INNOVATION FOR ITS OWN SAKE

The Type XXI U-boat

Marcus O. Jones

The origins of this article lie in a new study of the Nazi German economy by Adam Tooze, a fragment of which argues that the need to overcome the technological deficit built by the Western Allies in antisubmarine warfare from 1939 triggered a major shift in U-boat design and production after 1943.[1] Tooze points out that an emphasis on technological solutions to strategic and operational problems had by that point become a hallmark of the Nazis', and especially Hitler's, thinking. (Other examples were the Tiger and Panther tanks at Kursk, both of which types proved dysfunctional as platforms, and neither of which proved decisive to the outcome.) So interpreted, the Nazi penchant for imputing to innovation the means to solve a whole class of operational and strategic problems seems to resemble "technological fixes" in other fields of innovation.[2] In so arguing Tooze writes off the findings of Richard Overy, who points to the failure of the regime to develop positive relationships between industry and the war effort as reflecting a "peculiar irrationality of the 'Nazi social system.'" Tooze highlights the research of Ralf Schabel on jet-engine development in the aircraft industry, research asserting that exaggerated technological expectations resulted from Germany's hopeless strategic dilemma and that the systems themselves, while quite promising, were rushed into mass production and combat without adequate testing or development. Interestingly, he then characterizes Admiral Karl Dönitz's decision to embrace the Type XXI submarine in 1943, under the technocratic direction of Albert Speer's ministry, as reflecting both the increasing

Dr. Jones is associate professor of German economic and military history at the U.S. Naval Academy. He is the author of a study of German industry and occupation policy in World War II, as well as of articles on Bismarckian strategic policy and the U-boat campaigns of both world wars. Dr. Jones earned his PhD at Yale University in 2005.

Naval War College Review, Spring 2014, Vol. 67, No. 2

unreality of German armaments propaganda and a progressively more authoritarian cast of the German war economy.

While agreeing entirely with Tooze's identification of a strong relationship between Nazi Germany's broad strategic and economic problems and the technological innovations seen as panaceas for them, this paper argues that the U-boat Type XXI was nonetheless not nearly so unrealistic a solution as his account suggests, nor as reflective of a grossly dysfunctional culture of innovation as other commonly cited cases may be. If one assumes Nazi Germany's essentially flawed strategic decision to interdict the Allies' commerce traffic in the Atlantic, then the German navy, under the technological and operational constraints then prevailing, had no better option than to develop a platform that accomplished what the Type XXI promised. This revision of Tooze's case arises from the assumption that the culture of naval architecture and engineering before 1943, organized around largely traditional methods of design and construction, was wholly inadequate to Germany's strategic problems. In the absence of more promising alternatives, the decision to subordinate the shipbuilding industry ruthlessly to innovative technocratic priorities appears more rational than otherwise. It may also serve as a cautionary example of the extent to which social explanations of technological adaptation must include appreciation of the iron operational constraints on military effectiveness.

Naval warfare is arguably more revealing of the intimate connections between technological trends and broader political, economic, and military circumstances than is warfare of nearly any other kind. As Karl Lautenschläger has argued, "naval warfare in general is sensitive to changes in technology, because it is platforms as well as weapons that are necessary for combat at sea. Whereas armies have historically armed and supported the man, navies have essentially manned and supported the arm."[3] Determination of the reasons for the paths of innovation taken, as well as the pace and character of innovation itself, has bedeviled historians of technology for generations. Every military technological innovation is shaped by a complex of influences, but most notably by some conception, however well or poorly understood, of the operational scheme within which it is intended to fit.

The technologies that defined Germany's Atlantic campaigns had their roots in expectations about future conflict that seemed entirely reasonable in the 1930s but proved woefully misguided when the full implications of Hitler's strategic ambitions became apparent by 1942. In the decade before the war, the nascent Kriegsmarine envisioned a limited naval war primarily against France, and after 1938, England. The prevailing operational scheme, which found its strongest exponent in Admiral Erich Raeder, then commander in chief of the navy, emphasized a balanced fleet comprising heavy and light elements to threaten enemy

