace and aeromobility collapse without the continuous operation of radar, sonar enables ocean-space to be "continually 'beckoned' into being through the generative relationship of technology and human practice."[4] Sonar is key to the production of the ocean not only as an abstract space in maps and simulations but also as spaces of lived experience "whose embodied, emotional and practiced geographies remain to be adequately charted."[5] Those spaces include mobile spaces such as submarines, container ships, and research vessels as well as relatively fixed spaces and infrastructures such as undersea cables and the Clarion-Clipperton Fracture Zone (an area of the seafloor rich in minerals and thus attractive to deep sea mining firms); these spaces would cease to be functional or would be inaccessible if sonar's network of technologies, practices, and discourses were to fail. Attending to the logistical dimensions of sonar foregrounds the many military, commercial, industrial, and recreational activities in the ocean facilitated by underwater "pinging," which in turn have both short-term and long-term impacts on the material constitution and embodied experience of subsurface spaces.

In addition to the experiential, representational, and coordinative dimensions of logistical media, an eco-critical analysis might also explore the ways in which sonar incorporates, mobilizes, and transforms various environmental elements through the processes of research and design, manufacturing, distribution/

deployment, use, and disposal. Indeed, focusing exclusively on the way sonar impacts ocean space through its use in military, governance, industrial, and other activities may detract from an analysis of the spaces "behind" sonar (or the spaces on which the existence of sonar depends) that enable devices and techniques to be produced in the first place; an "eco-centric" materialism would direct attention precisely to the circulation "both material and sonic goods through infrastructural systems and the ways in which those human-made systems depended on natural systems to provide raw materials."[6] Ranging from the use of explosives to test the sonic properties of the ocean to large-scale mining of quartz for transducer arrays in anti-submarine sonars during the Second World War to the intended and unintended ways in which the sonar ping acts as a radiant in the ocean environment, the "long tail" of sonar stretches far beyond the aquatic spaces it which it is used.[7] Understanding sonar as an eco-sonic assemblage is key to tracing these imbrications between medium and environment and developing a critique of the broader political and ethical implications of sonar.

I conceptualize the relationship between sonar and ocean environment in terms of what Lisa Gitelman calls the "material meanings" of media, that is, the "nexus of cultural practices, economic structures, and perceptual and semiotic habits that make tangible things meaningful."[8] Like the conceptualizations of mediation in the work of Katherine Hayles and Bruno Latour, Gitelman's concept of material meanings emphasizes the manner in which media are products of ongoing alignments and interactions between widely dispersed social, cultural, and technological processes.[9] The concept of material meanings focuses attention on what is so often taken for granted in discussions of media transitions: the apparent "thingness" of a given medium—the sense that a medium is a self-contained instrument, device, or system rather than a disparate group of processes and practices—needs to be continually reproduced through the alignment of cultural, economic, semiotic, and perceptual ~~processes.~~ While media often survive despite changes in practices, economies, or habits, in some cases, those changes disrupt the meanings attached to the medium and to its material substrates, which in this case include water and sound as well as the various resources that are used in sonar's life cycle. Gitelman's concept of material meanings suggests that the "content" of media might be productively understood as consisting of transformations of material resources (vibration, electricity, labor, etc.) through (temporarily) stabilized networks of people, things, concepts, and institutions. Media transitions are key sites for eco-centric analysis because they tend to foreground a wide array of elements that are constitutive of a medium as well as the manner in which those resources may at times resist the roles assigned to them by designers and users.

The Hydrophonic Ocean

The material meanings of sonar were shaped by new forms of underwater mobility and new types of catastrophe produced at the intersection of modern transportation and communication technologies; the increasing speed of transportation led to a demand for early-warning systems that could detect distant threats. Initial designs for acoustic early-warning systems relied primarily on the sound-conducting properties of air or water. While over-the-air systems that used steam-powered sirens to project a warning signal to ships had been installed near lighthouses in the United States and Great Britain in the late nineteenth century, engineers soon turned their attention to underwater acoustic systems because of the efficiency of sound transmission in water as compared with air. In an early experiment in 1826 to measure the speed of sound in water, Swiss physicist Daniel Colladon designed an underwater trumpet that could pick up the sound of an underwater bell struck with a hammer ten miles away. Colladon calculated the speed of sound in water to be 1,435 meters per second (about three meters less than the current standard for fresh water) and "marveled that so little energy at the source could be transmitted so great a distance through the water medium and could still be detected by the trumpet receiver."[10]

Colladon's enthusiasm for water-based sound transmission may seem incidental to the development of contemporary global sonar networks and the debates surrounding them. Indeed, the cumbersome trumpet, which had to be lowered into the water by the operator who simultaneously pressed his or her ear to the trumpet's end, straining to hear the signal against a cacophony of waterborne noise, may seem to be little more than a proto-sonar curiosity. But the issue of energy transmission is key to the eco-sonic dimension of sonar, and the underwater trumpet design enfolded human, hydrological, and acoustical elements in what can be recognized today as a remarkably low-impact assemblage, in part because the trumpet used the acoustical properties of the water itself rather than electrical amplifiers to transmit sound.

