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MILITARY INNOVATION IN PEACETIME

by

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Introduction

> And it is worth noting that nothing is harder to take in hand, more perilous to conduct, or more uncertain in its success, than to take the lead in the introduction of a new order of things.[1]

> Military organizations are societies built around and upon the prevailing weapons systems. Intuitively and quite correctly the military man feels that a change in weapon portends a change in the arrangements of his society.[2]

> The early Greek imagination envisaged the past and the present as in front of us—we can see them. The future, invisible, is behind us....Paradoxical though it may sound to the modern ear, this image of our journey through time may be truer to reality than the medieval and modern feeling that we face the future as we make our way forward into it.[3]

Looking back over the military history of the twentieth century, what were the fundamental technological, conceptual, operational, and organizational factors that, during times of peace, gave rise to fundamental changes in how military organizations would fight future wars?[4] How long did it take individuals and organizations to move from a vague vision of a new or more effective way of fighting to mature capabilities they could exploit to underwrite success in actual combat? Did individuals or groups matter more in making progress toward such innovations—or is it even sensible to try to separate individual contributions from the organizational contexts in which they inevitably occurred? What barriers to progress were encountered, and how were they overcome? To what extent did successful peacetime innovation depend on having a specific enemy who posed a concrete threat? How important was competition, both between and within the military organizations of a given side, as well as with other nations? Finally, how necessary to successful innovation was conscious awareness of the long-term potential of the new way of waging war? These are the core questions that we will endeavor to address in this essay.

We have selected three instances of peacetime innovation from the period 1918-1939 to furnish the primary historical "data" for exploring these questions. The cases we have chosen are all relatively well known to historians: (1) the development of what came to be known as the *Blitzkrieg*;[5] (2) the rise of land-based or "continental" air power, by which we mean to encompass

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[1] Nicollo Machiavelli, *The Prince*, trans. W. K. Marriott, Vol. 23, The Great Books of the Western World (Chicago, 1952), p. 17.

[2] Elting Morison, *Men, Machines, and Modern Times* (Cambridge, MA, 1966), p. 36.

[3] Bernard Knox, *Backing into the Future: The Classical Tradition and Its Renewal* (New York, 1994), pp. 11-12.

[4] These questions are Andrew Marshall's. See A. W. Marshall, "Historical Innovation: Carrier Aviation Case Study," Memorandum for Distribution, Director of Net Assessment, Office of the Secretary of Defense, 27 June 1994, p. 2.

[5] The term Blitzkrieg seems to have been first coined by an American journalist; in recent decades, its meaning has become increasingly ambiguous even among scholars specializing in military affairs (George Raudzens, "Blitzkrieg Ambiguities: Doubtful Usage of a Famous Word," *War & Society*, September 1989, pp. 77-78). Kenneth Macksey has claimed that Adolf Hitler began exploiting the term for its propaganda value in 1936, but Hitler himself had little to do with the complex changes that gave rise to the kind of mobile, armored warfare that the German Army developed during the interwar period (*Guderian: Creator of the Blitzkrieg* [New York, 1976], p. 68). In fact, Dennis Showalter has noted that German officers generally did not begin using the word *Blitzkrieg*

the various "tactical" uses of air power in support of ground forces as well as the more independent application of air power traditionally termed "strategic bombardment;" and, (3) the maturation of carrier aviation. Inevitably, we also found it necessary to provide some discussion of each case's antecedents in World War I, as well as of the "report card" on innovation provided by the harsh test of World War II combat experience.

Our underlying purpose, however, is not to reexamine these historical episodes for their own sakes, but to use them as a basis for helping decision makers to think creatively about changes in the nature of war that may occur in coming decades. This deeper purpose obviously presumes the possibility of meaningful parallels between past military innovations and changes in the nature of war that may occur in the future. We will begin, therefore, by sketching this broader context.

The Interwar Period and the Next Military Revolution

The years 1918-1939, which separate World War I from World War II, witnessed profound changes in how technologically advanced military organizations would fight. The Germans restored movement to land warfare through creation of the *Blitzkrieg*; the RAF's Fighter Command capitalized on radio detection and ranging (radar) and development of advanced fighters like the Spitfire to assemble an integrated, air-defense "system of systems"; American and British bomber enthusiasts laid the doctrinal, technical, and organizational foundations for the strategic bombing campaigns of World War II; the Japanese and American navies advanced carrier aviation to the point that, in 1942, carrier-based aircraft supplanted the battleship as the heart of their fleets in the Pacific (during daylight at least); the American and German navies evolved concepts and equipment for submarine warfare on enemy commerce; and, the U.S. Marine Corps devised a viable approach to amphibious assaults on enemy-held territory.

In most of these cases of peacetime military innovation, technological developments played an enabling or facilitating role in precipitating fundamentally new and more effective ways of fighting. In a narrow and specific sense, such innovative developments were revolutionary. Yet the underlying technologies themselves (the internal combustion engine, radio communications, radar, etc.), as well as the new military systems to which they gave birth (airplanes, tanks, amphibious landing craft, aircraft carriers, radar, and so forth), formed only a part of these innovations, if not the smallest part.

Beyond the time required for the fragile airplanes and unreliable tanks of World War I to evolve into more mature weapons by the late 1930s, military services had to develop new organizational structures such as the panzer division or Fighter Command's organizational arrange-

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until after World War II began (lecture, "Military Revolutions in Modern German History," School for Advanced International Studies, Washington, DC, 16 November 1994). The German term for the kind of mobile, mechanized, combined-arms operations that characterized the German campaigns of 1939-40 was *Bewegungskrieg*, meaning mobile warfare (Telford Taylor, *The March of Conquest, The German Victories in Western Europe*, 1940 [New York, 1958], p. 311). In this essay, we will primarily use the term *Blitzkrieg* to refer to the particular combination of technological, weapon-system, conceptual, doctrinal, and organizational developments that lay at the core of German operations during World War II. Given this meaning, the term can also be understood as a concrete example of a peacetime military innovation sufficiently fundamental to change the way in which future wars would be fought (at least by competent, well-equipped militaries).

ments for the command and control of Britain's air defense. They had to integrate advanced weapon systems with appropriate tactics, operational concepts, and doctrines in order to realize the full potential of new ways of fighting. There was nothing inevitable about the outcomes; much of the more successful innovation that occurred was the result of *ad hoc* improvisation and was bedeviled by changing or uncertain political priorities. These processes were extraordinarily difficult to execute and were fraught with profound uncertainties.

To cite the most striking example, the stunning effectiveness of the German campaign against France and the Low Countries in May 1940 was not simply a matter of the Wehrmacht possessing better tanks, or having them in greater numbers. In fact, the Allies possessed a numerical edge of approximately 1.3-to-1 in tanks, while many of their armored fighting vehicles possessed superior protection and armament to German tanks.[6] Moreover, at the outset of the May 1940 campaign, the Allies had force-ratio advantages of around 1.2-to-1 in manpower, a slight edge in divisions (1.03-to-1), and, from Luxembourg to the Swiss border, the French had completed the Maginot Line; only in total aircraft and antiaircraft artillery did the Allies face substantial disadvantages at the theater level.[7] Consequently, we must look beyond both military hardware and theater-level force ratios to explain the magnitude of the German victory.

What mattered most was that the Germans had evolved sound concepts for mobile, combined-arms warfare and had trained their army to execute those concepts. To begin with, the *Reichswehr*'s post-World War I field-service regulations reflected meticulous study of the tactical lessons of 1917-1918. The 1933 *Die Truppenführung* ["Troop Leadership"]—a refinement of the 1921-1923 "Leadership and Battle with Combined Arms" prepared under General Hans von Seeckt[8]—emphasized combined arms, penetration, and exploration derived from the "storm-troop" or infiltration tactics that the Germans had developed at the end of World War I.[9] Further, the German Army retained its tradition of *Auftragstaktik* (mission-oriented orders) throughout the interwar period, an approach that strongly encouraged lower echelon commanders to exploit local

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[6] The French Somua 35 and B. I. bis tanks were considered superior to any of the German panzers (Douglas Porch, "Why Did France Fall?," *The Quarterly Journal of Military History*, Spring 1990, p. 33). Similarly, the British Matilda had stronger armor than the German tanks, and the 37-millimeter gun on the German Mark III was inferior to the British two-pounder (F. W. von Mellenthin, *Panzer Battles: A Study of the Employment of Armor in the Second World War*, trans. H. Betzler [Norman, OK, 1956], p. 12). On the other hand, the operational ranges and turret sizes of the panzers used in May 1940 favored the Germans.