naval and commercial interests in a dispersed manner. The primary role of submarines in this concept was twofold: to serve in a fleet-support and screening capacity, for which a limited number of larger, longer-range, and faster submarines would be required; and to conduct a commerce war of limited range and intensity against French, and later English, maritime assets in the eastern Atlantic, for which a large number of smaller, cheaper, and easily produced boats was necessary. Although some elements within the German naval command in the mid-1930s, notably Admiral Dönitz, envisioned a strategy of commerce interdiction that emphasized an autonomous role for U-boats, the then-prevailing doctrine saw the U-boat as but one of a broad mix of assets in a balanced fleet. Most importantly, and to the extent that the anticommerce strategy of Dönitz could be said to have shaped procurement decisions in the late 1930s and early phases of the Second World War, the notion of wolf-pack tactics against convoys made the acquisition of as large a number as possible of comparatively simple, inexpensive, medium-sized submarines a priority in naval planning. However, at no point before 1942/43 could the German navy be said to have enjoyed a substantial priority in German armaments production. As a result, the German navy began the war with scarcely more than two dozen oceangoing submarines, and not before 1942, arguably past the critical point of balance in its commerce war against Britain, did it have a number sufficient to mount consistent group operations.

As those familiar with the course of the Atlantic war until May 1943 understand, initial German success was gradually eclipsed by superior Allied technology, code breaking, organization, and especially shipbuilding capacity—arguably the most decisive single element in determining the outcome of the naval war. On the tactical level, where the platforms themselves were decisive, the increasing number and effectiveness of Allied convoy escorts and countermeasures, especially electronic means of detection, led to unacceptably high losses of the Types VII and IX U-boats that made up the bulk of the German fleet. According to the commander of the U-boat force, Dönitz, losses to mid-1943 amounted at most to 13 percent of the deployed boats. The severe setbacks that the fleet suffered in early 1943 amounted to some 30 to 50 percent of the deployed force, with losses in May 1943 of forty-three boats, or more than a boat a day on average.[4] The limited utility of conventional diesel submarines had become irrefutably obvious. If defensive tactics could deny the submarine surface mobility and compel it to rely on its subsurface capability for survival, then it became nearly useless as an offensive weapon. Defensive platforms detected U-boats with radar, sonar, high-frequency direction finding ("Huff Duff"), and—most effectively—roving aircraft, which became increasingly common by late 1943. Aircraft or surface ships could then prosecute the contact, compelling the boat to dive and holding it down long enough for a convoy to lumber away. With its slow surface and even

slower submerged speed, a conventional Type VII or IX U-boat was hard pressed to develop a second attack angle, and then only if antisubmarine units were not hounding it.

In a draft assessment of the naval strategic situation in September 1942, the Kriegsmarine High Command starkly expressed its first noteworthy reservations about whether the U-boat campaign could have the desired decisive effect on the Allies' capacity to sustain their war effort, a finding based as much on the vulnerability of existing platforms to Allied countermeasures as on anything else.[5] Although the finding was stricken, the final report acknowledged that "not one war in history was won by the use of a single weapon," a caution reflecting the simple fact that Germany could not sink enough tonnage fast enough to overcome the enormous American shipbuilding capacity.[6] Although Hitler had declared on many occasions that he considered U-boat warfare crucial for the overall war effort, not until after the surrender of the Sixth Army at Stalingrad did he seize on it as the sole remaining offensive potential available to the Third Reich and accord it a meaningful priority in war production.

These circumstances lay behind the radical shift in platform design and production priorities after 1943. The essential question facing the strategic leadership after the midyear debacle was whether to abandon the Atlantic—which would amount to an almost inconceivable admission by professional officers of the strategic bankruptcy of their service—or to redouble the effort and shift the terms on which commerce warfare was waged through evolutionary advances in platform survivability and effectiveness.[7] Dönitz, commander in chief of the German navy as of January 1943, opted for the latter, with the full backing of Hitler. The platform that would bring about this transformation was the Type XXI submarine.

Historians have generally thought of the Type XXI—along with other systems like the Me 262, V-1 and V-2 rockets, and the Tiger tank—as an example of *Wunderwaffen,* wonder weapons. Since 1945 many have fixated on the revolutionary military technologies that the Third Reich developed in the last two years of the war.[8] The cultural impetus behind the concept, as implicitly or explicitly acknowledged by historians in the uneven and largely enthusiastic literature on the subject, was an irrational faith in technology to prevail in operationally or strategically complex and desperate situations—a conviction amounting to a disease, to which many in the Third Reich were prone in the latter years of the Second World War.[9] To the extent that it shaped decision making, faith in the *Wunderwaffen* was a special, superficial kind of technological determinism, a confidence in the power of technology to prevail over the country's strategic, operational, and doctrinal shortcomings. To the extent that leaders, officers, engineers, and scientists after 1943 believed innovation to be the answer to Germany's strategic dilemmas,

they displayed a naive ignorance of how technology interacts with cultural and other factors to influence the course of events. In particular, they reflected a willful ignorance of the extent to which even substantial technological superiority has proved indecisive in human conflict throughout history.[10]