The design of the submerged trumpet and early hydrophones shared a number of key characteristics with acoustic early-warning systems designed to detect airborne threats, such as Alfred Mayer's topophone (or "sound placer"), which worked like a binaural stethoscope for detecting the grumbling of icebergs at sea and, later, the distant engine sounds of approaching war planes; Japanese "war tubas" that enabled the Japanese military to detect planes approaching the coast during the Second World War; and the massive sound mirrors constructed by the British military, which focused sound into a mobile microphone to detect and determine the bearing of aircraft engine noise.[11] ~~With the exception of the British sound mirrors, all~~ of these acoustic locators or "macrophones," as Case calls them, were motivated by the increase in the speed of attack and the consequent reduction in warning time brought about by the use of airplanes in the First World War.

The intensification and acceleration of marine transportation similarly made conventional maps and optical sighting untrustworthy. Coal- and oil-powered motors led not only to increased speed, but as Willem Hackmann notes,

> Ships were also growing in size—the outcome of improvements in steel production and steam-engine design. The increased draughts of these ships

> made it imperative to know the contours of the sea bed, the position of wrecks and of other underwater hazards. This information was also vital to those laying the numerous submarine telegraph cables.[12]

The sinking of the *Titanic* in 1912, which is "the UK's deadliest peacetime disaster," signaled a broader breakdown of the economic structures, perceptual habits, routines, and signifying systems that supported transoceanic transportation and communication.[13] At that time, acoustic warning systems consisted of underwater bells installed on or near rocks and other hazards, and were rung electrically, pneumatically or by wave power (see Figure 7.1). Ships could hear the warning bells through a battery-powered underwater microphone, or "hydrophone." The Boston-based Submarine Signal Company cornered the market for these devices in the early twentieth century, and by 1912 had established over one hundred shore stations to operate warning bells marking underwater hazards in Europe, Asia, and North America.[14] Despite the scale of the warning bell network, systems based on hydrophonic listening were of limited use for detecting silent and mobile threats at sea, such as the iceberg that sunk the Titanic.

The deployment of submarines in twentieth-century warfare intensified the need for instruments that could probe the depths for threats, and the solution in first two decades of the century was found largely in nonelectric systems such as the Walser apparatus (see Figure 7.2). Developed by Lieutenant G. Walser for the French Navy in 1917, the Walser gear captured sound through a pair of nonelectric, acoustic lenses, each three to four feet in diameter, mounted on the underside of ships, with horn-tubes transmitting the sound to the operator's headphones. In nonelectric systems like the Walser gear, large lenses or horns (or a combination thereof) captured, focused, and amplified sound picked up from the water. Many of these systems depended upon the use of the human binaural sense to determine bearing through differences in amplitude between the two ears, or by adjusting the length of the air channels in a grooved plate or rubber tubing between the lenses and the headphones until the sound transmitted to each ear had the same intensity.

While nonelectric, acoustic locators were used to detect aircraft well into the Second World War, several factors led to the shift away from this technology in underwater early-warning systems by the end of the First World War. While the development of Colladon's trumpet and other devices based on nonelectric focusing of sound were motivated by scientific and commercial interests, the military concern with detecting submarines moving through the water became the primary driver of underwater acoustics research and technological development from 1914 through to the Cold War. The material meanings of underwater acoustic media began to shift away from civilian applications and toward undersea warfare. As a consequence, the relatively large sound lenses required to focus acoustic energy in the water were perceived to be a major drawback. As Hackmann points