[7] Phillip A. Karber, Grant Whitley, Mark Herman, and Douglas Komer, "Assessing the Correlation of Forces: France 1940," BDM Corporation (McLean, VA, June 1979), pp. 2-3; also, Trevor N. Dupuy, *Understanding War: History and Theory of Combat* (New York, 1987), pp. 93-94. While the Germans had a substantial edge in total combat aircraft in May 1940, the opposing sides were nearly equal in single-/twin-engine fighters (ignoring British fighter strength retained in England). The Germans possessed 1,736 fighters; their opponents had some 1,590 (Klaus A. Maier, et al., *Das Deutsche Reich und der Zweite Weltkrieg*, Vol. II, *Die Errichtung der Hegemonie auf dem Europäischen Kontinent* [Stuttgart, 1979], p. 282). So the German preponderance in total aircraft (roughly 3,400 to some 1,700 Allied aircraft) was provided by some 1,680 bombers and dive bombers (*The Rise and Fall of the German Air Force: 1933-1945*, ed. Cyril March [Poole, 1983], p. 66). It should also be remembered that most of the French fighters available in May 1940 were no match for the Messerschmitt Bf 109E.

[8] James S. Corum, *The Roots of Blitzkrieg: Hans von Seeckt and German Military Reform* (Lawrence, KS, 1992), p. 200.

[9] Robert A. Doughty, *The Breaking Point: Sedan and the Fall of France*, 1940 (Hamden, CT, 1990), p. 30.

opportunities to the maximum extent.[10] In addition, officer training had long emphasized initiative, risk taking, and leading from the front at all levels of command in the German Army—in other words the basic leadership principles on which modern, mobile war depends.[11] Finally, exercises during the 1920s not only had included multi-divisional maneuvers, but taught German commanders to ignore the continuous front and so encouraged them to pay less attention to their flanks.[12]

Beyond doctrine, concepts, and training there were also organizational areas where the Germans moved significantly beyond their future opponents. As early as the mid-1920s the Germans were already recognizing that radio communications were a necessary adjunct to the demands for speed and opportunistic responses to unpredictable situations inherent in their doctrine. Thus, in contrast to their opponents, the Germans took full organizational advantage of communications technology by not only installing up-to-date radios and a radio operator in every tank but adding signal organizations that allowed battalion, regimental, and even division commanders to command from the front.[13] The panzer division itself, which represented a mechanized, combined-arms unit in which tanks were only a part of a larger whole, was a creation that rested on an intertwining of a realistic reading of the past with considerable intuition about the future.[14] Last but not least, the Germans worked at developing air support for ground forces, including armor, in the breakthrough battle (although by the outbreak of the war they had yet to work out effective means for close air support for advancing tank units).[15]

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[10] Doughty, *The Breaking Point*, pp. 326-327.

[11] Casualty data for key German formations during the May 1940 campaign such as Heinz Guderian's XIX Panzer Corps indicate that German officers took a disproportionately larger share of casualties than did their men (Doughty, *The Breaking Point*, p. 330). More importantly, the Germans also demonstrated, in contrast to the French, "an ability to continue fighting despite the loss of key leaders. Instead of permitting units to collapse because of unfamiliarity with the mission or with what was happening, officers stepped forward and successfully assumed the responsibility of leadership." (ibid., p. 331).

[12] Corum, *The Roots of Blitzkrieg*, pp. 185-186, 201-202, and 205.

[13] Hermann Balck, trans. Pierre Sprey, "Translation of Taped Conversation with General Hermann Balck, 12 January 1979," Battelle Institute, Columbus, OH, pp. 20-21. Walter Nehring, who was one of Guderian's staff officers for many years, emphasized after the war that "from the outset it was realized that, without a comprehensive communication network, the concept of high mobility and deep penetration by panzer divisions was unthinkable" (Macksey, *Guderian*, p. 51). Corum traces the Reichwehr's conviction that every tank needed a radio back to the views of the German armor expert Ernst Volckheim in 1924 (*The Roots of Blitzkrieg*, p. 108). Yet, as obvious as the requirement for a radio in every tank became to the Germans by the late-1920s, in May of 1940 only a few French tanks would be so equipped (ibid.). But it is also clear that the German view of the importance of radio communications between and among tanks was heavily influenced by their observation of the British experimental exercises into armored forces in the late 1920s and early 1930s.

[14] The first panzer battalion was created in 1934; the following year the first three panzer divisions were formed, although without tanks since equipment was still in short supply (Macksey, *Guderian*, pp. 63-64). The creation of the first panzer divisions in 1935 occurred at the direction of General Ludwig Beck, then head of the German general staff; Beck was also head of the committee that produced the 1933 Die Truppenführung under which the German army fought to the end of World War II (Corum, *Roots of the Blitzkrieg*, p. 140).

[15] In Poland the Germans did not yet possess the capability to use air power effectively in direct support of ground forces when the situation on the ground was relatively fluid or mobile. In fact, there were a number of incidents during the 1939 campaign in which German aircraft bombed German armored spearheads, including one which saw thirteen German soldiers killed and twenty–five more seriously wounded by the Luftwaffe. In April 1940 the

The result in May 1940 of these technological, tactical, doctrinal, and organizational developments was a bold operational approach that produced one of the most crushing military victories of the twentieth century. The final German plan resulted in the Wehrmacht's armored forces traversing the Ardennes and relying on well-led, well-coordinated infantry and artillery attacks to force the Meuse River.[16] But once armor was across, the Germans were in a position to exploit the breakthrough at a pace far swifter than the Allies could handle. As a result, Army Group A was able to envelop the Belgian Army, a substantial portion of the three French armies, and the British Expeditionary Force. In short, the German advances in land warfare that defeated France and pushed the British off the continent resulted from the artful integration of a number of interrelated and complex elements, many of which had long histories. Embedded military hardware such as the tank constituted only one of the components necessary for successful innovations.

Carrier aviation, strategic bombing, the integrated air-defense system that defeated the Luftwaffe during the Battle of Britain, and amphibious warfare all appear to be instances of integrated, combined-systems "military revolution" exemplified by the *Blitzkrieg* of May 1940. Needless to say, innovations of this sort rarely reach fruition over short periods of time. They require military organizations to weave together many disparate elements within a complex tangle of interactions created by the personalities, strivings, values, past experiences, history, visions, and cultures of the individuals and institutions involved. The process of military innovation in peacetime also appears to be highly nonlinear. What this observation means is that innovation displays the extreme sensitivity to current and initial conditions that gives rise to the loss of long-term predictability: the most minute differences in initial or current conditions can, over time, give rise to completely different outcomes, and can spell the difference between successful innovation and

1st Panzer Division had carried out a test exercise with the Luftwaffe on the use of close air support with advancing ground forces; the conclusion was that there were too many intractable problems to be solved, especially given the approaching start date for the campaign in the west (Williamson Murray, *German Military Effectiveness* [Baltimore, MD, 1992], pp. 113 and 115). For the evidence of the first examination of close air support and tanks in mobile war, see: 1st Panzer Division, Ia Nr. 232/40, 24 April 1940, "Zusammenarbeit Panzer-Stuka," National Archive and Record Service (NARS), T-314/615/00396.

