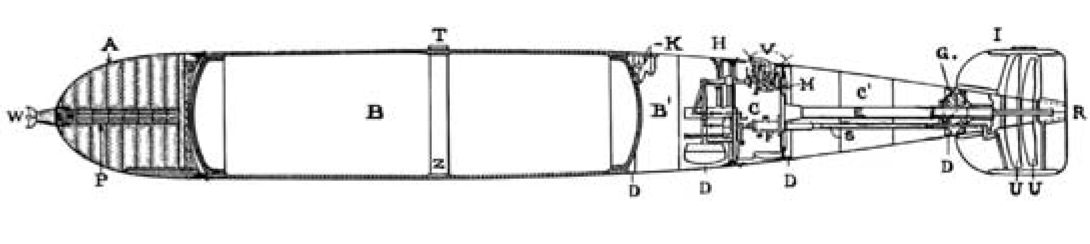

TORPEDO

Inventing the Military-Industrial Complex in the United States and Great Britain

KATHERINE C. EPSTEIN

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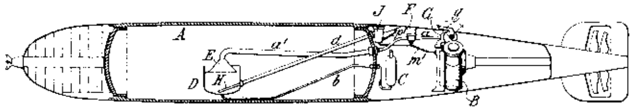

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To Mom, Dad, and Claire

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Every up-to-date dictionary should say that "peace" and "war" mean the same thing, now *in posse*, now *in actu*. It may even reasonably be said that the intensely sharp *preparation* for war by the nations is the *real war*, permanent, unceasing; and that the battles are only a sort of public verification of the mastery gained during the "peace" interval.

—WILLIAM JAMES, "The Moral Equivalent of War," 1910

TORPEDO

INTRODUCTION

"Our arms must be mighty, ready for instant action," President Dwight D. Eisenhower informed his fellow citizens in his 1961 Farewell Address, "so that no potential aggressor may be tempted to risk his own destruction." The need for constant preparedness and instantaneous readiness in turn demanded "an immense military establishment and a large arms industry," the conjunction of which was "new in the American experience." In the most famous passage of his speech, Eisenhower warned, "[W]e must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex."

Although the military-industrial complex is difficult to define, its meaning was clear enough for Eisenhower. It formed the vanguard of a broader political-economic transformation, one that involved "the very structure of our society." In an effort to defend against the external Soviet threat, Eisenhower feared, the United States would destroy itself from within. Defense contractors and a "scientific-technological elite" could hijack public policy, while defense spending could throw off the proper "balance between the public and private economy" and make government contracts "virtually a substitute for intellectual curiosity" in academia. As private interests corrupted public ones, and vice versa, core American liberties, like the free market and the free university, would give way. The United States would become a garrison state, its freedoms eroded in peacetime as previously they had been eroded only in wartime, and its people asked to make sacrifices once asked only of soldiers. In both time and space, therefore, the exigencies of preparing for modern war would collapse the distinctions between war and peace, between battlefront and home front, and between state and society.[1]

Embedded within these arguments were certain assumptions about US history and national identity. Eisenhower believed that the military-industrial complex and its associated developments were new for

Americans. Until the Korean War, he argued, the United States had no peacetime armaments industry: Once wars began, "American makers of plowshares" had needed time to "make swords as well." By and large, scholars have followed Eisenhower's chronology, agreeing that the military-industrial complex—and the attendant garrison state, warfare state, or national-security state—originated in the early Cold War or World War II at the earliest.[2] The novelty thesis is clearly correct if these phenomena are defined in terms of their scale.

But what if we define them differently? And what if we widen our gaze beyond the United States to take in another nation—Great Britain—with its own narrative of liberal exceptionalism?

This book maps a busy but unexplored intersection of military history, diplomatic history, the history of science and technology, business history, legal history, and policy history—an intersection that lies at the heart of the modern relationship between the state and society.

In the late nineteenth century, a new paradigm for procuring weapons brought the military-industrial complex into existence. Industrial naval technology was so sophisticated and expensive that traditional methods of building weapons in public-owned factories or purchasing them as finished products from private contractors did not suffice. Instead, governments had to invest in private-sector technology during the experimental phase. Collaboration on research and development made it difficult to determine whether the public or private sector owned the resulting intellectual property rights and led to numerous legal disputes, including two that rose to the Supreme Court in the United States and one that rose to the Law Lords in Great Britain. In the name of national security, the American and British governments pursued their intellectual property rights claims so aggressively that they encroached on those of the private sector. These battles over property rights were a problem that historians have not realized was a problem. Exploring them provides a valuable new perspective on the creeping militarization of peace in two liberal democracies and on the meaning of property as it relates to warfare rather than welfare.

In addition to their role in the invention of the military-industrial complex, torpedoes were crucial weapons systems. In a period of acute geopolitical tension, torpedoes created a revolution in naval tactics, strategy, and the very metrics of power, both for the hegemon (Britain) and for relative weaklings like the United States. Contrary to stereotypes of torpedoes as naval analogues to the improvised explosive devices (IEDs) used by insurgents against conventionally powerful armies, torpedoes were equally attractive to both the Davids and Goliaths of the sea, and there was nothing improvised about them. They were sold in a global marketplace by multinational firms, and they used extremely sophisticated industrial technology. Navies either had to purchase them on the open market and resign themselves to getting a product no better than what any other customer could buy, or they had to grapple with difficult research, development, and production challenges, which often led to lawsuits. Thus, in addition to the part they played in the origins of the military-industrial complex, torpedoes were at the nexus of the international arms race, globalization, and industrialization before World War I.

Torpedoes, Navies, and the Global Arms Market

Until the 1860s, the word *torpedo* did not mean what it means today. It referred to either floating bombs that would now be known as mines (such as those supposedly damned by Admiral David Farragut), or what are now called spar torpedoes (essentially a bomb attached to the end of a long pole projected from the bow of a warship). The modern torpedo, by contrast, is self-propelled and is therefore sometimes referred to as a fish or automobile torpedo.

Modern torpedoes trace their lineage back to the invention of a British engineer named Robert Whitehead.[3] Born near Manchester, England, Whitehead emigrated to France in the 1840s to find work as a marine engineer. In 1847, he moved to Milan, then part of the Austrian Empire, but the following year of revolutions drove him to the Adriatic Coast, where he eventually settled in Fiume (now Rijeka, Croatia) and began building engines for the Austrian Navy. In 1864, a retired Austrian naval officer named Giovanni de Luppis brought him plans for a primitive wooden torpedo (called *Der Küstenbrander*, "the coastal fireship"). The design proved unworkable, but Whitehead was sufficiently intrigued with the idea of a torpedo to start from scratch. He produced a new prototype by 1866, powered by a unique two-cylinder engine of his own design and capable of making roughly 6 knots for 200 yards. The key breakthrough came in 1868, when Whitehead solved its erratic depth-keeping. The Austrian Navy, Whitehead's patron, was delighted with the resulting improvements, but it could not afford to purchase the exclusive rights to the weapon.[4]

Whitehead's torpedo had several main components, as illustrated in

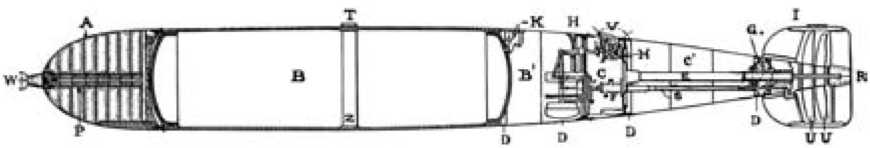


FIGURE I.1 Outline of a Whitehead torpedo. Although this diagram does not depict the design of the original Whitehead torpedo, this version of the Whitehead torpedo had the same basic layout. (*The Whitehead Torpedo. U.S.N., 45 cm × 3.55 m. Mark I, Mark II, Mark III, and 45 cm × 5 m. Mark I* [1898], plate 1, Historic Naval Ships Association)

Figure I.1. The tip of the torpedo contained the warhead, and the rest of the weapon existed to get the warhead to its target. The propulsion system consisted of a large flask (which took up most of the torpedo) carrying compressed air. The compressed air passed through a series of pipes to an engine, which turned the propellers through a series of rods and gears. The vertical guidance system—Whitehead's 1868 addition, known as The Secret—combined a hydrostatic valve, to control the depth, with a pendulum, to control the trim (i.e., whether the torpedo is pointed up or down). Until the mid-1890s, Whitehead's torpedo lacked a horizontal guidance system, and its effective range was limited by its inaccuracy.

Austria's inability to purchase the exclusive rights to Whitehead's torpedo opened the door for Britain. Both Whitehead and then-commander John Fisher (a future First Sea Lord) lobbied the Admiralty to try the device. It agreed, and trials were held in October 1870 with two torpedoes of different diameters. Overseen by a commission that included then-lieutenant A. K. Wilson (another future First Sea Lord), the trials were successful, and the Admiralty signed a nonexclusive contract to buy torpedoes from Whitehead's Fiume factory in 1871. In 1872, the Royal Laboratory (subsequently the Royal Gun Factory) at Woolwich, which was controlled by the army rather than the navy, began building Whitehead torpedoes for the Royal Navy under license from Whitehead. In 1890, Whitehead established a second factory at Weymouth, on the south coast of England, to build torpedoes for his best customer. His original factory at Fiume continued to take orders from navies all over the world.

The United States was an exception. Instead of buying torpedoes from Whitehead, the US Navy attempted to develop a domestic counterpart in parallel. Its best hope was a torpedo known as the Howell torpedo, invented by a US naval officer named J. A. Howell. The Navy began to test it in 1870. In contrast to the Whitehead torpedo, which relied on compressed air, the Howell torpedo relied on the energy stored in a flywheel for propulsion. Aside from its propulsive effect, the flywheel also exerted a gyroscopic effect on the torpedo, improving its accuracy in the horizontal plane. While it experimented with the Howell torpedo, the US Navy flirted periodically with the Whitehead Company, but to no avail. Not until 1891 did it begin buying Whitehead torpedoes.[5]

By that point, Robert Whitehead had made several significant improvements to his design. In 1875, he replaced his original two-cylinder engine with a three-cylinder version designed by the British engineering firm of Peter Brotherhood. The original single screw gave way to contra-rotating propellers, and Whitehead introduced a steering engine to amplify the effect of the depth mechanism on the horizontal rudders. In 1889, Whitehead began to build 18-inch (diameter) torpedoes in addition to his standard 14-inch model. By the mid-1890s, his torpedoes could make almost 30 knots for roughly 800 yards. The application of an invention known as the Obry gyroscope (named after the inventor, Ludwig Obry, and pictured in Figure I.2) to torpedoes in 1896 supplied a horizontal guidance system and began their transformation into accurate, high-speed, long-range weapons. Several years before the outbreak of World War I, torpedoes could travel at a speed of 45 knots (51 miles per hour) or run 10,000 yards (5.6 miles).[6] To put those numbers in perspective, Glenn Curtiss, the great American engineer, won the premier airplane racing event of 1909 by flying 47 miles per hour for 12.4 miles—and, of course, he did not have to contend with water resistance.[7] Over a fifty-year period, the speed of torpedoes had increased by roughly 800 percent, and their range by 5,000 percent. They were at the cutting edge of technology.

While torpedo technology changed, so too did the platforms for launching them. Indeed, the half-century before World War I may have witnessed more technological change for navies than any period before or since. The basic outlines are well known. Through the Napoleonic Wars, naval vessels were powered by wind, were made of wood, and fired muzzle-loading smooth-bore cannons maneuvered on carriages. In the mid-nineteenth century, they began a rapid transformation. Propulsion changed from sails

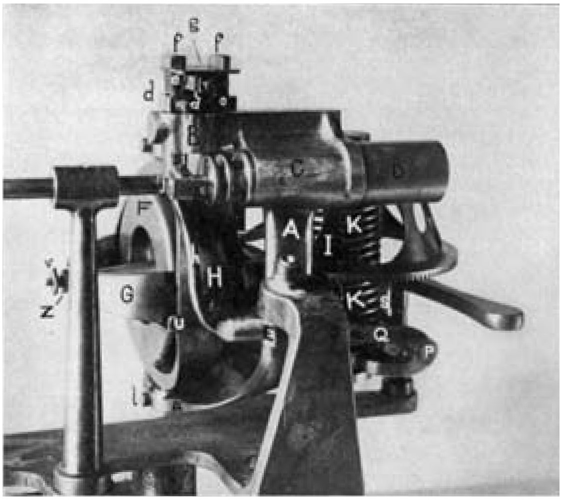


FIGURE 1.2 The Obry gyroscope. (*The Whitehead Torpedo. U.S.N., 45 cm × 3.55 m. Mark I, Mark II, Mark III, and 45 cm × 5 m. Mark I* [1898], plate 21, Historic Naval Ships Association)

powered by wind to engines (first reciprocating, then turbine) powered by fossil fuels (first coal, then oil). Wooden hulls were clad with iron and then replaced entirely by steel, increasing their ability to withstand artillery hits. Muzzle-loading smooth-bore cannons on carriages gave way to rifled breech-loading cannon on mechanized mounts (first hydraulic, then electric), which could shoot farther, more accurately, and more quickly. The growing ability of warships both to endure and to deliver artillery hits involved a celebrated race between armor and armament. Perhaps less well known, yet just as important, were changes in communications and targeting technologies. Navies experimented extensively with telegraph cables and radio for controlling movement at the strategic, operational, and tactical levels. The greater range and accuracy of modern guns were of little use if they could not be aimed and controlled, so navies also developed better targeting (also known as fire-control) systems, which were among the world's first analog computers.

Although it is natural to think of capital ships exclusively in terms of heavy armor and big guns, they were the most important type of vessel in driving torpedo development before World War I.[8] Even all-big-gun capital ships like the *Dreadnought* carried torpedoes.[9] Whereas capital ships had to aim their big guns at individual enemy ships, they aimed their torpedoes at the entire enemy formation, expecting to sink a proportion. With such a large and inviting target for torpedoes as compared to big guns, the effective range of the former could exceed that of the latter. The race between guns and torpedoes to out-range each other, so that one fleet could fire at another without being hit in return, was at least as significant as the better known race between guns and armor. The prospect that torpedoes might win the race led tacticians to fear that they would replace guns as the primary armament of capital ships, and even the battleship aficionado Kaiser Wilhelm II plotted for a "torpedo battleship."[10]

In addition to capital ships, smaller vessels also carried torpedoes. Torpedo boats, which many navies began to build in the 1870s, were the first vessels designed to use torpedoes as their primary weapons system. A short-lived type of vessel known as the torpedo catcher (or the torpedo gunboat) was developed in the 1880s to defend fleets against torpedo boats, but it soon became clear that the catchers lacked the speed to catch their prey.[11] The most durable type of vessel to emerge in direct response to torpedo development was the torpedo-boat destroyer, better known as simply the destroyer, which began to appear in the early 1890s. Originally intended to take on the *defensive* mission of the torpedo-boat catchers, destroyers soon showed *offensive* promise as torpedo boats themselves. Indeed, their greater size, durability, and sea-keeping ability made them better platforms for launching torpedoes than the torpedo boats had been. When firing torpedoes, destroyers used above-water, not submerged, tubes.

Perhaps surprisingly, submarines played little role in driving torpedo development before World War I. France led the way on submarines, introducing the first recognizably modern version in the early 1890s. It was followed by the United States and Great Britain around 1900. (Despite its later association with submarine warfare, Germany actually lagged in submarine development and likely had to rely on pirated French designs.[12]) Prewar submarines had limited utility as torpedo platforms. They were not true submarines but submersibles, spending most of their time on the surface of the water and submerging only to attack a target. Most submarines lacked sufficient surface speed to accompany battle fleets (i.e., they were not fleet-keeping submarines), which moved above 20 knots by 1914, and instead were confined to coastal patrol. They expected to fire their torpedoes at point-blank range of hundreds rather than thousands of yards. Thus it was surface vessels, especially capital ships, and not submarines that drove the development of faster, more accurate, and longer-range torpedoes.

Like many other armaments, torpedoes were built and sold in a global marketplace, featuring (like so many of today's markets) multinational corporations and transnational flows of capital, ideas, and technology. There were four international producers, who were distinct from those who built for just one country. The first, and most important, was the Whitehead factory in Fiume, which signed its first contract (with Austria-Hungary) in 1868 and its first international contract (with Britain) in 1871. It eventually sold torpedoes to twenty-three countries before World War I.[13] The second was the Berliner Maschinenbau Aktiengesellschaft (BMAG). It was sometimes referred to as the Schwartzkopff Company after its founder, who most likely stole plans from Whitehead in 1873 and began producing a near-duplicate of his torpedo shortly thereafter. BMAG sold to Japan, China, Spain, Sweden, and Germany—until the mid-1880s, when the German Navy ceased to buy from BMAG and instead built all its torpedoes in state-owned factories.[14] The third international producer was the Whitehead factory in Weymouth, England, which was originally established in 1890 to build solely for the British Navy but eventually sold on the open market. Finally, France's Schneider Company (better known for its guns) began to sell torpedoes internationally, but very little about its torpedo business is known.[15]

The international arms market had several distinctive characteristics. First, a number of armaments firms (like Whitehead) were multinational, with branches in more than one country. Some firms were subsidiaries of larger foreign conglomerates. In 1906, for instance, the great British armaments firms of Vickers and Armstrong-Whitworth purchased the Whitehead Company, including both its Fiume and Weymouth branches. Second, the line between public and private, and thus between state and nonstate actors, was blurry. Governments often operated quasi-private armaments factories to preserve security or stimulate competition, while private firms often received substantial investments from governments, making them quasi-public. Third, the armaments business usually required large up-front capital investments, and thus the number of producers within a given country was limited. Sometimes a single firm had a monopoly on a particular product (as with Krupp in German naval gun production), or a small number of firms had an oligopoly (as with Germaniawerft and Schichau in German torpedo-boat production). Finally, given the specialized nature of the goods being produced and the occasional ban on exporting, there was often just one consumer—the government—creating a so-called monopsony.

Under these conditions, producers faced several challenges. Not only did entering the armaments business require large capital investments, but so too did the constant plant upkeep to remain in the business. Demand was unreliable without a diversified consumer base. If a monopsonist government decided to stop purchasing, for whatever reason, demand collapsed. Government demand itself depended on unstable factors, like financial wherewithal and favorable tactical, strategic, and diplomatic circumstances. Monopsony empowered the consumer to set prices and specifications while depriving producers of leverage to protest. Producers often responded to their vulnerability by combining into rings or cartels.[16]

Monopsonies notwithstanding, consumers faced difficulties as well. If the producers did not find many consumers, neither did the consumers find many producers. To stimulate competition—and thus, in theory, to obtain better products at lower prices—consumers had three basic options.[17] One was to entice more private firms into the business. This task was not easy, despite the potentially lucrative rewards: for the reasons explained above, any intelligent firm would think twice about entering the armaments business. Overcoming firms' reservations usually required both a cash subsidy (whether in the form of direct injections or payment of artificially high prices) to help firms acquire the necessary start-up capital, and the promise of contracts to assure firms that they would receive returns on their investments. If governments were unable or unwilling to make large financial outlays or to promise orders to private firms, they could adopt the second option for stimulating competition, which was to establish a government factory. The globe was dotted with such plants: the US Navy's torpedo factory in Newport, Rhode Island; the Royal Navy's torpedo factory in Greenock; the Japanese arsenal in Kure; the French gun plant at Ruelle; the Russian iron works at Putilov; and the Austrian shipyard at Pola. Of course, these plants also required large financial outlays.

The third option for stimulating competition was perhaps the one most fraught with potential pitfalls: to allow private firms to sell internationally. By doing so, governments effectively gave up their monopsony. The market was flooded not only with additional consumers but also with additional producers because the armaments firms now had to compete with producers in other countries for international customers. Governments could then reap the benefits of international competition in their own countries. Even in the absence of any imperative to stimulate competition, governments might allow firms to sell abroad in order to keep the firms in business at lower cost to themselves. In effect, allowing companies to court foreign buyers stabilized demand, meaning that their home governments did not have to inflate demand artificially through subsidies or unnecessary orders.[18]

Despite such advantages, a significant drawback of this approach is easy to see: allowing armaments firms to sell abroad eroded secrecy. It was possible to minimize that risk by erecting various safeguards—for instance, by physically quarantining especially sensitive parts from the production of less sensitive ones, or by providing for damages if secrecy was breached—but it could not be eliminated. Thus, as we shall see in the following chapters, the global arms market offered benefits, but with costs.

Inventing the Military-Industrial Complex

Beginning with the introduction of the gyroscope in the mid-1890s, the growing accuracy, speed, and range of torpedoes posed grave challenges to conventional naval tactics. Traditional naval tactics called for capital ships sailing in close order and following visual signals from their leader to defeat their counterparts with heavy guns fired at point-blank range. Ships proceeding in close order and engaging at short ranges were extremely vulnerable, however, to torpedo fire. To deal with the torpedo threat, navies experimented with new formations, such as moving ships further apart in the line of battle or even breaking the line of battle into independent divisions, but the new formations created serious command-and-control problems. Navies also experimented with longer battle ranges to stay out of torpedo range, but the greater distances made it more difficult to achieve accurate gunfire. To cope with this challenge, navies sought to improve both their guns and their gunnery fire control. The result was a race for range between guns and torpedoes that raised the possibility that the entire system of tactics built around capital ships armed primarily with big guns would give way to one built around smaller vessels primarily armed with torpedoes.

The implications of torpedo development were equally profound at the strategic level. Traditional naval strategy, as elaborated in previous centuries by the Royal Navy, called for close blockade of enemies' coasts to stifle their trade combined with decisive battle to destroy their fleets and achieve full command of the sea. Torpedoes threatened both aspects of this system. Expensive capital ships were so vulnerable to torpedo attack by cheaper vessels in battle that fleet actions could seem too risky. Ships engaged in close blockade were overly vulnerable to torpedo attack by surface torpedo vessels under cover of darkness or by submarines at any time. One option was to move the blockade farther from the enemy's coast, but distant blockade (sometimes called loose blockade) was more difficult to enforce and was considered questionable under international law. By threatening to deprive navies of battle and blockade, torpedo development forced nations to look for fundamentally new ways of defining and applying naval power.

Thus, torpedoes played an important role in the intense naval competition preceding World War I. Navies everywhere poured enormous resources into increasing and conserving their relative power. In a classic example of a challenge-and-response dynamic, no sooner did one navy get a piece of technology than another navy invented a new piece of technology that rendered the former technology obsolete—and with it the massive peacetime investment needed to produce the technology on an adequate scale.[19]

The depreciation of peacetime investment was particularly problematic for navies. Until recently, naval warfare was far more technologically sophisticated than land warfare and required correspondingly greater peacetime investment. "You can go round the corner and get more guns, more rifles, more horses, more men who can ride and shoot," as Admiral Sir John Fisher once said, "but you can't go round the corner and get more Destroyers and more Cruizers [sic] and more Battleships." Lord Kitchener, Britain's War Secretary for the first two years of World War I, confirmed Fisher's claim: Equipping the British army, he claimed, "was not much more difficult than buying a straw hat at Harrods." With so many resources sunk into naval power, representing such a high opportunity cost, the stakes were higher in the event of failure.[20]

Industrialization exacerbated this dynamic, and torpedoes epitomized the process. Although a steamship is the more familiar symbol of industrialization at sea, a torpedo is at least as good a symbol: like steamships, torpedoes were metal, ran on engines, and were eventually powered by fossil fuels, but torpedoes could be produced in much larger numbers because they were relatively inexpensive and small compared to ships. Even as the miniaturization of torpedoes enabled them to be produced in bulk, however, it posed serious design and production challenges. Consider these figures: in an 1882 contract for Whitehead torpedoes, the Austrian Navy required that the margin of error on an overall length of 4.415 meters not exceed 5 millimeters (0.005 meters), and that the margin of error on an overall diameter of 35.6 centimeters (0.356 meters) not exceed 2 micrometers (0.0002 meters). On that order, precision meant margins of error within four decimal places and 0.001–0.0006 percent of overall sizes.[21] Miniaturization on that scale was not easy, and it was all the more difficult in view of the number of parts that had to be crammed into a torpedo. Consider some additional figures: whereas the standard small arm used by the US Army before World War I (the 1903 Springfield rifle) contained ninety parts, the standard torpedo used by the US Navy at roughly the same time contained about 500 parts—in the guidance systems alone.[22]

Given the many small, precisely machined, and tightly fitted pieces of metal that composed torpedoes, sending a prototype into production without putting it through a rigorous research and development (R&D) process could easily create manufacturing, quality control, assembly, and operational nightmares. The small size and relatively cheap per-unit cost of torpedoes did not spare them from the need for an expensive R&D process. In fact, miniaturization and large-scale production made it all the more necessary.

In these respects, torpedoes likely represented a cluster of devices sometimes called control technologies, and they have attracted relatively little interest from scholars. Although historians of that problematic late-nineteenth-century phenomenon known as the Second Industrial Revolution have moved well beyond the classic focus on railroads, electricity, and chemistry, naval historians still tend to study big things, often created by big corporations: armor, guns, and propulsion. If taken too far, this focus crowds out equally important narratives about smaller technologies, built by smaller businesses, that made the big stuff smart—control technologies in communications, data collection, and information processing, which together formed the nervous system for the heavy exoskeleton of the industrial beast. In navies, control technologies included targeting and guidance systems (both of which relied on cutting-edge gyrostabilization) and radio, which had different manufacturing requirements and were built by different types of firms compared to armor, guns, and propulsion. Perhaps most important, these control technologies, like torpedoes, required miniaturization on a scale that many other industrial technologies did not. Although the exact mixture of engineering challenges posed by torpedoes was unique, more generally those challenges typified an important class of industrial technology that has been under-studied by historians.[23]

Solving the challenges presented by industrial technology like torpedoes required a distinctive type of innovation, in which numerous activities occurred together rather than discretely or sequentially. Take basic science and applied science. Although the basic scientific principles at work behind industrial technology may not have been qualitatively more difficult than those behind preindustrial technology, they grew in quantity as the technology grew in sophistication. For instance, the science behind air flow in torpedo propulsion, which rested on the ideal gas law, was in some sense very simple, but applying it depended in part on the metal used for pipes and valves, which had their own chemical science of metallurgy.[24] Discovering a particular scientific principle was easier than combining it with other relevant principles and applying the result in order to create effective technology. Given the difficulty of the latter, basic science sometimes lagged behind applied science (or science sometimes lagged behind technology), reversing an idealized path of scientific-technological progress. To return to the propulsion example, even if the ideal gas law and metallurgical chemistry were not perfectly understood, it could still be possible to build a propulsion system that worked well enough (bearing in mind that the phrase *well enough* itself constituted a dependent variable), and perhaps later to deduce the underlying science from the technology. Thus, it was possible to have technology-led science as well as science-led technology.[25]

Similarly, invention, development, and production could occur at the same time, conducted by the same people in the same spaces.[26] Contemporary actors struggled to define these activities, the boundaries of which could have legal and financial implications. Did invention consist of coming up with a good idea, or did it consist of embodying that idea in a workable design? Did development end when a torpedo entered production, or did it continue when the design was tweaked during the torpedo's acceptance tests? Or was tweaking the design invention rather than development? Attempting to distinguish these activities from each other risks not only over-simplifying a complex historical reality but also obscuring the self-interest behind certain distinctions. When innovators seeking patents came up with a good idea but lacked the resources to turn it into a working prototype, it was in their interest to define their contribution as invention and to define others' contributions as "mere" development. When innovators seeking monetary compensation turned a good idea into a working prototype, it was in their interest to define invention in terms of labor and risk rather than in terms of coming up with a good idea. These issues may reasonably be characterized as being among the ontological and epistemological implications of industrialization.

As if these supply-side problems were not formidable enough, the demand side presented its own challenges. (Of course, those on the demand side—navies—were also on the supply side, engaged in invention, development, and production themselves.) Although many of those demanding torpedoes understood that the weapon had the potential to revolutionize tactics and strategy, determining exactly how that potential would translate into reality was extremely difficult. Even the best guesses had to contend against institutional factionalization in both the American and British navies, and agreements about the desired performance characteristics of torpedoes were temporary. Thus, the specifications that producers had to meet were not only strict but changing. Volatility characterized both the consumption and production environment.

In their ideal world, navies had unlimited resources and could invest heavily in all aspects of innovation to mitigate this volatility. In the real world, navies' resources were limited, and they had to make choices, all of which came with trade-offs. For instance, slowing production in favor of continued R&D risked having too few weapons in service when a crisis hit, while short-changing R&D in favor of production practically guaranteed more hiccups during the production process and problems with the weapons once they entered service. In the key sector of naval-industrial R&D infrastructure, Britain was far stronger than the United States, despite the traditional depiction of a declining Britain and a rising United States during this period. As a result, Britain was better able to perfect existing technology and test new technology thoroughly, while the United States had to take technological gambles. Precisely this pattern occurred with torpedo technology.

The effort to create an R&D infrastructure capable of developing successful torpedoes profoundly changed the relationship between state and society in the United States and Britain. The historian William McNeill associated this change with the emergence of command technology: technology commanded by the public sector from the private sector that was so sophisticated and expensive that neither possessed the resources to develop it alone.[27] As a result, they had to collaborate, meaning that, while such technology was commanded in the sense that government fiat replaced the market, it was not commanded insofar as governments required the cooperation of the private sector. Indeed, far from the smooth hierarchy perhaps implied by the metaphor of command, this cooperation could be extremely messy, for reasons alluded to above: both parties had leverage, and it was impossible to distinguish neatly among the various activities (science, invention, development, and production) involved in their collaboration.

My book draws out three implications of McNeill's thesis. First, command technology put a premium on the development of a kind of technology—which I will call servant technology—that could generate information needed to improve command technology. Second, the information generated by servant technology was itself a commodity because it had the power to affect market relationships by offering insight into the value of command technology. This commodified information was a distinctive kind of property. Third, the collaboration between the public and private sectors required to develop command technology raised fundamental and complex questions about the nature of property in relation to invention. When more than one party helped to invent a piece of technology, how could ownership of the intellectual property rights be established?

Answering this question generated serious friction between the public and private sectors. Conventional contract language, patent procedures, cost accounting methods, and pricing assumptions provided little guidance, because they were based not on the new collaborative procurement paradigm but on an older one, in which the public sector bought finished goods from the private sector as ordinary commercial products. In a series of legal battles over which side owned the intellectual property rights to technology that both had helped to invent, the governments won. To do so, they exploited two aggressive new legal strategies: applying eminent domain to intellectual property; and using anti-espionage legislation to control exports, that is, to regulate private commercial and proprietary rights—notwithstanding the fact that the legislation had been written for very different purposes. In every case, contractors protested that cutting them off from the global market would damage their property rights, but governments insisted that permitting private actors to share technological information freely would aid the governments' enemies. Courts tended to lose sight of private property rights when national security seemed to be at stake.[28]

McNeill's command technology, commanded by the public from the private sector, also had counterparts within each. Both governments and private firms sought to command technology internally by commissioning employees to solve certain problems, sometimes but not always in research laboratories, rather than relying on market competition to ensure that good ideas bubbled up. For internal command technology, just as for external command technology, the metaphor of command does not fully capture the dynamics of the relationship. Employees retained some leverage, and some important torpedo innovations emerged at the initiative of the employee rather than the employer. Internal command technology also created intellectual property problems for the same reasons that McNeillian (or external) command technology did: with multiple parties involved in the work of invention, both commander and commanded had claims to the intellectual property rights. Whereas the dispute in the case of external command technology was between the public and private sectors, the dispute in the case of internal command technology was between employer and employee.[29]

For two fundamental reasons, this book provides extensive technical information about torpedo technology and government contracting. First, an inability or unwillingness to come to grips with difficult technical information repeatedly led government officials and private firms into error, often with serious legal consequences. Second, technology and contracts are too often black-boxed—that is, placed inside a black box and not investigated carefully—leading to overgeneralized and overdetermined accounts that fail to capture the complexity and contingency of events as they appeared to decision makers at the time. It is true that neither torpedo technology nor government contracting lends itself to limpid prose (the joke that John C. Calhoun once tried to write a poem but only got as far as the word *whereas* comes to mind), but some measure of stylistic infelicity is surely preferable to sacrificing substance.[30]

Conversely, the examination of Germany and World War I is deliberately limited. Although Germany may be more closely associated with torpedoes than any other nation, it actually did not lead the world in torpedo development before World War I. The use of torpedoes in World War I is incidental to—and may even distort—the story being told here. Too often, the history of the decades before the war is examined as the prehistory to the war. This teleological approach tends to efface the contingency and complexity of the prewar period, which should be engaged on its own terms rather than as the prelude to another: after all, the people living through it may have guessed but did not know what was coming.

I hope that this book encourages new conversations. To give just one example, naval and military historians who work on technology could talk with legal historians about the legal issues raised by the contracting process, while legal historians could talk with military historians about the national-security implications of certain inventions, which merit a distinctive category within the study of intellectual property rights. Weapons acquisition in the industrial age is an extremely complex problem, and it is not the purview of any one field. It is also a problem worth exploring, because many of the difficulties that plagued the world a century ago are with us today: one does not have to listen very carefully to hear resonances between current events and a pre–World War I story about defense contracting, advanced weaponry, national security, property rights, state power, and the blurring of war and peace.

1

AMERICA'S WEAPONS OF THE WEAK

"The torpedo has become so excessively complicated, that any effort to simplify it must commend itself to all Naval men."

—BRADLEY FISKE, 1901

Most histories of the US Navy in the 1890s emphasize two events: the publication of Alfred Thayer Mahan's *The Influence of Seapower upon History* in 1890 and the Spanish-American War in 1898. The former called for command of the sea through battleship fleets, and the latter demonstrated the ability of heavy naval guns to win an empire at Manila Bay and Santiago Bay. Both fit neatly into a broader narrative that draws a straight line from the emergence of the so-called New Navy of steel vessels in the early 1880s to Woodrow Wilson's famous call for "a navy second to none" in 1916. If the key props in this story are battleships, then the most important actors are the entities who rationalized information and administration on land just as battleship fleets concentrated power at sea: the Secretary of the Navy, the Office of Naval Intelligence, the Naval War College, and the many boards (e.g., First Naval Advisory Board, Second Naval Advisory Board, Naval War Board, Strategy Board, and General Board) that serve as convenient signposts on the Navy's whiggish march to administrative centralization in most surveys of the subject. This naval narrative has become a staple in broader histories of the period.[1]

The story looks very different from the perspective of torpedo development. It is only a slight exaggeration to say that Mahan's book is a footnote at best, and the Spanish-American War might as well not have happened. Battleships play only a supporting role, and the stars are midlevel officers in the Bureau of Ordnance—one of the eight bureaus often cast as enemies of administrative rationalization—who would, in a later time, be called a technocratic elite. The issues confronting them required more technical knowledge than their professional or civilian superiors possessed, but their decisions were not narrowly technical. On the contrary, they had important legal consequences and fundamentally altered the relationship between the American state and society for the purposes of weapons procurement. Of course, the decision makers did not know at the time that they were inventing the modern military-industrial complex. They were just trying to get better torpedoes.

Between 1889 and 1896, two types of torpedo entered the US Navy's arsenal. In 1889, the Navy ordered fifty Howell torpedoes, required to have a range of 400 yards and a speed of 22.5 knots, from the Hotchkiss Ordnance Company, located in Providence, Rhode Island, which owned the rights.[2] In 1890 and 1891, the Navy arranged to have a US company, the E. W. Bliss Company of Brooklyn, New York, buy torpedo manufacturing rights from the Whitehead Company. An alternative to purchasing directly from Whitehead, the purpose of this licensing arrangement was to build up a domestic capability to manufacture the torpedoes.[3]

Why Bliss? The roots of the company went back to the machine-tool industry of New England, and its specialty was metal pressing—excellent preparation for torpedo production. The owner was Eliphalet Williams Bliss. Born in 1836 in Oswego County, New York, he worked for decades in Connecticut's machine-tool industry before establishing sole ownership of his own firm in Brooklyn in 1885 with $100,000 in capital (4,000 shares at $25 each). After taking over a press-making firm based in Meriden, Connecticut, in 1890, the Bliss Company drew attention from British investors, who purchased a controlling interest, until Bliss bought it back in 1893. The exact timing of the British purchase is unclear, but it almost certainly occurred before the Bliss Company signed its first torpedo contract with the US Navy in May 1891. Thus, even though the Navy acquired torpedoes of domestic manufacture, they were originally manufactured by a foreign-owned company. The Bliss Company may have been right to claim that "What Ford was to the automobile, Bell to sound, Edison to electricity and Carnegie to steel, Bliss was to the Pressed Metal Industry," but in this case, US industry did not happen without British money, and national security ran up against transnational capital flows.[4]

Torpedoes were not Bliss's only product, nor indeed his only product for the Navy. In the late 1890, while he negotiated the torpedo contracts, he won a contract to build artillery shells. To carry it out, he incorporated a new firm called the United States Projectile Company, initially capitalized at

$500,000 ($125,000 was needed for the new plant alone); it was absorbed by the Bliss Company in 1902. The Bliss Company also turned out a wide array of goods for civilian use, ranging from heavy machinery for industry to utensils for consumers.[5]

After a slow start, US torpedoes developed rapidly during the 1890s. During the first half of the decade, the 200 torpedoes in the Navy's arsenal changed little. The fifty Howell torpedoes all had a diameter of 14.2 inches and a length ranging from 9.6 feet to 12 feet; the 150 Whitehead torpedoes all had a diameter of 45 centimeters (roughly 18 inches) and a length of 3.55 meters (roughly 12 feet). None of them was required to go more than 800 yards, and their effective range was limited to 500 yards.[6] In the mid-1890s, however, the Bureau of Ordnance, which had the torpedo portfolio within the Navy Department, began to question whether the United States should continue to manufacture both the Howell and the Whitehead torpedoes, or settle on one. Early in 1896, the chief of the Bureau of Ordnance, W. T. Sampson, turned the question over to the Torpedo Board, a group of officers at the Naval Torpedo Station in Newport, Rhode Island headed by the commander of the Torpedo Station, George Converse. In reply, the board offered its qualified approval for manufacturing both kinds of torpedo. The Whitehead, it said, was a mature weapon whose only drawbacks were inaccuracy in the horizontal plane and the danger of its air flask exploding; thus the Navy should regard the Whitehead as its standard torpedo. The Howell, in contrast, was not a mature weapon, and it had "serious objectionable features," primarily the amount of time required to prepare it for launch and the use of steam and exhaust pipes to spin its flywheel. On the plus side, however, the Howell was accurate in the horizontal plane due to the gyroscopic force exerted by its spinning flywheel, and this feature alone was sufficient to warrant its continued manufacture and development, though on a limited basis.[7]

The Torpedo Board further recommended improvements in the performance of the Howell and Whitehead torpedoes, which required larger sizes. The Hotchkiss Ordnance Company, which owned the Howell torpedo, had recently developed an experimental torpedo with an 18-inch diameter, and the board recommended that the bureau manufacture it alone, for use aboard large ships, thus dispensing with the older 14.2-inch model. The board also renewed its recommendation, first made in September 1895, that the bureau begin developing a 5-meter, as opposed to 3.55-meter, Whitehead torpedo for use aboard ships larger than torpedo boats.[8]

The bureau acted quickly on the board's recommendations. Early in 1896, Sampson began negotiating with the Hotchkiss Ordnance Company for an 18-inch Howell torpedo. Three rounds of tests with the new model revealed a consistent flaw: the motor was unable to spin the flywheel in the required amount of time with the required amount of pressure. Perhaps discouraged by the results, Sampson asked the American Ordnance Company (which had taken over the rights to the Howell torpedo from the Hotchkiss Ordnance Company) to submit a bid for a lot of thirty-five 14.2-inch torpedoes. Specifications were drawn up, and on January 19, 1897, Sampson recommended to the Secretary of the Navy that the department make the purchase. Sampson even sent the contract to the printers.[9]

That was as far as it got. A week later, Secretary of the Navy Hilary Herbert had a conversation with Sampson in which he expressed doubts about the value of the Howell torpedo. "Evidently," Sampson speculated, "he had been listening to the opinions of some people who were averse to the use of the Howell torpedo."[10] Sampson urged him to appoint a board to report on the subject, which the secretary promptly did. It became known as the Miller Board, after its president, Merrill Miller, with the commander of the Torpedo Station (Converse) and the chief of the Office of Naval Intelligence serving as the other two members. The mandate of the board was essentially the same as that given to the Torpedo Board by Sampson in January 1896, when the latter board had recommended the continued development of both the Whitehead and the Howell torpedoes.

The Miller Board reached a different conclusion, delivering its report in February 1897. It noted that the time required to spin the flywheel and prepare the Howell for launch constrained its usefulness and that it could not be adapted for submerged discharge. As presently developed, therefore, the Whitehead was superior. Looking to future development, the board focused on the issue of propulsion, arguing that no matter how perfected the method, the Howell's reliance on the stored energy of the flywheel would limit it far more than the Whitehead's reliance on compressed air. Moreover, if a new device, the Obry gyroscope proved successful, one of the chief disadvantages of the Whitehead—its lack of accuracy in the horizontal plane—relative to the Howell would disappear, and the Whitehead's superiority would become even more marked. Based on the board's recommendations, Herbert ordered Sampson to prepare an order discontinuing the manufacture of Howell torpedoes.[11]

The Whitehead Torpedo and the Obry Gyroscope

Meanwhile, the Whitehead was running into its own problems, which illustrated the difficulty of procuring rapidly changing technology in a global market. In February 1896, at the same time the Torpedo Board recommended the continued manufacture of both the Howell and Whitehead torpedoes, it also recommended the development of a new, longer (5-meter instead of 3.55-meter) Whitehead torpedo. Within weeks of receiving the report, Sampson negotiated a preliminary deal for 100 "long" Whitehead torpedoes. In June 1896, however, a hitch arose over the speed requirement for the new torpedoes. The Torpedo Board had recommended that the minimum be set at 28.5 knots for 800 yards, but the Bliss Company protested that its information from the Whitehead Company said that the minimum should be a half-knot lower. In August, Sampson proposed an unorthodox compromise: the speed requirement should be set at either the highest obtained by comparable torpedoes abroad or at the average speed of the first five long torpedoes built by the Bliss Company. The company accepted the offer and it was embodied in the specifications. The bureau ordered 100 long torpedoes on October 21, 1896; these became known as the 5-meter Mark I torpedoes. Over the next several months, the bureau purchased an additional fifty-nine short torpedoes, which became known as the 3.55-meter Mark III torpedoes.[12]

Production of these 159 torpedoes intersected with a significant new piece of torpedo technology: the Obry gyroscope (named after its inventor, Ludwig Obry). Just over a month before the bureau ordered the Mark III and Mark I torpedoes, the Whitehead Company sent a circular to the US naval attaché in Berlin announcing that it had acquired the rights to the Obry gyroscope, which allowed accurate shooting up to 2,000 meters. About a week after receiving the letter, the Navy Department ordered a board, which became known as the Fiume Commission, to visit the Whitehead factory at Fiume and report on the gyroscope. Bureau officials alerted the Bliss Company of these developments and notified it that the department might wish to put the gyroscopes in the torpedoes about to be ordered. The company promptly replied that it had written to the Whitehead Company for information, and its chief engineer, F. M. Leavitt, unofficially opined that "[i]f the device pans out as well as the reports seem to show it would appear that it ought to be put in all the torpedoes in the service." Roughly two weeks after the department had received the Whitehead Company's offer, the Bliss Company reported that it had secured the rights to manufacture the Obry gyroscope in the United States (although negotiations over the exact terms continued). Buoyed by his correspondence with Leavitt and without waiting for the report of the Fiume Commission, the commander of the Torpedo Station (Converse) recommended that the Navy immediately procure two sample Obry gyroscopes for experimental purposes.[13]

The commission reported enthusiastically on December 10, 1896, that the Obry offered "marked advantages" to torpedoes, increasing their effective range by as much as 50 percent, and repeated Converse's recommendation that two sample gyroscopes be ordered immediately. A month later, the Torpedo Board endorsed the Fiume Commission's recommendations. The commission also enclosed a letter from the Whitehead Company dated December 9, 1896, offering three different purchasing arrangements: the Navy could buy the gyroscopes directly from the Whitehead Company at £50 (approximately $250) each, including royalty; it could buy the rights and manufacture them through the Bliss Company for a royalty of £30 (approximately $150) each; or, instead of paying a royalty per gyroscope, it could pay one lump sum for all time of £15,000 (approximately $75,000). The department chose the second option, and it ordered three sample gyroscopes.[14]

Both the Bliss Company and the Navy found dealing with the Whitehead Company frustrating. The Navy had been under the impression that if the sample gyroscopes were ordered quickly—as they were, in January 1897—the Whitehead Company could deliver them within ninety days. Ninety days came and went, and from March to May 1897, the correspondence between the bureau and the Bliss Company was peppered with queries by the former about when the sample gyroscopes would arrive and when the negotiations over the precise terms of manufacture would be concluded, and assurances by the latter that it was doing everything it could to hurry the Whitehead Company. Converse speculated that the delay "would indicate that either Mr. Whitehead is unusually slow in perfecting the device or else," more sinisterly, "he is not in haste to send the apparatus to this country." A sample finally arrived in mid-July. After familiarizing itself with the gyroscope, the Bliss Company put it in a torpedo, and trials began in early August 1897.[15]

In the meantime, a different question had to be settled about the 100 long torpedoes ordered in October 1896: their speed. In December 1896, the Bliss Company asked the bureau for a decision, offering to accept a speed of 26.5 knots, which the bureau's inspector of ordnance at the company considered reasonable. Sampson referred the question to the Torpedo Board and asked the Office of Naval Intelligence to collect information on what was required of 5-meter torpedoes abroad. That information only confused the situation further, because foreign navies used several different types of 5-meter torpedoes. As for the other way of determining the speed requirement, averaging the speed of the first five 5-meter torpedoes, the Bliss Company was not ready for speed trials until mid-April 1897 because of delays in the procurement of forgings for the torpedo air flasks. Once these trials were concluded, the Torpedo Speed Board—not to be confused with the regular Torpedo Board—delivered its report. Based on information from abroad and from the trials, the Speed Board recommended that the speed requirement be set at 28 knots for 800 yards, and the bureau agreed. Novel (and messy) contracting arrangements were necessary to deal with complex new technology.[16]

In another illustration of the same difficulty, just as the speed question was closed, the question of how the Obry gyroscope would affect the specifications and requirements for the 159 long and short torpedoes under contract opened. On June 21, 1897, E. W. Bliss himself wrote to the department to explain his company's quandary. It could not conduct regular acceptance tests for the torpedoes under contract while experimenting with the Obry gyroscope, and it would hurt the company financially to delay delivery of these torpedoes. Therefore, Bliss asked the Navy Department to waive temporarily the usual trials for torpedoes accepted without the Obry (of which there would probably be about forty), and if the department later decided to install the Obry in them, the company would conduct the acceptance tests with the gear installed. The Bureau of Ordnance was sympathetic and recommended that the department grant the request, promising to advise it on the desirability of installing the Obry as soon as tests were finished. The department agreed.[17]

In anticipation of favorable results with the Obry, the bureau began negotiating with the Bliss Company in early August 1897 over the terms on which it would install the gyroscope in the torpedoes under contract, letting the company choose whether to manufacture the gyroscopes itself or purchase them from the Whitehead Company. The Bliss Company preferred the former, pointedly reminding the Bureau of Ordnance about the desirability of domestic manufacture. It said that the price of manufacture and installation would average $546 per torpedo on the whole order of 159 torpedoes, dropping to $380 per torpedo on future orders. Attempting to preempt complaints over the price, the company favorably (but misleadingly) compared its quote to that given by the Whitehead Company in December 1896.[18]

With this offer on the table, the Torpedo Board submitted its preliminary and final official reports on the Obry gyroscope, having seen it run in both a long and a short torpedo. Its verdict was enthusiastic: The Obry was an "excellent practical apparatus," whose capacity to correct for deflection was "such as to improve the performance of the torpedoes one hundred per cent," and the Navy should adopt it. The bureau won the department's approval to install the gyroscopes in torpedoes under contract, pending determination of the final cost by a compensation board.[19]

Everything went smoothly until spring 1898, at almost the same time as the Spanish-American War began. The new commander of the Torpedo Station (T. C. McLean, who had recently succeeded Converse) found that when the short torpedoes with gyroscopes were fired from moving boats, they entered the water at a high angle, causing the tail to swing and the torpedo to roll, which in turn caused the gyroscope to malfunction and take on a new directional axis. This discovery set off a long and torturous search for a way to secure a flat dive of the short torpedoes and thus prevent the roll that deranged the gyroscope. The Torpedo Station discovered that the tail of the torpedo was too weak after space for the Obry rudders was cut away and recommended substantial changes in the construction of the torpedo. The Bliss Company argued that the problem lay with the spring that imparted rotation to the gyroscope wheel and required only a slight modification to the torpedo. These disagreements, which were really about who was to blame and who was responsible for fixing the problem, constituted the first significant controversy between the Bliss Company and the Bureau of Ordnance.[20]

At the same time, Torpedo Station officers also began to notice that gyroscopic torpedoes were not running as well in Newport as they had during their acceptance trials at the Bliss Company's range in Sag Harbor, New York. While the Navy's inspector at the company professed himself "at a loss" to understand the discrepancy, Washington Chambers, who was leading Torpedo Station efforts to improve the gyroscope, suspected "that the Obry is used . . . to pass a torpedo with curved trajectory"—in other words, that the company was using the Obry to cloak defects in the torpedo instead of using it to correct for inaccuracy from causes external to the torpedo.[21] The inspector, believing that Chambers was questioning his honor along with the company's, fired back: "I regret that such a 'suspicion' exists, and in justice to my assistants, the E. W. Bliss Co. and myself would respectfully state that no such curves have been observed by any of us." Chambers also questioned the quality of the company's workmanship, finding that the tails were too weak even before they were cut away to make room for the Obry rudders.[22]

The suspicion spread. After the bureau made emergency purchases of torpedoes directly from foreign companies in response to the outbreak of the Spanish-American War, the new chief of the bureau, Charles O'Neil, acidly informed the Bliss Company that the foreign torpedoes "exhibit many new and valuable features, none of which had ever been brought to the notice of the Bureau." In asking the chief of the Office of Naval Intelligence to obtain information directly from the Whitehead Company, O'Neil warned, "[I]t may be necessary to intimate, in the most diplomatic manner possible, that (for unaccountable reasons) the Bureau has failed utterly in its endeavor to secure information, from or through the E. W. Bliss Co., concerning the progress being constantly made in the field of torpedo development." An assistant inspector of ordnance at the Bliss Company felt the need to put out "private 'feelers'" to various naval attachés in order to have "a positive *check* on E.W.B. Co." McLean found it "remarkable that the Bliss Company did not avail itself of business connections and keep informed as to the 'state of the Art' in manufacture of torpedoes and gear."[23]

Although this friction boded ill for the future, it was secondary to fixing the gyroscopic torpedoes for the time being. This could not be done in time to get them into service during the Spanish-American War. Having promised in March 1898 to get the new gyroscopic torpedoes to the torpedo-boat flotilla assembled at Key West, Florida, as quickly as possible, O'Neil had to reverse himself when it became clear that they were giving "more or less uncertain" results in practice, and he further ordered the Torpedo Station not to return twenty short torpedoes to the Bliss

Company to be fitted with gyroscopes. As it turned out, a method for securing a flat dive for the torpedoes was not settled until March 1900, the tails were not adequately strengthened until May 1901, and efforts to improve the gyroscope's impulse spring were overtaken by other developments.[24]

Modified Gyroscopes

Washington Chambers, an officer at the Torpedo Station who did considerable experimental work, headed the gyroscope effort. Whereas the Obry gyroscope simply held the torpedo on a straight course, Chambers sought to design a gyroscope that would curve the torpedo through a preset angle. Torpedoes capable of angle (or curved) fire would not enter service for years, but the idea was tactically significant, and Chambers seems to have originated it. Mechanically, Chambers focused his efforts on replacing the gyroscope's pivot bearings with ball bearings and on replacing its spring impulse with air impulse. In tests stretching from 1900 to 1901, however, both failed: Chambers reported an "unavoidable rattle" with the ball bearings, indicating that they could not be fitted tightly enough and/or that they were not perfectly spherical due to defects in manufacture, and he abandoned air impulse when it proved unable to act quickly enough on the gyroscope.[25]

While Chambers worked on his designs, a competitor appeared on the scene: a gyroscope designed by John Moore, quarterman machinist in charge of the Torpedo Station's machine shop. Moore's design also had air impulse, but certain details distinguished its construction from Chambers's. Although Moore's gyroscope was not capable of angle fire, officers at the Torpedo Station believed that it could be adapted and that its construction was preferable to Chambers's. N. E. Mason, the new commander of the Torpedo Station, "unqualifiedly" recommended its adoption.[26]

Such optimism proved premature. Bad weather and the absence of a testing boat delayed the resumption of tests until spring 1902, whereupon it was discovered that the Moore gyroscope could not secure angle fire due to the weakness of its steering engine. Once the engine was strengthened, the torpedo made thirty-three of thirty-six successful runs, and Mason declared it "a practical success." One more round of tests with larger steering rudders decreased the tactical radius, and the officer in charge pronounced the gear "out of the experimental state" and declared that "direct ahead fire from broadside tubes is no longer a hope of the future but an accomplished fact." O'Neil decided that it would cost too much to install the gyroscope in older torpedoes, but he planned to put it in all new torpedoes.[27]

Engines and Air Flasks

During the five years required to develop the Torpedo Station's gyroscope, the rest of the torpedo's components were not ignored. Two parts received particular attention: the engine and the air flask. In October 1897, needing to replenish the bureau's stock of 5-meter torpedoes, O'Neil decided that the time had come to overhaul their design in search of higher speed. His decision set off a burst of negotiations and information gathering, interrupted by the outbreak of war but resumed thereafter.[28] After flirting with the idea of buying a sample torpedo embodying several new features from the Whitehead Company, O'Neil turned back to the Bliss Company. He hoped that the latter would be able to replace the reciprocating engine of the Whitehead torpedo with a turbine engine. He had written to Charles Parsons, British inventor of the turbine engine for ships, and the American Curtis Turbine Company, to ask whether their turbines might be adaptable to torpedoes. When informed by the Curtis Turbine Company that it had been working with the Bliss Company, apparently without O'Neil's knowledge, to adapt a turbine for use in torpedoes, O'Neil seems to have left the matter in the Bliss Company's hands. In view of the fact that priority of discovery would become a point of legal dispute, it is important to note that the bureau and the Bliss Company seem to have arrived independently at the idea of the turbine engine around the same time. In July 1899, the Bliss Company's experimental turbine torpedo was accidentally wrecked, and the company glumly advised the bureau that it should buy torpedoes directly from Whitehead. Undeterred, the bureau said it would stick with the Bliss Company because it believed that the Whitehead Company's torpedo needed improvement. In particular, the bureau was keenly interested in experimental nickel-steel (rather than simple-steel) flasks.[29]

The bureau had several reasons for its interest. One was the desire to increase the speed and range of torpedoes by raising the flask pressure from 1,350 pounds per square inch (psi) to 1,500 psi. O'Neil also feared what would happen if torpedo air flasks were struck by shell fragments in battle and exploded. To find out, he ordered the Torpedo Station to conduct ballistic tests on charged air flasks. He particularly wanted to know whether the flask would explode, indicating that the metal was relatively hard and brittle, or tear, indicating that it was relatively soft and elastic. After some delay, the Torpedo Station carried out the tests in June 1898, firing a 6-pounder shell into a flask charged to 1,350 psi.[30] The flask "burst like a big shell," the commander of the Torpedo Station privately reported to O'Neil:

> In fact its behavior was "Unfit for publication." May be [sic] the steel of the flask was too hard. It would have made havoc aboard ship. I saw it all very distinctly and could not but wish that I had been the only witness, as the results were not encouraging, in view of what might happen aboard ship. Of course an exploding shell, or the exploding of one's own ammunition by an enemy's shot could be just as dangerous, but reports of the test may be harmful at this time [i.e., in the middle of a war]. I have put *personal* on the envelope so that you will be first to see the report.[31]

The bursting of the flask was an alarming result.

O'Neil believed that a nickel-steel flask would allow a lower elastic limit and higher elongation while still increasing the overall strength of the flask—meaning that he could have a stronger flask that was also safer.[32] Accordingly, in September 1899, the bureau asked the Bliss Company to bid on new 5-meter torpedoes with the latest improvements in air flasks. After some haggling over the price, O'Neil agreed to order thirty torpedoes at $4,200 each, with a speed of 28.5 knots. These thirty torpedoes became known as Mark II 5-meter torpedoes.[33]

The Superheater

As the ink was drying on the contract, the Bliss Company approached the bureau with a new proposal. Although its experimental turbine torpedo had been wrecked the previous summer, one component had survived. "This one exception, however, is the most important one," declared the company, "as its object is to increase materially the speed of the torpedo."[34] It was the so-called superheater, which heated the remaining air in the air flask as the volume decreased, thus keeping up the pressure of the air acting on the engine. In contrast to later versions, this one was a dry (or hot-air) inside superheater (illustrated in Figure 1.1). The fuel (alcohol) for supporting combustion was stored in a reservoir (C in Figure 1.1) outside the air flask (A), but combustion occurred (D) inside the flask. The

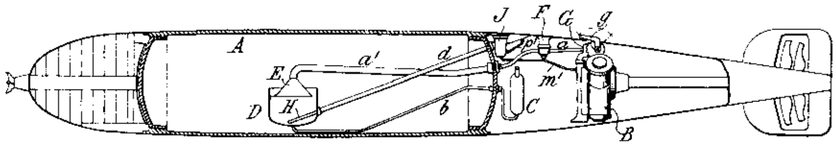


FIGURE 1.1. Leavitt's inside superheater. (Leavitt's United States Patent 693,872, figure 1)

combustion chamber was covered by an inverted hood (E), which funneled the heated air into a pipe (a´) leading out of the air flask to the engine (B). The relative air pressures in the air flask and the fuel reservoir regulated the rate of the fuel feed into the combustion chamber.

The designer of the superheater was Frank McDowell Leavitt, the Bliss Company's chief engineer. Born in Ohio in 1856, Leavitt was one of the five founding members of the E. W. Bliss Company when it was first incorporated in 1885. He was an expert in pressing and stamping machinery, and his first major invention was a can-making machine that cut costs across the canning industry. Although his various torpedo-related innovations ran into problems, these should not obscure his extraordinary talent as an engineer and inventor.[35]

The Bliss Company offered the bureau a novel testing and purchasing arrangement for Leavitt's superheater. If the bureau would let the company put the superheater in one of the new Mark II 5-meter torpedoes and it failed to increase the speed by a knot, the company would take the superheater out and deliver the torpedo like the others of its Mark. If the superheater increased the speed by a knot but for some reason the bureau did not want it, the company would take it out for a charge of roughly $600. If the superheater increased the speed and the bureau decided to adopt it in the experimental torpedo, the bureau would pay $500 for each half-knot increase over the contract speed of 28.5 knots. If the bureau decided to have it installed in all of the Mark II 5-meter torpedoes under contract, the company would install the superheater for a reasonable charge.[36]

Although O'Neil declined to commit the bureau to any decision about the whole order of thirty Mark II torpedoes, he agreed to the company's other terms regarding the use of a Mark II torpedo for experiments, including payment of $500 for every half-knot over the speed it would have achieved without the superheater. O'Neil ordered the company to proceed with experiments and to manufacture the other twenty-nine Mark II torpedoes so that they could be fitted with the superheater if the bureau so chose.[37]

The experimental torpedo was ready for tests in late July 1900. These were overseen by Bradley Fiske, the new inspector of ordnance at the Bliss Company. At 1,500 yards, the torpedo averaged 23.56 knots without the superheater and made 27.9 knots with it, an 18 percent increase. When tested with the superheater at 800 yards, the engine broke because it was unable to stand the increased horsepower caused by the superheater. In Fiske's opinion, "the superheating device is an improvement of far reaching importance," whose accomplishments would be limited only by the strength of the engine. He did not think there was time to put it in all the Mark II torpedoes, but he recommended that work continue with the experimental torpedo. The bureau accepted both of his suggestions. In the fall, once the engine of the experimental torpedo was repaired, it was run again at 800 yards, where it averaged 30.67 knots without the superheater and 35.45 knots with it, an increase of 15.6 percent. Despite the complications added by the superheater to "an apparatus already excessively complicated," Fiske recommended that it be adopted in future contracts.[38]

With Fiske's recommendation in hand, the bureau asked the Bliss Company to quote prices for various arrangements by which the superheater could be purchased. The company replied that it would charge $150,000 for the exclusive or nonexclusive American rights to the device, $500 for each torpedo fitted with the device, or $4,700 for each torpedo ordered in lots of twenty. The bureau decided to withhold its decision pending experiments with the heated Mark II torpedo at the Torpedo Station.[39]

The torpedo sat nearly untested for six months at the Torpedo Station because of bad weather and a personnel shortage—the latter an indication of the poverty of the Navy's research and development resources. The Torpedo Station was able to make only two runs before June 1901. Although the initial impression was unfavorable, full trials reversed this opinion. The heated torpedo averaged 35.6 knots at 800 yards, a 16 percent increase over the speed obtained in the fall acceptance trials, and more than 7 knots over the contract speed. The Torpedo Board declared the superheater simple, easy to understand, and no less durable than any other part of the weapon. It recommended that the bureau adopt the device in future torpedoes, but it argued against purchasing the exclusive American rights because it expected that a simpler and more efficient heater could be designed (and it was soon proven correct). Once the bureau had assurances from the Bliss Company that the engine could withstand the heated air, the Torpedo Station gave its blessing to place the superheater in the remaining twenty-nine Mark II torpedoes.[40]

The Turbine Engine

In September 1901, toward the end of the negotiations over the superheater, O'Neil was worried about the extra stress placed on the engine by the superheater. He dusted off an idea that had been contemplated for years: the use of a turbine engine. As previously discussed, O'Neil and the Bliss Company had independently arrived at the idea of using a turbine engine in early 1898, and the company had built an experimental turbine torpedo. It was wrecked in July 1899, however, and nothing could be salvaged from it except the superheater idea. After this setback, the turbine engine concept languished for two years while the bureau and the company focused on developing the Mark II torpedo and the superheater.

O'Neil revived the turbine idea in a letter to N. E. Mason, the commander of the Torpedo Station. Forwarding tentative specifications for a turbine torpedo, he requested Mason's opinion. Mason solicited advice from three of his subordinates, one of whom was G. W. Williams, a future commander of the Torpedo Station. Anticipating subsequent developments, two of the three worried that the rotation of the turbine would cause the torpedo to roll and interfere with its accuracy, but Williams discounted the possibility, and Mason shared his confidence.[41]

While the Torpedo Station considered the issue, Fiske, still the inspector of ordnance at the Bliss Company, began discussing the possibility of a turbine torpedo with Leavitt. Through Fiske, Leavitt proposed dynamometric tests with the turbine before putting it in a torpedo, at a cost probably not exceeding $3,000. (Dynamometric tests referred to the practice of running the engine against resistance in a device called a dynamometer to measure certain aspects of its performance, such as horsepower.) Fiske allowed that the price seemed high for a single experiment, but he justified it on the grounds that "[t]he torpedo has become so excessively complicated, that any effort to simplify it must commend itself to all Naval men." He requested permission to get a definite proposition from the Bliss Company, which O'Neil granted, requiring the company to guarantee that the turbine would generate at least 90 horsepower when using superheated air, the same as the reciprocating engine. The company agreed to build a turbine and conduct dynamometric tests for $3,000, and then to turn both the turbine and the data over to the bureau. O'Neil accepted the offer and ordered the company to proceed immediately. This was a landmark moment in the military-industrial complex: through the Bureau of Ordnance, the state was investing directly in experimental work instead of buying a finished product. Moreover, it was purchasing not only a physical commodity (the turbine), but also information (the data from the dynamometric tests).[42]

The turbine had its dynamometric tests six months later, in April 1902. The naval officer reporting on the tests, G. C. Davison, noted that it gave mixed results. By one measure of efficiency, it seemed inferior to the reciprocating engine, because it did less work for each pound of air. This definition of efficiency was partial, however, because the temperature and pressure of the air mattered—other things being equal, one pound of higher-pressure, hotter air does more work than one pound of lower-pressure, colder air. The turbine used air at a lower pressure, so that less work done per pound of air was to be expected, but it nevertheless developed a higher maximum horsepower: 108 to the reciprocating engine's 82. It was also simpler and more durable, the latter a particularly appealing feature when heated air was used. Davison said the company planned to conduct a second round of tests using higher air pressure in the hope of increasing the turbine's work per pound of air.[43]

Leavitt, who was overseeing the dynamometric tests, made two main points in his own report when the second round of tests was complete. First, although the turbine did less work per pound of air, it used air at a lower pressure than did the reciprocating engine, meaning that it would be able to utilize air in the flask after it had dropped below the pressure at which the reciprocating engine could use it. Second, the turbine could withstand higher heat, and because heat is directly proportional to pressure, the turbine could withstand higher pressures as well. Thus, the turbine could work across a greater range of pressures than could the reciprocating engine: it could start at a higher initial pressure than could the reciprocating engine, and it could keep working at a lower final pressure than the reciprocating engine. Accordingly, Leavitt calculated that the turbine was almost 20 percent better than the reciprocating engine. He predicted that the turbine could generate 100 horsepower without needing repair, which would give speeds of 36 knots at 900 yards, 34 knots at 1,000 yards, 32 knots at 1,200 yards, and 29 knots at 1,500 yards. The new inspector of ordnance at the company agreed with Leavitt, concluding that "[f]or durability and reliability the turbine has been proven to be the superior of the Whitehead engine."[44]

Satisfied that the Bliss Company had held up its end of the bargain, and probably eager to have his own people get their hands on the turbine (which was by then in a Mark II 5-meter torpedo), O'Neil had it shipped to the Torpedo Station for further experiments. Like the experimental heated torpedo, it languished there for several months due once more to a lack of qualified officers to conduct tests. During this time, events overtook it. The Bliss Company, encouraged by the performance of the turbine in dynamometric tests while jerry-rigged to a Mark II torpedo, began designing a new torpedo especially for the turbine. In November 1902, however, just as tests of the new torpedo were getting underway, a freak accident caused major damage to the torpedo (and to the arm of a foreman, which had to be amputated). This setback delayed tests for another year.[45]

Tactics

All of this activity—the choice of the Whitehead over the Howell; the introduction of new marks of torpedoes; the changes to the gyroscope; and the development of the nickel-steel air flask, superheater, and turbine engine—occurred in an atmosphere of great confusion over how the results would actually be used. Between 1895 and 1902, naval tactics began to change dramatically, largely as a result of the gunnery revolution led by Britain's Percy Scott. Improvements in gunnery lengthened the range at which tacticians expected future battles to be fought, creating new challenges and new opportunities in maneuvering and signaling. The United States was slow to adapt to the changes, in part because it lacked provision for the formal consideration of tactical problems. The Naval War College took its first steps toward filling the void in the early 1890s, when it introduced a new feature into its curriculum: a problem to be solved during the summer. Until 1901, however, the problems focused on solving strategic questions of interest to the United States, and tactics were discussed only insofar as they bore on the strategic issue at hand. The consideration of tactics in 1899, for instance, was restricted to "A discussion of the tactical value of the harbors of the North Atlantic, with respect to the position of our battleship fleet."[46]

In 1901, however, the College began to focus on tactics, specifically fleet battle tactics, as a subject in its own right. The solutions to the problems began to feature sections on battle tactics, and the new lecturer in tactics, Lieutenant Commander J. B. Murdock (who had served at the Torpedo Station in the late 1880s) reoriented the lectures to focus on the issue. By way of justifying the new emphasis, Murdock told his students "that we have to-day no battle tactics." Greater attention to tactics did not necessarily mean more attention to torpedoes, however: Murdock spent most of his time and energy introducing his students to a recent phenomenon called line-of-bearing tactics, which were designed to facilitate both gunnery and maneuvering, and preaching the importance of target practice, while barely mentioning torpedoes.[47]

The study of tactics received another institutional boost in 1900 with the establishment of the General Board, which collaborated with the War College to promote the subject. The General Board, headed by Admiral George Dewey, the victor of Manila Bay, was a purely advisory body that opined on subjects ranging from naval construction to strategy. Together, the General Board and the War College designed fleet maneuvers in 1901 and the problems to be solved by the summer conferences of War College students in 1901 and 1902. The 1901 maneuvers included attacks by torpedo boats on the battle fleet, but their main purpose was to test and improve the maneuverability of the battle fleet, not to develop torpedo tactics. Likewise, the solutions to the tactical problems presented at the 1901 and 1902 War College conferences focused overwhelmingly on concentrating gunfire, maneuvering so as to achieve it, and the command-and-control problems created by maneuvering. Fundamentally, the War College continued to think of gunnery as the controlling element in naval tactics, with torpedoes playing a supporting role.[48]

The Bureau of Ordnance and the Torpedo Station, however, were laying the groundwork for torpedoes to play a primary and independent role. The key figure in this effort was Charles O'Neil, the chief of the bureau from 1897 to 1903, during which time he was also president of the Board on Construction. Established in 1889, the Board on Construction brought together the chiefs of the bureaus involved in naval construction (construction and repair, steam engineering, equipment, and ordnance), along with the chief of the Office of Naval Intelligence, to advise the Secretary of the Navy on ship building.

Shortly after taking over from W. T. Sampson as chief of the Bureau of

Ordnance, O'Neil began a campaign to acquire an underwater torpedo tube for use in battleships. During Sampson's tenure, this prospect had been unlikely because Sampson had "no faith in under-water discharge" but instead had a pet scheme for an armored overwater tube, which he repeatedly referred to the Torpedo Board for report despite its denunciations of the idea and endorsements of underwater discharge. A few months after taking over, O'Neil moved aggressively to buy the rights and a sample submerged tube from the British firm Armstrong, Whitworth & Company.[49]

The utility of submerged tubes depended in large part on another initiative: the search for angle fire, inaugurated by Washington Chambers in 1898 and strongly supported by O'Neil. While opening some tactical possibilities for overwater torpedo fire, like firing a torpedo from a broadside tube directly ahead and in line with the keel, angle fire was most significant for submerged tubes. Unlike overwater tubes, which could be pivoted through a considerable degree of horizontal train, submerged tubes were fixed. Without angle fire, the whole ship had to be turned to the appropriate bearing to fire a torpedo from a submerged tube, a maneuver practically guaranteed to ruin its gunnery. With angle fire, the gyroscope merely had to be set to curve the torpedo through the appropriate angle, thereby making it independent of the firing ship's bearing, the train of the tube, and its initial line of fire. As previously discussed, however, Chambers's modified gyroscope proved unsatisfactory, and the Navy did not have an alternative to the Obry available until Moore's gyroscope in 1902.[50]

O'Neil also championed the pursuit of higher speeds and longer ranges in torpedoes by means of the superheater and turbine, and he was aware of their tactical significance. If the superheater increased torpedoes' speed, he realized, the time of the run would decrease, and greater errors in aiming the torpedo would be permissible. The bureau was already investigating how higher speed affected the probability of hitting the target, and O'Neil ordered the Torpedo Station to help. At the time, this was an innovative approach: the War College was thinking about the probabilities of hitting with gunfire, but it had not thought to apply the same calculations to torpedoes. O'Neil also asked Mason to consider how much the superheater could be used to increase the range at lower speeds. O'Neil concluded with the startling information that the bureau was thinking of requiring the distance gear in all future torpedoes to be set for at least 3,000 yards with the superheater and 2,000 without it—both significant increases over the 800 yards called for in the most recent specifications.[51]

None of these developments matured quickly enough, however, to save the submerged tubes of the five *Virginia*-class battleships from O'Neil when the question came before his Board on Construction in 1902. At that time, the most modern torpedoes in the Navy's arsenal were still the Mark II 5-meter torpedoes ordered in February 1900, which lacked superheaters, turbines, and angled gyroscopes. In opposing the installation of submerged tubes in battleships, O'Neil and the majority pointed to the limited range of torpedoes (800 yards at maximum speed) and the fact that the tubes were fixed, which made the probability of effective use "very remote" and reduced their efficiency "to a minimum." Given these limitations, the size and intricacy of submerged-tube installations, and the dangers arising therefrom, the majority recommended against installing them on battleships. The dissenting member of the board pointed vaguely to foreign practice and tried to cast his opponents as technologically regressive, but in fact O'Neil had a good grasp of the tactical possibilities and limitations of the Navy's torpedoes at the time.[52]

Aside from battleships, three other classes of ships that would later play a significant role in torpedo tactics were almost entirely ignored during this period: the torpedo boat, the torpedo-boat destroyer (or destroyer), and the submarine. The War College was exclusively concerned with maneuvering and concentrating the gunfire of battleships in the battleline, and was not yet thinking in terms of fleets containing several classes of vessels. Neither the bureau nor the Torpedo Station did much more. They seem to have given almost no thought to destroyers. Congress had forced submarines on an unwilling bureau, and although the Torpedo Station was friendlier, submarine commanders spent their energy on training their crews to operate the ship and not on maneuvering with the fleet. Aside from a series of experiments at the Torpedo Station in 1895 to discover how close torpedo boats could get to battleships before being detected, and the General Board's order to have torpedo boats participate in fleet maneuvers in 1901, torpedo boats were ignored. Indeed, they were ignominiously used as picket boats and mail ships during the Spanish-American War.[53]

Even though advances in torpedo technology did not immediately make themselves felt in naval architecture and tactics, the future looked bright for US torpedo development by the end of 1902. True, the Navy had not incorporated any of the three major improvements—the Moore gyroscope, the superheater, and the turbine—into torpedoes on a large scale, preferring to build from scratch rather than retrofit older models, but it seemed to have worked out their defects. Pending large-scale incorporation of these improvements, the concept of torpedo tactics remained in its infancy, but officers at the Bureau of Ordnance and the Torpedo Station grasped the potential of the subject. The relationship between the Navy Department and the Bliss Company had survived its first squabbles and grown stronger, thanks to Leavitt's design of a turbine engine and superheater. For better or worse, the Navy was now more dependent on the Bliss Company than ever before. An officer at the Bureau of Ordnance proudly declared, "A torpedo containing the Curtis turbine, the Leavitt superheater, and the new adjustable gyroscopic steering gear would be essentially an American torpedo and could not properly be called a Whitehead."[54] As the next decade would reveal, however, an essentially American torpedo was not necessarily a good torpedo.

2

BRITAIN'S WEAPONS OF THE STRONG

> "There would be naturally some reluctance on our part to be forced to some changes after what we have accomplished, but it is clear that we must hurry now so as not to allow foreigners too much start."
>
> —GEORGE GOSCHEN (First Lord of the Admiralty), 1897

In the decades before World War I, Great Britain was the most powerful nation in the world, and the Royal Navy was its most powerful arm. The body that oversaw the Navy was the Board of Admiralty—or simply the Admiralty. With roots stretching back centuries, the Admiralty was actually a medieval position known as the Lord High Admiral in commission, meaning that it was held not by an individual but by a group of individuals, collectively known as the Lords Commissioner of the Admiralty. The head of the Board was the First Lord, a civilian of Cabinet rank (and, despite the title of the office, not necessarily a peer). Four other civilians—two from Parliament, and two from the civil service at the Admiralty—served on the Board, joined by five naval officers. Of these, four comprised the Naval (or, after 1904, Sea) Lords, and the fifth served as the naval secretary. The Third Naval Lord was also known as the Controller and was responsible for naval materiel; the Director of Naval Ordnance and the Assistant Director of Torpedoes, responsible for ordnance and torpedoes, respectively, were part of his fiefdom. The Board of Admiralty was truly a board: the First Lord could not govern by fiat but needed the support of his professional colleagues.[1] Although the consultative nature of Admiralty administration sometimes led to remarkably wide-ranging analyses of seemingly narrow technical matters, it was still possible for officials to manipulate the policy process, especially when a highly technical matter like weapons procurement was at issue.

