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Book Review

Engineers of Victory: The Problem Solvers Who Turned the Tide in the Second World War by Paul Kennedy (New York: Random House, 2013), 464 pages

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It is now commonplace for countries to recognize the critical contributions of scientists to national defense. Scientists, especially in today's nuclear weapon states, have become an integral part of the states' weapons complexes, continually developing new weapons and, *ipso facto*, assessing the threats that have to be confronted. It was not always so. The key turning point was World War II. Paul Kennedy's excellent book, *Engineers of Victory*, is the history of the scientists, engineers, and other "middlemen" who forged the weapons used on the battlefields and the infrastructures used to support the military operations during this war.

Much of the history of the war from the Allied view is from the top—the grand strategy forged by the Allied leaders—and from the battlefield, the military operations focused on the soldiers, sailors, and airmen as well as on the commanders in the field. At the Casablanca Conference in January 1943, the Allied leaders set out several critical goals—gain command of the seas, gain command of the air, support the Soviet Union in its desperate struggle against the Germans, develop plans to invade Europe, and take the war to Japan in the Pacific. In the following year and a half roughly, all these goals were achieved—and how the Allies did this is the subject of Kennedy's book.

Given the goals set out at Casablanca, the central tasks as summarized by Kennedy in the five main chapters of the book were as follows: how to get convoys safely across the Atlantic, how to win command of the air, how to stop a blitzkrieg, how to seize an enemy-held shore, and how to defeat the tyranny of distance in the Pacific.

Paul Kennedy tells the story of World War II "from the middle." Naturally, there is a vast array of middlemen, and Kennedy could not focus on them

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all—for example, there is hardly any mention of the masters of industrial organization who drove the remarkable U.S. war production, or the Soviet engineers who contrived the equally impressive relocation of Soviet industry to the Urals and other points east as the Germans were over-running western Russia. There is very little mention of the code-breakers at Bletchley Park and elsewhere. Also, while Kennedy does mention the important role of various innovative weapons systems, such as the B-29 Superfortress, the Essex-class aircraft carriers, the F6F Hellcat carrier aircraft, and anti-tank weapons developed by the Soviet Union, he spends little time describing the development of these systems—though he does discuss the evolution of the Soviet T-34 tank.

Scientists and engineers played key roles in addressing all the tasks set out at Casablanca, but in Kennedy's telling, most dramatically in the Battle of the Atlantic against the Nazi U-boats and in the battle to gain control of the air, and these are the most riveting chapters of the book. The most dramatic scientific effort in the war, the Manhattan Project to develop nuclear weapons, falls outside the 18-month period after Casablanca and is scarcely mentioned.

In March 1943, U-boats sank over 600,000 tons of cargo headed to Britain and Russia from the U.S. with a minimum loss of subs—the Allies appeared on the verge of losing the Battle of the Atlantic. But in the next two months, the tides of war reversed dramatically and decisively. In June 1943, the Germans removed their U-boats from the North Atlantic, and they never again posed a serious threat to the convoys. Several factors, well described by Kennedy, explain the turn-around, among them the employment of drop tanks on patrol aircraft allowing them greater range to protect the convoys, greater numbers of escort craft and improved tactical operations of the craft, and the development and deployment of the hedgehog anti-submarine weapon (forward launched explosives detonating on contact) to complement depth charges. Kennedy also highlights the systematic application of operations research led by scientists such as P.M.S. Blackett, and decisive overall direction of the battle by British Admiral Sir Max Horton.

But perhaps the most significant factor was the development and deployment of microwave radar, small enough to be put on aircraft and escorts, and focused enough to detect conning towers of U-boats and to do so without the U-boats realizing that they were being detected. Where did the microwave radar come from? Radar of course had already played a crucial role in the war, especially in the Battle of Britain. Developed by Watson-Watt and colleagues in the late 1930s, and deployed on a string of radar towers along the British coast, the radars were able to detect incoming German bombers in time for the Spitfires and Hurricanes to take off and meet them. These radars typically employed wavelengths of between 1.5 and 10 meters. It was immediately understood how valuable it would be to deploy radars with much shorter wavelengths—on the order of 10 centimeters or less. The trouble, however, was that there seemed no way to generate such wavelengths at the power needed.