[16] The best discussion of the convoluted planning for the 1940 German campaign in the west remains Chapter 5 of Telford Taylor's *The March of Conquest*. Taylor makes clear that while Erich von Manstein and Hitler had been thinking about pushing armored forces through the Ardennes as early as fall 1939, their early conceptions would have used only three to four of the armored divisions, primarily to aid the advance of Army Group B (ibid., pp. 165-167). It was not until German plans for Case Yellow fell into Belgian hands from the forced landing of a German plane in Allied territory on 10 January 1940 that a major rethinking of the concept for the campaign became possible. Even then, it was General Franz Halder who decided to concentrate the main effort in the Ardennes (ibid., pp. 171-175). In fact, the revised plan that Halder brought to Hitler on 18 February 1940 concentrated the Schwerpunkt in the Ardennes to a far greater degree than Manstein had ever proposed (ibid., p. 172). That, of course, never prevented Manstein from abrogating full credit to himself.

failure.[17] For these reasons, the combined-systems "revolutions" of the interwar period typically took at least a decade to reach operational maturity, if not two.[18]

Not surprisingly, in the aftermath of May 1940, British and French perceptions of the abruptness with which land warfare had changed tended, understandably, to be quite different from those of the Germans. As victims, the natural response of British and French observers was to see themselves as having been defeated by the sudden, unpredictable advent of a profound change in warfare. Focusing on the most visible aspect of the Allied defeat, French, and British (and American) observers seized on the fast-moving German panzers and images of Stuka support spun by Goebbels' propaganda machine as the essence of an abrupt "revolution" in warfare.

Our principal aim is to examine the combined-systems military "revolutions" of 1918-1939 from the standpoint of peacetime innovation. The *hypothesis* behind this focus is that we are presently in the initial stages of a similar period of change. The advances since the late 1960s in microelectronics, information technologies and software, satellite communications, advanced sensors, and low-observable technologies all suggest extraordinary new capabilities. To cite Marshal Nikolai V. Ogarkov's 1984 characterization of the advances in nonnuclear weaponry—including development of "automated reconnaissance-and-strike complexes,"[19] long-range and high-accuracy munitions, and electronic-control systems—"make it possible to sharply increase (by at least an order of magnitude) the destructive potential of conventional weapons, bringing them closer, so to speak, to weapons of mass destruction in terms of effectiveness."[20]

The prospective parallels between our current situation and the combined-systems revolutions of the 1918-1939 period, then, should be obvious. As Andrew W. Marshall, the Director of Net Assessment in the Pentagon for over two decades, began suggesting in the early 1990s,[21] in

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17 Ian Stewart, *Does God Play Dice? The Mathematics of Chaos* (Oxford, England, 1989), pp. 66-72, 127-134, and 139-142; also, J. A. Dewar, J. J. Gillogly, and M. L. Juncosa, "Non-Monotonicity, Chaos, and Combat Models," RAND/R-3995-RC, Santa Monica, CA, 1991, pp. 3-6. Having made this basic observation about innovation, however, we would caution the reader not to leap to the conclusion that successful innovation, like strategic change in a corporation, is simply a matter of random rolls of the dice. As we will argue in the final section of this essay, visionary leaders can exercise far more control over the ultimate outcome of the innovation process than the embedded nonlinearities might initially suggest.

18 The integration of radar into a viable air-defense system offers no exception to the proposition that combined-systems innovations from the interwar period typically took a decade or longer to mature. As early as 1904 a young German named Christian Hülsmeyer had patented a "telemobiloscope" which he claimed could transmit radio waves and receive their reflections off a passing object. Alan Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," in Allan R. Millett and Williamson Murray, "Innovation in the Interwar Period," Report for the Office of Net Assessment, Columbus, OH, 1994, p. 433.

19 The Soviet paradigm for "reconnaissance-strike complexes" was the U.S. Assault Breaker, which began as a program in the 1970s (Paul N. Walker, "Precision-guided Weapons," *Scientific American*, August 1981, pp. 42-43; V. G. Reznichenko, *Taktika* [Moscow, Russia, 1978], p. 9 of Foreign Broadcast Information Service translation, JPRS [Joint Publications Research Service] Report: Soviet Union, Military Affairs, TACTICS, JPRS-UMA-88-008-L-1, 29 June 1988; and, S. Davydov and V. Chervonobab, "Conventional, But No Less Dangerous," Energiya: ekonomika, techniika, ekologiya, No. 7, 1987, pp. 43-48).

20 Interview with Marshal of the Soviet Union N. V. Ogarkov, "The Defense of Socialism: Experience of History and the Present Day," *Krasnaya zvezda*, lst ed. in Russian, 9 May 1984, pp. 2-3.

21 Since the fall of the Berlin Wall in 1989, Andrew Marshall has been perhaps the foremost advocate inside the Pentagon of the possibility that we might be entering a new period of fundamental change in how future wars will

the analogy between our current situation and the interwar period, we appear today to be somewhere near the beginning, perhaps in the equivalent time frame of 1922 or 1923.[22] In this context, the impressive use of satellites, stealth (low-observable technologies plus appropriate tactics), and precision-guided munitions during the 1991 Persian Gulf War are probably analogous to the November 1917 battle of Cambrai in the development of the *Blitzkrieg*.[23]

Cambrai represented the first large-scale attempt by the British to use a surprise tank attack to break through German entrenchments without a massive, extended preliminary artillery bombardment; it offered a tantalizing glimpse of how the tank might eventually change land warfare. But even for postwar tank enthusiasts like J. F. C. Fuller and B. H. Liddell Hart, Cambrai offered only a partial vision of future armored war and yielded little in the way of detailed forecast as to how things would actually work out in the Low Countries and France in May 1940.[24]

The difficulties of foreseeing the future during periods of major military change highlight the motivations and prospective benefits of revisiting the innovations of 1919-1939. The process of military innovation on this scale does not appear, on the historical evidence, to be linear or precisely predictable.[25] The leaders of the post-1918 German Army did not deliberately set out to create a new way of fighting, but rather aimed to build upon the operational, and particularly the tactical lessons of 1914-1918 in a coherent and effective fashion. By casting their net widely over the experiences of the last war and examining that experience realistically (at least at the tactical

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be fought. See, for example, Thomas E. Ricks, "Warning Shot: How Wars Are Fought Will Change Radically, Pentagon Planner Says," *The Wall Street Journal*, 15 July 1994, p. A1.

22 A. W. Marshall, "Some Thoughts on Military Revolutions," Office of Net Assessment (OSD/NA) memorandum, 27 July 1993, p. 2. Andrew F. Krepinevich, who did much of the initial work in OSD/NA on the revolution in military affairs, recalls that Marshall first associated our situation today with 1922 or 1923 (in the analogy to the interwar years) during the summer of 1991. Krepinevich's recollection is vivid because his own initial intuition was to associate Desert Storm with the Spanish Civil War of the 1930s rather than with the 1917 Battle of Cambrai (telephone conversation, 22 November 1994).

23 Marshall, "Some Thoughts on Military Revolutions," p. 2; see also, Commanders James R. FitzSimonds and Jan M. van Tol, "Revolutions in Military Affairs," *Joint Force Quarterly*, Spring 1994, pp. 24-31. FitzSimonds and van Tol have noted that, perhaps somewhat counterintuitively, the greatest changes in warfare have generally occurred during peacetime rather than wartime ("Revolutions in Military Affairs," p. 26). This insight reflects Steve Rosen's conclusion that peacetime military innovation, being driven by perceptions of structural changes in the national security environment and visions of hypothetical future wars involving new military capabilities, is fundamentally different from wartime innovation (Stephen P. Rosen, *Winning the Next War: Innovation and the Modern Military* [Ithaca, NY, 1991], pp. 52 and 76). During time of war, adaptation rather than innovation may better characterize what occurs.

24 For Fuller's first-hand account of the Battle of Cambrai, see Major General J. F. C. Fuller, *Memoirs of an Unconventional Soldier* (London, 1936), pp. 192-219. Although the Cambrai operation was originally proposed as a rapier-like raid, the British Third Army converted it into an attempt at a decisive battle, prevented the Tank Corps from holding any tanks in reserve, permitted the Cavalry Corps commander to command from the rear, and thereby precluded the cavalry forces from exploiting the breakthrough created by tanks working in coordination with infantry (ibid., pp. 188-191). The German counterattack that followed the Allies initial success at Cambrai was the first large-scale use of infiltration, exploitation tactics on the Western Front and quickly pushed the British back—in some cases beyond their original front (Corum, *The Roots of Blitzkrieg*, p. 9).