The Royal Navy had adopted the Whitehead torpedo in 1870. The main works of the Whitehead Company were in Fiume, but in 1890, with Admiralty encouragement, the Company established a second factory in Weymouth, on the south coast of England. Another source of supply was the Royal Gun Factory (RGF), part of the Woolwich Arsenal complex run by the War Office. By the mid-1890s, the Royal Navy had two models each for three different classes of torpedoes under manufacture: RGF and Whitehead models of a long 18-inch torpedo, RGF and Whitehead models of a short 18-inch torpedo, and RGF (Mark IX) and Whitehead models of a 14-inch torpedo. Of these, the first five were being produced in quantity, while the last—the 14-inch Whitehead model—was at an early stage of development. Problems with the 14-inch Whitehead model touched off a crisis that bedeviled the Admiralty's torpedo policy for years to come.[2]

In September 1894, the Fiume branch of the Whitehead Company sent a prototype 14-inch torpedo to England for trials. When it performed poorly, Assistant Director of Torpedoes William H. May took the opportunity to offer sweeping recommendations about Britain's future torpedo production policy. He urged that the Navy stop manufacturing different models for each class of torpedo and instead manufacture only one model per class (a practice hereafter referred to the pattern-unification policy). Because the 14-inch Fiume model submitted for trial had proven unsatisfactory, May suggested that the Navy adopt the RGF model for the 14-inch class, stop encouraging the Whitehead Company in Fiume to produce its own design, and instead ask the company to bid on building torpedoes according to the RGF design. Admiralty officials accepted May's recommendation about the 14-inch class and asked the Torpedo Design Committee, consisting of experts from HMS *Vernon*, the British torpedo school, and the RGF, to report on which 18-inch pattern it preferred.[3]

In reply, the majority of the committee went beyond their immediate terms of reference to oppose the pattern-unification policy. The committee was chaired by Baldwin Wake Walker, who was the captain of the *Vernon*. He and his colleagues argued against hasty adoption of the pattern-unification policy, reminding the Admiralty of "the enormous advantages to the Service gained in development of torpedo design, through association and competition with Mr. Whitehead in the past." By ending competition, the pattern-unification policy might stifle advances in torpedo design.[4]

May, the policy's champion, brushed off the committee's concerns, however, and instead recommended the immediate adoption of the 18-inch RGF pattern. He pointed out the "great advantage" of having the 18-inch and 14-inch RGF patterns that were "similar in all details of mechanism." Perhaps to remove a potential source of opposition to his recommendation, he also suggested that the Torpedo Design Committee be dissolved. His recommendations were approved, and the unification of patterns was complete. The Admiralty asked the Whitehead Company whether it would be willing to build both 14-inch and 18-inch torpedoes to RGF designs.[5]

Prolonged back-and-forth negotiations ensued over the nature of Admiralty assistance to the Company—whether, and when, it would supply drawings, a sample torpedo, and jigs and gauges—followed by a delay in the Admiralty actually getting the promised assistance to the company. As they dragged on, both parties to the negotiations cut corners in their haste to build the torpedoes. Pressured by the Admiralty, the Whitehead Company reluctantly agreed to tender for 150 14-inch and sixty 18-inch torpedoes despite misgivings over the vague inspection guidelines, and without having seen a sample torpedo, complete working drawings, or the specifications that it would be required to build to. The Admiralty, meanwhile, agreed to place a provisional order before the specifications were complete in order to allow the company to begin operations immediately. These shortcuts planted the seeds of future disputes.[6]

No sooner had the Admiralty placed the preliminary orders with the Whitehead Company to build RGF-pattern torpedoes than problems with the patterns began cropping up. Early in February 1895, the Admiralty learned that the 18-inch torpedoes showed negative buoyancy, meaning that they would sink at the ends of their runs. Walker, still the captain of the *Vernon*, was furious. He argued that RGF designers had miscalculated the relevant weights while reducing manufacturing limits to the minimum. The latter made the pattern less suitable as a universal type and for production by private firms because they did not share the RGF's capacity for "extreme accuracy" of manufacture and therefore could not be expected to build to the same minimal margins for error. More bad news soon arrived from Walker: the 14-inch torpedoes had the same problems as the 18-inch ones—likely due to the same similarity in mechanical details that May had touted as an advantage.[7]

Admiralty officials shared Walker's anger but failed to translate it into meaningful policy change. May's successor as Assistant Director of

Torpedoes (M. A. Bourke) launched a flank attack on his predecessor's pattern-unification policy, concluding that "a great error" must have been made in the design or manufacture of the 14-inch RGF Mark IX. The Senior (i.e., First) Naval Lord, Sir Frederick Richards, characterized the mistakes as "a very serious matter" requiring "full investigation and report as to where the fault lies." Admiralty officials promptly proceeded to sweep the matter under a rug by blaming the Torpedo Design Committee and the RGF rather than themselves for the problems.[8]

While the Whitehead Company worked on the flawed RGF patterns, it received another blow. In 1890, the Admiralty had decided to use the Whitehead Company as its sole private torpedo supplier, cutting a Leeds-based company called Greenwood & Batley out of the supply market (much as it would later cut the Whitehead Company out of the design market). In January 1896, however, the Admiralty began to worry that one private supplier was not sufficient. "[I]t appears most desirable," the Director of Naval Ordnance wrote, "that there should be a second [private] firm in competition with Whitehead." After the Whitehead Company's reply to an Admiralty inquiry failed to quell doubts about its production capability, the Admiralty invited Greenwood & Batley to reenter the market, ending the Whitehead Company's monopoly on private supply.[9]

Nevertheless, the Whitehead Company still retained an important role in the supply base, and with it some leverage over the Admiralty. When asked to tender for 220 torpedoes, the company showed signs of its mounting frustration. It insisted that it would have to raise the price per torpedo on the grounds that previous prices had been artificially low because the company had not seen the specifications when it made its tender—one of the shortcuts that the Admiralty had pressured it to take—and therefore did not appreciate the accuracy of the work required. It shifted the blame for delays onto the Admiralty's failure to provide drawings and specifications in a timely manner. And it complained of having to incorporate "glaring errors in design" in the RGF-pattern torpedoes. This last charge was a shot across the bow: going beyond the confines of the existing contract, the company was officially notifying the Admiralty of its dissatisfaction with the pattern-unification policy.[10]

Admiralty officials responded forcefully. Walker, the Assistant Director of Torpedoes, who two years earlier had opposed the pattern-unification policy and sharply criticized the RGF designs, now called the policy "a great economy and public utility." He professed ignorance about what "glaring errors in design" the company might have in mind, given that the RGF reported no problems with its torpedoes. The RGF was hardly a disinterested source for information on its own torpedoes, however, and a "glaring error in design" was already apparent: the weakness of the 14-inch RGF Mark IX afterbody, which would lead to the development of a new design a year later. Advised by the Director of Naval Ordnance that the "glaring errors" were "comparative trifles," George Goschen, the First Lord, ascribed the company's complaints to sour grapes. For the time being, the Admiralty's reply to the company smoothed over the dispute, and it accepted Whitehead's tender. This truce would not last.[11]

As the Gyroscope Turns

Weeks after the Whitehead Company's tender for 220 torpedoes was accepted, the British naval attaché in Vienna sent the Admiralty its first official report of an invention that would roil its dealings with the company: the Obry gyroscope. Following on its heels came the Whitehead Company's official circular describing three possible agreements for the gyroscope: purchase of the right to manufacture for a lump sum (later set at £20,000), purchase of the right to manufacture with a royalty payment of £25 on each gyroscope, or purchase of the gyroscopes directly from the company for £50 each. In forwarding the circular, the Weymouth branch of the company mentioned that it expected to have a gyroscopic torpedo in England within a month and that it would be happy to try the gyroscope before Navy representatives. Walker, the Assistant Director of Torpedoes, was enthusiastic about the "great importance" of the invention.[12]

On the same day that the Weymouth branch wrote to inform the Admiralty about the gyroscope, it sent a long letter describing its frustrations with the 14-inch RGF Mark IX torpedo forced upon it by the pattern-unification policy. It singled out the reducing valve (or reducer), which reduced the pressure of air from the air flask to one suitable for the engine, complaining that the valve allowed air pressure in the engine room to rise dangerously high and failed to prevent the engine from hanging on dead points (points in a reciprocating engine at which the admission of air to the cylinder fails to produce corresponding motion in the shaft due to the alignment of the piston, connecting rod, and shaft). Walker, the Assistant Director of Torpedoes, downplayed the company's critique of the reducer. Citing "experiments conducted at Woolwich," he conceded that the reducer allowed engine pressures to rise to dangerous levels when the engine hung on a dead point, but said that a company representative told him that dead points were easy to avoid. Walker neglected to mention that the "experiments at Woolwich" had originated in response to the explosion of several engines in RGF torpedoes in June 1896 and that competitive tests between Whitehead and RGF reducers had vindicated the Whitehead design.[13] His massaging of the truth was a telling example of how an official could exploit the technical ignorance of policy makers, who probably had no idea what a reducer or a dead point was, to influence an important policy question: in this case, whether the Admiralty should continue to rely solely on the RGF to design its torpedoes.

The coincidence of the Whitehead Company's frustrations with the 14-inch RGF Mark IX torpedo and its announcement of the gyroscope meant that there were simultaneously two very different dynamics in the Admiralty's relationship with the company in the closing months of 1896. In the battle over the Mark IX torpedo, the Admiralty held the upper hand thanks to its possession of a contract signed by the company. When it came to the gyroscope, however, the company held the upper hand thanks to its possession of the rights.

The Admiralty had two powerful reasons to want the gyroscope. One was its desire to keep abreast of foreign technological developments (which are discussed later in this chapter). The other was a recent crisis in discharging torpedoes from above-water stern tubes. In August 1895, a cruiser on the China Station reported that one of its torpedoes had been damaged in practice from an above-water stern tube. Further investigation confirmed that the stern tube was tactically valuable (because it prevented a victorious fleet from pursuing too closely) but that accurate shots could not be made from it when the ship was under helm, that is, turning. Torpedo experts immediately perceived the gyroscope's potential to solve the latter problem: the gyroscope would hold the torpedo steady on its initial line of fire, regardless of the motion imparted to the torpedo by the ship's turn.[14]

Thus the stern-tube problem was on the Admiralty's mind when its second official report on the gyroscope arrived. This report, by HMS *Vulcan*, the Navy's dedicated torpedo vessel in the Mediterranean, was longer and more substantial than the naval attaché's July account. While allowing that the gyroscope was still "experimental," the *Vulcan* praised the "marvelous" results achieved by it, and "strongly" urged the Navy to acquire gyroscopic torpedoes from the Whitehead Company for trial. In forwarding the *Vulcan*'s report, the senior officer on station observed that the prospect of obtaining accurate practice "from the large numbers of above-water and stern tubes we have in the service which are now unreliable, is a very important matter," adding that "no less than six" foreign nations had ordered gyroscopic torpedoes.[15]

The *Vulcan*'s report was passed to the *Vernon* for comment. The latter's commander, John Durnford, connected the gyroscope's relatively narrow technical aspects to its implications for Britain's naval supremacy. The device, he wrote, "promises to be the most important discovery that has been made in improving the value of the Whitehead torpedo since its introduction." It would ease certain considerations in naval architecture and correct any horizontal deviation by the torpedo regardless of how it was discharged, "stern tube included." Aside from specific tactical uses, he continued, "[t]his new invention will probably benefit weaker nations more than ourselves as by constant practice and superior training we have been able to get more out of the torpedo than others." Given that the invention had come and that foreign nations were taking it up, however, "I think it is most essential that we should try it at once, and carefully utilise its value, so that we may be able at least to place ourselves in as favorable a position as our neighbours." Although Britain stood to lose more from the invention than anyone else, it might be able to turn the gyroscope to its advantage.[16]

Probably the same day that Durnford's mixed message of fear and cheer landed on the desk of the Assistant Director of Torpedoes, so did a very different letter from the Whitehead Company. The company simply refused to bid on a new round of torpedoes, giving vent to more than two years of accumulated frustrations. "[A]s no suggestions of ours are ever taken into consideration," the company declared, "we feel we do not possess that amount of confidence and support essential to any firm who has to turn out satisfactory work for the Government." Again the Whitehead Company criticized the RGF design, pointing to lack of buoyancy, weak engines liable to explosion, and a faulty reducer, among other problems. To try to remedy the design flaws, the specifications required "such narrow limits and extraordinary exactness . . . that the cost and time required for manufacture is enormous." The company would not build any more torpedoes to RGF patterns; "we would rather close our works at Weymouth than again accept an order under the conditions of the present one."[17]

This ultimatum created space for a fresh pair of eyes to reexamine the

1894 pattern-unification policy. Possibly alone among the leading members of Britain's torpedo establishment, Durnford, the captain of the *Vernon,* was not a holdover from the pattern-unification decision. Stating frankly that the 14-inch RGF Mark IX torpedo had not lived up to expectations, he attacked the pattern-unification policy. "I am very strongly of the opinion that Whitehead & Co. will never make satisfactorily the Woolwich 14[-inch] torpedo," he declared. "It is against their interest and," even more to the point, "I believe it to be also against ours. I think we should utilise the unique experience of Mr Whitehead, (to whom much of the development is due) by encouraging the Firm to give us a Torpedo of their own design."[18]

Notwithstanding the fact that Durnford was making exactly the same case that he himself had made in Durnford's position, Walker, the Assistant Director of Torpedoes, now ranged himself on the opposite side of the argument. Walker said that the company "had steadily taken every opportunity to depreciate the Woolwich type, which, although not perfect, is considerably in advance of any torpedo" of either the company's or the RGF's design. The pattern-unification policy had been settled on after "exhaustive" trials that, at the time they were conducted, Walker had criticized as insufficient. He also expressed worry that trials between the RGF and a private firm would compromise the secrecy of the RGF design, "it having been proved impossible to keep such information secret carried out under such conditions"; left unspoken was that this concern conveniently protected the RGF design from competition. Walker therefore wanted to write the company off and rely exclusively on the RGF for the 14-inch Mark IX torpedoes. The Director of Naval Ordnance took up Walker's torch and assured the Controller that the RGF had a large enough supply capacity to meet the Navy's demands.[19]

The Controller at this time was none other than Admiral Sir John "Jacky" Fisher, the best remembered (if least understood) naval officer of his day. He had spent much of his time in a previous stint at the Admiralty as Director of Naval Ordnance battling the War Office, which ran the RGF, over the latter's failure to meet the Navy's gunnery needs, while overhauling gunnery procurement so that the Navy relied less on the RGF and more on private firms. Fisher was not impressed by assurances from Walker and the Director of Naval Ordnance that the 14-inch RGF torpedo was as good as the Whitehead Company's alternative. On the contrary, he welcomed the prospect of competitive trials between the RGF torpedo and the new Whitehead model, dryly observing that "it will be most satisfactory to ascertain definitively that the Woolwich pattern is so superior as stated to the Whitehead pattern." Fisher also dismissed Walker's fear that helping the company to carry out competitive trials between the Whitehead and RGF models would leak sensitive information about Britain's own naval technology: "There is no real secrecy on these matters wherever the trials are made." Fisher continued, "Obviously Mr. Whitehead deserves altogether special treatment; he is not merely the inventor of the torpedo that bears his name, but has kept the lead in improvements up to the present moment." It was clear to Fisher that the RGF's monopoly on torpedo design could not remain unchallenged.[20]

Other officials voiced a complementary but distinct set of considerations. Frederick Richards, the Senior Naval Lord (a position that would be renamed First Sea Lord in 1904), had harsh words for Whitehead:

> [I]t is not too much to say that no man ever did his Country a worse service. The millions which his invention has taxed his Country with up to the present would have built a large fleet. . . . But granted that he has made himself an indispensable nuisance, what the Admiralty has to guard against, is the position of being a useful tool in his hands, for purposes of advertisement to Foreign Powers.

Accordingly, Richards did not want to loan any of Britain's most recent, fastest destroyers to the company to conduct the trials. In view of foreign movement on the gyroscope, however, he was unwilling to ignore the invention entirely, and he recommended that the Admiralty purchase one or two gyroscopic torpedoes so that it could conduct its own trials. Even so, Richards concluded gloomily that purchasing the gyroscope "will unfortunately leave the Admiralty no nearer finality than is the beginning—there is always something in reserve."[21] The First Lord, Goschen, shared Richards' concerns. "We as the stronger nation, and who have [spent?] so much to perfect existing systems, are clearly sufferers from such a new invention," Goschen wrote. "There would be naturally some reluctance on our part to be forced to some changes after what we have accomplished, but it is clear that we must hurry now so as not to allow foreigners too much start, if the invention as appears probable, turns out to be an excellent one in trial."[22]

This exchange of minutes is significant for two reasons. First, the fact that senior Admiralty officials weighed in on the international ramifications of a piece of torpedo technology reflects the remarkably consultative nature of Admiralty decision making. Second, these minutes illuminate the Admiralty's attitude toward technological secrecy and technological change. Fisher's statement that "there is no real secrecy on these matters" is striking for its apparent lack of concern about security, but the navy had two safeguards in case secrecy was breached. One, already alluded to, was the "extreme accuracy" of RGF manufacture, which other suppliers could not match. Their shortcoming meant that, even if other nations copied the RGF design, their torpedoes would be mechanically inferior. In addition, given that all the accuracy in the world could not make up for a poor design, the more fundamental safeguard was the Royal Navy's "constant practice and superior training" cited by Durnford (above), which allowed the British "to get more out of the torpedo than others." This practice and training, in turn, required resources that only Britain possessed, as Richards and Goschen recognized, including both financial power and the best torpedo infrastructure (research and development, production, testing) that money could buy.[23] Richards and Goschen also realized, however, that any change in torpedo technology threatened to waste the resources sunk into the infrastructure. Foreign interest in the gyroscope reduced the likelihood that Britain could avoid spending money on it and that money spent would prove unnecessary. Admiralty officials focused on foreign development because it affected their assessment of the risks associated with investing in new technology.[24]

While Admiralty officials agreed in principle to investigate the gyroscope in early 1897, they were far from hammering out all the details. Walker, the Assistant Director of Torpedoes, wrote that the gyroscope seemed valuable enough to warrant a £25 royalty on each, and that if the Admiralty decided to take up the large-scale manufacture of gyroscopes in the future, any royalties paid per torpedo would go toward redeeming the £20,000 lump sum that had been quoted by the company in October 1896. Richards responded that payment of the lump sum was out of the question without trials. Negotiations over the shape of the trials were complicated: the company wanted to draw the Admiralty into its trials as much as possible, whereas the Admiralty wanted to limit its participation, fearing that the company was using it to advertise the company's wares to foreign powers, and preferred to buy sample gyroscopic torpedoes for private trials of its own.[25]

After a month of discussion, the two parties agreed to limited trials of the gyroscope under the company's direction in March 1897. Durnford, the captain of the *Vernon*, thought well enough of the gyroscope's performance in the trials to recommend urgently that Britain explore the device further, but he was not convinced that the gyroscope could withstand the demanding conditions of service use. Therefore, he stopped short of recommending its general adoption. Although Walker, on receiving Durnford's report, took a notably more skeptical tone, he agreed that additional trials were desirable. The Admiralty ordered four gyroscopes from the company at £50 each—£25 for the gyroscope plus £25 for the royalty—to be fitted to four RGF-pattern torpedoes, two 14-inch and two 18-inch. The company agreed, though it added £25 per gyroscope for fitting it to the torpedo, bringing the total cost of the order to £300 (4 × £75).[26]

The Demise of the Pattern-Unification Policy

The *Vernon* did not try the four gyroscopic torpedoes until December 1897. In the interim, Walker attempted to delay the adoption of the Obry gyroscope, despite his colleagues' growing interest in it. In October 1897, the Admiralty ordered four gyroscopic torpedoes from the Fiume branch of the Whitehead Company for a vessel in the Mediterranean Fleet, on the same terms that the Weymouth branch had recently been ordered to fit four torpedoes with gyroscopes. The vessel reported favorably on the gyroscopic torpedoes in November.[27] Shortly before the report arrived at the Admiralty, however, Walker disparaged the utility of the Whitehead gyroscope—citing "thoroughly reliable" sources who had told him that the Italians were planning to give up on the gyroscope. He also exploited the RGF's development of a rival gyroscope to argue that a decision on the Obry gyroscope should be postponed until the RGF model had been tried.[28] Accordingly, the *Vernon*'s highly favorable report of December 1897 on the Whitehead gyroscope, recommending the immediate purchase of eighteen gyroscopes for limited issue to seagoing vessels, produced no action at the Admiralty.[29]

While competition between the Whitehead and RGF gyroscopes mounted, so too did competition between their new 14-inch torpedo patterns. In mid-1897, seeking greater simplicity, strength, buoyancy, and speed, the Admiralty authorized the RGF to develop a new 14-inch design (which would evolve into the Mark X). Meanwhile, the 14-inch Whitehead design rejected by the Admiralty in 1894 had evolved to include a gyroscope and a much stronger engine, capable of withstanding 2,020 psi (by contrast, the Mark IX engine could withstand only 1,000 psi). The latter characteristic strongly appealed to Durnford, who was dissatisfied with the engines in the RGF Mark IX torpedo. He visited Weymouth to see the new Whitehead design and reported very favorably on it, singling out for special mention the engine strength, which "alone forms a very important improvement" over the Mark IX engines, and the reducer. On his own initiative, calculating that trials with the experimental RGF Mark X would take some time, he immediately ordered two of the company's new torpedoes to the *Vernon* for testing.[30]

Durnford's favorable report on the Whitehead model piqued the interest of the new Director of Naval Ordnance (DNO), Edmund Jeffrey, who asked whether money was available to purchase the sample torpedoes. Then Jeffrey went on leave. His subordinate, Walker, falsely claiming to be writing "for DNO" to the new Controller, A. K. Wilson, argued that the Whitehead pattern should not be tried unless it showed some "very obvious advantages . . . which could not be obtained" by RGF torpedoes. Of course, the Whitehead pattern *did* have a very obvious advantage—superior engine strength—and the support of both the Director of Naval Ordnance and the commander of the *Vernon*. Nevertheless, not knowing any better, Wilson approved Walker's minute, and the company was informed that the Admiralty was not interested in adopting its new design.[31]

Three months later, in February 1898, Walker dug himself a deeper hole. Alerting his colleagues that the supply situation for 18-inch torpedoes was unsatisfactory, he blamed the Whitehead Company and complained that it had missed a delivery deadline. Whether due to incompetence or deceit, Walker had his dates wrong: the original delivery date had indeed been December 1897, but the company, with Walker's approval, had secured an extension to March 1898. Moreover, Jeffrey, the Director of Naval Ordnance, went back to the archives and discovered a paper from January 1897 in which Walker had implied that the RGF had the supply capacity to meet the Navy's needs without the Whitehead Company—meaning that his announcement in February 1898 of the precarious supply situation undermined his credibility. Jeffrey declared that the deficiencies were not satisfactory and that he was preparing "a submission" on the whole question of the supply of Whitehead torpedoes.[32]

Jeffrey's submission did not bode well for Walker, but he obliviously injured his cause still further. In March 1898, the Weymouth branch of the Whitehead Company informed the Admiralty that it would have to close unless the Admiralty ordered more torpedoes from it, or allowed it to charge higher prices per torpedo. Weymouth cited the high cost of labor and material as one of the main causes of its lack of profit. Walker reacted with a lack of concern to Weymouth's news. He suggested that Weymouth was being disingenuous by failing to mention that the reason labor and material cost so much was because the company had located its factory so far from centers of labor and material, and he recommended that only 100 torpedoes be ordered from the company rather than the 200 Weymouth said were needed to keep it solvent. In fact, Walker was himself being disingenuous. The Admiralty—including (unfortunately for Walker) then–Assistant Director of Torpedoes Jeffrey—had supported the factory's location in Weymouth because it offered a perennial salt-water range for running torpedoes and proximity to the *Vernon* in Portsmouth. In effect, Walker was blaming the Whitehead Company for the Admiralty's decision.[33]

In a private submission to the controller (Wilson), Jeffrey set himself the task of undoing the damage that Walker's lies, and the pattern-unification policy, had done. Noting that Walker had opposed the pattern-unification policy when it was adopted in 1894, Jeffrey argued that the policy had caused "great difficulties." The question of reversing the decision had been brought up several times, and in March 1897, the Admiralty had told the Whitehead Company that it would try samples of the company's latest 14-inch pattern. In early September 1897, when the company had informed the Admiralty that its design was ready for trial, Jeffrey had asked if money was available, "and I went on leave immediately thereafter." Walker had exploited Jeffrey's absence to misrepresent his position. Having demolished the credibility of his mutinous subordinate, Jeffrey tipped his own hand: His opinion was "strongly in accordance" with that of Durnford and Fisher, who both opposed the pattern-unification policy. Like Fisher, Jeffrey put torpedoes into a broader context of weapons procurement. With gun design and production, the Admiralty

> . . . had preserved quite a free hand, with the result that we have made great progress. If we had tied ourselves to the Ordnance Factories, as regards all questions of design, we should undoubtedly now be in a very different position to what we are. When

> there is no competition, there is every inducement in a government factory to avoid trouble, by adhering to established patterns.

Because the Admiralty had given itself over to the RGF for torpedoes, its supply situation was "not very good," and Jeffrey believed "that competition and probably larger orders to trade, is the only way out of it." As a first step, it would be "very desirable" to try the new 14-inch RGF pattern against Whitehead's new 14-inch pattern. Wilson and others were convinced. Mindful of Weymouth's threat to close, the First Lord, Goschen, suggested writing "with full recognition of the importance which the Admiralty attach to their keeping open their works."[34]

It is impossible to say exactly how long Walker's hostility to the Whitehead Company delayed proper consideration of the company's torpedo and gyroscope designs, but it is clear that some delay occurred. It would likely have continued had Jeffrey (himself a former Assistant Director of Torpedoes) not taken the trouble to go back through the paper trail and piece together the evidence of Walker's mischief. More senior officials—the Controller, the Senior Naval Lord, and the First Lord—lacked the time and probably the knowledge for such detective work; they trusted Walker to do his job.

While Jeffrey overcame Walker's obstructionism on the 14-inch Whitehead torpedo, the logjam over the Whitehead gyroscope also broke. In March 1898, Walker had to inform his colleagues that the RGF gyroscope exhibited defects during preliminary trials and would require modifications before a final report could be rendered; in the interim, he endorsed the *Vernon*'s earlier suggestion to purchase eighteen Whitehead gyroscopes for further trials. His recommendation was approved.[35]

The Whitehead Company gained further momentum in July 1898, when its long-delayed 14-inch design was finally tried. According to the *Vernon*'s effusive report, the Whitehead design (which would become known as the 14-inch Weymouth Mark I) was faster, covered a longer range, and was stronger than the RGF Mark IX, and the Royal Navy should order 100 forthwith. Jeffrey, the Director of Naval Ordnance, seized the opportunity to administer the coup de grâce to the pattern-unification policy. Addressing a list of colleagues from which the Assistant Director of Torpedoes was strikingly absent, Jeffrey declared that the pattern-unification policy "has now received full trial; and the result has been great difficulties and delays, the present deficient supply of torpedoes being in great measure owing to our being confined to one type." The distortion of the design base had distorted the supply base, resulting in the absence of a reliable 14-inch pattern. Jeffrey "strongly" advocated reversing the pattern-unification policy and ordering some of the new 14-inch Whitehead-designed torpedoes. With approval of his recommendation, the pattern-unification policy ended.[36]

Additional victories were in store for the Whitehead Company. In August 1898, competitive trials between the RGF gyroscope and the Whitehead gyroscope showed the latter to be decidedly superior, and the *Vernon* recommended its introduction on a larger scale. In October, the first seagoing ship to get gyroscopic torpedoes—the Channel Squadron's *Majestic*, captained by Prince Louis of Battenberg—delivered a fulsome report. The practice made by the torpedoes was "so highly satisfactory," Battenberg wrote, "that I consider all torpedoes should be fitted with [gyroscopes] without delay." The *Vernon* was equally impressed, stating that the Whitehead gyroscope had "fully maintained" its reputation, shown its superiority to the RGF pattern, and could now confidently be recommended for general adoption. The new Assistant Director of Torpedoes, Charles Egerton, agreed. Although Egerton believed that the gyroscope could and would be improved, "the policy of waiting until the instrument has arrived at a more perfect stage of its development, would leave us behind other nations and is not recommended." The First Lord, Goschen, concurred: "It is often unwise to lose too much time in aiming at perfection." Accordingly, the Admiralty ordered the company to fit all 150 torpedoes under contract to take the gyroscope, and it ordered seventy-five gyroscopes. A month later, Jeffrey recommended that the Navy order 300 additional gyroscopes, which was also done.[37]

Although the orders for 375 gyroscopes in late 1898 were a quantum leap over the last order, which had been eighteen gyroscopes for limited issue to seagoing ships in March 1898, it was still comparatively ad hoc. In August 1899, Jeffrey, still the Director of Naval Ordnance, decided that the time had come to put gyroscope policy on sound long-term footing, and he went back to the archives to review the evolution of the policy. He discovered a financial and legal mess, at the heart of which was a question of royalties that the Admiralty had never fully answered.[38]

Royalties and the Treasury

The details of this saga are significant because they illuminate the larger dynamics of the relationship between the Admiralty and the private sector and between the Admiralty and the Treasury. In particular, they reflect the pervasive importance of intellectual property rights, while supplying yet another example of how those who mastered the necessary technical details (in this case, Admiralty officials) could exploit the ignorance of those who had not (in this case, Treasury officials) to escape oversight and undermine procedures for government accountability.

When the Admiralty first began to consider purchasing gyroscopes from the Whitehead Company, in early 1897, it had received several price quotations from the company. It had the company's initial offer from fall 1896 for £50 per gyroscope if supplied by the company, £25 royalty per gyroscope if manufactured by the government or its agents, or £20,000 as a lump sum for the right to manufacture any number of gyroscopes. In February 1897, the company added that it would charge £25 per fitting of the gyroscope to a torpedo. The same month, Walker, then the Assistant Director of Torpedoes, suggested that payment of royalties per gyroscope would go toward the redemption of the lump sum if the Admiralty ever decided to purchase the right to make as many gyroscopes as it wanted. This suggestion made its way into the Admiralty's deliberations without scrutiny.[39]

In March 1897, on receiving a report on the preliminary trials conducted at Weymouth under the direction of the company with its sample gyroscopic torpedo from Fiume, the Admiralty debated whether to order four gyroscopes to be fitted to torpedoes for further testing on the *Vernon*. The accountant general pointed out that, because the £25 royalty appeared to be 100 percent of the £25 cost of manufacture, Treasury regulations would require the Admiralty to obtain Treasury sanction before the Admiralty could guarantee payment for the four torpedoes. When the Admiralty wrote to the Whitehead Company on May 1, 1897, to inquire about its terms for fitting four gyroscopes, the Admiralty said that it expected the cost for each torpedo to come to £75—£25 for the gyroscope, £25 for the royalty, and £25 for the fitting—and it described the issue with the Treasury regulations, explaining that it would not recommend payment of the royalty to the Treasury without further proof that the royalty was justified by the value of the device. The implication was that the company would have to provide a few gyroscopes to the Admiralty free of royalty for trial, after which the question of royalties could be taken back up.[40]

On May 14, 1897, the company replied to say that it could not supply gyroscopes under those conditions at present, but that it was taking steps to patent the gyroscope so that it could supply the gyroscopes without an agreement on royalties. The implicit logic of the company's position was that it could not supply unpatented technology to the Admiralty without a royalty agreement of some sort because the lack of such an agreement might be taken to imply that the technology was unprotected; if the Admiralty decided to pirate the technology, the company would have no proof that the technology was protected without a royalty agreement. A week later, the company wrote again to the Admiralty to say that it had taken out the patents and could therefore supply the four gyroscopes for trial and any more that the Admiralty might wish to order, while leaving the settlement of a royalty agreement to a later date. It quoted prices of £50 per gyroscope—*without* itemizing the royalty—plus £25 for fitting each gyroscope to torpedoes.[41]

According to Jeffrey, the Director of Naval Ordnance, the lack of itemization was important: "No Treasury sanction appears . . . to have been asked for or to have been necessary for a case in which the patented article is purchased direct from the patentee and royalty is included in the price."[42] Jeffrey's reasoning seems to have been that holders of a patent could not pay royalties on that patent to themselves. If so, his use of the term *royalty*, which suggested that it had a discrete existence of its own within the price, was confusing. Even more problematic was the fact that, under the artfully named category of payments "over and above the actual price named for manufacturing and fitting" (a royalty by any other name sounding sweeter to Treasury ears), Jeffrey included £200 for the two 1897 orders of four gyroscopic torpedoes, or £25 for each gyroscope, which was, of course, the royalty amount. Here, he counted the £25 as a royalty because he wanted it to go toward redeeming the lump sum of £20,000 to be paid to the Whitehead Company. Thus, while the Admiralty's interest vis-à-vis the Treasury was to combine the royalty with the price, its interest vis-à-vis the company was to separate the royalty from the price. In short, Jeffrey was trying to have it both ways: to argue that there had been no royalty, so as to free the Admiralty from the obligation to seek Treasury sanction for the contracts; and to argue that there had been a royalty, so as to count it toward redemption of the lump sum.

Jeffrey was interested in the lump-sum possibility because he projected sufficiently high gyroscope needs—2,500 over the next five years—that the Navy would find it more economical to buy them wholesale rather than retail. He hoped, based on Walker's suggestion of February 1897, that the Whitehead Company would agree to count the royalties already paid (amounting to £10,025) toward the lump sum of £20,000. Considering that the Admiralty was trying to reap the rewards of risks borne by the company, the latter was not open to this idea. The company acknowledged, however, that the royalties already paid should allow it to modify its original offer, and it offered a counterproposal. The company would permit the £10,025 already paid to count toward defraying the £20,000 and accept the balance of £9,975, instead of requiring the Admiralty to start from scratch. In return, the Admiralty would agree to give the company a monopoly on its gyroscope supply for three years at a cost of £30 per gyroscope, the one exception to the monopoly being that the RGF would be permitted to manufacture a small number per year, say, twenty, so as to be in a position to supply the Admiralty when its monopoly agreement with the company ended.[43]

Jeffrey argued in favor of the monopoly proposal based on the Admiralty's projected needs. The proposal would benefit the Admiralty even more if it were defined in terms of numbers instead of time. Pointing out that the company probably thought the Admiralty's needs were lower than they actually were based on past trends, he suggested fixing the monopoly at 1,000 gyroscopes instead of at three years. His colleagues agreed, and the Financial Secretary added that the Admiralty might press for the right to have fifty instead of twenty gyroscopes made by the RGF each year.[44] The company accepted the Admiralty's proposed terms in their entirety. The Admiralty belatedly wrote to the Treasury for authorization, including this careful account of the negotiations: "[T]he exact proportion of the £50 [price] which was to be charged as royalty was not definitely agree [sic] to; but from correspondence it was assumed that about £25 was to be paid for that purpose." For good measure, the letter calculated the royalty's percentage of the total cost of manufacture not against the gyroscope alone (in which case it would have been 100 percent) but against the average price of an entire torpedo (in which case it was merely 6 to 7 percent). The understaffed Treasury authorized the necessary expenditures, and the Admiralty had a long-term gyroscope policy.[45] Events confirmed the wisdom of its decision to switch from royalty payments to a lump sum, and to define the monopoly in terms of numbers rather than time. It ordered so many gyroscopes in fiscal years 1900–1901 and 1901–1902 that the monopoly agreement bound it for only one financial year instead of the three originally sought by the company.[46]

Beginning with the Admiralty's order of seventy-five gyroscopes in October 1898, improvements were repeatedly introduced. The first was a switch from pivot bearings to ball bearings, which reduced friction and therefore increased the gyroscope's spin time (from 5 to 35 minutes). The second was the reduction in strength of the spring that started the gyroscope, which prevented the force of its release from breaking other parts of the gyroscope. The third was the replacement of the automatic clutch for holding the gyroscope in the cocked position with a more reliable mechanical (manual) clutch. The fourth was the introduction of more effective screws for holding the cups of the ball bearings in place. Finally, a valve in the gyroscope was changed to prevent oil and rust particles from fouling the gyroscope. Although these changes were the incremental results of mundane trial-and-error experiment rather than radical departures discovered from theoretical design work, they combined to produce a much more effective gyroscope.[47]

Technological Incrementalism

After years of wandering through the wilderness of the pattern-unification policy and kicking the gyroscope can down the road, the Navy's torpedo policy was, at least for the time being, on sound footing. The missteps had not entirely been in vain. The debacle with the reducer and engine of the 14-inch RGF Mark IX torpedo had concentrated attention on those two parts. Thus, while others put their hopes in the turbine engine, the Royal Navy was primed to improve the reciprocal engine.

The *Vernon* had begun experimenting with new reducers in 1896. Authorization to develop new designs of 14-inch and 18-inch RGF torpedoes in July 1897 and May 1898, respectively, provided motive and opportunity to develop new engines as well. The basic idea was to manipulate the air pressure acting on the engines, and the size of the parts acted on, to find the best combination. Various engines were designed, differing from each other in the diameter of the cylinders, the length of the pistons' stroke, the nature of the valves, and the cylinders' exhaust. The Navy also tried a four-cylinder engine in two experimental torpedoes in lieu of the usual three-cylinder engine in 1900. Although the four-cylinder engine increased the speed, it decreased the uniformity of the speed and the stability of the torpedo. Due to these problems, the Navy temporarily shelved the idea of a four-cylinder engine. It settled on a new 14-inch engine in 1897, and on a new 14-inch torpedo (the RGF Mark X) in 1898; it settled on a new 18-inch engine in 1899 and on a new 18-inch torpedo (the RGF Mark V) in 1901.[48]

The development of these new engine and torpedo designs also improved understanding of the Navy's existing designs. A series of experiments conducted in 1898 to determine the best speed and range settings for the new 18-inch torpedoes uncovered "some capabilities of our present torpedo which are not generally known," namely, that varying the setting of the reducer could dramatically increase the speed of the torpedo by roughly 5 knots over 300 yards and 1 knot over 600 yards. Another set of experiments produced a comparable revelation, which was that "in previous engine designs the size of the valve," an important factor in engine performance, "has been a matter of guess work."[49]

Guess work was perhaps too strong a term, given that a good deal of calculation and planning was involved in engine design, but it did point to a larger truth: the empirical nature of much design work. Scientific knowledge and mathematical calculations could carry the design process far, but only so far, and at some point the only way to figure out the best settings was to try many different ones. However frustrating for the designers, empiricism actually played to one of Britain's great comparative advantages, which was the extent of its research and development infrastructure. No other nation had the combination of money, range facilities, expertise, material, and personnel to undertake experiments of such scope and intensity. Trial-and-error design work could not be done, or could not be done as well, without such resources.

In 1902, a new development rendered the painstaking experiments of the past six years with reducers and engines partly irrelevant: the use of nickel-steel for air flasks. Nickel-steel allowed a quantum increase in the weight and pressure of air carried for a given volume—roughly a 20 to 33 percent increase in the weight of air (a smaller increase in 18-inch torpedoes than in 14-inch torpedoes), and a 25 percent increase in the pressure. In theory, these increases were desirable because they allowed greater speeds and ranges. The problem was that existing engines had been designed to work at a given pressure, and they had been settled on only recently after a prolonged development process. Thus, the prospect of changing them, problematic under the best of circumstances, was particularly unappealing. Accordingly, at a conference between representatives of the RGF and the *Vernon* in June 1902, it was decided to put off the design of new 14-inch and 18-inch engines that would be needed to get the most out of the new air flasks and to settle for modest, rather than optimal, improvements in speed and range for the time being.[50]

While calculating that the gyroscope and nickel-steel flasks were quantum leaps forward over any existing technology and demanded adoption, the Admiralty reached a different conclusion about the turbine engine. The RGF first carried out experiments with turbine propulsion of torpedoes in 1897, using a Parsons turbine. It failed. In 1901, the Assistant Superintendent of the RGF, Cecil Ryther Acklom—a key figure in British torpedo development for more than a decade—decided to try again using a different form of turbine. At first, his turbine's efficiency was well under half that of the latest reciprocating engine, but Acklom managed to get it up to well over half, though still less. Then a screw came loose while he was testing it, and the turbine was practically destroyed. Acklom had already spent £200, and he asked for £150 more to continue his efforts. The Director of Naval Ordnance turned him down, giving a clear indication of how much value—or lack thereof—the Admiralty attached to the development of a turbine engine.[51]

The Admiralty also decided not to adopt another new piece of torpedo technology: the superheater. In June 1901, F. M. Leavitt's British patent for the superheater was sent to the *Vernon*, but the device was judged too dangerous because of the risk of premature ignition and consequent bursting of the air flask to warrant trial.[52] Whether in response to the news of the Leavitt superheater, or on his own initiative, the intrepid Acklom began to work on his own design of a superheater.[53]

A year later, the E. W. Bliss Company approached the Admiralty about the superheater. The Bliss Company stated that the US Navy had made "exhaustive" tests of the device and found that it increased the speed of the torpedo by 16 percent over 800 yards, while creating "no complications of any kind." The new captain of the *Vernon*, Charles Egerton, was intrigued, judging a 16 percent increase in speed "certainly sufficient" to warrant trial—if it could be shown that the danger of premature ignition of the alcohol that heated the air had been overcome. Acklom was more openly skeptical: The company said that the tests had been "exhaustive," yet the Navy report it cited "only rests on 22 runs!" Egerton and Acklom agreed that the first order of business should be to get more complete details from the company, and the Admiralty wrote to the Bliss Company accordingly.[54]

In its reply, the company attempted to allay the Admiralty's fears over premature ignition of the superheater and offered to equip a sample torpedo with the device. Before doing so, however, it seemed to insist that the Admiralty buy the patent rights to the superheater. Though aghast that the company apparently expected the Navy to buy the patent rights without conducting trials, a "very unreasonable" attitude, Acklom thought the Navy should try "this ingenious device." Egerton agreed that trials were desirable, and that purchase of the patent rights was impossible without trials. The Admiralty informed the company of this decision and asked what the company would charge for two superheaters and drawings.[55]

The Bliss Company offered a counterproposal with terms very similar to those it had worked out with the US Navy: it would equip a torpedo with a superheater at no charge provided that the Admiralty agreed to try the torpedo in the presence of a company representative in England and to pay the company a certain amount for each half-knot of speed gained. The company would also need to come to some arrangement with the Admiralty about how many superheaters the Admiralty would purchase if the company's claims for it were borne out, suggesting that the number be spread over five years so that the payment per year would be comparatively low.[56]

Despite initial enthusiasm from Acklom, the Admiralty chose otherwise. According to the Assistant Director of Naval Ordnance, H. B. Jackson, the *Vernon* and the RGF agreed that the device was "too complicated and dangerous . . . even if a considerable gain in speed could be guaranteed at a moderate cost," and he recommended that the company's offer be declined, with thanks, and with an expression of the Admiralty's willingness to consider any simplified version of the device in the future. The company replied that the superheater was already very simple, but to no avail: as far as the Admiralty was concerned, the matter was closed.[57]

Tactics and Naval Architecture

The changes in torpedo technology discussed in this chapter had implications for tactics and naval architecture. Of the two subjects, tactics is the harder to track because it was the more decentralized. Nevertheless, surviving records make clear that many officers understood that the invention of the gyroscope portended a revolution in naval tactics. In addition to improving stern fire, which has already been alluded to, the gyroscope held out the possibility of attacking ships with torpedoes outside gun range. In his report on the first four gyroscopic torpedoes tried at the *Vernon* in late 1897, Durnford observed that "one of the first advantages would be a great increase of range . . . [which] would mean Boats could often afford to discharge their torpedoes at a range, practically safe from the gun-fire of the ships they are attacking."[58] The tactical importance of this prospect can scarcely be overstated. It meant that the torpedo, not the gun, might be the primary weapon in a naval battle and that a centuries-old system of tactics and naval architecture geared toward bringing the largest broadside concentration of fire on the enemy fleet might be rendered irrelevant.

Although the significance of this possibility was obvious, the exact increases in range were not. Far from a straightforward matter of physical measurement, determining the increases had to incorporate a variety of tactical considerations. In late 1899, Henry J. May, captain of a modern battleship in the Channel Squadron when he wrote, and the future leader of the War Course at the Royal Naval College, estimated that the gyroscope had increased the effective range of torpedoes to 2,400 yards, which he seems to have defined as the range at which torpedoes stood a one in three chance of hitting a two-mile-long enemy line of battleships. His estimate of range was three times longer than the Navy's torpedoes were designed to go, and 900 yards longer than the longest range at which the *Vernon* conducted long-range experiments by 1902. Jacky Fisher, commanding the Mediterranean Fleet, rated the effective range even higher, defining "the torpedo zone" as 4,000 yards, even though he did not actually believe that torpedoes could be aimed accurately for 4,000 yards.[59]

Fisher and May had two reasons for defining the torpedo zone so generously. First, they feared that ships at the end of the battle-line, or farthest from the control of the commanding admiral, might accidentally blunder into torpedo range. In combined exercises between the Channel Squadron and Mediterranean Fleet in 1901, May observed that, in its effort to obtain a superiority in gunfire, one side had unwittingly exposed the rear of its battle-line to "almost certain destruction" by torpedoes for a full 45 minutes without ever getting a chance to return torpedo fire. Commenting on exercises a year later, Fisher observed that one side risked losing several ships to torpedo fire, despite gaining superiority in gunfire, "[b]ecause the initial error was committed of approaching inside 4,000 yards, and thus giving no margin for keeping outside the Torpedo Zone." Second, in addition to poor command-and-control making a buffer zone necessary, Fisher, and possibly May, feared that an enemy fleet might quickly close the range in order to fire torpedoes, in which case the British fleet would need a buffer zone to give it time to turn away.[60] For these reasons, the range of torpedoes could be said to be effective not merely insofar as they stood a reasonable chance of hitting the target, but also insofar as they exerted an effect on the battle range. As of 1902, their effective range in the latter sense was roughly twice as long as it was in the former. Hence, Fisher was thinking of a *minimum* gunnery range that was double torpedo range.

These calculations explain his attempts to carry out long-range firing at 6,000 yards in 1899 and 1900. The Admiralty picked up on his efforts and introduced 6,000-yard practice into the fleet at large in 1901, but British gunnery was far from effective at that range.[61] It is dangerous to generalize because important variations existed depending on the nature of the gun (a heavy gun trained and elevated by clumsy hydraulic machinery was much more difficult to aim than a lighter, quick-firing gun capable of being manipulated by hand), the weather (clear conditions with good visibility and a calm sea to minimize roll and yaw made it possible to fire more accurately at longer ranges), and the nature of the engagement (one in which the range between fleets varied at a constant or changing rate made accurate gunnery much more difficult than one in which the range was constant); however, it is safe to conclude that the large-scale adoption of the gyroscopic torpedo in 1898 began a period in which torpedoes effectively outranged guns.

As torpedoes became more effective, the defenses of capital ships against small craft firing torpedoes became less effective. Experiments carried out early in 1902, on the assumption that small guns like 12-pounders (3-inch caliber) would be the first put out of action in a battle and that anti-torpedo craft responsibilities would devolve onto 4.7-inch and 6-inch guns, revealed that shrapnel fired from these guns could not stop small vessels (torpedo boats or destroyers) carrying torpedoes, and that shells had to be practically direct hits to stop them. Thus, the experiments suggested that the small- and medium-caliber guns of capital ships were useless against torpedo craft. In April 1902, acting on recommendations that had been made in January, a month before the experiments were reported, the Admiralty officially deemphasized the importance of the anti-torpedo craft armament in capital ships.[62]

The inability of capital ships to defend themselves against torpedo craft made other defenses imperative. In the early 1890s, the Navy began building a new class of vessel called the torpedo-boat destroyer, later shortened simply to destroyer. In effect, capital ships were contracting out the task of defending themselves to other vessels. By the late 1890s, destroyers were expected to make 30 knots. Their high speed came at the expense of strength, however, and they were unable to keep the sea in anything but the calmest weather. In 1900, prompted by the complaints of British destroyer commanders and inspired by the example of slower but stronger German destroyers, the Admiralty began to contemplate the design of slower but more seaworthy destroyers. In late 1901, the Admiralty decided that instead of requiring 30 knots, it would be content with 25.5 knots along with a stronger, more seaworthy vessel.[63]

Not all parties were happy with the decision. In the Mediterranean, Fisher believed that the problem was not that destroyers were too weak, but that they were being used for missions that should have been performed by other types of vessels. "Because we had an insufficiency of Cruisers," Fisher complained, "Destroyers, instead of 'laying to' in bad weather, had to be forced against heavy seas to carry information that should have been taken by Cruisers!" The misuse of destroyers was creating a mania for strength that they did not need; in fact, their frailty was "necessary and essential. . . . If we go [sic] making Destroyers stronger, they will be heavier, they will be slower and bigger, and will degenerate into vessels that won't catch anything and won't be able to run away!" While it was true that destroyers in the Mediterranean, unlike those in the Channel, had to operate at sea far from bases for long periods, Fisher thought the answer was not prolonged sea-keeping ability, but "towing by day for economizing coal and giving the crew rest." Sufficiently fast destroyers could wreak havoc during battle. Reporting on exercises in 1900, Fisher described "[t]he destroyers all dashing about like mad in the middle of it all! and torpedoing everyone! It is certainly the best thing I have ever seen and the most realistic."[64] As Fisher's reference to destroyers being "in the middle of it all" indicated, he did not contemplate destroyers joining the line of battle to fire their torpedoes while capital ships fired their guns; rather, the fear was that destroyers might be able to dash between opposing battle-lines and fire their torpedoes before capital ships, distracted by dealing with enemy capital ships, or other destroyers could destroy them.

In advocating the use of torpedo-boat destroyers as torpedo boats, Fisher hit upon another controversial point. Throughout the 1890s, destroyers carried either a gun armament (when they were expected to be used as torpedo-boat destroyers) or a torpedo armament (when they were expected to be used as torpedo boats). In July 1901, an Admiralty official pointed out that the system undermined preparedness and asked whether one alternative should be chosen over the other. The Admiralty decided to choose the gun armament, but disagreement by the commander of a major destroyer base touched off another round of debate. The Assistant Director of Naval Ordnance, H. B. Jackson, argued that destroyers should retain both armaments so that they could operate offensively as torpedo boats and defensively against torpedo boats, while the Director of Naval Intelligence, Reginald Custance, argued that their gun armament should be favored because their primary mission was to defend against torpedo boats. The Controller, W. H. May, and Senior Naval Lord, Lord Walter Kerr, backed Custance, and the matter was decided in favor of the gun armament. No sooner was the issue closed, however, than the commander of the Portsmouth instructional destroyer flotilla wrote to express his regret that destroyers would carry only the one torpedo tube associated with the gun armament, rather than the two tubes associated with the torpedo armament. The Commander in Chief of Portsmouth and the captain of the *Vernon* backed him. Not missing his chance, the recently overruled Jackson urged that the question be reopened, with added support from the Inspecting Captain of Destroyers, but May and Kerr refused to budge. It was with good reason that Kerr observed, "The use of Destroyers in company with battle ships is a vexed question"—as was nearly every tactical question from 1895 to 1902.[65]

With some exceptions, the Royal Navy's torpedo policy from the mid-1890s through 1902 was generally cautious and thoughtful. The exceptions were the decision to institute the pattern-unification policy over the objections of the expert Torpedo Design Committee (including then-captain of the *Vernon* B. W. Walker) and Walker's subsequent misconduct at the Admiralty, which delayed reversal of the pattern-unification policy and adoption of the gyroscope. Nevertheless, the Admiralty thoroughly tested the gyroscope before committing to it, and officials' decision to reject the turbine engine and superheater were perfectly rational given that the Royal Navy's superior research-and-development resources allowed it to improve existing technology and test new technology more than any other navy. The consultative nature of Admiralty decision making was noteworthy: on the gyroscope question, everyone from the captain of the *Vernon* to the First Lord weighed in, touching on issues ranging from tactics to national power. Debates over tactics and naval architecture revealed the extraordinary complexity of even seemingly simple matters, like determining torpedo range. Although the Royal Navy adopted new technology more slowly than the US Navy (or not at all), its behavior was not due to an irrationally conservative institutional culture, but rather to a rational analysis of material resources. Because it was the naval hegemon, the Royal Navy had more to lose from technological change than any other navy—but its superior resources also made it more likely than any other navy to exploit change.

3

THE US NAVY AND THE EMERGENCE OF COMMAND TECHNOLOGY

"[H]uman foresight is fallible, and many great and unforeseeable expenses may, and no doubt will be encountered."

—Bliss Company, 1905

In 1915, when the relationship between the US Navy and its primary torpedo supplier, the E. W. Bliss Company, had become fractious, Secretary of the Navy Josephus Daniels looked back in anger on their twenty-five-year history. He wrote:

> The relations between the United States Government and the Bliss Company have been peculiar, in that the latter have been the sole private manufacturers of torpedoes for the Government in the United States ever since we have been using these weapons. They have sold us many millions of dollars worth, and it is has been upon our suggestions and our expressed needs to them based upon our experience and our prevision [sic] that their torpedo of today has been developed. Furthermore, the Government has actually paid development costs to the Bliss Company.[1]

Given his reform-minded hostility to big business and his championship of government armaments production, Daniels's version of history, which pitted farsighted public servants against greedy private contractors, was convenient. It was also highly misleading. To be sure, the US Navy, or rather the Bureau of Ordnance, had indeed made suggestions based on its "prevision," and it had subsidized private-sector research-and-development (R&D) by paying artificially high prices for finished goods. But its "prevision" had proved less than accurate on occasion, and it had not subsidized

R&D for every part of the torpedo. It is unsurprising that Daniels missed such complexities. Neither he nor his predecessors as secretary had made the key decisions, and those who had in the Bureau of Ordnance were happy to promote a morality tale that blamed the private sector alone for shared miscalculations.

The tangled story of the search for a gyroscope illustrates the limitations of the bureau's own R&D process. In May 1902, as previously related, the Chief of the Bureau of Ordnance, Charles O'Neil, had announced his intention to put the gyroscope designed by Torpedo Station machinist John Moore in new torpedoes. He ordered the Torpedo Station to build twelve and opened negotiations with the Bliss Company to construct sixty—but then Washington Chambers, back at the Torpedo Station after service in the Philippines, disrupted proceedings by criticizing the performance of Moore's model.[2]

In response, O'Neil ordered the Torpedo Station to revisit the Moore gyroscope. The reply by the new commander of the Station, Frank Friday Fletcher, revealed the shortcomings in the R&D of the Moore gyroscope. Having combed the Torpedo Station's files, Fletcher found that the "complete record" on the Moore gyroscope, such as it was, consisted of three reports covering ninety-one runs. The three reports furnished insufficient data for determining the accuracy and reliability of the device, Fletcher felt, and thus he concluded that the desire for angle fire, which the Obry gyroscope could not accomplish, had unduly influenced its adoption.[3]

Two other developments weakened the case for the Moore gyroscope. First, Fletcher oversaw dramatic improvements to the Obry already in service. The most important change was to switch from pivot bearings to ball bearings for the axle bearings and the side bearings to reduce friction and hence to increase the spin time. With these two sets of bearings altered, by January 1904, the Obry gyroscope was able to spin for 42 minutes instead of the 13 minutes it managed with pivot bearings.[4] Second, a new competitor arrived on the scene: a gyroscope designed by F. M. Leavitt of the Bliss Company. Like the Moore gyroscope, Leavitt's used air impulse, but the arrangements for the air flow and for transmitting the actions of the gyroscope to the rudders differed. All three sets of bearings were old-fashioned pivot, rather than ball, bearings, and it was not initially capable of angle fire. Nevertheless, a preliminary report on Leavitt's gyroscope in November 1903 recommended further development.[5]

Shortly thereafter, Fletcher showed how imperfectly those guiding gyroscope development had thought through its implications. In a new report on the Moore gyroscope, Fletcher explained that torpedo fire, especially angle fire, involved more dependent variables than previously realized, making it much more difficult to solve torpedo fire-control problems. Specifically, the tactical diameters varied for individual torpedoes of the same mark (and for the same helm angle to right and left), and the transfer of the torpedo from its intended to actual course varied with the initial deflection and the helm angle. Moreover, the target range had to be known to aim angled shots. Fletcher's report demonstrated that the fire-control and tactical problems associated with gyroscope development and angle fire had not previously been appreciated in full.[6]

The confusion only increased. Although O'Neil signaled a preference for the Moore and Leavitt gyroscopes, he stepped down as chief of the bureau in March 1903. His successor, G. A. Converse, held the position for only five months before being replaced by N. E. Mason. Such rapid turnover was not conducive to developing a coherent gyroscope policy. For his part, Mason approached gyroscopes as a diner would a buffet, mixing and matching the features he liked best from the three models. In September 1904, Fletcher submitted three designs conforming to Mason's specifications.[7]

Development of the Moore gyroscope then stalled for three years, after losing to the Leavitt gyroscope in competitive trials in September 1904. In 1907–1908, it received further tests but was then put aside until 1911.[8] Instead, modified Obry gyroscopes, with spring impulse and ball bearings, went into Whitehead torpedoes, while Leavitt's gyroscope, now capable of angle fire, went into the new Bliss-Leavitt torpedoes, which are discussed later in this chapter. During that time, the Navy was never fully satisfied with the Leavitt gyroscope.[9]

Under Pressure

While the gyroscope tangle developed, a revolutionary torpedo entered naval service, largely due to pressure from the rest of the Navy, which vented its frustration over the state of US torpedo development at the 1903 US Naval War College conference. The hypothetical enemy before the officers gathered that summer was Germany, which presented special challenges from a torpedo perspective. In war games played to study the problem of fighting the German fleet, the US fleet lost all but once due to inferior speed and lack of torpedoes on its capital ships. "A number of tactical games carefully played to develop the value of torpedoes shows that they turn the scale of battle in their favor in a most decided manner," a special subcommittee appointed to study the issue reported, and "[n]o weight of guns and armor can precisely compensate for even the smallest torpedo armament." To solve the problem, the Naval War College concluded that US capital ships must carry (submerged) torpedo tubes and long-range torpedoes. Adding high-level backing, the General Board endorsed the Naval War College's conclusions in a letter to the Secretary of the Navy.[10]

Pressure to improve the Navy's torpedo armament came not only from the fleet but also from within the Bureau of Ordnance. At the same 1903 conference of the Naval War College, the torpedo officer of the bureau, F. K. Hill, lambasted the absence of submerged torpedo tubes on capital ships. While the short range of "our torpedoes as they now stand" might have justified the decision to keep submerged tubes off capital ships, Hill allowed, the justification "certainly does not apply to the most modern torpedoes developed."[11] Coming from the officer within the bureau with responsibility for torpedo development, this was a scathing indictment of US efforts.

The target of these criticisms from Hill, the Naval War College, and the General Board was obvious: Charles O'Neil, the chief of the Bureau of Ordnance and president of the Board on Construction. In the former capacity, O'Neil was responsible for torpedo development; in the latter capacity, he was responsible for the decision not to place submerged torpedo tubes on capital ships. Thus, he bore the brunt of these widespread complaints about the state of US torpedoes on capital ships. It is noteworthy that the fleet was demanding better torpedoes from the shore experts, like O'Neil, rather than parochial shore experts pushing the latest disruptive technology on a conservative fleet.[12]

Under pressure from within his own bureau and from powerful bodies outside it, O'Neil hastily committed to a radically new technology. In September 1903, the Bliss Company informed the bureau that it had repaired the experimental turbine torpedo wrecked the previous summer and was ready to submit it for trials. O'Neil soon met with company representatives in Washington to discuss the details of a new torpedo contract. With a tentative agreement in place, O'Neil sent the Bliss Company a draft contract and specifications on November 2, 1903. "As soon as the Bliss Company agree to the [enclosed] contract and specifications," he said, "the Bureau will give the order." Given the timing, this was a remarkable statement. Although the contract for the torpedoes was not actually signed until January 1904, two months after the trial turbine torpedo was tested, O'Neil was prepared to make the contract two weeks *before* he received the results.[13]

The report of the trials was favorable but expressed significant reservations. It praised the simplicity, reliability, strength, and durability of the turbine engine, which suited it better than reciprocating engines to run at the higher speeds and longer ranges enabled by the superheater. The report also pointed out, however, that the turbine engine had certain disadvantages compared to the reciprocating engine: turbine torpedoes could not have multiple speed and/or range settings because turbines ran most efficiently at the one speed for which they were designed, and the rotational velocity of the turbine could create unbalanced torque (a possibility first raised by the Torpedo Station in fall 1901).[14] In time, these disadvantages proved to be significant.

O'Neil used the report as an endorsement of his policy, however, and ignored its qualifications. In December 1903 and January 1904, he formalized the Navy's commitment to the Bliss-Leavitt torpedo—Bliss for the company, Leavitt for the engineer—by signing contracts for fifty-two torpedoes. In so doing, O'Neil failed to solicit the opinion of the commander of the Torpedo Station. He also failed to include two clauses that would later become standard: one that imposed penalties for delays in delivery, and another that protected the Navy's rights to devices of its own invention.[15] Experience with the first Bliss-Leavitt torpedoes taught the bureau that the technology was experimental, not perfected, and that these two clauses were necessary in a contract for experimental technology. O'Neil's premature commitment to an immature weapon laid the foundation for later struggles.

A Reasonable Share of Patriotism

It soon became evident that the Navy had failed to think through the implications of its commitment to the Bliss-Leavitt torpedo. In April 1904, George Converse, a former commander of the Torpedo Station and the new chief of the Bureau of Ordnance, fielded a novel proposition from the Bliss Company to sell the exclusive international rights to the Bliss-Leavitt torpedo. The company had been approached, it informed the bureau, by "[a] number of interests, having large dealings with foreign governments, and there is little doubt that we could quickly make connections which would lead to very large business." Although its business interests pointed abroad, the company wanted "to defer to the wishes of our own Government." Therefore, it asked the bureau to decide whether it wanted the exclusive rights or to free the company to pursue foreign sales. The company also enlisted its law firm, Herbert & Micou, to help make its case. "Herbert" was Hilary Herbert, former Democratic chair of the House Committee on Naval Affairs and Secretary of the Navy. "Micou" was Benjamin Micou, former chief clerk of the Navy Department. On April 23, 1904, on behalf of the Bliss Company, the firm formally offered to sell the exclusive rights for $1.5 million.[16]

Converse thought this too high a price. In a meeting with Herbert on April 25, he used the £50 (approximately $250) royalty that the Bliss Company paid to Whitehead on each torpedo (apparently assuming that the Bliss Company would charge the Navy a similar royalty on each Bliss-Leavitt torpedo), to calculate that the Navy would need to order 6,000 torpedoes at that royalty to make the exclusive rights of $1.5 million economical ($1.5 million divided by $250 equals 6,000). Because he did not think that the Navy would need 6,000 torpedoes, he concluded that it would not be economical for the Navy to pay the asking price of $1.5 million.[17]

Herbert was aghast at Converse's rationale. "My dear Mr. Secretary," he wrote in a personal letter to his successor as Secretary of the Navy, "the price of the royalty of an inferior torpedo that can be manufactured by any government that will pay the price, cannot be taken as a factor in estimating the value of the exclusive right to manufacture a torpedo so immensely superior as ours is to the Whitehead." Considering that a single $5,000 torpedo could put a $6,000,000 battleship out of action, that the Bliss-Leavitt torpedo was superior to the Whitehead, and that the performance of the Bliss-Leavitt torpedo was guaranteed by contract, the exclusive right to manufacture was "certainly" worth more than $1.5 million. Herbert's description of the Bliss-Leavitt torpedo was highly misleading: it had not yet proven its superiority to the Whitehead, and comparing the price of a torpedo to the price of a battleship was crude (a fairer comparison would have been between the price of the torpedo *plus* the platform needed to launch it against the price of a battleship). Nevertheless, the tension between international markets and national borders perceived by the Bliss Company was real. In a marvelous turn of phrase, Herbert assured the secretary that the officers of the Bliss Company had "a reasonable share of patriotism," and therefore would prefer to sell the exclusive rights to the United States, while implying that a "reasonable" need for profits might force the company to look elsewhere.[18]

While Herbert wrote as one politician to another, the Bliss Company took a more business-like tone, focusing on the key issue at stake: the exclusivity of the rights. Undermining the basis of Converse's logic, the company observed that it was not asking the government to pay any royalties. "The question, therefore, to be decided by our Government is not one of royalties," the company wrote, "but whether or not it is advisable to prevent any foreign Nation from possessing this weapon by obtaining control of it"—and in so doing, to deprive the company of foreign sales.[19]

The company's criticisms of Converse's logic were justified. It was indeed inapt, but not necessarily inept, given the novelty of the proposition he was offered. Converse conflated two purchasing arrangements that, despite certain similarities, were distinct. He was thinking of a one-time lump-sum royalty payment on a large lot of items in lieu of royalty payments on each item. Given that the company undoubtedly built hypothetical lost royalties into the price for the exclusive rights in much the same way that they were built into a lump-sum royalty, Converse was not entirely off base to be thinking in the latter terms. The factor he missed, as the company pointed out, was foreign sales. Although it was natural for a company in a global marketplace to think in such terms, it would have been unnatural for a naval officer to do so, since the Navy had rarely, if ever, wanted an item of domestic design and manufacture that excited foreign interest, let alone the exclusive rights to such an item.[20] The Bliss Company's offer was a new phenomenon, and it is not surprising that Converse fell back on an old way of thinking about the naval-industrial relationship.

Realizing that he was ill-equipped to handle this new phenomenon, Converse decided to seek advice. In May 1904, a board appointed at his request delivered its report on the Bliss Company's offer. After a brief overview of foreign torpedo performance, the board declared (incorrectly) that the Bliss Company had "perfected" a torpedo superior to foreign torpedoes. The military value of the torpedo, in the board's view, depended on the secrecy of not only its mechanical details, but "just as important or even more important" the results attained by it. The importance of secrecy was due to a challenge-and-response dynamic then prevailing among the world's navies (see the Introduction). "The development of war material has reached such a stage in all first class Naval Powers and the competition to obtain the best weapons is so close," the board explained, "that no sooner is it known that one nation has developed a weapon of a given power, than results are soon duplicated by similar weapons in other Navies." Given that the publication of results motivated competition, it was important not only to keep technological means secret, but also (less obviously) to keep technological results secret.[21]

Because the military value of exclusive rights depended on the ability to preserve secrecy, and because secrecy was likely to be breached, the board considered the military value of exclusive rights to be temporary. More permanent, and by implication more valuable, was a robust domestic supply system. Pointing to the great armaments firms of Vickers and Armstrong Whitworth in Britain, and of Krupp in Germany, the board wished "to emphasize the value to any Government of having within its borders well equipped commercial factories capable of producing war material." Although the board managed to avoid giving a direct yes or no to the question of whether the Navy should buy the exclusive rights at the asking price, the strong implication of its report was to answer in the negative. Acting on the logic of the board's report, Converse informed the Bliss Company that the Navy would not purchase the exclusive rights.[22]

Though abortive, these negotiations were significant. They revealed the clash of perspectives between a navy thinking in terms of national security and a business thinking in terms of international profit. They showed that what was commercially valuable for the Bliss Company was not necessarily militarily valuable for the Navy, and they underscored the difficulty of pricing a commodity when its value was still under debate. These problems would only become more acute when the Navy discovered that the technology at issue was not perfected but experimental.

The Origins of Command Technology

The experimental nature of the Bliss-Leavitt torpedo began to dawn on the Bureau of Ordnance in early spring 1905, with the arrival of reports on the performance of the first Bliss-Leavitt torpedoes ordered by O'Neil in late 1903 and early 1904. It soon became clear that the torpedoes had two serious problems: poor depth control in the vertical plane and poor accuracy in the horizontal plane. The latter was known as sheer, referring to the torpedoes' tendency to sheer off from their intended course before taking up a final course parallel but distant from their intended course. Clearly, the bureau was not dealing with a perfected technology.[23]

In fall 1905, naval officers advanced two different hypotheses to explain the sheer problem. One, championed by the assistant inspector of ordnance at the Bliss Company, G. C. Davison, identified the fundamental cause of the problem as partial cavitation (i.e., the formation of an air cavity) at the tail of the torpedo caused by the streamlines of water flowing past the torpedo as it moved through the water at high speeds, causing the propellers to work in fluids of different densities (water and air). Because the problem was most serious when the torpedo was on or near the surface, where the water had relatively little assistance from hydrostatic pressure to fill the space vacated by the torpedo as it moved, Davison focused on proper depth taking and depth keeping as the key to solving the problem.[24]

The other hypothesis was championed by a naval constructor working at the Washington Navy Yard named David W. Taylor (who would later become the Navy's Chief Constructor). He argued that the fundamental cause of the problem was not cavitation as the torpedo moved through the water, but initial roll as the torpedo moved through the air after discharge from above the water. The cause of this initial roll, both he and Davison agreed, was the unbalanced torque generated by the turbine engine. Thus, where Davison focused on depth taking and depth keeping as the solution, Taylor focused on balancing the turbine so that its net torque was zero.[25]

Although an apparently trivial issue, Davison's and Taylor's efforts to solve the sheer problem marked a watershed in the relationship between the American state and society with respect to weapons procurement. In tasking naval officers to solve the sheer problem, the state was investing directly in the development of experimental products by the private sector—in today's parlance, the state was collaborating with private industry on research and development (R&D). This collaboration departed from the traditional procurement process, in which the government either purchased finished products from the private sector or developed its own products from start to finish. Perhaps the most insightful student of this fundamental change in the procurement process was William McNeill, who coined the term *command technology* to describe weapons developed in this collaboration between state and society.[26] In essence, McNeill saw this collaboration, driven by the growing sophistication and expense of naval armaments in the late nineteenth and early twentieth centuries, as marking the birth of the modern military-industrial complex.

The involvement of multiple parties in the process of invention where previously there had been just one complicated the task of establishing who had invented what, and when. In particular, where the labor of invention was shared between state and society, how should ownership of the resulting property be divided? How could patents be assigned unless ownership was clear? Could contracts written for the purchase of finished products be adapted for experimental products? In addition to these legal implications, command technology had political-economic ramifications. What did it mean for the relationship between state and society when private intellectual property rights intermingled with public intellectual property rights? The stakes of command technology were high.

Command technology was so important and so complex that it spawned a new class of technology that, to extend McNeill's metaphor, might be called servant technology: that is, technology dedicated to generating information that could be used to improve command technology. The Bureau of Ordnance acquired two servant technologies in its effort to solve the sheer problem. One was a dynamometer, which measured various aspects of engine performance in a tank of water, so that valuable resources did not have to be spent in running torpedoes on a range. Another was an improved rolling register, which measured the torpedo's angle of inclination from the vertical as it moved through the water.[27] Both the dynamometer and rolling register increased the bureau's power to generate information and, by implication, to perform independent quality control on products sold by the Bliss Company.

Given its power to affect market relationships, the information generated by servant technology was a commodity unto itself. Indeed, it amounted to a distinctive type of property. Although intellectual property like patents and trade secrets had been around for centuries, such property could easily be reduced into material, or nonintellectual, property—a patent for an engine could be turned into an engine, a trade secret for a metallurgical formula could be turned into metal.[28] In contrast, commodified information could not readily be reduced into material form: data derived from servant technology could be used to improve command technology, but it could not be transformed into command technology. In fact, because commodities can be traded in markets as though they possess value in and of themselves, their value is at least partly independent of their convertibility to material form. Thus, the acquisition of information-generating servant technology amounted to a stronger position in the information-commodity market, giving servant technology some value independent of its contributions to command technology.

Separately and together, these trends—the emergence of command technology, the growing premium on servant technology, and the commodification of information—challenged traditional understandings of value, property, and ownership. The Bureau of Ordnance attempted to cope with these changes in a major new torpedo contract.

Contracts and Prices

Needing torpedoes to outfit new construction in October 1905, the Bureau of Ordnance—now headed by N. E. Mason—began negotiating a large new torpedo contract with the Bliss Company.[29] Mason was better equipped than many to understand the Bliss-Leavitt torpedo, having overseen the first tests of the Bliss-Leavitt superheater and turbine engine during his time as commander of the Torpedo Station from 1899 to 1902. Even with prior exposure to key technologies in the Bliss-Leavitt torpedo, however, Mason would struggle to master it.[30]

The emergence of the sheer problem in spring 1905 had taught the bureau that it was dealing with experimental technology and that it would therefore have to contribute to the process of improving the imperfect mechanisms. Realizing that some special contractual provision was necessary to protect its intellectual property rights in this collaborative process, it sought to introduce a new clause (hereafter referred to as the rights clause) that prohibited the Bliss Company from exhibiting or selling "any *device* the *design* for which is *furnished* [emphasis added]" by the bureau. To claim protection for a "*device or design*" invented by itself under the rights clause, the bureau had to "state to the [Bliss Company] *in writing, at the time* when the said *device or design* is itself *conveyed* to the [Bliss Company] by *written* communication from the [Bureau], that the [Bureau] considers that the said *device or design* is embraced within the provisions of this clause [emphasis added]."[31]

Because this clause came to be the central issue in a subsequent legal case, understanding it at its origins is vital. To begin with, it is clear that the initiative for inserting the clause came from the bottom up, not from the top down: the bureau, not the Secretary of the Navy or the Judge Advocate General, noticed the change in the procurement paradigm and perceived the necessity of some contractual adjustment. The bureau did ask the Judge Advocate General for advice, and the latter was responsible for formulating the exact language of the clause (including the key word *furnished*), but the bureau gave the Judge Advocate General clear instructions on what it wanted the clause to accomplish.[32]

Second, the purpose of the clause was ambiguous. On the one hand, its purpose could be to protect the bureau's rights to technology that it had helped to invent; on the other hand, its purpose could be to protect national security by preventing the Bliss Company from exporting sensitive technology. As the bureau wrote to the Judge Advocate General,

> There is no doubt that in the past Mr. Leavitt has received assistance and advice in developing his invention from the Bureau and its representatives, but up to the present the question of the right of the Bliss Co., to take advantage of such advice and assistance has never been brought up. As the situation stands to-day, however, the Bureau believes that it is in a position to assist Mr. Leavitt materially in the further necessary perfection of his invention, and it desires to so assist him, provided that by so doing it can secure better torpedoes for our navy, without assisting foreign governments in their armaments.[33]

These two potential purposes—protecting property rights and protecting national security—were obviously related, but they were also distinct. It is not mere pedantry to insist upon the distinction: interpreting the clause as a rights clause implied that any disagreement about its meaning was a narrow contractual matter, whereas interpreting it as a secrecy clause implied that such a disagreement involved broad public policy questions. As we shall see, these differing interpretations in turn implied different legal remedies.

Third, despite the involvement of the Judge Advocate General, the language was imprecise and left loopholes that either party could exploit. Four words in particular were problematic: *furnished*, *conveyed*, *device*, and *design*. The first two words did not require the bureau to have invented (or patented) technology protected under the clause, while the latter two words might be expanded to include mere principles or ideas as distinct from fully developed inventions. The Bliss Company imagined a nightmare scenario in which the bureau communicated a clever thought, let the company do all the hard labor of fleshing it out, and then claimed the intellectual property rights for itself despite having done no real work of invention. Thus, the company asked the bureau to agree that work protected under the clause "be properly confined to concrete improvements developed by the Bureau, and not necessarily include matters where the suggestion of a possible improvement is made by the Bureau and worked out by us." By letter, the bureau explicitly confirmed that the company's interpretation of these words was correct, but it did not change the contract itself.[34] To convince the company to accept the clause, the bureau went out of its way to assure the company that its interests were "amply" protected by the notification procedure, which required "prompt" notice in writing to trigger protection under the clause, leaving devices about which the bureau delayed communicating its intentions or communicated orally unprotected.[35]

The rights clause left both parties vulnerable. On the one hand, subsequent events confirmed the wisdom of the Bliss Company's fear that the words *furnished* and *conveyed* might mean that the bureau could claim protection for devices that it had done little work to invent. On the other hand, although the bureau intended that the clause would protect its contributions to command technology, the language was poorly adapted to the realities of such technology: the clause presumed that the bureau could come up with a "device or design" by itself and then supply prompt written notification about it, when the nature of command technology was such that the government could not finish a design without help, often in the nature of informal communications, from the private sector.

Appropriate contractual language was not the only novelty needed to deal with experimental technology: it also required appropriate risk assessment and pricing. In an echo of the debate over exclusive rights in 1904, the bureau complained that the price of the proposed new torpedoes was too high, and the company retorted that the bureau was using an inappropriate metric of evaluation. It explained:

> If the material to be furnished under the proposed contract were of such ordinary commercial character as to involve no other than the common risks incidental to a manufacturing business, and such as to enable costs, risks, and profits, to be accurately calculated, then we quite agree with the Bureau's contention that our price is unreasonably high. . . . As a matter of fact, [however,] the contract calls for a weapon having a performance far beyond anything yet offered to the United States or any other

> navy in the world. It is true, from data already at hand, we are firmly convinced that we can attain the high standard demanded, or naturally we would not enter into the agreement. But it is also true that no such weapon has ever yet been actually built. . . . [H]uman foresight is fallible, and many great and unforeseeable expenses may, and no doubt will be encountered and we feel that it is no more than reasonable and just that we should have a fair margin for unforeseen reverses, *as the burden of responsibility of them falls on us and the Bureau assumes none* [emphasis added]. We cannot but feel that the price we have asked does not [sic] more than fairly cover such contingencies.

The company was willing to lower the price, however, if the risks were redistributed: if the bureau would remove a penalty clause for delays, then the company would lower its price by $100 per torpedo. Mason felt that so small a reduction in price did not justify dropping the penalty clause and resigned himself to paying the higher price. The contract was signed in November 1905. The timetable for deliveries called for fifty torpedoes in 1906, 125 torpedoes in 1907, and 125 torpedoes in 1908.[36]

This timetable was ambitious. In 1904, even before the sheer problem revealed the experimental nature of the Bliss-Leavitt torpedo, the Bliss Company had struggled to meet its delivery dates for a smaller contract of fifty Bliss-Leavitt torpedoes. When the Bureau of Ordnance refused to extend the deadline, Leavitt wrote an extraordinary letter to Mason about the problem. Some parts of the torpedo "had to be newly designed and samples of such parts built and tested before the work as a whole could be done," Leavitt explained, and the delay in doing so was largely "due to the mental and physical incapacity of myself to work any faster than I have done."[37] Leavitt's letter pointed to a significant feature of the research and development of the Bliss-Leavitt torpedo, namely, the extraordinary degree to which it rested on the genius of one man. So integral was Leavitt to the process that his personal limits constituted a supply bottleneck. Thus the bureau signed the contract for 300 torpedoes despite knowing of Leavitt's and the company's struggles on a contract for fifty.

Sowing the Wind

As the contract for 300 torpedoes was negotiated in fall 1905, the Torpedo Station began trying to solve the sheer problem. Although the experiments along the lines of Davison's theory failed (and therefore will not be discussed further), the work of balancing the turbine along the lines of Taylor's theory was successful. From the start, the bureau intended to cover the balanced turbine with the rights clause and ordered the Torpedo Station not to reveal any information about it to the Bliss Company—but the bureau did not execute its intention effectively.[38]

In November 1905, following a preliminary experiment suggested by Naval Constructor Taylor to determine the unbalanced turbine's moment of inertia, the Torpedo Station outlined a method for balancing the turbine. This work was actually overseen by Davison, now at the Torpedo Station, even though the original idea was Taylor's. As it was, the turbine, though referred to as a one-wheel turbine, actually consisted of two wheels connected by an intermediate segment that changed the flow of air so that both wheels revolved in the same direction. The station suggested doing away with the intermediate segment and connecting the two wheels so that they would rotate in opposite directions, meaning that the torque of one would balance the torque of the other, as shown in Figure 3.1. The station built an experimental balanced turbine on these lines and tested it in the dynamometer tank in May 1906. These tests showed that the principle of the design was practicable and suggested that it would eliminate the sheer problem.[39]

Mason, the chief of the bureau, immediately appreciated the significance of the prospect of placing balanced turbines in the Bliss-Leavitt torpedoes. Although the bureau's past contributions to torpedo design had been minor, he told the Secretary of the Navy, the balanced turbine would make torpedoes with unbalanced turbines "markedly inferior." If the Bliss Company got control of the balanced turbine, Mason feared (presciently) that the company would try to sell it to foreign governments, and he was determined to avoid that outcome. Because part of the labor of balancing the turbine had been done by Davison and part by the government as a whole, Mason asked the secretary who owned the property.[40]

Replying to Mason's question regarding the export of technology to foreign governments, the only possible legal means of prevention that occurred to the secretary was Section 5335 of the Revised Statutes (a precursor to the modern United States Code), which embodied a law passed by Congress in 1799 to restrict the conduct of international relations to professional diplomats. It arose after a private citizen named George Logan

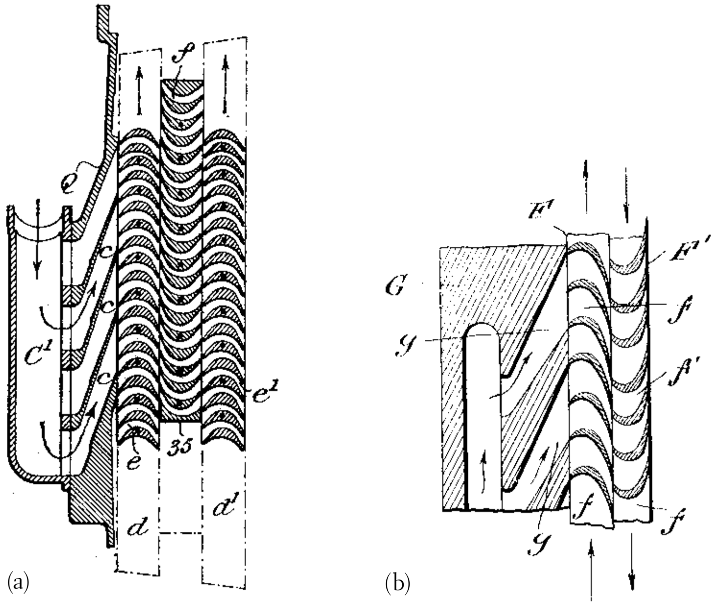


FIGURE 3.1 The (a) unbalanced and (b) balanced turbines, both viewed from the side. Leavitt's original unbalanced turbine is shown in (a); the intermediate wheel changes the direction of the flow of air between the two outer wheels so that they rotate in the same direction, as shown by the arrows. Davison's balanced turbine is shown in (b); note the disappearance of the intermediate wheel and the arrows showing that the wheels rotate in opposite directions. (Leavitt's United States Patent 748,759, figure 7; Davison's United States Patent 858,266, figure 6)

visited France in 1798 during the Quasi War and met with the French foreign minister in an unofficial effort to improve relations between the two countries; hence the law was informally known as the Logan Act.[41] It read in part:

> Every citizen of the United States . . . who, without the permission or authority of the Government, directly or indirectly, commences or carries on any verbal or written correspondence or intercourse with any foreign government, or any officer or agent thereof, with an intent to influence the measures or conduct of any foreign government, or of any officer or agent thereof, in relation to any disputes or controversies with the United States, or to defeat the measures of the Government of the United

> States . . . shall be punished by a fine of not more than five thousand dollars, and by imprisonment during a term not less than six months, nor more than three years.[42]

The secretary doubted whether the Logan Act could be made to penalize the communication of technological plans to foreign powers and said that a test case would be necessary to answer the question with certainty.[43]

In reply to Mason's question about whether Davison or the government owned the rights to the balanced turbine, the secretary requested more information about Davison, who responded by outlining the respective roles of the government and himself in balancing the turbine: he had submitted a sketch drawing of the device, the government had converted his sketch drawing into a detailed drawing, the government had constructed the turbine according to its detailed drawing based on his sketch drawing, and the government had tested the device. "In the strict sense of 'development,'" Davison concluded, "no assistance [by the government] was furnished." In the work of "demonstration," by contrast, the government did provide assistance and incur expense. Thus, in the sense of development as "the embodiment of the idea into a concrete object," as opposed to the "strict" sense, the government had provided some assistance.[44] These linguistic acrobatics underscored the difficulty of translating intellectual property rights into law when the lines between different parties to and different stages of the invention crossed so frequently.