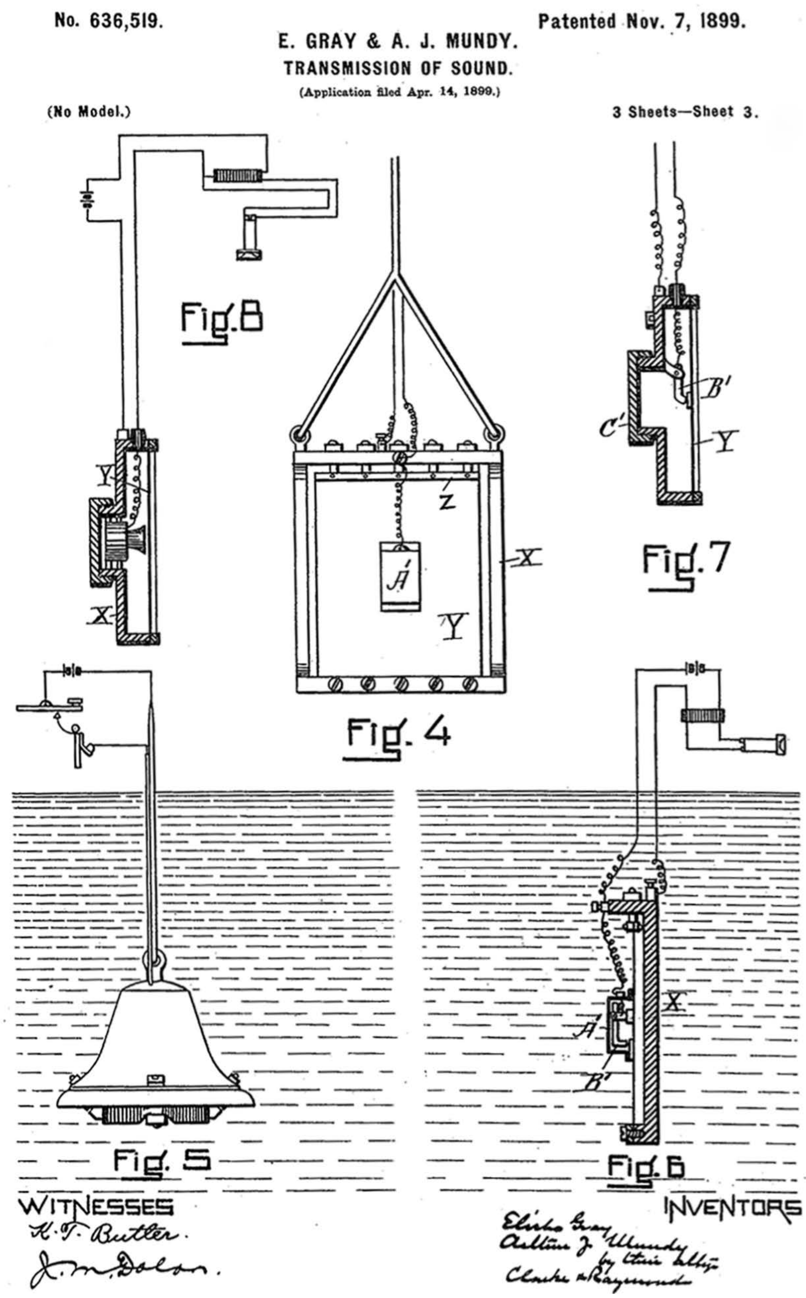

FIGURE 7.1 Schematic diagrams of the underwater bell and hydrophone system from Gray and Mundy's patent for "a new and useful improvement in the transmission of sound." While the patent notes that the bell could be rung pneumatically, the illustrations show an electromagnetically rung bell (Fig. 5) and battery-powered receiver in various configurations (Figs. 4, 6, 7, and 8).[15]

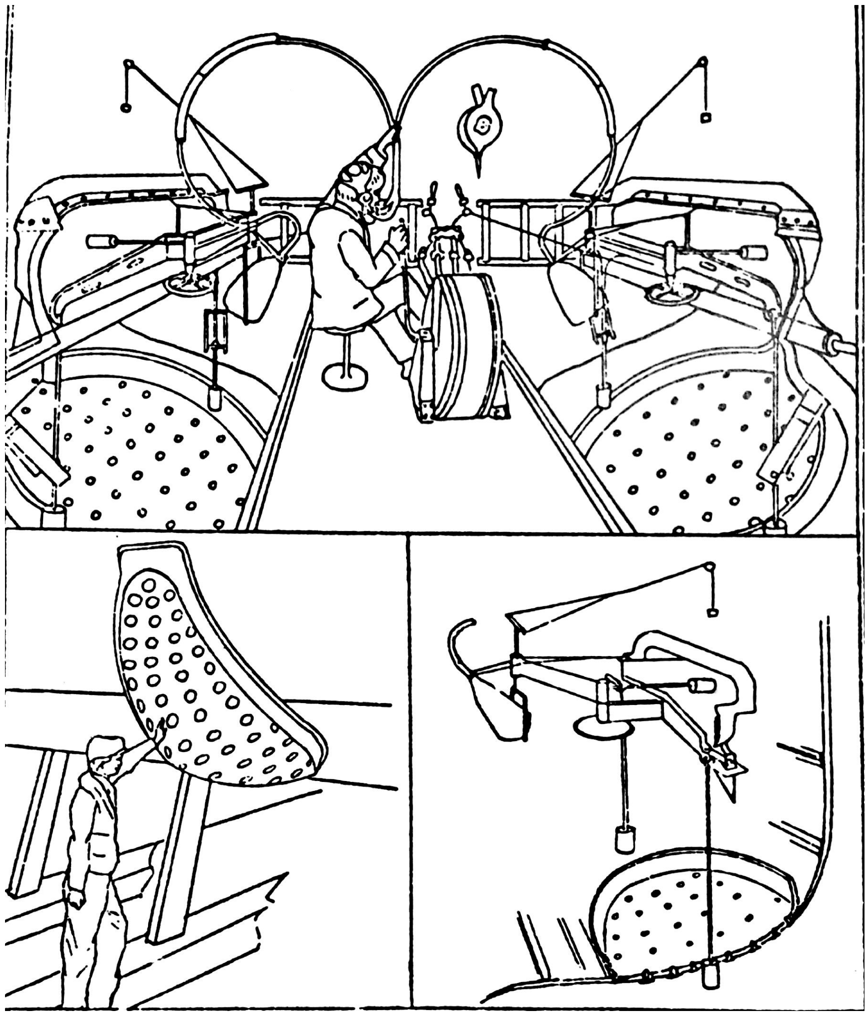

FIGURE 7.2 Installation of the Walser apparatus, with hull-mounted sound lenses and horn-tubes placed above each lens, carrying sound through adjustable tubing to the headphones.