25 To deny that future events are precisely predictable is not, however, to deny causality. On this crucial point, see Heinz-Otto Peitgen, Hartmut Jürgens, and Dietmar Saupe, *Chaos and Fractals: New Frontiers of Science* (New York, 1992), pp. 9-14. Nor should the denial of precise or detailed predictability be taken to deny that some individuals can develop surprisingly sound intuitions about the future.

and operational levels), they moved, in fits and starts, toward a new conception of fighting. They managed to do so, moreover, despite the constraints of the Treaty of Versailles and, until after Adolf Hitler's rise to power, meager defense budgets.

Indeed, it seems likely that, *even on the eve of the 1940 campaign*, few of even those German officers involved in development of armored warfare during the interwar period had a firm belief that their efforts would transform land warfare. Vagueness and uncertainty in gaming the 1940 campaign as to what the army high command should do if the three panzer corps got across the Meuse before the eighth or ninth day of the offensive confirms the inability of most German generals to predict in detail how a *blitzkrieg* campaign could play out against French and British opposition.[26] In his memoirs, even Guderian characterized his panzer corps' success in getting its rifle regiments across the Meuse on the fourth day as "almost a miracle."[27] Robert Doughty's meticulous reconstruction of the crossings supports Guderian's characterization. In fact, at numerous junctures, the operations of the three panzer corps that crossed the Meuse during the battles of 13-14 May 1940 succeeded by razor-thin margins and, in some cases, by sheer luck, while, in other cases, the initial attempts to cross failed completely.[28] Nevertheless, the cumulative result of these small differences was that, by the morning of 16 May, "the French Army teetered on the edge of collapse, and in subsequent days the Germans won one of the most decisive operational victories in military history."[29]

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[26] Guderian was "a brilliant man but an extremist and an egoist, with a personality that bordered on the fanatic" (Corum, *The Roots of Blitzkrieg*, p. 140). As a result, Guderian's memoirs are often unreliable on matters having to do with his personal role in the creation of the *Blitzkrieg* and the conduct of operations during World War II. According to his memoirs, he first proposed that XIXth Panzer Corps could force a crossing of the Meuse on the fifth day of the offensive at a war game that took place at Koblenz on 7 February 1940 (Heinz Guderian, *Panzer Leader*, trans. Constantine Fitzgibbon [New York, 1957], p. 69; for confirmation see, Franz Halder, *The Halder War Diary: 1939-1942*, ed, Charles Burdick and Hans-Adolf Jacobsen [Novato, CA, 1988], p. 95). It appears to have been at this exercise that Hitler questioned Guderian as to whether he would recommend heading for Paris or the Channel coast if XIXth Panzer Corps forced the Meuse on the fifth day. Guderian replied that while the decision was up to the High Command, in his opinion the main German attack should drive for the English Channel (ibid., pp. 70-71). Halder, then head of the German general staff, recorded in his war diary on 7 February the opinion that there was "no sense" in Guderian's proposal and that a concerted attack across the Meuse would be "impossible before the ninth or tenth day of the offensive" (*The Halder War Diary*, pp. 95 and 96). Further disagreement over the viability of Guderian's proposal that the panzer corps could force an early crossing of the Meuse without waiting for the infantry divisions to catch up ensued at a 14 February war game held at Mayen, headquarters of List's 12th Army (*Panzer Leader*, pp. 69-70). After yet another game in mid-March 1940, also attended by Hitler, Halder's diary entry reflected the following judgment on the issue of what to do after crossing the Meuse: "Decision reserved on further moves after the crossing of the Meuse" (*The Halder War Diary*, p. 106).

[27] Guderian, *Panzer Leader*, p. 84. For Balck's personal recollections of the crossing of the Meuse by lst Motorized Infantry Regiment, lst Panzer Division, XIXth Panzer Corps, on 13 May 1940, see Balck, "Translation of a Taped Conversation with General Hermann Balck, 13 April 1979," pp. 2-8. Balck, was the commander of lst Panzer's infantry regiment at the time. What is clear from the historical accounts of the crossings by the three panzer corps is that Hoth's crossing only succeeded through Rommel's extraordinary leadership, Reinhardt's panzer corps never made a successful crossing until the panzer corps on its flanks had succeeded, and only three of the six crossings initially attempted by Guderian's panzer corps got across the Meuse.

[28] Doughty, *The Breaking Point*, pp. 83, 135, 139, 164-165, 321, 323-324, and 329-332.

[29] Ibid., p. 331.

From the standpoint of understanding peacetime innovation, there is considerable danger in our retrospective awareness of how specific developments ultimately played out. The very act of historical reconstruction imposes a clarity and coherence on events that was neither present *nor possible* at the time. The riveting example of the May 1940 campaign suggests another troubling insight. If, as hypothesized, we *are* entering a period in which warfare is undergoing fundamental changes, then the dimensions of the Allied defeat in May 1940 underline the potentially catastrophic consequences of failing to keep abreast of such changes.

The interwar period also suggests that an early lead in an area of fundamental change, such as the British enjoyed in tank development in 1918, does not guarantee ultimate success. Arguably, multiple factors contributed to Germany's ultimate collapse in November 1918. Principal among them were approximately one million casualties that the German Army suffered during Ludendorff's offensives of mid-March to mid-July 1918,[30] the arrival in Europe of American troops in substantial numbers, and the considerable (if grudging and sporadic) improvements in Allied defensive and, later, offensive tactics after March 1918.[31]

Another major contributor to victory in World War I, even if the tank's role was perhaps not quite as large as advocates like Fuller believed at the time, was the increasing use of armor by Allied forces.[32] By late 1918, the British, especially, had a substantial lead in armored vehicles. Indeed, it is plausible to suggest that by 1918 the British Army "was in a position to learn how to use tanks against a reactive enemy and had developed all of the intellectual bases for *blitzkrieg* warfare."[33] How, then, did the British fail and the Germans succeed during the 1920s and 1930s in exploiting the tank to restore movement on the battlefield? Therein lies the deeper mystery that

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30 Timothy Travers, *How the War Was Won, Command and Technology in the British Army on the Western Front 1917-1918* (London, 1992), p. 108. The total of nearly one million German casualties from 21 March through mid-July 1918 is based on German Official History figures. The monthly figures are 235,544 casualties for March, 257,176 for April, 114,504 for May, 209,435 for June, and 183,300 or so for the first half of July (ibid.). "The reason for these heavy casualties was partly because German offensive tactics often reverted to the traditional mass infantry assaults after initial successes, thus leading to heavy casualties; and partly because German offensive tactics, however ingenious, never really solved the problem in 1918 of continuously attacking defenses that fought back with large amounts of firepower..." (ibid.).

31 To take our own advice, it is well to remember that, as late as August 1918, few if any on the Allied side imagined that the Great War would be over before winter (Fuller, *Memoirs of an Unconventional Soldier*, p. 318).

32 For Fuller's view of the role played by the tank in the Allied victory in World War I, see Major General John Frederick Charles Fuller, *Tanks in the Great War: 1914-1918* (New York, NY, 1920), pp. 287-288; also, J. F. C. Fuller, *The Conduct of War 1789-1961: A Study of the Impact of the French, Industrial, and Russian Revolutions on War and Its Conduct* (New Brunswick, NJ, 1961), pp. 176-177. More recent research into the tactical revolution that occurred on both sides during 1917-1918 suggests, however, that the importance of the tank in Germany's collapse was exaggerated by advocates like Fuller. In *Tanks in the Great War*, for example, Fuller wrote that the success of British tanks during the battle of Amiens (8-11 August 1918) foreclosed "all hope of [Germany] winning the war by force of arms" (p. 227). While the success at Amiens largely hinged on an effective combined-arms offensive in which British tanks played a crucial role, British offensives after Amiens emphasized an infantry-artillery combination with only a few tanks thrown in for good measure (Travers, *How the War Was Won*, pp. 45 and 175). Even though the British failed to exploit the tank in the final months of World War I, Travers' conclusion is that mechanical warfare had become a "genuine alternative in 1918" (ibid., p. 179). Corum argues that the Germans reached much the same judgment during the early 1920s (*The Roots of Blitzkrieg*, p. 22).