To secure the rights to the balanced turbine, the secretary suggested that Davison could take out a patent and assign it to the government. Davison agreed to do so, "contrary to the advice of friends and legal advisers," who told him that he could make substantial royalties by retaining control of the patent. Indeed, much as command technology made it difficult to establish ownership of intellectual property rights *between* the public and private sectors, so it complicated ownership *within* the public sector. Technology could be "commanded" from employees just as it could be commanded from an outside firm. In such cases of "internal" command technology, as Davison put it, the government employee was "sometimes placed in a position where he must choose between his own interests and the interests of his government."[45] Choosing not to press the matter, Davison applied for the patent in October 1906, and it was issued, as No. 858,266, in June 1907. Its issuance was "very gratifying," Davison acknowledged, "as the claims were unusually broad, so that the device should be absolutely protected in spite of any attempts to get around it."[46] Efforts like Davison's to secure broad patents may have been cynical, but they were common: two famous examples are the Selden patent in the automobile industry and the Wright brothers' patents for airplanes.[47]

Like the rights clause, however, Davison's patent was a pyrrhic victory, reflecting in equal parts the bureau's awareness of a problem and its failure to arrive at a solution. First, the very broadness of the claims reflected imprecision in describing the invention, which could leave the patent vulnerable to attack. Second, in publishing the balanced turbine by patenting it, the bureau imperiled any future claims to the secrecy of the balanced turbine under the rights clause. Thus, where the bureau had meant to strengthen its contract rights by acquiring patent rights, it had potentially weakened them. Third, after Davison disclaimed any interest in controlling the foreign patent rights, the Bureau let the Bliss Company buy them—a truly remarkable turn of events, considering the Bureau's desire to preserve the secrecy of the balanced turbine from foreign governments and prevent the Bliss Company from selling it abroad.[48]

Finally, the bureau's insensitivity to these issues reflected wider departmental weakness on matters of civil law, and broader governmental uncertainty regarding inventions made by government employees. The Navy Department lacked the personnel and procedures for dealing with a situation like Davison's: the Judge Advocate General did not handle the work of preparing Davison's patent application, which was instead contracted out to a private firm, and Davison had to pay these attorneys out of his own pocket, although he was reimbursed. Perhaps not coincidentally, in 1906 and 1907, the Bureau of Ordnance asked Congress for legislation that would permit it to take out patents in its own name.[49] Moreover, on the one issue where the Judge Advocate General did involve himself—preparing the legal instrument by which Davison would assign his patent rights to the government—he made a mistake and had to be corrected by the outside attorneys.[50] Similarly, the government as a whole lacked a policy on inventions by government employees. An investigation conducted by the Secretary of Commerce and Labor in 1908 discovered "many and varied opinions" and "no general statute" on the subject, which had received "desultory treatment." The result of this "equivocal state" was to discourage "inventive genius in the Government service."[51]

In addition to its missteps over the patent, the bureau also maladroitly executed the notification procedure in the rights clause. This mess began, innocently enough, when the Bliss Company asked the bureau to reduce the performance requirements for certain torpedoes under contract. That was on October 17, 1906—the exact dates are important because they were at the heart of a later lawsuit. In his reply of October 22, Mason informed the company that the torpedoes could meet their contract requirements "by the installation of an improved propelling mechanism" that increased the range and speed and eliminated sheer; this was, of course, a vague reference to the balanced turbine. On October 30, a group of bureau representatives met at the Bliss Company to witness tests of new torpedoes, where the balanced turbine "was brought up in a general way to give the Bliss Company the idea involved, but without details." On December 29, the commander of the Torpedo Station, Albert Gleaves, reported that the company "has recently actively been experimenting with a balanced turbine," and that these experiments had begun after the October 30 meeting of the Torpedo Board.[52]

At this point, more than two months after Mason had first vaguely tipped the bureau's hand about the balanced turbine, someone finally realized that the bureau should have held its cards closer to its chest. "If the Bliss Company succeeds by its own unaided efforts in developing a balanced turbine," Gleaves observed, "it will be in a position to entirely free itself from the obligations of [the rights clause]." Because the company had not yet passed "beyond the experimental stage" in developing the device, Gleaves recommended notifying the company that the rights clause covered the device, to which end the Torpedo Station could immediately supply a "sketch" that, by the terms of the rights clause, was necessary to establish a claim.[53]

By the time of this late warning, damage had already been done. For an improvement to be protected under the rights clause, the bureau had to state "in writing, at the same time when the said device or design is itself conveyed" to the Bliss Company, that it considered the "said device or design is embraced within the provisions of this clause."[54] The bureau had *orally* described the device to the Bliss Company *without* stating that it was covered under the rights clause, and *without* supplying the device or design thereof. The bureau did not notify the Bliss Company in writing that it intended for the rights clause to cover the balanced turbine until November 9, 1906, and it did not provide a drawing until January 9, 1907.[55] Thus, the bureau had created a window of anywhere from eighteen to seventy-nine days between revealing the existence of the balanced turbine and triggering protection under the rights clause. It could scarcely have done otherwise, given the underlying inapplicability of the clause to command technology.

The Supply Crisis

The bureau not only failed to anticipate important legal questions before committing to the Bliss-Leavitt torpedo, it also chose to rely heavily on the Bliss Company despite evidence that the company struggled to meet delivery deadlines. The predictable result was a supply crisis so serious that vessels were forced to sail for foreign stations without torpedoes, leading to the admission that the US bid for independence from the foreign Whitehead torpedo had failed.

The bureau and the Bliss Company could not fix the mechanical problems with the Bliss-Leavitt torpedo quickly enough for the company to be able to produce a reliable model in large quantities. Even as the Torpedo Station worked to balance the turbine in 1905 and 1906, the Bliss Company was requesting delivery due dates to be extended; but even with the extensions, Bliss-Leavitt torpedoes were failing to meet their performance requirements with regard to range and speed.[56] The situation came to a head in September 1906, when the commander of the Torpedo Station, Albert Gleaves, submitted a long analysis of the torpedo situation to Mason after witnessing Bliss-Leavitt torpedoes perform poorly on a visit to the company's Sag Harbor testing facility.

Over the past two years, Gleaves stated, various Bliss-Leavitt torpedoes had made 1,872 runs, which should have been enough to correct all the faults, but instead old flaws persisted and new ones emerged. The effort to fix them had created a backlog, as a result of which an armored cruiser division had just been forced to sail for its foreign station with torpedo tubes installed and its ordnance outfit complete—except for torpedoes. Though the Bliss-Leavitt torpedo would "undoubtedly" be perfected, in Gleaves' opinion, it was impossible to say how long the process would take given the Bliss Company's history of failing to meet its optimistic promises. In the meantime, he argued that the Navy should purchase Whitehead torpedoes abroad as an expedient. "There can be but little doubt that this action," Gleaves added, "would have a decided moral effect upon the E. W. Bliss Co., and would tend to hasten the complete development of their torpedo."[57]

Mason was prepared to go further. On October 17, he addressed a long memorandum to the Secretary of the Navy in which he laid the groundwork for the fable of an innocent bureau versus monopolistic contractors that Secretary Daniels would later come to adopt, leaving out evidence that the bureau should have known that it expected too much from the Bliss Company. The bureau had granted various extensions on torpedo contracts, Mason explained, some at the request of the Bliss Company, and some to allow the company to install improvements ordered by the bureau. Mason continued:

> While specific reasons for extensions have been urged in almost all cases, the contractors have laid great stress upon the fact that this is a new device and that delay and minor failures were therefore to be expected. This plea was submitted however after the delays and failures had occurred. Before the contract was awarded the company's communications were replete with promises of quick deliveries and wonderful performances. This plea had great weight with the Bureau, but recent events have forced the Bureau to the belief that it has been used in cases where the delay and failure were not limited to those to be expected in the process of evolution, but were more due to the reluctance of the company to discard auxiliary devices of proved inefficiency at an expense to itself and to inferior workmanship than to any other causes, the company hoping to pass the tests required by good luck and tinkering, or in case of failure to have the tests modified to fit the capabilities of the torpedoes.
>
> The Bureau has resisted the efforts of the contractors to force the acceptance of inferior weapons, but in all its dealings with this company concerning torpedoes the Bureau has been handicapped by the knowledge that, due to the monopoly held by the company, the Bureau would have to accept the terms offered or get no torpedoes. The Bureau has become convinced that a belief in the helplessness of the Government has influenced the E. W. Bliss Company in its prices, deliveries and workmanship.

While the bureau had long realized that "absolute dependence" on the Bliss Company was "a situation of serious disadvantage," only in the recent past had the bureau felt that it could do its part to provide "the obvious remedy" for the situation: setting up its own factory. Thanks to its invention of the balanced turbine, the bureau could acquire the rights to manufacture Bliss-Leavitt torpedoes in its own factory at an acceptable price. "That there may be a question of patent right [sic] to be decided, the Bureau admits," Mason added—and indeed there would be.[58]

Establishing a new factory would take time, however, and the Navy required immediate relief. Because that relief could not be obtained in the United States, the Bureau saw "no recourse save to purchase [torpedoes] abroad." Mason was reluctant to make the suggestion, but given that "the only beneficiaries of the opposite course would be a monopoly, who besides not being able to supply the Government's needs have in the past unhesitatingly taken advantage of the Government that protects it"—a description obviously calculated to win sympathy in a trust-busting era, regardless of accuracy—he thought the radical step justified.[59] In case the secretary missed the point, Mason drove it home in another letter a month later, writing that in the manufacture of torpedoes, "a monopoly exists closer than any combination of separate firms," and that it would be unwise to leave the government "helplessly subject to the dictation of a monopoly which has not in the past shown any evidence of disinterested beneficence."[60] Therefore, Mason asked the secretary to seek special appropriations for a torpedo factory and for purchasing torpedoes abroad, and the secretary did so.[61]

In February 1907, as the bureau prepared to go abroad for supply, the Bliss Company dropped two bombshells: It had "under course of construction, and nearly completed, a balanced turbine," and it was experimenting with "a heating device for heating the air outside the flask."[62] The first of these has been discussed sufficiently that its potential implications are clear. The second, the outside superheater (so-called because the heater was outside the air flask), was the next generation of superheater technology. In 1905, the British firm Armstrong Whitworth & Company and the Bliss Company had signed an agreement (discussed more fully later in this chapter) in which the Bliss Company promised not to block applications for US superheater patents by the Armstrong Company, and in return the Armstrong Company promised the Bliss Company the US rights to any improvements it made on Leavitt's original superheater. In the Bliss Company's experiments, the outside superheater developed 50 percent more energy than its latest inside superheater. The reason for this superiority had to do with the location of the combustion chamber, which is shown in Figure 3.2. When air was heated *before* passing through the reducer (as was the case in inside superheaters), it lost heat as its pressure

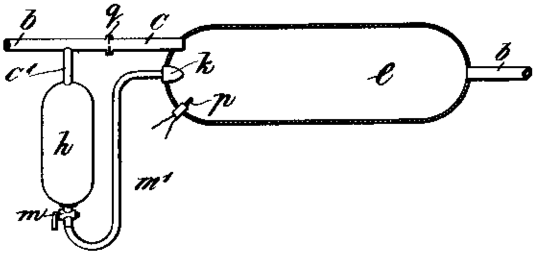


FIGURE 3.2 Armstrong's outside superheater. In the diagram, *e* is the combustion chamber, *k* is the fuel sprayer, *p* is the igniter, and *h* is the fuel reservoir. The air flask and reducer would have been to the left of the diagram, and the engine to the right. (Great Britain Patent 3,495/1905, figure 2)

was lowered by the reducer, and it reached the engine considerably cooler than it had been. When the air was heated *after* passing through the reducer, however, the drop in pressure and temperature was avoided, and the air reached the engine at nearly the same temperature to which combustion had heated it. Mason informed the company that he was "delighted" to hear about the promising results with the new superheater, and he did not mention the balanced turbine at all.[63]

While the bureau dealt with the fallout from its premature commitment to the Bliss-Leavitt torpedo by swallowing its pride and preparing to purchase Whitehead torpedoes, the Bliss Company suffered the consequences of its errors regarding its pricing of experimental technology. In May 1907, the company accepted that the torpedoes it had offered to the bureau with such fanfare in 1903 could not make their promised performance requirements, and it asked that the requirements be reduced. The bureau was willing to do so, but at a cost. "[A] price that was fixed at an exhorbitant [sic] figure in order to provide for extraordinary expense in the development of an extraordinary weapon," the Torpedo Station felt, "should not be paid when the extraordinary qualities are not required." The bureau had no intention of paying for an experimental weapon what it had been willing to pay for a perfected weapon.[64]

The company, however, had no intention of settling for a loss when it had poured so many resources into improving an experimental weapon. "In justice and equity," the company replied, "the conditions under which [the contract] was entered into should be taken into consideration." Contracts for commercial articles

> are based on the known performance of previous similar construction. For the performance of the torpedo there was no previous adequate data. The contracts were entered into by us in good faith and based upon what we fairly thought could be accomplished, but it was quite well understood by the Navy Department, as well as ourselves, that the performance required by the contracts was not based on results previously attained; but on certain improvements which at the time it seemed reasonable to suppose could be made.

Any board of naval officers looking over the facts would have to conclude that the company had "energetically and honestly grappled with a vast number of unforseen [sic] problems . . . and that these unexpected difficulties have been caused by unavoidable delays."[65]

The bureau was unmoved. Mason reviewed the dispute over the price of the torpedoes that had occurred in October 1905. At that time, to justify a price that the bureau considered excessive, the company had observed that the torpedoes were not conventional commercial articles, that their promised performance exceeded anything that had actually been achieved before, and that unforeseen difficulties were likely to arise—exactly the arguments that the company was repeating in 1907. "It is no more than reasonable and just," Mason directly quoted the company's letter of October 27, 1905, adding his own emphasis, "that we should have a fair margin for such reverses, as the <u>burden of responsibility for them falls on us and the Bureau assumes none</u>." Having stated that its price allowed profit and covered risk adequately, and having explicitly assumed the responsibility for failure, the company could not very well ask the bureau to accept inferior torpedoes at the same price.[66] By failing to anticipate the higher safety margins necessary for pricing experimental rather than perfected technology, the company had backed itself into a corner.

As the bureau's disputes with the Bliss Company over price unfolded from May to July 1907, its efforts to secure another source of supply came to fruition. With the approach of July 1, the beginning of the 1908 fiscal year, when new appropriations became available, Mason pressured the secretary for authorization to purchase torpedoes from the Whitehead Company. After some back and forth, the department authorized Mason to buy fifty of them. Final negotiations were carried out by bureau representatives in

Europe, and the contract was signed on July 3, two days after the money became available.[67] The torpedoes would become known as the 18-inch Whitehead Mark V torpedoes; they were the first Whitehead torpedoes purchased by the bureau in seven years, and the first the bureau ever bought directly from the Whitehead Company.

Things would get worse for the Bliss Company before they got better. Not only was the bureau now buying directly from Whitehead, but it was also giving consideration to building Whitehead torpedoes, instead of Bliss-Leavitt torpedoes, in the new government torpedo factory. Gleaves explained in his annual report for 1906–1907:

> Experience with the Bliss-Leavitt torpedo points unmistakably to its abandonment, and the return to the standard Whitehead torpedo, the accepted type of all other countries. The Torpedo Station fully appreciates the difficulties of such a radical step, but it feels that with the absolute knowledge of what obtains abroad on this subject, and the disheartening and discouraging efforts to perfect the Bliss-Leavitt, that it would be neglecting a paramount duty to withhold the recommendation that the Bliss-Leavitt torpedo be replaced by the latest . . . Whitehead torpedo, until the manufactures of the torpedo succeed in obtaining a reliable weapon capable of fulfilling with certainty the Bureau's requirements.[68]

The negotiations with the Whitehead Company began in earnest in October 1907, when its agent in Washington, H. C. Sheridan, was empowered to deal directly with the bureau. Sheridan, it should be noted, was associated with Vickers, one of the two armaments giants that purchased the Whitehead Company in 1906, rather than with Armstrong Whitworth & Company, the co-purchaser with Vickers. Sheridan offered the bureau the right to manufacture Whitehead torpedoes at a royalty of £100 (approximately $500) each, provided that the first lot consisted of at least 100 torpedoes, and the next two lots of at least fifty each.[69]

These propositions, Gleaves told Mason, brought the torpedo question "to its most critical stage": the bureau had to decide whether it would continue to develop the Bliss-Leavitt torpedo exclusively or take up the manufacture of the Whitehead torpedo. "It is a natural desire to have an American invention of this kind in the lead," Gleaves allowed, "but as we have only to do with the best, if the American invention is not the best, then it becomes necessary to look elsewhere for what the Government requires." After four years, from the "promise and expectation of being the most efficient torpedo in the world," the Bliss-Leavitt torpedo had developed a reputation "so shady that, so far as known, no other nation—except possibly France—will touch it." By contrast, over the past four years, the Whitehead torpedo had steadily improved. As a solution, Gleaves proposed that the Bliss Company be allowed as free a hand as possible to develop its torpedo, while the new government torpedo factory (hereafter Torpedo Factory) undertook the manufacture of 100 Whitehead torpedoes. Upon securing an acceptable offer from the Whitehead Company to build Whitehead torpedoes in the bureau's factory, Mason immediately made the purchase.[70]

Still more business was in store for the Whitehead Company. In late 1907, the bureau began to consider the purchase of torpedoes for new destroyers and submarines, effectively putting the Bliss-Leavitt and Whitehead torpedoes into direct competition. In trials, a new Bliss-Leavitt torpedo made only 34.9 knots for 1,200 yards and 32.6 knots for 2,000 yards; in contrast, the Whitehead torpedoes recently purchased by the bureau were guaranteed to make 27 knots for 4,000 yards. Keeping its options open, the bureau queried the Whitehead Company on the possibility of ordering either 100 or 130 Whitehead torpedoes and arranged a tentative agreement. Gleaves was strongly in favor of the Whitehead option, given the Bliss-Leavitt torpedo's record "of unbroken disappointments and unrealized promises," and a board of torpedo experts agreed with him.[71]

Adding weight to the experts' recommendations was the stunningly good performance of the reciprocating engine in the new Whitehead torpedoes. After experiencing frequent troubles with the initial batch delivered in early 1908, the Torpedo Station traced its difficulties to using the wrong type of oil to lubricate the engine—an example of how a small, cheap change could transform the outcome of a contract costing thousands of dollars. With the right lubrication, the reciprocating engine showed efficiency "considerably in excess" of any results obtained with the turbine, and it maintained that efficiency "for highly desirable variations of speed and range, a performance of which the turbine is inherently incapable." Moreover, there was "evidently no cause for apprehension on the subject of excessive and detrimental engine temperatures caused by this type of superheater." These statements demolished the foundation of the turbine's supposed superiority: its ability to withstand heated air.[72]

With any doubts about the Whitehead engine apparently erased, Mason informed the secretary that he wanted to purchase 130 Whitehead torpedoes, and the contract was signed in July 1908. The original requirements called for 40 knots for 1,000 yards and 30 knots for 4,000 yards; in November 1908, as the result of range running, they were changed to 41 knots for 1,000 yards and 29 knots for 4,000 yards. The specifications for a putatively more powerful Bliss-Leavitt torpedo, by contrast, called for 26 knots for 3,500 yards—a lower speed for a shorter distance.[73]

The supply crisis was the most concrete consequence of the Navy's commitment to the Bliss-Leavitt torpedo, while its return to the Whitehead torpedo marked the failure of its bid for independence. Yankee ingenuity and industry could not produce reliable weapons in sufficient quantities to arm its vessels; as a result, the United States slid back into colonial torpedo status.

The Superheater Royalty Dispute

Colonial status brought with it international legal complications. The Whitehead torpedoes purchased by the bureau in 1907 and 1908 contained superheaters potentially infringing the Bliss Company's rights under a 1905 contract with Armstrong Whitworth & Company (hereafter the Armstrong Company), mentioned previously. Like so many other torpedo contracts, the Bliss-Armstrong contract had not caught up to market realities, in particular the fluidity of international mergers and acquisitions, which raised difficult legal questions.

In April 1905, the Bliss Company had signed an agreement with the Armstrong Company relating to the control of superheater patents. Clause 2 of this agreement granted the Bliss Company "the sole and exclusive license and authority" to use any American superheater patents obtained by the Armstrong Company both in Bliss-Leavitt torpedoes and in Whitehead torpedoes sold to the US government. In Clause 9, the Armstrong Company agreed not to use superheaters covered under its US patents or grant other licenses for the same in Bliss-Leavitt torpedoes or in Whitehead torpedoes for the US government. Clause 11 obliged the Armstrong Company to defend the patents in case of infringement. In return, the Bliss Company agreed that it would not oppose the granting of US patents for superheaters to the Armstrong Company, and that it would pay a royalty of $25 on each torpedo fitted with superheaters covered by Armstrong's patents.[74]

Several factors complicated this seemingly straightforward agreement.

First, the exclusivity of the agreement—and hence whether it was an assignment or a license agreement—was open to question, which affected the Bliss Company's standing to sue for infringement of the patents covered by the agreement.[75] Second, Clause 11 of the agreement suggested that the Armstrong Company, not the Bliss Company, had the necessary standing to sue for infringement of the patents covered by the agreement. Third, all contracts signed by the bureau for torpedoes contained a clause obligating the contractor to hold the government harmless from any claims of patent infringement.[76] This clause implied that if third parties believed their patent rights to be infringed, the target of their claim could be the contractor only, not the government. Finally, in 1906, the Armstrong Company (with Vickers) became a partial owner of the Whitehead Company. While Clause 9 of its agreement with the Bliss Company prohibited the Armstrong Company from *licensing* the Whitehead Company, an independent firm as of 1905, to use Armstrong superheaters, the clause did not contemplate a circumstance in which the Armstrong Company owned the Whitehead Company.[77]

The advent of the torpedo supply crisis and the prospect of establishing a government factory prompted a flurry of communications regarding superheater patent rights and royalties. Negotiations beginning in autumn 1906 resulted in the Bliss Company's agreement to let the bureau purchase no more than 100 Whitehead torpedoes containing the Armstrong superheater, the amount of the royalty for the superheater to be settled later and agreed on by both the company and the bureau. This agreement cleared the way for the bureau's July 1907 purchase of fifty Whitehead torpedoes.[78]

Negotiations then began to cover any subsequent purchase of Whitehead torpedoes by the bureau. These negotiations were complicated by the fact that the firm negotiating with the bureau on behalf of the Whitehead Company was Vickers, which co-owned the Whitehead Company but did not control the superheater patents or have any arrangement with the Bliss Company, rather than the Armstrong Company, which co-owned the Whitehead Company, controlled the superheater patents, and had a licensing arrangement with the Bliss Company. Vickers knew that its standing regarding superheaters was vulnerable and sought to finesse the issue by conceding that the Bliss Company owned the US rights to the first Armstrong superheater patent while insisting that Vickers retained the rights to any improvements made to the Armstrong superheater by the

Whitehead Company. Of course, Vickers's position ignored the fact that the Armstrong Company's co-ownership of the Whitehead Company gave it at least as good a claim to any superheater improvements made by the Whitehead Company, as well as the fact that Armstrong's contributions to superheater development, without corresponding involvement by Vickers, actually gave Armstrong a stronger claim. For its part, the Bliss Company stated that it would charge a royalty of $750 for torpedoes made by the government, a royalty of $500 for superheaters made and installed by the government in Whitehead or other torpedoes, and a price of $650 (royalty of $500 plus production cost of $150) for superheaters made by the Bliss Company for installation in Whitehead or other torpedoes.[79]

The bureau now had a choice to make. Once Vickers revised its offer to allow the Torpedo Factory to build fewer torpedoes, the bureau decided that it would build Whitehead rather than Bliss-Leavitt torpedoes.[80] In June 1908, the bureau ordered superheaters from the Bliss Company for these government-built Whitehead torpedoes, thus avoiding any dispute with Bliss over royalty rights.[81] In July, the bureau ordered another 130 torpedoes from the Whitehead Company, plus the right to build, free of royalty charges, seventy-five Whitehead torpedoes at the Torpedo Factory except for gyroscopes and superheaters.[82] This July 1908 contract between the bureau and the Whitehead Company would spark the real controversy, but not until the very end of 1908.

New Bliss-Leavitt Torpedoes

While the bureau's and Bliss Company's experiences with the first Bliss-Leavitt models were little short of disastrous, the development of the 21-inch Mark II and Mark II Mod. 1 went more smoothly. The Mark II torpedoes accounted for 200, and the Mark II Mod. 1 accounted for fifty, of the remaining torpedoes under the November 1905 contract (the first fifty having constituted Mark I). When the Bliss Company had approached the bureau in February 1907 to discuss the design of the Mark II, the bureau effectively washed its hands of the matter, giving the company full freedom—and full responsibility—to develop the design. Of the changes between the Mark I and Mark II designs, two were especially noteworthy: the Mark II had the company's own balanced turbine and the outside superheater developed by the Armstrong Company.[83]

At first, the pattern of disappointment seemed to be repeating itself. Throughout 1907, the Mark II torpedoes performed poorly, exhibiting range, speed, and depth problems. Early in 1908, however, the company's position began to improve. The bureau had found, in running ten 21-inch Mark I torpedoes at Key West the previous spring, that they had heeling tendencies which caused sheer—despite the fact that they had received balanced turbines. In a throwback to Davison's old cavitation theory, Gleaves believed that the problem was caused by streamlines along the torpedo and at the propellers. The Bliss Company discovered the real culprit: The exhaust from the torpedo got mixed up with the propellers (effectively causing partial cavitation), "an accident of design which no one could have suspected of influencing the performance of the torpedo." This explanation of the sheer problem would later loom large in court, but the bureau did not appreciate its significance at the time. Mason gave the company some breathing room, and a remarkable admission, when he extended the deadline for delivering the Mark II torpedoes, on the grounds that "sufficient time for the development of this torpedo was not allowed in the original contract."[84]

The extension was more or less unnecessary. By September 1908, the Bliss Company had completed and passed through shop tests the remaining 250 torpedoes under the November 1905 contract, within the original time frame for final (though not initial) delivery, and the torpedoes were exceeding their contract requirements for range and speed. At Leavitt's urging, the bureau agreed to soften several requirements relating to buoyancy, depth keeping, and turning radius. In a more telling sign of progress, the bureau agreed to let the company bid on a new order of 21-inch torpedoes.[85]

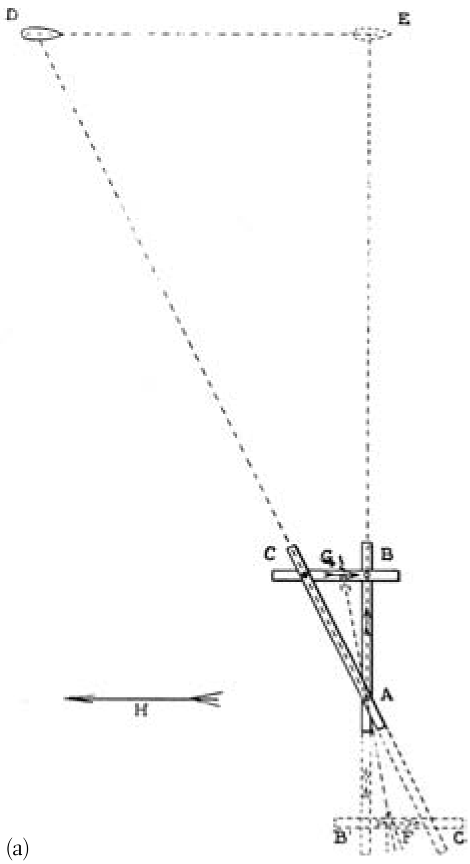
Tactics and Strategy

Although the fleet had pressured the Bureau of Ordnance to adopt the Bliss-Leavitt torpedo, naval officers subsequently failed to think through all the tactical and strategic implications of torpedo development. This failure says less about their intellectual abilities and more about the sheer difficulty of the problems they had to solve. The interactions among technology, tactics, and strategy—to say nothing of finance and Congress—were extraordinarily complex. Technological conservatism was not to blame; if anything, naval officers were too hasty in embracing new torpedoes.

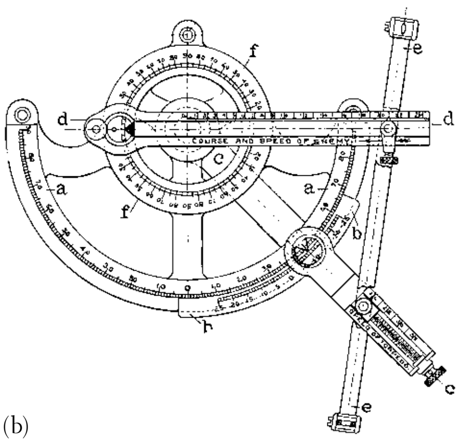
One limiting factor on the tactical effectiveness of faster, longer-range, and more accurate torpedoes was the lag in developing better fire-control (i.e., targeting) systems. The main instrument in torpedo fire control was the director, essentially a sophisticated slide rule. Using the course and speed of the enemy and the course and speed of the torpedo as input variables, the director worked on the principle of similar triangles, reproducing the large triangle formed among the location of the firing ship, the current location of the target, and the projected location of the target in smaller form on the director, as illustrated in Figure 3.3. In gunfire control, finding the range and correcting for roll, pitch, and yaw were serious challenges. In torpedo fire control, however, the torpedo's balance mechanism and gyroscope corrected for the effects of roll, pitch, and yaw. As long as the torpedo's speed was uniform, the range did not have to be known—but if the torpedo's speed varied, then the range had to be known so that an average speed could be calculated. To make an analogy, the director was to torpedoes as sights were to guns—not as range finders or range generators were to guns.

As Frank F. Fletcher had pointed out while testing the Moore gyroscope at the Torpedo Station, angle fire presented more difficult fire-control problems than straight fire. The first serious attempt to develop a director for angle fire began in June 1904. Fletcher submitted a design several months later, but the effort to account for all the relevant variables produced an instrument so complicated that the Bureau of Ordnance "hesitate[d] to order it placed aboard ship." In 1906, at the behest of the bureau, two officers at the Torpedo Station (H. I. Cone and the ubiquitous G. C. Davison) tried to simplify Fletcher's design. After a characteristically inadequate research and development process—twenty-five shots from a stationary ship against a target with a speed of 9 knots, which is to say, very easy conditions—Cone and Davison recommended the adoption of their design, and Mason approved. The Cone/Davison design became the Mark IV director.[86]

The Mark IV director could be used for straight or angle fire. When aiming a straight shot, three pieces were used, the same as a regular director: a bar representing the course and speed of the target (the enemy bar), a bar representing the course and speed of the torpedo (the torpedo bar), and a sighting bar. When aiming an angle shot, a fourth piece was used, namely, a circle running underneath the three bars and graduated in degrees. The intersection of the torpedo bar with this circle indicated the angle at which the gyroscope should be set. This angle then had to be corrected to account for the target range by reference to a precalculated table that showed the proper corrections for given gyroscope angles and target ranges.[87]



(a)



(b)

FIGURE 3.3 The torpedo triangle (a) and director (b). (*The Whitehead Torpedo, U.S.N. Parts III & IV. Above Water Launching Apparatus. Torpedo Directors* [1901], plate 65 and plate 69, Navy Department Library, Washington, DC)

Exclusions from the design were as significant as the inclusions. One absence was a correction for parallax due to the distance of the director from the tube, which had to be estimated, probably by reference to a table showing different parallax corrections for different target ranges.[88] Another omission was the proposed use of a gyroscope, in conjunction with timers, to measure both the change of target bearing and the rate of change of target bearing for conversion into target course and speed. The idea of mechanizing and automating the generation of bearing estimates was common in gunnery fire control, where greater accuracy and the elimination of human error were more important, but its proposed application to torpedo fire control was remarkable.[89] The most far-reaching proposal of all came from Davison, who, comparing directors to gun sights, argued that a supporting system distinct from the directors and their operators was needed to collect and calculate data needed for input into the director. He suggested that both plotting and automatic gyrocorrection for the effects of yaw should form part of an integrated torpedo fire-control system.[90] In effect, Davison sought to adapt the more sophisticated methods of gunnery fire control to torpedo fire control.

That level of sophistication was far off, however. In a tepid endorsement of the new director, the commander of the Torpedo Station rejected the idea of adding a telescope to the sighting bar on the grounds that sighting errors were "insignificant when compared with the other errors (course and speed of enemy; speed of torpedo; setting of gyro; tactical radius; etc.) which enter into the problem."[91] Although the Mark IV director was capable of dealing with angle fire in principle, it was error-ridden in reality.

In addition to the primitive fire-control system, a second important limitation on the tactical effectiveness of Bliss-Leavitt torpedoes was the inability to run them at single uniform speeds or to adapt them for multiple speeds. It might be thought that the culprit was the turbine engine because turbines ran most efficiently at the one speed for which they were designed. In fact, however, evidence indicates that the Navy ran turbine torpedoes at multiple speeds.[92] Different turbines for multispeed torpedoes were not developed, probably due to lack of resources.

The fact that the Navy, for whatever reason, was running the same turbine at different speeds suggests that the main obstacle to uniform-speed and multispeed torpedoes was not the turbine but the reducer, which governed the pressure of air admitted to the engine. Without an effective reducer, the torpedo's speed varied during its run. Uniform speed was crucial for targeting purposes because it eliminated the need to know the target range. The Navy struggled to develop even a single-speed reducer. As late as 1914, the Atlantic Torpedo Flotilla reported average variations of 3 knots over the course of a torpedo's run.[93] Under the circumstances, the Navy's failure to develop the more challenging multispeed reducer was unsurprising. "It is apparently impossible," the Bureau of Ordnance stated in formalizing the principle that each torpedo mark would have only one range and speed, "to get a controlling or reducing valve that can be accurately set for different speeds."[94]

In theory, two settings were desirable: a higher-speed, moderate-range setting for use from torpedo vessels, which would rely on surprise or the distraction of enemy capital ships to attack at relatively short ranges; and a lower-speed, long-range setting for use from capital ships, which would remain at long range from the enemy battle-line. If the same torpedoes were not capable of dual adjustment, then different torpedoes had to be built for different classes of vessels, reducing the ability to standardize parts. Moreover, the lack of a long-range setting on short-range torpedoes indirectly limited the tactical freedom of destroyers: either destroyers had to leave the ships that they were supposed to be defending from enemy torpedo craft to fire torpedoes at enemy capital ships, or they had to stay near their capital ships to protect them but forgo the opportunity to sink enemy capital ships. Without the ability to fire torpedoes at long range, destroyers could not perform offensive and defensive missions simultaneously. Thus, the failure to develop an effective reducer had wide-ranging consequences.

Despite these limitations on the likely effectiveness of torpedoes in combat, many officers believed that torpedoes would dramatically alter naval tactics. The disconnect between technological reality and tactical thought was due at least in part to habits of institutional communication, specifically the failure of the Bureau of Ordnance and the Torpedo Station on the one hand to exchange much information with the Naval War College on the other.[95] Piecing together the tactical implications of arcane technology like the reducer would have been difficult enough even with robust communication; it was well-nigh impossible if the officers most familiar with the technology failed to communicate with the officers thinking through the tactics most energetically.

It is possible to identify four tactical ideas that gained increasing traction as US torpedoes became faster, longer-range, and more accurate. First, some officers at the Naval War College realized that growing torpedo ranges would mean growing gunnery and battle ranges as ships sought to stay out of torpedo range.[96] Second, some officers recognized that the advent of longer-range torpedoes would transform the target from a single ship into a formation, in which case the probability of hitting could be calculated as the ratio of ship space to water space. Although torpedo fire control, as already explained, was much cruder than gunnery fire control, the size of the formation-as-target for torpedoes could more than make up for relative shortcomings in fire control, and it helps to explain why more and more officers were willing to rate the tactical significance of torpedoes at least as highly as that of guns.[97] Third, some officers appreciated the importance of speed in delivering a torpedo attack, possibly thanks to their study of the German fleet in 1903. This appreciation explains why the 1903 Naval War College conference recommended the addition of torpedo tubes not only to battleships but also to cruisers, and marks the origin of the idea to use a fast wing detached from the main column to rake an enemy battle-line with torpedo fire.[98] Fourth, some officers grasped that longer-range torpedoes could transform destroyer missions by enabling them to attack the enemy fleet without leaving the protection of their own fleet during a daylight battle.[99]

Even as the ability of destroyers to harm capital ships rose, the ability of capital ships to defend themselves against destroyers fell. In 1903, officers at the Naval War College had recommended the construction of all-big-gun capital ships, meaning that the intermediate battery (consisting of 8-inch and 6-inch guns on the *Virginia*-class battleships) would be eliminated and the torpedo-defense battery (that is, the battery relied on to stop torpedo craft like destroyers) would be restricted to 3-inch guns. When the Navy resumed ordering destroyers in 1906 after a seven-year interval, the new *Smith* class weighed 700 tons compared to the 430-ton *Truxtun* class of 1899. Given the growing size of destroyers, officers at the 1906 Naval War College conference concluded that 3-inch guns were too small for the torpedo-defense battery. In 1907, a board appointed to study the issue recommended that the torpedo-defense battery should consist of 6-inch guns. In effect, guns that had been designated as part of the intermediate battery on mixed-caliber capital ships were being redesignated as part of the torpedo-defense battery on all-big-gun ships. Aside from the question of size, US capital ships also lacked systems to control the fire of their torpedo-defense guns effectively, a weakness that further reduced their ability to defend themselves against torpedo attack.[100]

The apotheosis of ideas about the increasing tactical significance of torpedoes was the torpedo battleship conceived by Lieutenant Commander F. H. Schofield. As the name *torpedo battleship* implies, Schofield's proposal defied conventional dichotomies between torpedoes and capital ships—the tendency to see the former as Davids to the latter's Goliath. Schofield called for a vessel with the speed of a cruiser (to enable it to get within range and minimize the time spent under enemy gunfire) and the armor of a battleship (to enable it to withstand enemy gunfire) but with a primary armament of torpedoes rather than guns. Given its proposed speed, a more apt name might be the torpedo battle-cruiser. When Schofield put forward his torpedo battleship in 1907, it received a qualified endorsement from the War College but was temporarily derailed by the General Board's insistence on further study.[101] After another quantum leap in torpedo ranges, the torpedo battleship was resurrected by none other than William Sims in 1911, only to be killed for good by a negative report from the War College.[102] Although the torpedo battleship never passed beyond the drawing board, the fact that it was conceived and seriously studied reveals the degree to which torpedo development impelled officers to rethink the very foundation of naval tactics: the marriage of the capital ship and the big gun.

Officers' willingness to reimagine tactics in light of torpedo development was not matched in the realm of strategy. Given the US Navy's second-class status in the balance of naval power, and its need to defend a newly acquired Pacific empire after the Spanish-American War, one might expect that it gravitated to torpedoes and torpedo vessels as the inexpensive weapons of the weak. Instead, the US Navy preferred to invest in big guns and capital ships, competing symmetrically rather than asymmetrically against the great naval powers. Its choice requires explanation.

In the US Navy's eyes, the main argument against flotilla defense was budgetary. Torpedoes and torpedo craft cost less than big guns and battleships, and the Navy sought reasons to justify a larger budget, not reasons to cut it. As Theodore Roosevelt put it to Isaac Rice, founder of the submarine-building Electric Boat Company, naval officials "fear if they actively advocate submarines Congress will no longer vote for battleships."[103] True, the vast oceans surrounding the United States did not lend themselves to flotilla defense as readily as the narrow seas around Britain, but the harbors and waters of its newly acquired Pacific empire were another matter. Until 1907, the Navy refused to consider using flotilla defense to protect the Philippines, preferring instead to rely on its battlefleet to intimidate potential adversaries from attacking. In the face of naval opposition, Congress supported flotilla defense because it was cheaper, and it urged submarines on the resisting Navy. When combined with congressional pressure, a diplomatic crisis convinced the Navy to change course. Discrimination against Asian immigrants on the West Coast led to a war scare with Japan in late 1906 and converted the threat to the Philippines from abstraction to imminent reality. The Navy suddenly warmed to the idea of flotilla defense, proposing to move 60 percent of its submarine force into Asian waters. Its newfound interest stalled, however, once the threat had passed, and the Navy continued to rely on its battlefleet.[104]

What went wrong with US torpedo development between 1903 and 1908? In 1909, Gleaves's successor as the commander of the Torpedo Station, Mark Bristol, offered one possible answer. In 1904, he recalled, it was believed that the Bliss-Leavitt torpedo

> was to lead the world. It did then, and if it had not been for the short-sighted policy of the Bliss Company, that believed it had struck a 'get rich quick' scheme, which others could not beat, this torpedo or one on the same principles would still lead the world. . . . [B]y failing to improve the turbine, except in minor ways which our Government has virtually forced upon Mr. Leavitt, the Bliss-Leavitt torpedo today is inferior to the Whitehead except as to simplification of the mechanism due to the turbine.[105]

Bristol's explanation of what had gone wrong may have been true, but it was not the whole truth. Officers affiliated with the Bureau of Ordnance had their own reasons, regardless of the truth, to blame the company, which made a convenient scapegoat for diverting attention from the bureau's own mistakes.

Fundamentally, responsibility for the premature and overly optimistic commitment to the Bliss-Leavitt torpedo lay with the bureau. True, those who would command the Navy's vessels in battle (today's military would call them warfighters) pressured the bureau by identifying what they believed, for tactical reasons, to be a serious weakness in the Navy's torpedo armament—but that was their job. It was the bureau's job to resist that pressure if necessary, and when dealing with command technology, resistance was vital. Instead, the bureau failed to subject the Bliss-Leavitt torpedo to a sufficiently rigorous development process and therefore sent a deeply flawed weapon into production.

Belatedly fixing hidden mechanical flaws—for instance, balancing the turbine—proved easier than overcoming undetected intellectual challenges. Experimental technology required different pricing and risk assessment from perfected technology. The Bliss Company understood that some difference was necessary, but it did not understand just how extreme the difference was, and it had to swallow a financial loss in consequence. Command technology demanded seismic shifts in the relationship between the public and private sectors, with far-reaching legal and political-economic adjustments to match, and the bureau was only partly up to the challenge. Its insertion of the rights clause into the contract reflected awareness that some change was necessary, but its drafting of the notification procedure, its botching of the notification, and its application for a patent that potentially weakened its contract rights showed that it was unaware of all the necessary changes. The government would pay for the bureau's mistakes with a rash of lawsuits on the eve of World War I, and with a navy that was scarcely equipped to enter the war, even if its commander-in-chief had wanted it to.

4

THE ROYAL NAVY AND THE QUEST FOR REACH

> "You must remember that the inventor may be lured away from the Government service for his brains."
>
> —H. C. L. HOLDEN (Superintendent of the Royal Gun Factory), 1905

On October 20, 1904, Admiral Sir John "Jacky" Fisher became First Sea Lord. Two years later, the famous battleship HMS *Dreadnought* entered service, a symbol of the naval arms race and Anglo-German antagonism that culminated in World War I. These events serve as familiar signposts in many narratives of the prewar period, creating a neat, linear account of the origins of World War I. The reality was far more complex and interesting. Fisher did not want the *Dreadnought*, and he was not obsessed with the German threat. Too much was changing, technologically and diplomatically, to permit the Royal Navy to focus exclusively on big ships with heavy guns or on a single nation. Instead, Fisher preferred to build a fleet with flexible capabilities around destroyers, submarines, and a new type of vessel called the battle-cruiser. Torpedoes were crucial to his vision. Far from ignoring the weapons that might threaten British supremacy in capital ships, the Royal Navy surged ahead of other nations in torpedo development thanks to a revolutionary breakthrough in propulsion technology: the wet (or steam) superheater, so-called because water was injected into the combustion chamber, greatly increasing the volume of the fluid working on the engine and thus the range and speed of the torpedo. Alas for the Admiralty, however, success created as many problems as it solved.

In 1902, the Admiralty had undertaken a thorough reformation of torpedo practice "to bring this instruction in peace time more on a level with what will be done in war."[1] The advent of the gyroscope had eliminated unpredictable deflection by the torpedo, making it more accurate, but it had also lengthened effective torpedo ranges, making it more difficult to estimate the course and speed of the target. To improve officers' ability to estimate target course and speed, the Admiralty instituted fleet torpedo practice, in which vessels fired torpedoes with collision heads at each other.[2] Fleet torpedo practice was not intended to mimic the conditions of actual battle: in 1905, for instance, the maximum range allowed for firing torpedoes in fleet practice was 1,800 yards—not the longest range that torpedoes could run, and too short to be a likely battle range.[3]

The Royal Navy's first fleet torpedo practices, held in 1903 and 1904, immediately confirmed two ideas that had been circulating for at least a year. One was that the increase in torpedo ranges meant that a higher percentage of torpedoes would miss their targets due to errors in estimating target course and speed. To compensate for this higher miss rate, more torpedoes had to be fired, and in 1903, the Navy began experimenting with ways to increase the rate of fire from the submerged tubes of large ships. Working with existing tubes, one successful technique enabled the armored cruiser *Cressy* to beat the previous fleet-wide record of 2 minutes and 2 seconds with a reloading time of 50.75 seconds.[4] In addition, the Admiralty initiated the design process for a new tube to improve the loading time, and the winner was chosen in 1907.[5]

The introduction of fleet torpedo practice also confirmed that the increase in range made knowledge of the torpedo's speed more important. After the 1904 exercise, the commander of the Mediterranean Fleet noted that "the speed of a torpedo . . . must be an absolutely known quantity" and would "remain a grave source of error" if unknown.[6] When the speed varied over the range, the range had to be known in order to calculate the average speed. As long as ranges were short, say, within 1,000 yards, the effect of errors in estimating the average speed was small, but when the ranges lengthened, the effect of errors became large enough to make it likely that torpedoes would miss their targets. In 1903, the Royal Navy began experimenting with the reducer to determine whether a new model would produce more uniform speeds. Indeed it did, halving the variation in the speed of an 18-inch torpedo, and it was approved for all torpedoes. The reconstituted Torpedo Design Committee affirmed the desirability of uniform speeds and suggested appropriate ones for each Mark of torpedo in service.[7]

In addition to faster submerged fire and uniform speeds, the gyroscope also put a premium on new safety measures. If the gyroscope failed for any reason, the vertical rudders controlled by the gyroscope would lock in position and steer the torpedo in a circle back toward the ship that had fired it, turning it into a source of danger to the firing fleet. While the Navy worked to eliminate the causes of gyroscope failure, beginning in 1903 it embarked on a long effort to develop safety gear for rendering the gyroscope harmless in case of failure. Although several were tried from time to time, none proved satisfactory, and the search for a gyroscope safety gear continued into 1912.[8]

Transitional Models

At the close of 1902, the most modern torpedoes in the Navy's arsenal were the 14-inch Royal Gun Factory (RGF) Mark X* and 18-inch RGF Mark V*. They embodied both the promise and the problems of the previous seven years of torpedo development. They had the latest gyroscopes, valve groups, engines, and nickel-steel air flasks (and thus carried asterisks to distinguish them from the Mark X and Mark V), but they lacked engines designed to work with the higher flask pressures enabled by the use of nickel-steel. Instead of radical leaps like the US Navy's switch from Whitehead to Bliss-Leavitt torpedoes, the Royal Navy continued its habit of incremental change, updating first one part and then another, rather than everything all at once.

The 14-inch Mark XI torpedo, introduced in 1903, was the first to marry the nickel-steel flask with a new engine. Depending on the reducer setting, with a working pressure of 1,700 psi (as opposed to the 1,350 psi of simple-steel-flask torpedoes), the Mark XI could make around 29 knots for 600 yards and 24.5 knots for 1,500 yards.[9] No sooner was this breakthrough achieved, however, than the 14-inch torpedo was abandoned altogether in favor of the 18-inch size. In addition to tactical trends and the prospect of economy, which made the larger class more attractive, the Fiume branch of the Whitehead Company offered the Admiralty a promising new 18-inch model. It had a nickel-steel flask capable of being charged to 2,134 psi, along with a four-cylinder engine that used air more efficiently than the Navy's service three-cylinder engine. This Whitehead model passed into service the next year as the 18-inch Fiume III torpedo, capable of making uniform speeds of 32 knots for 1,000 yards and 20 knots for 3,000 yards. Slightly improved versions of these torpedoes became known as the Fiume III* and III**.[10]

While it ordered 100 of the new Whitehead Company torpedoes, the

Navy was determined to have a homegrown version. The Admiralty gave the reconstituted Torpedo Design Committee the task of overseeing the development of a new 18-inch model, but first the committee considered how to get more speed and range out of existing 18-inch versions without dramatically changing the engines or air flasks. One of the methods it pursued was heating the air—the first indication of British interest in the idea since the Admiralty had rebuffed the Bliss Company's offer to sell its superheater in 1901. The committee proceeded along lines very different from the Bliss superheater. One of its ideas was to introduce a long coil in contact with the surrounding ocean water through which the air had to pass before it entered the engines, the idea being that the water would warm the air as it passed to the engines. The other was to introduce a superheater between the air flask and the engine, in which a substance called thermit would be ignited and heat the passing air. The coil added a half-knot of speed over 1,500 yards, while the thermit increased the amount of work done by the engine by roughly 10 percent. Because either heating method would have taken time to develop for use in torpedoes on a large scale, the committee recommended charging air flasks to a higher pressure as the only way to get higher speeds quickly. Doing so enabled the nickel-steel 14-inch Mark X* and XI to add two knots to their speeds at 1,000 yards; if the extra pressure was put toward range rather than speed, it enabled 18-inch torpedoes to make nearly the same speeds for 2,000 yards as they had for 1,500 yards.[11]

Raising the action pressure of older torpedoes was essentially a stopgap measure, however. The Admiralty also asked the Torpedo Design Committee to consider two possibilities for an altogether new 18-inch design: one with a stronger engine and higher flask pressure, but of the same dimensions; and the other with a longer flask and thus a greater overall length. The committee preferred the latter because the extra air could be used to increase the speed or the range. It proposed a model, designated Mark VI, that would be a foot longer than the Mark V and have the Navy's first four-cylinder torpedo engine. Two experimental torpedoes were built to the committee's design and tested in 1905, along with six different four-cylinder engines. When the gain in speed proved less than expected, the committee concluded that the extra length was not worth complicating the stowage and loading arrangements, especially because experiments with new superheaters were promising. The Admiralty therefore decided to build the Mark VI torpedo to the same length as previous models, correctly anticipating that it would be the Navy's last unheated 18-inch torpedo. Manufacture of the Mark VI began in 1905.[12]

Superheaters and Supply

At that time, there were three prospective sources of improvement in British torpedoes: two involving superheaters, and one involving an internal combustion engine (as opposed to the existing external combustion engine). The latter was being developed by the Brotherhood Company, which built the engines for Whitehead torpedoes. One superheater was being developed by Armstrong, Whitworth & Company (hereafter the Armstrong Company), and the other by an officer in the Royal Navy named Sydney Undercliffe Hardcastle. Reconstructing the story of these three lines of development is extremely difficult. The extant documentary record is thin.[13] What little survives must be treated with extra care because it was largely generated in the course of subsequent litigation, the likely effect of which was partisan distortion. On a development of this importance, huge volumes of paperwork must have passed through the Admiralty Secretariat—and yet there is almost no trace of superheaters in ADM 1, the Admiralty Secretariat files at The National Archives. This striking absence could be due entirely to the normal archival "weeding" process; more likely, it is due both to normal weeding and to targeted weeding of papers that would have embarrassed the Admiralty if discovered during litigation.[14] The relevant corporate archives are also disappointing, though occasionally helpful.

Given these archival limitations, the origins of Armstrong's work on superheaters are murky. The earliest known date for Armstrong's involvement is November 1904, when it applied for its first superheater patent (GBP 25,003/1904), but its research on superheaters must have begun some time before that. This patent, filed under the name of William Horace Sodeau, the Armstrong engineer who spearheaded the company's torpedo work, was for an inside dry superheater, whose chief point of difference from the original Leavitt superheater was the use of a second fuel tank to better control the rate of fuel feed. In February 1905, Sodeau applied for a second and much more novel patent (GBP 3,495/1905), describing an outside (though still dry) superheater—but this patent was not accepted and published until February 1906, a noteworthy delay.

In September 1905, the Torpedo Design Committee tested an Armstrong superheater in an 18-inch RGF Mark IV torpedo. The device used on this occasion was an inside superheater, probably similar to the one covered by patent 25,003/1904, notwithstanding that Armstrong had applied to patent an outside superheater several months earlier.[15] Despite its relatively primitive design, the inside superheater added 6 knots in speed when the torpedo was set to run either 1,000 or 2,000 yards, and it nearly doubled the range for a given speed. "[N]o time should be lost in carrying out further experiments," the committee advised, because the device marked "a new era" in torpedo development and would "probably be shortly in the hands of all foreign Governments." The Navy should undertake its own development at Woolwich, under the supervision of a specially designated officer to hurry the pace. The Admiralty should also reach an agreement with Armstrong "so that modifications and improvements found necessary may not be immediately made common property and that the benefits of early experiments with this apparatus may rest with our service."[16] The committee realized from the outset that new legal instruments were needed to deal with the intellectual property rights questions inseparable from command technology.

The loss of records which might reveal whether and how the Admiralty acted on that realization is most unfortunate, because this episode represented an important moment in the evolution of the military-industrial complex in Britain. The officer assigned to oversee development of the Armstrong superheater was Lieutenant T. J. Croker, then attached to the *Vernon*. Croker had taken out a secret superheater patent himself in 1904, and in 1907 he would be reassigned as assistant to Hardcastle. Clearly, the situation was ripe for an informal and legally problematic exchange of information between the public and private sectors; it would be very interesting to know whether it occurred and how the Admiralty dealt with it.[17]

At almost exactly the same time that the Admiralty was testing the Armstrong superheater in Weymouth, a naval officer named Sydney Undercliffe Hardcastle, then stationed at Chatham, came up with his own idea for a superheater.[18] In December 1904, then–Engineer Lieutenant Hardcastle was transferred to Chatham Dockyard to care for and maintain torpedoes. Sometime during 1905, and not as part of his official duties, he began thinking about superheaters. In the fall of 1905, he gave a description of his idea—the exact contents of which came to be hotly disputed—for an outside superheater to the officer who supervised torpedo care and maintenance at Chatham and Portsmouth. This officer, Captain Gibbs, took Hardcastle's description to the Torpedo Design Committee, which considered it at a meeting on October 4, 1905. The committee found Hardcastle's idea sufficiently promising to recommend that he be transferred to the *Vernon* and given an assistant to develop the superheater further, and it also recommended that he take out a secret patent. The Director of Naval Ordnance (then-Captain John Jellicoe) swiftly approved both recommendations. On October 18, Hardcastle applied for a secret patent (GB 21,176/1905), and on October 22, he arrived at the *Vernon*. Thus, only a few months passed between Hardcastle's first ideas and his transfer to the *Vernon* to devote himself to the subject—hence the importance of the document that Gibbs carried with him to the meeting of the Torpedo Design Committee on October 4, 1905, and of Hardcastle's patent application, in establishing what Hardcastle knew and when he knew it.[19]

Hardcastle was deliberately vague in both documents, and with good reason. "I was very careful not to put too much through the office" at Chatham dockyard to give to Gibbs, Hardcastle later testified. "There was a danger in putting too much through the office," and it was "very desirable" not to mention anything more than was necessary to obtain a secret patent.[20] Hardcastle was not alone in fearing that his ideas would be stolen if he committed them to paper. In 1906, an interdepartmental committee charged with investigating the status of inventors in government service reported that the requirement of passing an invention through a long channel of communication in order to obtain patent protection "is apt to arouse the suspicion of the inventor that the nature of his invention may be divulged before he has obtained protection." Naval officers in charge of the Chatham, Devonport, and Portsmouth dockyards, backed by the captain of the *Vernon*, agreed that the existing regulations discouraged inventors. Hardcastle's reluctance to commit his ideas to paper at this stage, which later hampered his attempts to establish when he had conceived the various components of his invention, was by no means irrational.[21]

The procedure for seeking patent protection favored the government instead of the inventor, and the provision of secret patents was an especially powerful tool. Going back to the seventeenth-century Statute of Monopolies, the granting of patents in Britain was a matter of crown prerogative. By implication, what the crown could give, the crown could interfere with.[22] Without this principle, any parties besides the inventor and Patent Office examiners might reasonably have been excluded from viewing the patent application between its deposit and acceptance ("sealing"); with it, government departments had the justification they needed to see applications during the review period. The government classified the first secret patent in 1855, under the Patent Law Amendment Act of 1852.[23] By keeping a patent secret, the government could date its claim to prior discovery in the case of future litigation, without divulging the contents of its discovery. In effect, secret patents combined two incompatible forms of protection: trade secrets and patents. Trade secrets derive protection from nonpublication (but sacrifice proof of prior discovery), while patents prove prior discovery (but sacrifice secrecy). Literally a contradiction in terms, secret patents allowed the government to have its cake and eat it too.[24]

Roughly a month after Hardcastle arrived at the *Vernon* to work on his superheater, the Torpedo Design Committee met to consider the third line of torpedo development in Britain: a new Brotherhood engine. Judging from the committee's laconic description of "a torpedo engine in which carburetted air is exploded in the cylinders," Brotherhood's design was not for a superheater but for an internal combustion engine. The committee recommended that Brotherhood should be approached "with a view to obtaining exclusive rights as the invention promises to be of considerable value," and that the officer already designated to work on the Armstrong superheater (Lieutenant Croker) take on the Brotherhood engine as well. Brotherhood had already applied for a patent to cover the internal combustion engine, but it had not yet been published. The Admiralty reached an agreement with him to keep the patent secret and to pay royalties per engine linked to the increase in energy obtained.[25]

While Armstrong, Hardcastle, and Brotherhood worked on their inventions, a major change in the Navy's supply base occurred. In catastrophically short order, the top leadership of the Whitehead Company died: John Whitehead, Robert's son, in 1902; Count George Hoyos, Robert's Austrian son-in-law, in 1905; Robert himself in 1905; and E. P. Gallwey, the director of the Weymouth factory, in 1906. The Armstrong Company had been angling to enter the torpedo market for some time, and the board of directors now appointed a committee, chaired by Henry Whitehead (a relative of Robert), to deal with the question of buying the Whitehead Company in late 1905.[26] Alas, "the Whitehead interest is in so many hands, and what is worse most of them ladies," Henry reported, "that I see little chance of their coming to reasonable terms."[27] Admiralty involvement seems to have broken the logjam. Learning that the Whitehead Company was up for sale and fearing that it would fall into foreign hands, the

Admiralty summoned Sir Trevor Dawson, an executive at Vickers, the armaments firm and Armstrong rival, and asked him to buy it. The Admiralty made a similar approach to Armstrong. Sometime between January and May 1906, Vickers and Armstrong reached an agreement to purchase control of the Whitehead Company. Vickers and Armstrong each took 184 shares (or 368 total) of the 735 shares in the Whitehead Company, leaving 367 shares in the hands of the Whitehead family. The purchase price for 184 shares was roughly £200,000. The new owners registered the Weymouth branch as a separate company ("Whitehead Torpedo Works, Ltd.") under English law on January 1, 1907.[28]

Meanwhile, the inventors continued their work. According to Hardcastle's logbook, he first used water with his superheater in December 1905, shortly after his arrival at the *Vernon*, and he later claimed that he showed his wet superheater to the captain of the *Vernon* the following month. In July 1906, Hardcastle submitted provisional specifications for his patent 16,929/1906. The provisional specifications, which contained several important differences from the complete specifications submitted in February 1907, covered Hardcastle's efforts to adapt his superheater to work with paraffin oil (kerosene) rather than alcohol as a fuel. In August, Hardcastle carried out trials of his superheater in an 18-inch RGF Mark IV torpedo. The purpose of these trials was to test the ability of the engine to withstand heated air, and the superheater used for them was the one described in Hardcastle's patent 21,176/1905—a dry superheater—which still added 3 knots to the Mark IV torpedo for 1,000 yards. In October 1906, Hardcastle later claimed, the first range trials of a wet version of his superheater occurred, but they were not successful because the torpedo ran into the shore. Hardcastle believed that the culprit was a problem with the engine valves, and by December 1906, he had invented a new type to replace them. At the same time, Hardcastle submitted the first drawing of a wet superheater whose date both he and the Admiralty later accepted. The captain of the *Vernon* was sufficiently impressed to recommend Hardcastle's reassignment to the RGF, which had better facilities. Hardcastle moved from the *Vernon* to the RGF in January 1907, where he began to fit his wet superheater to an 18-inch Fiume III torpedo and to an 18-inch RGF Mark VI torpedo.[29]

As Hardcastle moved from an outside dry superheater to a wet superheater, the Armstrong Company was moving from an inside to an outside dry superheater. In December 1906, the company invited Admiralty representatives to witness trials of its newest superheater in a torpedo being built for the Japanese navy. Whereas the Armstrong superheater used in an 18-inch RGF Mark IV torpedo in the September 1905 trials was an inside version, probably conforming to Armstrong's patent 25,003/1904, the superheater in the Japanese torpedo—an 18-inch Fiume III type, likely reflecting Armstrong's recent purchase of the Whitehead Company—was an outside superheater, probably conforming to Armstrong's patent 3,495/1905. The outside superheater added 10 knots to the speed of the torpedo for 1,750 yards, compared to a 6-knot increase for 2,000 yards for the inside superheater. Although the Armstrong Company had permitted the Admiralty to assign an officer (Lieutenant Croker) to oversee development of its original inside superheater, the company kept the development of its outside superheater secret. Accordingly, the captain of the *Vernon* recommended that Croker be reassigned from working on Armstrong's inside superheater to assisting Hardcastle at the RGF. The Armstrong Company also dealt cautiously with its new partial subsidiary, the Whitehead Company, when the latter expressed a desire to become the sole owners of the Armstrong outside superheater. After some discussion, the Armstrong Company decided not to sell the superheater outright but instead to charge royalties on it.[30]

From the RGF, in February 1907, Hardcastle filed the complete specifications for his patent 16,929/1906. Unlike the provisional specifications, the complete version described a wet superheater, as the second of two possible constructions for preheating the fuel before it reached the combustion chamber. In it, Hardcastle provided for the injection of water into the combustion chamber "[t]o prevent excessive temperatures"—not to add to the volume of the working fluid, a related but distinct purpose. Hardcastle did not explicitly claim his use of water as a novelty, though he may have intended to do so with his claim to the constructions he described.[31]

In June 1907, the Admiralty began planning competitive trials of the Armstrong, Hardcastle, and Brotherhood systems. Hardcastle ran his wet superheater in an 18-inch Fiume III** torpedo in July 1907 and in an 18-inch RGF Mark VI* torpedo in October 1907. The other two systems were tried sometime during this period as well, Armstrong's in two Fiume III** torpedoes (one converted and one purpose-built) and Brotherhood's in a Mark VI* torpedo. Hardcastle's two torpedoes made 33 to 35 knots for 3,000 yards, both with considerable air remaining (meaning that they could have gone farther). Armstrong's heated Fiume III** torpedoes, with little difference between the converted and purpose-built models, made roughly 36 knots for 2,000 yards and 32 knots for 3,000 yards, compared to roughly 27.5 knots and 20 knots for cold versions of the same torpedoes, meaning that the heater added roughly 8 to 10 knots in speed. Although the Armstrong speeds were lower at 3,000 yards than Hardcastle's, the trials of Hardcastle's superheater were not complete, and the Whitehead Company was prepared to guarantee 40 knots for 1,000 yards and 32 knots for 3,000 yards using Armstrong's superheater, substantially better than any of the Navy's cold torpedoes. Accordingly, the Torpedo Design Committee recommended that fifty cold torpedoes be converted to take the Armstrong superheater.[32]

Procuring Heated Torpedoes

The story of heated torpedo procurement is intricate, but it must be told in order to understand the number and performance characteristics of the torpedoes in Britain's arsenal at any given time, which in turn must be known if we are to reconstruct the evolution of the Royal Navy's tactical and strategic thinking. In October 1907, based on the completed trials of the Armstrong superheater and the ongoing trials of the Hardcastle superheater, the Assistant Director of Torpedoes, Bernard Currey, wrote a minute that set the course of the Admiralty's procurement policy for heated torpedoes for the next two years:

> It is needless to point out the enormous value of [a] large increase in speed to the torpedo for use in destroyers or submarines. Every knot of increase renders speed and course of enemy less difficult to allow for, and therefore deliberate avoidance of the enemy more hopeless.
>
> For our large ships, increase of range of the torpedo will be a valuable addition, since it will tend to prevent close action, and, therefore, accentuate gunnery skill. Moreover, with numbers of ships in close formation the target even at 4,000 yards is by no means a small one.
>
> At all events, it is necessary for us to be in the van of all improvements in torpedo warfare.

He therefore submitted that the Navy should request money for two purposes. One was to convert 100 of the Navy's present cold torpedoes to heated torpedoes capable of making the longest possible range at 35 knots and thus obtain "varied seagoing experience." The other was to construct six new heated torpedoes—two each for the Armstrong, Hardcastle, and Brotherhood systems—capable of making 50 knots at 1,000 yards (far faster than any ship afloat).[33]

The Director of Naval Ordnance, John Jellicoe, strongly backed the Assistant Director of Torpedoes. Jellicoe's intense interest in the tactical implications of long-range torpedo development in subsequent squadron and fleet commands makes his decisions on torpedo procurement as Director of Naval Ordnance especially noteworthy. Jellicoe wrote:

> I am most anxious to obtain approval [for Currey's recommendations]. It is impossible to over emphasise the enormous importance of a very fast torpedo for our destroyers, and it is unnecessary to dwell on the tactical importance of long range torpedoes for the Fleet. I fully realise that the experiments are not final, but they should be pushed on with great energy. We must take the lead in this matter, and allow no one to be on the same level as ourselves.

Fisher, the First Sea Lord, concurred, and the policy was approved.[34]

Accordingly, the Navy undertook a series of conversions. For fiscal year (FY) 1907–1908, the Navy ordered the conversion of twenty-nine RGF Mark VI* torpedoes to take the Hardcastle superheater, plus the construction of the six experimental torpedoes recommended by Currey; for FY 1908–1909, it ordered the conversion of another twelve RGF Mark VI* torpedoes to take the Hardcastle superheater, plus fifty Fiume III** torpedoes to take the Armstrong superheater recommended by the Torpedo Design Committee. Because the weakness of the engines prevented converted torpedoes from going faster than 37 knots, the superheater was used to increase their range rather than their speed, and they were allocated to large ships rather than torpedo craft, which needed higher-speed torpedoes.[35]

The drop in torpedo orders while the Admiralty considered its procurement policy hurt private industry. Having purchased more than 600 torpedoes in FY 1905–1906, and more than 550 in FY 1906–1907, the Admiralty ordered just 113 in FY 1907–1908. Armstrong, the new owners of the Whitehead Company, keenly felt the decline. In April 1907, the manager of Whitehead's Weymouth branch informed the Admiralty that he would have to disband his labor force unless the Admiralty placed more orders. In May, the Armstrong board learned that the Weymouth works had received only one-quarter of the previous year's previous orders. Weymouth's first order from the United States, for fifty torpedoes, eased but did not overcome the crisis resulting from the lack of British orders. By the next year, the situation had scarcely improved, and the Armstrong board discussed the gloomy outlook at a meeting in June 1908. Two weeks later, Armstrong informed the Admiralty of its belief that Hardcastle's patents infringed Sodeau's. The timing of this bombshell supports Hardcastle's later contention that it was a ploy to pressure the Admiralty into ordering more torpedoes from the Whitehead Company. (As events unfolded, the Armstrong Company did not sue Hardcastle until 1922, in a case that went to the Law Lords, then the British equivalent of the US Supreme Court.)[36]

The Admiralty's relationship with its other torpedo supplier—the War Office, which ran the RGF—was also changing. In 1903, due to the lack of ranges long enough for adjusting future long-range torpedoes, the Admiralty had begun planning for a new range near the great dockyard of Chatham, much closer to the RGF at Woolwich than was the existing RGF range on the south coast at Portland. The price tag of £700,000 for the Chatham range was too high for the Admiralty, however, and it began searching for another location. It found one slightly northwest of Glasgow in Loch Long. Because of the distance from Woolwich, and because of the desirability of taking control of naval ordnance from the War Office, the Admiralty decided to build a new factory in the nearby town of Greenock along with its new range. Due to delays in transporting machinery to the new factory and in securing housing for workers, the Royal Naval Torpedo Factory (RNTF) did not begin producing torpedoes until late 1910 or early 1911.[37]

Notwithstanding this industrial dislocation, trials of Hardcastle's wet superheater in the RGF Mark VI* torpedo were completed in February 1908.[38] Hardcastle took out a third secret patent (27,347/1908) in December 1908, which described his mature system, shown in Figures 4.1 and 4.2. The heart of this patent was the combustion chamber, which Hardcastle termed "a special continuous pressure fluid generator." In many ways, it was similar to the combustion chamber described in patent 16,929/1906; but unlike the earlier patent, which mentioned water injection almost as an afterthought and solely in the context of reducing temperatures in the combustion chamber, patent 27,347/1908 emphasized water injection, not only to reduce temperatures but also to increase the volume of the working fluid in the engine.[39]

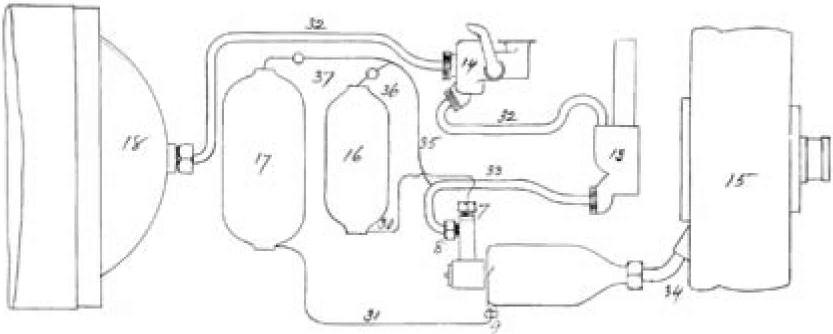


FIGURE 4.1 Hardcastle's wet superheater. In this diagram, *18* is the air flask, *17* is the water reservoir, *16* is the fuel reservoir, *13* is the reducer, *15* is the engine, and the bottle-like contraption between 9 and 34 (both pipes) is the combustion chamber. (Hardcastle's GBP 27,347/1908, figure 2, copy in T 173/257, The National Archives, Kew, England)

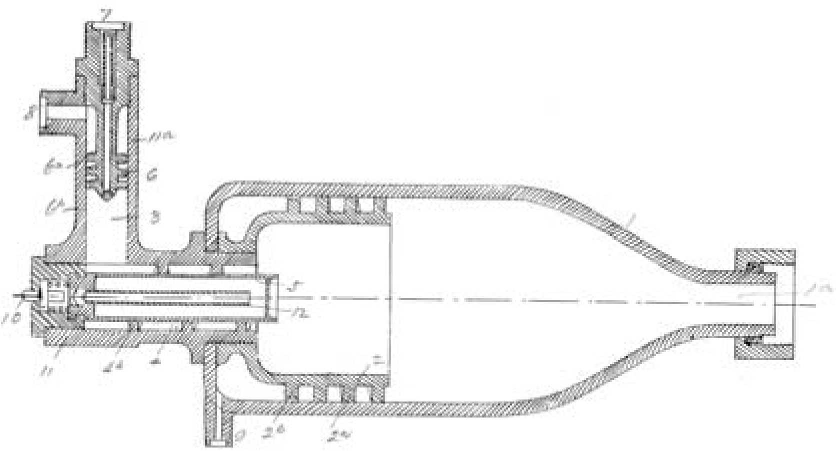


FIGURE 4.2 Hardcastle's combustion chamber; a close-up of Figure 4.1. In this diagram, 3 is the chamber where the fuel and air are mixed, and *1* is the shell of the combustion chamber. (Hardcastle's GBP 27,347/1908, figure 1, copy in T 173/257, The National Archives, Kew, England)

Yet again, lack of documentary evidence hampers precise dating of the Admiralty's commitment to the Hardcastle superheater. The official trials of Hardcastle's wet superheater in the RGF Mark VI* torpedo were not completed until February 1908, so the Admiralty must have been optimistic indeed to have ordered the conversion of twenty-nine Mark VI* torpedoes in late 1907. The performance of the Hardcastle superheater fully justified its confidence, taking the RGF Mark VI* torpedo from a cold 20 knots to a hot 34.25 knots for 4,000 yards, nearly a 15-knot gain in speed, and roughly 10 knots faster than the Armstrong superheater's 24.5 knots for 4,000 yards. The Admiralty's order of only twelve more Mark VI* torpedoes for FY 1908–1909, placed after the trials had been complete for several months, reflected not a lack of confidence in the Hardcastle superheater but the delaying effect of a debate over the desirable range and speed for the converted torpedoes. The first fifty Mark VI* torpedoes were converted to have the maximum possible speed at the expense of range (34.25 knots for 4,000 yards), but because they were being issued to ships, which needed range more than speed, it was decided to maximize their range instead of their speed (29 knots for 6,500 yards). Mark VI* torpedoes changed to maximize their range were redesignated Mark VI**. Having made a decision on the range question, the Admiralty ordered the conversion of 196 Mark VI** torpedoes for FY 1909–1910.[40]

In addition to converting cold torpedoes, the Admiralty was also developing new heated torpedoes. Again, the story is difficult to trace. The Admiralty ordered six experimental torpedoes in FY 1907–1908, intending to try the Armstrong, Hardcastle, and Brotherhood systems in two each. The Brotherhood internal combustion engine seems never to have made it into a torpedo, however, while the Whitehead Company brought out a new 18-inch torpedo, the Weymouth I, built around the Armstrong superheater and capable of making 41 knots for 1,000 yards or 28.5 knots for 4,000 yards. The Navy ordered twenty Weymouth I torpedoes in FY 1908–1909, but no more, because their performance was swiftly eclipsed by the combination of the Hardcastle superheater with the experimental torpedoes ordered in 1907–1908. Trials of these torpedoes seem to have succeeded very quickly because the Navy ordered 119 of them in FY 1908–1909. Of these 119 torpedoes, seventy-nine were designated the 18-inch RGF Mark VII, while forty were designated the Mark VII*, the asterisk indicating a slight change in the proportion of fuel to air to increase the range covered at 30 knots. The Mark VII and Mark VII* torpedoes made approximately 41 knots for 3,000 yards or 29 knots for 6,000 yards. With some changes, the Mark VII* remained the primary 18-inch torpedo in the Navy's arsenal until World War I.[41]

These numbers for heated 18-inch torpedoes are favorable compared to those of cold torpedoes, but they paled in comparison to those of a still more revolutionary development, the 21-inch heated torpedo. Because of their greater size, 21-inch torpedoes were able to carry much more air than 18-inch torpedoes, which greatly extended their range. Their engines were "merely adaptations" of those for the 18-inch Mark VII. The Navy ordered two experimental 21-inch torpedoes from the RGF and two from the Whitehead Company in FY 1908–1909. The Whitehead Company proved unable to get satisfactory results with its 21-inch torpedo and agreed to cancellation of the order, but the RGF 21-inch torpedo met with greater success. Passing into service in 1909 as the 21-inch RGF Mark I, these torpedoes could make 45 knots for 3,500 yards and 30 knots for 7,500 yards—the lower speed being one that the Navy had struggled to sustain for 1,000 yards less than a decade earlier. Experiments with a modified 21-inch Mark I, which would become the longer 21-inch Mark II, were already underway in 1908. The Mark II would be the Navy's first 10,000-yard torpedo, a 1,000 percent increase over the effective ranges of just a decade earlier.[42]

Because of the superiority of the RGF torpedoes with their Hardcastle heaters over those of the Whitehead Company, the Navy decided to manufacture only RGF heated torpedoes, to be built by the RGF and the Whitehead Company. To preserve the secrecy of the Hardcastle heater, the Navy had the Whitehead Company manufacture the torpedoes complete except for their balance chamber and heater fittings, passed the torpedoes cold, sent the torpedoes to the RGF to be fitted with heaters, and then passed them hot. After years of buying Whitehead Company patterns—the cold 14-inch Weymouth I, the cold 18-inch Fiume III, and the hot 18-inch Weymouth I—the decision to manufacture only RGF torpedoes marked a return to the pattern-unification policy of 1894–1898. In contrast to the first iteration, however, the superiority of the RGF patterns, thanks to their Hardcastle heaters, seems to have been real, not merely imagined. The return to the pattern-unification policy was accompanied, as the original had been in 1894–1895, by the dissolution of the Torpedo Design Committee.[43]

Compensating Hardcastle

While the Admiralty's procurement policy for heated torpedoes took shape, the question arose of whether and how Hardcastle should be compensated for his services. Once again, this question involved difficult problems related to intellectual property rights and putting a monetary value on new technology. And once again, the importance of these issues justifies following the debate in detail, as officials sought to invent solutions on the fly.