The decisive advance was the invention of the cavity magnetron in 1940 by John Randall and Harry Boot, two young physicists working at the physics department chaired by Mark Oliphant at the University of Birmingham. A working cavity magnetron (in the words of James Phinney Baxter, the chronicler of Allied science in WWII, the "most valuable cargo ever brought to these shores.") was brought over to the U.S. in September 1940 And the U.S. immediately and impressively through the newly established Radiation Laboratory at MIT and Bell Labs, developed and produced the over one million microwave radars deployed throughout the war. It is noteworthy that one other critical British advance brought to the U.S. in 1940, the so-called Frisch-Peirels Memorandum that galvanized the U.S. Manhattan Project, also was done at the Physics Department of Birmingham.

Like the Battle of the Atlantic, the battle to achieve command of the air also involved a dramatic reversal of fortune—this time a little later, in late 1943 and early 1944. By the fall of 1943, both U.S. and British bomber losses on missions deep into Germany were unsustainable. The problems were several, but the most compelling was the lack of fighter escorts that could accompany the bombers to Berlin and beyond. It seemed indeed an almost impossible task to develop a fighter escort with a range great enough to fly with the bombers and nimble enough when over Germany to combat the German fighters. But it happened.

The key, as told well by Kennedy, was the development of the P-51 Mustang. The Mustang was designed by a group at North American Aviation under British contract with prototypes sent to Britain in 1941. It was then test flown in April 1942 by the Rolls Royce test pilot, Ronnie Harker, who marveled at the handling of the aircraft and its amazingly low air resistance but pointed out how badly under-powered it was. Harker noted that if the plane were merged with the Rolls Royce Merlin engine, which was itself designed in the early 1930s by the design genius Henry Royce shortly before he died, it would have outstanding characteristics. Kennedy relates how this was eventually accomplished, a story made more dramatic by the obstinate opposition of folks in the United States, who did not like the idea of a hybrid plane, partly U.S. and partly British. However, once the Mustang came into wide service, it changed the tenor of the air war decisively and led to the destruction of the Luftwaffe in the early months of 1944—critical in that it allowed the Allies complete air superiority on D-Day.

The inventions and innovations by the Allies that Kennedy chronicles are impressive. In part, Kennedy attributes the success to a culture of encouragement "that permitted the middlemen . . . the freedom to experiment, to offer ideas and opinions, and to cross traditional institutional boundaries." But, of course, several German technical developments were impressive as well, among them, the V-2 rocket, the Me-262 jet aircraft, and the advanced U-boat developed in the last year of war. What the Germans did less successfully was to develop the scientist-soldier collaboration that marked British and U.S. war efforts (a collaboration, incidentally which contrasted sharply from what had transpired in WWI, where the scientists and military seldom worked cooperatively or effectively). Regular communication between scientists and operational leaders was poor, and that is one crucial reason the Allied scientific work ultimately far out-paced that of Germany (and Japan).

After the war, scientists and the other engineers of victory became permanently mobilized into the now familiar weapons complexes. The dangers of this were most famously addressed by U.S. President Dwight Eisenhower in his farewell address of 17 January 1961:

> A vital element in keeping the peace is our military establishment. Our arms must be might, ready for instant action, so that no potential aggressor may be tempted to risk his own destruction. . . . American makers of plowshares could, with time and as required, make swords as well. But now we can no longer risk emergency improvisation of national defense; we have been compelled to create a permanent armaments industry of vast proportions. . .. This conjunction of an immense military establishment and a large arms industry is new in the American experience.. . . Yet we must not fail to comprehend its grave implications.. . . In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist.

Naturally, the scientists working in the arms industries will, it may be expected, continually push for new weapons development. During the war, the laboratories established in the U.S., such as the Radiation Laboratory at MIT and the Radio Research Laboratory at Harvard, were not controlled by the military. While to a large degree, that is still the case in the main nuclear weapon laboratories, Los Alamos, Livermore, and Sandia, scientists here also will be expected to push for new weapons development. This makes it essential that defense issues be examined by independent scientists and in forums such as provided by this journal.