33 Rosen, *Winning the Next War*, p. 127.

this essay will attempt to probe: understanding better why some military organizations innovate more successfully than others.

Given what we have already suggested about the degree to which military innovation in peacetime is unavoidably nonlinear, contingent, and infected with serendipity, it seems best to avoid theoretical generalizations in probing for answers. Instead, we shall concentrate on the more modest but defensible aim of identifying, based on what history reveals about innovation during the interwar period, some of the specific actions, bureaucratic tactics, and strategies that senior-level officials in the current Pentagon, military as well as civilian, might consider implementing in order to facilitate innovation in coming years. The following observation in Steven Rosen's *Winning the Next War* suggests the kind of insights we believe will be more useful than abstract generalizations: "Peacetime innovation has been possible when senior military officers with traditional credentials, reacting not to intelligence about the enemy but to a structural change in the security environment, have acted to create a new promotion pathway for junior officers practicing a new way of war."[34]

The compelling motivation for examining interwar innovation is the hope that the U.S. military can avoid the kinds of failure that enveloped Allied armies in May 1940. To entertain such a hope suggests that even if precise or detailed theories are not possible, the sharpening of broad intuitions about the nature of war in the early twenty-first century is by no means a futile enterprise. A corollary to the proposition that some military organizations master innovation better than others is that some individuals develop better intuitions about future warfare than others, however inchoate or partial such intuitions might be. J. F. C. Fuller, for instance, recognized during the last year of World War I that the tank was more of a psychological weapon than a material one and that its greatest potential lay in the possibility of unhinging or paralyzing the brain of opposing armies, corps, and divisions rather than in destroying them physically.[35] According to Fuller, he first had this intuition during March 1918 when he saw "tens of thousands of men pulled back by their panic-stricken headquarters" as German units employing infiltration tactics broke Fifth Army's lines by "devouring" entire positions.[36] By May 1918 Fuller had elaborated

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[34] Ibid., p. 251.

[35] Fuller, *The Conduct of War 1789-1961*, pp. 241 and 256; also, *Memoirs of an Unconventional Soldier*, pp. 321-322 and 324-325. As Fuller put the basic insight in one of his more succinct formulations: "At Cambrai what was the predominant value of the tank? It was its moral effect. It showed clearly that terror and not destruction was the true aim and end of armed forces. That is to say: To attack the nerves of an army, and through its nerves the will of its commander, is more profitable than batter to pieces the bodies of its men." (J. F. C. Fuller, *Lectures on F.S.R. III (Operations between Mechanized Forces)* [London, 1932], p. 7). Interestingly this passage went on to endorse the even greater potential of air power to execute "brain warfare": "The aeroplane also proved this, and even more dramatically; for not only could it attack the will of an army by avoiding its body, but also the political will and national will behind the army." (ibid.). For other examples of Fuller's appreciation of the moral impact of tanks, see *Tanks in the Great War: 1914-1918*, pp. xvii, 148-149, 152-153, 155-156, 216, 224, 227-229, and 253. Worth adding is that although the German general staff did not push the development of tanks during 1917-1918, from June 1918 to the end of the war the German Army tended to be jittery whenever tanks "were supposed (let alone known) to be present" (Macksey, *Guderian*, pp. 17, 20, and 22). Note, too, that by the spring of 1918 one of the principle concepts of the new German offensive doctrine was the disruption of the enemy's equilibrium.

[36] Fuller, *The Conduct of War 1789-1961*, p. 241; also, Timothy T. Lupfer, *The Dynamics of Doctrine: The Changes in German Tactical Doctrine During the First World War* (Fort Leavenworth, KS, July 1981), pp. 41-42 and 48.

his insight in a memorandum entitled "Strategic Paralysis as the Object of the Decisive Attack."[37] Jumping ahead to May 1940, the functional shattering of otherwise more-or-less intact forces that Fuller postulated in 1918 was precisely what the French pilot Antoine de Saint Exupéry observed from overhead during the reconnaissance missions he flew over the collapsing French Army during that campaign. In every region through which the German armor divisions had passed, he wrote, "a French army, even though it seems to be virtually intact, has ceased to be an army. It has been transformed into clotted segments. The armored divisions play the part of a chemical agent precipitating a colloidal solution. Where once an organism existed they leave a mere sum of organs whose unity has been destroyed."[38]

Notwithstanding Exupéry's testament to Fuller's vision, Doughty has argued persuasively that it is to embrace "myth" to believe that the German High Command in May 1940 had purposely adhered to Fuller's concept of "attack by paralyzation," whatever more ambitious hopes panzer enthusiasts like Guderian harbored.[39] The most likely interpretation of German motives is that the immediate purpose of the thrust through the Ardennes was to achieve the traditional *Kesselschlacht desiderata* of encirclement and annihilation,[40] and the degree of success that the Germans achieved in May 1940 seems to have surprised them as much as their adversaries.[41] Only in retrospect can we see the degree to which Fuller's May 1918 intuition about the prospective operational and strategic effects of armored warfare was closer to the mark than that of the German High Command in early May 1940.[42]

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[37] Fuller, *The Conduct of War 1789-1961*, p. 242. For the full text of Fuller's May 1918 memorandum, later retitled "Plan 1919"—and known to historians by the latter title—see *Memoirs of an Unconventional Soldier*, pp. 322-336.

[38] Antoine de Saint Exupéry, trans. Lewis Galantière, *Flight to Arras* (New York, 1942), p. 56.

[39] Doughty, *The Breaking Point*, p. 323. Doughty grants that a few officers may have accepted Fuller's notion of brain warfare. Still, the sharp struggle between Kleist and Guderian that resulted in Guderian's resignation on 17 May 1940 "clearly demonstrates the concerns of the German High Command about the pace and vulnerability of the XIXth Panzer Corps" (ibid.). As for Guderian's personal views, he was intimately familiar with Fuller. In fact, Guderian initially turned to Fuller when he was seeking "guidance with regard to the development of armoured warfare—notwithstanding the implication in a paragraph on page 20 of [the English edition alone] *of Panzer Leader* that Liddell Hart provided the principal inspiration" (Macksey, *Guderian*, pp. 40-41, 48, and 65). (As Corum has noted, the paragraph in question was added by Liddell Hart to the English edition and did not appear in Guderian's own German edition—*The Roots of Blitzkrieg*, p. 141.) However, Guderian's conception, as reflected in his pre-World War II writings, seems to have focused less on "brain warfare" than on the notion of exploiting the speed of panzer units "to be able to move faster than hitherto: to keep moving despite the enemy's defensive fire and thus to make it harder for him to build up fresh defensive positions" (Macksey, *Guderian*, p. 72). This emphasis on speed, on getting the "green light to the very end of the road," once panzer units had gotten "out on the loose," reflects the spirit of Guderian's memoirs far more than Fuller's discussions of brain warfare (Guderian, *Panzer Leader*, p. 75).

[40] Doughty, *The Breaking Point*, p. 323.

[41] R. V. Jones' view in June 1940 was that the Germans had been so surprised by their own success that, by then, they "had no coherent plan for the immediate future." R. V. Jones, *The Wizard War: British Scientific Intelligence 1939-1945* (New York, 1978), p. 92.

[42] The principal shortcoming in Fuller's thinking about armored warfare during the 1920s and 1930s was that he envisioned fast-moving tanks driving directly at command elements and headquarters without the accompanying combined-arms support that was so central to German success in May 1940.

Case 1: Mobile Warfare (*Bewegungskrieg*) with Armor

The *evolutionary* character of *Blitzkrieg* as an innovation, at least from a German perspective, seems a useful point of departure. Given the prescience of Fuller's intuitions about the tank's potential as a psychological weapon, the contrast between German experience, on one hand, and those of the British and French on the other offers insight into the concrete actions, bureaucratic tactics, and strategies that ultimately made the difference between successful innovation and failure. Through a number of conceptual choices, fortuitous happenings, and institutional circumstances, the Germans extended the doctrinal and tactical advances they had made during 1917-1918 to restore movement to the battlefield in the early years of World War II. At the same time, however, this achievement depended on their ability to preserve and extend the combat experiences from World War I, as well as on doctrinal and institutional continuities.