In April 1908, two months after the conclusion of trials with Hardcastle's wet superheater, the captain of the *Vernon* recommended that Hardcastle be promoted as a reward for his invention. The Assistant Director of Torpedoes, Currey, observed that the value of the superheater "could scarcely be over-estimated," but he attempted to arrive at an estimate by comparison with what the Admiralty had agreed to pay for the two competing systems: a royalty of £10 each for Brotherhood's internal combustion engine, and a probable price increase of £20 to £25 per Whitehead torpedo fitted with Armstrong's superheater. The Admiralty had never purchased the former, and the latter was inferior to Hardcastle's superheater. During the three years that Hardcastle had spent developing his superheater, Currey added, his pay had been "rather less than he would have drawn elsewhere." The Director of Naval Ordnance, R. H. Bacon, supported the *Vernon*'s recommendation that Hardcastle receive early promotion. The engineer-in-chief chimed in that, ordinarily, Hardcastle would not receive promotion until 1915 at the earliest and would pass over 132 officers if promoted immediately; he instead suggested that Hardcastle's name be considered for early promotion after reaching the senior list in 1911. Naval Branch, which handled personnel questions and reported to the Second Sea Lord, shifted the debate away from promotion and back to a monetary award, noting that Hardcastle's invention was "to some extent outside the usual work of an Engineer Officer"—an important point because it implied that Hardcastle had conducted the work with limited government assistance. The Second Sea Lord concurred with the suggestion of a monetary award instead of promotion and recommended that the issue be referred to the Patents Committee, which probably reported to the Director of Contracts. Orders to this effect were duly given.[44]

The Armstrong Company's challenge to the validity of Hardcastle's patents arrived in the midst of the Patents Committee's deliberations. Around October 1908, the Admiralty received replies from two experts it had consulted on the patent question. One was the Treasury Solicitor, who provided legal counsel to all government departments.[45] Although the Admiralty had a Naval Law Branch, it lacked in-house counsel on matters relating to civil law and therefore had to rely on the Treasury. It was happy to do so, for reasons explained by the Admiralty Secretary in 1902:

> [T]o create a Legal Department in the Admiralty at all commensurate with that of the Treasury Solicitor's Department . . . would involve an expenditure (at the cost of the Navy Vote) virtually prohibitive. . . . [This course] would deprive the Admiralty of the very favourable conditions under which at present thoroughly responsible legal advice is obtained at once without cost to this Department.[46]

Fiscal realities constituted a powerful impediment to bureaucratic empire building. In addition to the Treasury Solicitor, the other expert consulted by the Admiralty was a "Mr. Swinburne" (almost certainly the same James Swinburne, patent attorney, consulted by the Admiralty in 1913 in regard to Arthur Pollen's fire-control system). According to the Director of Contracts, Swinburne argued that the Armstrong patents were "bad for want of subject matter," meaning that Hardcastle could not have infringed them.[47]

The Assistant Superintendent of the Royal Gun Factory, Lieutenant Cecil R. Acklom, also contributed to the debate over rewarding Hardcastle. From January 1907 through 1908, while Hardcastle was stationed at the RGF, Acklom was his de facto supervisor. Acklom praised Hardcastle's superheater as a great success and noted that it could be used for commercial purposes other than torpedoes, such as impact-wheel turbines and high-speed boats and motor cars. Hardcastle was "entirely responsible for the invention," and although he had "of course been greatly assisted by his position and by the use of public money," he would lose "the commercial value of the invention" if it was taken over by the government.[48] The juxtaposition of the contradictory claims that Hardcastle was "entirely responsible" for the invention, on the one hand, and that he was "greatly assisted" with the invention, on the other, reflected one of the difficulties in dealing with sophisticated industrial technology. The question of "status"—meaning how much government assistance had contributed to Hardcastle's invention—obviously affected the question of how much the government should reward Hardcastle.[49]

If one difficulty was separating Hardcastle's work from the government's, another difficulty was pricing the invention, regardless of who had done the work. The superheater's monetary value was "not easy to assess," Acklom observed, and the best metric was "to consider what the British Government would be likely to pay to an outside inventor for such apparatus [sic]." The Armstrong superheater added 6.5 knots, while Hardcastle's added 15 knots. Acklom put the royalty value of the Armstrong superheater (which Armstrong did not charge as royalty, but undoubtedly built into the price of the torpedo) at £15, and the royalty value of the Hardcastle superheater at £40, these figures being roughly proportional to the speed differential. Because the Admiralty had possessed a superheater similar to Armstrong's without any question of royalties two years ago (this may have been a reference to the earlier dry version of Hardcastle's superheater, but it is unclear), Acklom deducted the £15 royalty for the Armstrong results from the £40 royalty for the Hardcastle results to arrive at a net royalty value of £25 per Hardcastle wet superheater. The average annual torpedo order was 392, which would produce net royalties of £9,800 (392 × £25) per year. With orders for war material being so uncertain, that average number might hold good for only five years, during which period the total royalties would come to £49,000. Conversions of old torpedoes to take the superheater would generate further revenue at a rate of £100 per torpedo (this sum representing the royalty value of £25 plus an estimated £75 for the work of adapting the torpedo to take the superheater), which would add an additional £12,000 if 120 torpedoes were converted over that five-year span. Thus, Acklom's hypothetical outside inventor would make a total of £61,000 off the Hardcastle superheater over a five-year period. Of course, Hardcastle was not an outside inventor; he had received some £15,000 worth of assistance, Acklom estimated, from the government in developing his superheater. Deducting this sum from the £61,000 would leave Hardcastle with £46,000. To account for the facts that the "details" of the superheater "were worked out as a part of the general work of the [RGF]," and that the "idea . . . came to Mr. Hardcastle as a Naval Officer," however, Acklom would slash two-thirds off the £46,000 for Hardcastle, leaving him with an award of £15,000.[50]

In October 1908, the question of an award to Hardcastle was referred to the Admiralty Awards Council, composed of the Director of Naval Ordnance (R. H. Bacon), the Director of Naval Construction (Philip Watts), the Director of Contracts (F. W. Black), and the Assistant Director of Contracts (C. A. Oliver). These men decided to use a different metric from Acklom's for evaluating Hardcastle's superheater. "We prefer not to consider the case in the light of the ultimate success of the invention which has undoubtedly been materially helped and accelerated by the assistance afforded by the A.S.R.G.F. [Assistant Superintendent of the Royal Gun Factory] and his Staff," the Awards Council explained, "but rather from the point of view of what would have been a reasonable sum to have promised the inventor in the event of success at the time of his originally submitting his ideas to the Admiralty with a view to their development at the public expense." This metric avoided the difficulty of separating Hardcastle's work from the government's, but only to substitute another problem, namely, determining what ideas Hardcastle had submitted, and when. This determination was not necessarily easy to make, because (as already noted) Hardcastle had good reason not to submit all his ideas at once for fear that they would be stolen.[51]

The Awards Council ignored this complication, however, and imposed an artificially simple solution. When Hardcastle submitted his ideas to the Admiralty, "the invention was entirely the property of the inventor," the Awards Council argued, "but all subsequent work may be looked on as a performance of his duty, in that he was specially appointed to the '*VERNON*' and Torpedo Factory to develop the invention and was paid his service pay for the work performed." Instead of considering what Hardcastle could have obtained commercially for his finished invention, the Awards Council considered "what sum an outside firm would have been likely to have given for the crude invention before the details had been worked out and the ultimate practical success obtained." The Awards Council dismissed Acklom's quantification of the government assistance (£15,000) given to Hardcastle on the grounds that it was "considerable and impracticable of assessment." Using its preferred metric rather than Acklom's, and taking into account the Second Sea Lord's promise that Hardcastle would be eligible for early promotion, the Awards Council recommended that Hardcastle be awarded £5,000—a third of the sum recommended by Acklom.[52]

Hardcastle learned of his fate in December 1908. The Admiralty informed him that he would be noted for early promotion, that he would receive an award of £5,000 "in full discharge of all claims which he may have in respect of this invention" (subject to Treasury approval), and that he must keep the award strictly secret. Hardcastle confirmed "that the award of a grant of £5,000 will be accepted in full discharge of all claims in respect of this invention and every effort will be made to keep the matter strictly secret as directed." The Treasury approved the £5,000 award, and Hardcastle was promoted early to Engineer Commander in 1912.[53]

Was £5,000 and early promotion a fair reward? The answer depends on the metric used to determine the value of the superheater. Acklom used one (the commercial value of the mature version of the superheater), while the Awards Council used another (the commercial value of the earliest version of the superheater). Each of these metrics had its advantages and disadvantages: Acklom's avoided the need to estimate the value of an experimental technology, at the cost of trying to untangle Hardcastle's and the government's development work; the Awards Council's avoided the former difficulty only by oversimplifying the distinction between Hardcastle's and the government's work. It is noteworthy that both Acklom and the Awards Council tried to establish the commercial value of the device, that is, what Hardcastle might have received for it as a private inventor on the open market, and neither justified the award with reference to Hardcastle's existing salary. The sum of £5,000 represented an enormous financial windfall for a naval lieutenant, amounting to at least a decade's worth of salary. The unspoken calculation was what Hardcastle might make if he bolted the Navy for greener private pastures. "You must remember that the inventor may be lured away from the Government service for his brains," the superintendent of the RGF reminded the interdepartmental committee investigating service inventors in 1905, "and then the Government will have to pay a very much higher price for his inventions."[54] The Admiralty had to make it worth Hardcastle's while to stay in, and for that calculation, the relevant metric was not Hardcastle's existing naval salary but his potential commercial salary and profits. By that standard, if Acklom's calculations were correct, then the Admiralty got Hardcastle's superheater on the cheap.

Hardcastle later concluded that the Admiralty had not rewarded him adequately and appealed for more money. On the surface, he had no grounds to complain, because he had accepted the £5,000 "in full discharge of all claims." The Admiralty's lawyer put the case against Hardcastle this way:

> [I]f the Admiralty or any Government Department and an inventor are to be in the position of two bargaining forces, or bargaining parties, one can always consider the possibility of an arrangement by which something in the nature of an interim award is made, that is to say, a smaller award would naturally be offered to an inventor if he were at the same time given the right

> again to approach the awarding body for a further award, having regard to the subsequent history of his invention. . . . [B]ut where one has a case where it is definitely stated that the sum given is in full discharge of all obligations of one side to the other, in my respectful submission that means that a larger sum has been offered, and would naturally be offered where there is to be no right to come back for further consideration. . . . [T]hat is exactly the position in this case. What is a Government Department to do in future? . . . [I]f a claimant is to come and have a further award it is a case really of 'Heads I win, tails you lose.'[55]

That argument was persuasive, Hardcastle's lawyer countered, only if the inventor and the government department were analogous to free agents in a private, competitive market—but Hardcastle was no free agent: "the true position of subordinate officers dealing with such departments" means that "there is no bargain."[56] Much as experimental technology was not an ordinary commercial product, so an inventor in government employ was not an ordinary commercial agent, and he was therefore incapable of making an ordinary commercial bargain.

Even more important, perhaps, than the outcome was the process that produced it. In particular, the existence of the Admiralty Awards Council, and its function to make government employment financially competitive with private employment, was significant. It meant that the Admiralty had a system to incentivize innovation. Although the Admiralty might spend £5,000 to buy ten torpedoes without batting an eye, a request for £5,000 to be paid to an individual officer was sure to raise Treasury eyebrows, and it cannot have been made lightly. Fairness to Hardcastle aside, the Admiralty was serious about technological change. The inadequacy of its commitment in Hardcastle's case became apparent only after World War I.

The Torpedo Protection Problem

The question of awards to service inventors was only one of many problems raised by rapid technological change. Another was that the growing accuracy, range, and speed of torpedoes demanded new methods of protecting ships. In June 1902, the Controller, William May, proposed experiments to determine the vulnerability of capital ships to underwater explosion. May told the Director of Naval Construction:

> Considering the far reaching effect of such an explosion on the structure of ships as at present built, the enormous cost of the modern ships and the increasing range and improved accuracy of the Torpedo, I am most firmly impressed with the view that we should make every effort to safeguard our ships from the destructive effect of Torpedoes. I look upon this problem as by far the most important that the Designer has to overcome, and I consider no trouble or expense should be spared in carrying out experiments that may possibly gradually lead up to the protection of a large ship from submarine explosion.

After going back and forth over securing a suitable target, which turned out to be the *Belleisle*, May circulated the idea to the rest of his colleagues. The First Lord, the Earl of Selborne, concurred: "I believe this experiment to be the most important we have yet tried."[57]

When the experiment was finally carried out in October 1903, the results were discouraging. It was "apparently impossible with plates and angles of the sizes at present in use and with our present system of riveting to construct a side capable of withstanding the explosion of such a large charge of gun cotton." With regret, May told his colleagues that "with our present knowledge it is not possible to make a ship invulnerable against the attack of the 18" Whitehead, without going to a prohibitive size." May preserved the secrecy of this conclusion by ordering the results of the experiments to be "defaced" from the *Belleisle* before the ship was sold, and the report not to be printed.[58]

Not long after the *Belleisle* experiments confirmed that better construction could not protect capital ships from torpedo attack, the ability of small craft to deliver torpedo attacks improved. In 1904, the Navy figured out a way to fire torpedoes fitted for submerged discharge from above-water tubes, which meant that destroyers, whose torpedo-carrying capacity was limited, could borrow torpedoes from capital ships. At the same time, another potential defense against torpedo attack was stripped away. In January 1904, the Ordnance Committee (a joint War Office–Admiralty committee) reported that 9.2-inch guns firing shrapnel shells with special fuses could sink a torpedo boat even without making a direct hit—"but she would probably float long enough," the Director of Naval Ordnance gloomily elaborated, "to get off her torpedoes." In any case, he thought the method impracticable due to issues with the fuse. Therefore, he concluded, in a fleet action "you would have to rely on your own fire from as many small Q.F. [quick-firing] guns as were still available, manœuvring [sic] the fleet so as to bring the attacking boats astern, and above all on the counter attack of your own destroyers."[59]

The ability of the *River*-class destroyers ordered in 1902 to perform this mission was unclear. In 1903, the Admiralty's bumptious new Parliamentary and Financial Secretary, H. O. Arnold Foster, launched a withering attack on the class, arguing that it had not kept pace with foreign development: the Germans' new destroyers managed to achieve speeds of 29 knots without sacrificing strength and weight, compared to the 25.5 knots of the *River* class. The Construction Department sharply opposed his claims about German performance and defended the *River* class. Commanders of the *River*- class destroyers lent their support to the department's argument, confirming that these destroyers were capable of accompanying a fleet without towing. In theory, the seaworthiness of the *River* class improved its ability to defend a fleet from enemy torpedo boats.[60]

As reports praising the sea-keeping abilities of the *River*-class destroyers poured in, however, so too did a gloomy assessment of destroyers' gunnery and, by implication, of their ability to defend a fleet from attack by torpedo craft. In October 1904, the captain of HMS *Excellent*, the gunnery school, and the captain of a destroyer flotilla jointly reported on experiments with the light, quick-firing, anti-torpedo craft armament carried by destroyers. They concluded that the effect of vibration would make it impossible to shoot accurately at speeds over 15 knots and that it would be impossible to distinguish between a hit and a miss against another destroyer over 1,000 yards. Accordingly, they defined the range within which light quick-firing guns stood a reasonable chance of hitting their targets as 1,000 yards—which was well within the range of gyroscopic torpedoes (and close to the range of even nongyroscopic torpedoes). The situation was even worse at night because the effective range of existing searchlights was only 500 yards. "The only defence against TO Boat attack at present is 'invisibility'—I think, and will remain so," Jellicoe, the Director of Naval Ordnance, sighed. "Our present search lights don't illuminate a boat far enough off to knock her out before she can fire." Even if destroyers could make hits, the captains pointed out, referring to Ordnance Committee experiments conducted in 1901–1902, hits from 12-pounder and smaller guns could not be relied on to stop destroyers. Therefore, they recommended the development of a new gun that could be relied on to stop destroyers. The Admiralty acted on their recommendation in late 1905 and early 1906 by commissioning designs of a new 4-inch gun.[61]

The Admiralty's decision came none too soon. In January 1906, discouraging experiments were carried out against the old destroyer *Skate*, fitted out to represent a new French destroyer.[62] In analyzing the results for his colleagues, Jellicoe began by pointing out that anti-torpedo craft armament needed to be able to inflict heavy damage quickly, partly to prevent targets from advancing after they were hit, and partly because, in night actions, searchlights would not be able to keep targets in sight for very long. The *Skate* experiments revealed that only the 4-inch gun could inflict such damage, not the 12-pounder (3-inch) or 3-pounder (47-millimeter). As a result, Jellicoe concluded that future ships should carry an anti-torpedo armament of 4-inch guns firing new 31-pound shells instead of the old 25-pound shells, especially because new French destroyers carried one-inch armor around their engine and boiler rooms. It might be objected, Jellicoe observed, that the high rate of fire obtainable with the smaller 12-pounder and 3-pounder guns would compensate for the small effect of each hit, but this argument "falls to the ground when it is realised that with the fire under proper control the number of rounds that can be fired per minute from 3-pr., 12-pr., or 4-inch is very much the same." Recent practice had shown that fire control was necessary to obtain good results, as well as "the extraordinarily small chance of hitting a torpedo boat at night even under the most favourable conditions, and therefore the absolute necessity for obtaining the maximum possible effect from a hit." In fact, the speeds of torpedo craft, combined with limits on British searchlights, meant that one hit might be all that could be obtained. Accordingly, Jellicoe recommended that 12-pounder and smaller anti-torpedo armament be abandoned, and that the high-velocity and low-velocity 4-inch guns take their place on ships and destroyers, respectively. The Director of Naval Construction and the Controller endorsed his views, and the First Sea Lord and First Lord approved.[63]

Tactical Uncertainty

The debate over the best defensive armament of destroyers was complicated by the fact that officials disagreed about the proper mission of destroyers. In a work written shortly before his death in 1904, B. W. Walker—the former Assistant Director of Torpedoes, then commanding the Cruiser Division of the Mediterranean Fleet—protested that destroyers were being misused as cruisers, a practice "somewhat like employing a racehorse to haul coal." When the Channel Fleet conducted tactical exercises in 1907, its second-in-command complained that destroyers "do not appear to appreciate the work which they are more immediately required to do, which to my mind is not to torpedo the enemy's battleships, but to deal with his destroyers." His superior, Lord Charles Beresford, also pointed to the confusion surrounding destroyers' missions and urged that "some fundamental principles be tried and established without delay." The commander of the Home Fleet's destroyers, Lewis Bayly, emphatically agreed that the priority for destroyers was to deal with enemy torpedo craft, not with enemy capital ships, and that this principle needed to be inculcated in them during peacetime in order to prepare them for war. While agreeing with Bayly about the prioritization of destroyers' duties, the Director of Naval Intelligence, Edmond Slade, nevertheless argued that destroyers might sometimes need to attack enemy capital ships, and he refused to dictate destroyers' missions on the grounds that it would unduly limit fleet commanders' freedom of action. Thus, disagreement over the defensive armament of destroyers was compounded by disagreement over their proper targets.[64]

For capital ships determined to stay outside torpedo range, the storm raging over the role of torpedo craft was beside the point. The development of gyroscopic torpedoes had significantly increased effective torpedo range, and this increase had important implications for British gunnery policy. Because naval officials sought to keep capital ships outside effective torpedo range (plus a buffer zone), their guns had to be able to hit at ever longer ranges. By 1906, the Admiralty "had increased its estimate of likely battle ranges from 6,000 to 8,000 yards, ordered that battle practice be carried out at ranges of 6,000 to 7,000 yards, and extended the notion of long battle range from 8,000 to 9,000 yards." In general, although the details were extremely complicated and the trend not unobstructed, the increase in battle ranges worked to the advantage of a faction interested in developing a sophisticated fire-control system invented by Arthur Pollen. At ranges beyond 5,000 yards, continuously or even frequently observing the fall of shot to correct for gun-aiming errors was impossible. This difficulty put a premium on the ability to calculate ranges mechanically based on infrequent range observations, as Pollen's system promised to do.[65]

Like gyroscopic torpedoes, heated torpedoes changed British tactical assumptions and gunnery policy dramatically. In late 1907, before the experiments with Hardcastle's superheater were completed, the Assistant Director of Torpedoes, Currey, had observed that long-range torpedoes "will tend to prevent close action, and, therefore, accentuate gunnery skill." In late 1908, after the Navy had completed experiments with and placed a large order for the Mark VII torpedo, and while it was experimenting with the 21-inch Mark I and Mark II torpedoes, Currey went a step farther: "In considering the use such long range torpedoes in ships can be put to it is pointed out that a 'Fleet's broadside of torpedoes' fired at the centre of an opposing Fleet would be a very formidable means of offence at a commencement of a battle *before even the guns come into action*." The Director of Naval Ordnance, Reginald Bacon, agreed: "We have it now in our power to construct a torpedo which should effect considerable damage on a line of ships outside practical gunnery range." For Bacon, though not for many other officers, the conviction that British guns would not be able to outrange torpedoes constituted a powerful argument against further increases in battle ranges and continued development of Arthur Pollen's sophisticated but expensive fire-control system, and a correspondingly powerful argument in favor of developing Frederic Dreyer's inferior but cheaper alternative.[66]

The Fisher Synthesis

Although tactics remained unclear in the face of the increasingly long-range torpedoes, a revolutionary strategic consensus was emerging around them. When Jacky Fisher took over as First Sea Lord in October 1904, his main task was to reduce naval expenditures. A lower budget meant that the Royal Navy might have to sacrifice one of its two traditional missions, protecting the home islands and defending the empire (namely, its trade and communications). Indeed, the historian Arthur Marder, who wrote the first major studies of the prewar Royal Navy, interpreted two of Fisher's chief reforms—the so-called redistribution of the fleet, which removed capital ships from distant stations to concentrate them in home waters, and the scrapping policy, which eliminated smaller vessels that could be used for commerce protection—in just these terms, as analogous to Rome's recall of the legions. Thus, the conventional wisdom holds that Fisher abandoned imperial defense in order to concentrate on the German threat to the home islands.[67]

Subsequent scholarship has shown, however, that Fisher was up to something very different. Fisher formed his strategic views during his command of the Mediterranean from 1899 to 1902, not in the North Sea. The Mediterranean was the linchpin of the British Empire, and the enemies there were France and Russia, not Germany. Rapid changes in British diplomacy (the Japanese alliance in 1902, the French entente in 1904) hardly disposed Fisher to think in terms of permanent threats. Instead of focusing on a particular enemy, he wanted to build flexible capabilities that could respond across a range of scenarios. He believed that technology would allow him to do so despite reductions in the Navy's budget. The central vessels in his vision were not battleships—slow, expensive battleships that were extremely vulnerable to torpedoes—but torpedo craft and battle-cruisers fitted with superior fire-control systems, along with revolutionary command-and-control systems.[68]

In a scheme known as flotilla defense, torpedo craft (destroyers and submarines, also known as flotilla craft) would deny the Channel, North Sea, and Mediterranean to enemy vessels, deterring them from invasion and interference with imperial trade. Calling the "risk fleet" bluff of the German Admiral Alfred von Tirpitz, Fisher accepted that British capital ships could not risk entering the North Sea, and then he turned Tirpitz's logic against the Germans: as long as the Germans could not enter the North Sea either, then Britain would achieve its end. A torpedo-based strategy of deterrence could achieve that objective just as effectively—and much more cheaply—than a gun-based strategy of decisive battle. In short, Fisher answered the risk fleet with a risk flotilla.[69]

While torpedo craft defended the narrow waters of the Channel, North Sea, and Mediterranean, battle-cruisers would control the high seas elsewhere. If the battle-cruisers got caught in a battle with enemy capital ships, they would use their superior speed and fire-control systems to hit the enemy while remaining outside the enemy's range so that their weaker armor protection would not be a problem. An extraordinary series of innovations known as the War Room System would track enemy merchant vessels and guide the battle-cruisers to them. Marrying advances in telegraphy with more centralized command-and-control, the War Room System would allow the Admiralty to replace blockade of the enemy's coast with global economic warfare.[70]

Far from recalling the legions, therefore, Fisher created a new fiscal-technological-strategic synthesis that would allow the Navy to continue performing its traditional missions more effectively and possibly more cheaply. In so doing, he fundamentally redefined the metrics of naval power. Rather than measuring naval power in big guns and battleships, Fisher's strategy measured power in torpedoes, torpedo craft, battle-cruisers, fire control, and communications. Rather than seeking command of the sea through decisive battle, Fisher sought denial and control of the sea through flotilla defense, battle-cruisers, and the War Room System.

Fisher was happy to let others believe that he believed in battleships. In a period of financial retrenchment, Fisher's main goals were to preserve the Navy's budget—and particularly its construction budget—from Army depredations and to ensure that he could maintain Britain's capacity to build warships by feeding industry with regular contracts. The latter goal in particular was not likely to win supporters in a Liberal government. With strong incentive to mislead, Fisher publicly played up the German threat in the North Sea and Britain's corresponding need to build capital ships, even as he took a very different line in private. "[T]he English Navy is *now* four times stronger than the German Navy," he cheerfully informed the king, "but we don't want to parade all this, because if so we shall have Parliamentary trouble. . . . [I have recently read a paper] convincingly showing that we don't want to lay down any new ships at all—*we are so strong*. It is quite true!"[71] By catering to the crudest metrics of naval power, Fisher fooled not only contemporary politicians but also historians into thinking he believed his own propaganda.[72]

Torpedo development from 1903 through 1908 was a double-edged sword for the Royal Navy. Gyroscopes made torpedoes more accurate, but they required new practice regimes and safety devices for reliable use. The Hardcastle superheater increased torpedoes' range and speed, but it created friction with the Armstrong Company and eventually with Hardcastle himself. The relocation of the torpedo factory from Woolwich to Greenock gave the Navy control of this vital piece of naval ordnance, but it disrupted the supply base at an important moment. Torpedoes made possible the strategy of flotilla defense, which enabled the Royal Navy to perform all its traditional missions despite budget cuts, but they created severe tactical headaches. None of these dilemmas would go away.

5

COMMAND TECHNOLOGY ON TRIAL IN THE UNITED STATES

"[T]he patent laws were intended for the protection of the inventor and produce, and not for the oppression of the consumer."

—G. W. WILLIAMS, 1912

In the five years before the outbreak of World War I in Europe, the Bureau of Ordnance suffered the consequences of its earlier errors in dealing with command technology—and it repeated them. First, the bureau's dispute with the Bliss Company over superheater royalties, which had been simmering since 1907, boiled over, culminating in a lawsuit. Next, the Bliss Company tried to export torpedoes containing the balanced turbine, leading the government to file a lawsuit that went all the way to the Supreme Court. As both parties grappled with the consequences of their earlier actions, the pace of technological development offered them no respite. The wet superheater, which enabled dazzling new speeds and ranges, developed the problems that normally attended command technology. To stimulate the Bliss Company, the bureau invited another firm, the Electric Boat Company (better known for its involvement in submarines), to design torpedoes with wet superheaters, only to be sued again for patent infringement, in another case that went all the way to the Supreme Court. Thus, by 1914, the government was involved in three torpedo-related lawsuits. In its quest for legal victory, and under cover of so-called national security imperatives, the government took inconsistent positions and repeatedly infringed private intellectual property rights—all over technology it did not fully understand and was unsure how to use in battle.

At the very end of 1908, the bureau's dispute with the Bliss Company over superheater royalties came to a head. In 1907, the bureau had purchased fifty torpedoes from the Whitehead Company in an effort to alleviate the supply crisis, and the Bliss Company had agreed to a special waiver of its superheater rights for that order. The bureau had not negotiated a waiver with the Bliss Company for its subsequent order of Whitehead torpedoes, however, and in January 1909, the Bliss Company threatened to sue the government to recover royalties on the Whitehead torpedoes not covered by the 1907 waiver. Then the issue temporarily died down, only to resurface a year later, when the Bureau of Ordnance ordered the seventy-five torpedoes from the government Torpedo Factory at Newport authorized by the July 1908 contract with the Whitehead Company.[1]

The bureau knew from the start that these seventy-five torpedoes presented potential patent problems. In March 1910, a month after ordering the first twenty-five, Mason asked the Torpedo Station to investigate the subject of superheater rights. Mark Bristol, the commander of the Station, suggested that the department consult the Patent Office, but he also ventured his own interpretation. Considering the Bliss Company's royalty of $500 on superheaters to be "exhorbitant [sic]" and "out of proportion," he proposed that the bureau should build the torpedoes with superheaters and leave the Bliss Company to take its royalty claims to court. When asked to lower its royalty on superheaters, the Bliss Company refused. The royalty of $500 "is not based on cost of manufacture," the company informed the bureau, but rather on "its value in improving the weapon, of which it forms a small part."[2] Private and public metrics of value and price conflicted, just as they had in regard to the balanced turbine.

Shortly after this acrimonious exchange, the Patent Office delivered its opinion on superheater rights. It ruled that the (dry outside) superheater used in the Whitehead torpedoes ordered in 1907 and 1908 was "dominated" by two patents assigned to Armstrong Whitworth & Company (hereafter the Armstrong Company).[3] Because the Bliss Company controlled the rights to these two patents by virtue of its 1905 agreement with the Armstrong Company, the implication of the Patent Office's ruling was that the bureau would have to pay royalties on superheaters used in these torpedoes. In April 1911, the bureau swallowed its objections and purchased seventy-five superheaters from the Bliss Company at $650 each.[4]

The Patent Office ruling arrived in the midst of a renewed torpedo supply crisis. Two weeks earlier, the Bliss Company had requested an extension on a 1909 contract for 100 Bliss-Leavitt torpedoes of a new type. Mason responded by turning back to the Whitehead Company. In late March 1911, he concluded an agreement for 180 Whitehead torpedoes, including gyroscopes and superheaters. This contract also granted the bureau the right to make 100 Whitehead torpedoes free of royalty charges at the Torpedo Station, raising anew the prospect of a fight over patent rights with the Bliss Company.[5]

New leadership found the supply situation no more acceptable. Nathan Crook Twining replaced N. E. Mason as chief of the bureau in May 1911.[6] When he arrived at the bureau, Twining privately confided that "the torpedo situation is very unsatisfactory and I don't see my way clear yet of making it any less so." The department was also unhappy with the situation. "I know there is an impression in the Secretary's mind, and in the minds of other people," Twining acknowledged to the secretary's aide, "that the Bureau has not been keeping up to the mark in several ways for some time past." In October 1911, evidently on his own initiative and presumably out of impatience, the secretary ordered Twining to solicit a bid from the Whitehead Company for fifty torpedoes. Twining did so, the company complied, and another contract was signed on October 25, 1911, which, together with the March 1911 contract, gave the Navy 230 torpedoes under contract with the Whitehead Company.[7]

The Steam Torpedo

After Leavitt's invention of the first inside dry superheater in 1900, and its installation in the first Marks of Bliss-Leavitt torpedoes, the next major step in the evolution of the technology was the switch to an outside dry superheater in the 21-inch Mark II and Mark II Mod. 1 torpedoes. The Bliss Company also installed the outside superheater in its then-experimental 18-inch torpedo, which would become the Mark VI.[8]

The first signs of the new superheater's obsolescence arrived within a year. In March 1908, courtesy of the Brazilian naval attaché in Washington, the bureau received a copy of the January 1908 issue of the *Revista Maritima Brazileira* ("Brazilian Maritime Journal"), which contained an article describing a *wet* superheater under trial by the Whitehead Company at Fiume.[9] This wet (or steam) Fiume superheater, which should not be confused with the dry (or hot-air) superheaters developed by its sister company in Weymouth in cooperation with the Armstrong Company, was based on the work of Johann Gesztesy, an officer in the Austrian navy who held both Austrian and British patents.[10] The bureau sent a copy of the article to the Torpedo Station in January 1908, and it later claimed to have sent a copy to the Bliss Company in March 1908.[11]

The Gesztesy/Fiume wet superheater was only one of several under development around the world. Two others were British—one developed by the Armstrong Company, jointly with the Whitehead Company's Weymouth branch, and the other by the British Admiralty, working from Hardcastle's design. The Bliss Company owned the US rights to the Armstrong wet superheater through its 1905 agreement with the Armstrong Company, which was issued its first US wet superheater patent (No. 964,574) in July 1910 and its second (No. 1,008,871) in November 1911.[12] The wet superheater used in Bliss-Leavitt torpedoes conformed to the first of these Armstrong patents.[13] The remaining two superheaters were American in origin: one by the Electric Boat Company, working from a design by the omnipresent G. C. Davison; and the other by the Torpedo Station, working from a design by an ordnance engineer (a civilian employee of the Navy) named Harvey D. Williams.

The bureau's work on wet superheaters at the Torpedo Station is shrouded in mystery. It is unclear when exactly that work began and how it related to another initiative undertaken by the bureau in late 1907 or early 1908—namely, the design of an alternative to the Bliss-Leavitt and Whitehead torpedoes. This initiative was closely associated with H. D. Williams and should not be confused with a subsequent initiative to develop a Navy "Standard" torpedo, discussed below. The first documented reference to a torpedo designed by Williams appeared in August 1907, when Williams was still at the bureau. In May 1908, he was ordered to the Torpedo Station and given a draftsman named O. A. Thelin as an assistant. Over the next two years, four torpedoes were constructed to Williams's design, and he experimented with a wet superheater.[14]

The other US wet superheater was being developed by the Electric Boat Company, better known for its control of the Holland submarine patents. The Electric Boat Company's torpedo work was led by a familiar name: G. C. Davison, designer of the Navy's balanced turbine; he resigned from the Navy on January 1, 1908, to become a vice president at the Electric Boat Company. The torpedo design community having been a small one (not unlike the torpedo history community of today), he was followed in June 1909 by O. A. Thelin, the draftsman who had been assigned as H. D. Williams's assistant at the Torpedo Station. Davison also took his notebooks containing information derived from experiments conducted at government expense. Although Davison had assigned the patent for the balanced turbine to the government, he would assign all his subsequent patents to the Electric Boat Company.[15]

By mid-1910, the three lines of US development—Williams at the Torpedo Station, the Bliss Company (via its agreement with the Armstrong Company), and Davison at the Electric Boat Company—had progressed sufficiently that Mason ordered the Torpedo Board to consider what characteristics the next generation of torpedoes should possess. The board delivered its report in July 1910. For armored cruisers, it recommended the development of 18-inch turbine torpedoes capable of 26 knots for 4,000 yards. While unimpressive in an international context, this performance represented a significant advance over the then-latest 18-inch Bliss-Leavitt torpedoes (Mark VI), which were guaranteed for only 2,000 yards. To meet the goal of a 26-knot, 4,000-yard torpedo, the board recommended that the bureau try to develop the Bliss-Leavitt Mark VI torpedo and the Williams torpedo, and invite the Electric Boat Company to design an experimental 18-inch type.[16]

The board's ideas about 21-inch torpedoes were even more radical. It recommended that the bureau try to develop a longer (21-foot instead of 5-meter) 21-inch torpedo capable of 30 knots for 10,000 yards. By way of comparison, the most recent 21-inch Bliss-Leavitt torpedo, the Mark III, was guaranteed to make only 26 knots for 4,000 yards. Suggesting that work with the Williams torpedo focus on perfecting an 18-inch model, the board recommended that the Bliss Company and the Electric Boat Company be asked to develop 21-inch × 21-foot designs (referred to hereafter as 21-foot torpedoes instead of 21-inch torpedoes, to distinguish them from 21-inch × 5-meter torpedoes).[17]

Mason acted quickly on the board's recommendations. On August 5, 1910, the bureau interviewed Davison to discuss the possibility of the Electric Boat Company entering the torpedo business. Three days later, Davison opened the written negotiations over the pricing of an 18-inch torpedo. As had been evident with the early Bliss-Leavitt torpedo contracts, the question of price was fraught with difficulty for experimental work. Because the work was experimental, Davison explained, the Electric Boat Company was unwilling to make ambitious performance guarantees, while the bureau was unwilling to pay for experimental work (as opposed to a finished product). To reduce the bureau's risk to a level that it might accept, Davison suggested taking the price and performance of the bureau's best recent torpedoes—the 18-inch Whitehead Mark V and the 21-inch Bliss-Leavitt Mark III—as a base, and then adding premiums for better performance. He proposed a minimum of $5,000 for no less than 26 knots for 4,000 yards.[18]

Davison called this proposal liberal to the bureau, and indeed it was. The bureau was guaranteed to get a torpedo at least as good as its present models for the same price. The Electric Boat Company bore all the risk—namely, if its torpedoes failed to meet the guaranteed performance, it would get no remuneration for its expenditures on experimental work; and even if it exceeded the guaranteed performance, it was unlikely to recover more than a fraction of those expenditures. Of course, Davison did not offer this liberal scheme out of generosity. "Our object in making this offer is to demonstrate the torpedo with a view to future orders," Davison frankly stated, and "[w]e also assume that the Bureau in ordering an experimental torpedo, would do so with a view to placing further orders in event of a satisfactory demonstration."[19] The justification for taking on so much risk was the possibility of big rewards in the future—but the assumption about the bureau's purpose was a dangerous one. Instead of bringing a new manufacturer into the business, the bureau's purpose could just as plausibly have been (as Davison later concluded it was) to stimulate its existing manufacturer (Bliss). And if the company was being used as a pawn and was not being tested on its merits, then its risk-reward calculus rested on a fundamentally flawed assumption.

As for building a 21-foot torpedo, Davison explained that the company had not undertaken any detailed plans, but that the range and speed could be extrapolated from estimates of the 18-inch torpedo's performance. Based on what the bureau had paid for previous 21-inch Bliss-Leavitt torpedoes, Davison stated that the lowest price the Electric Boat Company would accept for a 21-foot torpedo was $7,500 for a guarantee of 26 knots for 5,000 yards. After some bickering over the price, specifications, and delivery date, the bureau and the Electric Boat Company reached agreement on both the 18-inch and 21-foot experimental torpedoes. The company agreed to deliver the former within twelve months and the latter within eighteen months. The contracts were signed in January 1911.[20]

The bureau was also negotiating with the Bliss Company. In September 1910, a month after opening negotiations with the Electric Boat Company, the bureau asked the Bliss Company to bid on experimental 18-inch and 21-foot torpedoes, proposing the same terms that it was hammering out with the Electric Boat Company. The bureau gleefully exploited the leverage it acquired from placing another firm in competition with the Bliss Company—leverage that the bureau had previously lacked. "It is imperative that this question shall be taken up at as early a date as possible," Mason wrote, "as the Bureau is in a position to make contracts with another firm for similar experimental torpedoes." The Bliss Company reluctantly accepted the bureau's terms and signed contracts for experimental 18-inch and 21-foot torpedoes in February 1911.[21]

Meanwhile, after signing the contracts for two experimental steam torpedoes, the Electric Boat Company worked on them quietly until October 1911, when Davison made a different proposition: independent of the experimental torpedoes, he offered to sell the rights to his wet superheater (also known as his steam generator), which could then be installed in Whitehead or Bliss-Leavitt torpedoes to convert them from hot-air to steam torpedoes. He had first proposed this shop-license agreement (so-called because it would license the bureau to build the Electric Boat superheater in government shops) in August 1910, but it had been lost in the negotiations over the two experimental torpedoes. Now, forwarding a drawing of his wet superheater, he proposed to fit it in a torpedo for trial after the bureau agreed to pay royalties of $1,000 on each of the first ten torpedoes containing the device, $900 on each of the next ten, and $800 on each torpedo thereafter.[22]

Asked to comment on Davison's proposal, G. W. Williams, the commander of the Torpedo Station (not to be confused with H. D. Williams, the ordnance engineer), advised against accepting it. The details supplied by Davison were insufficient to allow the bureau to judge whether and how it differed from wet superheaters being tested by the Bliss Company and the Torpedo Station, Williams worried, and the bureau might "possibly involve itself in dispute, if not in litigation, with the other companies." The bureau ignored his advice, however, telling him that Davison's "generator is not in any sense a superheater, that it has been patented, and it is believed not to conflict with the present superheater rights."[23] The bureau's understanding of the situation was incorrect, but patent law prevented it from checking the validity of Davison's claims. Until the United States entered World War I, no government department besides the Patent Office could see patent applications (or attempt to have a patent classified as secret). Thus, even if the bureau had wanted to exercise due diligence, its options were limited. Despite further assurances, Davison did not secure his first wet superheater patent (No. 1,036,080) until August 1912.[24]

Notwithstanding Williams's warning, the bureau forged ahead, sending Davison the terms on which it would agree to have him install his superheater in two 18-inch Whitehead torpedoes. The agreement was not signed until April 1912, but the bureau shipped the two torpedoes to Davison in January 1912. The contract for the two Whitehead conversions became known as the shop-license agreement. Together with the January 1911 contracts, the shop-license agreement meant that the Electric Boat Company was working on four torpedoes: building two experimental Davison torpedoes (one 18-inch, one 21-foot), and converting two Whitehead torpedoes (both 18-inch) to take Davison's wet superheater.[25]

Although the Bliss Company signed its steam torpedo contracts after the Electric Boat Company, it had its experimental torpedoes ready sooner, in November 1911—a ten-month turnaround. Its speed probably reflected the fact that it did not have to develop its own wet superheater but instead imported its version from the Armstrong Company. In trials before the Torpedo Board, the 21-foot torpedo performed well at 4,000 yards and made a 10,000-yard run at an estimated 27.76 knots. The steam 18-inch torpedo showed large increases of speed and range over the latest hot-air 18-inch torpedo (the Mark VI). In June 1912, the bureau and Bliss Company signed contracts for 240 Bliss-Leavitt 18-inch steam torpedoes (Mark VII) and for fifty Bliss-Leavitt 21-foot steam torpedoes (Mark VIII).[26]

In the meantime, the Bliss Company had also built a steam version of its 21-inch by 5-meter Mark III torpedo. At trials in June 1912, the new prototype made 26 knots for 7,000 yards (compared to the hot-air Mark III's 26 knots for 4,000 yards). This torpedo was the prototype for the Bliss-Leavitt Mark IX, which, together with the 18-inch Mark VII and 21-foot Mark VIII, would become the backbone of the Navy's torpedo arsenal through World War I and the interwar period.[27]

Royalty Pains

In late 1910, under mysterious circumstances, the ordnance engineer H. D. Williams resigned from the Navy. Nevertheless, the Torpedo Station continued to develop two of his experimental torpedoes until early 1911. There the paper trail on the Williams torpedo abruptly ends, and the fate of his torpedoes is unknown.[28] For several months, no trace of a station-designed torpedo or superheater appears in the record, although it is likely that the station continued to experiment with the wet superheater that had originated with Williams in the hope of avoiding royalty payments to the Bliss

Company. Then, in December 1911, a new project appeared: the development of a Navy Standard torpedo. Although it ultimately failed, it generated significant developments in intellectual property rights along the way.

The Standard torpedo project probably emerged from the same impulse to develop a design independently of the Bliss Company that had given rise to the Williams torpedo, but it was quite distinct from the Williams project, and it may have been related to the arrival of new leadership at the bureau and the Torpedo Station. In May 1911, Twining had become chief of the bureau, and G. W. Williams had become commander of the Torpedo Station.[29] Seven months later, the bureau asked the station to consider designing a torpedo by mixing and matching the best parts regardless of the manufacturer, even at the cost of paying royalties. Williams liked the idea and thought that royalties could be avoided altogether, "except as regards possibly the superheater, and it is probable that a new superheater may be devised with details different from the present superheater." The station had in mind a torpedo with a dry superheater rather than a wet superheater.[30]

In December 1911, the bureau ordered the Torpedo Factory to build seventy-five torpedoes, probably as part of the 100 torpedoes authorized by the March 1911 contract with the Whitehead Company.[31] For the last seventy-five torpedoes built by the Torpedo Factory, it will be recalled, the bureau had ordered superheaters from the Bliss Company, but in January 1912, Williams proposed that the bureau instead reopen the question of superheater rights. The Bliss Company's rights had never been judicially confirmed, he argued, and even if they had been, the size of the royalty would still be open. While recognizing that the patent rights of inventors were protected by laws enacted under specific authorization of the US Constitution (specifically, Article 1, Section 8), Williams submitted

> that the whole tenor of the Constitution is that the relations between the government and the individual and between individuals shall be subject to the rules of equity; that the written laws themselves are but a codification of the rules of equity, and that it was never intended by the framers of the Constitution or the framers of the law made in pursuance of constitutional authorization that inventors or others should receive an unjust compensation. It is believed that the patent laws were intended for the protection of the inventor and produce, and not for the

> oppression of the consumer. This would seem to be a reasonable assumption in any case, and in view of the history of the development of the superheater it is thought that the consumer—in the case at issue, the government—should be exempt from an exorbitant charge as a matter of equity, even should *the right of eminent domain* be held as not applicable to property consisting of patent rights. [Emphasis added]

To explain why the government should be equitably exempt from high royalties, Williams reviewed the history of superheater development. Leavitt had been responsible for the "idea" of burning a combustible (alcohol) in the impulse air to increase the energy, and his "method" consisted of burning alcohol in the air flask. The government had paid high prices for early Bliss-Leavitt torpedoes to support the development of the torpedo, effectively investing in experimental technology. Given this investment, the government should be allowed to build superheaters free of royalty. Williams suggested that the bureau try to reach an equitable understanding with the Bliss Company by agreement or through arbitration, and that if those efforts failed, the bureau would be "ethically and legally" justified in manufacturing superheaters without the company's consent, leaving settlement of the company's claims to the Court of Claims if the Company insisted on them.[32]

The legal and philosophical ambition of Williams's letter was as extraordinary as it was problematic. In essence, Williams was arguing that the government deserved a share of the intellectual property rights to the superheater because the government had indirectly subsidized superheater development by paying artificially high prices for finished torpedoes. This argument ignored two awkward facts. First, accounting habits would have made it impossible to put exact dollar figures on the government's versus the Bliss Company's contributions: correspondence between the bureau and the Bliss Company did not distinguish between expenditures on research and development (R&D) and expenditures on the final products.[33] Second, the government had not contributed direct labor to developing the Bliss-Leavitt wet superheater, which, unlike the balanced turbine, had been developed by the Armstrong Company. It may be that Williams lost sight of this fact in the morass of intellectual property rights to different parts of the Bliss-Leavitt torpedo. Regardless, he was effectively using the government's contributions to the rest of the Bliss-Leavitt torpedo as a Trojan horse to attack the Bliss-Armstrong rights to the superheater.

Perhaps the most striking aspect of Williams's letter was his reference to eminent domain, a legal doctrine that was long, if fitfully, established in US law. Eminent domain referred to the power of the government to seize property for public use in return for compensating the owners. In the US Constitution, the last clause of the Fifth Amendment (known as the Takings Clause) enshrined and limited the federal government's power of eminent domain by stating that private property could not "be taken for public use, without just compensation." Into the nineteenth century, the most common type of property to be taken was land. As types of property multiplied, to include physical property other than land and nonphysical forms of property like corporate shares, so too did the scope of eminent domain.[34]

Williams's reference to eminent domain occurred as the concept was evolving in real time. In June 1907, the great German armaments firm of Krupp had sued William Crozier, the US Army Chief of Ordnance, in the Supreme Court of the District of Columbia (which, despite its name, was a trial rather than an appellate court). Krupp accused Crozier, as an agent of the US government, of infringing Krupp's US patents for guns and carriages, and it sought an injunction to prevent the government from continuing to violate its patents as well as compensation for the royalties it was owed. When the DC Supreme Court found in Crozier's favor, Krupp appealed to the DC Court of Appeals, which reversed the lower court's decision in 1908. Crozier then appealed to the US Supreme Court, which heard the case in April 1911 and handed down its decision in April 1912. Meanwhile, in June 1910—that is, between the decision by the DC Court of Appeals and the hearing of the case before the Supreme Court—Congress had passed a statute enlarging the jurisdiction of a court known as the Court of Claims, also located in the District of Columbia, to hear claims by patentees against the government or its agents.[35]

The Supreme Court held that the new law enabled the government to take intellectual property rights through eminent domain. It was "the purpose of the statute" that enlarged the Court of Claims' jurisdiction to provide for "the exercise of the power of eminent domain" by creating a judicial forum in which aggrieved patentees could seek retroactive compensation. The "public nature" of the patents in question—namely, their relevance to national security—was clear. The government's compensatory duty "may be adequately fulfilled by an assumption on the part of government of the duty to make prompt payment of the ascertained compensation—that is, by the pledge, either expressly or by necessary implication, of the public good faith to that end . . . which the statute plainly implies." Because the Court of Claims could award compensation for a taking, an injunction as originally sought by Krupp was out of the question: the two forms of remedy were incompatible.[36]

The Supreme Court's decision in *Crozier v. Krupp* was problematic. On the one hand, permitting injunctive relief or requiring proactive compensation would effectively nullify the power of eminent domain: anyone whose property was being taken, even if the taking would clearly advance the public good, could stop the process by getting an injunction or by refusing to accept compensation. On the other hand, the government could abuse the power by claiming a public good where none existed or by providing too little compensation.

The potential for abuse grew, even where good faith existed, with the complexity of the property being taken. Torpedo patents constituted a highly complex form of property. Torpedoes were not systems but systems of systems, each of which had its own intellectual property rights. For instance, the government might reasonably claim to have contributed to the invention of the balanced turbine in Bliss-Leavitt torpedoes, but it could not reasonably claim to have contributed to the invention of the Armstrong superheater used in Bliss-Leavitt torpedoes. It was difficult enough to untangle either the technological or the legal threads that made up the Bliss-Leavitt torpedo; it was probably impossible for the government to untangle both at the same time because doing so would have required officials who were equally expert in the technology and the law, or the administrative wherewithal (which did not exist) to bring ordnance and legal experts into close contact with each other. It might be urged that for the purpose of compensating a hypothetical taking of the Armstrong superheater through eminent domain, the value could be determined simply with reference to its commercial price—but Williams had begun from the premise that the commercial price was excessive. Moreover, Williams proposed a taking not on the grounds that the Armstrong superheater was vital for a public good (like national security), but on the (false) grounds that the government had subsidized its development.

Williams was not the only naval official to track *Crozier v. Krupp*. In 1908, Congress had created a new position in the Navy Department called the solicitor, who operated out of the office of the Secretary of the Navy.[37] The Judge Advocate General continued to handle military legal matters like courts-martial, while the solicitor handled civil matters such as contracts.[38] In his annual report for 1911, the solicitor noted the statute that enlarged the jurisdiction of the Court of Claims to hear patent cases.[39] The next year, the solicitor drew attention to the case of *Crozier v. Krupp*, remarking that it extended the power of eminent domain to intellectual property rights. "This privilege is of great value to the department in ordinary times," the solicitor observed, "and will save it, in times of war, from annoyances of a kind that have reflected discredit on the patriotism of some citizens in times past."[40] At last, the Navy Department had a legal expert in the form of the solicitor to handle these troublesome issues, but many of the key decisions about torpedo development with legal implications had already been made, and the solicitor was not in close contact with ordnance officials.

By early February 1912, the general layout of the Navy Standard torpedo, which had sparked Williams's search for a way around the Bliss Company's superheater rights, was complete. Nevertheless, the impressive performance of the experimental Bliss-Leavitt steam torpedoes, the signing of the shop-license agreement for the Davison superheater, and progress with its own wet superheater prompted the Torpedo Station to suggest waiting on developments with steam torpedoes before proceeding further with its hot-air Standard design. The bureau agreed with the station's suggestion, noting "that the method of increasing the range used by the E. W. Bliss Company has been experimented with for some time by the Naval Torpedo Station, and so far as the Bureau is informed this method is not patented and could be used by the Bureau if the other methods of steam generation should fail after the completions of the experiments." Accordingly, in lieu of developing a torpedo design, the station reported that it would experiment with the wet superheating methods used by the Bliss Company and Whitehead Company.[41]

This seemingly mundane statement was actually a very curious one: How could the station experiment with Whitehead wet-superheating methods, given that the Navy's most recent Whitehead torpedoes used dry superheaters, and Whitehead's first US patent for wet superheaters (No. 1,028,073) was not issued until May 1912? The likely answer was that the Torpedo Station was working from a description and detailed drawings of the Whitehead wet superheater pirated in fall 1911 by Mark Bristol, who, after leaving the station, became the bureau's inspector at the Whitehead Company's Weymouth works, as well as its unofficial spy.[42]

As the station prepared to infringe the Whitehead Company's property rights, it continued to search for a way around the Bliss Company's. Acting on the Torpedo Station's suggestion, the Bureau of Ordnance asked the Bliss Company to reduce its superheater royalties. When the company refused, the bureau submitted a memorandum to the department on the subject, emphasizing the bureau's willingness to let the Court of Claims handle the matter. In April 1912, the department granted the bureau authority to build the superheaters without further reference to the Bliss Company, and the bureau ordered the station to build seventy-five superheaters in June 1912. The issue of superheater royalties to the Bliss Company then died down for a year as others came to the fore.[43]

Reaping the Whirlwind

The Bliss Company occasionally tried to sell its torpedoes to foreign customers. At first, to the extent that the Bureau of Ordnance knew of these efforts, it does not seem to have protested strongly.[44] After 1906, the situation changed in two important respects. First, the bureau believed it had made a significant contribution of its own to the Bliss-Leavitt torpedo in the form of the balanced turbine.[45] Second, the series of orders placed by the bureau with the Whitehead Company between 1907 and 1911 gave the former the right to station an inspector at the Weymouth works and thus enabled it to gather more information about foreign torpedo developments. In May 1911, Mark Bristol became the bureau's inspector at Weymouth, followed by J. V. Babcock in August 1912. Both had recently served at the Torpedo Station and were familiar with the Navy's torpedo situation.[46]

Thus they were eminently qualified to perform not only their official duty of inspecting torpedoes at Weymouth, but also their unofficial duty of spying for the bureau. They scored several intelligence coups: Bristol procured drawings of the Fiume wet superheater, while Babcock made off with drawings of a new type of depth mechanism and the Hardcastle superheater. The information they gathered on these devices was sufficiently detailed that the Torpedo Station managed to build and experiment with all three, and it even went so far as to consider putting the Hardcastle superheater in US torpedoes.[47]

Bristol and Babcock watched the Whitehead Company's Fiume branch and the British navy particularly closely because they appeared to be the most important foreign centers for long-range torpedo development. The two officers kept the bureau informed about Fiume's work on a two-cylinder, horizontal alternative to the usual Brotherhood four-cylinder engine, and on Britain's development of the Hardcastle superheater. By September 1912, Babcock was convinced that both Fiume and the British were struggling with their reciprocating engines in long-range steam torpedoes.[48]

Babcock enjoyed excellent personal relations with the director of the Whitehead Company's Weymouth branch, Edgar Lees, and with the director of the Fiume branch, Albert E. Jones. "Through personal acquaintanceships and resulting confidences therefrom," Babcock unofficially informed Twining, the chief of the bureau, on November 22, 1912, "there is reason to believe that the Bliss Company do [sic] not view torpedo developments for us in such a way that they would hesitate in delegating foreign rights of manufacture." In view of the trouble being experienced with reciprocating engines, he suspected that the Bliss Company was trying to sell its turbine torpedoes abroad. As to the company's possible motives, Babcock speculated,

> Bliss are [sic] undoubtedly prompted in such procedure from reasons of financial profit, as their patents built abroad means royalties or at least reciprocal treatment in a similar way. Such a course perhaps is natural from their standpoint, but it strikes me that we are vitally interested parties and should be consulted. . . . Experimental and development work is of course costly, but it would appear that although we do not pay for it as such, still it is sufficiently included in the contract price of finished article [sic] as not to cause much loss to them, and that hence we have some degree of claim on the disposal of such accomplishments to any but ourselves.

The claim to have indirectly subsidized experimental work through inflated prices was, of course, the same logic G. W. Williams had used in regard to the Bliss-Armstrong superheater; it was much more plausible in the case of the balanced turbine. If the Bliss Company sold its torpedo abroad, "it would simply mean that important developments in work for us and with our financial support, would pass into the hands of the principle [sic] foreign services as a commercial article."[49] Several days after alerting Twining, Babcock learned that Lees and Jones, the Whitehead Company directors, would be visiting the United States. Realizing that it would be much cheaper for foreigners "to simply take our present development and proceed on from there" rather than building a turbine engine from scratch, Babcock feared that "such is the real object of the approaching visits of two such leading torpedo men."[50]

Twining responded to Babcock's warnings with alacrity. On December 9, the bureau informed the company that it had to comply with the rights clause from the 1905 and subsequent contracts, which prohibited the Bliss Company from reselling technology invented by the bureau, especially in regard to the balanced turbine.[51] The next day, Leavitt sent a letter to the bureau rejecting the bureau's claim that the rights clause covered the balanced turbine. If the government prohibited the company from demonstrating its turbine torpedo in the United States, the company believed that it could simply take the torpedo abroad for demonstration, but it asked the government to save it the inconvenience of doing so by lifting the prohibition.[52] Twining refused to oblige. If foreign navies acquired the balanced turbine, he argued, the US Navy would lose a "decided advantage." The Navy Department believed that the restrictions imposed by the rights clause were "so far reaching as to prohibit the exportation, without the Government's sanction, of any device that may be used for war purposes manufactured in this country embodying the *principle* of balanced turbines [emphasis added]."[53] Both sides dug in their heels.

Clearly sensing that the issue was not going away, the bureau undertook two initiatives. First, it began combing its files for records related to the development of the balanced turbine. On December 13, Albert L. Norton, the bureau's torpedo officer, summarized his historical findings.[54] The chronology and pieces of correspondence to which Norton referred would form the basis of the government's case in court. The bureau's second initiative was to ask the Bliss Company, in a meeting on December 18, to submit an offer for the exclusive international rights to the Bliss-Leavitt torpedo—the same rights that the bureau had declined to purchase in May 1904. The next day, the company offered to sell the rights for $1.5 million, just as it had in 1904. Although the government had worried in 1904 that the publication of patents would erode the secrecy of the torpedo and thus the value of the exclusive rights, the company wrote, "We believe in view of the history during the last number of years in connection with the developments of this torpedo that it has been clearly demonstrated that the publication of those patents or later patents in no way prevented the matter from being kept secret."[55] Though intended to reassure the bureau, this was a foolish statement because it could be (and was) used to attack the company's argument that the bureau had itself eroded the secrecy of the balanced turbine and compromised its claims under the rights clause by taking out Davison's patent.[56]

The bureau forwarded the company's offer to the department on December 26, 1912. This was the first time since 1906, when Mason had inquired about patenting the balanced turbine and preventing US citizens from transmitting plans of technology to foreign powers, that the bureau had brought the balanced-turbine issue to the department, and two noteworthy changes had occurred in the interim. First, as mentioned above, the position of solicitor had been established in 1908 to handle matters of civil law like this one, and Twining directed his inquiry to this new administrative machinery.[57]

Second, new and potentially relevant legislation was available. In 1906, the only possible legal means that the secretary of the Navy could think of for preventing the export of technological plans to foreign powers was Section 5335 of the Revised Statutes, which was based on the 1799 Logan Act. In March 1911, however, Congress passed a measure called the National Defense Secrets Act, or National Defense Act—not to be confused either with the National Defense Act of 1916, to which it bore only an indirect relation, or with the Espionage Act of 1917, to which it was a direct precursor. The 1917 Espionage Act is still used today, but the 1911 National Defense Secrets Act has been more or less forgotten. The 1911 act read in part:

> [W]hoever . . . without proper authority, obtains, takes, or makes, or attempts to obtain, take, or make, any document, sketch, photograph, photographic negative, plan, model, or knowledge of anything connected with the national defense to which he is not entitled; . . . or whoever, being lawfully intrusted [sic] with any such document, sketch, photograph, photographic negative, plan, model, or knowledge, willfully and in breach of his trust, so communicates or attempts to communicate the same, shall be fined not more than one thousand dollars, or imprisoned not more than one year, or both.

It should be noted that the law dealt with both unlawfully and lawfully obtained information.

Although the 1911 act mirrored the 1799 Logan Statute insofar as both dealt with the international communication of information, they had different intents: the latter meant to regularize diplomacy, while the former meant to prevent espionage. In reporting on the proposed bill in 1911, the House Judiciary Committee described its purpose as follows:

> The effect of this bill is to protect the Nation against spying in time of peace.
>
> The necessity for such protection has increased with the growing importance of national preparation for war in time of peace. . . . In this contest of preparations, the question of knowledge on the part of the enemy is of vital importance, particularly in the case of the location of forts, of batteries, of mines and torpedoes. Such knowledge may indeed actually settle the contest.
>
> To prevent the acquisition of this information, nearly all of the nations of the world with any developed system of national defense, except the United States, have upon their statute books stringent laws under which they can restrain and to a degree prevent spying by inflicting punishment upon persons found guilty. America alone has no such law and our national defense secrets as a consequence have no protection against spies.[58]

The examples of espionage that the report went on to provide made clear that Congress had in mind a particular kind of information, that bearing on the location of the nation's physical defenses, and a particular kind of espionage, traditional state-on-state spying.

The Bureau of Ordnance saw an opportunity to apply the act to very different information, actors, and purposes from what Congress had intended. Aside from information relating to physical defenses, the bureau sought to include intellectual (i.e., nonphysical) information relating to national defense; instead of traditional state-on-state espionage, the bureau sought to control the complex public–private nexus that was the international arms market; and instead of preventing espionage, the bureau sought to regulate proprietary and commercial rights.[59] Under patent law, "[h]as not the Navy Department the exclusive rights to dictate as to the uses to which material including the principle of Balanced Turbine Engines may be put," Twining asked the solicitor, "and, under the National Defense Act, the power to enforce such dictation?"[60] In other words, instead of bringing a civil suit against the company for patent infringement, could the government instead bring a criminal prosecution against the Bliss Company with fines and imprisonment as possible penalties?

Using the National Defense Act, instead of patent law, to enforce patent rights was clearly not what Congress had intended—yet Twining was not alone in thinking along these lines. His idea had much in common with Williams's idea of applying eminent domain to patent rights. True, their purposes differed—whereas Williams sought to avoid paying royalties, Twining sought to control exports—but both men contemplated seizing through a legal loophole intellectual property rights to technology that the bureau had most likely not helped to develop: the Bliss-Armstrong superheater in Williams's case, the entire Bliss-Leavitt torpedo (not just the balanced turbine) in Twining's case. Williams's method would apply a very old legal doctrine to very modern technology, while Twining's method would apply a 1911 statute retroactively to a 1905 contract. In both instances, a novel legal theory originated not with lawyers but with technocrats.

The theory did not end with them, however. On January 9, 1913, the department decided in the bureau's favor. It held that the rights clause covered the balanced turbine, that the government could apply the penalties prescribed by the clause if the Bliss Company exhibited or sold torpedoes containing the balanced turbine, and that the government could also seek equitable remedies necessary to protect its interests.[61]

No sooner had the department handed down its decision on the balanced turbine than the bureau stepped into a new mess. For some time, the Bliss Company had struggled to maintain uniform horsepower and speed in several types of Bliss-Leavitt torpedoes. To deal with the problem, the assistant inspector at the Bliss Company suggested trying a two-stage reducer (which became known as the double or compound reducer) in place of the existing one-stage reducer, and the Torpedo Station began working on the idea. On January 14, 1913, four days after the department handed down its decision on the balanced turbine, the bureau's inspector at the company, F. L. Sawyer, reported that he had finally convinced the company to experiment with a double reducer, and that the results were promising. The Bliss Company, he wrote, "had been furnished *verbally* with the *idea* [emphasis added]," and the bureau had supplied the same in writing on January 4, 1913. To comply with the requirements of the rights clause, Sawyer "urgently recommended that the Bureau inform the E. W. Bliss Company in writing that this device, method or idea be considered as falling within the meaning of [the rights clause]"—a recommendation he had first made a month earlier. The bureau so notified the company on January 18, quoting Sawyer's letter of January 14 verbatim.[62]

The bureau's handling of the double reducer in 1911–1913 was almost an exact replay of its handling of the balanced turbine in 1905–1907, and in both cases, it botched the job. Where the contract required *written* communication of a *device or design,* bureau representatives had *orally* communicated to the Bliss Company the *idea* of the balanced turbine in October 1906 and the *idea* of the double reducer to the Bliss Company in 1911–1912. As previously noted, the bureau had drafted the provision in a way that made it impossible to meet, no matter how intelligently observed, because of the dynamics of McNeillian command technology: the provision required the communication of a mature design, when command technology required the collaboration of private industry to make it mature. The bureau had set itself up for failure.

And the Bliss Company knew it. On February 10, 1913, on the advice of legal counsel, the company rejected the department's decision that the rights clause covered the balanced turbine, and a week later, it responded to the bureau's application of the rights clause to the double reducer.[63] Calling attention to the notification procedure in the rights clause, the company wrote,

> We regard it as perfectly clear from the language of the contract that it has no application to mere intangible ideas or principles, and that it applies solely to a device embodied either in a model, or in a working drawing constituting a design illustrating such device. Furthermore we regard it as necessarily implied by the language of the contract that the device or design to be furnished to us by the Bureau in order to be covered by said clause must be one of which we are not already in possession, and must be something essentially novel, since obviously to include matters of common knowledge or ordinary shop expedients, would be contrary to the spirit of the contract. It clearly was not intended that this clause should entitle the Bureau to notify us of things already known or used, or of mere intangible ideas and thereby to put us under any restriction concerning such things. In our view the intent of the clause in question was that in the event that the Bureau should at any time work out any new improvement and embody it either in an operative device or in a drawing or design of such device, and should communicate it to us, that such device or design should be within the prohibition

> of [the rights clause], if the proviso giving us notice thereof was also complied with. Any interpretation obligating us beyond this we cannot accept.[64]

The company's eruption over the bureau's application of the clause to the double reducer covered the case of the balanced turbine equally well. Indeed, the company had laid the groundwork for its position during the negotiations over the rights clause in 1905, when it asked, and the bureau agreed, that the clause be "confined to concrete improvements developed by the Bureau, and not necessarily include matters where the suggestion of a possible improvement is made by the Bureau and worked out by us."[65]

To complicate matters further, the gathering storm over the sale of Bliss-Leavitt torpedoes containing the balanced turbine to the Whitehead Company intersected with the fracas over the payment of superheater royalties to the Bliss Company. On May 2, the Bliss Company demanded the payment of royalties on superheaters used in the Whitehead torpedoes built or purchased by the bureau. The company had let this issue lie since December 1910, probably because others had dominated its relationship with the bureau, and the timing of its resurrection was likely an attempt to gain leverage in the balanced-turbine case. A week later, the Bliss Company informed the department that it would sell the foreign rights to the Bliss-Leavitt torpedo by June 1, 1913, to the Whitehead Company unless enjoined (i.e., prevented by an injunction).[66]

The bureau responded to both threats by holding its ground. As for superheater royalties, Twining stuck to his predecessor's line that the Bliss Company's real argument was with the Whitehead Company, and he repeated his recommendation to let the Bliss Company turn to the courts if it wanted to press the matter.[67] As for the foreign rights to the Bliss-Leavitt torpedo, the department immediately asked the Attorney General to seek an injunction preventing the Bliss Company from selling them.[68] On May 27, the bureau produced a brief for the guidance of the US attorney for the Eastern District of New York, which contained Brooklyn (the site of the Bliss factory) and formed part of the Second Circuit. Much of the brief recapitulated the chronology of relevant correspondence dating back to the conception of the balanced turbine in 1905 presented in Norton's memorandum of December 13, 1912, mentioned earlier. From its summary of correspondence, the bureau asked the district attorney to note

> that the idea of turbine propulsion was conceived in the Bureau of Ordnance, and that the improvements for which the United States holds assigned patent rights for causing the turbines and their gear to revolve in opposite directions, thereby placing the entire propelling mechanism in dynamic balance, was <u>the principle or method</u> [emphasis in the original] whereby the application of turbine propulsion of torpedoes was made possible, and that this principle and method is so covered by the patents assigned to the United States that any application of turbine propulsion whereby turbine wheels and their interconnecting gearing, by which the propellers are driven, is caused to be in dynamic balance by means of having the turbines revolve in oppose directions, is covered by the restrictions of [the rights clause].[69]

The bureau's statement contained three problems. First, it had not been alone in conceiving the idea of turbine propulsion; as we saw previously, the Bliss Company had independently arrived at the same idea at roughly the same time. Second, the bureau conflated patent and contract protection. Third, the bureau equated *principle* and *method*. These were arguably distinct—*principle* could mean a general idea, whereas *method* could mean a particular arrangement of mechanical details—and the distinction was a key one, as this lawsuit and others would show.

Thus a series of decisions made by ordnance officers almost entirely without expert legal counsel over the course of a decade dragged the whole US government into a lawsuit against the sole private domestic supplier of a crucial weapons system. The US attorney who would try the case plaintively asked the Bureau of Ordnance to send someone to advise him, "inasmuch as there is much in the contents of these papers of a technical character."[70]

On May 27, the US attorney filed a formal bill of complaint (hereafter the complaint) at the district court, which subpoenaed the Bliss Company and ordered it to show cause why an injunction should not be issued. Over the next two months, the government filed an amended complaint, the Bliss Company's attorneys filed an answer to the amended complaint, and the judge, Van Vechten Veeder, issued a temporary injunction while the case was pending.[71]

The government's amended complaint, dated June 24, 1913, set the terms of the case. To begin with, the government brought the case in equity, a legal term of art distinguishing it from a case at law.[72] The government sought an injunction on the grounds that no other remedy could compensate for the erosion of national security that would result if the Bliss Company were permitted to sell abroad. The government singled out two contracts as being at issue: the November 1905 contract for 300 × 21-inch Bliss-Leavitt torpedoes and a June 1912 contract for 120 × 18-inch Mark VII Bliss-Leavitt torpedoes. Although the complaint averred that the government had contributed to nine distinct parts of the torpedo, including the double reducer, making eleven contributions in all, the crux of the government's case concerned the balanced turbine. The government further claimed that the Bureau of Ordnance had conceived the balanced turbine in late 1906 and early 1907 and that the bureau had "duly informed" the Bliss Company that the rights clause applied. As evidence for its claim to have invented the balanced turbine, the government noted Davison's patent. The government charged the Bliss Company not only with violating the contracts, but also with violating the National Defense Act. In sum, the government's case rested on the three related but distinct pillars of contract, patent, and statute, with the most emphasis placed on the first.

In its amended answer to the complaint, dated June 24, 1913, the Bliss Company counterattacked on a number of fronts. First, it demurred from the government's contention that the efficiency of the Bliss-Leavitt torpedo "is entirely due, or is due in great measure" to the balanced turbine. Second, it argued that the principle of the balanced turbine had been widely known before 1906; that it had conceived a balanced turbine before the government; and that it, not the government, had designed the particular balanced turbines used in Bliss-Leavitt torpedoes. With this set of arguments, the company was effectively suggesting that any design "furnished" by the bureau under the rights clause had to meet tests associated with patentability, for instance, whether the design was known in the prior art and whether someone skilled in the art could re-create the invention based on the patent specifications.[73] Third, the company denied that the government had duly applied the rights clause protection to the balanced turbine. The foregoing were largely questions of fact. The company also challenged the government's interpretation of the law. It claimed that it had violated neither the contract nor the National Defense Act, and it moved to dismiss that portion of the government's complaint resting on the act, on the grounds that the government could not bring such an action in equity—the idea being that equity was inapplicable where a statute provided a remedy. As for the patent aspect of the government's case, the company sought to turn it against the government: by taking out the Davison patent, the government compromised the secrecy of the balanced turbine, effectively nullifying its attempted application of the rights clause; and by buying the rights to Davison's foreign patents, the company had the same rights to the balanced turbine abroad as the government claimed to have in the United States. In sum, the company argued that the government had misapplied the contract, sought to turn Davison's patent against the government, and tried to remove the pillar of the National Defense Act.

On November 10, 1913, the trial of *United States v. E. W. Bliss Company* began. The company charged straight at the loophole created by the bureau's careless communications with it about the balanced turbine in October 1906. With Leavitt maintaining that he had never believed the unbalanced turbine to be responsible for the sheer problem, the company argued that the balanced turbine had actually been Vice President F. C. B. Page's initiative. Page testified that the balanced turbine had been a matter of "general talk" in fall 1906. Having had the "thought" of the balanced turbine for some time, Page made his first effort to put it into a "practical design" on November 1, 1906, immediately after returning from the crucial October 30 meeting of the Torpedo Board, and before the company received either written notification of the application of the rights clause to the balanced turbine on November 9, 1906, or a drawing of the balanced turbine on January 9, 1907. The government volleyed back that such formalities were beside the point. "The Government's contention is that under the language of the contract, a design may be disclosed to those skilled in the art verbally," one of its attorneys stated, "without the necessity of its being necessarily a drawing." In fact, the notification procedure in the rights clause required a "device or design," not a verbal description. Apparently the government believed that a thousand words were worth a picture.[74]

While the notification process was at issue, so too was the very definition of the balanced turbine. Was it a "principle" or a "design"? Was it the turbine wheels alone, or did it include the gearing and shafting? Was it defined by its construction or by its function? The seemingly arcane debate over these questions must be understood, partly because it touched on fundamental questions about the nature of invention, and partly because it had significant legal implications.[75]

The testimony of Delbert Decker demonstrated the dangers of failing to come to grips with these issues. Decker had been the examiner for Davison's balanced turbine patent application at the Patent Office, and he appeared as a witness for the government. On direct examination, Decker claimed that he understood "the operation of the mechanism" in Davison's patent, and that the Davison design "dominate[d] the structure" of the balanced turbine used in Bliss-Leavitt torpedoes. On cross-examination, the company's attorney asked Decker what he meant by "balanced turbine." Decker replied, "I mean [the term] to apply to a turbine in which different stages [i.e., wheels] are mounted upon the same axis to rotate in opposite directions." To achieve this balance, as Davison's patent stated and Decker affirmed, it was "essential" to make the speed of rotation and weight of the wheels such that their moments of inertia would be equal. The attorney then directed Decker's attention to the part of the construction that governed the speed of rotation, namely, the gearing. Decker admitted that he had not examined the gearing ratio to determine whether the counterspeeds were identical because he did "not consider the connecting gearing as part of the balanced turbine."[76]

The attorney had put Decker on the horns of a dilemma. Decker had to admit either that he had approved a patent missing an essential component (details of gearing), or that an essential component of the patent as he had approved it (equality of inertias) was actually inessential. In his effort to escape his dilemma, he contradicted himself: first, he said that equal moments of inertia were essential; then, he said that the gearing, which was essential to the moments of inertia, was inessential. These statements were not co-tenable.

Decker's confusion indicated that he had not fully thought through the nature of the invention disclosed in Davison's patent—or indeed through the nature of invention more broadly. In laying his trap for Decker, the Bliss attorney was getting at the crucial distinction between a principle and a design, just as the Bliss Company had done in its dispute with the bureau over the double reducer. Davison's patent covered a principle; in leaving out information, like details of the gearing, needed to apply the principle in practice, it failed to specify a design (in fact his patent vaguely described two possible constructions). The silence may well have been deliberate on Davison's part: recall his comment that "the claims were unusually broad, so that the device should be absolutely protected in spite of any attempts to get around it." Covering a principle seemed to offer much broader protection than committing to a particular design. What the tactic ignored, as the Bliss Company insisted, was that working out a design could be much more difficult than discovering a principle—the implication being that the true inventive act, deserving of patent protection, consisted of the former, not the latter. Thus, the stakes involved in Decker's testimony were high.[77]

The Bliss Company also attacked Decker's notion of mechanical essence, insisting that function as well as construction defined an invention. The company argued that the balanced turbine failed to perform its function—eliminating initial roll and sheer—and thus could not be considered a true invention. As the company noted, the 21-inch Mark I torpedoes run by the government at Pensacola in the winter of 1907–1908 had shown a tendency to roll and sheer even though they had balanced turbines. A later type of Bliss-Leavitt torpedo also showed a tendency to roll despite containing balanced turbines (and despite being submerged-discharge torpedoes, which, according to the government's theory of initial roll worked out in 1905, should have made them practically immune to rolling even with *un*balanced turbines).[78] The company claimed, as it had since 1908, that it was not the unbalanced turbine that caused roll, but the exhaust from the torpedo getting mixed up with the propellers and causing partial cavitation—just as Davison had originally theorized in 1905.[79] The solution was not the balanced turbine but a bulkhead that redirected the exhaust.

The company made a powerful case that the balanced turbine did not really matter that much. Why, then, had the government placed this technology at the center of its suit? Without knowing more specifically what different officials thought, it cannot be said whether the government was cynically suppressing its knowledge or sincerely ignorant: it may have really thought that this technological molehill was a legal mountain. There is certainly good reason to believe that torpedo specialists did not fully understand the science behind gyroscopic forces.[80] If even the specialists lacked comprehension, what hope did nonexperts have?

For Judge Veeder, these issues were beside the point: the controlling parts of the case were the two contracts, not Davison's patent or philosophical questions about the nature of invention.[81] The rights clause had been inserted when "the Navy Department was carrying on extensive independent experiments with torpedoes, utilizing the skill and experience of its own officers." The purpose of the clause was "to protect the Government in its contribution to the joint result" of its own and the Bliss

Company's work. The word *furnished* in the rights clause was important, in Veeder's view, and it did not require that designs "furnished" under the clause be, in effect, patentable. True, it may be observed, the company had pushed for different language when negotiating the clause in October 1905, but without success, and the government, just as much as the company, had linked the applicability of the rights clause to Davison's patent. Nevertheless, Veeder's interpretation of the meaning of *furnished* was defensible as a strict reading of the contract.

Less defensible was his failure to engage the Bliss Company's contention that the bureau had not followed the notification procedure under the rights clause. If Veeder was to construe the meaning of *furnished* so narrowly, then he might have construed the notification procedure equally narrowly—especially because, when the Bliss Company had protested the language of "furnishing" while negotiating the contract in 1905, the bureau's response had been to assure it that the notification procedure "amply" protected its interests. Instead, Veeder ignored the evidence adduced by the company to demonstrate that the bureau had not supplied notification "in writing" until one month after it first began discussing the balanced turbine, or a drawing until three months later. In effect, he made the company bear the burden of its failure to negotiate contractual language requiring patentability, but he did not make the bureau bear the burden of its failure to negotiate contractual language permitting less stringent notification procedures.

While Veeder's narrow construal of the meaning of *furnished* enabled him to avoid testing the design "furnished" to the Bliss Company for patentability, it did not relieve him, as he himself realized, of the need to decide whether the "design" furnished to the company matched the devices actually used in Bliss-Leavitt torpedoes. This need brought him right back to the difficult techno-philosophical questions about the nature of invention that his interpretation of the word *furnished* otherwise allowed him to ignore. In effect, it forced him to engage the question of whether the "design" furnished to the company was in fact a design or, as the company claimed, a mere principle. In determining whether the design as furnished matched the balanced turbine used in Bliss-Leavitt torpedoes, Veeder's criterion was this: "[D]o the essential features and function of the device appear? If they do, then mechanical alterations, though they add to its efficiency or even improvements which disclose invention, are immaterial." Here, Veeder ran into the same tensions that doomed Decker. If the essence was all that mattered, then Veeder's dismissal of mechanical alterations made sense. But if, as he stated, the function also mattered, then he could not dismiss mechanical alterations that improved the functioning (nor could he overlook the evidence presented by the Bliss Company that the balanced turbine did not, in fact, perform its function of eliminating sheer). Moreover, his statement in one clause that invention consisted of developing new essence contradicted his statement in the next clause that inessential mechanical alterations could also disclose invention.

Veeder awarded the government the injunction it requested, although he rejected its appeal to the National Defense Secrets Act. He did so not because he found it wrong to apply a statute retroactively to a contract, but for the technical reason that a court of equity lacked jurisdiction to enjoin a crime.

The award of an injunction on the one hand, and the rejection of the National Defense Secrets Act on the other, begged the question of whether the case was about property rights or about secrecy and national security. Both in his interpretation of the rights clause and in his rejection of the statute, Veeder had implied that the case was about property rights: the government had contributed labor to the balanced turbine, and the purpose of the rights clause was to protect the intellectual property rights arising from that labor. A desire to preserve secrecy and national security was not incompatible with the intention to protect property rights, but it was not identical, nor was it the plain meaning of the rights clause. The government's decision to patent the balanced turbine gave it an interest in severing the issue of property rights from national security because disclosing the invention to the world weakened the credibility of its claim that the case was about secrecy and national security. If the case was about property rights, however, the most obvious remedy was monetary damages, not an injunction. What irreparable harm was an injunction needed to prevent, given that the patent had already compromised secrecy and national security? It might be urged that the patent did not disclose the secret of the balanced turbine (as indeed the Bliss Company had foolishly intimated), but that objection implied that the specifications were so vague as to invalidate the grant of a patent in the first place, and to belie an important part of the government's case to have supplied a "design" rather than a mere principle. The government was on the horns of a dilemma; Veeder let it off. Both the Circuit and Supreme Courts affirmed his decision.[82]

The effect of the courts' decisions was to reward the government for bad faith, incompetence, or both. The government succeeded in using the rights clause to secure for free the exclusive rights to the Bliss-Leavitt torpedo that it had been unwilling to purchase at the company's asking price, despite the facts that it had flubbed the notification procedure and that the balanced turbine did not actually solve the sheer problem. "We gave the government an opportunity [actually two] to purchase the universal rights to the torpedo," a Bliss Company representative observed before the start of the trial, "and it did not take it."[83] Whatever the implications of the government's victory for national security, it was a defeat for private property rights.