The origins of the Type XXI program lay in a test platform built in 1939–40 by a brilliant propulsion engineer, Helmuth Walter, who intended it to serve as a prototype of a genuine submarine weapon.[11] Submarines to that point, their name notwithstanding, had actually been little more than extremely slow, vulnerable, largely helpless torpedo boats capable of brief submergence. The underwater speed and endurance of standard U-boat types were insufficient to stalk and close on typical convoys, though they traveled at speeds of only eight knots or less, and were barely adequate against slower formations; U-boats were forced to spend the bulk of their time on the surface, vulnerable to all manner of countermeasures. Walter's test bed, designated *V80,* achieved an impressive twenty-eight knots submerged and seemed to address the need for a genuine high-speed underwater platform. The boat suffered from a range of thorny technical problems, however, most notably the type and quantity of fuel required by the closed-cycle Walter engine—highly volatile Perhydrol, or hydrogen peroxide. To power the boat the Perhydrol was reduced by chemical processes, generating extremely high-pressure gases that spun a propeller-geared turbine at nearly twenty thousand revolutions per minute. A submarine operating such a closed-cycle system could remain submerged as long as its fuel supply permitted. However, the Walter turbine required colossal amounts of fuel to meet even modest performance parameters, far outstripping the bunkerage capacity of existing U-boat designs. Walter, ever inventive, therefore conceived of a U-boat with a pressure hull of a figure-eight form: the top half would house the machinery, weapons, and the crew, while the bottom would contain the large amount of fuel necessary to power the turbine. The design draft was designated the Type XVIII.

In a November 1942 meeting on U-boat design projects, the director of naval construction, Heinrich Ölfken, along with a pair of engineers, Friedrich Schürer and Klaus Bröking, happened on the idea of utilizing the Walter architecture to house a conventional electric propulsion system able to drive the boat at underwater speeds higher than those attained by existing designs.[12] The lower loop of the figure eight, where Perhydrol would have been stored, afforded space for an enormous increase in battery capacity, effectively triple that of a conventional Type IX U-boat.[13] The massive battery plant would run a powerful electric-drive system, necessitating diesel power to charge the batteries much less often than current boats required. Preliminary testing revealed that the performance of the hybrid design, although it fell far short of the prototype Walter boat, far exceeded

that of existing platforms, especially underwater. Admiral Dönitz, still commander of the submarine force, agreed that the concept merited further development and approved additional design work and testing. Theoretical calculations and modeling were complete by January 1943; five months later, the naval staff was provided with a preliminary design draft.

The resulting boat, designated Type XXI, displaced some 1,620 tons and was capable of a submerged sprint of eighteen knots sustained for an hour and a half, a moderate speed of from twelve to fourteen knots for ten hours, and silent running at five knots for sixty hours. Most importantly, it was designed from the outset to incorporate the sensors, countermeasures, and other devices understood by that point to be indispensable in the commerce war: water-pressure-controlled automatic depth-keeping equipment, an improved passive listening array, active sonar, a radar-search receiver, effective active radar, and a snorkel. Dönitz presented the Type XXI design to Hitler at a conference on 8 July 1943 to win his approval for the additional allocations of resources and labor required to realize a production program. Having persuaded Hitler, Dönitz issued an order on 13 August for the full-scale transition to building *"Elektroboots."* Initially, he had intended the Type XXI to replace the outmoded Type IX, but after the catastrophic performance of his boats in May 1943 he determined that it should take the place of the Type VII convoy-attack boat as well.