Source: From Hayes, 1920, p. 20.[16]

out, the British Admiralty refused to install Walser gear on Royal Navy ships because

> it was considered too fragile for sea use, repairs could only be effected in dry dock, and it required a great deal of space. Moreover, Royal Navy ship architects had a great reluctance to cut holes in the hulls for any form of extraneous apparatus.[17]

Nonelectric, binaural locators were capable of filtering out noise even while the search ship moved at high speeds, but during the First World War the American and British navies nevertheless turned to relatively noisy hydrophones, which were distributed to anti-submarine flotillas in the thousands.[18]

While signal-to-noise ratios remained a central problem in Allied anti-submarine operations in the First World War, the industrialization of warfare led to a new concern with increasing the scale or mass of military deployments while simultaneously organizing militaries into "small, homogenous, and comparatively informal" units.[19] Military forces were not only larger than ever before (soldiers now numbered in the millions) but also consisted largely of civilian reservists.[20] American and British navies enlisted merchant fishing ships and organized them into submarine-hunting flotillas. While remarkably precise, sensitive, and capable of continuous monitoring of the ocean's sonic environment, nonelectric listening systems were simply too large to be installed on most ships, and the context of industrialized warfare demanded that equipment be produced quickly and "in large quantities."[21] Simple hydrophones based on Elisha Gray's design (inspired by the telephone transmitter) that could either be lowered into the water on the end of the pole or built into the ship through a relatively minor alteration of the hull solved the problem of mass production and rapid and large-scale deployment much more easily than the Walser gear and similar systems with their bulky sound lenses and intricate systems of acoustic "plumbing."

Although it required relatively little electricity, the hydrophone inaugurated the age of electrified underwater listening since, like the telephone transmitter on which it was based, it required a continuous current to transform sound as variations in water pressure into modulated electrical signals. While research and design continued to attend to the problem of noise reduction, engineers pursued solutions involving electrical delay lines, compensators, and amplifiers through the interwar period and the Second World War ~~rather than through mechanical and binaural designs.~~ From an eco-centric perspective, the merit of earlier technologies based on human muscle power and listening labor is that they "distributed the energy costs" of acoustic detection and localization "between human exertion and apparatus."[22] But in the context of the "first machine war," when "it was possible to grasp the relative warmaking potential of most countries simply by glancing at a diagram depicting annual coal and steel production," traditional forms of sonic knowledge associated with nonelectric systems became increasingly devalued.[23] The war of 1914–18 led to a decidedly industrial logic of listening: with the hydrophone and, later, the "pinging" sonar oscillator, the "burden" of listening was increasingly "borne by electric power created by the burning of fossil fuels."[24]

The electrification of underwater listening was driven by naval concerns with the extraction of locational information from underwater sound (for the purpose of targeting) and with reducing noise that interfered with the detection and identification of submarines and other vessels. Chief among the sources of noise in the sea was the "self noise" of the search ship itself, the engines and propeller of which were so loud that anti-submarine flotillas had to turn off ship engines to hear submarines through hydrophones. This slow, methodical search strategy was soon displaced by systems that would permit relatively clear signals to be heard through equipment even while the search ship was in motion. The concern with speed, with more rapid and continuous acoustic detection and tracking, and with faster responses to suspicious sounds with patterns of depth charges, drove the development of devices containing multiple hydrophones (over twenty in some systems) that could be towed behind the search ship, the incoming signals focused and amplified with electrical delay lines and compensators.[25]

Curiously, this new category of noise-suppressing, electrified, towed hydrophones were called "fish," and individual devices were given the names of animals, such as the Eel and the Rat—devices deployed by the Royal Navy in the First World War. Sonar incorporated a familiar and comforting image of "nature" at the same time as underwater listening became increasingly distant and insulated from the motor noise generated by fleets of search vessels and increasingly dependent upon electricity generated by coal-powered engines. Naturalized in name, electro-acoustical fish make legible the broader sonic division of the ocean whereby signals or sounds that are considered to be useful are captured, processed, and analyzed in spaces that are sealed off from the roar of engine emissions, propeller noise, explosions, and the sound of sonar itself.