Indeed, the government had emphasized national security precisely because it understood that its property rights claim was weak. After reviewing the documents provided by the Navy Department in November 1913, the US attorney trying the case wrote to the Attorney General:

> [W]e were struck with the idea that in so far as the contracts themselves are concerned, which, as the Navy Department claim, the Bliss Company were about to violate, our evidence in that respect was far from as strong as were [sic] either anticipated or desired. After a consultation, therefore, it was deemed advisable for us to take two other points of attack, namely, that the Bliss Company should not be allowed to exhibit the torpedo, or any various parts of it, to a foreign government, because it would be a violation of the National defense act [sic]; and because it was absolutely contrary to public policy that a weapon of defense, many of the principal parts of which were suggested, and several of the parts which were designed by the government should be turned in to a weapon of offense, as it would be if the Bliss Company were permitted to show the designs and exhibit the working parts of the torpedo, and demonstrate the action of the torpedo as a whole to a representative of a foreign power. . . .
>
> The case is far from as strong as represented [i.e., by the Navy Department] at the time action was requested or as I could wish it to be, but no effort will be spared to bring it to as successful a termination as possible.[84]

Thus the government deliberately framed the case as a matter of public policy rather than as a matter of law because it feared losing on the legal merits alone.

No sooner had the government won the balanced-turbine case against the Bliss Company than the company exhumed the issue of superheater royalties on Whitehead torpedoes built by the government. In May 1914, the company sued the government in the Court of Claims (the same court that had heard *Crozier v. Krupp* for infringing the superheater patents that it controlled by virtue of its 1905 agreement with the Armstrong Company. Because the court did not hand down its decision until 1917, this is not the place to discuss it, except for one aspect. The court's decision in favor of the government turned on its ruling that the Bliss Company was a mere licensee rather than the owner of the patents under the 1905 agreement and thus lacked the standing to sue for royalties in the Court of Claims. Neither the 1910 statute that expanded the jurisdiction of the Court of Claims nor the Supreme Court's ruling in *Crozier v. Krupp* had contemplated this particular circumstance. It was yet another example of the law lagging behind rapid changes in technology and business practices. In policy terms, the court's ruling in *E. W. Bliss Co. v. United States* gave businesses little incentive to license technology for articles produced for the government because it deprived them of a forum to sue the government. If businesses did not license the technology, then either they or the government had to invent the technology by themselves—a situation that, as demonstrated by the case of the balanced turbine, raised problems of its own.[85]

Electric Boat Company v. United States

By late 1912, when the bureau's dispute with the Bliss Company over the visit of the Whitehead representatives was unfolding, the Electric Boat Company had four outstanding torpedoes under contract: one 18-inch Davison torpedo, one 21-foot Davison torpedo, and two 18-inch Whitehead torpedoes for conversion to the Davison superheater. In November 1912, the Electric Boat Company sent both of the Whitehead torpedoes to the Torpedo Station for testing. In mid-January 1913, the company informed the station that it had executed its Whitehead contract and would make no further demonstrating tests, and it asked the bureau for payment. Just what had happened with the two torpedoes between November 1912 and January 1913 became the subject of a dispute that again revealed the difficulties of dealing with command technology.

In its letter requesting payment, the Electric Boat Company argued that, despite the poor condition of the two torpedoes supplied by the bureau for conversion, the addition of the Davison wet superheater had enabled them to demonstrate their ability to meet the contract range and speed requirements in the dynamometer tank.[86] Williams, the commander of the Torpedo Station, disagreed. The torpedoes, especially the engines, had developed flaws due to the Davison superheater; the dynamometer runs had been informal tuning-up runs, not official demonstrating runs; and runs in the water, not only in the dynamometer tank, were necessary to satisfy the terms of the contract. The bureau agreed with Williams and refused the company's request for payment. The contract, it pointed out, had called for the installation of the wet superheater in two Whitehead torpedoes and for the following:

> The installation of steam generating device [i.e., wet superheater] shall cause these torpedoes to have an increased range of at least . . . 6,000 yards *on their demonstration* at the Naval Torpedo Station; it being understood that this device is to be capable of increasing the range to . . . 8,000 yards. The requirement of 6,000 yards minimum range is the lowest that will be considered as fulfilling the above services for the conversion of the two torpedoes *submitted for test and demonstration* [emphasis added].

The bureau argued that the torpedoes had not demonstrated their ability to meet the contract range and speed requirements.[87]

In his return volley a couple of days later, Davison tried a different approach. The bureau's intent in making the contract had been not to secure a torpedo of a particular range and speed, Davison argued, but to stimulate competition. The company had been "undoubtedly the first in the field with a device on [the wet superheater] principle [in fact it had not been first], as is shown by the dates of our patents," and its experiments had been the first to show the potential of wet superheating to increase speed and range. Because of its trail blazing in the field—not because of demonstrated ability to meet particular range and speed requirements—the bureau awarded a contract to the company. Davison had not worried about causing damage to the engines because his superheaters "were regarded as experimental and merely for the purpose of demonstrating to the Bureau what could be accomplished." Where the bureau argued that it had contracted for an ordinary developed commercial article, Davison was arguing that it had contracted for an extraordinary experimental one—exactly the same argument that the Bliss Company had made about early Bliss-Leavitt torpedoes. Given that the intent of both parties had been to show the device's potential rather than to achieve a specific performance, the Electric Boat Company "assumed that by delivering the torpedoes at Newport we had fulfilled our contract." If so, it was an unjustified assumption, because the contract explicitly called for demonstration after delivery. More justified was the company's assumption that the government, not itself, would bear the responsibility for making any demonstrations. "So far as the wording of the contract is concerned," Davison noted, "there is nothing which calls upon us to make any tests," and the company, knowing the risks and expenses of testing, would never have agreed to the contract if it expected to conduct the tests itself. The most that the bureau could require the company to help with was dynamometer tests; the idea that the company was responsible for open-water tests, which required an extensive supporting apparatus of boats, personnel, and ranges, was absurd. On February 11, 1913, however, the bureau informed Davison that it would not budge.[88]

Probably crossing the bureau's letter in the mail was a letter from the Electric Boat Company dated February 12 about the 21-foot Davison torpedo. The company had originally undertaken development of the two experimental Davison torpedoes in response to encouragement from the bureau, Davison explained, and with every reason to believe that if the torpedoes did well, the company would receive a large volume of orders. The 18-inch torpedo was nearly ready for test, but the company did not want to complete the 21-foot torpedo in view of changed market conditions: instead of competing on an open playing field, its 21-foot torpedo would be competing against an already successful model, the Bliss Company's. "We believe that, due to the conditions existing," Davison continued, "we rendered to the Bureau a real service merely by undertaking this work." Here he was implying, as he had with regard to the two converted Whitehead torpedoes, that his company's willingness to accept the contract, regardless of its torpedoes' performance, had stimulated competition that had led to the development of better products. This claim of indirect responsibility for the products of other companies was obviously problematic, but it was not absurd: as we shall see, a bureau official later admitted its force. Accordingly, Davison asked the bureau to compensate the company for the work it had done on the 21-foot torpedo, even though the company would not finish it; in return, the company would turn over its drawings, material, and patents associated with the 21-foot torpedo (excluding superheater patents) to the bureau for unrestricted use. Davison's proposal intrigued the bureau, which entered into exploratory negotiations with Davison in March 1913, but it still wanted Davison to complete the 21-foot torpedo.[89]

In April 1913, trials of the two converted Whitehead torpedoes resumed, and those of the 18-inch Davison torpedo began, at the Torpedo Station. In late July, having gotten disappointing results, the station suspended trials of all three. It recommended that the bureau give up on the two Whitehead torpedoes and send the 18-inch Davison torpedo back to the Electric Boat Company for more work.[90] Several days later, Davison sent the bureau a long letter reviewing his company's position on all four torpedoes. For the most part, he recapitulated familiar arguments, but he made a new and ominous point that hinted at a patent dispute in the offing. When the company had made the shop-license agreement for its wet superheater with the bureau in April 1912,

> the Bureau had no steam generator [i.e., wet superheater] working on this *principle* in sight. Since that time, the Bliss Company has developed a heater or steam generator which works virtually on the same *principle* and the Torpedo Station is now experimenting with a very similar device. Just how much assistance the knowledge of our generator was to the Torpedo Station, it is difficult to say, but it is a fact that experiments were not begun at the Torpedo Station until after our device had been made known to the Bureau [emphasis added].

In sum, he concluded, the company had spent a great deal of money to perform work of value to the bureau, and it did not wish to spend any more. Therefore, he asked the bureau to cancel the contracts for all four torpedoes after arranging to buy such work (drawings, materials, patents) on them as the company had produced, and to reconsider the shop-license agreement for the Davison superheater.[91]

The bureau promised to have the Torpedo Board take up the whole subject of contracts with the Electric Boat Company at its next meeting; in the meantime, it ordered experiments with the two converted Whitehead torpedoes, but not the 18-inch Davison torpedo, at the Torpedo Station to continue. Before the Torpedo Board had a chance to meet, one of the two converted Whitehead torpedoes sank, and the Torpedo Station halted testing. Davison was annoyed, complaining that the bureau had dealt "very harshly" with the company and repeating his arguments that the company deserved payment. The station and Davison were able to reach a temporary armistice, agreeing to run the remaining (i.e., unsunk) Whitehead torpedo several times in the dynamometer and the water. It managed a run of 27 knots for 6,050 yards, the first successful run by any of the company's four torpedoes, and the commander of the Torpedo Station was sure that the company would declare victory again and demand payment.[92]

In the midst of this brewing crisis over the company's four torpedoes, Davison touched off another one. On September 16, 1913, he forwarded the bureau a copy of an opinion by the Electric Boat Company's patent attorneys, Pennie, Davis, & Goldsborough.[93] Davison had sent the attorneys sketches of both the Torpedo Station's wet superheater and the Bliss Company's wet superheater, along with a sketch of his own wet superheater, and asked whether the former designs infringed the latter. The attorneys held that they did. Both the Torpedo Station's and the Bliss Company's superheaters "involve the *idea* of burning fuel with the air in a combustion chamber so as to produce products of combustion of high temperatures, and injecting water into the products of combustion to reduce their temperature and increase their volume [emphasis added]." Davison had applied for his first wet superheater patent, No. 1,030,080, in March 1909. The "primary object" of that patent was to produce a device that would generate the desired range and speed, with sufficient reliability and safety of operation, and the "characteristic idea" of the patent was to make the water and the fuel supplies mutually depend on the same source of pressure, subsidiary to the main air supply. "The patent contains specific claims, as is usual, for this refinement of the invention," the attorneys argued, "but it also contains broader claims which cover the underlying idea above stated."[94] This statement, that an idea could dominate specific claims, was absolutely crucial to the attorneys' case—and, as it turned out, highly dubious (it was also exactly the same argument that the government was making in its case against the Bliss Company). The attorneys acknowledged that, "[s]trictly speaking," the Bliss and Torpedo Station superheaters differed in certain mechanical details (for instance, which pressures governed the fuel and water supply), but they argued that these details were not "essential" to Davison's claims, which were not "limited" to these particular details. Therefore, it was "quite clear," they concluded, that the Bliss and Torpedo Station superheaters infringed Davison's patent. And so it was—as long as their claim that a general idea could be patented and held to dominate various arrangements of details went unchallenged.[95]

At the Torpedo Station, Williams was asked to comment on Davison's demand for royalties. To evaluate it, Williams had tried to learn about Davison's superheater work while at the station, but he had found it to be scarce

> due to the fact that Mr. Davison kept the records of his official investigations in a note book, which he took away with him when he was detached from the Torpedo Station. He had this notebook in his possession at a date not in the remote past. This notebook appeared to be of the type and grade furnished by the Government for the use of Officers at the time of Mr. Davison's tour of duty at the Torpedo Station.[96]

The implication, of course, was that Davison had stolen commodified information gained at government expense and used it in developing his superheater at the Electric Boat Company. His theft gave the government a claim to have participated in the development of his superheater even after he left the station.

On September 27, the Torpedo Board took the comprehensive look at the bureau's contracts with the Electric Boat Company that Twining had promised Davison in August. The board recommended canceling the contracts for the four torpedoes without penalty to the company, but it was unable to decide whether the company should be compensated for the work it had performed by purchasing its drawings, material, and patents. This question was "intimately connected" with the shop-license agreement covering the Davison wet superheater, "and in the consideration of this connection there arose questions of contract and patent law which the Board found itself unable to decide without the assistance of specialist attorneys." Notwithstanding this acknowledged lack of expertise, the board believed that "a true and equitable decision in regard to the rights in these matters can only be reached after a thorough judicial investigation"—i.e., by going to court—and it recommended that the bureau make no payments for the four torpedoes to the company until such an investigation of the superheater occurred. The bureau approved the board's report and communicated its decision to the Electric Boat Company, requesting a proposition that covered both the four torpedoes and the Davison superheater.[97]

While the bureau awaited the company's reply, *United States v. E. W. Bliss Company* went to trial in Brooklyn, New York.

Davison answered on November 18, 1913. Although the company disagreed with the bureau's view that the shop-license agreement could not be disentangled from other issues, the company was willing to agree to cancellation of the shop license and payment of a one-time lump sum for its superheater rights, as long as the lump sum was adequate. That is, the government could not merely reimburse the company for its expenses in developing the superheater; it also had to account for the sacrifice of income from potential royalty agreements with others. Given that the company considered the potential royalties to be large, the minimum lump sum that it would consider was $1.5 million.[98]

Davison sent another letter on November 18, 1913, that the bureau must have found even less pleasant. Having already given notice that the Electric Boat Company's patent attorneys considered the Bliss Company's and Torpedo Station's wet superheaters to infringe Davison's patents, Davison now demanded payment of royalties under the shop license of April 1912. He understood that the bureau doubted the validity of the company's claims, so he asked the bureau to obtain the opinion of the Commissioner of Patents himself. He included a statement of the company's position for transmission to the commissioner.[99]

In an endorsement for the department dated December 20, 1913, the bureau went straight at the company's key contention that a principle, as opposed to a particular mechanical arrangement, was patentable. If the "essential" "idea" of wet superheaters was to use a mixture of air, fuel, and water for motive power, then the first patent for a wet superheater was not Davison's, but one taken out by Hudson Maxim in 1900 (No. 641,787). The idea was also the same as the "principle" of the Gesztesy superheater, which both the bureau and the Bliss Company had learned about in the spring of 1908 from the *Revista Brazileira Maritima*. Thus, Davison had not been first in the US field of wet superheater development, contrary to his claims. Even if the date of Davison's claim was conceded, his responsibility had not been clear. At the Torpedo Station in 1906–1907, "[Davison] was in a position where it was his duty to obtain and use to advantage all information relative to the improvement of torpedoes," the bureau observed, "and he undoubtedly used much of the data and information obtained at the Torpedo Station in the development of the [wet superheater]"—information that, the bureau did not need to add, had been obtained at government expense. Despite the benefit of this information, talent, and capital, the Electric Boat Company had not been able to meet its minimum contract requirements, while the Bliss Company had succeeded. There were differences among the Davison, Bliss, and Torpedo Station superheaters, "and the question of infringement of the patents, in the opinion of the Bureau, can only be settled by the courts."[100]

Two weeks after firing off this broadside to the department, the bureau turned its epistolary guns on the Electric Boat Company. Davison's view that the government had benefited merely by the company taking on the contracts and stimulating competition, regardless of its failure to fulfill the contract, the bureau argued,

> can hardly be considered sound. Contracts were entered into with the Company, and depending on the success of the Company, both parties were supposed to benefit. Had the Company been successful, it would have been in the field with a torpedo presumably valuable enough to afford a good market for the Company's product and they [sic] would have profited accordingly. In other words, it was an ordinary business venture which depended for its reward on the skill, perseverance, and capital of the firm, and which, failing these necessary factors, might result in loss and this loss can not [sic] be borne by the Navy Department.

As for the company's offer to sell its superheater rights for $1.5 million, the government had to determine the validity of the patents in question before it could determine their value and therefore would take no further steps in the matter "until a careful legal investigation has made it clear whether the Company has any rights at stake."[101]

The author of this letter was Joseph Strauss, who had replaced Twining as chief of the bureau on October 21, 1913.[102] In writing to the Electric Boat Company, the novelty of Strauss's office may have affected his stance. If Davison's emphasis on the intent of the contracts was justified, then Strauss's unfamiliarity with the history of the contracts mattered. And if there was a learning curve for the bureau chief to understand the complexities of dealing with command technology, then Strauss's depiction of the contracts as "an ordinary business venture"—which, as Davison kept insisting, they were not—can be plausibly attributed to inexperience.

The dispute between the bureau and the Electric Boat Company over superheater rights contained a heavy dose of irony, if not hypocrisy, arising from the twisted menage-à-trois among the bureau, the Electric Boat Company, and the Bliss Company. To review, the government was accusing the Bliss Company of infringing Davison's balanced turbine patent, while the Electric Boat Company was accusing the government of infringing Davison's superheater patent in Bliss-Leavitt torpedoes, while the Bliss Company was accusing the government of infringing its Armstrong superheater patents in Whitehead torpedoes. On the Electric Boat Company's side, the irony was that the breadth of Davison's superheater patent claims, which he intended as a strength, could be turned into a source of weakness. The company had written its superheater patents with "sufficient scope to fully protect our interests"—in other words, not so much to describe the invention as constructed as to prevent others from patenting anything like it, which had been precisely the strategy Davison had followed in drafting his balanced turbine patent.[103] On the government's side, the irony concerned its argument about the patentability of principles. Even as it argued against the Electric Boat Company that a principle could not be patented (where it did not control the relevant patents), it argued against the Bliss Company that a principle could be patented (where it did control the relevant patents).

After receiving the bureau's refusal to purchase its superheater rights in January 1914, the company evidently disengaged for several months. On April 29, 1914—probably just a few weeks after the Bliss Company demanded the payment of royalties for the Armstrong superheaters used in the government's Whitehead torpedoes—Davison reengaged, tersely demanding payment of royalties under the shop-license agreement for the wet superheaters used in Bliss-Leavitt torpedoes purchased by the government.[104]

To counter the claim, Albert L. Norton, the bureau torpedo officer who had gathered materials for the balanced-turbine case, produced a seventy-seven-page memorandum. He spent the bulk of it analyzing the differences between Davison's and the Bliss Company's wet superheaters in excruciating detail. This was precisely the level of detail that the Electric Boat Company's attorneys had failed to engage because they believed that the general principle of Davison's superheater dominated the details, rendering them irrelevant. Based on his detailed review, Norton argued that "[t]he specific method" claimed by Davison as a novelty did not appear in the Bliss wet superheater and therefore the Electric Boat Company's claim for royalties on the Bliss superheater was invalid. Norton suspected, however, that the Electric Boat Company did not really care about the merits of the claim, but rather was using it "in order to force the Bureau of Ordnance to purchase certain material"—namely, the drawings, material, and patents associated with the two Davison torpedoes. As far as "the LEGAL rights" of the government were concerned, Norton recommended that the bureau not succumb to the company's ploy, but instead refuse to pay royalties, decline to buy the material associated with the Davison torpedoes, and cancel the contracts without penalty to the company. Norton continued:

> However there is another aspect to the situation, that is one of moral obligation or equity. Without doubt there is much in the claim of Mr. Davison that the undertaking of contracts by the Electric Boat Company spurred on other contractors to a more rapid development of a long range torpedo. Also it is a fact that the Electric Boat Company has expended a considerable sum (without recompense) in the development of their steam generator and their type of torpedo, including much of the valuable time of Mr. Davison.

There was "a middle ground" on which the Navy Department might meet the Electric Boat Company. The department could cancel the shop-license agreement; purchase the 18-inch Davison torpedo, which was finished but had not met its contract requirements; and buy the drawings and material associated with the unfinished 21-foot Davison torpedo. The price would be a lump sum not to exceed $50,000, and in exchange, the company would agree to quit its claims for royalties by assigning its patent rights to the government. If the company rejected this proposal made out of "moral obligation or equity," then the government should behave in accordance with its "LEGAL rights."[105]

On June 16, 1914, the department finally decided to cancel the Electric Boat Company's contracts, reserving its decision on penalties pending the bureau's negotiations with the company. The next day, Davison and Strauss met to negotiate. Among other things, Strauss probably proposed to buy the experimental torpedo material and patent rights for $50,000, as Norton had suggested, and he evidently invited the Electric Boat Company to undertake new contracts for torpedoes. On June 23, 1914, Davison replied that the invitation was "attractive"—and that whatever reimbursement the government paid for its experimental torpedoes would contribute to the capital necessary for the enterprise. He was unwilling to give up the company's superheater patent rights for a small lump sum, however, and insisted on the payment of royalties, though he was willing to renegotiate the terms of the shop-license agreement. No reply from the bureau was found, and on July 29, 1914, the company filed suit in the Court of Claims to recover royalties on the superheater used in Bliss-Leavitt torpedoes purchased by the government. The case would eventually go to the Supreme Court, which decided in favor of the government, but in the meantime, World War I began.[106]

New Directions

By late 1912, the Bliss Company was able to offer more or less reliable torpedoes in large numbers. Its trio of steam torpedoes—the 18-inch Mark VII, 21-foot Mark VIII, and 21-inch Mark IX—had many parts in common, meaning better standardization, and they were more mature when presented to the bureau than previous Bliss-Leavitt torpedoes had been. Perhaps the most telling evidence of their reliability was the fact that the Torpedo Factory switched from manufacturing Whitehead torpedoes (Mark V) to Bliss-Leavitt torpedoes (Mark VII) in 1913.[107] As evidenced by the lawsuits already discussed, however, these successes did not make the tension in the company's relationship with the bureau disappear.

The context for this tension was that the Navy's torpedo needs had been increasing exponentially. As shown in Figure 5.1, in 1910, the Bureau had ordered 161 torpedoes; in 1911, the number more than doubled to 331; in 1912, the number dropped slightly to 290; in 1913, the number rose to 329; and in 1914, the number more than doubled to 664. Since 1911 at least, supply shortages had restricted capital ships (which carried 21-inch and then 21-foot torpedoes) to only 75 percent of their full allowance. To bring them up to their full allowance, equip new construction, replace losses, and fill out a reserve, the bureau estimated in fall 1913 that 1,133 new torpedoes were necessary, the sooner the better. As frustrating as its experience in dealing with the Bliss Company had been, both want and need pointed to the Bliss Company's involvement in solving the problem. The bureau still preferred torpedoes with turbine rather than reciprocating engines, and no other supplier of turbine torpedoes had the necessary elasticity in its supply capacity. In 1912, after receiving contracts for a grand total of two torpedoes in 1911, the Bliss Company received contracts for 290 torpedoes—a 14,500 percent

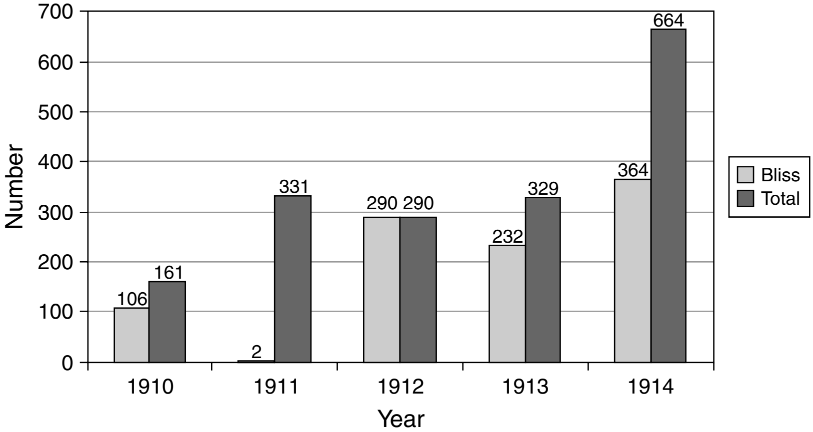


FIGURE 5.1 Torpedo orders.

increase. In 1913, its orders dropped slightly to 232, but the trend was only temporary.[108] To cope with these increases, Twining proposed a novel long-term agreement with the Bliss Company in 1913. It was agreed to in May 1914, but—"for some reason," the company's attorney put it in 1918, upon resuming the negotiations—it was never executed.[109]

The delay in executing the 1914 agreement likely resulted from Strauss's arrival at the bureau. Based on the dates, the agreement was clearly Twining's initiative. He was surely no great fan of the Bliss Company, but he may have resigned himself to dealing with it. Strauss brought with him no such resignation, and he swiftly accelerated or began four initiatives to reduce the government's dependence on the company.

First, Strauss sought to increase the government's own production by adding the Naval Gun Factory in Washington, DC, to the Torpedo Factory in Newport as a supplier. The roots of this policy went back to September 1913, within Twining's tenure, when the bureau informed the Torpedo Station that it would have the Gun Factory manufacture some torpedo parts, leaving final assembly to the station. In January 1914, however, after Strauss had arrived, the bureau ordered not just parts but 100 complete torpedoes from the Gun Factory. When Williams, the commander of the station, and his successor J. K. Robison, protested, Strauss shut them down.[110] He told Robison:

> Of course, I am thoroughly familiar with Williams' arguments, which were in line with your own, and have carefully considered them. While I think competition between the two plants will be an excellent thing, it is not the principal object that I had in view in allotting one hundred torpedoes to the [Gun Factory]. I have been for the last five months in consultation with the Bliss people and find that they are a most difficult company to do business with. They have practically had a monopoly of the torpedo business for twenty years, and as near as I can learn have resisted every attempt to advance until they have been forced to take a new step. Besides this, their prices are exhorbitant [sic]. I have been quite frank with them about it and have warned them that the eventual result will be that we will take over the entire manufacture of torpedoes ourselves. . . .
>
> As to competition:- that is a secondary matter but it is one not to be despised. I mean not only competition in price of product but competition in design, and it is quite possible that a new set of men at work on the same problem will devise schemes not thought of at the Torpedo Station.

Pointing to the relationship between the British Royal Naval Torpedo Factory and the Whitehead Company's Weymouth works as an example of how to achieve competition, Strauss observed that the American competition should be between the Torpedo Station and the Bliss Company. "Unfortunately, the latter firm has not displayed the right spirit," Strauss concluded, "and we must therefore get our competition from another source." The order to the Gun Factory stayed, and the government had two of its own plants in business.[111]

While Strauss's desire to bring the Gun Factory into torpedo production was primarily concerned with the manufacturing aspect of torpedo work, his second initiative dealt mostly with the design element. The context for this initiative was that the increase of manufacturing work at the Torpedo Station had forced it to neglect its experimental research from 1908 to 1912, while the Torpedo Factory first got up and running and then increased its output. Over the course of 1912, when the station actually had a slight decrease in orders from the previous year, it resumed experimental work on a larger scale, believing that improvements in design were unlikely "if dependence is placed solely on the ingenuity of the personnel of [the Bliss]

Company." By late 1913, it had unofficially evolved a department dedicated to experimental work.[112]

In November 1913, after taking over as chief of the bureau, Strauss called Williams down to Washington to consult about putting the experimental department on more formal and permanent footing. "There is demanded a systematic effort, through a considerable period of experimentation, toward the production of a service type of torpedo," Strauss declared, incidentally confirming that the bureau had not given up on the idea of developing its own alternative to the Bliss Company.

> [The Bureau] is aware that ideas have been advanced, worked with for a while, and then abandoned because the officer most interested had been detached and replaced by some other officer, and this does not pertain to the Torpedo Station alone but to all other places where the Bureau's activities take shape. The defect can not [sic] be cured by increasing the term of service of any officer, for the reason that the term might be prolonged beyond any reasonable tour of shore duty that the Department would be willing to assign any officer or perhaps that the officer would be willing to take. We are therefore compelled to rely on civilian assistance.

Strauss had been impressed by the experimental departments at two private firms, and he was convinced that the key to success was to free the department from any but experimental work. He authorized Williams to look for a suitable engineer to head the experimental department at the station and promised to try to find him additional draftsmen.[113]

It was not mere coincidence that Strauss looked to the private sector as a model for the type of experimental department he wanted to establish at the Torpedo Station. The late nineteenth and early twentieth century witnessed the birth of the private-sector industrial research lab. This new institution emerged partly in response to some of the same forces behind the emergence of McNeillian command technology. Much industrial technology was so sophisticated and expensive, and required such careful testing before it could be sent into large-scale production, that lone inventors increasingly lacked the resources to develop it by themselves. Just as private firms needed the help of governments in developing industrial weapons, so did some inventors need the help of firms in developing industrial technology. On the firms' part, the creation of industrial research labs was in part an attempt to control and strengthen an otherwise unpredictable and unreliable inventive process. Relying solely on new ideas to bubble up from outsiders might have worked in a preindustrial age, when inventors could bring well-developed inventions to firms, but in the industrial era, firms had to "command" inventions from the top down and from within, in much the same way that governments came to "command" weapons technology from the private sector and to treat firms as quasi–state agents. Industrialization had changed the nature of invention, and it evoked similar responses from both the private and public sectors.[114]

Strauss's initiative also suggests that government-sponsored big science, along with the iron triangle that existed among the military, industry, and academia, had its roots well before the archetypal example of the Manhattan Project. This is not to say that a small research lab at the Torpedo Station before World War I (or the Naval Radio Telegraphic Laboratory, established in 1908) remotely compares with the scale of World War II and Cold War government-sponsored research.[115] Rather, it is to propose that certain essential dynamics of this phenomenon predated World War I. They arose not only from the complexity of industrial science and technology, but also from government pay and promotion practices. Strauss needed people who could focus on long-term research and development projects, and the Navy's personnel system effectively prevented uniformed officers from playing that role.

In January 1914, Williams wrote to the presidents of Columbia University, Lehigh University, and the Massachusetts Institute of Technology, all of which had good engineering programs, to solicit applications for the new position. One applicant asked Williams to be "perfectly frank" with him about what the position entailed. "[T]he Government pays less for brains and more for hands than almost any other employer," Williams replied with the requested frankness.

> The experts which are employed by the Government at the low rates of pay, apparently find their compensation in the practically unlimited facilities for experimentation which are placed at their disposal, the opportunities for achieving distinction in their work, with its consequent prestige which, after being gained, places them in the position to consider offers from outside firms which are willing to pay high salaries for known efficiency.

Strauss found fault with each of the applicants, however, and decided that a freshly graduated college student would actually be better, so he kicked the can down the road until summer graduation season.[116]

By then, the third of Strauss's initiatives, namely, an effort to buy torpedoes from the Whitehead Company, was in play. In summer 1913, during Twining's tenure, the bureau had placed an order for two 21-inch and five 18-inch steam torpedoes from the Fiume branch of the Whitehead Company. These torpedoes had two distinctive features: a steam superheater designed by Gesztesy, and a two-cylinder engine designed by the Whitehead Company. In early 1914, Strauss began negotiating with the Whitehead Company for a much larger order. The outbreak of war in August, however, induced the bureau to end negotiations for fear that the company would not be able to deliver.[117]

The last of Strauss's initiatives met with a similar fate. In March 1914, he wrote to the De Laval Steam Turbine Company to ask whether it might be willing to design a new turbine engine as an alternative to the Curtis turbine used in Bliss-Leavitt torpedoes. After a flurry of letters, the De Laval Company concluded that the project was wrong for it:

> The cost of the development would be excessive and after the development is accomplished there is not a great volume of business to absorb this development charge. Further, we do not believe we could be assured of sufficient business to warrant the risk of assuming this development.[118]

A better illustration of McNeill's thesis about "command technology" would be difficult to find. As though to underline the wisdom of the De Laval Company's risk assessment, the Bliss Company sued the government to recover superheater royalties two months later.

Unlocking New Angles

On top of legal headaches, naval-industrial tensions, and the development of the steam torpedo, the bureau also had to deal with promising but disruptive changes in gyroscope technology during this period. Until 1909, the bureau used the Leavitt gyroscope in Bliss-Leavitt torpedoes and the Obry gyroscope in Whitehead torpedoes. The former was capable of angle fire; the latter was not. The Moore gyroscope, an air-driven gyroscope capable of angle fire, had been unceremoniously put into storage in 1908, where it stayed for almost three years, a testament to the limited R&D resources at the Torpedo Station and to the necessity of a robust experimental section to handle long-term projects as later desired by Strauss. In February 1911, Mark Bristol, the station commander, dug a Moore gyroscope out of storage, apparently on his own initiative, and ran it eighty times on the gyroscope stand. It performed very well. Without actually running it in a torpedo, Bristol and the bureau agreed that it should be put in the seventy-five hot-air Whitehead torpedoes (Mark V Mod. 3) then being manufactured at the Torpedo Factory.[119]

The Moore gyroscope (by then known as the Mark II Mod. 2 gyroscope) went into just the seventy-five Whitehead torpedoes and some old hot-air Bliss-Leavitt torpedoes.[120] Other Whitehead torpedoes received updated versions of the Obry gyroscope, which had a spring impulse and ball bearings but was not capable of angle fire, while the new Bliss-Leavitt steam torpedoes received Leavitt gyroscopes, which had air impulse and ball bearings and were capable of angle fire.[121]

Notwithstanding this capability, the Navy lacked fire-control mechanisms that could exploit it. As of 1914, the latest directors were the Mark VI and Mark VII, which were based on the same principles as the Cone-Davison Mark IV director.[122] On at least one occasion, the bureau rejected a device for plotting and computing the correction for angle fire on the grounds that the errors it sought to correct were "so small" in comparison to those arising from incorrect estimates of target course and speed and from variation in the speed and deflection of the torpedo that it was not worth the added complication. In 1913, the Torpedo Station allowed that such a device would become necessary "when the Fleet seriously considers curved fire"—the implication being that it had not done so yet.[123]

Gyroscopes made targeting more difficult in another way. As torpedo ranges lengthened, the effects of delays in the unlocking of the gyroscope grew more serious. The unlocking interval, as it was known, referred to the period between the torpedo's launch and the assumption of control by the gyroscope. Officers had known that the unlocking interval was a source of error for targeting purposes as early as 1903, but as long as ranges remained relatively short, there was little reason to worry.[124] Increasing ranges increased concern. Imagine a straight-shot torpedo that deflects 1° from its intended line of fire during the unlocking interval: at a range of 1,000 yards, it is only 17.5 yards from its point of aim; whereas at a range of 10,000 yards, it is 174.6 yards (or more than the length of a battleship) from its point of aim. In 1910, when the U.S. Navy's most modern torpedoes had a range of roughly 4,000 yards but the Torpedo Board called for steam torpedoes with a range of 10,000 yards, torpedo officers embarked on a three-year effort to shorten the unlocking interval. Their quest was mostly unsuccessful, foundering on the complexity of the changes that would have to be made to gyroscopes and firing tubes, and on the lack of cooperation from the Bliss Company, which had no incentive to make changes that were unnecessary for passing torpedo acceptance tests.[125]

Tactics and the 10,000-Yard Torpedo

The significance of errors like deflection was not fixed but depended on the tactical circumstances in which torpedoes would be used. Although tactics in the five years before World War I remained a contested subject, many ideas rooted in previous years developed further. One was the realization that growing torpedo ranges could transform destroyer missions. William Sims, then commanding the Atlantic Torpedo Flotilla, predicted that the 10,000-yard torpedo would make destroyers an "essential element of daylight battle." Instead of firing their torpedoes at short range in surprise nighttime attacks, destroyers would fire them during battle at ranges beyond which "any gun can be expected to make more than occasional chance hits against such small targets." The War College and the General Board agreed.[126]

Indeed, their bullishness on destroyers armed with long-range torpedoes led them to kill permanently F. H. Schofield's plan for a torpedo battleship, which enjoyed a brief revival with the advent of steam torpedoes. Sims argued that the 10,000-yard torpedo made Schofield's vessel more rather than less desirable: because the torpedo battleship could fire torpedoes from longer ranges, it would need less armor to protect itself from enemy gunfire and could use the weight saved to achieve greater speeds.[127] Although the War College disagreed, reasoning that destroyers could do the same job at less cost, Sims's was not a voice in the wilderness.[128] The so-called battle-cruiser proposed by officers at the 1909 War College conference looked more like Schofield's torpedo battleship than like the archetypal British battle-cruisers. In fact, at least one US officer expressed puzzlement at the Royal Navy's practice of making guns rather than torpedoes the primary armament of battle-cruisers.[129] To him, battle-cruisers seemed like the ideal vessels for the fast-wing tactics first envisioned several years earlier, in which a detached wing with greater speed than the main column would attempt to cap the enemy line and rake it with torpedoes.

Together, the tactical ideas contemplated in response to the long-range torpedo portended a revolution in the metrics of naval power. As Sims wrote in 1911,

> [W]e know very little of the relative fighting value of the battleship or cruiser as opposed to the number of the smaller vessels that could be built for the same money. In this connection, I mean the relative fighting value under the conditions of a modern battle—that is, which would under these conditions, [sic] be able to inflict the most damage on the enemy's fleet, the large vessel or the number of small vessels that could be built at the same cost?[130]

In considering Sims's question, bear in mind that the battleship's gunnery target was a single small vessel, whereas the destroyer's torpedo target was a formation of ships stretching for several miles, and that a torpedo hit likely would do significantly more damage than a shell hit. If a 700-ton destroyer armed with long-range torpedoes could sink a 20,000-ton battleship armed with 12-inch guns from outside the battleship's effective gunnery range (which was limited not so much by the physical range of the guns as by their targeting systems), was it smarter to use the same sum of money to buy one battleship or multiple destroyers? Stripping the battleship armed with the heavy gun of its status as the defining standard of naval power, Sims proposed to treat it simply as a unit of power. From this perspective, different vessels could substitute for the battleship, as it were.

While Sims's vision shows the willingness of US officers to rethink naval power in fundamental ways, it also reflects their failure to grasp certain limiting factors. Despite the proximity of the Torpedo Station and the War College, torpedo specialists communicated very little with tactical thinkers. The result was that many officers were ignorant about the technical characteristics and performance capabilities of US torpedoes, as attendees at the 1910 War College conference admitted.[131] This ignorance manifested itself in several ways. For instance, officers showed no awareness that enabling destroyers to attack at long range during a daylight battle would compromise their ability to make short-range attacks at night.[132] Because of the lack of multispeed reducers (or multiple turbine engines for the same torpedo), destroyers carrying long-range/low-speed torpedoes could not carry short-range/high-speed torpedoes for nighttime attacks. In any case, the US Navy was woefully short of destroyers because it had not ordered any between the *Truxtun* class of 1899 and the *Smith* class of 1906.[133] Similarly, command-and-control weaknesses would likely have prevented the use of fast-wing tactics. Year after year, War College conference attendees lamented the primitiveness of signaling techniques then available, which restricted the fleet to simple column tactics; controlling a wing detached from the column presented far greater challenges.[134] Thus, far from responding to torpedo development too cautiously, US officers tended to respond too enthusiastically, without fully appreciating how technological realities might limit tactical theory.

Ill-equipped to exploit the long-range torpedo itself, the US Navy was also vulnerable to long-range torpedo attacks by its enemies. As many officers realized, the fleet had far too few destroyers to defend its capital ships. The capital ships showed little ability to defend themselves: in experiments conducted in the winter of 1910–1911, their torpedo-defense batteries failed to cope with the high change-of-range rate that ensued when cruisers (which were larger targets than destroyers) employed fast-wing tactics.[135] Because capital ships carried their big guns on the centerline, they had to fight with their broadsides exposed to the enemy in order to bring their heaviest gunfire to bear, meaning that they presented a much larger target for torpedoes than they would have fighting bows-on.[136]

Presenting such a target made it all the more important for US capital ships to fight outside torpedo range, but they conducted gunnery practices only at distances inside torpedo range. The danger zone of a 10,000-yard, 26-knot torpedo was actually much larger than 10,000 yards. For instance, during the 11.5 minutes a 26-knot torpedo took to cover 10,000 yards, a 20-knot fleet advancing toward it would cover 8,000 yards, thus giving the torpedo an effective range of 18,000 yards, nearly twice its physical range.[137] In battle practices conducted from 1912 to 1914, however, US capital ships fired their big guns at a maximum range of only 11,760 yards.[138] After studying the first Anglo-German battles of World War I, US officers concluded that the prewar US Navy had underestimated battle ranges by some 5,000 yards.[139] Thus, the US Navy most likely could not have achieved decisive gunnery results in battle without exposing its capital ships to torpedo fire.

While the performance of US torpedoes improved during this period thanks to the invention of the wet superheater, the performance of naval officials lagged. The same pattern that characterized the bureau's dealings with private industry from 1903 to 1908 repeated itself from 1909 to World War I. Instead of learning from earlier mistakes in dealing with the Bliss-Leavitt torpedo, for instance, bureau officials repeated them in dealing with the double reducer and blundered into a second dispute over superheater rights, despite clear and prescient warnings from the commander of the Torpedo Station. Although these errors were made by ordnance specialists, they dragged the entire US government into three lawsuits, two of which (the balanced-turbine case against the Bliss Company and the superheater case against the Electric Boat Company) went to the Supreme Court. Remarkably, the government took opposite positions in these two cases—in one, defending the patentability of principles; in the other, challenging the patentability of principles—yet managed to win both. In so doing, the bureau displayed persistent disregard for private intellectual property rights.

As if the legal headaches associated with command technology were not enough, the bureau also had to confront difficult technological and tactical challenges. The best propulsion system was of little use if the torpedo could not be aimed accurately, and the same dazzling ranges enabled by the steam superheater created new targeting problems because the gyroscope unlocking interval had more serious consequences. Many officers attempted to coordinate tactical thought with changing torpedo technology, but they failed. Hampered by poor communications with torpedo specialists, and needing to understand myriad technical issues in order to generate sound tactics, they simply did not know or lost sight of some details—like the implications for destroyer missions of lacking a multi-speed reducer, which in any case would have forced the turbine engine to run inefficiently at speeds other than those for which it had been designed. In tactics as in the lawsuits, decisions made by ordnance officers years earlier had far-reaching repercussions that would have been difficult to detect at the time they were made.

6

A VERY BAD GAP IN BRITAIN

"[W]e are left with a very bad gap in the torpedo armament of the Navy."

—HMS *Vernon*, 1914

In July 1914, the Admiralty planned to convene a conference at Spithead. A wide array of strategic and tactical issues, such as "Position of Battle Fleets in war time with reference to employment in the North Sea" and "General consideration of the duties of Battle Cruisers," was considered for discussion.[1] The July crisis and ensuing outbreak of World War I meant that the conference did not happen, but what is striking in reading over the agenda is the range and importance of topics that were up for debate because they remained unsettled. World War I caught the Royal Navy in a state of flux. Its lack of agreement on so many subjects reflected not stupidity or lack of effort but the difficulty of the problems it confronted—problems that were often created by past solutions. The long-range torpedoes using Hardcastle's superheater were a case in point: although itself a great success, the steam superheater was merely a system among systems and required a number of auxiliary technologies to exploit its full potential, generating as many questions as it answered.

The 21-inch Mark I torpedoes with Hardcastle superheaters tried by the Navy in 1908 were limited to a length of 18.5 feet so that they could fit in existing torpedo tubes. The increase in length to 22 feet for the 21-inch Mark II torpedoes allowed a 34 percent increase in the weight of air carried. The Navy ordered four Mark II torpedoes in 1909 and experimented with them in 1910; it was sufficiently confident of success, and desirous of permitting manufacturers to accumulate material in advance, to order 224 Mark II torpedoes in 1909, before the four experimental torpedoes had been tried. As it turned out, depth-keeping problems at speeds above

45 knots prevented the projected speed of 50 knots from being attained, and the greater air charge of the Mark II was used to attain a 2,500-yard increase in range, but not an increase in speed, over the Mark I. The approved speeds and ranges for the Mark II were 45 knots for 4,500 yards and 28–29 knots (depending on whether the torpedo was fitted for submerged discharge) for 10,000 yards. Despite the slightly disappointing speed performance, the 21-inch Mark II was the Navy's first 10,000-yard torpedo.[2]

Notwithstanding the impressive speed and range of the converted and heated torpedoes, two problems bedeviled them: poor direction keeping and poor depth keeping. The converted 18-inch Mark VI** H torpedo suffered from zigzagging (but not depth-keeping problems), while the heated 18-inch Mark VII and VII* torpedoes and both 21-inch torpedoes displayed bad depth taking and depth keeping (but not zigzagging).[3] (Depth taking referred to a torpedo's ability to "take" its proper depth at the beginning of its run, while depth keeping referred to its ability to "keep" its proper depth over the course of its run.) The culprits behind the problems with the two 18-inch models were solved in a series of experiments from 1909 to 1911.[4]

Problems with the 21-inch torpedoes proved more intractable. One issue—the torpedoes' tendency to break the surface and remain on it after discharge—was solved in 1911 by increasing the clearance of certain pivots in the balance mechanism by a mere 0.02 inches. "This cure, though somewhat unscientific," the *Vernon* sheepishly admitted, "has proved most efficacious."[5] It was also a remarkable example of mechanical miniaturization and precision engineering. A more fundamental problem remained, however. The ignition of the superheater caused a rapid acceleration of heated torpedoes shortly after discharge, rendering proper adjustment of the depth mechanism very difficult, the torpedoes liable to rise or dive sharply upon discharge, and recovery of their proper depth unlikely. To solve the problem, the *Vernon* began experimenting in 1911 with a depth gear known as the Ulan gear (so named after its inventor) but could not get it to work satisfactorily and stopped trying in 1914. At the same time, the *Vernon* began experimenting with a new type of valve for the depth mechanism. Although it worked well in an 18-inch torpedo in 1911, it was not perfected for 21-inch torpedoes until 1912, whereupon it was approved for both diameters. Evidently it was not a complete success, however, because British torpedoes suffered serious depth problems in the first year of the war.[6]

The propulsion system of British torpedoes remained fairly stable. The design of the Hardcastle superheater experienced only minor upgrades.[7] Strikingly, engine technology changed little, despite the much higher heat to which the engines of heater torpedoes were subjected. The Director of Naval Ordnance reported to his successor in 1909 that after 35,000 cumulative yards of running, the engine of a heated 18-inch Mark VII torpedo was in perfect condition except for cracks to the engine belt, which did not interfere with the efficiency of the engines. The most serious problem to arise from the high heat was damage to the springs controlling various engine valves. To address this problem, the *Vernon* began experimenting in 1913 with a new type of engine valve, but the experiments were not completed before the war. Notwithstanding these issues, a telling measure of the Navy's satisfaction with its reciprocating engines was the *Vernon*'s quick rejection of a "well thought out" design of a combined generator (i.e., combustion chamber) and turbine engine.[8]

On the eve of the war, the Navy began to introduce new versions of its 18-inch and 21-inch steam torpedoes. The 18-inch Royal Naval Torpedo Factory (RNTF) Mark VIII was a heated, high-speed, short-range torpedo designed especially for submarine use, capable of making 41 knots for 1,500 yards and 29 knots for 3,000 yards. Additional versions of the 21-inch Mark II entered service, up to the Mark II***, which had a slightly higher air pressure than the original Mark II, increasing its range at 29 knots from 10,000 yards to 10,750 yards. The Navy put a 21-inch Mark III torpedo capable of making at least 11,700 yards (if not 13,000 yards) at 29 knots through preliminary trials before deciding to postpone its introduction, and this torpedo apparently never entered service. In its place, the Navy developed the 21-inch RNTF Mark IV torpedo, which entered service in 1916. By that time, the Navy had decided that the 10,000-yard range setting was useless, and so the 21-inch Mark IV was given settings of 45 knots for 4,500 yards and 25 knots for 15,000 yards.[9]

Angle Fire

The Royal Navy had begun experimenting with an angled gyroscope capable of curving the torpedo from its initial line of fire in 1907, but the effort faltered. As discussed in Chapter 1, a significant implication of the angled gyroscope was that it allowed large surface ships to fire their torpedoes from fixed submerged tubes regardless of helm. The significance of angled gyroscopes was even greater for submarines, at least in theory. Until the E-class submarines of 1912, Royal Navy submarines carried fixed torpedo tubes only in the bow and stern, not on the beam; in contrast, ships carried at least two fixed tubes on the beam, in addition to a stern tube. A vessel that carried tubes on three of four sides was more likely to get a shot than one carrying tubes on only two of four sides; if the former had to turn to bring a tube to bear on the target, it would probably have had to turn through a smaller angle than the latter to do so. To compound the difficulty, submarines were more difficult to maneuver than surface ships. Thus, submarines had a greater need for a device that would obviate the need to maneuver.

At the initiative of the submarine service, the Navy directed its first attempts at developing angled gyroscopes in 1907 toward submarines rather than surface ships. Trials showed that three experimental designs were unsuitable for submarines, however, due to the large and unpredictable "advance" of the torpedo along its initial line of fire before the gyroscope began to curve it. Because submarines fired torpedoes at short ranges—no more than 1,500 yards, and usually closer to 500 yards—from their targets, a large and unpredictable advance would have left them uncertain about whether a torpedo would complete its curve and steady itself on its ultimate course before reaching its target. Because ships fired at longer ranges, however, a large and unpredictable advance was less problematic, and therefore the Navy turned to trying the angled gyroscope from ships.[10]

Before trials on a ship occurred, the Navy began investigating the possibility of a barless training (as opposed to fixed) tube as an alternative to the angled gyroscope. Dispensing with the bar (illustrated in Figure 6.1) was a prerequisite for building a submerged training tube. In addition, the officer commanding the Navy's submarines, Sydney Hall, saw that barless discharge was necessary for broadside tubes on submarines, probably because they lacked the space for a motor to run the bar in and out. He regarded the advantages of broadside discharge for submarines as "enormous" and so "obvious" that he did not identify them, but he undoubtedly had in mind the fact that broadside tubes would require submarines to maneuver less to get a shot and would allow them to attack from other directions than bows-on, which required them to turn at least eight points to make their escape.[11]

Experiments with barless discharge in 1909 and 1910 were sufficiently promising that the Admiralty convened a conference in May 1910 to

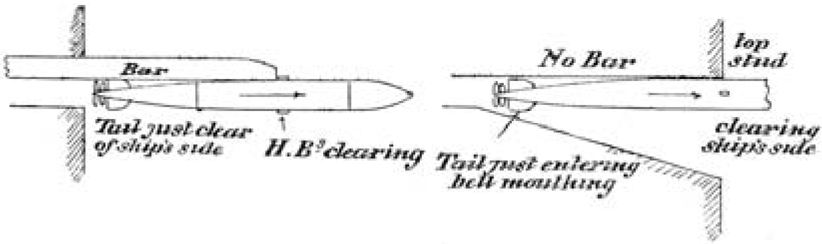


FIGURE 6.1 Bell-mouthing torpedo tubes (*H.B.* stands for "hook brackets"). (Annual Report of the Torpedo School [H.M.S. *Vernon*], 1910, p. 40, ADM 189/30, The National Archives, Kew, England)

discuss the design of a barless training tube. The key change for a purpose-built barless tube was bell-mouthing. In a typical tube, the bar guided the torpedo as it left the tube, preserving its trim and preventing its after-end from clanging against the mouth of the tube. In a barless tube, higher impulse pressures could compensate for the lack of a guide bar to some degree, but a bell-mouth gave the torpedo a larger margin for error in losing its trim as it left the tube (see Figure 6.1). Aside from bell-mouthing, the conference also decided that the barless tube's arc of training should be 35° before and 20° abaft the beam. It requested authorization for the Portsmouth navy yard to design a tube embodying these features.[12]

Before approving the conference's request, the Controller, Admiral Sir John Jellicoe, asked for an update on the development of the angled gyroscope, which was clearly an alternative to the training tube. In spring 1910, the *Vernon* had carried out trials of an angled gyroscope capable of curving the torpedo at angles of 10°, 20°, 30°, and 40° from its initial line of fire. The trials were successful, the Assistant Director of Torpedoes informed Jellicoe, but even so, he wanted to proceed with the design of a training tube because he was not sure that angled gyroscopes could be used in very high-speed torpedoes. His uncertainty probably related to the poor direction keeping and depth keeping of some early high-speed heater torpedoes, discussed above. In any case, Jellicoe approved the idea of a barless training tube, and the order went out to Portsmouth Yard in August 1910.[13]

In December, the *Vernon* reported that the design was ready and asked for a conference, which was held in March 1911. The participants proposed a number of modifications to Portsmouth Yard's design and asked for £10,000 to manufacture a prototype. The First Sea Lord, A. K. Wilson, quashed the idea. "The object to be attained by the training tube has been, to some extent, met by the successful trials of the angled gyro," Wilson wrote. "I do not think the probable advantages are sufficient to justify the expense of proceeding further with these trials for which the £10,000 now asked for would only be the first instalment [sic]." Despite protests, Wilson refused to budge, and so the idea of a barless training tube died.[14]

The fine performance of the angled gyroscope doubtless helped to kill it. A further round of successful trials in November 1910 persuaded the *Vernon* to recommend the limited issue of angled gyroscopes to ships for seagoing tests. When these occurred in 1912, they vindicated the Admiralty's faith in the device, and it was approved for all torpedoes intended for submerged discharge from ships. The only further significant change to the concept of the angled gyroscope before the war was to reduce the gradation of the angles from 10° to 5°. The Admiralty did not reverse its 1907 decision against fitting angled gyroscopes to submarines' torpedoes.[15]

The adoption of angled gyroscopes was not the only major development in gyroscope technology during this period. In 1907, the same year that the Navy began experimenting with angled gyroscopes, it also began experimenting with air-driven gyroscopes. Distinct from purely spring-driven gyroscopes, in which the gyroscope wheel received a powerful initial impulse but no subsequent impulses, air-driven gyroscopes relied on a spring for the initial impulse but then on air to accelerate and maintain the velocity of the wheel's rotation. The Navy likely began investigating air-driven gyroscopes for fear that spring-driven gyroscopes could not provide a sufficiently long spin time for heated torpedo runs. Air impulse enabled a higher rotational speed than the spring alone, thereby increasing the gyroscope's directive power. Continued experimentation with air-driven gyroscopes led to the selection of a Royal Gun Factory (RGF) over a Whitehead Company design in 1911 and its wide-scale adoption in 1912, at the same time as the Admiralty approved the adoption of angled gyroscopes. The relative safety of air-driven gyroscopes compared to spring-driven gyroscopes also allowed the *Vernon* finally to end its decade-long search for a gyroscope safety gear.[16]

In addition to its work with air-driven gyroscopes, the Navy experimented with air-spun gyroscopes. Whereas the latter received both its initial and subsequent impulses from air, the former received its initial impulse from a spring and only subsequent impulses from air. The chief appeal of the air-spun gyroscope was that it could cause the gyroscope to start spinning more quickly than a spring impulse. In the 1909 experiments with barless tubes discussed previously, the *Vernon* discovered that torpedoes fired from a moving ship deflected 1° to 2° abaft their line of fire before their gyroscopes gained sufficient rotational speed to take over.[17] This unpredictable but small deflection mattered little when ranges were short, but it doubtless became a concern as ranges lengthened due to heater torpedoes. The Navy's desire to develop a barless tube also must have lent urgency to its quest for a faster gyroscope release.

The *Vernon* first tested an air-spun gyroscope designed by the RGF in 1910. The new Royal Naval Torpedo Factory (RNTF) took over the RGF's work in 1911, and the manufacture of experimental air-spun gyroscopes was approved in 1912. When tried in 1913, however, they were not a success, and further trials were suspended due to the pressure of other work. Nevertheless, the *Vernon* managed to salvage one idea from the air-spun attempt, namely, the early release of the gyroscope to take up its proper direction. By reducing the size of a gyroscope part called the driving sector, the *Vernon* was able to shorten the time lag between the start of the torpedo and the release of the clutch that held the gyroscope in place. Gyroscopes with their driving sectors reduced were known as short-release gyroscopes. They reduced the average horizontal deviation at 2,000 yards by more than half, and the short-release feature was approved for future air-driven gyroscopes in 1913.[18]

Supply and Demand

The advent of converted and heater torpedoes posed procurement and allocation challenges: What vessels would get the new weapons? Tactical assumptions determined the answer. Destroyers firing torpedoes at shorter ranges against single ships needed higher speeds to minimize the effects of errors in estimating enemy course or speed; capital ships fired torpedoes at longer ranges against an enemy formation and therefore could afford greater errors in estimation. Thus, converted 18-inch heated torpedoes whose engines could not withstand the high speeds enabled by superheaters were issued to capital ships rather than destroyers. The heated 18-inch Mark VII and VII* torpedoes, whose engines were designed to withstand higher speeds, went to torpedo craft. The short 21-inch Mark I torpedoes went to the *Beagle*-class destroyers of the 1908–1909 building program because their construction was too far advanced to allow the lengthening of their tubes to take the 21-inch Mark II torpedoes first ordered in fiscal year 1909–1910. For the time being, submarines, which fired their torpedoes at very short ranges, continued to be supplied with cold 18-inch Mark V* torpedoes adjusted to run 1,000 yards at 32.5 knots.[19]

The large-scale conversion of cold torpedoes to heaters had begun in fiscal year 1908–1909, when money for 100 conversions was appropriated. Half of these conversions were of the much inferior 18-inch Fiume III** torpedo, useless for destroyers due to its limited speed and useless for ships due to its limited 4,000-yard range (run at only 21 knots). Thus, only fifty conversions were left over for the much superior 18-inch RGF Mark VI* torpedo, also useless for destroyers due to its limited speed but useful for ships due to its 6,000-yard range at roughly 29 knots—although it was believed in early 1908 that the maximum range of the converted RGF torpedoes was only 3,000 yards. In February 1908, the Admiralty approved a proposal by the Director of Naval Ordnance to expand the program for converting RGF torpedoes in order to supply the Navy's forty-five large ships with two converted torpedoes each. As a result, the number of conversions increased sharply from fifty Mark VI* conversions in fiscal year (FY) 1908–1909 to 196 Mark VI** conversions in FY 1909–1910.[20] This increase was borne solely by the RGF: although the Whitehead Company as well as the RGF built heater torpedoes of RGF design, only the RGF carried out conversions of RGF torpedoes, and the RNTF was not yet up and running.[21]

In April 1909, the Director of Naval Ordnance, Reginald Bacon, proposed another major expansion of the conversion program.[22] Bacon believed that the advent of long-range heater torpedoes would force capital ships to fight within torpedo range and thus obviated the need for fire-control systems that could enable longer gunnery ranges; in part for that reason, and in part because he distrusted mechanization (despite his technical expertise), he supported Frederic Dreyer's gunnery fire-control system over Arthur Pollen's.[23] Observing that the Navy had heated torpedoes "very superior, so far as is known" to foreign ones, and that converted torpedoes on ships would be "invaluable for use during a fleet action, and would give us a very great advantage over our possible enemies should they only possess 4,000 yard torpedoes," Bacon suggested a five-fold increase in the allowance of converted torpedoes, from two to ten per ship, going all the way back to the pre-*Dreadnought* battleships of the *King Edward VII* class and including the three *Invincible*-class battle-cruisers.[24]

Obstacles stood in the way of expanding the conversion program, however. The money for converting old torpedoes was the sum left over after spending for new torpedoes, and the new heated 18-inch and 21-inch torpedoes had turned out to be more expensive than anticipated, leaving little money available for conversions. Unless the pace of conversion increased, Bacon informed his colleagues, the expanded scheme would require seven years for completion. To increase the pace without providing additional money in FY 1909–1910 would throw the brunt of the work on FY 1910–1911, more than could be handled that year. Therefore, Bacon requested an additional £20,000 to spend in FY 1909–1910. His request was approved, with the First Lord, Reginald McKenna, adding that he should raise the matter again as soon as the supplemental £20,000 was spent. The expansion and acceleration of the conversion program increased the burden on the RGF.[25]

Increases in the allowance of new heated torpedoes added to the RGF's burden. In December 1908, the Assistant Director of Torpedoes, Bernard Currey, had proposed that, because of the greater effectiveness of heated over cold torpedoes, ships with two broadside tubes should carry the same number of torpedoes that they had carried when they had four tubes, and that destroyers should carry at least two instead of one torpedo per tube. Calculations by the Director of Naval Construction revealed that battleships of the 1908–1909 and 1909–1910 programs and destroyers of the 1909–1910 program could carry enough tubes and torpedoes that the Navy would need almost double the previous number of torpedoes to outfit new construction.[26]

In addition to the increase in torpedo allowances to vessels, in November 1911, the new First Lord, Winston Churchill, advocated that the Navy's torpedo reserves be brought up to full establishment. In reply, Bacon's successor as Director of Naval Ordnance, A. G. H. W. Moore, suggested that their allowance be increased, agreed that the reserves for destroyers be increased, and further proposed that the allowance for future destroyers (i.e., the 1911–1912 *Acasta*/K class) be increased from six to eight. Due to the difficulties of expanding production, Moore planned to prioritize the *Acasta* class before turning to the allowance of older destroyers and even then to limit the increase to destroyers carrying 21-inch torpedoes. Based on Moore's estimate that 100 torpedoes would be required for this program, the Superintendent of Ordnance Stores calculated that the proposed increases would cost £131,200, plus an extra £43,000 if the increased allowance was to include destroyers of the 1912–1913 program (the *Laforey*/L class). In March 1912, the Admiralty approved the increases for both the 1911–1912 and 1912–1913 classes.[27]

In September 1912, the new Director of Naval Ordnance, F. C. T. Tudor, broached the topic of reserves and allowances again. Hoping to expand the allowance increase to include older destroyers once the new ones were outfitted, Tudor proposed that all destroyers back to the 1908–1909 *Beagle* class receive the same increase from six to eight. In addition, he proposed to increase the allowance for submarines from seven to ten for each pair of tubes, plus an extra 6 percent for replacements, to create a 10 percent general reserve for ships and destroyers, and then to increase the 18-inch torpedo allowance for *Tribal*- and *River*-class destroyers from six to eight. The Financial Secretary, noting pointedly that only one of Tudor's proposals—the increase for the *Beagle* class—had been contemplated in the March 1912 increase, calculated that Tudor's program would cost £470,500 (nearly one-quarter of the cost of a 1911–1912 *Iron Duke*–class battleship). Even so, in November 1912, the Admiralty approved the program in its entirety, except that it set the general reserve at 5 percent instead of 10 percent.[28]

A major dislocation in the supply base exacerbated the potential impact of these several increases in demand. The Navy's torpedo factory was then in the middle of moving 450 miles from the RGF in Woolwich to the new RNTF in Greenock. The Admiralty seems to have underestimated both the difficulties involved in the transfer and the ability of its existing supply base to meet demand. In late 1909, the Director of Naval Ordnance had predicted that only a month of production would be lost as a result of the transfer, but the effects were still being felt years later, and the RNTF did not begin production until late 1910 or early 1911.[29]

These delays doomed a proposal made by the commander-in-chief of the Home Fleet (Admiral George Callaghan) in 1912 to rearm capital ships back to *Dreadnought* with 21-inch torpedoes in lieu of 18-inch torpedoes. "It would be practically impossible to get these additional 21-inch Torpedoes within a reasonable period," the Superintendent of Ordnance Stores wrote, "in view of the large orders to be placed, and of the fact that we are limited to two sources of supply," namely, the Whitehead Company and the RNTF. The Assistant Director of Torpedoes agreed that the supply shortage was the "chief objection" to Callaghan's idea, "although no doubt it would be advantageous."[30]

The supply situation also handicapped the Navy's efforts to carry out realistic long-range torpedo practice. Fleet torpedo practice was not designed to simulate real battle conditions. Tactical fleet exercises were more realistic, but they forbade destroyers from firing torpedoes and required them to fire lights indicating a hypothetical launch instead of torpedoes for fear that the destroyers would be unable to recover their torpedoes in the confusion inherent to a tactical exercise. In August 1912, Callaghan informed the Admiralty that he wanted to carry out exercises in which destroyers "browned" the battle-line with real torpedoes, rather than merely firing lights to indicate when torpedoes would have been fired, "in order that actual and not merely suppositious [sic] results may be arrived at."[31] The cheeky commander of one of the destroyer flotillas in the Home Fleet chimed in: "In view of the fact that the Battle Practice of a Battle Ship costs about the same as a 21 inch Heater Torpedo and that we accept this expenditure by the Battleship without comment, why not accept a percentage loss of Torpedoes and write them off annually whether they are lost or not?"[32]

The Admiralty had a different perspective. The effect of losing a torpedo, observed the Director of Naval Ordnance, Tudor, was "not directly commensurate with the money value of the torpedo." With the factories at full output, if torpedoes were lost in practice, it might not be possible to complete the torpedo outfits of new construction, let alone to complete recently approved increases in the reserves. Tudor proposed a compromise: half of the participating destroyers could fire lights, as usual, while the other half could fire their torpedoes to run a fraction of the range to the battle-line, and follow them to recover them.[33]

Callaghan was having none of it. "[I]t is not considered that satisfactory results could be obtained in the manner proposed," he informed the Admiralty. "Whenever torpedoes are fired they should be fired to hit; little value can be placed on calculated results, the data for which would, at best, be unreliable."[34] The Admiralty refused to budge, however. While "generally" concurring with his argument, the Admiralty thought it "perhaps not altogether applicable" to the situation at hand. Because destroyers were almost as fast as torpedoes, observing their action in following their torpedoes would indicate whether their torpedoes would have crossed the track of the enemy battle-line. Observations thus gained could be collated with data gained from fleet practice, which showed that the probability of striking a ship between the van and rear of the battle-line roughly equaled the proportion of ship space to water space. Then the overall probability of hitting a ship in a browning attack by destroyers could be calculated, presumably by multiplying the probability of a torpedo reaching the target area by the probability of it striking a target if it reached the target area.[35] The reliability of the Admiralty's method seems doubtful, however, because the destroyers would have followed their torpedoes only 2,500 yards or so, leaving another 7,500 yards over which the torpedoes' course would have been projected, not actual. Though more realistic than having all destroyers fire lights, the compromise of having half the destroyers fire their torpedoes over part of the range was hardly as realistic as having all destroyers fire their torpedoes over the whole range, not least because it failed to account for the possibility of the target altering course to avoid the torpedoes. The results would still have to be "calculated," to use Callaghan's term, but instead of placing "little value" on them, both Callaghan and the Admiralty seem to have placed a good deal of value on them (see below).

Finally, the supply shortage hampered efforts to develop realistic expectations about the control of torpedo fire in action. In late 1912 or early 1913, the Inspector of Target Practice proposed firing torpedoes during gunnery battle practice, as the results "up to date point to the necessity of more opportunities of combined firing of guns and torpedoes being afforded." The Director of Naval Ordnance, Tudor, was open to the idea as long as adequate arrangements for recovering torpedoes could be made, but Jellicoe, back at the Admiralty as Second Sea Lord, doubted that adequate arrangements were possible and proposed to defer combined gun-and-torpedo battle practice until the torpedo reserves were in a better condition.[36] The potential significance of this lost opportunity is discussed below.

Torpedo Settings and Tactics

In April 1912, the Director of Naval Ordnance, Tudor, sparked a debate by suggesting a series of readjustments to torpedo speed and range settings. This debate is worth following in some detail because it reveals the extraordinary complexity of a seemingly narrow technical matter and because it provides insight into the tactical assumptions of present and future fleet commanders on the eve of war. Tudor's proposals were as follows:

- changing converted torpedoes' single adjustment (low speed/long range) to a dual adjustment (adding lowest speed/extreme range)
  - long range (actual): 6,000 yards at 29 knots, for 18-inch Mark VI***
  - extreme range (proposed): 10,000 yards at 22 knots, for 18-inch Mark VI***
- changing heated torpedoes' double adjustment (high speed/short range and low speed/long range) to a triple adjustment (adding lowest speed/extreme range)
  - short range (actual):
    3,000 yards at 41 knots, for 18-inch Mark VII*
    3,500 yards at 45 knots, for 21-inch Mark II
  - long range (actual):
    6,000 yards at 29 knots, for 18-inch Mark VII*
    10,000 yards at 28 knots, for 21-inch Mark II
  - extreme range (proposed):
    10,000 yards at 22 knots, for 18-inch Mark VII*
    12,000 yards at 22 knots, for 21-inch Mark II[37]

While Tudor's proposal made the rounds ashore, of particular interest are the replies received from the Navy's premier battle fleet, the Home Fleet. Jellicoe, the future commander of the wartime Grand Fleet, was then commanding the Second Battle Squadron, which was effectively the Home Fleet's tactics-development unit. Jellicoe argued against any extreme-range setting at only 22 knots. He feared that such slowness would make the allowable error in estimating target course and speed too small, and it would give the target too much time to take evasive action during the torpedo's run. His ideal torpedo would have dual adjustments for short range of 4,500 yards at 45 knots and long range of 10,000 yards at 30 knots. He did not want the short-range setting to exceed 5,000 yards, meaning that any potential increase in the torpedo's power should go toward increasing the speed up to that range. He opposed building single-adjustment torpedoes of different patterns for ships and destroyers not only because it would make supply and distribution more complicated, but also on the tactical grounds that ships might find the high-speed setting at 4,500 yards "of great value" in certain circumstances. This tactical rationale is significant because it lends support to the thesis, discussed at greater length below, that Jellicoe envisioned taking a fleet well within enemy torpedo range, and it suggests that Jellicoe contemplated not only a decisive gunnery advantage at medium ranges but also firing a torpedo salvo before turning away.[38]

For the same reasons as Jellicoe, the commander-in-chief of the Home Fleet, Callaghan, agreed that the proposed extreme-range setting for 21-inch torpedoes was undesirable, and he therefore opposed the triple-adjustment idea. Callaghan doubted that 18-inch torpedoes with the present 6,000-yard long-range setting would be useful to ships, on the grounds that battle fleets would close to so short a range as 6,000 yards only late in an action, by which time the equipment needed to aim torpedoes would have been wrecked by gunfire. He suggested rearming all capital ships back to the *Dreadnought* with 21-inch torpedoes capable of 10,000 yards; as discussed above, this proposal foundered on the supply shortage. As for the short-range settings, Callaghan thought that the 4,500-yard/45-knot setting of the 21-inch Mark II would be useful to ships in dark or misty weather, but that the 3,000-yard/41-knot setting of 18-inch Mark VII* torpedoes would have too short a range to be useful to ships. Destroyers would need the short-range setting on 18-inch torpedoes, however, so he recommended keeping it for the sake of interchangeability and redistribution in later years. The Admiralty accepted Jellicoe's and Callaghan's recommendations to stick with the double-adjustment system and to seek increases in speed at present ranges rather than increases in range.[39]

Torpedo Fire Control

The application of the superheater and the angled gyroscope to torpedoes greatly increased their potential tactical utility—but the theoretical ability to hit meant little without an effective targeting system. While gunnery targeting in this period has received careful attention from historians, torpedo targeting has not. The following section represents an exploratory effort to outline the parameters of a complex and difficult problem that merits further study.

The Navy basically had three different types of vessels capable of delivering torpedo attacks (putting aside the vexing question about the role of scouts and light cruisers): capital ships, destroyers, and submarines. As a general rule, capital ships were expected to fire their torpedoes at long range in a browning attack against the enemy battle-line, destroyers were expected to fire their torpedoes at medium range against single ships, and submarines were expected to fire their torpedoes at short range against single ships.

These expectations were not set in stone, however. For example, as already mentioned, Jellicoe contemplated capital ships firing torpedoes at medium range. A proposal to outfit submarines with heated torpedoes capable of covering medium ranges was put forward after the 1912 maneuvers.[40] Perhaps most controversial of all was Callaghan's idea of using his destroyers to make a long-range browning attack, which provoked an energetic debate at the Admiralty.[41] Uncertainty over what vessels would attack what targets at what range must have made the procurement of equipment for aiming torpedoes very difficult.

Even without knowing the precise conditions of use, there was clearly a trade-off between firing against single ships at short range and browning attacks at long range. On the one hand, the small size of a single-ship target made targeting more difficult. On the other hand, the shorter range in the case of single-ship targeting facilitated observation and estimation of target course and speed, and reduced the probability that errors in estimating the target course and speed would cause a miss. Therefore, both single-ship and browning attacks could reasonably claim the greater need for accuracy in targeting; whether one had a greater claim than the other could be determined only by a more thorough investigation of the effects of error under various conditions of attack than the present work can undertake.

The Navy's basic equipment for torpedo targeting remained the director. When the director was mounted directly above the tube, the range of the target did not have to be known. When the director was mounted away from the tube, however, the range had to be known in order to account for parallax between the tube and the director. The correction for parallax was applied on an extra piece of the director called the tangent bar, which changed the line of sight. Other required input data for the director were the speed of the torpedo, the speed and course of the firing ship, and the speed and course of the target. Of these, the easiest to get was the speed of the torpedo, which (assuming uniform speed) was a known constant. The firing ship's course was the next easiest, and then the firing ship's speed, but keep in mind that the ease of ascertaining and transmitting the firing ship's speed was changing in the period under discussion.[42] The Navy did not acquire an electric log (the Forbes speed log) for continuously measuring the firing ship's speed until roughly 1912.[43] The speed and course of the enemy had to be either estimated by direct observation or calculated from a plot representing at least two observations. The former was easier because, aside from the inconvenience of having to make a calculation, plotting required knowledge of the range. The equipment for finding, keeping, and transmitting the range to various control positions in the vessel was also changing.

The introduction of the angled gyroscope complicated the director and required additional input data, especially when the director was not mounted directly over the tube. All directors for use with angled gyroscopes were changed to swivel around a central pillar through the angle for which the gyroscope was set. Allowing for angle fire in directors mounted away from the tubes was more difficult, requiring more calculations and additional input variables. One was the torpedo's turning radius, which in theory was the same for all torpedoes within the same mark and was found by experimental running at the torpedo ranges, but in practice could vary within the same mark due to the eccentricities of individual torpedoes. The significance of this variation in terms of causing error is unclear. Another input variable was the distance that the torpedo traveled from the tube before beginning its turn, also known as the advance. This distance varied with the impulse pressure used to discharge the torpedo from the tube, so that, in theory, it was a known constant for a given impulse charge. It might be assumed that variation in this constant could not have been a significant cause of error, given that the advance must have been small compared to the remaining distance covered by the torpedo on its way to the target. Recall, however, that the reason for the Navy's abandonment of the angled gyroscope for submarines was the impossibility of allowing "with sufficient accuracy for the large and variable advance" of the torpedo along its initial line of fire.[44] In any case, a table could be organized by firing angle for each director position showing the adjustments that needed to be made to the tangent bar, one of which varied with the range and another of which did not.[45]

Error could creep into the torpedo targeting process at a number of points. For all directors, whether mounted directly above or at a distance from the torpedo tube, errors in estimating the firing ship's speed or the target speed and course would cause the torpedo to be fired too early or too late. These errors also affected directors mounted away from the torpedo tube, as did errors in estimating the target range, or deviation by an individual torpedo from the supposed constants of advance and turning radius. Any of these miscalculations would have thrown off the tangent-bar setting and the line of sight, again causing the torpedo to be fired too early or too late.

In addition to errors in estimating and inputting data, there was also potential for errors in transmitting data. Unless the transmission of the data was automated, there was bound to be a time lag between the generation and receipt of data, during which the accuracy of the data might degrade. In addition, the manual transmitter (that is, a human being) might make a mistake. As the instruments for acquiring data like range and bearing for the sake of gunfire became more effective, the temptation to use the same data for torpedo purposes must have grown. The needs of gunnery and torpedo fire control were at odds in at least two ways, however. To fire torpedoes from fixed submerged tubes on the correct bearing without angled gyroscopes, it was necessary to turn the whole ship—but it was practically impossible to maintain accurate gunfire during a turn. In theory, Arthur Pollen's Argo Clock Mark V of 1913 might have offered a way out of this dilemma by providing the Royal Navy with helm-free gunnery fire-control equipment, but the Navy chose not to adopt it.[46]

Moreover, although the angled gyroscope allowed torpedoes to be fired from fixed submerged tubes without turning the whole ship, it exacerbated the competition for skilled fire-control personnel.[47] In 1910, a conference was held at the Admiralty to determine the fire-control arrangements of future armored ships, after which the Director of Naval Ordnance circulated a list of the personnel needed to man the armored tower in which the torpedo as well as gunnery targeting instruments were located. He provided just one officer for torpedo purposes, to man the director. Effectively, this one officer was responsible not only for adjusting the director but also for acquiring the input data needed to adjust the director and for working the telegraph that sent the correct gyroscope angles to the torpedo tubes. If he wanted to acquire input data from the gunnery instruments instead of by direct observation, he had to work a phone to the transmitting station where gunnery data was collected and calculated. To perform the same collection, calculation, and transmission functions for gunnery purposes, at least a dozen men were provided. Even if adequate personnel for torpedo control had been provided, the Royal Navy would have had to conduct practice sessions in conjunction with their gunnery counterparts to make them effective, practice that the Royal Navy was unwilling to undertake because of the same supply shortage that prevented Callaghan from carrying out long-range destroyer exercises.[48]

One way to avoid these problems was to develop instruments for ascertaining the input data needed for the torpedo directors—target course and speed—especially for torpedo purposes instead of relying on hand-me-downs from the gunnery equipment. The first serious attempt to develop such an instrument for torpedo purposes was a so-called speed-and-course-of-enemy indicator, which was designed by a midshipman named Macnamara in 1906. The instrument did poorly in trials at first, but the *Vernon* reissued it in modified form for trial at sea.[49]

Officers in the battleship *Bellerophon* reported unfavorably on the modified Macnamara indicator in 1910. Target bearings could not be taken from the instrument itself but had to come from the compass, the application of the bearings was limited, and the bars for representing the firing ship's speed and the enemy's course sometimes fouled each other. As a plotting instrument, the indicator was "rudimentary." In a sweeping statement, the *Bellerophon*'s officers argued that

> a separate plotting system for torpedo work is necessary, as the most suitable ship to fire torpedoes in action is not necessarily, or usually, the one the guns are firing at; this plotting system should be self-contained, *i.e.*, independent of range-finders used for gunnery purposes, and the necessary staff for working it should be at the torpedo officer's disposal.[50]

It is noteworthy that this proposal came from a capital ship instead of a destroyer. Although the target for capital ships in a browning attack was very large—a battle-line could stretch for miles—the officers of the *Bellerophon* evidently felt that a better system than estimating target course and speed by eye or relying on gunnery instruments for the data was needed.