One crucial element that shaped the Wehrmacht's approach in 1940 was the fact that its predecessor, the *Reichswehr,* undertook a comprehensive exploration and rethinking of tactical developments that had occurred during the last two years of World War I. In 1917 the Germans had developed mobile defense in depth based on strong points and counterattacks; they subsequently developed the offensive infantry-artillery tactics that gave rise to their costly "victories" of spring 1918.[43] In the aftermath of World War I they not only analyzed this experience with remarkable objectivity, but took steps to ensure that a realistic appraisal of the "lessons learned" from 1917-1918 formed the conceptual framework of the postwar army.

Two key developments in late 1919 and early 1920, both involving Seeckt, laid the foundation for this outcome.[44] The first had to do with decisions as to the character and composition of the postwar army, the *Reichswehr*. The Treaty of Versailles had limited the German Army to 100,000 men (only 4,000 officers) and demanded the abolishment of the general staff. Besides forcing massive reductions in manpower, these restrictions raised fundamental questions. How could the *Reichswehr* hope to retain the cadre for a mass army? Given the severe limits on officer strength, which officers from the Imperial army should be retained? And how to save the general staff from disbandment?

Based on his experiences from the Eastern Front in World War I, where well-trained, well-led, and well-equipped German forces had consistently defeated larger enemy forces, Seeckt concluded that, in future wars, numbers would "no longer be the key to victory."[45] As a result, in a report to the army high command of February 1919, Seeckt "broke dramatically with German military tradition by advocating the creation of a small, elite professional army based on voluntary

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[43] Lupfer, *The Dynamics of Doctrine*, pp. 1-54.

[44] Seeckt was hardly a revolutionary innovator with regard to the potential of the tank. In 1928 after his retirement he wrote: "Many prophets already see the whole army equipped with armored vehicles and the complete replacement of the horseman by the motorized soldier. We are not yet that far." Bundesarchiv/Militärarchiv, W 10-1/9, Oberstleutnant Matzky, "Kritische Untersuchung der Lehren von Douhet, Hart, Fuller, und Seeckt," Wehrmachtsakademie, Nr. 90/35 g.K., Berlin, November 1935, p. 44.

[45] Corum, *The Roots of Blitzkrieg*, p. 30.

recruitment rather than conscription."[46] Underlying his recommendation was a sense that only a well-trained, professional army could conduct the kind of fluid, opportunistic, mobile operations that he advocated.

Subsequent events gave Seeckt a unique opportunity to impose his view of future war on the *Reichswehr*. By June 1919 he was acting head of the general staff and head of the commission charged with reorganizing the army in accordance with Versailles' provisions. In November 1919 he officially dissolved the general staff on Allied orders, but became the chief of its successor organization, the *Truppenamt*, a device which preserved the general staff's personnel and training for the new army.[47] Next, in the wake of the failed putsch of March 1920, General Walter Reinhardt, commander in chief and Seeckt's opponent in almost every area, lost his position and Seeckt assumed command of the *Reichswehr*.[48] He retained both positions until late 1926. Seeckt retained the prestige of the imperial general staff, ensured that general staff officers who desired to remain joined the new army, and molded the *Reichswehr* into a small but highly trained professional army. In effect, he turned the command structure over to general staff officers. As a result there was not only a change in administrative control, but in cultural patterns as well.[49]

The other key development of 1919-1920 stemmed from Seeckt's decision in late 1919 and early 1920 to order creation of no less than fifty-seven committees and subcommittees to examine the last war's battlefield lessons. His charge to those involved in the work was a model of clarity and rigor. They were to produce:

> short, concise studies on the newly gained experiences of the war and consider the following points: a) What new situations arose in the war that had not been considered before the war? b) How effective were our pre-war views in dealing with the above situations? c) What new guidelines have been developed from the use of new weaponry in the war? d) Which new problems put forward by the war have not yet found a solution?[50]

For the most part, general staff officers led the committees and, in the end, over 400 officers became involved in the work.[51] Because the majority of these officers had firsthand experience with

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[46] Ibid., p. 29.

[47] Ibid., p. 33.

[48] Ibid., p. 29.

[49] It is worth noting that the future Field Marshal Erwin Rommel was not a general staff officer, but he was a thorough and avid student of military history. Thus, not surprisingly, he turned his memoirs of the First World War (*Infantrie greift an* [Berlin, 1937]) into a thoughtful and insightful examination of leadership on the contemporary battlefield. By comparison, there were no "muddy boots" soldiers in the British Army who published comparable books during the interwar period. For a particularly insightful discussion of how seriously Rommel took the intellectual aspects of the military profession, see David Fraser, *Knight's Cross, A Life of Field Marshal Erwin Rommel* (New York, 1993).

[50] Corum, *The Roots of Blitzkrieg*, p. 37. A similar effort to examine the experience of World War I in the air was initiated by the German Air Service (Luftsreitkräfte) on 13 November 1919 (ibid., p. 144).

[51] The contrast between the development of German Army Regulation 487 and British postwar efforts to revise tactics is especially striking. Whereas the development of Regulation 487 literally involved hundreds of the best German officers, the British War Office in 1920 turned the task of rewriting the infantry tactical manual to Basil H. Liddell Hart, who was then a twenty-four-year-old lieutenant of limited military experience (Corum, *The Roots of Blitzkrieg*, p. 39).

the tactical and doctrinal developments of 1917 and 1918, the reports rested on solid, realistic assessments of what had actually occurred, not on what generals might have believed to have happened. The result was the extraordinary Army Regulation 487 ("Leadership and Battle with Combined Arms"), Part I of which appeared in 1921 and Part II in 1923.[52]

The tactical and conceptual progress that the *Reichswehr* made in the 1920s was not necessarily daring when compared, for example, to British pioneering efforts in armored warfare during the same period.[53] However, the Germans were more realistic and imaginative in tying what actually happened in exercises during the 1920s to the general understanding and tactical conceptions of their entire army. A report on the army's first experiments with motorized troops in the Harz mountains in 1922 underlines this capacity to feed the experience gained in exercises to the army as a whole. Seeckt noted in his introduction:

> I fully approve of the Harz exercise's conception and leadership, but there is still much that is not clear about the specific tactical use of motor vehicles. I therefore order that the following report be made available by all staffs and independent commands as a topic for lectures and study. Troop commanders must see to it that experience in this area is widened by practical exercises.[54]

Because of Versailles' ban against tanks, there were considerable hurdles in the way of progress, even towards such simple things as gaining insight into how motor vehicles actually worked and functioned on the battlefield.[55] However, German doctrinal conceptions, by emphasizing exploitation, speed, leadership from the front, and combined arms, provided a solid framework for thinking not only about how the *Reichswehr* might employ tanks against an enemy, but how a potential opponent might utilize armor against German forces.[56] After all, during World War I the Germans had accumulated greater experience in coping with tanks than had the Allies. From 1929 to 1933 they were also able to accumulate firsthand experience with tanks at the Kazan tank school in Russia.[57] Nor were the Germans reluctant to learn from their former adversar-

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[52] Corum, *The Roots of Blitzkrieg*, p. 39.

[53] As late as fall 1934, the chief of the German general staff was underlining that the Germans had much to learn from the British. In the introduction to a report that was widely circulated throughout the German Army, Beck commented: "The (1934) maneuver [with armored forces] caused a great sensation in England and resulted in many challenges. Once again results showed that the leadership of large mechanized formations, even in an army as motorized as the English, which has the most sensitive experience in the world, nevertheless, ran into considerable difficulties and that reality can be disappointing. On the other hand, one gains the impression that English tank troops were brilliantly led and performed in outstanding fashion." Der Chef des Truppenamts, Dez. 1934: "England; Manöver des Panzerverbandes, 18. bis 21.9.34," NARS T-79/16/000790.

[54] Reichswehrministerium, Chef der Heeresleitung, Betr: "Harzübung, 8.1.22," NARS T-79/65/000622.