One cannot exaggerate the importance of the experience of the U-boat service in May 1943 to Dönitz's decision to shift production to an entirely new platform in wartime. As the officers and sailors who manned the U-boat fleet, and who had fought so doggedly, now found, no amount of willpower or doctrinal ingenuity on the basis of existing boat types could overcome the collective effects of the countermeasures the Allies employed so well by 1943. The obsolescence of the German navy's U-boats, which in the early years of the war had been the scourge of the British war effort, had come about so quickly and completely that it was compelled in the circumstances of a failing war to attempt a leap in submarine capability simply to have any hope of affecting the Battle of the Atlantic. In other words, Dönitz argued, his submariners had no choice but to innovate further, on the basis of their disadvantage. Thus understood, the capabilities of conventional U-boats by 1943 represented a "reverse salient" in a technological system (in this case, the interlocking network of technologies and practices of a maritime commerce war as a whole)—that is, "components in the system that have fallen behind or are out of phase with the others."[14] In technological terms, the reverse salient is the weak link that impedes progress. The concept has its origins in descriptions of warfare, where it refers to a section of an advancing military front that has fallen behind the rest, typically becoming the point of weakness in an attack and a zone, a sack, of vulnerability in defense, a lagging element that

prevents the rest of the force from fulfilling its objective. Until the reverse salient is corrected, an army's progress comes to a halt. "When a reverse salient cannot be corrected within the context of an existing system, the problem becomes a radical one, the solution of which may bring a new and competing system."[15]

Even had Germany produced a large number of Type XXI boats in time to field them during the war, or brought forth any at an earlier date, it is doubtful whether they could have corrected the salient and fulfilled the promise of the *Wunderwaffen*. Historians have spilled much ink to argue how revolutionary a technology the Type XXI was and how qualitatively different would have been the terms on which the Battle of the Atlantic was fought had Nazi Germany sent substantial numbers of these high-performance platforms to sea. But a sober consideration of the new boat's capabilities in the context of existing Allied countermeasures makes plain that it would not have shifted the terms as much as Dönitz and the rest of the German leadership hoped. The Type XXI offered no expansion of missions beyond the three basic ones performed by submarines between the outbreak of the First World War and the launch of nuclear-powered USS *Nautilus* in 1954: coastal defense, naval attrition, and commerce warfare.

To be sure, the class certainly stood to enhance the ability of the German submarine force to fulfill its missions more effectively. But it could not have enabled the force to perform the other three significant roles of submarines that arose later in the twentieth century: projection of power ashore, fleet engagement, and assured destruction. Only the nuclear submarine, with its ability to remain submerged as long as the crew could feed itself and remain sane, offered navies the means of fulfilling those tasks, and then only in conjunction with technologies as yet undeveloped during the war. Most importantly, the Type XXI would have done nothing to solve the target-acquisition problem, arguably the single greatest obstacle to success in the U-boat campaign against Allied shipping. Without long-range patrol aircraft to detect convoys and fix their positions, submarine commanders had to rely on what could be glimpsed from atop the conning towers of their tiny craft. Limiting the effective range of observation was not only the submarine's low freeboard but the generally miserable weather of the North Atlantic Ocean. Even patrol lines of U-boats strung out across large areas frequently missed sizable convoys, and the vast majority lumbered by anyway. Only the Luftwaffe, which Hermann Göring guarded with jealousy and bile, could address that deficiency. For these reasons, it is important to understand the Type XXI as an evolutionary technological development of existing undersea warfare technologies, as opposed to a platform of the kind that changes entirely the nature of naval power altogether.[16]

However, in the design and production of the Type XXI lay evidence of innovation greater than that represented by the platform itself. The two principal

shortcomings in the German navy's approach to commerce interdiction in the Atlantic lay, first, in its resource disadvantage in the war economy relative to the other services—an inferiority that was itself a function of the lesser strategic significance of the Atlantic war for the Nazi regime—and second, in the capacity constraints of the German shipbuilding industry. The former shortcoming was addressed to some extent on a political level in mid-1943, when Dönitz secured Hitler's acknowledgment of the importance of the U-boat war and approval for the Type XXI program, along with his promise, however nebulous, to resource it adequately. Dönitz dealt with the latter in a more radical manner. No amount of political capital could extract a higher unit productivity from the already-stretched shipbuilding industry, which was understood by that point to be essential to turning the tide of the Atlantic war. Certainly, one could not reasonably expect Type XXI submarines to be produced at the same rate as earlier types, or anything like it, as the new design was far larger, more complex, expensive, and resource and manpower intensive than its predecessors. A transformation of shipbuilding itself was essential.