To create such a system, the Navy experimented with a number of instruments before the war. In 1912, an officer named A. M. Y. Brown proposed a partial method for adjusting the director called deflection plotting. From the scant details given in the *Vernon*'s annual reports, it seems that deflection referred to the angle at which the director's sight bar was fixed relative to the bar indicating the path of the torpedo, rather than to its gunnery meaning of rate-across. If so, then the goal of plotting the deflection was presumably to find the slope of a line connecting the plotted points corresponding to the rate at which the deflection was changing to be able to predict the correct deflection during periods when direct observation of the target was impossible. Deflection plotting may also have been an attempt to get around the need for knowing the range. The idea of using plotting for torpedo control, instead of relying exclusively on observations of target course and speed, indicated dissatisfaction with existing methods for predicting the target's location (position keeping). Another officer, W. M. James, invented a combined deflection-plotting board and slide rule so that the necessary deflection could be read directly off the board. A third officer, B. E. Reinold, invented a system for automatically setting James's instrument with data obtained from a range finder, gyrocompass receiver, and the Forbes speed log. James's and Reinold's ideas indicated a desire to mechanize and automate the process of torpedo control.[51]

In its annual report for 1913, the *Vernon* made its first attempt at laying out a comprehensive policy for torpedo fire control. Its important statement deserves to be quoted at length:

> The advantages of deflection plotting, notably its simplicity, have led to its very general adoption in the Fleet in one form or another. A considerable number of methods of ascertaining the director angle or deflection, and of applying them when found, have been proposed from various quarters.
>
> In some cases these consist of means for finding the bearing rate [i.e., the rate at which the target bearing changed] to be afterwards [used as the basis for calculating other necessary data]; in others, instruments are used which aim at eliminating even the small amount of calculation involved in that process.
>
> There is no doubt that, in action, calculations of any kind by the use of slide rules or otherwise, will be extremely liable to error; consequently methods which avoid calculations, provided they are sufficiently accurate, are much more likely to be successful.
>
> The majority of these [non-calculating] methods, however, rely for their accuracy on the taking of two observations of the bearing of the enemy, with a time interval between. With the present facilities for taking bearings, even in ships fitted with gyro compasses, the accuracy with which bearings can be taken is much too small for two observations only to give results of any value; though in certain cases a spurious accuracy is attained by

> the failure to realise the exactness requisite in taking bearings, more particularly at long ranges.
>
> Thus in these [non-calculating] methods, accuracy is sacrificed to simplicity.
>
> Several proposed methods obtain accuracy at the cost of unwieldiness or obvious impracticability under the conditions likely to obtain in action.
>
> These attempts at dealing with the problem continue to show the necessity for automatic means of finding the enemy's course and speed, director angle, or deflection, if the accuracy of the means of controlling torpedo fire is to be commensurate with the accuracy attainable with the weapons themselves.

In the *Vernon*'s opinion, the combined deflection plotter and slide rule invented by James fell short of requirements: it could not give any more accurate results than a series of bearings taken with existing equipment, and it, like any form of slide-rule calculator, would be difficult to use in action.[52]

More promising, from the *Vernon*'s perspective, was a device invented by an officer named J. R. Middleton for automatically indicating when torpedoes should be fired; it did not need manual calculations to find the bearing rate or to derive the deflection from the bearing rate. It consisted of hand gear for training a telescope to keep on the target. The hand gear was connected to a shaft that turned a roller, which in turn rotated on the surface of a disk driven at constant speed by a motor. The roller took up a position at the center of the disk proportional to the rate at which the hand gear was turned. A mechanical calculator in two parts calculated the total deflection due to the bearing rate (which reflected changes in both the firing ship's and the target's course and speed) and the deflection due to the course and speed of only the firing ship; the two deflections were added or subtracted depending on whether the target was drawing ahead or astern, and each had a pointer. A gyrocompass receiver worked on a differential gear in the telescope rod to eliminate the effect of the firing ship's yaw. The input data necessary for the calculator were the speed of the firing ship, the torpedo speed, and the mean range. Once the data were entered, the operator kept the telescope trained on the enemy by turning the hand gear, firing when the pointers on the two parts of the calculator came into line and rang a buzzer.[53]

The ingenious disk-roller arrangement at the heart of Middleton's device was known as a variable-speed drive. These drives exploited the fact that objects at different distances from the center of a rotating disk move at different speeds: an object on the outer edge of a rotating disk turns through a larger distance than one closer to the center in the same amount of time. Variable-speed drives had been a staple of gunnery fire-control instruments since 1906. The idea of using hand gear to tune the variable-speed drive was very likely borrowed from gunnery fire-control equipment designed by Frederic Dreyer, and it was surely no coincidence that the Navy asked the same firm, Elliot Brothers, which built Dreyer's equipment, to manufacture prototypes of Middleton's. The prototypes were still being constructed when World War I broke out.[54]

Neither Middleton's device nor deflection plotting offered a way to determine the range at any given moment or to predict (i.e., keep) the range. The *Vernon* noted that the only way to achieve range keeping was to know the rate at which the range was changing (the range rate), but it considered the range rate less important than deflection, "particularly as it is probable that in many cases in action torpedo fire will be directed at ships in a line at which gun-fire is being directed, so that data obtained by the gun control using all rangefinders which are intact will be available for both purposes."[55] For reasons already discussed, the assumption that gunnery data could be used for torpedo purposes was probably too sanguine.

The Navy experimented with other methods for determining deflection based on the bearing rate. One was a gyrostatic bearing plate worked off the training gear of the range finder for torpedo control; another was a sophisticated slide rule, known as a dumaresq, that was modified for torpedo purposes. A third possibility was to keep the target on a constant bearing, but that method was difficult with existing compasses and made the firing ship an easy gunnery target.[56]

When the war broke out, most ships lacked any such instruments beyond extemporizations, and the only equipment being readied for new ships was the two prototypes of Middleton's device, which offered no guarantee of success.[57] The situation was "very far from satisfactory," the *Vernon* and the commanders of the Grand Fleet agreed.

> It goes without saying that any ship having long-range torpedoes should have something better to set directors by than estimation. Rate of change of bearing [i.e., bearing rate] is as important

> to the Torpedo Officer as rate of change [i.e., range rate] is to the Gun Officer, yet while the latter is supplied in every ship with a complete set of instruments for determining this, the Torpedo Officer gets practically nothing even in ships fitted with the gyro compass.
>
> In the ordinary course of events the whole matter would have in due course solved itself, the various extemporised instruments at sea being gradually evolved and eliminated until a satisfactory instrument was found. The outbreak of war has completely knocked this process on the head and we are left with a very bad gap in the torpedo armament of the Navy.[58]

This "very bad gap" would bear further study.

War Plans and Battle Tactics

For many years, scholars broadly agreed on the Navy's tactical thinking and war plans before World War I. Their consensus, which rested on the work of Arthur Marder, had several features. Marder argued that, tactically, the Navy was dominated by the desire for centralized command-and-control, a rigid battle-line, and the achievement of gun and torpedo fire superiority by capping the enemy line ("crossing the T").[59] As for war planning, Marder claimed that the Navy planned to conduct amphibious operations and to establish a blockade of the German coast, in support of which it planned to seize a base in the North Sea.[60] This interpretation of naval tactics and strategy fit into a broader understanding about the origins of World War I, army–navy relations, and British grand strategy. The plans' orientation to the North and Baltic seas, rather than the Mediterranean Sea or the Atlantic and Pacific oceans, emphasized the centrality of the German threat, rather than imperial defense, in the Admiralty's thinking. The implausibility of the plans' expectations—that the Germans would come out to fight, and that amphibious operations could work—demonstrated the strategic ineptitude of the Admiralty and helped to explain why Britain opted for the War Office's plan for the continental commitment. So too did the inability of blockade to deliver fast results in the expected short war. The navy's strategic failures could be blamed on its unwillingness to develop a serious planning staff, which contrasted unfavorably with the army's establishment of the Imperial General Staff. Taken together, the naval war plans suggest that the root cause of the war was the Anglo-German antagonism, and that the Admiralty failed to offer a credible short-war alternative to the continental commitment.[61]

Recent scholarship has offered a comprehensive and more persuasive alternative, based on more sophisticated conceptualization and greater command of the relevant archives. At the operational and strategic levels, there were at least three other emerging strands of policy, largely complementary but not dependent upon each other. One was a return to Fisher's ideas about flotilla defense in home waters, driven mainly by concerns over the difficulty of operating a battlefleet in the North Sea. In the 1913 maneuvers, Callaghan's blue fleet failed to bring Jellicoe's red fleet to battle; Callaghan concluded from the experience that a battlefleet stationed off the northern coast of Scotland could not defend the east coast of Britain without sweeping so far south into the North Sea as to expose itself to unacceptable risk from torpedo craft and mines. Instead of redeploying the battlefleet, the Admiralty opted to strengthen the flotilla defense of the east coast.[62]

The second emerging strand of policy was the "substitution policy," which was driven primarily by financial considerations. It referred to the replacement of battleships by flotilla craft. When Churchill became First Lord in 1911, Fisher tried to convince him that a combination of battlecruisers and flotilla craft could fulfill the Navy's missions more effectively and more cheaply than could battleships. Churchill was impressed, but his professional naval advisers did not endorse Fisher's views, and financial necessity did not yet compel him to abandon a battleship-based standard of construction. He therefore proceeded temporarily with a conventional, battleship-centered strategy. By late 1913, however, Britain's financial outlook was again darkening, and in the well-known estimates crisis of January 1914, Churchill promised to reduce the Navy's budget for 1915 in return for getting the budget he wanted in 1914. The only way he could achieve cuts of the necessary magnitude was by substituting flotilla craft, chiefly submarines, for battleships. Churchill later described this substitution policy as follows:

> I immediately resumed my plans for converting two of these ships into a much larger number of smaller vessels. I proposed to treat these dreadnoughts not as Capital Ships but as units of power.[63]

In so doing, Churchill was prepared to take the revolutionary step of redefining Britain's naval construction standard in terms of more than battleships. His professional advisers, bowing to financial necessity, were prepared to take this step with him. In 1914, the Admiralty began to implement the substitution policy, but the outbreak of war complicated its execution.[64]

The third emerging strand of Admiralty policy was something known as "economic warfare," which arose from changes in the global economic system. Contrary to Marder, the Admiralty did not believe that the only methods of applying naval power were battle, amphibious operations, and blockade. The only type of blockade recognized under international law was close blockade, and as officials then and historians since have realized, the advent of torpedo boats and submarines made close blockade suicidal. Indeed, the Royal Navy had abandoned the idea of a close blockade by 1889 (except for a brief resuscitation of the idea during Arthur Wilson's tenure as First Sea Lord from 1910–1912, to the horror of the rest of the Navy).[65]

Historians have assumed that the Royal Navy responded to the demise of close blockade by deciding to move its blockade farther away from the enemy coastline, where capital ships would be less vulnerable to surprise torpedo attack, but in fact, key decision makers had given up on the idea of blockade altogether. For one thing, distant blockade was of questionable legality under international law. For another, the notion of blockade—whether close or distant—depended on eighteenth-century commercial practices that had ceased to exist by the late-nineteenth century. To work, the system required ownership of a vessel (and the corresponding papers) to imply ownership of its cargo; a belligerent would board the vessel, ask to see the papers (which identified the origin and ultimate destination of the vessel and cargo), and send the vessel to prize court if it was headed for an enemy port. But trade did not work that way by the turn of the century. Instead, thanks to the transformation of credit practices and communications, ownership of a particular cargo might change hands multiple times during a vessel's voyage, while a vessel might not decide on its ultimate destination until it approached within wireless range of a coast and learned where it could fetch the highest prices for its cargo. Thus, the papers that a vessel carried no longer accurately reflected ownership of the cargo or its ultimate destination. How then was a blockading vessel to know whether or not to send a merchant vessel to prize court?[66]

Because it could not know, the Royal Navy developed a new plan for applying economic pressure known as economic warfare. In its assumptions, aims, and methods, it differed fundamentally from blockade. Perhaps the most important difference was that blockade was a long-war strategy, whereas economic warfare was a short-war strategy. It was premised on the twin beliefs that modern industrial, capitalist economies could not survive a long war, but that the British economy could weather a war better than the German economy could thanks to Britain's dominance of global finance, trade, and communications. The plan therefore sought to hasten Germany's descent into the economic abyss (and accompanying social revolution) while insulating the British economy from the worst effects. The method was to deny Germany access to British capital markets and merchant shipping. Britain owned close to 80 percent of the world's ocean-going merchant shipping capacity (not the much lower 45 percent figure that is usually cited).[67] Without having to bother with international law, Britain could use Orders-in-Council and municipal law to prohibit British ship owners from carrying cargo to Germany. Stripped of access to British credit and shipping capacity, German trade would dwindle to almost nothing.

At a meeting on December 6, 1912, the Committee of Imperial Defence (CID) endorsed the Navy's economic warfare—not the Army's continental commitment—as the cornerstone of British grand strategy in the event of war. This meeting, not the better-known one on August 23, 1911, was the key CID meeting before the war; significantly, there were nine cabinet ministers at the December 1912 meeting, but only six at the August 1911 meeting. In a major constitutional innovation, the prime minister predelegated authority to the Admiralty to take steps to implement economic warfare upon the outbreak of war without coming back to the cabinet for permission.[68] It may be urged, by way of argument, that only the full cabinet, not the CID, had constitutional authority to determine British grand strategy. But it must be remembered that if the full cabinet had not authorized economic warfare, neither had it authorized the continental commitment.[69] The Admiralty had a far stronger case than the War Office to claim the approval of the political executive for its plans. Thus the Admiralty did offer a credible short-war alternative to the continental commitment, and Britain chose the former.

Although the strategy of economic warfare did not envision a decisive battle with the German fleet in the North Sea, the Navy could not ignore that possibility. Agreement on how to fight such a battle was elusive, however, largely due to the disruptive effect of torpedoes. Some officers advocated the use of destroyers offensively against the enemy fleet; others wanted destroyers confined to a defensive role protecting their own fleet. Some wanted to adopt divisional tactics (in which the fleet operated in divisional units instead of in a single line); others thought that limits on existing command-and-control capabilities made divisional tactics foolish. Some proposed to deal with the torpedo threat by fighting at very long ranges or by maneuvering; others had different ideas.[70]

The most imaginative solution came from Jellicoe.[71] The problem with fighting at long ranges or with maneuvering to avoid torpedoes, Jellicoe realized, was the inability to achieve decisive results with existing gunnery fire-control capabilities. Arthur Pollen's fire-control system might have allowed the Navy to achieve decisive results under such difficult conditions, but in 1910, the Admiralty decided to adopt Frederic Dreyer's fire-control system instead of Pollen's. Dreyer's system was cheaper, but its general performance was inferior to Pollen's. It could not cope well with the high and changing change-of-range rates (hereafter simply range rates) that fleets engaging and maneuvering to avoid torpedoes would encounter. Nevertheless, it had some attractive features for dealing with easier conditions. Improved range finders, introduced in 1912, enabled more accurate range observations to be taken, which could then be plotted on paper. The range plot could be averaged quickly to produce a number called the mean range-finder range of the moment. From the range plot, a range rate could also be estimated. If the range was changing, the mean range-finder range of the moment could be fed into a machine (a clock) that used the estimated range rate to generate the estimated range at any given moment, and this estimated range could be used to set the gun-sights. The estimated ranges were automatically plotted on paper, where they could be checked against a plot of observed ranges, and the clock could be adjusted manually if the two plots did not coincide. The combination of the plotting system with the clock was known as the Dreyer Table.

When ranges were within 10,000 yards, which was the effective limit of the new range finders, and when the range rate was not changing, the combination of the improved range finders and the Dreyer Table could produce ranges so accurate that only one or two shots to check the range (ranging shots) were necessary, after which the fire became so accurate that continuous spotting to check the fall of shots was unnecessary. The system of setting the sights from the Dreyer Table without continuous spotting, based on the mean range-finder range of the moment, was known as range-finder control. Guns had to fire in simultaneous salvos (i.e., not independently) if spotting was necessary because the splashes from independent shots made spotting impossible; obviating the need to spot meant that the guns could fire independently, rather than in salvos, and as rapidly as possible. This method was known as rapid-independent fire. If the gun-layers could also overcome wave action, roll, and yaw to keep their guns continuously on the target (a method known as continuous aim), then they could, in theory, maintain a devastating fire.

To work, the system depended on several conditions. The enemy had to be visible and within 10,000 yards so that the range finders could take accurate initial ranges. The seas had to be calm enough, or the mechanical training of the guns adept enough, to keep the guns continuously on the target. Finally, the enemy fleets had to be steaming more or less in straight lines in the same direction (though not necessarily parallel) so that the range rate was not changing rapidly, because the Dreyer Table could not generate sufficiently accurate ranges when the range rate was changing rapidly. But the need to steam on a straight line within 10,000 yards of the enemy raised serious problems from a torpedo perspective: one's own fleet would be highly vulnerable to a browning attack from the enemy. How could the Royal Navy achieve decisive results given the limitations in its gunnery without intolerably exposing itself to long-range torpedoes?

Beginning in 1912, Jellicoe developed a novel answer to this question. At the start of an engagement, the British fleet would rapidly approach the enemy fleet. During this phase, the range rate would be high, and neither fleet would have the gunnery fire-control capabilities to inflict serious damage on the other. Once the British fleet reached medium range, it would turn onto a course parallel with the enemy so that the range would be constant. (The British expected the Germans to engage in similar tactics.) While the courses were parallel, the guns would adopt range-finder control and rapid-independent continuous-aim fire to inflict decisive damage on the enemy fleet. Given existing torpedo speeds of 30 knots for 7,000 or more yards, an eight-gun broadside, a heavy-gun firing interval of 30 seconds, and accurate initial range observations, the British fleet would be able to steam on a parallel course for five to eight minutes, during which time each heavy gun would be able to make twenty-four to thirty-eight hits. Before the browning torpedoes inevitably fired by the enemy could reach the British fleet, it would execute a simultaneous turn-away and simply outrun the torpedoes. Even if torpedoes managed to reach the British line after the turn-away, it would be in line abreast, offering its ends rather than its broadsides, which would greatly reduce the probability of torpedo hits.

In these ways, torpedo development strongly influenced Jellicoe's tactical ideas. The lack of careful scholarly investigation into German tactical thinking makes it impossible to assess with any confidence whether Jellicoe's expectations about German battle tactics were correct when he developed them. It is true that they proved not to match German tactics during the war, but no one has asked whether the mismatch was due to British countermeasures, a question that would need to be answered before criticizing Jellicoe for lack of foresight. German torpedoes (which also possessed steam superheaters and angled gyroscopes) were roughly equivalent to British torpedoes at this time, and it is suggestive, though not conclusive, to note that German capital ships carried several more torpedo tubes than their British counterparts.[72] But to focus on German intentions or Jellicoe's assessment of German intentions is to miss the broader point: if German torpedo capabilities were even remotely comparable to British capabilities, then the Royal Navy (like every other navy) faced the fundamental problem of determining how to achieve decisive results without exposing its fleet to crippling losses from torpedoes. If the Royal Navy wanted to avoid risking its fleet to torpedoes, it had to fight outside ranges at which decisive gunnery results could be achieved; if it wanted to achieve decisive gunnery results, then it had to fight inside torpedo ranges. Jellicoe believed he had found a way—probably the only way—to achieve decisive gunnery results while fighting inside torpedo range without unduly exposing his fleet to torpedo attack.[73]

Jellicoe's technical-tactical synthesis became secret Admiralty policy in 1912. Several factors account for the timing. The first large-scale order for 21-inch Mark II torpedoes capable of making 10,000 yards had been placed in 1909, but the supply bottleneck, discussed previously, probably prevented them from entering service in large numbers until 1911 or so. In 1911, Jellicoe took over command of the Home Fleet's Second Division (renamed the Second Squadron in 1912), which served as the Navy's technological-tactical laboratory. Assisted by Dreyer, Jellicoe experimented with various fire-control systems, including Dreyer's, and with 21-inch torpedoes. Long-range firing with 21-inch torpedoes in 1912 suggested that 75 percent of those fired would be "dangerous to the enemy." To deal with the torpedo threat, Jellicoe tried divisional tactics, but he found that they presented insuperable command-and-control problems. The elimination of divisional tactics left a turn-away as the best option for dealing with the torpedo threat. In late 1912, Jellicoe rejoined the Admiralty as Second Sea Lord, and within two weeks of his return, the Admiralty informed Pollen that it was rejecting his fire-control system on "unspecified tactical grounds." Presumably, Jellicoe had convinced his fellow board members that the technical-tactical synthesis built around Dreyer's system, range-finder control, and the turn-away would work.

Torpedo development is at the center of new interpretations about British tactics and strategy, and it belongs there. The development of increasingly long-range and accurate torpedoes made traditional battle tactics based on a close-order gunnery engagement at short range suicidal, and it stimulated the search for new tactics, some of which assigned torpedoes a significant auxiliary, if not a primary, role. The development of small craft to deliver torpedo attacks, first in the form of surface torpedo boats and in most devastating form as submarines, rendered the Navy's traditional strategy of close blockade equally impractical, and contributed to its search for new methods of applying naval power, which culminated in its plan for economic warfare.

Appreciating this "revisionist" history of British naval policy before World War I—which is really the first orthodox history based on adequate command of the relevant primary sources—requires much more than a naval perspective. To be sure, the variables privileged in conventional naval histories (capital ships and foreign policy) still matter. But as we have seen, other variables mattered more. Chief among them was finance, followed closely by domestic politics, globalization, and an array of naval technological changes beyond capital ships (such as torpedoes, fire control, and communications). Indeed, the "revisionist" history is not really naval history at all by "orthodox" standards.

Torpedo development confronted the Royal Navy with extremely difficult problems from 1909 to the start of World War I. Although the Hardcastle superheater was a great success, undergoing remarkably minor changes during this period, the Navy did not solve the depth-keeping errors caused by high torpedo speeds before the outbreak of war. It introduced angled gyroscopes in 1912, but the vessels that needed them most—submarines—did not get them. Limitations on torpedo fire control prevented the Navy from fully exploiting the angled gyroscope, while budgetary and supply shortcomings hampered the Navy's efforts realistically to estimate the effects of torpedoes in battle. The Navy's failure to develop torpedo fire control as energetically as it developed torpedoes left it with "a very bad gap," in the words of the *Vernon*'s and the Grand Fleet's commanders, when World War I broke out. The significance of torpedoes' speed, range, and accuracy cannot be assessed without exploring these related issues.

The Navy did better at accounting for limitations in its gunnery fire-control systems. Jellicoe developed a novel technical-tactical synthesis that held out the hope of inflicting decisive gunnery damage despite the long-range torpedo threat. The conditions required for this synthesis to work did not occur at the Battle of Jutland, however. Instead of engaging at medium range with low range rates, the fleets engaged at long range with sometimes high range rates. When the German fleet disengaged, Jellicoe did exactly what two decades of British tactical thinking suggested he do: he turned away. He may have lost his chance at immortality—but he did not lose any of his capital ships to the torpedoes fired by the retreating German fleet.[74]

CONCLUSION

Sir John Fisher famously wrote, "Strategy should govern the types of ships to be designed. Ship design, as dictated by strategy, should govern tactics. Tactics should govern details of armaments."[1] Less famously, the chief of the Bureau of Ordnance, N. C. Twining, wrote: "To make progress, change is inevitable; change diversifies type; the ultimate type develops the tactics for that type, and tactics must conform to material, not material to tactics, when material improves."[2] In fact, as both men undoubtedly realized, too much was changing too quickly for industrial navies before World War I to achieve the neat, linear relationship either man described. Naval officials, as two scholars have observed, "were confronted by technical, personnel, economic, administrative, and financial problems that were arguably of greater scale, difficulty, and complexity than [those] facing the executives of any other department of state or private corporation."[3] The present work illuminates five problems in particular.

The first was the multiplicity and interdependence of variables. Practically every significant naval technology changed in the decades before World War I—not just the obvious big-ticket items like armor, guns, and propulsion, but also the equally important nervous systems, so to speak, like communications and targeting. All of these changing variables depended on each other. Torpedo development did not pause for a decision on how to arm destroyers, for instance, and a decision on destroyer missions could not wait on superheaters to mature, even though these decisions obviously had implications for each other. The reality confronting navies was complex and nonlinear.[4]

Second, all of these changing technologies required substantial capital investments. The price of each final product represented only a small fraction of the total outlay required to transform sophisticated industrial technology from a good idea into a working weapon capable of being produced in sufficiently large numbers and operated by personnel of varying competence (recall the De Laval Company's response to an invitation to enter the torpedo-engine business: "The cost of the development would be excessive and after the development is accomplished there is not a great volume of business to absorb this development charge"). Moreover, every cost sunk into a particular technology represented an opportunity cost for another technology. The US Navy's decision to invest in first-generation dry inside superheaters, for example, may help to explain why the Royal Navy beat it to third-generation wet superheaters. The interaction of many changing variables made it impossible to predict with certainty the actual uses of naval technology in war; thus, procurement decisions involving large capital expenditures had to be made on the basis of probabilities.

Third, officials had to exist in three time zones. They had to try to salvage investments in past technologies (or legacy systems) that rapidly became outdated; they had to choose the best options from existing technologies, knowing that these too would soon be obsolete; and they had to support the development of next-generation technology lest competitors overtake them. As a result, navies had to work with heterogeneous technologies.[5] At the most obvious level, it was impossible to put together an entire battle-line of ships with equal speeds and gun power; the largest unit at which homogeneity could be achieved was the division. At a less obvious level, we have seen how a commitment to one generation of torpedo technology created supply shortages and distribution dilemmas when the next generation came along.

Fourth, industrial technology like torpedoes required experts with technical knowledge, or what would later be called technocratic elites. It was possible for these elites to manipulate the policy process and escape accountability due to the technical ignorance of their colleagues and especially their civilian superiors. Examples range from the ability of the Bureau of Ordnance to convince the Secretary of the Navy that procurement mistakes were the Bliss Company's fault, to B. W. Walker's misconduct over the pattern-unification policy, to (biggest of all) Fisher's success in protecting the Royal Navy's construction budget by catering to politicians' crude metrics of naval power. Of course, technocratic elites were not always so elite themselves: consider the failure of US torpedo experts to understand the science behind the balanced turbine, or the *Vernon*'s occasional discoveries that slight tweaks could improve torpedo performance.

Fifth, the category of policy itself was not fixed. Before 1905, for instance, the Bureau of Ordnance had no policy for protecting its contributions to torpedo technology because none seemed necessary. The insertion of the rights clause in contracts after 1905 reflected a dawning realization that a problem existed and that a policy was needed to deal with it. The bureau never wrote a document conveniently titled "Policy on Protecting Intellectual Property Rights," but the existence of a policy can be inferred from evidentiary fragments like the rights clause and letters among the Bureau of Ordnance, the Torpedo Station, and the Bliss Company. Even when the parameters of a new policy area were defined, administrative changes needed to generate and implement policy—like the creation of the office of the solicitor—lagged, leaving ordnance officials in charge of legal decisions for a time.

Proper appreciation of these problems has important implications for how historians approach the policy process. To begin, it means that the achievement of empathy with policy makers, which ought to be a prerequisite to judging their decisions as right or wrong, is extraordinarily difficult. Policy, at the tactical and strategic levels alike, was an accretion of day-to-day problem solving, sometimes but not always with sensitivity to long-term consequences, and rarely committed to documents with titles revealing their significance.[6] These problems were so often of a highly technical nature that simply understanding them as they appeared to policy makers, let alone assessing attempted solutions, is a high bar to clear. Any search for lessons is likely to produce erroneous conclusions. The identification of lessons requires a clear causal chain and a judgment: "B resulted from A, and B was a bad outcome, so the lesson is not to do A." Given the complex interactions among the variables confronting policy makers and the difficulty of understanding how officials pieced the variables together, hypotheses about causal chains and policy outcomes are tentative at best. To expect these hypotheses to sustain the confident adumbration of lessons or judgments about decision makers' wisdom is to misunderstand the nature of the policy process.

Finally, common tropes in naval histories of the prewar period are unhelpful categories of analysis for trying to understand the policy process. The *Dreadnought* revolution, the arms race, the Anglo-German antagonism, technological progressivism and conservatism, navalism: these concepts were current at the time, in government, in the press, in the public mind, in professional journals. As such, they are important subjects of historical study—but they were *not* the categories of analysis used by the actual naval policy makers on any given issue. Fisher, for instance, did not ask himself each day how the *Dreadnought* revolution was going, as though it were a Platonic form the Royal Navy might emulate; rather, he wondered how to address a bewildering array of financial, technological, tactical, and diplomatic problems within a limiting domestic-political context. By the same token, Charles O'Neil, the long-time chief of the Bureau of Ordnance, did not make decisions because he was trying to be progressive or conservative (a dichotomy that breaks down anyway) but because he wanted to solve certain problems. On the one hand, he "conservatively" opted against placing submerged torpedo tubes on *Virginia*-class battleships because their installation was difficult and torpedoes were not yet capable of angle fire; on the other hand, he had "progressively" initiated the Navy's procurement of submerged tubes in the first place because he believed they might be tactically useful. Asking whether he was conservative or progressive is the wrong question and ensures that we will miss the actual dynamics of his decision making.

Indeed, attempts to apply categories like *conservative* and *progressive* to the naval policy process create what might be called policy pieces, after John Keegan's critique of battle pieces in his classic *The Face of Battle*.[7] In battle pieces, Keegan's term for traditional battle narratives, narrators sacrificed particularities to generalities (for instance, by lumping individual soldiers into faceless groups), and they sought to cultivate not understanding but emotion (for instance, national pride). In policy pieces, narrators retroactively apply categories of analysis that were not used by decision makers at the time to the policy process, and they group individual officials into larger units like the Admiralty or the Navy, thereby reducing a vast array of particular variables into generalities. In effect, to return to an idea mentioned in the Introduction, these techniques function as control technologies, which rely on "the destruction or ignoring of information in order to facilitate processing."[8] While the means of policy pieces are to generalize about particulars, the goal is not to understand but to judge, often for the purpose of drawing a lesson. Policy pieces render officials faceless as surely as battle pieces render soldiers faceless. If there is a single key to reconstructing their faces, it is to realize that the essential element of policy making was dilemma, just as the essential element of battle is fear. Naval policy makers before World War I did not choose between good and bad options: they chose between better and worse ones.

Torpedoes and Naval Power

In *The Structure of Scientific Revolutions*, Thomas Kuhn introduced the concepts of scientific paradigms and anomalies, which historians of technology and war have adapted to speak of technological and strategic paradigms.[9] Torpedoes have generally been depicted as anomalies within tactical and strategic paradigms defined in Mahanian terms, in which capital ships with heavy guns sought command of the sea through decisive battle.[10] Or, to use the language of today's armed forces, the torpedo presented an asymmetrical threat to a conventionally powerful navy, much as insurgencies present an asymmetrical threat to conventionally powerful armies today. According to this logic, the US Navy, as a relatively weak power seeking to revise the naval status quo, had every reason to embrace the torpedo; the Royal Navy, as the hegemon seeking to conserve the status quo, had every reason to reject the torpedo. Given the small size and cheapness of torpedoes and torpedo vessels compared to big guns and battleships, casting the former as Davids to the latter's Goliaths has a superficial logic.

Beneath the surface, however, this logic breaks down. To begin, a more appropriate unit of comparison to a battleship is not a single torpedo but a single torpedo plus all of its auxiliary systems (launching platforms, targeting systems, etc.). More important, the dichotomy of torpedoes and torpedo vessels versus big guns and capital ships is oversimplified. Battleships carried torpedoes as an integral part of their armament, and many naval officers limited torpedo vessels to secondary roles in battle, like charging in for the kill after the guns had wounded their prey, thus leaving the primary importance of capital ships unchallenged. In these contexts, torpedoes were adjuncts to, not anomalies within, the capital-ship paradigm.

In other contexts, to be sure, torpedoes could topple the paradigm. Both the American and British navies flirted with the idea of using destroyers to launch torpedoes at capital ships during the early stages of a battle, giving primacy to torpedoes rather than to guns. In strikingly similar language, William Sims in the United States and Winston Churchill in Great Britain considered that torpedoes could fundamentally redefine the metrics of naval power. Sims wrote, "[W]e know very little of the relative fighting value of the battleship or cruiser as opposed to the number of the smaller vessels that could be built for the same money. In this connection, I mean the relative fighting value under the conditions of a modern battle—that is, which would under these conditions, [sic] be able to inflict the most damage on the enemy's fleet, the large vessel or the number of small vessels that could be built at the same cost?"[11] Equally willing to rethink traditional definitions of naval power, Churchill stated that on winning cabinet approval to build four capital ships, "I immediately resumed my plans for converting two of these ships into a much larger number of smaller vessels. I proposed to treat these dreadnoughts not as Capital Ships but as units of power."[12] Sims and Churchill were open to new standards of naval power despite the fact that their respective nations occupied very different levels in the international naval hierarchy. The logic of common technological and tactical changes could dominate the logic of the asymmetric distribution of power.

Torpedoes shattered prevailing strategic paradigms in the last place that the David-versus-Goliath stereotype would suggest. By making battles riskier for capital ships and by making close blockades impossible, torpedoes threatened two traditional foundations of naval strategy. One might assume that the British, who especially relied on these foundations, would therefore prove especially hostile to torpedoes, but more nearly the reverse was true. Granted, examples of hostility to torpedoes can be found in British naval circles—recall First Naval Lord Richards's comment, for instance, that "no man did his country a worse service" than Robert Whitehead. Even where it existed, however, hostility did not prevent Richards and others from investing enough resources to stay at the forefront of torpedo development. In any case, the hostility disappeared entirely when Fisher became First Sea Lord in 1904. Fisher believed that he could use torpedoes and torpedo craft, along with advances in capital-ship design, communications, and fire control, to carry out the Navy's traditional missions in the face of budget cuts. Instead of seeking command of the sea through decisive battle, Fisher sought control and denial of the sea in the service of home and imperial defense. Fisher's contemporaries and most historians have conflated his propaganda with his actual policy.

Naval officials had reason to camouflage their real views about the morality as well as the power of torpedoes, and historians have proven gullible in crediting their attempts to stigmatize torpedoes as "illegitimate" or the "weapons of the weak." No doubt some British naval officers regarded torpedoes as sneaky and uncivilized, and yet any moral qualms they may have had did not prevent them from spending large sums of money to stay in the forefront of torpedo development. Officers without moral qualms had excellent reason to pretend that they did. Delegitimizing torpedoes might discourage other nations from developing them, removing a threat to Britain's naval hegemony and reducing Britain's need to spend money on torpedoes in order to stay abreast of foreign development. The Royal Navy pursued a similar strategy when it came to submarines, feigning disinterest and loudly denouncing them, even as it carefully monitored foreign development and made plans to leapfrog the competition.[13] Although torpedoes certainly could be the weapon of the weak, they could also be the weapon of the strong, as Fisher realized. Perhaps this very strength gave the British the self-confidence to embrace the torpedo.

Indeed, the US experience suggests that torpedoes were not so much weapons of the weak as weapons of the insecure and financially comfortable. Compared with the Royal Navy, the US Navy was an ambitious pipsqueak—prime candidate, if torpedoes were really the natural weapons of the weak, to embrace the torpedo wholeheartedly. And yet something closer to the opposite occurred. Whereas naval circles in Britain embraced torpedo-based flotilla defense as a means to cut costs without sacrificing strategic ends, politicians interested in cutting the budget forced it on a reluctant navy in the United States, and then only to a limited degree. The US Navy was so determined to preserve its budget, and perhaps to prove itself as a major power, that it mimicked the behavior it associated with naval hegemony (building capital ships) and rejected the behavior of the real naval hegemon (flotilla defense). The US Navy was proof that the Royal Navy's efforts to persuade other navies that it embodied an ideal, even as it acted contrary to that ideal, succeeded.

Technological Change and the Nature of Innovation

The thesis that the dominant navy within a particular paradigm embraced anomalous technology more than the weaker navy seems to falter when it comes to the pace of technological change. The Americans adopted the gyroscope and superheater before the British, who did not adopt the turbine engine at all. If the Royal Navy was so keen on torpedoes, why did it adopt new torpedo technology more slowly than the US Navy? The answer has to do with the balance of power and the nature of innovation.

Both navies adopted the gyroscope, a key invention, but they did so at different paces and for different reasons. Tactically, the main impetus for American interest in the gyroscope was that it would facilitate submerged torpedo fire; for the British, it was that the gyroscope would allow torpedoes to be fired outside gun range. At the time, the Royal Navy had much less reason than the US Navy to be worrying about submerged fire: it had fired thousands of submerged shots, while the US Navy had fired zero. Inexperience primed the Americans to emphasize an implication of the gyroscope that experience allowed the British to deemphasize.

The two navies also moved at different paces in their negotiations over and adoption of the gyroscope. The US Navy worked through an intermediary, the Bliss Company, and on the basis of trials with one gyroscope lasting eight days in late 1897, ordered the gyroscope to be installed in all 159 torpedoes then under contract. In contrast, the Royal Navy purchased several trial gyroscopes for itself from the Whitehead Company, not working through an intermediary, and it put the device through several phases of trials, including limited issue to seagoing ships, which the Americans skipped. Britain placed its first bulk order in late 1898, a year later than the Americans had made a comparable commitment. Only in late 1899 did Britain pay a lump sum, which the Americans never did.

The pattern repeated itself with the superheater, another key invention. The Americans adopted Leavitt's original dry outside superheater in 1901. When the Bliss Company offered to sell the superheater to the Admiralty, a British officer noted with horror that that the supposedly "exhaustive" American trials "only rests on 22 runs!"[14] The Admiralty turned down the Bliss Company's offer and instead began to conduct its own superheater experiments in 1904. These were rapidly overtaken by the efforts of Hardcastle and the Armstrong Company in 1905. Just when the US Navy was introducing the dry outside superheater—imported from a British firm, the Armstrong Company, via the Bliss Company—the Royal Navy was finalizing the details of Hardcastle's wet outside superheater. It entered service in 1908, two years before the Americans even began to solicit wet superheater proposals from the Bliss Company and the Electric Boat Company, and four years before the Americans placed contracts for steam torpedoes with the Bliss Company. Even then, with the failure of the Electric Boat Company to produce a homegrown wet superheater, the US Navy still had to rely on a British firm, the Armstrong Company, for the wet superheaters used in Bliss-Leavitt torpedoes. While building up two sources of domestic supply, the British managed to overtake the Americans, skipping two steps—the dry inside and dry outside superheaters—that the Americans passed through. The time thus saved helped the British to beat the Americans to the wet outside superheater by four years, despite their later start in superheater development.

Also helping the British was their decision to stick with the reciprocating engine, despite periodically flirting with the idea of the turbine engine. The US Navy committed prematurely to the turbine engine in 1903 and then had to spend the next six years making it work. The process involved much wasted effort on unnecessarily balancing the turbine when, in fact, errant exhaust was to blame for the torpedoes' tendency to roll. The process also generated great discord with the Bliss Company, culminating in a lawsuit that went all the way to the Supreme Court. These efforts dominated the US Navy's experimental and production agenda and came with a high opportunity cost. In late 1905, for instance, while Hardcastle was having the first inklings of his superheater ideas, the US Navy was struggling to fix the turbine engine while wrestling with the Bliss Company over intellectual property rights in relation to the balanced turbine. Without the opportunity cost that came with committing to the turbine, the Royal Navy was free to concentrate on superheater development.

The relative weakness of the US Navy explains its relative openness to change only in a very particular sense. The explanation is not that the torpedo was the "weapon of the weak" (see above), but that the US Navy was weak in research and development (R&D) resources. This weakness hampered the US Navy's efforts to compete with the Royal Navy in torpedo development. Perhaps counterintuitively, given the tendency to think of torpedoes as asymmetrical weapons of the weak, the US Navy's interest in torpedo development was *symmetrical*: the US Navy compared its torpedoes to other torpedoes, not to capital ships. In an asymmetrical competition of torpedoes against capital ships, the Royal Navy's superiority in the latter was a weakness. In a symmetrical competition of torpedoes against torpedoes, the Royal Navy's superiority in R&D resources was a strength. To compensate, the US Navy had to find an area in which it enjoyed a comparative advantage. The only possible candidate was theoretical design work, which did not require the same experimental infrastructure as a trial-and-error approach to technological change: brains were cheap compared to torpedo ranges, testing barges, and personnel. Poor in the latter, the Americans could never hope to compete with the British if torpedo technology changed through an incremental, empirical process. Their only hope was to change torpedo technology through bold leaps in design, trusting to the drafting room rather than the testing range. Unable to look before they leapt, they paid for their poverty with a troublesome turbine and corresponding delay in superheater development.[15]

Lack of infrastructure likely helps to explain why none of the three really successful wet superheaters—the Armstrong, Hardcastle, and Gesztesy models—were American. The Americans could compete at the relatively primitive level of dry superheaters, but their lack of R&D resources crippled them when it came to the much more advanced technology of wet superheaters (the difference in sophistication can be seen by comparing Figure 1.1 on page 30 with Figures 4.1 and 4.2 on page 117). Granted, the basic principle behind wet superheaters was not much more advanced than that behind dry superheaters. For both, the idea was that hot air was better than cold air. Applying the basic principle was much more difficult, however, for wet superheaters than for dry superheaters. Whereas it was comparatively simple to draw up a working design for a dry superheater, optimizing wet superheaters required extensive trial and error. Neither the US Navy nor the Bliss Company had the facilities to undertake such experiments, at least not without sacrificing other efforts that they deemed more important. The Royal Navy did have the resources, and what is more, two private companies (Armstrong and Whitehead) were able to undertake R&D work on a greater scale than the US Navy (let alone the Bliss Company).[16]

Consideration of the nature of innovation and of the distinctions among various types of knowledge illuminates the role of material resources in explaining the different experiences of the US Navy and the Royal Navy in torpedo development. As we have seen, the difference between principles and designs carried legal significance. The former implied a general idea, while the latter implied a specific application of that idea. This distinction between principles and designs had some similarities to the distinctions between natural laws and inventions, between basic and applied science, and between science and technology. In patent practice, for instance, natural laws (like, say, the law that pressure is directly proportional to heat) could only be discovered, not invented. Invention required the creation of something new, not the revelation of something already in existence. This definition implied that only applied science (not basic science) and technology (not science) could be patented. At heart, the issue was ontological and epistemological: Do objects exist because we know them, or do we know them because they exist?

Industrial technology like torpedoes had implications for this question. On the one hand, it could increase the difficulty of working out a principle in practice. Developing a balanced turbine required far more resources than, say, developing a sword. In contrast, the underlying principles were of comparable difficulty (or simplicity): equal moments of inertia cancel each other out, and sharp objects with momentum hurt people. On the other hand, the sophistication of industrial technology meant that each application of knowledge involved more basic science. The relevant principles may not have gotten more difficult in quality, but they had grown in quantity. The science underlying torpedoes involved, to give only a partial list, the metallurgy of the air flask, the chemistry of the reaction in the combustion chamber, the physics of the engine, and the fluid dynamics of the torpedo moving through water. It is clear that designers did not always understand the basic science before applying it. Recall the sheepish admission that British engine design was based on guesswork, or the inability of US officials to understand the gyroscopic forces affecting the turbine engine.[17] Although science-led innovation occurred, so too did technology-led innovation, in which basic science often played catch-up with applied science.[18] Design work was neither purely deductive and theoretical nor purely inductive and empirical: it was a combination. The relationships between principles and designs, basic science and applied science, and science and technology were interactive and nonlinear rather than progressive and linear.

R&D resources helped with both science-led and technology-led innovation, but they were particularly important for the latter in the case of torpedo development. Consider the turbine engine. It showed that a firm with relatively few R&D resources could design and build sophisticated industrial technology, but it also showed that the lack of adequate R&D was crippling when it came to producing turbine torpedoes in large quantities (recall how Leavitt's "mental and physical incapacity" constituted a supply bottleneck).[19] If the basic science was not going to be fully understood in any case, then the existence of adequate R&D resources to engage in trial-and-error application became more crucial, not less. While brains may have been enough for the initial design work, testing prototypes to ensure that they could be produced on a large scale required servant technology, ranges, barges, and personnel, to name just a few resources. Without extensive R&D resources, the momentum of single versions of a technology (like the turbine engine) was difficult to sustain, while multiple versions of the same technology (like the wet superheater) were unlikely to occur in the first place.[20] A full sociological theory of innovation must account for material as well as intellectual resources.

Because the American government and private sector had relatively few

R&D resources for torpedo purposes compared to their British counterparts, technology-led innovation hurt them disproportionately. Given the balance of R&D power, it was in the American interest to try to shift to science-led innovation, where their R&D weakness was less damaging. The Americans' efforts to escape the limits of their material infrastructure, however ineffectual, may have resulted from a rational push-pull dynamic. The push was the fact that they would remain at a comparative disadvantage in the status quo because they lacked the R&D resources necessary to exploit fully the technology that defined the status quo. The pull was the hope that they could exploit their theoretical, as opposed to empirical, designing abilities to invent better technology, and with it a new status quo in which they enjoyed a comparative advantage. The Americans' underestimation of the difficulty involved in perfecting designs of the gyroscope, the superheater, and the turbine may have been a by-product of a rational fear that they would remain at a comparative disadvantage in the technological status quo, and of a rational hope that they would come out at a comparative advantage by trying to revise the status quo. Their priority of invention, when it existed, is better explained by material weakness than by superior ingenuity.

As hegemon within the status quo, Britain experienced a different, but not quite inverse, push-pull dynamic. The push was the fear that change would lead to relative loss. In connection with this prospect of relative loss, the British had to account for one variable much more carefully than did the Americans, namely, the pace of foreign development. The US Navy was sufficiently far off the lead that, in relative terms, it effectively had nowhere to go but up; accordingly, there was little chance that foreign advances would destabilize its relative position. For the hegemonic British, however, there was a very high probability that foreign advances would destabilize its relative position. But as the case of the gyroscope demonstrates, the Royal Navy considered the positive as well as the negative implications of change, especially the possibility that it might be able to exploit change to widen its relative lead; this was the pull for Britain. The fact that technological change *simultaneously* offered the prospects not only of net loss and no gain *but also of net gain* is crucial to understanding the Admiralty's calculations. The prospect of net gain was not negligible, because the same existing infrastructure that gave Britain more to lose than any other nation also meant that it was better positioned than any other nation to turn change to its advantage.

Command Technology and Intellectual Property

According to the historian William McNeill, a new weapons procurement paradigm emerged in the late nineteenth century, with command technology at its heart. Previously, when governments purchased naval technology from the private sector, it was a finished commercial product. The new command technology was so expensive and sophisticated, however, that private firms could not develop it successfully by themselves. Thus, the government could not buy the technology as a finished commercial product but had to invest in R&D by the private sector.

The present work illuminates several significant implications of McNeill's thesis. First, it shows how command technology encouraged the development of servant technology, that is, technology that generated information for improving the performance of command technology. Dynamometers, rolling registers, and testing tanks were all examples of servant technology. Second, the information generated by servant technology was a commodity unto itself because it had the power to affect market relationships by offering insight into the value of command technology. This commodified information was also a distinctive kind of property, neither physical property nor the same as traditional forms of intellectual property. The acquisition of information-generating servant technology meant a stronger position in the information-commodity market, giving servant technology some value independent of its contributions to command technology. Third, command technology created serious intellectual property disputes between the public and the private sectors. With both involved in the work of invention, it became very difficult to establish who had invented what and when. Corresponding intellectual property rights problems arose when technology was commanded internally from employees, the difference being that the ensuing disputes occurred between employer and employee rather than between governments and private firms.

Not every piece of torpedo technology was an example of McNeill's thesis about command technology. The Obry gyroscope, for instance, fit into the old paradigm. In the United States, gyroscope development by the US Navy and the Bliss Company proceeded separately, as did development by the Whitehead Company and the Royal Gun Factory in Britain: the public investment in private R&D that characterizes command technology did not apply. The superheater and the turbine engine, in contrast, were examples of command technology—but not in both countries. Only in the United States did the Navy invest in the Electric Boat Company's experimental wet superheater and the Bliss Company's experimental turbine. In Britain, the Royal Navy did not adopt the turbine engine, and it developed the Hardcastle superheater internally, not in collaboration with a private firm. While Armstrong's superheater patent infringement lawsuit against the Admiralty was the rough British equivalent of the Electric Boat Company's and Bliss Company's superheater lawsuits against the Navy Department, the Royal Navy did not have to deal with an equivalent to the US lawsuit over the turbine engine. In short, Britain avoided the worst legal headaches of torpedo command technology.

It achieved this outcome for three reasons. One was the greater extent of its R&D infrastructure. Neither the public nor the private sector in the United States could match the experimental facilities of the Royal Gun Factory, Royal Navy Torpedo Factory, Whitehead Company, or Armstrong Company—let alone the merger of Whitehead's and Armstrong's resources after 1906, which probably created industrial research capabilities on a scale more commonly associated with the interwar period and World War II than the pre–World War I period.[21] Because the British government itself had greater resources and could contract with private firms possessing greater resources, it had less need to collaborate with the private sector in developing new technology. Lacking resources on a comparable scale in either the public or the private sector, the US government had to assist private firms in developing particularly expensive and sophisticated new technology.

The second reason that the Royal Navy avoided the worst headaches of McNeill's command technology was that it incentivized innovation within the Navy through the Admiralty Awards Council. To reward its leading superheater expert (Hardcastle) for his invention, for instance, the Admiralty Awards Council granted him £5,000 and accelerated promotion. The US Navy lacked a similar body and gave its leading superheater expert (Davison) nothing. What happened? Hardcastle stayed in the Royal Navy while Davison bolted for the private sector—taking his government notebooks with him and then suing the government, for good measure. Keeping Hardcastle was well worth £5,000 and early promotion.

By institutionalizing incentives for innovation in the form of the Admiralty Awards Council, the Royal Navy kept one of its brightest minds from fleeing to the private sector. The Royal Navy could therefore support Hardcastle's efforts internally instead of having to invest in private experimental efforts to maintain a relationship with him. Avoiding investment in the private sector meant that the Royal Navy avoided one of the common pitfalls of McNeill's command technology: a dispute between the public and private sectors over intellectual property rights. To maintain a relationship with Davison, in contrast, the US Navy had to invest in experimental efforts by the Electric Boat Company, and a lawsuit resulted.

Of course, the Royal Navy's method of internalizing invention did not prevent disputes altogether; it merely kept them from involving the private sector. Hardcastle later concluded that he had been exploited and put in a claim for additional compensation. As Davison's case shows, the relevant comparison for Hardcastle's award was not his naval salary (by which standard the award was exceedingly generous) but what he could have made in the private sector (by which standard the award was much less generous). Contrary to what one might expect, Admiralty and Awards Council officials never suggested that Hardcastle should be grateful for what he got: they accepted the need to measure his award against the private sector, not against his naval salary. Given this acceptance, the award may not have been generous, but it nevertheless reflected some understanding of the military-industrial complex and technological change.

More slowly than the British, the US Navy also came to see the advantages of internalizing invention. In 1913–1914, as we saw, the Bureau of Ordnance tried to set up a government research lab modeled on industrial research labs in the private sector. This effort sought to solve one result of industrialization (McNeill's command technology) with another (the research lab, a type of internal command technology). The government would avoid McNeill's command technology and its attendant intellectual property rights problems by internalizing the R&D process instead of sharing it with the private sector. Recognizing that the nature of invention had changed in the industrial era, the US Navy would no longer rely on ad hoc personnel rotations, just as private firms no longer relied exclusively on outside inventors to bring them products. Rather, the Navy would try to command technology from within, rather than commanding it from the private sector. Of course, avoiding the costs of external command technology would create a new set of costs, in the form of having to pay for lab equipment and employees. Even with internal command technology, intellectual property rights problems would still arise (as Hardcastle's case shows), this time pitting the government against its own employees rather than against the private sector. In either case, the commander as well as the commanded participated in the work of invention.

The third reason that Britain avoided the worst headaches of command technology was its legal system, specifically its patent laws and anti-espionage legislation. Together, they meant that the British government had more tools at its disposal than the American government for constructing what one scholar has called the "fundamental category [of] National Security Information."[22] Since 1852, the British government could classify patents as secret, and since 1889, it had an Official Secrets Act. The United States lacked any provision for secret patents until World War I, when Congress authorized the classification of patents related to national security. This improvised measure lapsed at the end of the war but was reinstated at the start of World War II. Only in 1951 did Congress put this ad hoc approach on a permanent footing with the passage of the Invention Secrecy Act.[23] Furthermore, the United States lacked any equivalent to Britain's Official Secrets Act until the National Defense Secrets Act of 1911. The Americans lagged a century behind the British when it came to secret patents and several decades behind them when it came to anti-espionage legislation.

This lag put the US government at a disadvantage in dealing with command technology. Secret patents allowed the British government to respond effectively to two characteristic difficulties of command technology: establishing property rights in a potentially collaborative process of invention, and maintaining secrecy in a competitive industrial and geopolitical environment. Hardcastle's secret patents established prior discovery against future claimants without publicizing his work. The US government could not do the same for Davison's work on turbines and superheaters, even if he had remained in government service. In the case of the balanced turbine, the government had Davison take out a (public) patent to protect itself from rival claims by the Bliss Company, despite its desire to keep the technology secret. The Bliss Company recognized that the government was on the horns of a dilemma and exploited the US government's vulnerability: How could the government claim that the balanced turbine was secret, the Bliss Company asked, when it had published the technology in the form of a patent? The inability to take out secret patents exposed the US government to attack.

Like secret patents, anti-espionage legislation was an important weapon for the state in dealing with command technology. Thanks to Britain's superior R&D infrastructure, which enabled private firms to develop sophisticated torpedo technology without government assistance, and to the Admiralty's institutionalization of incentives for innovation, which enabled it to keep Hardcastle in the Navy, the British government did not have to threaten anyone with the Official Secrets Act in regard to torpedo technology. Its reticence had nothing to do with character, however, and everything to do with lack of opportunity. When opportunity knocked, as it did in the case of Arthur Pollen's fire-control system, the British government proved perfectly willing to use anti-espionage legislation to regulate proprietary and commercial rights.[24] The US government was equally assertive, and thanks to its comparative mishandling of torpedo technology, it had more opportunities than the British to showcase its aggression. As soon as it had anti-espionage legislation at its disposal in the form of the National Defense Act of 1911, the US government used it to prosecute the Bliss Company. The government was equally assertive with patent law, taking contradictory positions in its cases against the Bliss Company and the Electric Boat Company.

Command technology was only one subset of a larger class of technologies likely to elicit predatory behavior from governments. It invited such behavior because it was developed in collaboration between the state and society and because it was militarily sensitive. Other probable triggers for state interest in technology would include dual-use (civilian and military) potential or, in the case of purely civilian technology developed with government aid, the potential for commercial profits. It is not surprising to find governments trumpeting the inviolability of property rights when they have nothing to lose. Their commitment to property rights was tested when security or money was at stake. In such cases, if the present study is any indication, they proved less than liberal.

The military-industrial complex began in the late-nineteenth century, not in the mid-twentieth century. Between torpedoes' interaction with industrialization and the new relationship between the government and the private sector, they may fairly be said to have helped to put *industrial* and *complex* in the military-industrial complex. It was, to be sure, smaller in scale than when President Eisenhower described it in 1961, but many of its essential dynamics—and dangers—were in place: replacement of the market by command, public-sector investment in private-sector technological development, the role of technocratic elites in the policy process, the beginnings of big science, and government outreach to academia. Before World War I, the differences between peace and war were already eroding.

ABBREVIATIONS

ACNTS	Assistant Commander of the Naval Torpedo Station, Newport, RI, United States
Adm	Original Admiralty file
ADM	Admiralty file in The National Archives, Kew, England
ADNO	Assistant Director of Naval Ordnance, Admiralty
ADT	Assistant Director of Torpedoes, Admiralty
AL	Admiralty Library, Portsmouth, England
ART	Annual Report of the Torpedo School (HMS *Vernon*). Citations are given in the format ART: last two digits of year/page number(s). Citations to this source do not give an archive because it can be found in multiple archives, as explained in the "Archival Sources" (see p. 235).
ASRGF	Assistant Superintendent of the Royal Gun Factory
AsstSecNav	Assistant Secretary of the Navy
B	Box
BB*	
BBB*	
BF	Brass Foundry, Woolwich, England
BT	Board of Trade file in The National Archives, Kew, England
BuOrd	Bureau of Ordnance, Navy Department
CAC	Churchill Archives Centre, Churchill College, University of Cambridge, England
CINC	Commander in Chief
CIO	Chief Intelligence Officer, Navy Department
CNTS	Commander of the Naval Torpedo Station, Newport, RI, United States
CoNav	Chief of the Bureau of Navigation, Navy Department
CoO	Chief of the Bureau of Ordnance, Navy Department
CSOF	Chief Superintendent of Ordnance Factories

*At NARA, in RG74/E25 (BuOrd official files), the box numbering restarts twice. I adopted "B" to apply to the first series, "BB" to apply to the second series, and "BBB" to apply to the third series.

Ct. Cl.	Court of Claims
DeptNav	Navy Department
DNO	Director of Naval Ordnance, Admiralty
DoJ	Department of Justice
E	Entry
F	Folio
FDSF I	Arthur Marder, *From Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904–1919*, vol. 1, *The Road to War, 1904–1919* (London: Oxford University Press, 1961)
FinSec	Financial Secretary
FNR	Nicholas Lambert, *Sir John Fisher's Naval Revolution* (Columbia: University of South Carolina Press, 1999)
FY	fiscal year
GB	General Board
GBP	Great Britain Patent
HML	Hagley Museum and Library, Wilmington, DE, United States
IDNS	Jon Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (Boston: Unwin Hyman, 1989)
IoO	Inspector of Ordnance
JAG	Judge Advocate General, Navy Department
M	Microfilm
Med	Mediterranean
NARA	National Archives and Records Administration, Washington, DC, United States
NARA II	National Archives and Records Administration, College Park, MD, United States
NDL	Navy Department Library, Washington, DC, United States
NGF	Naval Gun Factory, Washington, DC, United States
NHC	Naval Historical Collection, Newport, RI, United States
NMM	National Maritime Museum, Greenwich, England
NTS	Naval Torpedo Station, Newport, RI, United States
NYT	*New York Times*
OP	Ordnance Pamphlet
PA	Nicholas Lambert, *Planning Armageddon: British Economic Warfare and the First World War* (Cambridge, MA: Harvard University Press, 2012)
PQ	*Principal Questions dealt with by the Director of Naval Ordnance*. Citations are given in the format PQ/Year/Minute Number/Page Number(s), with the exception of citations for the years 1912–1913, which are given in the format PQ/Year/Folio Number/Page Number(s). Citations to this source do not give an archive because it can be found in several archives, as explained in the "Archival Sources" (see page 235).

R	Reel
RCAI	Royal Commission on Awards to Inventors
RG	Record Group
RGF	Royal Gun Factory, Woolwich, England
RNC	Royal Naval College, Greenwich, England
RNM	Royal Naval Museum, Portsmouth, England
RNTF	Royal Naval Torpedo Factory, Greenock, Scotland
R.P.C.	*Reports of Patent, Design, Trade Mark, and Other Cases* (British law reports series)
SC	Ship's Cover
SecAdm	Secretary of the Admiralty
SecNav	Secretary of the Navy
SNGF	Superintendent of the Naval Gun Factory, Washington, DC, United States
SRGF	Superintendent of the Royal Gun Factory, Woolwich, England
SRNTF	Superintendent of the Royal Naval Torpedo Factory, Greenock, Scotland
SUPP	Ministry of Supply file in The National Archives, Kew, England
T	Treasury file in The National Archives, Kew, England
T&W	Tyne and Wear Archives, Newcastle, England
TDC	Torpedo Design Committee
TNA	The National Archives, Kew, England
ToR	"Transcript of Record," *E. W. Bliss Co. v. United States*, 248 U.S. 37 (1918). Available through the Gale/Cengage Learning database "The Making of Modern Law: U.S. Supreme Court Records and Briefs, 1832–1978."
USP	United States Patent
USNWC	United States Naval War College
V	Volume
VA	Vickers Archive, University of Cambridge Library, Cambridge, England
VG**	
VR**	
WO	War Office file in The National Archives, Kew, England
WP	*Washington Post*

**At NARA, the idiosyncratic organization of RG74/E26 (semiofficial BuOrd files) is reflected in my abbreviations. They are:

B1B/VR (B[ox] 1, B[ound papers], V[olume] R[ed])

B1B/VG (B[ox] 1, B[ound papers], V[olume] G[reen])

B1L (B[ox] 1, L[oose papers])

References to these files appear only in Chapter 5.

ARCHIVAL SOURCES

The *Principal Questions Dealt with by the Director of Naval Ordnance* (cited as PQ, though known in some years as *Important Questions Dealt with by the Director of Naval Ordnance*) can be found in multiple locations. The most complete coverage appears in ADM 256/21–44, TNA, covering the years 1889 through 1913. The volumes for January–June 1889, 1903, 1904, 1907, and 1908–1911 can be found only in ADM 256 at TNA. However, ADM 256 is missing the *Principal Questions* for 1888, which can be found only in the Priddy's Hard Archive at the Hampshire Record Office under call number 109M91/PQ1, as well as for 1912 and 1913, which can be found only at the Admiralty Library under call number Ja 397. Priddy's Hard Archive and the Admiralty Library both contain most of the volumes but are missing several.

Copies of the Annual Reports of the Torpedo School (HMS *Vernon*) can also be found in multiple locations. There is a complete run in ADM 189, TNA—ART94 is ADM 189/14, ART95 is ADM 189/15, and so on. Copies can also be found at the HMS *Collingwood* Communications and Radar Museum.

United States

National Archives and Records Administration, Washington, DC

- RG45, Naval Records Collection
  - E45, Letters Received from Commanding Officers of Squadrons
  - E502, Subject File of the US Navy, 1775–1910
- RG74, Records of the Bureau of Ordnance
  - E19, Letters Received from Navy Yards and Stations, 1842–1884
  - E25, General Correspondence, 1885–1944 (use with E29, Indexes to Correspondence)
  - E26, Semi-Official Correspondence of the Chiefs of the Bureau of Ordnance, 1904–1920
  - E201, Miscellaneous
- RG80, Records of the Office of the Secretary of the Navy

E19, General File of the Secretary of the Navy, 1897–1915

E180, Letters Sent by the Board on Construction, 1890–1893, 1898–1909

E285, General Board Letter-Books

RG125, Records of the Navy Judge Advocate General

E22, General File, 1905–1908

National Archives and Records Administration, College Park, MD

RG60, Records of the Department of Justice

E112, Straight Numerical Files

E418, Attorney General's Patent Policy Survey

Navy Department Library, Washington, DC

Naval Historical Collection, Newport, RI

Naval Torpedo Station records

RG8, Intelligence and Technological Archives, 1910–1938

RG12, Student Problems and Solutions, 1894–1953

RG13, Student Theses

RG14, Faculty and Staff Presentations, 1886–1970

RG15, Guest Lectures, 1894–1992

Hagley Museum and Library, Wilmington, DE

Accession 1893, Elmer Sperry Papers

Great Britain

The National Archives, Kew

ADM, Records of the Admiralty

ADM 1, Admiralty Secretariat Papers

ADM 116, Admiralty Case Files

ADM 189, Annual Reports of the Torpedo School

ADM 245, Admiralty Awards Council Papers

BT, Records of the Board of Trade

BT 31, Companies Registration Office: Files of Dissolved Companies

SUPP, Records of the Ministry of Supply

SUPP 5, Ordnance Establishments: Headquarters and Factory Records, 1664–1988

T, Records of the Treasury

T 173, Records of the Royal Commission on Awards to Inventors (Tomlin Commission)

WO, Records of the War Office

WO 32, Registered Files

Royal Naval Museum, Portsmouth

130/87, Reginald Tupper Papers

Admiralty Library, Portsmouth

HMS Collingwood *Communications and Radar Museum, Fareham*

Annual Reports of the Torpedo School

Brass Foundry, Woolwich

Ships' Covers

National Maritime Museum, Greenwich

THU, James Richard Thursfield Papers

Priddy's Hard Archive, Hampshire Record Office, Winchester

109M91/PQ, Copies of the Principal Questions Dealt with by the Director of Naval Ordnance

Tyne & Wear Archives, Newcastle

Accession 31, Rendel Papers

Accession 130, Armstrong Board Minutes

Vickers Archive, Cambridge University Library, Cambridge

Document 57, Royal Arms Commission Files

Document 771, V. F. G. Pritchett, *Vickers Limited Group of Companies: A Short Account* (NB dated and credited incorrectly)

Document 782, Whitehead Torpedo Works Files

Microfilm R306–307, Albert Vickers Papers

Churchill Archives Center, Churchill College, Cambridge

FISR, John Fisher Papers

NOTES

The abbreviations given in the Notes can be explained by referring to the "Abbreviations" (pages 231–233).

Introduction

1. Quotations are from Eisenhower's Farewell Address, available at http://millercenter.org/president/speeches/detail/3361. For context on his views, see Robert R. Bowie and Richard H. Immerman, *Waging Peace: How Eisenhower Shaped an Enduring Cold War Strategy* (New York: Oxford University Press, 1998), especially 96–108; Gerald Clarfield, *Security with Solvency: Dwight D. Eisenhower and the Shaping of the American Military Establishment* (Westport, CT: Praeger, 1999); Aaron Friedberg, *In the Shadow of the Garrison State: America's Anti-Statism and Its Cold War Grand Strategy* (Princeton, NJ: Princeton University Press, 2000), especially 56–58, 127–39, 225–35; William McLenahan, Jr., and William H. Becker, *Eisenhower and the Cold War Economy* (Baltimore, MD: Johns Hopkins University Press, 2011); and James Ledbetter, *Unwarranted Influence: Dwight D. Eisenhower and the Military-Industrial Complex* (New Haven, CT: Yale University Press, 2011). See also *Enterprise and Society* 12, no. 1 (March 2011), especially the articles by Bernstein and Wilson and by Engel.

   A small but notable group of scholars has dated the origins of the military-industrial complex to the nineteenth century: see Benjamin Franklin Cooling, *Gray Steel and Blue Water Navy: The Formative Years of America's Military-Industrial Complex, 1881–1917* (Hamden, CT: Archon Books, 1979); Kurt Hackemer, *The U.S. Navy and the Origins of the Military-Industrial Complex, 1847–1883* (Annapolis, MD: Naval Institute Press, 2001); and Thomas Heinrich, *Ships for the Seven Seas: Philadelphia Shipbuilding in the Age of Industrial Capitalism* (Baltimore, MD: Johns Hopkins University Press, 1997), 99–121. Merritt Roe Smith's *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca, NY: Cornell University Press, 1977) could also be interpreted in this way. Complementing these works is the relatively recent wave of historiography coming out of the policy and legal history fields on the robustness of the federal state in US history. For an introduction to this literature, see *Journal of Policy History* 18, no. 1 (2006) (devoted to the subject of nineteenth-century political economy); William J. Novak, "The Myth of the 'Weak' American State," *American Historical Review* 113, no. 3 (June 2008): 752–72; and Brian Balogh, *A Government out of Sight: The Mystery of National Authority in Nineteenth-Century America* (New York: Cambridge University Press, 2009). A comparable literature exists for the nominally weak British state, going back to the long eighteenth century; for example, see John Brewer, *The Sinews of Power: War, Money, and the English State, 1688–1783* (Boston: Unwin Hyman, 1989); and Patrick K. O'Brien, "The Nature and Historical Evolution of an Exceptional Fiscal State and Its Possible Significance for the Precocious Commercialization and Industrialization of the British Economy from Cromwell to Nelson," *Economic History Review* 64, no. 2 (2011): 408–446. David Edgerton's incisive work, particularly *England and the Aeroplane: An Essay on a Militant and Technological Nation* (Houndmills, England: Macmillan, 1991), *Warfare State: Britain, 1920–1970* (Cambridge: Cambridge University Press, 2006), and *Britain's War Machine: Weapons, Resources, and Experts in the Second World War* (New York: Oxford University Press, 2011), updates the thesis for the late-nineteenth and early-twentieth centuries.

2. See, for example, Richard Overy, *Why the Allies Won* (New York: W. W. Norton, 1995), 190; Michael Hogan, *A Cross of Iron: Harry S. Truman and the Origins of the National Security State, 1945–1954* (Cambridge: Cambridge University Press, 1998), 1–5; James Sparrow, *Warfare State: World War II Americans and the Age of Big Government* (New York: Oxford University Press, 2011), 1–8, 243, 258–60.
3. Unless otherwise indicated, the following account draws on Edwyn Gray, *The Devil's Device: The Story of Robert Whitehead, Inventor of the Torpedo* (Annapolis, MD: Naval Institute Press, 1991), 14–59, 77–89.
4. Marina Cattaruzza and Antonio Casali, *Sotto i mari del mondo: La Whitehead 1875–1990* (Rome: Laterza & Sons, 1990), 12. The price for the exclusive rights demanded by Whitehead was too high for Austria given that its finances were poor in the wake of the war with Italy, and the weapon was unproven.
5. The records relating to the 1869 delegation can be found in RG45/E45 (M89/R230) and RG74/E201/Subject 14/B16, NARA. On the flirtations, see Marvin to Simpson, March 18, 1871, RG74/E201/Item 15/B12; Kirkland to Jeffers, December 8, 1873, and Braine to Case, September 29, 1874, RG74/E201/Subject 14/B16, NARA; Lines to House, January 10, 1877, RG74/E19/B175/V21, NARA; John Whitehead to Sicard, April 13, 1882 (and related letters), RG74/E19/B177/V25, NARA; McLean to John Whitehead, March 14, 1883 (and related letters), RG74/E201/Item 27/B27 (see also RG74/E19/B178/V26), NARA.
6. This paragraph is based on Peter Bethell, "The Development of the Torpedo,"

pts. 1–7, *Engineering* 159–61 (May 25, 1945, to March 15, 1946): 7, copy available as call number P 894, AL. See also Gray, *The Devil's Device*, 145, 152–55.

7. "Curtiss Wins Aeroplane Cup," *NYT*, August 29, 1909, p. 1.
8. Although its exact meaning varied over time, the phrase *capital ships* generally referred to battleships, armored cruisers, and battlecruisers, which could all join the line of battle.
9. The phrase *all big gun* meant that the gun armament of ships consisted only of big guns (say, 12-inch or larger) intended to fire at enemy capital ships and contained no intermediate battery (say, of 6-inch guns) intended to take on enemy vessels other than capital ships.
10. Ivo Lambi, *The Navy and German Power Politics, 1862–1914* (Boston: Allen and Unwin, 1984), 375.
11. David Lyon, *The First Destroyers* (London: Mercury Books, 2005), 13–14.
12. Eberhard Rössler, *The U-boat: The Evolution and Technical History of German Submarines*, trans. Harold Erenberg (Annapolis, MD: Naval Institute Press, 1981), 10–16.
13. Benito Petrucci, *WASS: 133 Years of History* (Rome: Ciuffa Editore, 2008), 414.
14. Eberhard Rössler, *Die Torpedos der deutschen U-Boote: Entwicklung, Herstellung und Eigenschaften der deutschen Marine-Torpedos* (Herford: Koehler, 1984), 16–19, 29–39; Gray, *The Devil's Device*, 94–96; Petrucci, *WASS*, 98, 126. Happily for the punnish (and Hunnish) historian, *Schwartzkopff* sounds nearly like *Schwarzkopf*, which means "Blackhead"—the perfect name for Whitehead's competitor.
15. See, for example, Bristol to Twining, September 25, 1911, BuOrd 24587/10 (B.1-11), RG74/E25/B1263, NARA; and Babcock to Twining, January 5, 1913, BuOrd 25415 (BIR-16-13), RG74/E25/BB164, NARA.
16. See Clive Trebilcock, "The British Armaments Industry, 1890–1914: False Legend and True Utility," in *War, Economy, and the Military Mind*, ed. Geoffrey Best and Andrew Wheatcroft (London: Croom Held, 1976), 92.
17. Note that the following schema maps closely onto Jan Glete's typology of procurement options for early modern navies; see Jan Glete, *Navies and Nations: Warships, Navies and State Building in Europe and America, 1500–1860*, vol. 1 (Stockholm: Almqvist and Wiksell International, 1993), 13–15.
18. For the same considerations in a later period, see Jeffrey Engel, *Cold War at 30,000 Feet: The Anglo-American Fight for Aviation Supremacy* (Cambridge, MA: Harvard University Press, 2007), 60–61.
19. See Geoffrey Parker, "Introduction: The Western Way of War," in *The Cambridge History of Warfare*, ed. Geoffrey Parker (Cambridge: Cambridge University Press, 2005), 6–10.
20. Fisher to Thursfield, November 6, 1900, THU 1/1/1, NMM; Kitchener quoted in Jon Sumida, "Forging the Trident: British Naval Industrial Logistics, 1914–1918," in *Feeding Mars: Logistics in Western Warfare from the Middle Ages to*

the Present, ed. John Lynn (Boulder, CO: Westview Press, 1993), 217; N. A. M. Rodger, "From the 'Military Revolution' to the 'Fiscal-Naval State,'" *Journal for Maritime Research* 13, no. 2 (November 2011): 122–23. Jan Glete's work on early modern navies is also very suggestive on this point.

Two qualifications are in order. First, the British army was a long-service small volunteer army. Short-service mass conscript armies were still less technologically advanced than navies, but they did present procurement challenges that differed significantly from those presented by long-service armies. Second, even long-service armies could pose difficult procurement challenges. Merritt Roe Smith, in *Harpers Ferry Armory and the New Technology: The Challenge of Change* (Ithaca, NY: Cornell University Press, 1977), and David Hounshell, in *From the American System to Mass Production, 1800–1932* (Baltimore, MD: Johns Hopkins University Press, 1984), 15–65, have shown how the early nineteenth-century US Army evolved what could be considered (albeit problematically) a proto-military-industrial complex to manufacture small arms, and that this "American system of manufactures" played a central role in American industrial growth. Even so, it is clear that navies, in both the United States and Great Britain, were far more technologically advanced than armies by the late nineteenth century, and that they posed correspondingly more serious problems of capital depreciation, especially in countries with professional long-service armies.

21. Cattaruzza and Casali, *Sotto i mari del mondo*, 48.
22. William Brophy, *The Springfield 1903 Rifles: The Illustrated, Documented Story of the Design, Development, and Production of All the Models of Appendages, and Accessories* (Mechanicsburg, PA: Stackpole Books, 1985), 230; Sawyer to Theiss, March 20, 1911, BuOrd 22997/16, RG74/E25/B1180, NARA.
23. The literature on control technologies is too extensive to list here, but a good starting point is James Beniger, *The Control Revolution: Technological and Economic Origins of the Information Society* (Cambridge, MA: Harvard University Press, 1986). Philip Scranton's *Endless Novelty: Specialty Production and American Industrialization* (Princeton, NJ: Princeton University Press, 1997) is a classic challenge to the habit of defining industrialization, and particularly the Second Industrial Revolution, in terms of heavy industry, large corporations, and mass production. On targeting systems, see Jon Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (Boston: Unwin Hyman, 1989), which offers striking parallels to torpedoes in terms of intellectual property rights. On gyrostabilization, see Thomas P. Hughes, *Elmer Sperry: Inventor and Engineer* (Baltimore, MD: Johns Hopkins University Press, 1971). On radio, see Timothy Wolters, "Managing a Sea of Information: Shipboard Command and Control in the United States Navy, 1899–1945" (Ph.D. Diss., Massachusetts Institute of Technology, 2003).

24. The ideal gas law is the equation $PV = nRT$, where P = pressure of gas, V = volume of gas, n = amount of substance of gas, R = the universal gas constant, and T = temperature of gas.
25. See Philip Scranton, "Technology-Led Innovation: The Non-Linearity of US Jet Propulsion Development," *History and Technology* 22, no. 4 (December 2006): 337–67. See also David Edgerton, " 'The Linear Model' Did not Exist: Reflections on the History and Historiography of Science and Research in Industry in the Twentieth Century," in *The Science-Industry Nexus: History, Policy, Implications*, Nobel Symposium 123, ed. Karl Grandin, Nina Wormbs, and Sven Widmalm (Sangamore Beach, MA: Science History Publications, 2004), 31–57; and Joel Mokyr, *The Gifts of Athena: Historical Origins of the Knowledge Economy* (Princeton, NJ: Princeton University Press, 2002), 85–104.
26. I owe the framing of this point to Hermione S. Giffard, "The Development and Production of Turbojet Aero-Engines in Britain, Germany, and the United States, 1936–1945" (Ph.D. diss., Imperial College London, 2011), esp. 9–61.
27. William McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago: University of Chicago Press, 1982), 278–79.
28. The literature on the history of patents specifically and intellectual property rights more broadly is extensive, but the following are good starting points: Adrian Johns, *Piracy: The Intellectual Property Wars from Gutenberg to Gates* (Chicago: University of Chicago Press, 2009); B. Zorina Khan, *The Democratization of Invention: Patents and Copyrights in American Economic Development, 1790–1920* (New York: Cambridge University Press, 2005); Christine MacLeod, *Heroes of Invention: Technology, Liberalism and British Identity* (Cambridge: Cambridge University Press, 2007); and Alain Pottage and Brad Sherman, *Figures of Invention: A History of Modern Patent Law* (Oxford: Oxford University Press, 2010).
29. See Catherine L. Fisk, *Working Knowledge: Employee Innovation and the Rise of Corporate Intellectual Property, 1880–1930* (Chapel Hill: University of North Carolina Press, 2009), esp. 173–239; and Christine MacLeod, "Negotiating the Rewards of Invention: The Shop-Floor Inventor in Victorian Britain," *Business History* 41, no. 2 (April 1999): 17–36.
30. Richard Hofstadter, *The American Political Tradition and the Men Who Made It* (New York: Vintage, 1989), 95.

1. America's Weapons of the Weak

Epigraph: Fiske to O'Neil, October 11, 1901, BuOrd 9558/01, RG74/E25/B480, NARA.

1. On the naval narrative, see, for example, Charles Paullin, *Paullin's History of Naval Administration* (Annapolis, MD: U.S. Naval Institute, 1968), 335–471; Harold Sprout and Margaret Sprout, *The Rise of American Naval Power,*

1776–1918 (Princeton, NJ: Princeton University Press, 1944), 183–303; Walter Herrick, *The American Naval Revolution* (Baton Rouge: Louisiana State University Press, 1966), especially pp. 54–85; Stephen Howarth, *To Shining Sea: A History of the United States Navy, 1775–1991* (New York: Random House, 1991), 231–320; Kenneth Hagan, *This People's Navy: The Making of American Sea Power* (New York: The Free Press, 1991), 176–258, 389–90; Robert O'Connell, *Sacred Vessels: The Cult of the Battleship and the Rise of the U.S. Navy* (Boulder, CO: Westview Press, 1991).

On the naval narrative in broader histories, see, for example, David M. Pletcher, *The Awkward Years: American Foreign Relations under Garfield and Arthur* (Columbia: University of Missouri Press, 1962), 116–36; Walter LaFeber, *The New Empire: An Interpretation of American Expansion, 1860–1898* (Ithaca, NY: Cornell University Press, 1963), 58–60, 93, 121–27, 229–41; James Abramson, *America Arms for a New Century: The Making of a Great Military Power* (New York: The Free Press, 1981), 20–9, 47–8, 120–3; Thomas Misa, *A Nation of Steel: The Making of Modern America, 1865–1925* (Baltimore, MD: Johns Hopkins University Press, 1995), 95–96; Paul A. C. Koistinen, *Mobilizing for Modern War: The Political Economy of American Warfare, 1865–1919* (Lawrence: University Press of Kansas, 1997), 26–47; Dirk Bönker, *Militarism in a Global Age: Naval Ambitions in Germany and the United States before World War I* (Ithaca, NY: Cornell University Press, 2012), 101–16.