[55] Guderian himself claimed after World War II that he had never seen the inside of a tank when he was tasked to teach tank tactics in 1928; the general staff rectified this weakness by packing him off to Sweden for four weeks' service with a Swedish tank unit. Guderian, *Panzer Leader*, p. 12.

[56] German tank experience during World War I was much more limited than the Allies, although the Germans created nine tank companies in 1918 (Corum, *The Roots of Blitzkrieg*, p. 122). In the judgment of Ernst Vockheim, one of the German tank officers during World War I, the Germans' "most successful" tank battle occurred in October 1918 north of Cambrai when ten German tanks managed to plug a hole in the line created by a British tank-led advance (ibid., p. 123).

[57] Corum, *The Roots of Blitzkrieg*, pp. 191-195.

ies. A *Reichswehr* report examining British maneuvers in 1926 noted that armored vehicles now possessed the ability with increased speed to strike out independently and that motorized infantry and artillery might accompany them. The report further added:

> In addition, with existing models, one can now clarify what will happen with tanks behind the enemy's main line of resistance after a successful breakthrough. Tanks can be used: for attacks on the enemy's rear positions, against advancing reserves, as well as against command posts and artillery emplacements. For such tasks, present-day tanks are far more capable than older models. We, therefore, recommend that, in exercises, armored fighting vehicles [or mock representations of tanks since the Germans had no armor at this time] be allowed to break through repeatedly in order to portray this method of fighting and thus to collect added experience.[58]

This report is interesting for a number of reasons. First, it extrapolated from British experience to suggest how the *Reichswehr* might use tanks to develop the *Reichswehr*'s own conceptions of penetration and exploitation. Second, it directed that future German maneuvers take into account possibilities that the *British* maneuvers had already revealed. Finally, it recommended that the *Reichswehr* acquire a wide base of experience in future exercises to evaluate the possibilities that mobile, armored warfare might offer. Significantly, the Germans were seeking not only to improve their own offensive capabilities, but exploring how to defend themselves against such capabilities in the hands of the enemy.

Such interest does not suggest that the Germans embraced the tank's potential with starry-eyed enthusiasm. In truth, through 1939 there was considerable skepticism about the potential of panzer units. As General Gerd von Rundstedt, who led Army Group A's drive (and the panzer forces) through the Ardennes in May 1940, commented to Guderian at the end of an armor exercise in the late 1930s: "All nonsense, my dear Guderian, all nonsense."[59] Nevertheless, Rundstedt's skepticism did not prevent him—and officers like him—from recognizing that tanks might extend the infantry's capacity to exploit tactical situations. On the other hand, German armor advocates remained fully within a combined-arms framework in which infantry and artillery would extend the tank's potential. This larger framework was crucial to the Germans' deadly effectiveness in World War II, while their British counterparts consistently proved incapable of integrating armor within a larger framework—a judgment that includes British armor officers as well as those of the artillery and infantry.[60]

Armored innovation gained further impetus when the Nazi regime came to power and provided a blank check to the German military. But the innovation that ultimately took place in-

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[58] Reichswehrministerium, Berlin, 10.11.26, "Darstellung neuzeitlicher Kampfwagen," NARS T-79/62/000789. The general accuracy and perception of this report on the British maneuvers suggest a number of interesting possibilities. Since the Germans did not have a military attaché in London until the early 1930s and German intelligence was to prove so abysmal throughout World War II, the authors are inclined to believe that the Germans were reading the reports in the British press with great care—reports that went well beyond what British army evaluators of these maneuvers were suggesting. One of the reporters of these maneuvers was B. H. Liddell Hart and it is probable that his reports, which were forward thinking in their interpretation of what had happened on the Salisbury plain, formed much of the basis for the German Army's analysis of British experiments with armor.

[59] M. Plettenburg, *Guderian: Hintergründe des deutschen Schicksals, 1918-1945* (Düsseldorf, 1950), p. 14.

[60] See in particular Williamson Murray, "British Military Effectiveness in World War II," in *Military Effectiveness*, vol. III, *The Second World War*, ed. by Allan R. Millett and Williamson Murray (London, 1988), pp. 107-121.

volved considerable support from the top as well as intelligent experimentation at lower levels.[61] In 1935 the army's high command—Werner von Fritsch, the commander-in-chief, and Ludwig Beck, chief of the general staff—authorized creation of three panzer divisions, all of which retained a strong reliance on combined arms.[62] That same year Beck conducted a general staff tour—a crucial component in the education of future general staff officers at the *Kriegsakademie*—on how the army might best utilize a panzer corps even though no operational panzer divisions yet existed. The following year, 1936, the general staff under Beck's direction examined potential operations for a hypothetical panzer army.[63] The speed with which the Germans established armored formations *and* included them within the broader operational conceptions of the army stands in stark contrast with the British and French experiences.

Yet the problems that armored advocates encountered in Britain and France suggest no easy, simple, or clear-cut negative lessons, whatever their differing levels of success with interwar innovation. For the French, the stark lesson drawn from their catastrophic casualties in the war was that all offensive operations, except those that were tightly controlled, were not worth the price. Even the substantial gains that the Germans made in spring 1918 had come at a cost of approximately a million casualties—a price that French generals, not to mention civilians and politicians, were unwilling even to consider. It was not that the French failed to believe that breakthrough and exploitation operations were possible—rather they believed that breakthroughs and mobile exploitation would prove too costly even for the Germans. They were surely wrong insofar in 1939 and 1940, although there would later be some solace in events like the decimation of the German panzer forces at Kursk in 1943.[64]

The British Army's failure to innovate during this period is harder to understand. Certainly the peculiar choices, and strategic decisions of the British government placed considerable constraints on innovation and innovators. Up to March 1939 the strategy of British governments was that never again would the nation commit its army to the European continent; funding levels throughout the interwar period fully matched that strategy.[65] What is surprising is the extent to

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61 Again, the picture in Guderian's memoirs of the general staff and its chief, Ludwig Beck, providing substantial opposition to the development of the panzer force is a self-serving fabrication.

62 The emphasis on combined arms is stressed in a large number of the documents internal to the panzer forces themselves. See in particular: Kommando der Panzertruppen, Ia op. Nr. 4300, Berlin, 10.11.36, "Bemerkungen des kommandierenden Generals der Panzertruppen in Jahre 1936 und Hinweise für die Ausbildung, 1936-37," NARS T-79/30/005913; Kommando der Panzertruppen, Ia Nr. 3770/37, Berlin, 15.11.37, "Besichtigungsbermerkungen des kommandierenden Generals des kommandos der Panzertruppen in Jahre 1937," NARS 79/30/000937; and Generalkommando VII Armeekorps, Ia Nr. 59/38 g., "Vervendung von Panzereinheiten im Kampf der verbundenen Waffen," NARS T-79/69/00317.

63 Erich von Manstein, *Aus einem Soldatenleben* (Bonn, 1958), p. 241.

64 Doughty's *The Seeds of Disaster*, as well as his *The Breaking Point*, are particularly good at laying out both the difficulties with which the French High Command grappled during the interwar period and the fundamental unwillingness and inability of senior French military leaders to accept the possibility that others might wage future war in a fashion very different from their conceptions.

65 See particularly Michael Howard, *The Continental Commitment* (London, 1975). What made it particularly difficult for the British Army to listen to Liddell Hart's tactical and operational ideas was the fact that he was the intellectual theorist for the Chamberlain government's obdurate policy of refusing to prepare the army for a continental commitment.

which the army experimented with conceptions of armored warfare during portions of the interwar period.