In 1942, German U-boat construction, which by this point accounted for the bulk of total shipbuilding capacity, was organized around largely traditional methods of design, engineering, and production. The navy enjoyed a preeminent position in defining standards and regulating construction processes, as well as generally warm relations with the traditional shipyards, all of which guaranteed a high level of quality but did not meet the demands of mass production in a materiel-intensive war effort. That unsuitability was apparent as early as 1941, when the minister for munitions, Fritz Todt, broached the possibility of setting up a "Main Committee" for shipbuilding, based on the promise of industrial self-regulation, to centralize and make more efficient U-boat production. Rudolf Blohm, head of the enormous Blohm und Voss shipyards and an archreactionary capitalist, chaired the new organization, along with Ernst Cords of Krupp Germaniawerft. A key obstacle to higher rates of production at acceptable cost was the navy's custom of ordering boats on a quarterly basis; true mass production of the requisite components, large and small, required larger orders over lengthier periods of time, for which manufacturers could plan and invest on an appropriate scale.[17]

The committee quickly brought about a partial and largely successful reorientation of production of the conventional Type VIIC, the standard U-boat class of the war. Noteworthy in these early reforms were the establishment of long-series production and the subcontracting of major-component manufacture on a provisional basis to inland steel-construction firms—the latter being a critical, often-overlooked precedent of the Type XXI program. Moving production of major subcomponents to inland subcontractors permitted the specialization of

manufacturing processes and reduced the time a U-boat spent in the slips during assembly, important for increasing shipyard throughput and for reducing the yards' vulnerability to Allied strategic bombing.

As already described, with Dönitz's appointment as commander in chief of the German navy in January 1943, just prior to the disastrous convoy battles of May, came a major shift in the orientation of the U-boat fleet. Dönitz was persuaded that nothing short of an industrial miracle would supply enough Type XXI boats to tip the balance of the Atlantic war. In a devil's bargain, therefore, he relinquished the navy's traditional strict control over ship design, engineering, and construction to Albert Speer's armaments ministry, which at that point was expanding its control into every corner of the German war economy. Speer's price for the manpower and raw materials to mass-produce the new class of submarine was the subordination of the dockyards to his ministry. Even with the backing of his powerful organization, however, the best initial estimates for an accelerated development program foresaw the arrival of the first boats only in late 1944, with series production beginning in March 1945.[18] Conventional U-boats had generally required between two and two and a half years to mature from concept to serial production; assuming that a conventional development curve applied as well to the Type XXI—an optimistic assumption, since it was a far larger and more complex boat—the earliest the new class could join the fleet would be 1946. A breathing space for the Allies of more than two years would presumably mean the loss of the Atlantic entirely.

To close the time gap, Speer resolved to break the conservative engineering and construction culture of the established dockyards with a radical program of modular construction and dispersed, serialized component manufacturing. In July 1943 he appointed Otto Merker, an impetuous forty-year-old industrial engineer with extensive experience in automobile and fire-engine manufacturing, to head the Main Committee for Ship Construction. Merker proposed that the new class of U-boats be assembled from eight large, prefabricated sections weighing between seventy and 130 tons apiece, assembled inland by firms that had been to that point, in most cases, rolling and shaping plate steel for pressure hulls. The advanced design and engineering work for the new class and the detailed planning for its production were assigned to a new, centralized organization called the Ingenieurbüro Glückauf, established in Blankenburg/Halberstadt to take over tasks traditionally handled by the yards of individual shipbuilders. Intense Allied bombing and communication difficulties drove the decision both to centralize the Ingenieurbüro and to situate it far from the waterfront. Nearly 50 percent of all German steel firms were to be involved to varying extents in manufacturing and assembling the hull sections and machinery for the new boats; many of the vendors had never before performed high-precision finished work and

would require substantial technical direction to meet the exacting standards of pressure-hull construction. The prefabricated sections were to be transported by barge on inland waterways to three final assembly points: Blohm und Voss in Hamburg, Deschimag in Bremen, and Schicau in Elbing, east of Danzig. Utilizing such methods, Merker claimed, the first Type XXI could be launched by 1 April 1944, with production rising to thirty boats per month by autumn of that year. In fact, with the entire organization leaning ruthlessly toward the lofty production targets, the first copy was launched—amid great fanfare—less than three weeks late, on 19 April 1944, the day before Hitler's birthday.

Nonetheless, the Type XXI U-boats had almost no impact on the outcome of the Second World War, save perhaps to absorb large amounts of manpower and resources that might have been devoted more wisely to the manufacture of aircraft, armored vehicles, artillery, and munitions. Indeed, a senior engineer in the naval shipbuilding program estimated that a single Type XXI submarine consumed a volume of armaments-grade steel equivalent to some thirty tanks, a meaningful offset for the war in light of the much shorter production time for an armored vehicle.[19] By that logic, the program cost the war effort some five thousand tanks, a very consequential figure, and could be said to have hastened the defeat of Germany on the Eastern Front. The new class hardly seemed a formidable prospect at the outset, at any rate. The first copy, assembled hastily as a showpiece for the führer's birthday, leaked so badly upon launching that it required pontoons to remain afloat; following the ceremony, it was towed immediately to dry dock for extensive repair.