2. Contract between Hotchkiss Ordnance Company and Secretary of the Navy, January 4, 1889, B3-225, NTS; "Specifications for the Manufacture of Howell Automobile Torpedoes and Launching Apparatus, 1888 [sic]," January 3, 1889, ibid.; Sampson to Hotchkiss IoO, October 18, 1894, BuOrd 6593/94-LS22/606 with 4728/94, RG74/E25/B203, NARA.
3. See DeptNav, *Report of the Secretary of the Navy* (1890), 51st Cong., 2nd Sess., H. Exec. Doc. 1, pt. 3, p. 25, and *Report of the Secretary of the Navy* (1891), 52nd Cong., 1st Sess., H. Exec. Doc. 1, pt. 3, pp. 16–17. For context, see Benjamin Franklin Cooling, *Gray Steel and Blue Water Navy: The Formative Years of America's Military-Industrial Complex, 1881–1917* (Hamden, CT: Archon Books, 1979), 15–84.
4. See "A New Brooklyn Company," *Brooklyn Eagle*, December 31, 1885, p. 4; E. W. Bliss Co., *The Third Dimension of Invention* (Detroit, 1948), 1–4, 15–20 (quotation on pp. 2–3).
5. See "To Make Shells," *Brooklyn Eagle*, December 29, 1890, p. 4; "Brooklyn's Big Industries," *Brooklyn Eagle*, June 27, 1893, p. 24; "Absorbs U.S. Projectile Co.," *Brooklyn Eagle*, March 15, 1902, p. 20.
6. For the dimensions, see "Specifications for the Manufacture of Howell Automobile Torpedoes and Launching Apparatus, 1888 [sic]," January 3, 1889, B3-225, NTS; "Specifications for the Manufacture of Whitehead Automobile

Torpedoes," January 23, 1891, B7-137, NTS. The Navy referred to the Howell torpedo in inches and feet, presumably because it was a US invention, and to the Whitehead torpedo in centimeters and meters, presumably because it was a European invention. On effective range, see Torpedo Board to Converse, October 23, 1895, B15-142, NTS. Note that the Torpedo Board used the term *effective range* rather loosely.

7. Sampson to Converse, January 20, 1896, BuOrd 627/96-LS33/346 with 790/96, RG74/E25/B249, NARA; Torpedo Board to Sampson, January 23, 1896, BuOrd 790/96, ibid.
8. Torpedo Board to Sampson, September 20, 1895, BuOrd 6327/95 with 5906/95, RG74/E25/B234, NARA.
9. For the negotiations, see Sampson to Hotchkiss Ordnance Co., February 3, 1896, BuOrd 790/96-LS34/160, RG74/E25/B249, NARA; Ordway [Hotchkiss agent] to Sampson, February 24, 1896, BuOrd 1701/96 with 790/96, ibid.; Ordway to Sampson, July 9, 1896, BuOrd 5185/96 with 790/96, ibid.; Sampson to American Ordnance Co., December 15, 1896, BuOrd 9371/96-LS47/190 with 9454/96, RG74/E25/B274, NARA; Ordway to Sampson, December 19, 1896, BuOrd 9454/96, ibid.; Converse to Sampson, January 13, 1897, BuOrd 513/97 with 9454/96, ibid.; Sampson to Herbert, January 19, 1897, BuOrd 9454/96-LS88/479 with 9454/96, ibid. On the flywheel, see Sampson to Hotchkiss Ordnance Co., March 13, 1895, BuOrd 8005/95-LS24/253 with 8133/93, RG74/E25/B184, NARA; Fletcher, Smith, and Ziegemeier [NTS officers] to Converse, December 1, 1896, enclosure to BuOrd 11/97 with 9454/96, RG74/E25/B274, NARA; Wood [IoO, American Ordnance Co.] to Converse, January 2, 1897, enclosure to BuOrd 497/97 with 9454/96, ibid.; Converse to Sampson, January 12, 1897, BuOrd 497/97 with 9454/96, ibid.; Wood to Sampson, January 18, 1897, BuOrd 613/97 with 9454/96, ibid.
10. Sampson to Converse, February 1, 1897, B15-142, NTS.
11. Miller Board to SecNav, February 4, 1897, BuOrd 1639/97 with 1022/97, and endorsement thereon, RG74/E25/B282, NARA. Edwyn Gray's explanation for the demise of the Howell torpedo (in Edwyn Gray, *The Devil's Device: The Story of Robert Whitehead, Inventor of the Torpedo* [Annapolis, MD: Naval Institute Press, 1991, 122]) is incorrect; what doomed the Howell was not its lack of speed or range, but the time required to prepare it for action.
12. Sampson to Bliss Co., February 6, 1896, BuOrd 790/96-LS34/262, RG74/E25/B249, NARA; Bliss Co. to Sampson, February 12, 1896, BuOrd 1377/96 with 790/96, ibid.; Sampson to Bliss Co., February 14, 1896, BuOrd 1377/96-LS34/251 with 790/96, ibid.; Bliss Co. to Sampson, February 18, 1896, BuOrd 1561/96 with 790/96, ibid.; Sampson to Converse, June 18, 1896, BuOrd 4568/96-LS39/583 with 790/96, ibid.; Sampson to Bliss Co., August 29, 1896, BuOrd 4812/96-LS42/513 with 790/96, ibid.; "Specifications for the

Manufacture of Whitehead Automobile Torpedoes, U. S. N., Mark III," September 26, 1896, RG45/E502 (Envelope, "Mines and torpedoes, reports, correspondence & miscellaneous data relative to, 1871–1899"), NARA; Bliss to Sampson, September 14, 1896, BuOrd 6864/96, RG74/E25/B266, NARA; Sampson to Bliss Co., March 24, 1897, BuOrd 2261/97-LS51/346 with 2261/97, RG74/E25/B286, NARA; Bliss Co. to Sampson, March 26, 1897, BuOrd 2371/96 with 2261/97, ibid.; Acting CoO to Bliss Co., March 30, 1897, BuOrd 2371/97-LS516–17 with 2261/97, ibid.

13. Whitehead Co. (Weymouth) to Vreeland, September 11, 1896, BuOrd 5424/96 with 6864/96, RG74/E25/B266, NARA; Sampson to Bliss Co., October 12, 1896, BuOrd 7296/96-LS44/226 with 6864/96, ibid.; Converse to Leavitt, October 16, 1896, B14-143, NTS; Leavitt to Converse, October 19, 1896, B15-142, NTS (contains quotation); Converse to Sampson, October 21, 1896, BuOrd 7877/96 with 790/96, RG74/E25/B249, NARA; Converse to Sampson, October 27, 1896, BuOrd 8044/96 with 790/96, ibid.
14. Fiume Commission to SecNav, December 10, 1896, B18-152, NTS, including enclosure Whitehead Co. (Fiume) to President, Fiume Commission, December 9, 1896; Converse to Sampson, January 8, 1897, BuOrd 271/97 with 6864/96, RG74/E25/B266, NARA; Sampson to Bliss Co., May 24, 1897, BuOrd 3581/97-LS54/228 with 6864/96, ibid.
15. Converse to Leavitt, March 23, 1897, B15-142, NTS (contains quotation); Acting CoO to Bliss Co., May 12, 1897, BuOrd 7590/96-LS53/497–8 with 6864/96, RG74/E25/B266, NARA; Bliss Co. to Sampson, May 14, 1897, BuOrd 3554/97 with 6864/96, ibid.; Bliss Co. to Sampson, May 15, 1897, BuOrd 3581/97 with 6864/96, ibid.; Bliss Co. to Sampson, July 14, 1897, BuOrd 5007/97 with 6864/96, ibid.; Bliss IoO to Converse, July 24, 1897, B18-152, NTS.
16. Bliss Co. to Sampson, December 23, 1896, BuOrd 9591/96 with 9590/96, RG74/E25/B275, NARA; Rittenhouse to Sampson, December 24, 1896, B15-142, NTS; Sampson to Converse, December 28, 1896, BuOrd 9454/96, RG74/E25/B274, NARA; Wainwright to Converse, January 29, 1897, B15-142, NTS; London Naval Attaché to SecNav, March 20, 1897, BuOrd 2204/97 with 9590/96, RG74/E25/B275, NARA; Leavitt to Converse, March 22, 1897, B15-142, NTS; Bliss Co. to Sampson, April 3, 1897, BuOrd 2590/97 with 9590/96, RG74/E25/B275, NARA; Converse to Sampson, April 9, 1897, BuOrd 2748/97 with 9590/96, ibid.; Rittenhouse to Sampson, April 13, 1897, BuOrd 2847/97 with 9590/96, ibid.; Sampson to Bliss Co., May 18, 1897, BuOrd 3558/97-LS64/46, with 9590/96 ibid. For the reports of the Speed Board, see Rittenhouse and Fletcher, May 7, 1897, B15-142, NTS; May 13, 1897, BuOrd 3558/97 with 9590/96, RG74/E25/B275, NARA; June 17 and 23, 1897, BuOrd 4440/97 with 9590/96, ibid.
17. Bliss to SecNav, June 21, 1897, BuOrd 4485/97 with 6864/96, and endorsements thereon, RG74/E25/B266, NARA.

18. Acting CoO to Bliss Co., August 10, 1897, BuOrd 5424/97-LS58/248–9 with 6864/96, RG74/E25/B266, NARA; Bliss Co. to O'Neil, August 12, 1897, BuOrd 5861/97 with 6864/96, ibid.
19. Torpedo Board to O'Neil, August 28 (contains quotations) and September 21, 1897, BuOrd 6459/97 and 6962/97, respectively, both with 6864/96, ibid.; O'Neil to SecNav, September 23, 1897, BuOrd 6962/97-LS60/371–72 with 6864/96, ibid.; Acting SecNav to O'Neil, September 24, 1897, BuOrd 7061/97 with 6864/96, ibid.; O'Neil to Bliss Co., September 27, 1897, BuOrd 7061/97-LS60/498–500 with 6864/96, ibid.; SecNav to Swift, October 2, 1897, BuOrd 7351/97 with 6864/96, ibid.; O'Neil to Bliss Co., February 23, 1898, BuOrd 1316/98-LS68/555–56 with 6864/96, ibid.
20. McLean to O'Neil, May 23, 1898, BuOrd 7044/98, RG74/E25/B335, NARA; O'Neil to Sears, June 2, 1898, BuOrd 7404/98 with 4979/98, RG74/E25/B328, NARA; Sears to O'Neil, June 3, 1898, BuOrd 7621/98 with 6864/96, RG74/E25/B266, NARA; McLean to O'Neil, June 4, 1898, BuOrd 7806/98 with 7044/98, RG74/E25/B335, NARA; O'Neil to McLean, June 8, 1898, BuOrd 7832/98-LS81/230 with 7044/98, RG74/E25/B335, NARA; Sears to O'Neil, June 12, 1898, BuOrd 8218/98 with 4979/98, RG74/E25/B328, NARA; O'Neil to McLean, June 14, 1898, BuOrd 8218/98 with 7044/98, RG74/E25/B355, NARA; McLean to O'Neil, June 15, 1898, BuOrd 8420/98 with 7044/98, ibid.; Sears to O'Neil, June 15, 1898, BuOrd 8364/98 with 2214/98, RG74/E25/B319, NARA; McLean to O'Neil, June 17, 1898, BuOrd 8484/98 with 4979/98, RG74/E25/B328, NARA; O'Neil to McLean, June 18, 1898, BuOrd 8420/98-LS82/285–6 with 7044/98, RG74/E25/B335, NARA; McLean to O'Neil, July 2, 1898, BuOrd 9324/98 with 7044/98, ibid.
21. Sears to O'Neil, June 12, 1898, BuOrd 8218/98 with 4979/98, RG74/E25/B328, NARA; Chambers to McLean, August 30, 1898, enclosed in Bliss IoO to O'Neil, August 16, 1898, BuOrd 11446/98 with 7044/98, RG74/E25/B335, NARA.
22. Sears to O'Neil, September 21, 1898, BuOrd 11446/98 with 7044/98, ibid.; Chambers to McLean, June 1898, B5-145 and B21-171, NTS.
23. O'Neil to Bliss Co., November 28, 1898, BuOrd 1900/98-LS94/242–44 with 7455/97, RG74/E25/B302, NARA (contains first quotation); O'Neil to CoNav for ONI, November 30, 1898, BuOrd 1900/98 with 7455/97, ibid. (contains second quotation); Bliss IoO to McLean, December 4, 1898, Ms. Coll. 280/B1/F3, NHC (contains third quotation; emphasis in original); McLean to Poundstone, December 8, 1898, ibid. (contains fourth quotation).
24. O'Neil to CINC North Atlantic Squadron, March 19, 1898, BuOrd 2787/98-LS71/116, RG74/E25/B322, NARA; O'Neil to McLean, June 18, 1898, BuOrd 8364/98 with 2214/98, RG74/E25/B319, NARA; O'Neil to Sears, August 17, 1898, BuOrd 11446/98 with 7044/98, RG74/E25/B335, NARA. Additional

relevant papers can be found in B23-174, NTS; and with BuOrd 7044/98, RG74/E25/B335, NARA.

25. For more on Chambers, see Mason to O'Neil, August 29, 1899, Torpedo Station's Annual Report for FY 1898–1899, B21-171, NTS; and Stephen Stein, *From Torpedoes to Aviation: Washington Irving Chambers and Technological Innovation in the New Navy, 1876–1913* (Tuscaloosa: University of Alabama Press, 2007). On the experiments, see Chambers to McLean, July 5, 1898, B21-171, NTS; McLean to O'Neil, December 15, 1898, BuOrd 15274/98 with 7455/97, RG74/E25/B302, NARA; Chambers to McLean, May 16, 1899, B21-171, NTS; documents with BuOrd 2034/99, RG74/E25/B372, NARA; and documents with 10407/00, RG74/E25/B437, NARA.
26. Chandler to Mason, September 30, 1901, enclosure to Mason to O'Neil, October 2, 1901, BuOrd 9235/01 with 10407/00, ibid.; Mason to O'Neil, October 2, 1901, BuOrd 9235/01 with 10407/00, ibid. (contains quotation).
27. Mason to O'Neil, April 21, 1902, 21 April 1902, BuOrd 3296/02 with 10407/00, ibid. (contains first quotation); Williams to Mason, June 1, 1902, BuOrd 4449/02 with 10407/00, ibid. (contains second quotation); endorsement by O'Neil to Mason, May 3, 1902, BuOrd 3296/02 with 10407/00, ibid.
28. O'Neil to SecNav, October 6, 1897, BuOrd 7397/97-LS61/278 with 7455/97, RG74/E25/B302, NARA; O'Neil to Bliss Co., October 8, 1897, BuOrd 7455/97-LS61/370, ibid; "Specifications for the Manufacture of Whitehead Automobile Torpedoes, U. S. N., 5 m × 45 cm, Mk I," December 1, 1897, RG45/E502 (Envelope "Mines and torpedoes, reports, correspondence & miscellaneous data relative to, 1871–1899"), NARA; Bliss Co. to O'Neil, January 3, 1899, BuOrd 74/99 with 7455/97, RG74/E25/B302, NARA.
29. O'Neil to Parsons, January 28, 1898, BuOrd 867/98-LS67/515 with 7455/97, ibid.; O'Neil to Curtis Co., January 29, 1898, BuOrd 867/98-LS67/516 with 7455/97, ibid.; Curtis Co. to O'Neil, January 31, 1898, BuOrd 1013/98 with 7455/97, ibid.; O'Neil to CoNav for CIO, December 16, 1898, BuOrd 1900/98 with 7455/97, ibid.; O'Neil to Bliss Co., June 5, 1899, BuOrd 5625/99-LS107/16–17 with 7455/97, ibid.; Bliss Co. to O'Neil, July 19, 1899, BuOrd 7353/99, RG74/E25/B389, NARA; Acting CoO to Bliss Co., July 31, 1899, BuOrd 7353/99-LS110/239, ibid. On the flasks, see O'Neil to Midvale Steel Co. IoO, April 29, 1899, BuOrd 3666/99-LS104/222 with 7455/97, RG74/E25/B302, NARA; O'Neil to Bethlehem Iron Co. IoO, April 29, 1899, BuOrd 3666/99-LS104/203–4 with 7455/97, ibid.; Torpedo Board to McLean, July 25, 1899, sections A–B, B18-152, NTS.
30. O'Neil to Rittenhouse, September 30, 1897, BuOrd 7053/97-LS61/63 with 3407/97, RG74/E25/B290, NARA; O'Neil to Commandant Newport Naval Station, December 10, 1897, BuOrd 9256/97-LS65/274, RG74/E25/B307, NARA; O'Neil to McLean, May 23, 1898, BuOrd 9256/97-LS79/343, ibid.

31. McLean to O'Neil, June 6, 1898, BuOrd 8500/98 with 9256/98, RG74/E25/B436 [misfiled, should be in B307], NARA.
32. O'Neil to McLean, November 28, 1898, BuOrd 8023/97 with 7455/97, RG74/E25/B302, NARA. The elastic limit referred to the amount of stress that metal could stand before it began to deform elastically (as opposed to plastically—elastic deformation was reversible, plastic deformation was permanent). The lower the elastic limit, the less stress it took to deform the metal elastically. The elongation percentage measured how much a metal stretched when pulled; a 25 percent elongation for a 2-inch specimen meant that the specimen began at 2 inches and, after being stretched, ended at 2.5 inches. The higher the percentage, the stretchier the metal.
33. O'Neil to Bliss Co., September 6, 1899, BuOrd 5625/99 with 7455/97, RG74/E25/B302, NARA; Bliss Co. to O'Neil, September 25, 1899, BuOrd 9361/99 with 7455/97, ibid.; O'Neil to Bliss Co., October 6, 1899, BuOrd 9361/99 with 7455/97, ibid.; Bliss Co. to O'Neil, October 9, 1899, BuOrd 9816/99 with 7455/97, ibid.; O'Neil to Bliss Co., October 12, 1899, BuOrd 9816/99 with 7455/97, ibid.
34. Bliss Co. to Herbert & Micou, February 7, 1900, BuOrd 1538/00, RG74/E25/B410, NARA.
35. On Leavitt, see St. John's Alumni Association, *1789–1889: Commemoration of the One Hundredth Anniversary of St. John's College* (Baltimore, MD: William K. Boyle and Son, 1890), 109–10; Bliss Co., *Third Dimension*, 21–22; "A Naval Officer's Marriage," *NYT*, November 21, 1883; "A New Brooklyn Company," *Brooklyn Eagle*, December 31, 1885, p. 4; "Lieut. Commander James C. Cresap," *NYT*, August 8, 1901; "Others Gathered His Fruit," *NYT*, August 8, 1895, p. 2; "Mechanical Engineers, in Big Demand, Win Quick Success," *NYT*, October 19, 1913, p. SM11; "Frank M'D Leavitt, Inventor, Dies at 72," *NYT*, August 7, 1928, p. 21; "Leavitt Left $1,200,345," *NYT*, March 23, 1929, p. 11; "Stevens Names Buildings," *NYT*, November 6, 1946, p. 29.
36. Bliss Co. to Herbert & Micou, February 7, 1900, BuOrd 1538/00, RG74/E25/B410, NARA.
37. O'Neil to Bliss Co., February 9, 1900, BuOrd 1538/00-LS122/480–81, ibid.; O'Neil to Bliss Co., February 24, 1900, BuOrd 1538/00-LS123/542–43, ibid.
38. Fiske to O'Neil, August 1, 1900 (contains first quotation), and O'Neil's endorsement thereon, August 6, 1900, BuOrd 8113/00 with 1538/00, ibid.; Fiske to O'Neil, September 10,1900, BuOrd 9404/00, RG74/E25/B434, NARA; Fiske to O'Neil, December 1, 1900, BuOrd 12387/00 with 9404/00, RG74/E25/B479 [misfiled, should be in B434], NARA (contains second quotation).
39. O'Neil to Bliss Co., December 5, 1900, BuOrd 12387/00-LS146/39–40 with 9404/00, ibid.; Bliss Co. to O'Neil, December 10, 1900, BuOrd 12715/00 with 9404/00, ibid.; O'Neil to Bliss Co., December 13, 1900, BuOrd 12715/00 with

9404/00, ibid. The fact that the price quotations for the exclusive and nonexclusive rights were the same is puzzling; the exclusive rights should have cost more in order to make up for the loss of foreign sales. Either there was a typo in the form of a missing zero, or the Bliss Company had not yet begun to think in terms of a global marketplace.

40. Mason to O'Neil, April 18, 1901, BuOrd 3970/01 with 9404/00, RG74/E25/B479 [misfiled, should be in B434], NARA; Torpedo Board to Mason, June 10, 1901, enclosure to Mason to O'Neil, June 12, 1901, BuOrd 5830/01 with 9404/00, ibid.; O'Neil to Fiske for Bliss Co., September 13, 1901, BuOrd 8686/01-LS167/208 with 9404/00, ibid.; Bliss Co. to Fiske for O'Neil, September 23, 1901, BuOrd 8943/01 with 9404/00, ibid.; Miller to Mason, September 30, 1901, and Chandler to Mason, September 30, 1901, enclosed in Mason to O'Neil, October 1, 1901, BuOrd 9404/00, ibid.; O'Neil to Bliss Co., October 3, 1901, BuOrd 8943/01-LS168/396 with 9404/00, ibid.; Bliss Co. to O'Neil, October 7, 1901, BuOrd 9374/01 with 9404/00, ibid.; Mason to O'Neil, November 19, 1901, BuOrd 10950/01 with 9404/00, B30-168, NTS.
41. O'Neil to Mason, September 11, 1901, BuOrd 8621/01 with 9558/01, RG74/E25/B480, NARA; Miller to Mason (September 14, 1901), Chandler to Mason (September 16, 1901), and Williams to Mason (October 3, 1901), enclosures to Mason to O'Neil, October 11, 1901, BuOrd 9563/01 with 9558/01, ibid.
42. Leavitt to Fiske, October 10, 1901, enclosed in Fiske to O'Neil, October 11, 1901 (contains quotation), BuOrd 9558/01, ibid.; O'Neil to Fiske, October 14, 1901, BuOrd 9558/01-LS168/175–76, ibid.; Bliss Co. to O'Neil, October 18, 1901, BuOrd 9791/01 with 9558/01, ibid.; O'Neil to Bliss Co., October 19, 1901, BuOrd 9593/01-LS169/449 with 9558/01, ibid.
43. Davison to O'Neil, April 26, 1902, BuOrd 3677/02 with 9558/01, ibid.
44. Leavitt to Bliss Co., May 19, 1902, enclosure to Pollock to O'Neil, May 24, 1902 (contains quotation), B31-161, NTS.
45. Bliss IoO to Hill (BuOrd torpedo officer), June 11, 1902, B31-161, NTS; Acting CoO to Bliss IoO, June 12, 1902, BuOrd 4704/02-LS184/531 with 9558/01, RG74/E25/B480, NARA; Fletcher to O'Neil, September 8, 1902, BuOrd 7682/02 with 9558/01, ibid.; Chambers Board to O'Neil, November 19, 1903, BuOrd 13021/03 with 9558/01, ibid.
46. Ronald Spector, *Professors at War: The Naval War College and the Development of the Naval Profession* (Newport, RI: Naval War College Press, 1977), 71–73; Solution to the Problem of 1899, Section C, RG12, NHC.
47. Murdock, "Battle Tactics," lecture delivered June 20, 1901, RG14/B2, NHC (contains quotation); Murdock, "Naval Tactics (4)" and "Naval Tactics (5)," lectures delivered summer 1902, ibid.
48. Dewey to Commander, North Atlantic Squadron, March 22, 1901, RG80/E285/B1/V1, pp. 181–83, NARA; Crowninshield [temporary president, General

Board] to SecNav, November 25, 1901, ibid., pp. 390–93; Solution to Problem of 1901, Appendix B: Tactics, RG12, NHC; Solution to Problem of 1902, "Note" and Murdock's paper, ibid.

49. Sampson to Converse, August 31, 1895, BuOrd 5822/95 with 5906/95, RG74/E25/B234, NARA; Torpedo Board to Sampson, September 20, 1895, BuOrd 6327/95 with 5906/95, ibid.; Sampson to Converse, February 1, 1897, B15-142, NTS (contains quotation); Sampson to Converse, March 24, 1897, BuOrd 1435/97, ibid.; Converse to Sampson, April 5, 1897, ibid.; Poundstone to Converse, April 10, 1897, ibid.; Sampson to Converse, May 25, 1897, BuOrd 3602/97 with 619/97, RG74/E25/B280, NARA; Torpedo Board to Sampson, June 1, 1897, BuOrd 4101/97 with 619/97, B15-142, NTS. The negotiations with Armstrong can be found with BuOrd 5841/97, RG74/E25/B297, NARA.
50. O'Neil to McLean, February 24, 1899, BuOrd 2034/99-LS99/528, RG74/E25/B372, NARA; Chandler to Mason, September 30, 1901, enclosure to BuOrd 9235/01 with 10407/00, RG74/E25/B437, NARA; O'Neil to Fletcher, September 10, 1902, BuOrd 7734/02, B32-164, NTS.
51. O'Neil to Mason, June 7, 1901, BuOrd 3970/01, B30-168, NTS.
52. Board on Construction [majority] to SecNav, January 20 (contains quotation) and December 27, 1902, RG80/E180/V6/P191 and RG80/E180/V7/P55–60, respectively, NARA; Bradford [minority] to SecNav, February 12, 1902, RG80/E180/V6/P218, NARA.
53. Nicholas Lambert, "The Influence of the Submarine Upon Naval Strategy, 1898–1914" (Ph.D. Diss., Oxford University, 1992), 70–75. See also the bundle of letters from October 1895 in B15-142, NTS, and B. H. McCalla, "Lessons of the Late War," lecture delivered June 1, 1899 at USNWC, pp. 21–24, RG15/B1, NHC.
54. Davison to O'Neil, April 26, 1902, BuOrd 3677/02 with 9558/01, RG74/E25/B480, NARA.

2. *Britain's Weapons of the Strong*

Epigraph: Minute by Goschen, January 17, 1897, Adm G7032/96, ADM 116/519, TNA.

1. See Nicholas Lambert, *Sir John Fisher's Naval Revolution* (hereafter *FNR*) (Columbia: University of South Carolina Press, 1999), 16.
2. For a concise overview of the establishment of the Weymouth works, see "Précis of patterns relative to the trials of New Torpedoes Manufactured by Whitehead and Co.," attachment to minute by May (ADT), September 28, 1894, Adm G5476/94, ADM 116/412, TNA. I use the term *Whitehead torpedoes* here to indicate that these torpedoes were produced by the Whitehead Company. In terms of design rather than production, the RGF torpedoes were essentially Whiteheads as well.

3. TDC to CINC Portsmouth, September 6, 1894, enclosure to Salmon to SecAdm, September 14, 1894, Adm G5476/1894; minute by May, September 28, 1894, and minutes by DNO, Controller, and First Naval Lord on Adm G5476/94, ADM 116/412, TNA. On May, see *FNR*, 200.
4. Walker to CINC Portsmouth, December 15, 1894, Adm G46/95, ADM 116/403, TNA.
5. SecAdm to Whitehead Co. (Weymouth), October 19, 1894, Adm G5478/7434/94, ADM 116/412, TNA; minute by May, January 8, 1895, and endorsements thereon, Adm G46/95, ADM 116/403, TNA (contains quotation); SecAdm to Whitehead Co. (Weymouth), January 30, 1895, Adm G46/805/95, ADM 116/403, TNA.
6. Whitehead Co. (Weymouth) to SecAdm, October 29, 1894, Adm G6413/94, ADM 116/412, TNA; SecAdm to Whitehead Co. (Weymouth), November 21, 1894, Adm G6413/8380/94, ibid.; Whitehead Co. (Weymouth) to SecAdm, November 27, 1894, Adm G7009/94, ibid.; Whitehead Co. (Weymouth) to SecAdm, December 8, 1894, Adm G7245/94, ibid.; DNO to Whitehead Co. (Weymouth), December 28, 1894, ibid.; Whitehead Co. (Weymouth) to SecAdm, December 30, 1894, Adm G7581/94, ibid.; Whitehead Co. (Weymouth) to SecAdm, January 9, 1895, Adm G226/95, ibid.; Whitehead Co. (Weymouth) to SecAdm, February 28, 1895, Adm G1157/95, ibid.; Whitehead Co. (Weymouth) to SecAdm, March 6, 1895 (date approximate), Adm G1312/95, ibid.; Whitehead Co. (Weymouth) to SecAdm, July 2, 1895, Adm G3583/95, ibid. For the preliminary torpedo orders, see minutes on Whitehead Co. (Weymouth) to SecAdm, January 9, 1895, Adm G226/95, ibid.; and minutes on Whitehead Co. (Weymouth) to SecAdm, February 5, 1895, Adm G737/95, ibid.
7. DGOF to DNO, February 9, 1895, NO3407/95, ADM 116/403, TNA; Walker to DNO (February 21, 1895), Bourke (for DNO) to DGOF (February 23, 1895), DGOF to DNO (March 4, 1895), NO3407/95, ibid.; Walker to CINC Portsmouth, March 7, 1895, Adm G1497/95, ibid. (contains quotation); Walker to CINC Portsmouth, March 29, 1895, enclosure to minute by Bourke, May 3, 1895, Adm G1497/95, ibid.
8. Minutes by Bourke, May 3, 1895 (contains first quotation), and Richards, May 6, 1895 (contains second quotation), Adm G1497/95, ibid.; minutes by Bourke, June 15, 1895, and Spencer, June 29, 1895, Adm G3258/95, ibid.
9. Minutes by Walker (January 29, 1896), Kane (January 31, 1896, contains quotation), and FinSec (February 6, 1896), Adm G543/96, ADM 116/519, TNA; Walker to Whitehead Co. (Weymouth), February 10, 1896, Adm G934/96, ibid.; Whitehead Co. (Weymouth) to Walker, February 12, 1896, Adm G934/96, ibid.; minute by Walker, February 17, 1896, Adm G543/96, ibid.; SecAdm to Greenwood & Batley, March 25, 1896, G782/1862/96, PQ/96/2406/232–33.

10. SecAdm to Whitehead Co. (Weymouth), June 4, 1896, Adm G2704/3452/96, ADM 116/519, TNA; Whitehead Co. (Weymouth) to SecAdm, June 15, 1896, Adm G3552/96, ibid. (contains quotation).
11. Minutes by Walker, June 30, 1896 (contains quotation), and Goschen, July 10, 1896 (contains quotation), Adm G3552/96, ibid.; SecAdm to Whitehead Co. (Weymouth), July 18, 1896, Adm G3552/4360/96, ibid.; ART96/19; ART97/23.
12. Vienna Naval Attaché to Monson (Ambassador), July 23, 1896 (forwarded to the Admiralty on July 28), Adm G5560/96, ADM 116/519, TNA; Whitehead Co. (Weymouth) to SecAdm, September 7, 1896, enclosing undated circular letter from the Whitehead Co., Adm G5127/96, ibid.; minute by Walker, September 7, 1896, Adm G5127/96, ibid. (contains quotation); SecAdm to Whitehead Co. (Weymouth), October 8, 1896, Adm G5127/96, ibid; Whitehead Co. (Weymouth) to SecAdm, October 24, 1896 (setting lump sum at £20,000), Adm G5995/96, and minutes thereon, ibid.
13. Whitehead Co. (Weymouth) to SecAdm, September 7, 1896, Adm G5246/96, PQ/96/2424/278–80; minute by Walker, October 1, 1896, Adm G5246/96, ibid. (contains quotation); ART96/21–27.
14. ART96/36–37; SecAdm to CINCs Mediterranean and Channel Fleets, July 16, 1896, Adm G3695/95, PQ/97/2487/71–72; minute by Fisher, June 24, 1896, Adm G3695/4425/96, ibid.; Durnford to CINC Portsmouth, October 27 and November 21, 1896, Adm G5708/96, ART96/Appendix K; minutes by Walker, December 1, 1896, and Kane, December 2, 1896, Adm G5708/96, SC146/F106, BF.
15. Robinson (commanding the *Vulcan*) to Senior Officer Poros, November 23, 1896, enclosure to CINC Med to SecAdm, December 7, 1896, Adm G7032/96, ADM 116/519, TNA; minute by Drury, November 24, 1896, on Adm G7032/96, ibid. The senior officer did not name the six nations.
16. Durnford to Walker, December 17, 1896, Adm G7032/96, ibid.
17. Whitehead Co. (Weymouth) to SecAdm, December 15, 1896, Adm G7098/96, ibid.
18. Durnford to Walker (for DNO), January 2, 1897, Adm G7098/96, ibid.
19. Minutes by Walker, January 8, 1897 (contains quotations), and Kane, January 23, 1897, Adm G7098/96, ibid.
20. Minutes by Fisher, January 12 and February 6 (contains quotations) 1897, Adm G7098/96, ibid.; Ruddock Mackay, *Fisher of Kilverstone* (Oxford: Clarendon Press, 1973), 187–93.
21. Minute by Richards, February 11, 1897, Adm G588/97, ADM 116/519, TNA.
22. Minute by Goschen, January 17, 1897, Adm G7032/96, ibid.
23. For a striking later parallel, see Jeffrey Engel, *Cold War at 30,000 Feet: The Anglo-American Fight for Aviation Supremacy* (Cambridge, MA: Harvard University Press, 2007), 57–59, 71–72.

24. There are fascinating parallels between this Admiralty debate and the issues discussed in Peter Galison, “Removing Knowledge,” *Critical Inquiry* 31, no. 1 (Autumn 2004): 233–37.
25. Minutes by Walker, February 2, 1897, and Richards, February 11, 1897, Adm G588/97, ADM 116/519, TNA; Whitehead Co. (Weymouth) to SecAdm, February 24, 1897, Adm G1061/97, and minutes thereon, ibid.
26. SecAdm to Whitehead Co. (Weymouth), March 11, 1897, Adm G1061/1700/97, ibid.; Whitehead Co. (Weymouth) to SecAdm, March 12, 1897, Adm G1419/97, and minutes thereon, ibid.; SecAdm to Whitehead Co. (Weymouth), March 19, 1897, Adm G1419/1865/97, ibid.; Whitehead Co. (Weymouth) to SecAdm, March 20, 1897, Adm G1788/97 and minutes thereon, ibid.; Durnford to CINC Portsmouth, March 26, 1897, Adm G1866/97, and minutes thereon, ibid.; SecAdm to Whitehead Co. (Weymouth), May 1, 1897, Adm G1788/2670/97, ibid.; Whitehead Co. (Weymouth) to SecAdm, May 22, 1897, Adm G2954/97 and minutes thereon, ibid.; SecAdm to Whitehead Co. (Weymouth), June 29, 1897, Adm G2954/2854/97, ibid.
27. Minute by Burke (for DNO), September 28, 1897, Adm G5143/97, and minutes thereon, ibid.; SecAdm to Whitehead Co. (Fiume), October 4, 1897, Adm G5143/5803/97, ibid.; SecAdm to Whitehead Co. (Fiume), October 22, 1897, Adm G5424/97, ibid.; Robinson to CINC Med, November 20, 1897, Adm G6333/97 and minutes thereon, ibid.
28. The RGF design had actually been developed two or three years earlier, but officials took interest in it only after the development of the Whitehead gyroscope; see ART97/30. See also PQ/98/2627 and minute by Walker, May 5, 1898, Adm G2023/98, ADM 116/519, TNA. On the approval of Walker’s recommendation, see minutes on Adm G5953/97, ibid. See also Durnford to Jeffrey, December 10, 1897, and Jeffrey to Durnford, January 11, 1898, Adm G6333/97, ibid.
29. Durnford to CINC Portsmouth, December 28, 1897, Adm G58/98, ibid.
30. Whitehead Co. (Weymouth) to SecAdm, February 24, 1897, G1061/97, ibid.; Whitehead Co. (Weymouth) to SecAdm, September 2, 1897, Adm G4695/97, ibid.; minute by Walker, July 15, 1897, Adm G3818/97, ibid.; Durnford to Jeffrey, September 6, 1897, Adm G4708/97, and September 8, 1897, Adm G4695/97, ibid. (contains quotation).
31. Minutes by Jeffrey (September 9, 1897), Walker (November 12, 1897, contains quotations), and Wilson (November 18, 1897), Adm G4695/97, ibid.; SecAdm to Whitehead Co. (Weymouth), November 27, 1897, Adm G4695/6914/97, ibid.
32. Minute by Walker, January 8, 1897, Adm G7098/96, ibid.; Whitehead Co. (Weymouth) to SecAdm, June 1, 1897, and Walker’s minute of June 3, 1897 thereon, Adm G3052/97, ibid.; SecAdm to Whitehead Co. (Weymouth), June 23, 1897, Adm G3052/3727/97, ibid.; minutes by Walker (February 8, 12, and 14, 1898) and Jeffrey (February 12 and 14, 1898, contains quotation), G647/98, ibid.

33. Whitehead to SecAdm, March 1, 1898, Adm G1107/98, PQ/99/2736/320–28; minute by Walker, n.d. but March 1898, Adm G1107/98, ibid.; "Précis concerning Messrs. Whitehead establishing works in England, and result with regard to orders to them and Greenwood & Batley," enclosure to minute by Jeffrey, March 28, 1898, Adm G1107/98, ibid. The relevant minute in the "Précis" was G6482/90.
34. Jeffrey to Wilson, March 19, 1898 (contains first quotations), and minute by Wilson thereon, March 19, 1898, Adm G1457/98, ADM 116/519, TNA; minutes by Jeffrey (March 28, 1898), Richards (April 1, 1898), and Goschen (April 25, 1898, contains final quotation), Adm G1107/98, PQ/99/2736/321–22.
35. Minutes (all March 1898) on Adm G1474/98, ADM 116/519, TNA.
36. Durnford to CINC Portsmouth, July 22, 1898, Adm G4171/98, ibid.; minute by Jeffrey, July 15, 1898 (contains quotations), and others on Adm G3915/98, PQ/99/2736/329–31.
37. Durnford to CINC Portsmouth, August 27, 1898, Adm G4871/98, ADM 116/519, TNA; Battenberg to Commander of Channel Squadron, October 1, 1898 (contains first quotation); Adm G5598/98, ibid.; Durnford to DNO, October 5, 1898, Adm G5598/98, ibid. (contains second quotation); minutes by Egerton, October 11, 1898 (contains third quotation), and Goschen, October 21, 1898 (contains fourth quotation), Adm G4871/98, ibid.; SecAdm to Whitehead Co. (Weymouth), October 25, 1898, Adm G4871/6243/98, ibid.; "Précis of correspondence in regard to Whitehead Gyroscopes," enclosure to minute by Jeffrey, August 31, 1899, Adm G5661/99, ADM 116/579, TNA.
38. Minute by Jeffrey, August 31, 1899, Adm G5661/99, ibid.
39. Undated circular letter from the Whitehead Company, September 1896, Adm G5127/96, ADM 116/519, TNA; Whitehead Co. (Weymouth) to SecAdm, October 24, 1896, Adm G5995/96, ibid.; Whitehead Co. (Weymouth) to SecAdm, February 24, 1897, Adm G1061/97, ibid.; minute by Walker, February 2, 1897, Adm G588/97, ibid.
40. Minute by Accountant General on draft letter, April 9, 1897, Adm G1788/97, ibid.; SecAdm to Whitehead Co. (Weymouth), May 1, 1897, Adm G1788/2670/97, ibid. The draft letters show that the final copy sent was very carefully worded.
41. Whitehead Co. (Weymouth) to SecAdm, May 14, 1897, Adm G2649/97, ibid.; Whitehead Co. (Weymouth) to SecAdm, May 22, 1897, Adm G2954/97, ibid.
42. Jeffrey, comment on G1474/98 in "Précis of correspondence in regard to Whitehead Gyroscopes," enclosure to minute by Jeffrey, August 31, 1899, Adm G5661/99, ADM 116/579, TNA.
43. Minutes by Jeffrey, August 31, 1899, and others on Adm G5661/99, ibid.; SecAdm to Whitehead Co. (Weymouth), October 21, 1899, Adm

G5661/6686/99, ibid.; Whitehead Co. (Weymouth) to SecAdm, October 27, 1899, Adm G7085/99, ibid.

44. Minutes by Jeffrey, November 2, 1899, and FinSec, November 13, 1899, on Adm G7085/99, ibid.; SecAdm to Whitehead Co. (Weymouth), November 27, 1899, Adm G7085/7672/97, ibid.
45. Whitehead Co. (Weymouth) to SecAdm, November 29, 1899, Adm G7912/99, ibid.; SecAdm to Treasury, December 21, 1899, Adm G7912/8247/99, ibid. (contains quotation); Treasury to SecAdm, January 3, 1900, Adm G81/00, ibid. On the Treasury's staffing problems, see Jon Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (Boston: Unwin Hyman, 1989), 25.
46. ART00/39; ART01/39.
47. ART98/37; ART00/38, 40; ART01/39; ART02/29.
48. On the orders, see minutes on Adm G3818/97, ADM 116/519, TNA; and Adm G2006/98, mentioned in PQ/99/2741/345. Details on the new designs and the experiments can be found in ART96/22–30; ART97/23–25; ART98/19–20, 32–33, 36–37, 50–54; ART99/19–23; ART00/34, 49–53; ART01/36–37, 40–41; and ART02/26–28. On stability, see Peter Bethell, "The Development of the Torpedo," *Engineering* 159–61 (May 25, 1945, to March 15, 1946): 14 (copy available as call number P894, AL).
49. ART98/51–53 (first quotation on p. 51); SRGF to Durnford, November 2, 1899, NO6185, copy in ART99/22–23 (contains second quotation).
50. ART02/26–27. Expressed in absolute terms instead of percentages, the increases in weight and pressure for 14-inch torpedoes were from 34.75 to 46.25 lbs., and from 1,350 to 1,700 psi; and for 18-inch torpedoes, from 77.55 to 94.5 lbs., and from 1,400 to 1,700 psi.
51. ART97/41; Acklom to CSOF, July 1, 1901, NO11668/01, PQ/01/2842/143–44; Egerton (for DNO) to CSOF, August 6, 1901, NO11668/01, ibid.
52. Alluded to in a minute by Egerton (captain of the *Vernon*), July 25, 1902, Adm G7197/02, Docket "Application of Heat to Compressed Air for Torpedoes. Consideration of Commercial Offer," ADM 1/7657, TNA. Leavitt's patent was GBP 10,126/1900.
53. Alluded to in Acklom to DNO, August 5, 1902, Adm G7197/02, Docket "Application of Heat to Compressed Air for Torpedoes. Consideration of Commercial Offer," ADM 1/7657, TNA.
54. Bliss Co. (Paris) to SecAdm, July 12, 1902, Adm G7197/02, ibid. (contains first quotation); Egerton to DNO, July 25, 1902 (contains second quotation), and Acklom to DNO, August 5, 1902 (contains third quotation), Adm G7197/02, ibid.; Controller to Bliss Co. (Paris), August 13, 1902, Adm G7197/9036/02, ibid.
55. Bliss Co. (Paris) to SecAdm, September 16, 1902, Adm G9487/02, ibid.; Charlton (for Egerton) to DNO, September 23, 1902, Adm G9487/02, ibid.;

minute by Jackson (for DNO), November 11, 1902, Adm G9487/02, ibid.; Controller to Bliss Co. (Paris), November 19, 1902, Adm G9487/13319/02, ibid.; Bliss Co. (Paris) to SecAdm, November 22, 1902, Adm G12350/02, ibid.; Acklom to DNO, December 9, 1902, Adm G12350/02, ibid. (contains quotation); Egerton to DNO, December 17, 1902, Adm G12350/02, ibid.; SecAdm to Bliss Co. (Paris), January 8, 1903, Adm G12350/397/02, ibid.; Bliss Co., *The Third Dimension of Invention* (Detroit, MI, 1948), 38.

56. Bliss Co. (Paris) to SecAdm, February 9, 1903, Adm G1820/03, and February 10, 1903, Adm G1890/03, Docket "Application of Heat to Compressed Air for Torpedoes. Consideration of Commercial Offer," ADM 1/7657, TNA.
57. Minutes by Egerton, February 12, 1903, and Acklom, March 2, 1903, Adm G1820/03, ibid.; minute by Jackson, March 4, 1903, Adm G1890/03, ibid. (contains quotation); SecAdm to Bliss Co. (Paris), March 13, 1903, Adm G1890/3696/03, ibid.; Bliss Co. (Paris) to SecAdm, March 17, 1903, Adm G3622/03, ibid.; minute by Jackson, March 24, 1903, Adm G3622/03, ibid.
58. Durnford to CINC Portsmouth, December 28, 1897, Adm G58/98, ADM 116/519, TNA.
59. Comments by May, December 10, 1899, printed in ART00/37–38; Fisher, "Mediterranean Fleet, 1899–1902," p. 22, FISR 8/1, CAC (contains quotation).
60. May to president of RNC Greenwich, May 22, 1902, p. 4, Docket "Remarks by Capt. H. J. May, C.B., R.N., Royal Naval College. I.—On the Report of the Operations of the Combined Mediterranean and Channel Fleets, 1901 (N.I.D., No. 652). II.—On the Relative Value of Stern and Quarter Torpedo Discharges from Ships," ADM 1/7617, TNA (contains first quotation); Fisher, "Mediterranean Fleet, 1899–1902," p. 22, FISR 8/1, CAC (contains second quotation); Fisher, Appendix A in "Extracts from Confidential Papers: Mediterranean Fleet, 1899–1902", p. 118, ibid. See also Jon Sumida, "The Quest for Reach: The Development of Long-Range Gunnery in the Royal Navy, 1901–1912," in *Military Transformation in the Industrial Age*, ed. Stephen D. Chiabotti (Chicago, IL: Imprint, 1996), 59.
61. Sumida, "The Quest for Reach," 50–51.
62. Minute by DNO, June 13, 1901, PQ/02/2881/85; report by Ordnance Committee, February 21, 1902, ibid.; minutes on G537/02, PQ/03/2904/7–8.
63. See SC184/F8–8j and F14, BF; minutes on S22945/01, SC184/F22, BF.
64. Fisher, "Extracts from Confidential Papers: Mediterranean Fleet, 1899–1902," pp. 49–51, FISR 8/1, CAC (contains first quotations); Fisher to Lady Fisher, September 29, 1900, in *Fear God and Dread Nought: The Correspondence of Admiral of the Fleet Lord Fisher of Kilverstone*, vol. 1, *The Making of an Admiral, 1854–1904*, ed. Arthur Marder (Cambridge, MA: Harvard University Press, 1952), 161–62 (contains final quotation).

65. President of Mobilization Committee to CINC Devonport, July 2, 1901, G5489/01, and minutes thereon, PQ/03/2902/2–3; CINC Devonport to SecAdm, March 27, 1902, G3044/02, ibid.; minutes by ADNO (April 30, 1902), Custance (May 5, 1902), May (June 4, 1902), and Kerr (June 5, 1902), G3044/02, PQ/03/2902/3–5; J. B. de Robeck to CINC Portsmouth, August 14, 1902, L11548/02, PQ/03/2910/16; CINC Portsmouth to SecAdm, August 22, and captain of the *Vernon* to DNO, September 14, 1902, L11548/02, PQ/03/2910/16–17; minutes by Jackson (September 19, 1902), May (October 17, 1902), Inspecting Captain of Destroyers (November 7, 1902), and Kerr (November 10, 1902), L11548/02, PQ/03/2910/17–21; minute by Kerr, November 17, 1900, Docket "Study of Naval Tactics. Supply of Captain King-Hall's Naval War Game to the Fleet," sub-docket "Naval Tactics (in reply to Admiralty Letter M165 of 14 Apr 1900)," ADM 1/7461B, TNA (contains quotation).

3. *The US Navy and the Emergence of Command Technology*

Epigraph: Bliss Co. to Mason, October 27, 1905, BuOrd 17761/60, RG74/E25/B842, NARA.

1. Daniels to Secretary of Commerce, July 9, 1915, Dept 17755/14:32, RG80/E19/B679, NARA. For context on Daniels's views, see Melvin Urofsky, *Big Steel and the Wilson Administration: A Study in Business* (Columbus: Ohio State University Press, 1969), 117–51, 192–96.
2. O'Neil to CNTS, September 22, 1902, BuOrd 6041/02, RG74/E25/B511, NARA; O'Neil to CNTS, January 31, 1903, BuOrd 6041/02-LS200/535, ibid.; Fletcher to O'Neil, February 4, 1903, BuOrd 1494/03 with 6041/02, ibid.; O'Neil to Fletcher, February 6, 1903, BuOrd 1494/03-LS201/238 with 6041/02, ibid.; O'Neil to Bliss Co., February 6, 1903, BuOrd 1494/03 with 6041/02, ibid.; Fletcher to O'Neil, February 9, 1903, BuOrd 1669/03 with 6041/02, ibid.; O'Neil to Fletcher, February 12, 1903, BuOrd 1718/03-LS201/491 with 6041/02, ibid.; O'Neil to Bliss Co., February 26, 1903, BuOrd 1494/03-LS202/483–4 with 6041/02, ibid.; Bliss Co. to O'Neil, February 27, 1903, BuOrd 2453/03 with 6041/02, ibid.; Bliss Co. to O'Neil, March 26, 1903, BuOrd 3679/03 with 6041/02, ibid.; O'Neil to Fletcher, April 2, 1903, BuOrd 1718/03-LS206/141 with 6041/02, ibid.; Chambers to Fletcher, May 9, 1903, BuOrd 5918/03 with 6041/02, ibid.
3. O'Neil to Fletcher, Chambers, Davison, Williams, and Chandler, June 20, 1903, BuOrd 3679/03 with 6041/02, ibid.; Fletcher to O'Neil, July 25, 1903, BuOrd 8946/03 with 6041/02, ibid. (contains quotation).
4. Sargent to Fletcher, August 1, 1903, enclosure to BuOrd 14468/03 with 6041/02, ibid.; Fletcher to O'Neil, September 19, 1903, BuOrd 10850/03, RG74/E25/B566, NARA; Moore to Fletcher, October 26, 1903, B36-135, NTS; Fletcher to Leavitt, January 18, 1904, B42-347, NTS.

5. Chambers Board to O'Neil, November 19, 1903, BuOrd 13021/03 with 9558/01, RG74/E25/B480, NARA.
6. Fletcher to O'Neil, November 25, 1903, BuOrd 14468/03 with 6041/02, RG74/E25/B511, NARA; see also Fletcher to O'Neil, July 8, 1903, BuOrd 8221/03 with 6041/02, ibid.
7. Bliss Co. to O'Neil, October 29, 1903, BuOrd 12865/03, RG74/E25/B664 [misfiled, should be in B575], NARA; O'Neil to Fletcher, December 19, 1903, BuOrd 14468/03-LS227/402–3 with 6041/02, RG74/E25/B511, NARA; Fletcher to Converse, June 13, 1904, BuOrd 6858/04 with 9890/03, RG74/E25/B565, NARA; Fletcher to Mason, September 20, 1904, BuOrd 11010/04 with 9890/03, ibid.
8. Chambers Board to SecNav, September 27, 1904, BuOrd 11932/04 with 12865/03, RG74/E25/B664 [misfiled, should be in B575], NARA; Mason to Gleaves, April 6, 1907, BuOrd 19339-LS381/27, RG74/E25/B935, NARA; Gleaves to Mason, December 28, 1907, BuOrd 19339/48, ibid.; Mason to Gleaves, January 4, 1908, BuOrd 19339/48-LS420/311, ibid.; Gleaves to Mason, January 11, 1908, BuOrd 19339/50, ibid.; Gleaves to Mason, March 13, 1908, and Mason's endorsement thereon, March 18, 1908, BuOrd 19339/52, ibid.; ACNTS to Mason, May 1, 1908, and Mason's endorsement thereon, May 2, 1908, BuOrd 19339/53, ibid.
9. Mason to Gleaves, January 31, 1905, BuOrd 16647, B45-131, NTS; Bristol to Mason, October 15, 1908, BuOrd 18631/15, RG74/E25/B900, NARA; Bliss IoO to Bristol, June 14, 1909, B64-213, NTS; Bristol to Mason, June 28, 1909, BuOrd 17761/456, RG74/E25/B844, NARA. For the Navy's dissatisfaction with the Leavitt gyroscope, see, for example, Gleaves to Mason, February 7, 1905, BuOrd 16279/5, RG74/E25/B727, NARA; Gleaves to Mason, November 17, 1906, BuOrd 17761/150, RG74/E25/B843, NARA; Torpedo Board to Mason, March 30, 1907, BuOrd 18172/16, RG74/E25/B873, NARA; Bristol to Mason, October 15, 1908, BuOrd 18631/15, RG74/E25/B900, NARA.
10. Supplementary Tactics, Question 2, p. 43, Problem of 1903, RG12, NHC; Tactical Committee, "Tactics: Report of a Special Committee," September 18, 1903, ibid.; Supplementary Tactics, Question 4, pp. 45–46, ibid. (quotation on p. 46); "Tactics: Report of a Special Committee, Appendix B: Torpedoes," pp. 6–7, ibid.; Dewey to SecNav, GB 420, September 26, 1903, RG80/E285/B1/V2/P368–69 NARA.
11. F. K. Hill, "Submerged Torpedo Tubes and Tactics of the Torpedo," lecture delivered at USNWC in August 1903, RG8/B112/F1, NHC. Underlining in the original.
12. For an alternative explanation, see William McBride, *Technological Change and the United States Navy, 1865–1945* (Baltimore, MD: Johns Hopkins University Press, 2000), 55.

13. Bliss Co. to O'Neil, September 15, 1903, BuOrd 10986/03 with 9558/01, RG74/E25/B480, NARA; Bliss Co. to O'Neil, October 29, 1903, BuOrd 12865/03, RG74/E25/B664 [misfiled, should be in B575], NARA; O'Neil to Bliss Co., November 2, 1903, BuOrd 12865/03, ibid. (contains quotation).
14. Chambers Board to O'Neil, November 19, 1903, BuOrd 13021/03 with 9558/01, RG74/E25/B480, NARA.
15. See "Contract for Fifty Bliss-Leavitt Torpedoes, U.S.N., 5m. × 45cm., Mark III, Fitted for Overwater Discharge," January 11, 1904, enclosed in Chambers Board to SecNav, September 27, 1904, BuOrd 11932/04 with 12865/03, RG74/E25/B664 [misfiled, should be in B575], NARA. For the two clauses, see "Contract for the Manufacture of Torpedoes, U.S. Navy, Fifty (50) Torpedoes, 5m × 45c/m Mark IV," B50-158, NTS, and "Contract for the Manufacture of 300 Torpedoes for the U.S. Navy, Bliss-Leavitt 5-meter, 21-inch, Mark I," B45-151, NTS, respectively.
16. Bliss Co. to Converse, April 21, 1904, BuOrd 4647/04 with 12865/03, NARA RG74/E25/B575 (contains quotation); Herbert & Micou to Converse, April 23, 1904, BuOrd 4681/04 with 12865/03, ibid.
17. For a report of the meeting, see Herbert to SecNav, 26 April 1904, BuOrd 4681/04 with 12865/03, ibid.
18. Ibid.
19. Bliss Co. to Herbert & Micou, April 27, 1904, enclosure to Herbert & Micou to Converse, April 28, 1904, BuOrd 4681/04 with 12865/03, ibid.
20. John Holland's submarine was not an exception: although it did excite foreign interest, the US Navy did not want it. See Nicholas Lambert, "The Influence of the Submarine upon Naval Strategy, 1898–1914" (Ph.D. Diss., Oxford University, 1992), 70–89.
21. For Converse's request, see Converse to Fletcher, April 29, 1904, BuOrd 4681/04-LS239/382–3 with 12865/03, RG74/E25/B664 [misfiled, should be B575], NARA; for the Board's report, see Fletcher Board to SecNav, May 19, 1904, BuOrd 7218/04 with 12865/03, RG74/E25/B575, NARA (contains quotations). The United States was not alone in fearing that publication of results would motivate competition. In 1908, the British informed the US naval attaché that their best results were 1,000 yards at 34 knots and 2,000 yards at 26.5 knots (see CIO to Mason, February 11, 1908, BuOrd 16664/104, RG74/E25/B766, NARA). In fact, the best British results were more like 4,000 yards at 35 knots with the RGF Mark VI* torpedoes they were then converting to heated torpedoes in large numbers, while the experimental heated Mark VII torpedoes they ordered in 1907 were capable of 3,000 yards at 41 knots, or 6,000 yards at 29 knots. In other words, the British deliberately underreported the results they were getting.
22. Fletcher Board to SecNav, May 19, 1904, BuOrd 7218/04 with 12865/03, RG74/

E25/B575 NARA (contains quotation); Converse to Bliss Co., May 28, 1904, BuOrd 4647/04-LS242/288–90 with 12865/03, ibid.

23. Gleaves to Mason, February 7, 1905, BuOrd 16279/5, RG74/E25/B727, NARA; Gleaves to Mason, March 18, 1905, BuOrd 16279/10.5, ibid.; Bliss IoO to Mason, May 17, 1905, BuOrd 16928/13, RG74/E25/B790, NARA; Bliss IoO to Gleaves, June 1, 1905, B45-131, NTS; Davison to Bliss IoO, August 15, 1905, enclosed in BuOrd 18172/7, RG74/E25/B873, NARA.
24. Davison to Bliss IoO, August 10, 1905, enclosed in BuOrd 18172/8, RG74/E25/B873, NARA; Davison to Bliss IoO, August 15, 1905, enclosed in BuOrd 18172/7, ibid.; Davison to Bliss IoO, August 24, 1905, enclosed in BuOrd 16928/33, RG74/E25/B790, NARA; Davison to Bliss IoO, October 16, 1905, BuOrd 16928/48, ibid.; and Davison to Bliss IoO, September 18, 1905, BuOrd 16928/42, B45-131, NTS. For more on Davison, see "G. C. Davison Dies," *NYT*, May 9, 1935, p. 21.
25. Taylor to Mason, October 23, 1905, BuOrd 17761/55, RG74/E25/B842, NARA. Taylor also wondered whether water might be streaming past the holes leading to the depth mechanism so quickly that it did not have a chance to act on the mechanism, thus leading the torpedo to think (as it were) that it was at a higher depth than it really was. Taylor's understanding of hydrodynamic forces was ahead of his time; see Frederick Milford, "US Navy Torpedoes—Part Two: The Great Torpedo Scandal, 1941–43," *Submarine Review* (October 1996): 3–6.
26. William McNeill, *The Pursuit of Power: Technology, Armed Force, and Society since A.D. 1000* (Chicago: University of Chicago Press, 1982), 278–79.
27. On the dynamometer, see Mason to Gleaves, September 14, 1905, BuOrd 18533-LS302/204, RG74/E25/B893, NARA; Gleaves to Mason, February 21, 1906, BuOrd 18533/4, ibid.; Gleaves to Mason, March 7, 1906, BuOrd 17761/97, RG74/E25/B842, NARA. On the register, see Mason to Gleaves, October 18, 1905, BuOrd 17761/41, B45-131, NTS; Gleaves, "Torpedoes," lecture delivered at USNWC on 23 July 1906, pp. 58–59, RG8/B111/F1, NHC.
28. B. Zorina Khan, "Innovations in Law and Technology, 1790–1920," in *The Cambridge History of Law in America*, vol. 2, *The Long Nineteenth Century, 1789–1920*, ed. Michael Grossberg and Christopher Tomlins (New York: Cambridge University Press, 2008), 493. See also Morton J. Horwitz, *The Transformation of American Law, 1780–1860* (Cambridge, MA: Harvard University Press, 1977), 31–62, and *The Transformation of American Law, 1870–1960: The Crisis of Legal Orthodoxy* (New York: Oxford University Press, 1992), 145–51.
29. Unfortunately, some of the records for this contract negotiation have disappeared, but the most important papers can be reconstructed. The BuOrd file number for this contract was 17761. Letters 17761/53–548 are in RG74/E25/B842–844, where they belong, but letters 17761/1–52 are missing. History cards for the missing letters, which provide short summaries, can be found in RG74/

E25/B24. Important exchanges with the Judge Advocate General can be found in the JAG records, while some of the key letters with the Bliss Company were re-printed in subsequent legal records; these are cited below.

30. For background on Mason, see "Mason Succeeds Converse," *NYT*, August 2, 1904, p. 2; "Admiral Mason to Retire," *WP*, October 6, 1912, p. E4.
31. See "Contract for the Manufacture of 300 Torpedoes for the U.S. Navy, Bliss-Leavitt 5-meter, 21-inch, Mark I," November 22, 1905, B45-131, NTS.
32. Mason to JAG, October 16, 1905, and JAG to Mason, October 19, 1905, JAG 649/3 (would be the missing BuOrd 17761/43), RG125/E22/B130, NARA.
33. Mason to JAG, October 16, 1905, JAG 649/3, RG125/E22/B130, NARA. See also Mason to Bliss Co., October 16, 1906, BuOrd 17761/43, copy in ToR, p. 314.
34. Bliss Co. to Mason, October 19, 1905, BuOrd 17761/52 (contains quotation), and Mason to Bliss Co., October 21, 1905, BuOrd 17761/52, copies in ToR, pp. 315–16.
35. Mason to Bliss Co., October 28, 1905, BuOrd 17761/59-LS309/131–32, RG74/E25/B842, NARA.
36. Bliss Co. to Mason, October 27, 1905, BuOrd 17761/60, RG74/E25/B842, NARA (contains quotation); Mason to Bliss Co., October 28, 1905, BuOrd 17761/60-LS309/133, ibid.; "Contract for the Manufacture of 300 Torpedoes for the U.S. Navy, Bliss-Leavitt 5-meter, 21-inch, Mark I," B45-131, NTS.
37. Leavitt to Mason, May 13, 1905, BuOrd 15157/18, RG74/E25/B680, NARA.
38. Mason to Gleaves, November 7, 1905, BuOrd 17761, NTS B45-131.
39. Mason to Gleaves, November 10, 1905, BuOrd 17761/55-LS311/346–48, RG74/E25/B842, NARA; Gleaves to Mason, January 12, 1906, BuOrd 17761/93, ibid.; Gleaves to Mason, July 28, 1906, BuOrd 17761/109, ibid.
40. Mason to SecNav, September 15, 1906, JAG 649/4 (BuOrd 17761), RG125/E22/B130, NARA.
41. John B. Moore, *A Digest of International Law*, vol. 4 (Washington, DC: Government Printing Office, 1906), 448–50.
42. Section 5335 can be viewed in *Revised Statutes of the United States*, 2nd ed. (Washington, DC: Government Printing Office, 1878), 1036. With slightly different wording, the Logan Act was originally dated January 30, 1799, and appears in 1 *Stats at Large of USA* 613.
43. Newberry to Mason, September 21, 1906, BuOrd 20113/2, RG74/E25/B982, NARA.
44. Ibid.; Davison to Mason, October 2, 1906, endorsement on BuOrd 20113/2, RG74/E25/B982, NARA.
45. Davison to Mason, October 22, 1906, BuOrd 20113/3, ibid. For private-sector parallels, see Catherine L. Fisk, *Working Knowledge: Employee Innovation and the Rise of Corporate Intellectual Property, 1880–1930* (Chapel Hill: University of North Carolina Press, 2009).

46. Acting SecNav to Mason, September 21, 1906, BuOrd 17761/119, RG74/E25/B982, NARA; Davison to Mason, December 8, 1906, B50-158, NTS (contains quotation).
47. James M. Rubenstein, *The Changing U.S. Auto Industry: A Geographical Analysis* (London: Routledge, 1992), 56–60; Herbert A. Johnson, "The Wright Patent Wars and Early American Aviation," *Journal of Air Law and Commerce* 69, no. 21 (Winter 2004), especially 24, 27–34.
48. Davison to Mason, 8 December 1906, B50-158, NTS; Bliss Co., "Answer as Amended," 24 June 1913, p. 12, ToR.
49. See CoO to SecNav, 1 October 1906, in DeptNav, *Annual Report of the Navy Department*, 59th Cong., 2nd Sess., 1906, pp. 517–18; and CoO to SecNav, 17 October 1907, in DeptNav, *Annual Report of the Navy Department*, 60th Cong., 2nd Sess., pp. 474–75. For context, see "Department of Justice, Patent Policy Survey: Navy Department," pp. 71–73, Folder "Navy Department," RG60/E418/B2, NARA II.
50. JAG to Mason, December 22, 1906, BuOrd 20113/11, RG74/E25/B982, NARA; Wilkinson & Fisher to Mason, January 15, 1907, BuOrd 20113/12, ibid.; Wilkinson & Fisher to Mason, April 5, 1907, and endorsements thereon, BuOrd 20113/16, ibid.
51. Secretary of Commerce and Labor, *Report Concerning Patents Granted to Officers and Employees of the Government*, 60th Cong., 1st Sess., 1908, pp. 7–8; Davison's patent is discussed on p. 39. On U.S. government employee-inventors, see Fredrik Neumeyer, *The Employed Inventor in the United States: R&D Policies, Law, and Practice* (Cambridge, MA: MIT Press, 1971), esp. 214–18.
52. Bliss Co. to Mason, October 17, 1906, BuOrd 17761/128, RG74/E25/B843, NARA; Mason to Bliss Co., October 22, 1906, BuOrd 17761/128-LS358/374–75, ibid. (contains first quotation); Gleaves to Mason, December 29, 1906, B50-158, NTS (contains second and third quotations). The government later theorized that a visit from a Japanese naval officer in December 1906 lent urgency to the company's effort to build a balanced turbine, and it may have been right, but being right still would not change the fact that the bureau failed to supply a drawing until January 1907 (see US brief for the Second Circuit Court of Appeals in *United States v. E. W. Bliss Co.*, p. 34, copy with BuOrd 27741/24, RG74/E25/BBB238, NARA).
53. Gleaves to Mason, December 29, 1906, B50-158, NTS.
54. Clause 19, "Contract for the Manufacture of 300 Torpedoes for the U.S. Navy, Bliss-Leavitt 5-meter, 21-inch, Mark I," B45-131, NTS.
55. Mason to Bliss Co., November 9, 1906, BuOrd 17761/128-LS361/231–32, RG74/E25/B843, NARA; endorsement by Mason, January 9, 1907, BuOrd 20361/3, RG74/E25/B1003, NARA.

56. Gleaves to Mason, April 7, 1906, BuOrd 16928/65, and April 11, 1906, BuOrd 16928/67, RG74/E25/B790, NARA; Bliss Co. to Mason, June 12, 1906, BuOrd 15157/36, RG74/E25/B680, NARA; Bliss IoO to Mason, July 23, 1906, BuOrd 17761/108, RG74/E25/B842, NARA; Bliss Co. to Mason, July 25, 1906, and endorsements thereon, BuOrd 15157/37, RG74/E25/B680, NARA; Bliss IoO to Mason, July 30, 1906, BuOrd 16928/86, RG74/E25/B790, NARA.
57. Gleaves to Mason, September 15, 1906, BuOrd 17761/116, RG74/E25/B843, NARA.
58. Mason to SecNav, October 17, 1906, BuOrd 19800-LS358/135–42, RG74/E25/B958, NARA.
59. Mason to SecNav, October 17, 1906, BuOrd 19800-LS358/135–42, ibid.
60. Mason to SecNav, January 27, 1907, BuOrd 19800, ibid.
61. Mason to SecNav, January 27, 1907, BuOrd 19800, ibid.; "An Act Making Appropriations for the Naval Service," March 2, 1907, 34 *Stat*. 1176 at 1180.
62. Leavitt to Mason, February 15, 1907, BuOrd 17761/212, RG74/E25/B843, NARA.
63. Mason to Bliss Co., February 26, 1907, BuOrd 17761/212-LS375/390, ibid.
64. Bliss Co. to Mason, May 16, 1907, BuOrd 17761/233, ibid.; Torpedo Board to Mason, May 23, 1907, BuOrd 18172/18, RG74/E25/B873, NARA (contains quotation); Mason to Bliss Co., May 25, 1907, BuOrd 17761/233-LS387/543–44, RG74/E25/B843, NARA.
65. Bliss Co. to Mason, June 25, 1907, BuOrd 17761/250, ibid.
66. Mason to Bliss Co., July 8, 1907, BuOrd 17761/250-LS393/546–50, ibid.
67. Mason to SecNav, May 29, 1907, BuOrd 19800/1-LS388/208–9, and June 5, 1907, BuOrd 19800-LS389/125-26, RG74/E25/B958, NARA; SecNav to Mason, June 17, 1907, BuOrd 19800/50, ibid.; Mason to SecNav, June 18, 1907, BuOrd 19800/50-LS391/67, ibid.; JAG to Mason, June 19, 1907, BuOrd 19800/51, ibid.; Gleaves and Davison to SecNav, August 10, 1907, para. 4, RG8/B111/F2, NHC.
68. Gleaves to Mason, August 17, 1907, para. 9, NTS Annual Report for FY1906/7, B55-209, NTS.
69. Sheridan to Mason, October 17, 1907, BuOrd 21017/5, RG74/E25/B1043, NARA; Sheridan to Mason, October 25, 1907, BuOrd 21017/6, ibid.; Sheridan to Mason, October 28, 1907, BuOrd 21017/8, ibid.; Whitehead IoO to Mason, October 29, 1907, BuOrd 21017/12, ibid. On Sheridan, see "H. C. Sheridan, District Banker," *WP*, February 2, 1962, p. B4.
70. Gleaves to Mason, October 29, 1907, BuOrd 21017/9, RG74/E25/B1043, NARA. (contains quotations); Sheridan to Mason, January 3, 1908, BuOrd 21017/15, ibid.; Mason to Sheridan, January 4, 1908, BuOrd 21017/15-LS420/365, ibid.
71. Gleaves to Mason, October 29, 1907, BuOrd 21017/9, ibid.; Acting CoO to Bliss Co., November 29, 1907, BuOrd 20160/12-LS415/253, RG74/E25/B987, NARA;

Bliss IoO to Mason, January 31, 1908, BuOrd 20065/8, RG74/E25/B979, NARA; Williams to Mason, March 23, 1906, BuOrd 21723/1, with enclosed draft specifications and contract, RG74/E25/B1086, NARA; Gleaves to Mason, March 26, 1908, BuOrd 21719/2, ibid. (contains quotation); Torpedo Board to Mason, April 1, 1908, BuOrd 18172/26, RG74/E25/B873, NARA. See also Dewey to SecNav, January 4, 1908, GB 420-2, RG80/E285/B2/V5/P182, NARA.

72. See Gleaves to Mason, February 1, 1908, B62-199, NTS; Gleaves to Mason, April 6, 1908, ibid. (contains quotations).
73. Mason to SecNav, May 16, 1908, and endorsements thereon, BuOrd 21723/4, RG74/E25/B1086, NARA; Mason to Sheridan, June 16, 1908, BuOrd 21723/4-LS448/218, ibid.; "Contract for Torpedoes," enclosed in Mason to Whitehead IoO, October 17, 1908, BuOrd 21723/29-LS463/347, ibid.; Whitehead Co. Weymouth to Whitehead IoO, November 13, 1908, and Whitehead IoO to Mason, November 13, 1908, BuOrd 21723/44, RG74/E25/B1087, NARA; Mason to Whitehead IoO, November 23, 1908, BuOrd 21723/44, ibid.; paras. 18 and 94B, "Specifications for the Manufacture of Bliss-Leavitt Automobile Torpedoes, U.S.N., 5m × 21", Mark II," B60-209, NTS.
74. A copy of the agreement was not found. The following descriptions of the agreement are taken from *E. W. Bliss Company v. United States*, 53 Ct. Cl. 47 (1917).
75. This question of the exclusivity of the license and legal standing—not any other of the complicating factors discussed here—was the issue on which the court's decision in *E. W. Bliss Company v. United States* (53 Ct. Cl. 47) turned.
76. See, for example, "Contract for Torpedoes," July 7, 1908, clause 9, enclosure to BuOrd 21723/29, RG74/E25/B1086, NARA.
77. The Court of Claims mistakenly stated the exact opposite: "It does not appear that Armstrong & Co. had any interest in Whitehead & Co. or in torpedoes made by that Company" (*E. W. Bliss Co. v. United States*, 53 Ct. Cl. 47 (1917)). Whether and how a correct appreciation of this fact might have changed the court's opinion is unclear.
78. Mason to Bliss Co., October 18, 1906, BuOrd 20160-LS358/107–8, RG74/E25/B987, NARA; Bliss Co. to Mason, December 1, 1906, BuOrd 20160/6, ibid. The original records pertaining to the 1907 agreement were not found; the account here is taken from the Bliss Company's petition of May 29, 1914 in *E. W. Bliss Co. v. United States*, 53 Ct. Cl. 47 (1917), p. 6, a copy of which can be found as BuOrd 28200/12 in RG74/E25/BBB316, NARA.
79. Sheridan to Mason, October 25, 1907, BuOrd 21017/6, RG74/E25/B1043, NARA; Sheridan to Mason, November 4, 1907, BuOrd 21017/11, ibid.; Mason to Bliss Co., November 9, 1907, BuOrd 20160-LS412/17–18, RG74/E25/B987, NARA; Bliss Co. to Mason, November 25, 1907, BuOrd 20160/12, ibid.

80. Torpedo Board to Mason, December 4, 1907, BuOrd 18172/23, RG74/E25/B873, NARA; Sheridan to Mason, January 3, 1908, BuOrd 21017/15, RG74/E25/B1043, NARA; Mason to Sheridan, January 4, 1908, BuOrd 21017/15-LS420/365, ibid.
81. The original record of this order was not found; this account is taken from the Bliss Company's petition of May 29, 1914 in *E. W. Bliss Co. v. United States*, 53 Ct. Cl. 47 (1917), p. 7, a copy of which can be found as BuOrd 28200/12 in RG74/E25/BBB316, NARA.
82. See "Contract for Torpedoes," July 7, 1908, enclosure to BuOrd 21723/29, RG74/E25/B1086, NARA.
83. Bliss Co. to Mason, December 17, 1906, BuOrd 17761/172, RG74/E25/B843, NARA; Mason to Bliss Co., February 1, 1907, BuOrd 17761/172-LS372/286, ibid.; Bliss IoO to Mason, July 12, 1907, BuOrd 20939/2, RG74/E25/B1038, NARA; Bliss IoO to Mason, March 6, 1908, BuOrd 20939/30, and Bristol to Mason, November 23, 1908, BuOrd 20939/82, ibid.
84. Bliss IoO to Mason, May 3, 1907, BuOrd 17761/224, and December 11, 1907, BuOrd 17761/325, RG74/E25/B843, NARA; Gleaves to Mason, May 18, 1907, para. 8, BuOrd 19339/41, RG74/E25/B935, NARA; Bliss Co. to Mason, January 17, 1908, para. 6, BuOrd 17761/342, RG74/E25/B843, NARA (contains first quotation); Mason to Bliss Co., February 19, 1908, BuOrd 17761, enclosed in BuOrd 17761/386, RG74/E25/B844, NARA (contains second quotation).
85. Leavitt to Mason, September 17, 1908, and Bliss IoO's (September 21, 1908) and Bristol's (October 5, 1908) endorsements thereon, BuOrd 17761/378, ibid.; Mason to Bliss Co., October 7, 1908, BuOrd 17761/378-LS463/362, ibid.; Bliss Co. to Mason, November 30, 1908, BuOrd 17761/387, ibid.; Mason to Bliss Co., December 9, 1908, BuOrd 17761/387-LS472/469, ibid.; Bliss Co.to Mason, December 11, 1908, BuOrd 17761/389, ibid.; Mason to Bliss Co., December 15, 1908, BuOrd 17761/389-LS474/9, ibid.
86. Fletcher to Mason, October 18, 1904, BuOrd 12283, RG74/E25/B659, NARA; Torpedo Board to Fletcher, October 18, 1904, enclosed in BuOrd 12283, ibid.; Mason to Gleaves, July 11, 1905, BuOrd 12283-LS294/98–9, ibid. (contains quotation); Gleaves to Mason, July 14, 1905, BuOrd 12283/10, ibid.; Torpedo Board to Mason, September 7, 1905, BuOrd 12283/11, ibid.; Mason to Clark, Davison, and Cone, September 15, 1905, BuOrd 12283/11, ibid.; Davison to Mason, October 6, 1905, BuOrd 12283/13, ibid.; Cone to Mason, October 20, 1905, BuOrd 12283/14, ibid.; Clark to Mason, October 26, 1905, BuOrd 12283/15, ibid.; Torpedo Board to Mason, December 12, 1905, BuOrd 12283/17, ibid.; Cone and Davison to Gleaves, May 26, 1906, enclosed in BuOrd 12283/20, and Mason's endorsement of July 3, 1906, thereon, ibid.
87. "General Description of Torpedo Director, U.S. Navy, Mark IV" (October 1907), B59-169, NTS.

88. Ibid, pp. 1–2. Such a table is mentioned in Gleaves to Mason, May 31, 1906, BuOrd 12283/20, RG74/E25/B659, NARA.
89. Clark to Mason, October 26, 1905, para. 2, and Gleaves' endorsement thereon, November 4, 1905, BuOrd 12283/15, RG74/E25/B659, NARA.
90. Davison to Mason, October 6, 1905, para. 3 and section under "Course and Speed Finder," BuOrd 12283/13, RG74/E25/B659, NARA. Mason referred Davison's suggestion to the Fire Control Board then in session; see Mason to SecNav, December 15, 1905, BuOrd 12283/17-LS316/444, ibid.
91. Gleaves to Mason, July 5, 1906, endorsement on BuOrd 12283/20, ibid.
92. Gleaves, "Torpedoes," lecture delivered at USNWC on July 23, 1906, p. 42, B52-157, NTS; Gleaves to Mason, October 6, 1906, para. 7, BuOrd 19377/12, RG74/E25/B938, NARA.
93. Sims to SecNav, March 11, 1914, para. 8, B80-232, NTS.
94. For the failed efforts, see Fletcher to Bristol, May 31, 1904, B39-223, NTS; Fletcher to Hepburn, July 8, 1904, B42-347, NTS; P. Williams to Fletcher, September 13, 1904, and Fletcher to Mason, September 22, 1904, BuOrd 11140/04 with 9890/03, RG74/E25/B565, NARA; Gleaves to Mason, January 17, 1905, BuOrd 15157/5, RG74/E25/B680, NARA; Torpedo Board to Mason, September 5, 1905, B44-358, NTS; and Mason to Gleaves, September 18, 1905, BuOrd 17761/28, B45-131, NTS (contains quotation).
95. R. C. Smith, "Naval Tactics: Problems Suggested by War College Games, 1908–1909," lecture delivered at USNWC, July 8, 1909, p. 12, RG14/B2, NHC; Charles Belknap, "Torpedoes," lecture delivered at USNWC, n.d. (but summer 1911), p. 13, RG8/B111/F3, NHC; J. K. Robison, "Development of Torpedoes and Mines," lecture delivered at USNWC, August 26, 1914, p. 1, RG8/B111/F4, NHC.
96. Tactical Committee to Sperry, "Tactics: Report of a Special Committee. Report of Tactical Committee. Appendix E: First Tactical Study of the Black Fleet," n.d. but Problem of 1903, RG12, NHC.
97. Conference attendees, Answer to Supplementary Tactics Question 4, n.d. but Problem of 1903, RG12, NHC; Fiske to Sperry, "Tactics: Report of a Special Committee. Report of Tactical Committee. Appendix B: Torpedoes," n.d. but Problem of 1903, ibid.; Rodgers to Sperry, "Tactics: Report of a Special Committee. Report of Tactical Committee. Appendix G: The Comparison of Squadron Tactics for the Gun with Squadron Tactics for the Torpedo," September 1903 (no day), Problem of 1903, ibid.; Bernadou to Sperry, "Tactics: Report of a Special Committee. Report of Tactical Committee. Appendix F: Second Tactical Study of the Black Fleet," September 19, 1903, Problem of 1903, ibid.
98. Tactical Committee to Sperry, "Tactics: Report of a Special Committee. Report of Tactical Committee. Appendix E: First Tactical Study of the Black Fleet," n.d. but Problem of 1903, RG12, NHC; conference attendees, Answer to

Supplementary Tactics Question 2, n.d. but Problem of 1903, ibid.; Committee on Tactics and the Strength and Composition of the Fleet, Answers to Questions 25 and 27 (pt. 3, pp. 4–6, 15–19), September 21, 1904, Problem of 1904, ibid.