Active Acoustics

If, in the First World War, the war-making potential of a nation could be estimated based on its production of coal and steel (key constraints for the production and operation of weapons, ships, and railroads), by the Second World War another set of figures became more significant in terms of war-making potential: "the number of automobiles made, the quantity of aluminum (for aircraft) extracted, and the quantity and quality of the electronic products assembled."[26] Between the two world wars, speed became paramount in decision-making about the development and organization of both transportation and communication infrastructures. The shift in military command to "speed rather than sheer mass" had significant implications for the eco-sonic dimensions of undersea warfare. As vessels became faster and capable of communicating by means of radio with each other via relays through headquarters, decision-making could be decentralized to smaller units. The notorious "wolf pack" tactic developed by German U-boat commanders was a particularly devastating form of decentralization, in which U-boats would disperse in the North Atlantic searching for Allied convoys. Upon spotting a convoy, the U-boat would communicate with others and coordinate an attack. Moreover, the invention of the snorkel (permitting the diesel engines to run with most of the ship submerged) meant that the U-boat could remain fully or partially submerged for extended periods and dive to greater depths and sail at higher speeds below water to avoid retaliation. In response to the tremendous increase in the mobility, invisibility, and flexibility of U-boat fleets, Allied navies invested in the development of electrified listening systems. While "unplugged" hydrophonic devices with complex systems of sound lenses and adjustable air-filled channels to focus and amplify distant sounds continued to be deployed in anti-submarine flotillas in the First World War, the desire for detection at greater ranges and for the extraction of more accurate locational information from underwater sound led to an arms race in submarine design and acoustic countermeasures. Nonelectrical systems were not necessarily simpler or easier to build and use than their electrified successors, but the growing demand for more accurate targeting information at greater ranges from the target led to the application of electrical techniques for amplifying signals picked up by hydrophones—and, by the interwar period, to expansive research and development projects on active acoustics in the United States and in Great Britain.

The shift to active acoustics—what the British Admiralty called "asdic" and the US Navy called "echo-ranging"—occurred during the interwar period and continued through the Second World War. Whereas horn-, lens-, and hydrophone-based systems listen "directly" to the sounds emitted by objects in the water, active acoustic systems project a sonic or ultrasonic pulse ("ping") into the water, listen for echoes, and use the delay between ping and echo to calculate the distance between the search vessel and the target. Although nonelectric "pings" can be generated by nonelectric means (e.g., via explosive charges), virtually all active acoustic systems developed during and between the two world wars relied on relatively high-powered, ultrasonic (i.e., above the range of human hearing) transducers. The principal reason for this shift was the fear that U-boats would soon be able to travel more efficiently in three dimensions; that is, that they could operate at greater depths and for prolonged periods on relatively quiet, electric motors. At the end of the First World War, British scientists advised their American counterparts that "submarines could be silenced to such a degree that passive sonar systems would not be efficient against them . . . Echo location gear, active sonar, was recommended."[27] Even with electrification, it was anticipated that hydrophones would soon become obsolete with the development of U-boats that could remain submerged for extended periods on battery power. The proposed solution to the silencing of submarines and their ability to drop out of sight and out of the range of hydrophones was to ensonify or acoustically "light up" the ocean with ultrasonic pings.

While the passive/active dualism obscures the way hydrophones and other listening techniques act upon ocean sound, the notion of "active" acoustics is useful to the extent that it highlights the manner in which acoustic force is applied to ocean space to extract information rather than collecting and repurposing already existing sound waves in the ocean. Initial forays in the use of active acoustics for underwater detection were made by the Canadian inventor Reginald Fessenden, who in 1913 developed a device he called an "oscillator"—a magnetostrictive transducer that radiated a continuous tone into the water and could then oscillate or switch to a "passive" mode to receive echoes reflected off objects in the water.[28] Around the same time, French physicist Paul Langevin and Russian émigré Constantin Chilowsky experimented with thin sheets of mica to generate ultrasonic frequencies, echoes of which would be picked up by a hydrophone. By 1918, Langevin developed a piezoelectric electric device in which a quartz mosaic sandwiched between two steel plates would act as both the transmitter of ultrasonic pulses as well as the receiver of returning echoes.[29] In the United States, following the First World War, and in anticipation of another undersea war, the National Defense Research Committee and the Office of Naval Research helped enlist scientists and engineers in sonar research from institutions including Columbia University, Harvard University, and the University of California, as well as telecommunications and electronics firms such as AT&T, General Electric, RCA, and Westinghouse.[30] This new alignment of military, industrial, and academic institutions once again altered the economic structures of underwater sound, which were now oriented not only to problems of navigation and threat detection but also to the problem of targeting increasingly fast, quiet, and deep-diving submarines. Military funded researchers redefined the problem of how to destroy a submarine from a question of building better sonar gear to "fundamental research" in oceanography and hydroacoustics and the drilling of such knowledge into sonar operators, or "ping men" (or simply "pings") as they were informally referred to in the Navy, to increase the efficiency of sonar in diverse water conditions and to enable echoes from targets to be distinguished from background noise. "Pinging" was not only a defensive measure to enable threat detection and avoidance but also a method of attack based on the extraction of locational information from underwater sound that would then facilitate more accurate barrages of depth charges.