The extraordinary complexity of the new boats, the novelty of the tactical concepts they made possible, and the difficulties of training new crews to man them in the mine-infested waters of the Baltic—to say nothing of the vagaries of producing them as the Western Allies relentlessly bombed German production centers—ensured that none of the roughly eighty produced by the end of 1944 was fit for action on delivery. Only two sallied forth on war patrols before the end of hostilities; neither sank an enemy vessel. Early Type XXI hulls suffered from defective diesel-engine superchargers, faulty hydraulic torpedo-loading systems, trouble-prone steering systems, and countless other deficiencies, making them decidedly less of a threat than originally foreseen. The improvised character of the boats' production made addressing these early shortcomings daunting. Basic to modern naval shipbuilding—and among the greatest challenges to effective platform development throughout the history of modern military procurement—is the feedback loop from the fleet back to the design bureau and shipyard about the actual operation of a vessel on patrol and in combat. Almost no early iteration of a ship class emerges from the slipways in a form optimized for its mission, and countless changes, large and small, factor into subsequent iterations.[20]

The very processes that ensure the efficiency of serial production make such loops challenging, if not impossible, to establish. It had been this concern that lay at the core of navy objections to the abdication of authority over shipbuilding to the Speer organization, and it proved a major reason for the checkered early history of the program.

Certainly, the authors of the production concept had enormous obstacles to surmount to realize its potential.[21] As has been noted, few of the inland firms tasked with constructing the hull segments and machinery could initially meet the standards required, at least under the fraught circumstances of a failing war and the ruthless timetables established by Speer's organization. The tolerances involved in submarine construction were and remain extremely exacting. Type XXI hull sections were initially delivered to the shipyards with deviations of up to three centimeters in some cases and had to be torn apart and reconstructed properly—with massive outlays of time and effort—in the ways. Pressure testing revealed potentially lethal defects in the welding of the first boats, a result of poorly fitting components, new inspection standards, and construction methods unfamiliar to the facilities performing them. But the design agency, engineering staff, and shipyards addressed and overcame these problems by autumn 1944.

However, easily the greatest impediment to full realization of the serial production process, as postwar assessments make clear, was the intense and devastating Allied bombing campaign against its key components, especially the shipyards and installations at the waterfront.[22] The increasing vulnerability of the shipbuilding industry to bombing had made it necessary to scatter and move production away from launch sites. Enormous resources and labor were devoted to the construction of an elaborate inland system of barges and cranes to transship the boat segments to the finishing yards. The delivery system never really functioned smoothly, and in any case a sizable administrative apparatus was required to oversee the just-in-time process. The ingenuity of the Merker organization was never adequate to the challenge of Allied strategic bombing, the downstream effects of which were felt at every point.

As Tooze sensibly points out, "the disappointment of the XXI programme was due to the familiar problems of pushing a revolutionary new design straight from the drawing board into mass production, without extensive testing."[23] He faults the Speer ministry in particular, for clinging stubbornly to the system of dispersed sectional construction, arguing that an evolutionary approach to production, instead of a revolutionary new one, would have likely yielded more favorable results. Indeed, the engineer Friedrich Schürer raised such concerns in late 1943, as the joint complications involved in both a radical new platform and novel methods of engineering and production became increasingly clear.

He suggested that the construction of the first boat proceed in a conventional, customized fashion, to develop experience with the platform itself. As Merker pointed out, however, to build the first Type XXI by conventional means would require no less than eight months, while the sectional method, however flawed, would require only four. The entire apparatus of dispersed sectional construction, moreover, was scheduled to commence operation in April 1944.[24] Merker's argument cuts to the entire point of the program—time was of the essence. The desperate operational and strategic circumstances of the German naval campaign in the Atlantic necessitated no less than an all-or-nothing approach to the production of the only platform that offered any prospect of success against an overwhelming Allied technological and materiel advantage.