99. Tactical Committee to Sperry, "Tactics: Report of a Special Committee. Report of Tactical Committee. Appendix E: First Tactical Study of the Black Fleet," n.d. but Problem of 1903, ibid.

100. See conference attendees, "Considerations as to the Advisability of Suppressing the Intermediate Battery of Battleships," pt. 8, pp. 71–76, Problem of 1903, ibid; Committee on Tactics and the Strength and Composition of the Fleet, Answer to Question 35 (pt. 3, pp. 34–38), September 21, 1904, Problem of 1904, ibid.; conference attendees, Answer to Question 28 (pt. 3, pp. 20–25), n.d., Problem of 1906, ibid.; conference attendees, Answer to Question 10 (pt. 6, pp. 53–54), n.d., Problem of 1907, ibid.; Marsh Board to SecNav, October 15, 1907, RG8/B112/F1, NHC.

101. Dewey to SecNav, March 27, 1907, RG80/E285/B2/V5, p. 5, NARA; Dewey to SecNav, November 27, 1907, ibid., pp. 158–160; endorsement by Board on Construction to SecNav, October 11, 1907, RG80/E180/V9/P288–289, NARA.

102. Sims, Answer to Question 11, n.d., vol. 3, pt. 2, p. 63, Problem of 1911, RG12, NHC; Tactical Committee to Rodgers, September 20, 1911, RG8/B113/F2, NHC. Schofield submitted a dissenting report on September 21, 1911; see ibid. See also Norman Friedman, *U.S. Battleships: An Illustrated Design History* (Annapolis, MD: Naval Institute Press, 1985), 143–44.

103. Quoted in J. D. Scott, *Vickers: A History* (London: Weidenfeld and Nicolson, 1962), 65.

104. This account rests on Lambert, "Influence of the Submarine," 89–102.

105. See Bristol, "Lecture on Torpedoes," lecture delivered at USNWC on August 26, 1909, pp. 10–11, RG8/B111/F3, NHC.

4. The Royal Navy and the Quest for Reach

Epigraph: Testimony of Colonel H. C. L. Holden [SRGF], October 25, 1905, Appendix VII, p. 62, "Report of the Inter-Departmental Committee Appointed to Consider the Regulations as to the Taking out of Patents by Officers and Subordinates in Government Employment, with Appendices, 1905–06," WO 32/5080, TNA.

1. Minute by ADNO, July 16, 1902, G5272/02, PQ/03/2914/33–35; see also his minute of January 21, 1903, G694/03, PQ/03/2914/36–37.

2. Collision heads were collapsible heads that prevented the bodies of torpedoes from injury upon impact with a ship.

3. *Torpedo Manual*, vol. III., 1898, pts. I–II (with 1906 Addenda) (Admiralty, Gunnery Branch, January 1, 1906), pp. 195–97, Jb 59, AL.
4. An ironic achievement, given that the *Cressy* would be sunk, along with the *Aboukir* and the *Hogue*, by a single German U-boat on September 22, 1914.
5. "Paper Prepared by the Director of Naval Ordnance and Torpedoes for the Information of His Successor," December 31, 1903, p. 16, AL; May to President of RNC Greenwich, August 1, 1902, ADM 1/7617, TNA; ART03/vi, 46; ART04/45–51, Appendix H; ART05/34–38; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1907, pp. 37–38, AL.
6. CINC Mediterranean to SecAdm, n.d. (but reporting on practice carried out August 15, 1904), quoted in ART04/62.
7. ART03/38–41; PQ/04/3011/229–30; Second Report of the TDC, n.d. but submitted August 29, 1904, ART04/134–36.
8. "Paper Prepared by the Director of Naval Ordnance and Torpedoes for the information of His Successor," December 31, 1903, p. 17, AL; ART03/45; ART04/35–40, 45–46; ART05/28–29; ART06/17; minutes on G5864/06, PQ/06/3224/685–86; ART 07/16–17; ART08/11; ART 09/19; ART 10/48–49; ART 11/26–29; ART 12/18.
9. ART03/47.
10. ART03/53–54; "Paper Prepared by the Director of Naval Ordnance and Torpedoes for the information of His Successor," December 31, 1903, p. 16, AL; ART04/41; ART05/19.
11. Minute by DNO, January 12, 1904, G514/04, PQ/04/3011/229–30; SecAdm to CINC Portsmouth, February 6, 1904, PQ/04/3011/230; First Report of the TDC (with six appendices), n.d. but submitted on August 29, 1904, ART04/121–33; see especially appendixes E and F of the TDC's report. I found no further documentary trail for these two avenues of heating experiments, despite the committee's request to continue working on them. On flask pressures, see ART04/vii, 53; ART05/x, 30–31.
12. Third Report of the TDC, n.d. but late 1904 or early 1905, ART04/141–43; ART05/21–26.
13. To give one example, the "Paper Prepared by the Director of Naval Ordnance and Torpedoes for the Information of His Successor" (1907), p. 36, AL, tantalizingly mentions that the Admiralty accepted an offer from the American Bliss Company to try one 21-inch and two 18-inch Bliss-Leavitt torpedoes. The negotiations should have generated an extensive paper trail, but I could not find it.
14. The Admiralty appears to have carried out just such a targeted weeding of papers related to gunnery fire control for the period 1910 to 1914, when it likely infringed Arthur Pollen's patents. See Norman Friedman, *Naval Firepower:*

Battleship Guns and Gunnery in the Dreadnought Era (Annapolis, MD: Naval Institute Press, 2008), 297, n. 21.

15. These were probably the experiments promised in ART 1904/54 and mentioned in ART 1905/x, and they occurred more than a year before the better known experiments with the Armstrong heater in Japanese torpedoes. The fact that it was an inside superheater is not stated but can be inferred from the committee's reference to "the use of fuel in [as opposed to outside] air vessels" (Briggs to Jellicoe, September 27, 1905, T 173/257, TNA), and from the distinction the TOC drew a week later between the Armstrong superheater and Hardcastle's outside superheater (Briggs to Jellicoe, October 5, 1905, T 173/257, TNA).
16. Briggs to Jellicoe, September 27, 1905, T 173/257, TNA.
17. See Briggs to Jellicoe, December 1, 1905, ibid.
18. On Hardcastle's background, see his service record, ADM 196/133 TNA; and Hardcastle to Robertson, April 15, 1926, T 173/257, TNA.
19. Hardcastle's service record, ADM 196/133, TNA; Hardcastle to Robertson, April 15, 1926, T 173/257, TNA; transcript of proceedings in Hardcastle's RCAI claim (hereafter Hardcastle's RCAI claim), p. 5, T 173/649, TNA; Briggs to Jellicoe, October 5, 1905, and Jellicoe to Briggs, October 7, 1905, T 173/257, TNA.
20. Examination of Hardcastle by Moritz, April 4, 1927, Hardcastle's RCAI claim, p. 37, T 173/649, TNA; reexamination of Hardcastle by Moritz, April 4, 1927, Hardcastle's RCAI claim, p. 76, ibid.
21. "Report of the Inter-Departmental Committee Appointed to Consider the Regulations as to the Taking out of Patents by Officers and Subordinates in Government Employment, with Appendices, 1905–06" (especially Appendix VI, "Précis of remarks by Admiralty officials on the working of the existing regulations"), April 30, 1906, quotation on p. 5, WO 32/5080, TNA.
22. T. H. O'Dell, *Inventions and Official Secrecy: A History of Secret Patents in the United Kingdom* (Oxford: Clarendon Press, 1994), 9–10. This principle of interference was given statutory codification in the Patents, Designs, and Trade Marks Act of 1883 (46 & 47 Vict. c. 57), Section 27; see also Jan Vojáček, *A Survey of the Principal National Patent Systems* (New York: Prentice-Hall, 1936), 102.
23. O'Dell, *Inventions and Official Secrecy*, 4–22; Vojáček, *A Survey*, 99–104. The first secret patent was for the "Application of Incendiary Materials to Be Used in Warfare."
24. *Patent* comes from the Latin *patens*, meaning "open," so "secret patent" literally means "secret open thing."
25. Briggs to Jellicoe, December 1, 1905, T 173/257, TNA (contains quotations); "Paper Prepared by the Director of Naval Ordnance and Torpedoes for the information of His Successor," 1907, p. 37, AL. Sodeau's and Hardcastle's

superheaters were designed for external combustion engines: both the mixture of the fuel and air and combustion occurred in the combustion chamber, which was external to the torpedo engine. In Brotherhood's design, the fuel and air were mixed in the carburetor, but combustion (explosion) did not occur until the mixture was inside the engine. The number of Brotherhood's secret patent is unknown, but it should not be confused with Brotherhood's public patent 6,789/1905, applied for in March 1905 and accepted in March 1906.

26. Board minutes of November 16, 1905, and January 18, 1906, Accession 130/1267 (Minute Book #2), T&W. On the family relationship between Henry ("Harry") and Robert, see Saxton Noble to Albert Vickers, November 30, 1910, Microfilm R306, VA.
27. Henry Whitehead to Rendel, January 25, 1906, Accession 31/7269, M1076, T&W.
28. J. P. Davison, "The Whitehead Torpedo Companies," February 21, 1935, Document 57, Folder 47, VA (the copy labeled "Document 771" misidentifies the author as V. F. G. Pritchett and the date as February 20, 1935); Edwyn Gray, *The Devil's Device: The Story of Robert Whitehead, Inventor of the Torpedo* (Annapolis, MD: Naval Institute Press, 1991) 176–78; Armstrong board minute of May 17, 1906, Accession 130/1267 (Minute Book #2), T&W; registration papers in BT 31/17962/91493, TNA.
29. Examination and reexamination of Hardcastle by Moritz, and Whitehead's cross-examination of Hardcastle, April 4, 1927, Hardcastle's RCAI claim, pp. 39, 69–72, 77–78, T 173/649, TNA; Hardcastle to Gamble, September 29, 1908, enclosed in Hardcastle to Robertson, April 15, 1926, T 173/257, TNA; Hardcastle to Briggs, undated but ca. August 29, 1906, enclosed in Briggs to DNO, August 29, 1906, ibid.; Briggs to DNO, August 29, 1906, ibid.; Briggs to DNO, December 17, 1906, ibid.
30. ART06/24–25; Briggs to Jellicoe, December 17, 1906, T 173/257, TNA; Armstrong board minutes of January 24, April 10, and July 3, 1907, Accession 130/1267 (Minute Book #2), T&W.
31. A copy of Hardcastle's patent can be found in T 173/257, TNA. His was actually the second patent for a wet superheater in Britain—two Austrians, Johann Gesztesy and Julius von Petravic, had left complete specifications for a wet superheater (GBP 7,390/1906) in September 1906—but no litigation resulted.
32. Briggs to Jellicoe, June 13, 1907, and Gamble to Jellicoe, October 28, 1907, T 173/257, TNA; Hardcastle to Gamble, September 29, 1908, enclosed in Hardcastle to Robertson, April 15, 1926, ibid.; ART06/23; ART07/25–30; ART08/18. See ART 07/19–20 for differences between the Mark VI and VI* torpedoes.
33. Minute by Currey, October 22, 1907, G16396/07, PQ/09/3345/156–57. These six torpedoes must be identical with the six Mark VII torpedoes mentioned in ART08/7 as being carried over from FY 1907–1908.

34. Minute by Jellicoe, October 22, 1907 (contains quotation), and replies thereto, G16396/07, PQ/09/3345/156–57.
35. ART07/30; ART08/18; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1909, p. 22, AL; minute by DNO, February 29, 1908, G3264/08, PQ/09/3346/157–58.
36. ART 05/12; ART 06/8; ART 07/8; Lees to SecAdm, April 13, 1907, enclosed in Lees to Albert Vickers, April 13, 1907, M306, VA; Armstrong board minutes of May 30, June 18, and July 25, 1907, Accession 130/1267 (Minute Book #2), T&W; Hardcastle to SecAdm, November 22, 1922, enclosed in Hardcastle to Robertson, April 15, 1926, T 173/257, TNA. The letter from Armstrong warning of patent infringement was not found, but it is dated (July 2, 1908) and described in a minute by the Director of Contracts, October 17, 1908, CP Patents 229, quoted in Admiralty Awards Council, Report 26, "Award to Engineer Lieutenant S. U. Hardcastle, R.N.," ADM 245/1, TNA. For the case, see 41 R.P.C. 38 (1923; trial court decision); 41 R.P.C. 189 (1924; appellate court decision); and 42 R.P.C. 543 (1925; Law Lords' decision).
37. "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," December 31, 1903, p. 18, AL; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," February 1905, p. 22, ibid.; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1907, p. 42, ibid. Undated article "Clyde Torpedo Factory. Progress of Work at Greenock. Difficulties Regarding Housing," and Acklom, "Notice. Transfer to Greenock," September 8, 1910, in SUPP 5/177, TNA.
38. Hardcastle to Gamble, September 29, 1908, enclosed in Hardcastle to Robertson, April 15, 1926, T 173/257, TNA.
39. A copy of this patent can be found in T 173/257, TNA.
40. Hardcastle to Gamble, September 29, 1908, enclosed in Hardcastle to Robertson, April 15, 1926, T 173/257, TNA; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1909, p. 22, AL; ART06/14; ART08/18–19; ART09/7, 11; minutes on G16396/07, PQ/09/3345/156–57. But note that ART08/7 suggests that twenty-nine of the Mark VI* conversions were carried on the FY07/08, not the FY08/09, budget.
41. ART08/7, 19; ART 09/7, 11; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1909, p. 22, AL.
42. Minute by DNO, March 7, 1908, G3264/08, PQ/09/3346/157–58 (contains quotation); "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1909, p. 24, AL; ART09/11; minute by Currey, December 17, 1908, G18178/08, SC224/F34, BF.
43. "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," 1909, p. 22, AL; minutes on G18020/07, PQ/08/3329/124.

44. Minutes by Gamble (April 10, 1908), Currey (April 30, 1908—contains first and second quotations), Bacon (April 30, 1908), Engineer-in-Chief (undated), Naval Branch (May 21, 1908—contains third quotation), and Second Sea Lord (undated), A4321/08, described in Admiralty Awards Council, Report 26, "Award to Engineer Lieutenant S. U. Hardcastle," ADM 245/1, TNA. Admiralty letters were preceded by a letter or letters indicating the branch which wrote them—"G" for Gunnery, "M" for Military, and so on. One prefix was "CP (Patents)." "CP" presumably referred to the Contract and Purchase Department, headed by the Director of Contracts, and the "(Patents)" probably referred to a section within the Contract and Purchase Department. The Patents Committee probably reported to this section.
45. Admiralty Awards Council, Report 26, "Award to Engineer Lieutenant S. U. Hardcastle," ADM 245/1, TNA.
46. Minute by SecAdm, December 10, 1902, "Admiralty. War Organization of Staff. Secretary's Report," Docket "Admiralty, War Organization of Staff," ADM 1/7658, TNA.
47. Jon Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (Boston: Unwin Hyman, 1989) (hereafter *IDNS*), 238; Director of of Contracts, October 17, 1908, CP(Patents) 229/08, described in Admiralty Awards Council, Report 26, "Award to Engineer Lieutenant S. U. Hardcastle," ADM 245/1, TNA (contains quotation).
48. Remarks by Acklom, October 3, 1908, described in ibid.
49. For a striking parallel, see Graeme Gooday, "Combative Patenting: Military Entrepreneurship in First World War Telecommunications," *Studies in History and Philosophy of Science* (2013; in press): 6–8.
50. Remarks by Acklom, October 3, 1908, described in Admiralty Awards Council, Report 26, "Award to Engineer Lieutenant S.U. Hardcastle," ADM 245/1, TNA.
51. Admiralty Awards Council, Report 26, "Award to Engineer Lieutenant S. U. Hardcastle," ADM 245/1, TNA.
52. Ibid.
53. SecAdm to CINC Portsmouth, December 3, 1908, CP Patents 237/43255/08, forwarded to Hardcastle on December 4, T 173/257, TNA (contains first quotation); Hardcastle to SecAdm, December 8, 1908, ibid. (contains second quotation); minute by Toop (Engineer Admiral, Personnel), January 6, 1922, on Treasury letter S11342/22, ibid.
54. Testimony of Colonel H. C. L. Holden (SRGF), October 25, 1905, Appendix VII, p. 62, "Report of the Inter-Departmental Committee Appointed to Consider the Regulations as to the Taking out of Patents by Officers and Subordinates in Government Employment, with Appendices, 1905–06," WO 32/5080, TNA.

55. Argument by Whitehead, April 4, 1927, Hardcastle's RCAI claim, pp. 85–87, T 173/649, TNA.
56. Argument by Moritz, April 4, 1927, Hardcastle's RCAI claim, p. 15, ibid.
57. Minute by May, June 30, 1902, G6604A/02, Docket "Proposed Experiments with the view of finding the best means of protecting bottoms of ships against explosive effects of Torpedoes," ADM 1/7687, TNA (contains first quotation); minutes by May, January 26, 1903, and Selborne, February 1, 1903 (contains second quotation), G1064/03, Docket "Belleisle. Plan of Target for Torpedo Attack. Proposed further experiment," ibid.
58. Admiral Superintendent Portsmouth to SecAdm, October 17, 1903, G13107/03, Docket, "HMS 'Belleisle.' Report of Torpedo Experiments," ibid.; minutes by Berry [for DNC] to May (December 1, 1903—contains first quotation), May (December 7, 1903—contains second quotation), May (December 30, 1903—contains third quotation), and others, G13107/03, ibid. See also the discretion at work in ART03/37.
59. See ART04/Appendix E; minute by DNO, March 25, 1904, G4421/04, PQ/04/3067/310–11 (contains quotations).
60. Minute by Arnold Foster, February 16, 1903, S5661/03, SC184/F94, BF. There are many examples of the DNC's opposition in SC184, but see, for example, the minute by Deadman, March 19, 1903, S5661/03, SC184/F94, BF. For the commanders' reports, see SC184b/F88, F115, and F172, BF.
61. Erksine and Charlton to CINC Portsmouth, October 28, 1904, G15020/04, PQ/05/3145/500–508; Jellicoe to Tupper, November 13, 1905, 130/87(90), Tupper Mss., RNM (contains quotation); minutes on G17235/05, PQ/06/3246/731–33, and G189/06, PQ/06/3247/734–35.
62. Modeling the enemy on a French destroyer was less unlikely than it might seem: notwithstanding the 1904 entente, British defense officials spent the first half of 1905 discussing war plans against France (see Nicholas Lambert, *Planning Armageddon: British Economic Warfare and the First World War* (Cambridge, MA: Harvard University Press, 2012) (hereafter *PA*), 47–50).
63. Report by Superintendent of Experiments (Ordnance Committee), January 31, 1906, G2116/06, PQ/06/3210/630–34; minute by Jellicoe, May 8, 1905, G6789/05, SC128b/F155, BF; minutes by Jellicoe, February 12, 1906 (contains quotations), and others, G2116/06, PQ/06/3210/634–38.
64. Walker, *The Employment of Cruisers and Destroyers* (Admiralty: Intelligence Department, 1906), 38, Eb164, AL (contains first quotation); Custance to Beresford (July 7, 1907, contains second quotation), and memorandum by Beresford (July 30, 1907, contains third quotation), enclosed in Beresford to SecAdm, August 1, 1907, Docket "Tactical Exercises. Channel Fleet, 5th Cruiser Sqdn. Scouts and Destroyers. June and July 1907," D675/1907, ADM 1/7795, TNA; Bayly, "Duties of Destroyers in War," n.d. but enclosed in CINC

Home Fleet to SecAdm, November 10, 1907 (contains fourth quotation), and minute by Slade, December 12, 1907 (contains fifth quotation), SC242/F11a, BF.

65. Sumida, "The Quest for Reach: The Development of Long-Range Gunnery in the Royal Navy, 1901–1912," in *Military Transformation in the Industrial Age*, ed. Stephen D. Chiabotti (Chicago: Imprint, 1996), 50–51, 59–60, 66 (quotation on p. 59). I have relied on Sumida's work regarding British gunnery rather than that of John Brooks because Brooks, by his own admission (see "Notes and Comments," *Journal of Military History* 70, no. 1 [January 2006]: 198), did not conduct research in the Pollen papers, an indispensable source for the task he set himself. Friedman (*Naval Firepower,* 41–65) endorses Sumida's interpretation.
66. Minute by Currey, October 22, 1907, G16396/07, PQ/09/3345/156–57 (contains first quotation); minutes by Currey, December 17, 1908 (contains second quotation; emphasis added), and Bacon, December 17, 1908 (contains third quotation), G18178/08, SC224/F34, BF; Sumida, "The Quest for Reach," 74. See also Bacon, *From 1900 Onward* (London: Hutchinson & Co., 1940), 165–66; I thank Bruce Taylor for sending me the relevant extracts.
67. Arthur Marder, *The Anatomy of British Sea Power: A History of British Naval Policy in the Pre-Dreadnought Era, 1880–1905* (Hamden, CT: Archon Books, 1964; first edition 1940), 489–91, and *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904–1919*, vol. 1, *The Road to War, 1904–1919* (London: Oxford University Press, 1961), 38–43; Aaron Friedberg, *The Weary Titan: Britain and the Experience of Relative Decline, 1895–1905* (Princeton, NJ: Princeton University Press, 1988), 135–208.
68. Ruddock Mackay, *Fisher of Kilverstone* (Oxford: Clarendon Press, 1973), 224–72, 306–26; *IDNS*, 37–70, 158–62, 256–65, 316–18; Nicholas Lambert, *Sir John Fisher's Naval Revolution* (Columbia, SC: University of South Carolina Press, 1999) (hereafter *FNR*), 1–11. Battle-cruisers had the armament of battleships but less armor, so they were faster than battleships.
69. Nicholas Lambert, "Admiral Sir John Fisher and the Concept of Flotilla Defence, 1904–1909," *Journal of Military History* 59, no. 4 (October 1995): 639–60, and *FNR*, 120–26.
70. Jon Sumida, "British Capital Ship Design and Fire Control in the Dreadnought Era: Sir John Fisher, Arthur Hungerford Pollen, and the Battle Cruiser," *Journal of Modern History* 51, no. 2 (June 1979): 205–30, and *IDNS*, especially 37–51, 89–100. On the War Room system, see Lambert, "Strategic Command and Control for Maneuver Warfare: Creation of the Royal Navy's 'War Room' System, 1905–1915," *Journal of Military History* 69, no. 2 (April 2005): 361–410.
71. Fisher to King Edward VII, October 4, 1907, quoted in *FNR*, 142. See also *FNR*, 143–54, and Andreas Rose, "'Blue Water' vs. 'Blue Funk': Julian Corbett,

the C.I.D. and the Myth of the German Peril: A Case of Naval Expertise and Public Policy (1907–1909)" (paper, Naval History Symposium, United States Naval Academy, Annapolis, MD, September 2011).

72. See also Jon Sumida, "Sir John Fisher and the *Dreadnought*: The Sources of Naval Mythology," *Journal of Military History* 59, no. 4 (October 1995): 619–37.

5. *Command Technology on Trial in the United States*

Epigraph: Williams to Twining, January 23, 1912, BuOrd 25562/3, RG74/E25/BB198, NARA.

1. Bliss Co. to Mason, December 22, 1908, BuOrd 17761/393, RG74/E25/B844, NARA; Fraser & Usina (Bliss Co. attorneys) to SecNav, January 23, 1909, BuOrd 17761/403, ibid.; endorsement by Mason to SecNav, February 6, 1909, BuOrd 17761/403, ibid.; AsstSecNav to Bliss Co., March 13, 1909, BuOrd 17761/403, ibid.; Mason to Bliss Co., January 24, 1910, BuOrd 21017, RG74/E25/B1043, NARA; Bliss Co. to Mason, January 28, 1910, BuOrd 21017/105, ibid.; Mason to Bliss Co., January 31, 1910, BuOrd 21017/105-LS538/264, ibid.; Mason to Bristol, February 1, 1910, BuOrd 21017-LS538/368, ibid.; Mason to Bristol, February 11, 1911, BuOrd 21017-LS600/494, ibid.; Bristol to Mason, February 16, 1911, BuOrd 21017/132, ibid.
2. Bristol to Mason, March 19, 1910, BuOrd 21017/108, ibid.; Bristol to Mason, April 19, 1910, BuOrd 21017/111, ibid.; Bristol to Mason, December 8, 1910, BuOrd 21017/121, ibid. (contains first quotation); Leavitt to Mason, December 20, 1910, BuOrd 21017/122, ibid. (contains second quotation).
3. Commissioner of Patents to SecNav, January 12, 1911, BuOrd 21017/127, ibid.
4. No record of this purchase was found, but it is mentioned in the Bliss Company's petition of May 29, 1914 in *E. W. Bliss Co. v. United States*, 53 Ct. Cl. 47 (1917), pp. 7–8, a copy of which can be found with BuOrd 28200/12 in RG74/E25/BBB316, NARA.
5. Mason to Bliss Co., December 28, 1910, BuOrd 22866-LS592/429–30, RG74/E25/B1173, NARA; Bliss Co. to Mason, December 28, 1910, BuOrd 22866/60, ibid.; Bliss Co. to SecNav, January 17, 1911, BuOrd 22997/12, RG74/E25/B1180, NARA; Sheridan to Mason, January 24, 1911, BuOrd 24126/1, RG74/E25/B1249, NARA; Mason to Sheridan, February 6, 1911, BuOrd 24126/1-LS599/418–19, ibid.; Mason to SecNav, February 11, 1911, BuOrd 24126/2-LS1/33–34, ibid.; Bristol to Mason, February 11, 1911, B72-204, NTS. See also "Contract for Torpedoes," March 29, 1911, B72-204, NTS.
6. For more on Twining, see "Twining Made Chief," *WP*, May 12, 1911, p. 5; "Rear Admiral Twining Dies While on Vacation," *WP*, 6 July 1924, p. 6.
7. Twining to Glennon, June 24, 1911, RG74/E26/B1B/VG/PP50–51, NARA (contains first quotation); Twining to Andrews, July 21, 1911, RG74/E26/B1B/VG/PP122–29, NARA (contains second quotation); Sheridan to Twining, October 12,

1911, and Twining's endorsement thereon, October 13, 1911, BuOrd 24733/1, RG74/E25/B1267, NARA; "Contract for Torpedoes," October 25, 1911, B77-314, NTS.

8. Bliss IoO to Mason, October 25, 1907, BuOrd 20065/2, RG74/E25/B979, NARA. The "Mark V" torpedo referred to in this letter was in fact the prototype Mark VI.
9. See Mason to Gleaves, March 20, 1908, BuOrd 21715-LS432/257, RG74/E25/B1086, NARA. An original copy of this article can be found with that letter; an English translation can be found in the "Addition to the Record" before the Supreme Court in *Electric Boat Co. v United States*, 263 U.S. 621 (1924) (available through the Gale/Cengage Learning database "The Making of Modern Law: U.S. Supreme Court Records and Briefs, 1832–1978").
10. Austrian Patent 21315, issued September 11, 1905; Austrian Patents 24150 and 28050, issued May 10, 1906, and April 10, 1907, respectively. The latter of these two patents was taken out with Julius von Petravic, of gyroscope fame, and it was identical to a British patent that the two men applied for in March 1906 and were awarded in March 1907 (GBP 7,390/1906).
11. Mason to Gleaves, March 20, 1908, BuOrd 21715-LS432/257, RG74/E25/B1086, NARA; Norton to Twining, May 26, 1914, BuOrd 25373/39, para. 3, RG74/E25/BB156, NARA.
12. USP 964,574 was equivalent to Sodeau's GBP 6,081/1907. The delay between application and issue suggests that a battle over competing wet superheater patents was raging behind the scenes. Armstrong/Sodeau had previously taken out a string of US patents for a dry inside superheater (827,891 and 828,432) and then a dry outside superheater (835,262; 850,307; and 944,975).
13. Norton to Strauss, May 26, 1914, pp. 64–75, BuOrd 25373/39, RG74/E25/BB156, NARA.
14. On Williams, see "Cornell Alumni News," vol. 33, no. 23 (16 March 1931), p. 277, downloaded from http://ecommons.library.cornell.edu/bitstream/1813/3548/13/033_23.pdf, 23 July 2009; Gleaves to Mason, August 7, 1907, BuOrd 18172/20, RG74/E25/B873, NARA; Mason to Gleaves, May 8, 1908, BuOrd 21017-LS442/472, RG74/E25/B1043, NARA; Bristol to Mason, August 5, 1909 (Annual Report for FY 1908), para. 31A, B66-173, NTS; Bristol to Mason, September 28, 1909, ibid.; ACNTS to Bristol, June 25, 1910, enclosing Williams to Yarnell, June 24, 1910, BuOrd 21017/114, RG74/E25/B1043, NARA.
15. On Thelin, see Norton to Strauss, May 26, 1914, BuOrd 25373/39, para. 3, RG74/E25/BB156, NARA; on the notebooks, see endorsement by Williams, October 11, 1913, BuOrd 25373/30, ibid.
16. Mason to Bristol, July 20, 1910, BuOrd 18172-LS568/213–14, RG74/E25/B873, NARA; Torpedo Board to Mason, July 26, 1910, BuOrd 18172/41, RG74/E25/B874, NARA; "Specifications for the Manufacture of Bliss-Leavitt Automobile

Torpedoes, 5.2 Meters by 45 Centimeters, Mark VI" (October 1909, OP 42), enclosed in BuOrd 23873/3, RG74/E25/B1229, NARA.

17. Torpedo Board to Mason, July 26, 1910, BuOrd 18172/41, RG74/E25/B874, NARA. Why the Navy abandoned the metric system is unclear, but the long 21-inch torpedo was known as the 21-foot torpedo instead of as the 6.3-meter torpedo, while the standard 21-inch torpedo continued to be known as the 5-meter instead of as the 17-foot torpedo.
18. Davison to Mason, August 8, 1910, BuOrd 23713/1, RG74/E25/B1223, NARA.
19. Ibid.
20. Acting CoO to Electric Boat Co., September 6, 1910, BuOrd 23713/1-LS574/169–71, RG74/E25/B1223, NARA; Davison to Mason, September 9, 1910, BuOrd 23713/2, ibid.; Mason to Davison, October 6, 1910, BuOrd 23713/2-LS579/288–91, ibid.; Davison to Mason, October 10, 1910, BuOrd 23713/3, ibid.; Davison to Mason, September 10, 1910, BuOrd 23754/2, RG74/E25/B1226, NARA; Mason to Davison, October 6, 1910, BuOrd 23754/2-LS579/280–82, ibid. (contains price scale for 21-foot torpedo); Davison to Mason, October 20, 1910, BuOrd 23754/5, ibid.; "Contract for the Manufacture of One Davison 5.2m. × 45cm., Type Torpedo, for the United States Navy," B73-315, NTS.
21. Mason to Bliss Co., September 6, 1910, BuOrd 23754-LS574/167–68, RG74/E25/B1226, NARA; Acting CoO to Bliss Co., September 9, 1910, BuOrd 23753-LS574/172–73, ibid.; Mason to Bliss Co., October 6, 1910, BuOrd 23754/3-LS579/231–32, ibid. (contains quotation); Leavitt to Mason, February 7, 1911, BuOrd 23754/12, ibid.
22. Davison to Mason, August 8, 1910, BuOrd 23712/1, RG74/E25/B1223, NARA; Davison to Twining, October 20, 1911, BuOrd 23712/2, ibid.
23. Endorsements by Williams to Twining, October 27, 1911 (contains first quotation), and Norton to Williams, November 4, 1911 (contains second quotation), BuOrd 23712/2, ibid.
24. Gustavus Weber, *The Patent Office: Its History, Activities and Organization* (Baltimore, MD: Johns Hopkins University Press, 1924), 32–39, 51–52; Davison to Twining, December 16, 1911, BuOrd 23712/5, RG74/E25/B1223, NARA.
25. Davison to Mason, December 6, 1911, BuOrd 23712/3, ibid.; Twining to Electric Boat Co., February 1, 1912, BuOrd 25373/6-2/11, RG74/E25/BB156, NARA; Davison to Twining, February 5, 1912, BuOrd 25373/7, ibid.; endorsement by Acting SecNav to Twining, March 26, 1912, BuOrd 25373, ibid. For the shipment of the torpedoes, see Norton to Electric Boat Co. Inspector, January 10, 1912, BuOrd 25373/1-0, ibid. A copy of the shop license can be found in the "Transcript of Record," pp. 7–9, *Electric Boat Co. v. United States*, 263 U.S. 621 (1924) (available through the Gale/Cengage Learning database "The Making of Modern Law: U.S. Supreme Court Records and Briefs, 1832–1978").

26. Torpedo Board to Mason, November 19, 1911, BuOrd 18172/48, RG74/E25/B874, NARA; Norton to Bliss Co., January 17, 1912, BuOrd 25325/3-0, RG74/E25/BB145, NARA; Twining to Bliss Co., January 18, 1912, BuOrd 25145-1/27, RG74/E25/BB64, NARA. The first 120 × 18-inch torpedoes kept their Mark VII designation, while the second 120 became known as Mark VII Mod. 1 because of their different reducers. The fifty Mark VIII torpedoes were originally known as Mark III Mod. 1 or as Mark IV, the logic being that they were the next 21-inch mark after the 21-inch Mark III torpedoes. But they were eventually re-designated as Mark VIII on account of their longer length.
27. Torpedo Board to Twining, June 13, 1912, BuOrd 26969/1, RG74/E25/BBB135, NARA; Sawyer's endorsement of August 30, 1912, BuOrd 26969/8, ibid.; Asst Bliss IoO to Sawyer, September 14, 1912, BuOrd 26969/10, ibid.
28. For the date of his resignation, see Mason to SecNav, November 25, 1910, BuOrd 16773/76-LS587/373, RG74/E25/B775, NARA. His departure may have been related to irregularities in the reimbursement requests he submitted for his lodging in Newport, Rhode Island; see the bundle with BuOrd 20784 (especially 20784/8), RG74/E25/B1025, NARA.
29. For more on Williams, see "Williams," entry in *Dictionary of American Naval Fighting Ships*, available at http://www.history.navy.mil/danfs/index.html, downloaded June 12, 2012; "Naval Operation Chief's Aid [sic] Post Remains Unfilled," *WP*, 23 August 1925, p. A4.
30. Norton to Williams, December 1, 1911, BuOrd 24824, RG74/E25/B1268, NARA; Williams to Twining, December 11, 1911, BuOrd 24824/2, ibid. (contains quotation).
31. Twining to Williams, December 30, 1911, 21017/173. This letter was not found, but it is described in Williams to Twining, January 23, 1912, BuOrd 25562/3, RG74/E25/BB198, NARA.
32. Williams to Twining, January 23, 1912, BuOrd 25562/3, RG74/E25/BB198, NARA.
33. There is considerable literature on the creation and solution of new accounting problems in other contexts during this period. As a starting point, see H. Thomas Johnson and Robert S. Kaplan, *Relevance Lost: The Rise and Fall of Management Accounting* (Boston: Harvard Business School Press, 1987), 1–92; and Arthur L. Norberg, "High-Technology Calculation in the Early 20th Century: Punched Card Machinery in Business and Government," *Technology and Culture* 31, no. 4 (October 1990): 753–779.
34. Lawrence M. Friedman, *A History of American Law,* 3rd ed. (New York: Touchstone, 2005), 124–25, 167–70; Morton J. Horwitz, *The Transformation of American Law, 1780–1860* (Cambridge, MA: Harvard University Press, 1977), 63–108, 259–61; idem, *The Transformation of American Law, 1870–1960: The Crisis of Legal Orthodoxy* (New York: Oxford University Press, 1992), 146–48.

35. *Krupp v. Crozier*, 32 App. D.C. 1 (DC Court of Appeals, 1908); *Crozier v. Krupp*, 224 U.S. 290 (1912); 36 *Stat*. 851. The expanded jurisdiction did not cover government employees, who were still not permitted to bring claims against the government; see "Department of Justice, Patent Policy Survey: Navy Department," p. 16, n. 31, Folder "Navy Department," RG60/E418/B2, NARA II.
36. *Crozier v. Krupp*, 224 U.S. 290 (1912).
37. 35 *Stat*. 218; JAG to SecNav, September 30, 1907, in DeptNav, *Annual Report of the Navy Department*, 60th Cong., 1st Sess., 1907, p. 112. Paullin does not mention this development in his *History of Naval Administration*.
38. JAG to SecNav, September 15, 1908, in DeptNav, *Annual Report of the Navy Department*, 60th Cong., 2nd Sess., 1908, p. 81.
39. Solicitor to SecNav, October 1, 1911, in DeptNav, *Annual Report of the Navy Department*, 62nd Cong., 2nd Sess., 1911, p. 161.
40. Solicitor to SecNav, October 1, 1912, in DeptNav, *Annual Report of the Navy Department*, 62nd Cong., 3rd Sess., 1912, p. 92. See also Solicitor to SecNav, October 1, 1913, in DeptNav, *Annual Report of the Navy Department*, 63rd Cong., 2nd Sess., 1913, p. 92.
41. Williams to Twining, February 9, 1912, BuOrd 25940/1, RG74/E25/BB284, NARA; endorsements by Norton to Williams, February 17, 1912 (contains quotation), and by ACNTS to Twining, February 19, 1912, BuOrd 25940/1, ibid.
42. The detailed drawings and description were not found, but Bristol alludes to them in Bristol to Twining, September 25, 1911, BuOrd 24587/11, pp. 13–14, RG74/E25/B1263, NARA.
43. Twining to Bliss Co., March 13, 1912, BuOrd 25562-3/25, RG74/E25/BB198, NARA; Bliss Co. to Twining, March 19, 1912, BuOrd 25562/9, ibid.; Twining to SecNav, March 22, 1912, BuOrd 25562-4/15, ibid.; Acting SecNav to Twining, Dept 17755/13, RG80/E19/B679, NARA.
44. See, for example, Bliss IoO to Mason, October 4, 1905, B45-131, NTS.
45. See the letters concerning two visits by Japanese officers in December 1906 and May 1907 with BuOrd 19539, RG74/E25/B945, NARA.
46. On Bristol, see "Admiral Bristol Is Dead in Capital," *NYT*, May 14, 1939, p. 63. On Babcock, see "Captain Strite to Assume Command of Naval Unit," *The Technique* (Georgia School of Technology), April 7, 1945, 26 no. 19, p. 1; William S. Sims, *The Victory at Sea* (London: John Murray, 1920), 204–5.
47. On unofficial spying, see Bristol to Twining, June 25, 1911, RG74/E26/B1L, NARA. On the Fiume superheater, see Bristol to Twining, September 25, 1911, BuOrd 24587/11, pp. 13–14, RG74/E25/B1263, NARA. On the depth mechanism, see Babcock to Twining, October 20, 1911, BuOrd 23839/5, NTS B77-314, and ACNTS to Twining, October 15, 1912, B73-315, NTS. On the Hardcastle superheater, see Babcock to Craven, December 21, 1912, RG74/E26/B1B/VR,

NARA. In this letter, Babcock refers to "BIR-5," his fifth intelligence report, which was not found, but it was probably dated sometime in November 1912. "I have finally managed to walk off with the whole British famous Hardcastle torpedo," Babcock crowed of BIR-5. "I think this with my previous reports on the same subject undoubtedly is the first authentic information that has escaped the inner circles." On the Torpedo Station's consideration of using the Hardcastle superheater in its torpedoes, see Williams to Twining, February 11, 1913, BuOrd 25940/2, RG74/E25/BB284, NARA. Stealing intellectual property was an American tradition; see Doron S. Ben-Atar, *Trade Secrets: Intellectual Property and the Origins of American Industrial Power* (New Haven, CT: Yale University Press, 2004).

48. Bristol to Twining, June 25, 1911, RG74/E26/B1L, NARA; Bristol to Twining, July 25, 1911, BuOrd 24587/4, RG74/E25/B1263, NARA; Babcock to Twining, August 29, 1912, RG74/E26/B1B/VR, NARA; Babcock to Twining, September 1, 1912 (BIR-1), B73-315, NTS; Babcock to Twining, September 14, 1912 (BIR-3), ibid.; Babcock to Twining, September 21, 1912 (see Confidential Appendix), BuOrd 25082/104, RG74/E25/BB37, NARA; Babcock to Twining, October 2, 1912, RG74/E26/B1B/VR, NARA; Babcock to Twining, October 30, 1912 (BIR-4), B68-229, NTS; Babcock to Twining, February 7, 1913 (BIR-12), BuOrd 25415, RG74/E25/BB164, NARA; and Babcock to Twining, ca. February 7, 1913 (BIR-16), BuOrd 25415, ibid.
49. Babcock to Twining, November 22, 1912, RG74/E26/B1B/VR, NARA.
50. Babcock to Twining, November 29, 1912, ibid. See also Babcock to Twining, November 27, 1912, ibid.
51. Twining to Sawyer, December 9, 1912, BuOrd 26775/4, RG74/E25/BBB113, NARA; Sawyer to Bliss Co., December 9, 1912, enclosure to BuOrd 26775/5, ibid.
52. Leavitt to Twining, December 10, 1912, BuOrd 26775/6, ibid.
53. Twining to Bliss Co., December 13, 1912, BuOrd 26775/5, ibid.
54. Norton to Twining, December 13, 1912, BuOrd 26775/9, ibid. For more on Norton, see "Commander Norton's Rites," *WP*, June 20, 1922, p. 7.
55. Bliss Co. to Twining, December 19, 1912, BuOrd 27741/1, RG74/E25/BBB238, NARA.
56. See US brief for the Second Circuit Court of Appeals in *United States v. E. W. Bliss Co.*, p. 67, copy with BuOrd 27741/24, RG74/E25/BBB238, NARA.
57. Endorsement by Twining to Solicitor, December 26, 1912, BuOrd 27741/1-1/3, ibid.
58. House Committee on the Judiciary, Report 1942, January 19, 1911, *Bill to Prevent the Disclosure of National Defense Secrets*, H.R. 26656, 61st Cong., 3rd sess., p. 2.

59. Compare to the Espionage Act of 1917, as discussed in Peter Galison, "Secrecy in Three Acts," *Social Research* 77, no. 3 (Fall 2010): 949–50.
60. Endorsement by Twining to Solicitor, December 26, 1912, BuOrd 27741/1-1/3, RG74/E25/BBB238, NARA.
61. Acting SecNav to Twining, January 9, 1913, Dept 17755/14, RG80/E19/B679, NARA.
62. Bliss Co. to Twining, June 5, 1912, BuOrd 26862/4, and endorsement thereon, RG74/E25/BBB125, NARA; Sawyer to Mason, February 21, 1911, BuOrd 22866/83, RG74/E25/B1173, NARA; endorsement by Williams to Twining, October 24, 1911, BuOrd 24587/11, RG74/E25/B1263, NARA; Torpedo Board to Twining, April 23, 1912, para. 17, BuOrd 26542/6, RG74/E25/BBB86, NARA; endorsement by Sawyer to Twining, December 10, 1912, BuOrd 25698/90, RG74/E25/BBB236, NARA; Bliss Co. to Twining, December 12, 1912, BuOrd 25698/92, ibid.; Twining to Bliss Co., January 4, 1913, BuOrd 25698/92-1/15, ibid.; Sawyer to Twining, January 14, 1913, BuOrd 25698/102, ibid. (contains quotations); Twining to Bliss Co., January 18, 1913, BuOrd 25698/102, ibid.
63. Bliss Co. to Twining, February 10, 1913, BuOrd 27741/5, RG74/E25/BBB238, NARA.
64. Bliss Co. to Twining, February 18, 1913, BuOrd 25698/127, RG74/E25/BBB236, NARA.
65. Bliss Co. to Mason, October 19, 1905, BuOrd 17761/52, copy in ToR, p. 315.
66. Bliss Co. to SecNav, May 9, 1913, BuOrd 27741/6, RG74/E25/BBB238, NARA.
67. Endorsement by Twining to SecNav, May 22, 1913, BuOrd 28200/1, RG74/E25/BBB316, NARA.
68. Roosevelt (Acting SecNav) to Twining, May 14, 1913, BuOrd 27741/6, RG74/E25/BBB238, NARA.
69. Norton to Youngs (District Attorney), May 27, 1913, BuOrd 27741, ibid. In the federal court system, the United States is divided into circuits, which are subdivided into districts. District courts are trial courts, circuit courts are appellate courts, and the Supreme Court is the highest appellate court.
70. Youngs to Attorney General, May 19, 1913, enclosed in Assistant Attorney General to SecNav, May 20, 1913, Dept 17755/14:7, RG80/E19/B679, NARA.
71. Copies of the "Complaint," the "Complaint as Amended," and the "Answer to the Complaint" can be found in the ToR. They should not be confused with briefs, which the parties did not submit until after testimony was taken at trial. For more on Veeder, see "Van V. Veeder Dies," *NYT*, December 5, 1942, p. 15.
72. On law versus equity, see Friedman, *A History of American Law*, xvii–xix, 97–99.
73. These tests were in sections 24–26 of the Patent Act of 1870 (16 *Stat*. 198).

74. Leavitt's testimony, November 18, 1913, pp. 170–85, ToR; Page's testimony, November 18, 1913, pp. 148–52, ibid.; Moses O'Brien's testimony, November 11, 1913, pp. 63–64, ibid.; comment by Coles, November 20, 1913 (contains quotation), p. 204, ibid.
75. For context, see Alain Pottage and Brad Sherman, *Figures of Invention: A History of Modern Patent Law* (Oxford: Oxford University Press, 2010), 65–84; and Joshua D. Sarnoff, "Patent-Eligible Inventions After *Bilski:* History and Theory," *Hastings Law Journal* 63 (December 2011): 63–90. For a striking parallel, see Christine MacLeod, "'A Delicate Business': Wartime Airplane Designs and their Post-war Evaluation, 1919–1924," *Studies in History and Philosophy of Science* (2013; in press): 1–11.
76. Decker's testimony, November 11, 1913, pp. 64–73, T.R.
77. Decker was not the only Patent Office examiner to struggle with complex technical issues. See Rodney K. Worrel, "The Wright Brothers' Pioneer Patent," *American Bar Association Journal* 65 (October 1979): 1512–18. Davison quotation from Davison to Mason, December 8, 1906, B50-158, NTS.
78. Williams's testimony, November 11, 1913, p. 51, ToR.
79. Leavitt's testimony, November 21, 1913, pp. 229–31, ibid.
80. See Bristol to Twining, July 21, 1911, BuOrd 24587/1, and endorsements thereon, RG74/E25/B1263, NARA; Craven to Twining, June 12, 1913, BuOrd 28298/1, and endorsements thereon, RG74/E25/BBB324, NARA. These exchanges show a remarkable diversity of opinion on the gyroscopic properties of the turbine. The Bureau decided to seek help from the civilian gyroscope expert Elmer Sperry; unfortunately, the relevant Bureau file is missing (it should be BuOrd 28502 in RG74/E25/BBB346), but the correspondence can be partially reconstructed from Sperry's papers (see Folder "Gyroscope Company, Aerial Torpedo, Prism Fire," Box 29, Sperry papers (Accession 1893), HML).
81. A copy of Veeder's opinion, dated April 14, 1914, on which the next several paragraphs are based, can be found with BuOrd 27741/31, RG74/E25/BBB238, NARA.
82. For the higher courts' decisions, see *United States v. E. W. Bliss Co.*, 224 F. 325 (2nd Cir. 1915), and *E. W. Bliss Co. v. United States*, 248 U.S. 37 (1918).
83. Quoted in "Torpedo Decision Held Up," *WP*, June 27, 1913, p. 6.
84. Youngs to Attorney General, 22 November 1913, DoJ 167037-20, RG60/E112/B1530, NARA II.
85. See *E. W. Bliss Company v. United States*, 53 Ct. Cl. 47 (1917).
86. Davison to Williams, January 10, 1913, B73-315, NTS; Davison to Twining, January 14, 1913, BuOrd 25373/18, RG74/E25/BB156, NARA.
87. Endorsement by Williams to Twining, January 20, 1913, BuOrd 25373/18, RG74/E25/BB156, NARA; Twining to Electric Boat Co., January 23, 1913, BuOrd 25373/18, ibid. (contains quotation).

88. Davison to Twining, January 25, 1913, BuOrd 25373/20, ibid. (contains quotations); Twining to Davison, February 11, 1913, BuOrd 25373/20-2/25, ibid.
89. Davison to Twining, February 12, 1913, BuOrd 25145/16, RG74/E25/BB64, NARA (contains quotation); endorsement by Twining to DeptNav, February 24, 1913, BuOrd 25145/16-3/5, ibid.; Davison to Twining, March 17, 1913, BuOrd 25145/18, ibid.; Davison to Twining, April 5, 1913, BuOrd 25145/19, ibid.
90. Norton to Davison, April 10, 1913, BuOrd 25373/22-4/22, RG74/E25/BB156, NARA; Williams to Twining, July 29, 1913, BuOrd 25724/7, RG74/E25/BB245, NARA.
91. Davison to Twining, August 4, 1913, BuOrd 25145/21, RG74/E25/BB64, NARA.
92. Twining to Electric Boat Co., August 8, 1913, BuOrd 25145/21, ibid.; Williams to Twining, September 2, 1913, B73-315, NTS; Twining to Electric Boat Co., September 6, 1913, BuOrd 25373/28-9/20, RG74/E25/BB156, NARA; Davison to Twining, September 8, 1913, BuOrd 25373/29, ibid. (contains quotation); agreement between Davison and Williams, September 12, 1913, B73-315, NTS; endorsement by Williams to Twining, September 18, 1913, BuOrd 25373/29, RG74/E25/BB156, NARA.
93. For more on this firm, which specialized in patent cases, see Dean Stockett Edmonds, *Random Reminiscences of Sixty Years in Law Practice: The Memoir of Dean Stockett Edmonds*, ed. Charles Miller (Danbury, CT: Rutledge, 2000), especially pp. 86–88.
94. *Claims* in this context was a term of art, referring to the "claims" section that concluded every patent.
95. Pennie, Davis, & Goldsborough to Electric Boat Co., August 19, 1913 (contains quotations), enclosed in Davison to Twining, September 16, 1913, BuOrd 25373/30, RG74/E25/BB156, NARA.
96. Endorsement by Williams to Twining, October 11, 1913, BuOrd 25373/30, ibid.
97. Torpedo Board to Twining, September 27, 1913, BuOrd 26542/10, RG74/E25/BBB86, NARA (contains quotations); endorsement by Twining to Norton, October 4, 1913, BuOrd 26542/10, ibid.; Acting CoO to Electric Boat Co., October 4, 1913, BuOrd 25145/21, RG74/E25/BB64, NARA.
98. Davison to Strauss, November 18, 1913, BuOrd 25145/27, ibid.
99. Davison to Twining, November 18, 1913, BuOrd 25373/34, RG74/E25/BB156, NARA.
100. Endorsement by Strauss to SecNav, December 20, 1913, BuOrd 25373/34-12/31, ibid.
101. Strauss to Electric Boat Co., January 6, 1914, BuOrd 25145/27, RG74/E25/BB64, NARA.
102. On Strauss, see "Adm. Strauss, Mine-Laying Expert, Dies," *WP*, December 31, 1948, p. B2.

103. Davison to Twining, September 24, 1913, BuOrd 25145/24, RG74/E25/BB64, NARA.
104. Davison to Strauss, April 29, 1914, BuOrd 25373/36, RG74/E25/BB156, NARA.
105. Norton to Strauss, May 26, 1914, BuOrd 25373/39, ibid. Davison had stated that the company's expenditures on the two Davison torpedoes were $56,356.65 (Davison to Twining, September 29, 1913, BuOrd 25145/25, RG74/E25/BB64, NARA), by which standard Norton's proposed $50,000 was low, but not grotesquely so.
106. Roosevelt to Strauss, June 16, 1914, BuOrd 25145/28, RG74/E25/BB64, NARA; Davison to Strauss, June 23, 1917, BuOrd 25145/29, ibid. (contains quotation); Johnson (Electric Boat Co. attorney) to Strauss, July 1, 1914, BuOrd 25145/31, ibid.; Petition dated July 29, 1914 in "Transcript of Record," pp. 1–5, *Electric Boat Company v. United States* (263 U.S. 621, 1924).
107. See Acting CoO to Williams, July 22, 1913, BuOrd 25562, RG74/E25/BB198, NARA.
108. Mason to SecNav, May 6, 1911, BuOrd 23736/13, RG74/E25/B1225, NARA; Twining to SecNav, November 7, 1912, BuOrd 27593-12/1, RG74/E25/BBB226, NARA; Twining to SecNav, October 4, 1913, BuOrd 27593, ibid. These numbers have been reconstructed from twenty-nine different orders with six different suppliers (the Bliss Company, the Electric Boat Company, the Naval Torpedo Station, the Naval Gun Factory, the Whitehead Company at Weymouth, and the Whitehead Company at Fiume).
109. The government subsequently manufactured more than 1,000 Bliss-Leavitt torpedoes after 1913 without paying royalties. In 1920, the government and the company signed a contract retroactively covering these torpedoes and providing for royalties thereon, on the basis of the unsigned agreement reached in 1913–1914. This 1920 contract also led to a lawsuit. See Twining to SecNav, October 4, 1913, BuOrd 27593, RG74/E25/BBB226, NARA; Bliss Co. to Strauss, May 9, 1914, enclosing draft agreement, BuOrd 28200/7, RG74/E25/BBB316, NARA; Strauss to Bliss Co., May 12, 1914, BuOrd 28200/7, ibid.; Bliss Co. to Strauss, May 18, 1914, BuOrd 28200/9, ibid.; Towne (Bliss attorney) to SecNav, December 24, 1918, quoted in *E. W. Bliss Co. v. United States* (74 Ct. Cl. 14, 1932).
110. Acting CoO to Williams, September 17, 1913, BuOrd 25562-10/1, RG74/E25/BB198, NARA; Williams to Twining, September 22, 1913, BuOrd 25562/70, ibid.; Strauss to Commandant, Washington Navy Yard, BuOrd 25562-0, ibid.; Williams to Strauss, January 17, 1914, BuOrd 25562/118, ibid.; Williams to Strauss, February 18, 1914, BuOrd 25562/134, ibid.; Robison to Strauss, April 7, 1914, B83-235, NTS.
111. Strauss to Robison, April 10, 1914, RG74/E26/B3/V3, NARA.
112. Williams to Strauss, December 24, 1913, BuOrd 27593/17, RG74/E25/BBB226, NARA.

113. Strauss to Williams, January 2, 1914, BuOrd 27593/17, ibid. See also Bristol to Mason, May 18, 1909, para. 12, BuOrd 18172/35, RG74/E25/B873, NARA.
114. See, for example, Leonard S. Reich, *The Making of American Industrial Research: Science and Business at GE and Bell, 1876–1926* (Cambridge: Cambridge University Press, 1985); David Hounshell and John Kenly Smith, Jr., *Science and Corporate Strategy: Du Pont R&D, 1902–1980* (Cambridge: Cambridge University Press, 1989), 1–55. For important qualifications about the relationship between inventors and corporate research labs in the United States, see Thomas P. Hughes, *American Genesis: A Century of Invention and Technological Enthusiasm, 1870–1970* (New York: Viking, 1989); Naomi R. Lamoreaux and Kenneth L. Sokoloff, "Inventors, Firms, and the Market for Technology in the Late Nineteenth and Early Twentieth Centuries," in *Learning by Doing in Markets, Firms, and Countries*, ed. Naomi Lamoreaux, Daniel Raff, and Peter Temin (Chicago: University of Chicago Press, 1999), 19–57; and Tom Nicholas, "The Role of Independent Invention in U.S. Technological Development, 1880–1930," *Journal of Economic History* 70, vol. 1 (March 2010): 57–82. As Hermione Giffard has argued, the independent inventor and corporate research lab, usually presented as dichotomous categories, do not exhaust the sources of industrial innovation (see Giffard, "The Development and Production of Turbojet Aero-Engines in Britain, Germany, and the United States, 1936–1945" [Ph.D. diss., Imperial College London, 2011], esp. 9–61).
115. On those subjects, see Peter Galison and Bruce Hevly, Eds., *Big Science: The Growth of Large-Scale Research* (Stanford, CA: Stanford University Press, 1992); Lillian Hoddeson et al., *Critical Assembly: A Technical History of Los Alamos During the Oppenheimer Years, 1943–1945* (Cambridge: Cambridge University Press, 1995); and Timothy Wolters, "Managing a Sea of Information: Shipboard Command and Control in the United States Navy, 1899–1945" (Ph.D. Diss., Massachusetts Institute of Technology, 2003), 73–74. Gordon Adams (in *The Politics of Defense Contracting: The Iron Triangle* [New York: Transaction Publishers, 1989]) coined the phrase *iron triangle* to apply to Congress, the military, and industry; Paul Edwards (in *The Closed World: Computers and the Politics of Discourse in Cold War America* [Cambridge, MA: MIT Press, 1997], 47) replaced Congress with academia.
116. Williams's letters to presidents, January 5, 1914, B79-306, NTS; E. R. Morgan to Williams, January 10, 1914, ibid. (contains first quotation); Williams to Morgan, January 17, 1914, ibid. (contains second quotation); Strauss to Williams, January 30, 1914, RG74/E26/B3/V4, NARA.
117. For the 1913 order, see Sheridan to Twining, June 10, 1913, BuOrd 28287/1, RG74/E25/BBB323, NARA; Sheridan to Twining, September 2, 1913, BuOrd

25562/63, RG74/E25/BB198, NARA; and Benito Petrucci, *WASS: 133 Years of History* (Rome: Ciuffa Editore, 2008), 102. For the 1914 negotiations, see the bundle with BuOrd 28840, RG74/E25/BBB383, NARA.

118. Strauss to De Laval Co., March 3, 1914, BuOrd 28993-3/14, RG74/E25/BBB326, NARA; De Laval Co. to Strauss, March 30, 1914, BuOrd 28993/4, ibid. (contains quotation).
119. Bristol to Mason, February 15, 1911, and endorsements thereon, BuOrd 18631/21, RG74/E25/B900, NARA.
120. See *Description of Gyro Gear Mark II, Modification 2, Used in Mark V, Mod. 3, and Mark IV, Mod. 1 Torps*, November 1913, OP 429, NDL. The 75 Whitehead Mark V Mod. 3 torpedoes were likely the orders dated February 1, 1910; October 20, 1911; and February 11, 1911 (see February 1, 1910, BuOrd 21017-LS538/368, RG74/E25/B1043, NARA; Bristol to Mason, February 16, 1911, BuOrd 21017/132, ibid.). The hot-air torpedoes were 18-inch Bliss-Leavitt Mark III torpedoes that, upon conversion, were redesignated Mark IV and Mark IV Mod. 1 (see *Description of Mark IV, Mod. 1, 5 m by 45 cm, Torpedo (Converted at Naval Torpedo Station from Mark III)*, May 1914, OP 449, B70-290, NTS).
121. On the Obry gyroscope, see *The Whitehead Gyro Gear, Mark I Mod. 2 and Mark I Mod. 3, Fitted in 5.2 m. × 45 cm* [*sic*], *Mark V, and Mark V Mods. 1, 2, and 4,* [*sic*] *Torpedoes and Notes on Care, Handling, and Adjustments*, October 1913, OP 425, NDL. On the Leavitt gyroscope, see *Description of the Bliss-Leavitt, 5.2m × 45cm Torpedo Mark VII and Gyro Gear, Mark VII*, pp. 53–66, January 1914, OP 436, NDL.
122. See "Description of Mark VI and Mark VII Directors," typescript n.d., esp. p. 1, B68-229, NTS.
123. W. T. Hall to Twining, June 7, 1913, BuOrd 28322/1, RG74/E25/BBB326, NARA; Williams to Twining, September 3, 1913, BuOrd 28322/2, ibid. (contains second quotation); Hall to Strauss, November 4, 1913, and Williams's endorsement thereon, BuOrd 28682/1, RG74/E25/BBB362, NARA; Strauss to Hall, January 6, 1914, BuOrd 28682/1, ibid. (contains first quotation).
124. See, for example, Fletcher to O'Neil, November 25, 1903, para. 7, BuOrd 14468/03 with 6041/02, RG74/E25/B511, NARA; Leavitt to Mason, February 2, 1905, BuOrd 16686, RG74/E25/B769, NARA; and Gleaves to Mason, February 14, 1905, BuOrd 16686/3; ibid.
125. The documentary trail for these efforts is too lengthy to list in full here, but the first mention of a device (known as the double lever) to shorten the unlocking interval can be found in Superintendent NGF to Mason, March 14, 1910, endorsement on BuOrd 23014/2, RG74/E25/B1182, NARA. A particularly full report of the efforts is given in Williams to Twining, December 26, 1912,

BuOrd 25568/69, RG74/E25/BB203, NARA. The Bliss Company's lack of cooperation can be seen in Sawyer to Twining, April 19, 1913, BuOrd 25568/82, and endorsements thereon, RG74/E25/BB203, NARA. The decision to end the quest for torpedoes under contract is in Torpedo Board to Twining, September 27, 1913, para. 5, BuOrd 26542/10, RG74/E25/BBB86, NARA.

126. Sims, Answer to Question 11, n.d., vol. 3, pt. 2, p. 63, Problem of 1911, RG12, NHC (contains quotations); Rodgers to Aide for Operations, October 5, 1911, and endorsement by Dewey to SecNav, October 25, 1911, BuOrd 23696/2, RG74/E25/B1222, NARA.
127. Sims, Answer to Question 11, n.d., vol. 3, pt. 2, p. 63, Problem of 1911, RG12, NHC.
128. Tactical Committee to Rodgers, September 20, 1911, RG8/B113/F2, NHC.
129. Report of 1st and 3rd Committees on Question 10, August 11, 1909, vol. 2, pt. 2, Problem of 1909, RG12, NHC; R. H. Robinson, Answer to Question 2, September 1, 1912, p. 117, Problem of 1912, ibid.
130. Sims, Answer to Question 11, n.d., vol. 3, pt. 2, p. 50, Problem of 1911, ibid.
131. Conference attendees, Answer to Question 12, September 17, 1910, vol. 1, Problem of 1910, ibid.
132. See, for example, Rodgers to Aide for Operations, October 5, 1911, and endorsement by Dewey to SecNav, October 25, 1911, BuOrd 23696/2, RG74/E25/B1222, NARA.
133. Schofield to SecNav, September 9, 1907, BuOrd 21141/1, RG74/E25/B1050, NARA; endorsement by Dewey to SecNav, October 30, 1907, RG80/E285/B2/V5/P145, NARA; Norman Friedman, *U.S. Destroyers: An Illustrated Design History* (Annapolis, MD: Naval Institute Press, 1982), 10–25
134. See, for example, conference attendees, "Action of the Conference upon Questions of Tactics Previously Reported upon by All Standing Committees," Answer to Question 43, n.d., pt. 4, p. 14, Problem of 1904, RG12, NHC; Answer to Question 36, n.d., part 3, pp. 34–35, Problem of 1906, ibid.; Answer to Question 13, n.d., part 6, pp. 60–61, Problem of 1907, ibid.; Answer to Question 6, September 15, 1910, vol. 1, p. 88, Problem of 1910, ibid.
135. See W. S. Pye, Answer to Question 1, n.d., vol. 3, pt. 1, p. 7, Problem of 1911, ibid.
136. See Yates Stirling, "Notes on Tactical Principles," n.d. but War College Long Course 1911–1912, pp. 28–30, RG13, NHC.
137. See unidentified officer, "Advantages of Long-Range Torpedoes," n.d. but ca. October 1911, RG8/B112/F2, NHC.
138. Data taken from J. H. Klein to CNO, "Battle Practice—Discussion," May 10, 1915, RG8/B96/F4, NHC.
139. Ibid.; H. E. Yarnell, "The Principles and Practice of Tactics as Applied to Naval Conditions of the Present Day," May 30, 1915, p. 6, RG13, NHC.

6. A Very Bad Gap in Britain

Epigraph: ART14/36.

1. See "Draft Agenda for War Conference" prepared by Jackson, June 11, 1914, OD106/14, Docket "Spithead Conference, July 1914," ADM 1/8380/150, TNA.
2. ART09/11–12, 22; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, p. 24, AL; ART 11/36.
3. Torpedoes converted from cold to hot are referred to as "converted" and denoted by an "H" after the mark designation, for example, 18-inch Mark VI** H. New heated torpedoes are referred to as "heated" torpedoes, and the "H" after their mark designation is omitted, per the Navy's convention.
4. ART09/12; ART10/16; ART11/29–30.
5. ART11/17.
6. ART11/17–19; ART12/13–14; ART13/17; ART14/25; ART15/vii, 29, 44–45.
7. ART10/27, 30; ART11/30, 32; ART12/20–22; ART13/24–25; ART14/27–28.
8. "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, p. 24, AL; ART10/23–24, 60–61; ART11/21–22 (quotation on p. 21); ART13/19; ART14/26.
9. ART13/10–11; ART14/9.
10. ART07/30; ART09/20; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, p. 25, AL; minute by ADT, 10 June 1910, SC251/F134, BF.
11. ART09/25; minutes by Hall, August 11 and November 12 (contains quotation) 1909, SC291/F1, BF.
12. Minutes by Phipps Hornby, October 30, 1909, and Nicholson, November 19, 1909, CN0936/09, SC291/F1, BF; ART09/25; ART10/40; report of conference, May 4, 1910, G0303/10, SC257m/F13, BF.
13. Minutes by Jellicoe (June 6, 1910), Nicholson (June 8, 1910), and Jellicoe (June 8, 1910), G0303/10, SC257m/F13, BF; SecAdm to Admiral Superintendent Portsmouth, August 10, 1910, G0303/18344/10, ibid.; ART10/46–48.
14. Phipps Hornby to Adm Supt Portsmouth, December 9, 1910, G0719/10, SC257m/F17, BF, minutes by ADT (Nicholson) (December 22, 1910), ADT (Charlton) (March 10, 1911), Wilson (March 31, 1911, contains quotation), G0719/10, SC257m/F17–18, BF; Phipps-Hornby to CINC Portsmouth, April 27, 1911, G0306/11, SC257m/F19, BF; minutes by Charlton (May 15, 1911) and Wilson (June 21, 1911), G0306/11, SC257m/F20, BF.
15. Minute by ADT, December 12, 1910, G0721/10, SC257m/F17, BF; ART11/25; ART12/16; ART13/21; ART14/27, 46.
16. ART07/17; ART09/20; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, p. 25, AL;

ART10/50; ART11/24; ART12/16, 18. If the spring of a spring-driven gyroscope failed to release, generally due to a failure to cock it, the gyroscope wheel would not spin and the gyroscope rudders would go hard over one way, producing a circular run that might endanger friendly vessels. If the spring of an air-driven gyroscope failed to release, however, the air would still spin the wheel, not acting quickly enough to keep the torpedo on its initial line of fire but exerting enough directive force on the gyroscope rudders to prevent them from going hard over and causing a circular run. This safety benefit was certainly realized by 1911, if not earlier.

17. ART09/26; ART10/51.
18. ART10/51–52; ART11/25; ART12/17–18; ART13/21.
19. Minute by Bacon, April 16, 1909, G5891/09, PQ/08–11/3360/178–80; "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, pp. 22–23, AL; "Paper Prepared by the Director of Naval Ordnance and Torpedoes for the Information of His Successor," May 30, 1912, G0596/12, p. 2, AL; ART09/14; ART11/51.
20. See minutes on G3264/08, PQ/09/3346/157–58. It is unclear what classes the DNO was including in the forty-five large ships.
21. "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, pp. 22–23, AL.
22. For more on Bacon, see Nicholas Lambert, *Sir John Fisher's Naval Revolution* (Columbia, SC: University of South Carolina Press, 1999)(hereafter *FNR*), 50–55, 81–83.
23. Sumida, "The Quest for Reach: The Development of Long-Range Gunnery in the Royal Navy, 1901–1912," in *Military Transformation in the Industrial Age*, ed. Stephen D. Chiabotti (Chicago: Imprint, 1996), 74; Sumida, *In Defence of Naval Supremacy: Finance, Technology, and British Naval Policy, 1889–1914* (Boston: Unwin Hyman, 1989) (hereafter *IDNS*), 132–36, 151–52.
24. Minute by Bacon, April 16, 1909, G5891/09, PQ/08–11/3360/178–80.
25. Minutes by Bacon, April 16, 1909, and McKenna, May 21, 1909, G5891/09, PQ/08–11/3360/178–80.
26. Minutes by Currey, December 17, 1908, and Watts, January 12, 1909, G18178/08, SC224/F34, BF.
27. Minutes by Churchill, November 14, 1911, and Moore, December 22, 1911, PQ/12/F43/P330–36.
28. Minutes by Tudor, September 28, 1912, and Macnamara, October 23, 1912, ibid.; see also the note on the bottom of PQ/12/F43/P336. For the cost of the *Iron Duke* class, see *IDNS*, Table 16.
29. "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 1909, G19535/09, p. 26, AL. On the dates, see the undated article "Clyde Torpedo Factory. Progress of Work at Greenock.

Difficulties Regarding Housing," and Acklom, "Notice. Transfer to Greenock," September 8, 1910, in SUPP 5/177, TNA.

30. Minutes by Superintendent of Ordnance Stores (December 24, 1912, contains first quotation), ADT (February 8, 1913, contains second quotation), and others on G01247/12, PQ/13/F5/P44–51.
31. Callaghan to SecAdm, August 3, 1912, Docket "Maneuvers 1912," ADM 1/8269, TNA. According to the *Oxford English Dictionary*, the term *browning* comes from bird hunting: *to fire into the brown* meant to fire indiscriminately at a flock of birds rather than to aim at a particular bird. Thus, *to brown a fleet* meant to fire at a formation rather than at a single ship. Callaghan planned for destroyers to carry out browning attacks from their own battle-line not only in practice but also in war; see Jon Sumida, "Expectation, Adaptation, and Resignation: British Battle Fleet Tactical Planning, August 1914–April 1916," *Naval War College Review* 60, no. 3 (Summer 2007): 104.
32. Henderson to Commodore (T), August 8, 1912, Docket "Maneuvers 1912," ADM 1/8269, TNA.
33. Minute by Tudor, January 20, 1913, ibid.
34. Callaghan to SecAdm, January 21, 1913, ibid.
35. SecAdm to Callaghan, April 7, 1913, M0158/13, PQ/13/F2/P2–8.
36. Minutes by Tudor, January 24, 1913 (contains quotation), and Jellicoe, January 27, 1913, G097/13, PQ/13/F3/P9–10.
37. Tudor to SRNTF and captain of the *Vernon*, April 3, 1912, PQ/13/F5/P16. Tudor's numbers vary slightly from those given elsewhere but are roughly comparable.
38. Jellicoe to Callaghan, October 11, 1912, G01247/12, PQ/13/F5/P41–43; Jon Sumida, "A Matter of Timing: The Royal Navy and the Tactics of Decisive Battle, 1912–1916," *Journal of Military History* 67, no. 1 (January 2003): 85–136 (especially 103–4).
39. Callaghan to SecAdm, October 22, 1912, G01247/12, PQ13/F5/P38–40; minutes on G01247/12, PQ/13/F5/P44–51.
40. Brandt to CINC Home Flt, July 22, 1912, Docket "Maneuvers 1912," ADM 1/8269, TNA.
41. See SC284/F112, BF. See also *FNR*, 216–21.
42. *Torpedo Manual for His Majesty's Fleet*, vol. 3, *Whitehead Torpedoes. Air Compressors. Net Defence and Obstructions.* (London: Eyre and Spottiswoode, 1909), 313–25, Jb 61, AL.
43. Norman Friedman, *Naval Firepower: Battleship Guns and Gunnery in the Dreadnought Era* (Annapolis, MD: Naval Institute Press, 2008), 28.
44. "Paper Prepared by the Director of Naval Ordnance for the Information of His Successor," November 24, 1909, G19535/09, p. 25, AL.
45. ART12/xiii–xiv.

46. *IDNS*, 215, 247.
47. The competition for skilled personnel went back several years; see *FNR*, 111–15, and reporting by Hughes-Onslow in a 1909 paper on gunnery fire control of the "momentous fact" that gunnery fire-control personnel "are taken very largely from the torpedo personnel so that it would be impossible to use these essential weapons" (quoted in *IDNS*, 156).
48. Minutes by Moore, August 18 and December 21, 1910, G0655/10, PQ/12/F5/P29–35.
49. ART06/21–22; ART09/22.
50. ART10/34.
51. ART12/27.
52. ART13/29–30.
53. ART13/30.
54. *IDNS*, 208–11; Friedman, *Naval Firepower*, 41–42, 48; ART14/31.
55. ART13/30.
56. ART14/32. On the dumaresq, see *IDNS*, 74.
57. ART14/36.
58. Ibid.
59. Arthur Marder, *From the Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904–1919*, vol. 1, *The Road to War, 1904–1919* (London: Oxford University Press, 1961) (hereafter *FDSF* I), 395–404.
60. *FDSF* I, 367–95.
61. See, for example, Marder, *FDSF* I, 119, 367–94; Samuel Williamson, *The Politics of Grand Strategy: Britain and France Prepare for War, 1904–1914* (Cambridge, MA: Harvard University Press, 1969), 44–45, 50–51, 103–9, 194–95, 238–40; Michael Howard, *The Continental Commitment: The Dilemma of British Defence Policy in the Era of the Two World Wars* (London: Temple Smith, 1972), 44–55; Paul Kennedy, *The Rise of the Anglo-German Antagonism, 1860–1914* (London: Allen and Unwin, 1980), 279, 449; Paul Haggie, "The Royal Navy and War Planning in the Fisher Era," in *The War Plans of the Great Powers, 1880–1914*, ed. Paul Kennedy (London: George Allen & Unwin, 1979), 118–32; Paul Halpern, *A Naval History of World War I* (Annapolis, MD: Naval Institute Press, 1994), 21–22, 157; Hew Strachan, *The First World War*, vol. 1, *To Arms* (Oxford: Oxford University Press, 2001), 378–403. Recent attempts to resuscitate key aspects of Marder's arguments by Shawn Grimes (in "The Baltic and Admiralty War Planning, 1906–1907," *Journal of Military History* 74, no. 2 [April 2010]: 407–37) and Matthew Seligmann (in several articles, culminating in *The Royal Navy and the German Threat, 1901–1914: Admiralty Plans to Protect British Trade in a War against Germany* [Oxford: Oxford University Press, 2012]) are unpersuasive in light of Nicholas Lambert, *Planning Armageddon: British Economic Warfare*

and the First World War (Cambridge, MA: Harvard University Press, 2012) (hereafter *PA*), which rests on a significantly broader and deeper archival base.

62. *FNR*, 284–91; see also 211–21, 261–72.
63. Churchill, first draft of *The World Crisis* manuscript, quoted in *FNR*, 274.
64. The preceding account is based on *FNR*, 243–49, 274–80, 296–303. Christopher Bell's recent attempt ("Sir John Fisher's Naval Revolution Reconsidered: Winston Churchill at the Admiralty, 1911–1914," *War in History* 18, no. 3 [2011]: 333–56) to challenge Lambert's argument is unconvincing, for reasons explained by Lambert in his reply ("On Standards: A Reply to Christopher Bell," *War in History* 19, no. 2 [2012]: 217–40).
65. Alan Cowpe, "The Royal Navy and the Whitehead Torpedo," in *Technical Change and British Naval Policy, 1860–1939*, ed. Bryan Ranft (London: Hodder and Stoughton, 1977), 31–32; *FNR*, 83–86, 199–211.
66. *PA*, 63–65, 85–101, 109–16.
67. Ibid., 238–40.
68. Ibid., 176–81.
69. Williamson, *The Politics of Grand Strategy*, 187–204, 311, 362; Holger Herwig and Richard F. Hamilton, *Decisions for War, 1914–1917* (Cambridge: Cambridge University Press, 2004), 132–33.
70. See Sumida, "A Matter of Timing," 88–92.
71. The next several paragraphs regarding Jellicoe's solution are based on *IDNS*, 218–20, and especially on Sumida's articles "A Matter of Timing," 93–104, and "Expectation, Adaptation, and Resignation," 104–107. Norman Friedman supported Sumida's findings in *Naval Firepower*, 84–91.
72. Eberhard Rössler, *Die Torpedos der deutschen U-Boote: Entwicklung, Herstellung und Eigenschaften der deutschen Marine-Torpedos* (Herford: Koehler, 1984), 31–37; Julian Corbett, *History of the Great War, Based on Official Documents: Naval Operations*, vol. 3 (New York: Longmans, Green, and Co., 1923), 362, n. 2.
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74. See Andrew Gordon, *The Rules of the Game: Jutland and British Naval Command* (Annapolis, MD: Naval Institute Press, 1996), 433–63.

Conclusion

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4. On this theme, see Alan Beyerchen, "Clausewitz, Nonlinearity, and the Unpredictability of War," *International Security* 17, no. 3 (Winter 1992–93): 59–90.
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7. John Keegan, *The Face of Battle* (New York: Penguin, 1976), 35–45. I owe the idea of the policy piece à la Keegan to Jon Sumida, who described it in remarks at the Military Frontiers conference at the Mershon Center of The Ohio State University in May 2009.
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10. See, for example, Robert Love, *History of the U.S. Navy, 1775–1941* (Harrisburg, PA: Stackpole Books, 1992), 373–76; Arthur Marder, *From Dreadnought to Scapa Flow: The Royal Navy in the Fisher Era, 1904–1919*, vol. 1, *The Road to War, 1904–1919* (London: Oxford University Press, 1961), 329–30.
11. Sims, Answer to Question 11, n.d., vol. 3, pt. 2, p. 50, Problem of 1911, RG12, NHC.
12. Churchill, first draft of *The World Crisis* manuscript, quoted in Nicholas Lambert, *Sir John Fisher's Naval Revolution* (Columbia: University of South Carolina Press, 1999) (hereafter *FNR*), 274.
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15. For a striking parallel, see Adam Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi Economy* (New York: Viking, 2007), 610–24, on the Nazis' weakness-induced hope for "miracle weapons."
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21. See Kendall Birr, "Science in American Industry," in *Science and Society in the United States*, ed. David D. Van Tassel and Michael G. Hall (Homewood, IL: The Dorsey Press, 1966), 66–70.
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23. Herbert Foerstel, *Secret Science: Federal Control of American Science and Technology* (Westport, CT: Praeger, 1993), 165. Apparently the Department of the Navy developed a workaround in 1924: inventors would assign their patents to the Department "in trust" while the patent was pending at the Patent Office, with title to revert to the inventor once the patent was issued; meanwhile the Patent Office would keep the patent pending, and therefore secret, for as long as the Department wanted. See "Department of Justice, Patent Policy Survey: Navy Department," Folder "Navy Department," RG60/E418/B2, NARA II.
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