According to the *Oxford English Dictionary*, the term "ping" appears in literature in the early nineteenth century, when it was used interchangeably with "ring" to denote "a short, resonant, high-pitched (usually metallic) sound, as that made by the firing of a bullet, the ringing of a small bell." The popularization of the term in the Second World War coincides with the incorporation of hydrophone and echo-ranging techniques into the broader category of "sonar," which referred to a range of passive and active techniques for manipulating underwater sound. The electro-acoustical discourse of ping produced a new experience of underwater acoustic transmissions as force and more specifically as firepower, an association that appears early on in the development of echo-ranging, and centers around a set of analogies between the transmission of electrical power and the mechanical acceleration of projectiles. In his patent for the echo-ranging oscillator, filed in 1916, Fessenden boasted that his invention could reach full power (1,600 watts) in under one-thousandth of a second, which, if translated into mechanical acceleration, "would give a 12 inch shell three times the velocity it has when fired from a 12 inch gun."[31] The association of pings with precisely controlled, destructive force is also evident in the discourse of sonar operators in the Second World War. Frank Curry, who served as sonar operator in the Royal Canadian Navy during the Second World War, described ping in terms of projectiles in an entry in his war diary in 1943: "Quite an interesting time pinging transmissions off all the neighboring ships and to follow a convoy down the harbor, ship by ship."[32] Decades later, Curry's short book describing his experience as a sonar operator continues to articulate ping as weaponized sound, cutting through the water: "We [took] up continuous anti-submarine search, our piercing asdic operating continuously, night and day . . . we beamed out transmissions, 3,000 yards every few seconds, listening carefully to echoes in our earphones as we trained the oscillator."[33]

The figuration of ping in terms of firepower was motivated in part by the close relationship between echo-ranging and targeting. The deployment of depth charges was to a large extent controlled by the interpretation of echoes in the sonar room; sonar was no longer a means of detecting and evading submarines but a system for targeting them. Ping was used as weaponized sound in diverse ways during and after the war. Curry notes that, as a result of depth charges with shallow settings, the crew frequently

> found the ocean surface covered with thousands of fish, floating dead. Those caught in the centre of the explosions were mangled and torn, but those further out were simply killed by shock . . . The fish were cleaned and turned over to the cooks.[34]

After the war, whalers devised new uses for ping as a sonic weapon. Initially, surplus naval sonar devices were sold to European whalers for use in whale hunting in the Southern Ocean but these were soon replaced by sonar equipment specifically designed for whale hunting. By the 1950s, whalers in Norway, Great Britain, Denmark, and Japan were using commercial sonar equipment to track whales while they dove, as ships would position themselves to kill the whale with explosive harpoons once it surfaced. In baleen whale hunting, pings were used not only to track and locate the whale but also to frighten them,

> resulting in escape behavior in which the animals swam at high speed near the surface in a straight line away from the sound source. This caused them to tire more quickly and made it easier to follow the whale and kill it.[35]

In both military and commercial whaling applications, the discourse and embodied experience of ping as a piercing beam or projectile rested on certain assumptions about ocean water. If mechanized underwater bells and nonelectric hydrophones were being displaced by electroacoustic pings, this meant that the model for underwater acoustic space was no longer tied to the concentric emanations of biological, geological, or mechanical sounds but rather to the linear transmissions of electric media. "Good water" was pliable, seemed to have no mediating effects on the range, direction, or intensity of pings, permitted pings to move in predictable trajectories, and returned clear echoes to the listening gear. Yet the ocean rarely conformed to this ideal. In addition to breakdowns of equipment, echo-ranging was frequently disrupted by vast "scattering layers" of marine organisms, which reflected sonar pings, and variations in water conditions, which bent transmissions downward and produced "shadow zones" beyond the reach of sonar. One postwar report by the US Navy noted that despite the efforts of engineers to build more powerful and discriminating sonar systems, there had been only modest gains in terms of the range at which submarines could be detected. According to the report, "This is because the limitations are generally not in the apparatus itself but in the sea water which carries the sound wave. And the sea has its full quota of perversities to trouble the sound man."[36] Although the report describes itself as a "record of achievement" by the National Defense Research Council (NDRC) and the academic and industrial institutions it supported during the war, more efficient and powerful sonar gear only led to marginal increases in the effectiveness of anti-submarine detection. The key part of the medium that had yet to be fully understood was the ocean water itself, which could propagate transmissions over long distances in ideal conditions but more frequently scattered, bent, absorbed, and otherwise distorted those transmissions.