As Dönitz well understood, a small number of even superlative boats would have produced little change in the Atlantic. The only hope for an effective naval interdiction strategy lay in building the Type XXI in numbers similar to, or greater than, those in which the Type VIIs had been constructed before 1943, thereby overcoming simultaneously the Allied superiorities in technology and in materiel. As we have seen, that goal was not achieved. But even so, it is astounding that a platform as complex and resource intensive—by the standards of any combatant nation—as the Type XXI could move from the drawing board to the water in a year, and by a radically new manufacturing process. The technology of the platform itself ultimately amounted to no more than an incremental or evolutionary improvement in the German ability to close the Atlantic; it most probably would not have realized the extraordinary effectiveness hoped for by its proponents then and admirers today. But the innovative method of constructing the new class represented a revolutionary transformation of economic practice in a war defined primarily by the mobilized productive potentials of the combatants.

NOTES

An earlier version of this article was delivered to the U.S. Naval Academy's Seventeenth Naval History Symposium in September 2011 and will be appearing as chapter 9 of the selected proceedings of that symposium, *New Interpretations in Naval History,* forthcoming from the Naval War College Press.

1. Adam Tooze, *The Wages of Destruction: The Making and Breaking of the Nazi German Economy* (London: Allen Lane, 2006), pp. 611–18.

2. See the definition, building on the enthusiastic notions of Alvin Weinberg about nuclear power and the guarded optimism of John G. Burke in his reflections on engineering education, in Lisa Rosner, ed., *The Technological Fix: How People Use Technology to Create and Solve Problems* (New York: Routledge, 2004), pp. 1–3. A technological fix is a useful innovation intended to solve a problem but that frequently distracts attention from other or better solutions or leads to worse problems. The record of such fixes in areas as wide-ranging as horticulture and computer networking demonstrates that initial assumptions are rarely, if ever, fulfilled, and

that technological fixes generally wind up as partial solutions to complex problems.

3. Karl Lautenschläger, "Technology and the Evolution of Naval Warfare," *International Security* 8, no. 2 (Fall 1983), p. 5; Phillips Payson O'Brien, ed., *Technology and the Evolution of Naval Combat in the Twentieth Century and Beyond* (Portland, Ore.: Frank Cass, 2001).

4. Bundesarchiv-Militärarchiv [hereafter BA-MA] RM6/374, Die deutsche Seekriegführung, 6 August 1945. Dönitz's interim solution to the high losses—reallocation of assets to other theaters and truncated patrol patterns—amounted to a temporary strategic abandonment of the Atlantic war.

5. Frigattenkapitän Heinz Assman, "Entwurf der Lagebeurteilung vom 20. September 1942," cited in Werner Rahn, "Der Seekrieg im Atlantik und Nordmeer," in *Das Deutsche Reich und der Zweite Weltkrieg,* vol. 6, *Der globale Krieg: Die Ausweitung zum Weltkrieg und der Wechsel der Initiative 1941 bis 1943,* ed. Militärgeschichtliches Forschungsamt (Stuttgart, Ger.: Deutsche Verlags-Anstalt, 1990), p. 304.

6. "Lagebetrachtung vom 20. Oktober 1942: Stand und Aussichten der U-bootkriegs, Anlage 1," in *Die deutsche Seekriegsleitung,* vol. 3, *Denkschriften und Lagebetrachtungen,* ed. Michael Salewski (Frankfurt am Main, Ger.: Bernard & Graefe, 1973), p. 303.

7. The author gladly concedes that there are grounds to argue that either a strategic abandonment of the Atlantic to the Western Allies or a less-intensive spoiling strategy of limited commerce interdiction and harassment would have been a more sensible alternative to the decision to redouble the effort. Such concerns belong in another venue; for strategic context, see Werner Rahn, "Strategische Optionen und Erfahrungen der deutschen Marineführung 1914 bis 1944: zu der Chancen und Grenzen einen mitteleuropäischen Kontinentalmacht gegen Seemacht," in *Deutsche Marinen im Wandel: vom Symbol nationaler Einheit zum Instrument internationaler Sicherheit,* ed. Rahn (Munich, Ger.: Oldenbourg, 2005), pp. 220–25.

8. A good introduction is provided by Ulrich Albrecht, "Military Technology and National Socialist Ideology," in *Science, Technology and National Socialism,* ed. Monika Renneberg and Mark Walker (New York: Cambridge Univ. Press, 1994), pp. 88–125.