The notion of ocean "space," then, was complicated by the growing awareness that this space was not empty but crowded with the action of waves, interactions with organisms, the atmosphere, and structures in the water formed by heat and pressure gradients that could facilitate or resist the transmission of pings. Consequently, Allied navies initiated large-scale research programs in underwater acoustics, which sought to identify and map the various hydrological, geological, and biological structures that interfered with the smooth flow of pings and echoes through the ocean. In 1941, NDRC, Division 6 was established for anti-submarine research and development, and by 1945 there were approximately three thousand scientists and other staff working on this project.[37]

But not all interactions between sonar and the ocean environment were considered to be worth studying; what is noteworthy about the postwar frenzy of activity in ocean acoustics is the manner in which concern with enhancing military command and control systems influenced the way scientists problematized the sonar-ocean relationship. Of particular interest to the US Navy from about 1937 through the Cold War was a layer of water approximately 4,000 feet below the surface called the "deep sound channel," which Maurice Ewing demonstrated in an experiment in 1945 could carry low-frequency sound over 1,000 miles.[38] The deep sound channel would later be instrumentalized or perhaps "infrastructuralized" as the hydroacoustic backbone of the US Navy's Sound Surveillance System (SOSUS), a global network of hydrophones and signal processing stations developed in the 1950s to track the movements of Soviet submarines.[39] More recently, the deep sound channel has been exploited in US Navy's Surveillance Towed Array Sensor System (SURTASS), a high-powered, low-frequency, active sonar system, which has generated considerable controversy due to the lethality of its pings demonstrated in mass stranding events, and also due to the Navy's declaration that it plans to deploy SURTASS in 75 percent of the world's oceans.[40]

Despite the ongoing efforts of environmental groups to litigate the navy's use of SURTASS, US courts have ruled that the value of high-powered sonar for national security outweighs the public interest in biodiversity. Rather than merely representing or coordinating movement through a preconstituted space, ping reshapes the ocean according to the motivation of dromological institutions to eliminate obstacles to the projection of bioacoustic force. Global sonar networks, which once consisted of hydrophones anchored to the seabed and other fixed infrastructure, now float freely according to what Paul Virilio called the "dromocratic" ideal of "displacement without destination in time and space," perhaps most clearly articulated in the right of the state to transform the ocean into a "vast logistical camp" of military preparedness, even if this entails the continuous ensonification of international waters and bodies therein.[41] The contemporary ocean is now an acoustic system, the mandate of which is to operate as a platform for the free flow of naval vessels and their bioacoustic projections.

While the interplay between sonar and the ocean environment has been scrutinized by generations of scientists working within and outside of military institutions, many interactions between ping and the ocean environment have been neglected until recently. Because the predominant use of sonar in naval operations is to act as a navigational, surveillance, and targeting mechanism, sonar's capacity to act more directly on bodies as a sonic weapon was practically ignored until the development of high-powered, low-frequency, active sonar in the 1980s. As Nate Cihlar notes, "the [United States] Navy has never addressed the possible effects of direct transmission of acoustic energy into bodily tissue and resonant cavities occurring when bodies are submerged in water."[42] Sound transmits more efficiently through a uniform medium; changes in the medium (e.g., moving from water to air) disrupt the transmission of sound. Whereas the body reflects 99.7 percent of acoustic energy in air, 100 percent of that energy will penetrate rather than reflect off a body in water if that body is composed mostly of water. The relatively uniform sound-conducting medium formed by bodies of water and bodies composed of water means that, beyond locational information, ping also produces "tissue rupture and hemorrhaging in various organs; yet, the Navy has failed to satisfactorily address the issue."[43]

Conclusion

In his short story, "Ping," ([1966] 1995) Samuel Beckett draws attention to what is so often obscured in postwar military discourses of sonar—that is, that ping does not only operate through prostheticization of vision and hearing; ping also exerts acoustic force on bodies in the water. While "Ping" seems to describe something like echo-ranging from the standpoint of a scanning, locating, targeting subject, it also incorporates fragments of an experience of *being pinged* in a breathless sequence of words with machinic regularity: "Ping perhaps a nature one image same time a little less blue and white in the wind. White ceiling shining white one square yard never seen ping perhaps away out there one second ping silence."[44] The story's repeated references to the storyteller's body parts (legs, toes, hands, etc.) are suggestive of the sonar scan, rotating back and forth along an arc searching and monitoring subtle changes in environment, which in "Ping" blurs into the body. As Elisabeth Bregman Segrè notes, the short, repeated words and phrases "may appear easy to understand" but in the end "our sense of logical, linear progression is thwarted, particularly by the interminable repetitions. Our habitual processes of understanding the written word prove to a large extent inoperable."[45]

Through its repetitions and refusal to cohere or progress as a linear narrative, "Ping" is one of the many cultural texts in this period that engage with postwar society's increasing occupation with the potential for catastrophe in the vast and complexly interconnected sociotechnical systems. Catastrophe, as Mary Ann Doane argues, emerges through the conjuncture of technological failure and confrontation with death.[46] "Ping" may recall or anticipate a number of potential and actual catastrophes, but for Western readers during the Cold War, the catastrophe mostly closely associated with sonar may have been nuclear war. Kathryn Schulz reinterprets "Ping" in relation to humanitarian uses of military sonar to search for missing Malaysian Airlines flight MH370 in March 2014:

> We ping in search of connection, and we ping to indicate our presence. It is the latter sound we hope to hear this week, as a device called a Towed Pinger Locator searches the Indian Ocean for a missing plane, like a child playing Marco Polo, in an unimaginably large pool, alone.[47]

Reflecting the tone of news media coverage of the sonar-based search, Schulz extracts sonar from the political history of relations between media and environment and celebrates technological and scientific breakthroughs enabled by the collaboration of military and commercial organizations in the search for the missing plane. Beckett's "Ping" becomes an homage to the irrepressible human desire for connection, diverting attention from the catastrophic potential of logistical media demonstrated by MH370's disappearance.

But in light of sonar's long history of violent manipulations of the ocean environment, it is also possible to read the nonlinear, cyclical, repetitious "Ping" as an allegory for, or perhaps an anticipation of, contemporary anxieties at the intersection of logistical media technology and *ecological* catastrophe; in this sense, we might understand the circularity of "Ping" as a gesture toward eco-sonic ruptures in the illusion of technological progress. Ping has played a major role in eco-catastrophe by facilitating the instrumental mapping of ocean depth for the expansion of military and commercial shipping, the deep sea extractive industries, whaling, and the seafood industry; by producing mass stranding events as legally acceptable and even necessary collateral damage through the application of low-frequency, acoustic force to nonhuman bodies in sonar testing, training, war games, and simulations; by reconfiguring the subsurface ocean as a vast platform for the maneuvering of nuclear arsenals; by insulating military operations through layer upon layer of electronic mediations from the anthropogenic noise such operations produce; and by consuming ever-greater quantities of nuclear or fossil fuels in the name of increasing the range, accuracy, and informational payload of sonar pings.

While it may seem tempting to embrace passive acoustics as an alternative to the projection of acoustic force in active systems, it is worth remembering that SOSUS and other hydrophone-based systems sustained military fantasies of perfect surveillance and control over the flow of nuclear weapons in the oceans for nearly half a century, and that this precarious circulation of nuclear missiles on submarines has the potential to literally end the world. Rather than arranging our options in stark terms such as passive versus active acoustics, we can instead develop a "green-media archeology" that will "uncover alternative media histories that are models for emergent practices."[48] We might look past the hydrophone to the nonelectric underwater trumpets, grooved plates, and labyrinthine air tubes, not as archaic curiosities but as sources for a new model of media development that strives toward the minimization rather than the expansion of media infrastructures.

Notes

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2 Jacob Smith, *Eco-Sonic Media* (Oakland: University of California Press, 2015), 13.

3 Judd Case, "Logistical Media: Fragments from Radar's Prehistory," *Canadian Journal of Communication*, 38, no. 3 (2013): 380.

4 Peter Adey, Lucy Budd, and Philip Hubbard, "Flying Lessons: Exploring the Social and Cultural Geographies of Global Air Travel," *Progress in Human Geography*, 31, no. 6 (2007): 776.

5 Ibid., 775.

6 Smith, *Eco-Sonic Media*, 14.

7 John Shiga, "Sonar: Empire, Media and the Politics of Underwater Sound," *Canadian Journal of Communication*, 38, no. 3 (2013): 368; John Shiga, "Sonar and the Channelization of the Ocean," in *Living Stereo: Histories and Cultures of Multichannel Sound*, edited by Paul Théberge, Kyle Devine, and Tom Everrett (New York, NY: Bloomsbury, 2015), 86.

8 Lisa Gitelman, "Media, Materiality, and the Measure of the Digital; or, The Case of Sheet Music and the Problem of Piano Rolls," in *Memory Bytes: History, Technology and Digital Culture*, edited by Lauren Rabinovitz and Abraham Geil (Durham, NC: Duke University Press, 2004), 203.

9 See N. Katherine Hayles, *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature and Informatics* (Chicago, IL: University of Chicago Press, 1999) and Bruno Latour, "Drawing Things Together," in *Representation in Scientific Practice*, edited by Michael E. Lynch and Steve Woolgar (Cambridge, MA: MIT Press, 1990), 19–68.

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11 Case, "Logistical Media," 386–389.

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18 Gary Weir, *An Ocean in Common: American Naval Officers, Scientists, and the Ocean Environment* (College Station: Texas A&M University Press, 2001), 9.
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20 Ibid., 150.
21 Lasky, "Review of Undersea Acoustics to 1950," 287.
22 Smith, *Eco-Sonic Media*, 25.
23 Van Creveld, *Command in War*, 189.
24 Smith, *Eco-Sonic Media*, 31.
25 See Hackmann, *Seek and Strike*, 58, and Lasky, "Review of Undersea Acoustics to 1950," 287.
26 Van Creveld, *Command in War*, 189.
27 Lasky, "Review of Undersea Acoustics to 1950," 288.
28 Frost, "Inventing Schemes and Strategies," 471–472.
29 Hackmann, *Seek and Strike*, 77–82.
30 Lasky, "Review of Undersea Acoustics to 1950," 292–293.
31 As cited in Frost, "Inventing Schemes and Strategies," 471.
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45 Elisabeth Bregman Segrè, "Style and Structure in Beckett's *Ping*: 'That Something Itself,'" *Journal of Modern Literature*, 6, no. 1 (1977): 127.
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