9. Serious scholarship on the *Wunderwaffen* and the interconnections of technology, politics, military research and development, the armaments industry, and the administrative organization of the Third Reich remains limited to Ralf Schabel, *Die Illusion der Wunderwaffen: die Rolle der Düsenflugzeuge und Flugabwehrraketen in der Rüstungspolitik des Dritten Reiches* (Munich, Ger.: Oldenbourg, 1994), and Michael J. Neufeld, *The Rocket and the Reich: Peenemünde and the Coming of the Ballistic Missile Era* (New York: Free Press, 1995).

10. George Raudzens, "War-Winning Weapons: The Measurement of Technological Determinism in Military History," *Journal of Military History* 54, no. 4 (1990), pp. 403–34. Raudzens's conceptual confusions and imprecisions notwithstanding, his argument underscores how strongly wedded many in the modern age of military conflict have become to technological panaceas.

11. Emil Kruska and Eberhard Rössler, *Walter-U-Boote,* Wehrwissenschaftliche Berichte (Munich, Ger.: J. F. Lehmann, 1969), vol. 8. On Walter, see Karl Günther Strecker, *Vom Walter-U-Boot zum Waffelautomaten: die Geschichte eines großen deutschen Ingenieurs und der erfolgreichen Konversion seiner Rüstungsfirma* (Berlin: Köster, 2001).

12. Ölfken, cover letter to a staff lecture, 30 November 1943, p. 123, BA-MA RM 7-98.

13. Abschrift, Typ XXI Enstehungsgeschichte, 25 June 1943, 0143, BA-MA N379-146.

14. Thomas Parke Hughes, "The Evolution of Large Technological Systems," in *The Social Construction of Technological Systems: New Directions in the Sociology and History of Technology,* ed. Wiebe E. Bijker, Thomas P. Hughes, and Trevor J. Pinch (Cambridge, Mass.: MIT Press, 1987), p. 73. Similarly, "as the system evolves toward a goal, some components fall behind or out of line. As a result of the reverse salient, growth of the entire enterprise is hampered, or thwarted, and thus remedial action is required"; Hughes, *Networks of Power: Electrification in Western Society, 1880–1930* (Baltimore, Md.: Johns Hopkins Univ. Press, 1983).

15. Hughes, "Evolution of Large Technological Systems," p. 75.
16. See Seekriegsleitung IIIa to I op, 24 June 1943, pp. 425–26, BA-MA RM 7-98, for a penetrating and refreshingly frank German "red team" analysis of the limitations of the Type XXI as a prospective undersea platform. Such dissenting assessments by senior naval staff personnel reveal a rejection of the basic operational and tactical suppositions of the new program. Of greater historical significance, however, is the argument that the doctrinal and technological prerequisites for defeating a Type XXI–like threat were by 1945 already securely in place; see Owen R. Cote, Jr., *The Third Battle: Innovation in the U.S. Navy's Silent Cold War Struggle with Soviet Submarines,* Newport Paper 16 (Newport, R.I.: Naval War College Press, 2003), pp. 13–18.
17. Ölfken and Arendt, "Die Baumethoden der deutschen U-Boote," 28 March 1948, p. 18, BA-MA N518-5.
18. Hauptamt Kriegsschiffbau, Aktenvermerk, 13 October 1943, pp. 18–19, BA-MA N379-146. As the note makes clear, a conventional construction path for the first boat was considered and rejected.
19. Heinrich Waas, "Eine Besprechung über den U-Boot-Krieg bei Hitler in der Reichskanzlei im Herbst 1942 und ihre Bedeutung für den Kriegsverlauf," *Geschichte in Wissenschaft und Unterricht* 38 (1987), p. 692.
20. Memorandum to Admiral Fuchs, re Organisation K-Amt, 19 June 1944, BA-MA N379-146.
21. The U.S. Navy began designing and constructing nuclear-powered attack submarines in large modular segments in the late 1980s and encountered problems nearly as debilitating as those to which the Type XXI production method gave rise. The construction yards at Electric Boat and Newport News required years to work the kinks out of what has since become a smooth process. See William J. Brougham, "Accuracy Control Risk Management for Modular Submarine Hull Construction" (master's thesis, MIT, Cambridge, Mass., 1999).
22. On the scale of the problem during the war, see "Über die Besprechung des Ob.d.M. mit dem Führer auf dem Berghof vom 4.–6. Mai 1944," 17 May 1944, pp. 242–45, BA-MA RM 7-189.
23. Tooze, *Wages of Destruction,* p. 616.
24. Hauptamt Kriegsschiffbau, Aktenvermerk, 13 October 1943. See also Dr. Heinrich Ölfken, Vortag, pp. 126–27, BA-MA RM 7-98.