To begin with, there were serious difficulties reconciling such experiments with British politics and political guidance to the military. Moreover, the very culture of the army militated against the prospects for utilizing such experiments to drive doctrinal and institutional change; and although the regimental culture of the army played an important role in getting British soldiers to fight with cohesion and courage, it encouraged an idiosyncratic approach to tactics, in which every regiment did its own thing.[66] There was also a significant group of officers generally disinterested in the serious study of their profession and more interested in the tradition of regimental sports. Percy Hobart, the great tank pioneer wrote his wife in 1939 during the period in which he was working up what would eventually turn into the 7th Armored Division the following account of dealing with his regimental officers:

> I had the cavalry CO's in and laid my cards on the table. They are such nice chaps socially. That's what makes it so difficult. But they're so conservative of their spurs, and swords and regimental tradition, etc., and so certain that the good old Umpteenth will be all right..., so easily satisfied with an excuse if things aren't right, so prone to blame the machine or the machinery. And unless someone upsets their polo, etc., for which they have paid heavily—it's so hard to get anything more into them or anymore work out of them. Three days a week they come in six miles to Gezirah Club for polo. At 5 pm it's getting dark: they are sweaty and tired. Not fit for much and most of them full up of socials in Cairo.[67]

To add to the difficulties, never during the course of World War I did the British Army develop a coherent doctrinal framework that applied uniformly across its forces on the Western Front.[68]

Thus, there was little attempt in Britain to examine the last war for tactical or other lessons that might prepare the army better for the next conflict. Not until 1932 did the current chief of the imperial general staff (CIGS), Lord Milne, establish a committee to examine the lessons of World War I. Milne's brief to the committee suggests a straightforward willingness to come to grips with the weaknesses that had appeared during the war and which remained embedded within the army's structure. The committee was to "study the lessons of the late war, as shown in the various accounts, and to report whether these lessons are being correctly and adequately applied to our manuals and in our training generally."[69] However, the committee's report—a highly critical one at that—was not ready until Milne's successor, General Montgomery Massingbird, had taken office, and Montgomery Massingbird was the worst kind of "looking-good" soldier. He immediately suppressed the findings and had a sanitized version issued that covered up the army's

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66 See Brian Bond, *British Military Policy Between the Two World Wars* (Oxford, England, 1980), especially chapter 2, "The Character and Ethos of the British Army between the Wars."

67 Kenneth Macksey, *Armoured Crusader* (London, England, 1967), p. 159.

68 See Travers, *How the War Was Won*, chapter 2, which documents the unwillingness of the British Army to choose between mechanical and manpower warfare in late 1917 and 1918. The British Army's inability to implement a coherent doctrinal outlook was also evident in the defensive failures of March 1918 (ibid., pp. 70-71 and 89-90).

69 Quoted in Harold R. Winton, *To Change an Army, General Sir John Burnett-Stuart and British Armored Doctrine, 1927-1938* (Lawrence, KS, 1988), p. 127.

tactical deficiencies over the course of the war.[70] To compound the disregard for the study of recent military experience, the volumes in the official history not only were late (the last ones appeared after World War II), but deliberately skewed the historical record to present the army's performance in a more favorable light.[71]

Despite such obstacles, the British carried out an innovative series of experiments with armor in the late 1920s and early 1930s that contributed to the creation of the German panzer force after Hitler came to power.[72] How to explain this ironic result? Here individual leadership played a crucial role. Lord Milne, CIGS from 1926 to 1934, backed the armored experiments with a substantial portion of the army's scarce funding throughout his stewardship.[73]

Unfortunately, he received little support from the innovators during the period and their general condemnation thereafter. In 1926 Milne offered Fuller command of the experimental armored force established that year. The division commander under whom the experimental unit would work, General Sir John Burnett-Stuart, had already indicated an enthusiasm for working with innovators. While the new force was in the process of being established, he wrote to the War Office:

> [W]hat help are you going to give me in organizing, launching, and guiding this experiment? It is no use handing it over to an ordinary divisional commander like myself. You must connect with it as many enthusiastic experts and visionaries as you can; it doesn't matter how wild their views are if only they have the touch of divine power. I will supply the common sense of advanced middle age.[74]

But Fuller had the extraordinary temerity to turn the assignment down because he, as a lieutenant colonel, had not received all of the demands he had made on the CIGS—a choice his biographer has characterized as "probably the worst decision of his life."[75] Fuller's decision to refuse assignment to the experimental unit was also probably influenced by his disapproval of the decision to operate the experimental force in conjunction with the more traditional branches, the artillery and infantry.

Over the interwar years Fuller became more and more of an ideologue advocating creation of an all-tank army—an approach that was politically ill-advised in the British Army and which both World War II and German panzer forces proved erroneous. Hence Fuller, who represented both innovators inside the army and pressure for innovation outside the army, rejected the help of those with whom he might profitably have worked. Unlike German innovators who maintained a healthy respect for artillery and infantry, Fuller refused to see the necessity of combined arms in

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70 Ibid., p. 131.

71 Timothy Travers, *The Killing Ground: The British Army, The Western Front, and The Emergence of Modern Warfare, 1900-1918* (London, 1988), pp. 203-249.

72 General Oswald Lutz, the chief of armored development in Germany until 1938, told Sir John Dill during the latter's visit to Germany in 1935 "with some pride that the German tank corps had been modeled on the British." See Public Records Office (PRO) CAB 16/112, DRC 31, 9.10.35, p. 271.

73 In fact Milne went so far as to suggest in a speech in 1927 that someday in the future the British Army would be an all-armored force. Murray, *The Change in the European Balance of Power*, p. 85.

74 Quoted in Winton, *To Change an Army*, p. 76.

75 A. J. Trythall, *'Boney' Fuller: The Intellectual General* (London, 1977), pp. 118-20.

the world of mechanized, maneuver war.[76] British innovation with tanks, therefore, remained outside the army mainstream, and the innovative process that the experiments with armor might have developed into became a "we versus them" contest between old and new.

The 1926 and subsequent British maneuvers were not complete successes, but did indicate the potential for mechanized warfare. The 1926 exercise that so impressed the Germans involved a stunning twenty-five-mile march that wrecked the defending forces' position. Burnett-Stuart expressed considerable support for a serious consideration of the maneuvers' implications in a talk given at the exercise's conclusion:

> I know that a lot of you will not like the tactics which you saw employed by the Light Group in these manoeuvers. You will think them risky. But I assure you that in armored war these things will be tried, they will probably come off, there will always be people who will chance their arm this way, and you have got to be prepared to meet them when they do.[77]

The evidence suggests, then, that British innovators rejected not only those whom they regarded as troglodytes in the army's upper levels, but also overtures from a number of forward-thinking officers in the traditional branches. The result split the army into two separate camps (with the radical innovators, by far, the smaller) and insured that innovative ideas played little role in preparing British ground forces for war. Even more disturbing the innovators influence failed to grow after the German victories of 1939-1940 should have suggested that the army reconsider its tactical approach to war.[78]

To summarize the heart of this case: in the aftermath of World War I the *Reichswehr*, under Seeckt's far-sighted leadership, developed a relatively objective and clear vision of future land warfare. While this vision of mobile, fluid war was quite general, for the remainder of the interwar period the German Army pursued this vision with remarkable "clarity and single-mindedness."[79] The Germans thoroughly explored and promulgated the lessons of World War I with remarkable singleness of purpose; they maintained intellectual flexibility by allowing open debate of even the most radical alternatives without penalty;[80] and, by the late 1920s, they had so "unlearned" the trench-warfare mentality of World War I that they could operate at the tactical level without the "safety" net of continuous, linear fronts.[81]

On the other hand, neither the British nor French developed anything approaching the clarity of vision, much less the underlying conceptual framework, requisite for mobile, combined-

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[76] Throughout the interwar period, Liddell Hart saw more clearly than Fuller the need to place tank formations in a combined-arms context. Still, by the late 1920s, he had also become caught up in the campaign to slander the British Army's senior leaders for their supposed stupidity and ignorance.

[77] Quoted in Winton, *To Change an Army*, pp. 80-81.

[78] In fact the evidence suggests that Field Marshal Alan Brooke, the CIGS during the war, had a policy of excluding anyone with experience in armored warfare from ever commanding a division—much less an armored division—an extraordinary state of affairs.

[79] Corum, *The Roots of Blitzkrieg*, p. 198.

[80] Ibid., p. xvi. There was no parallel in the interwar German Army to Dwight David Eisenhower's experience in 1920 when he was threatened with a court martial if he continued advocating stronger tank forces than those accepted in official doctrine (ibid., p. 141).

[81] Ibid., pp. 185-186.

arms warfare. Nor were innovators within the British and French armies able, even as late as 1939-1940, to push their institutions beyond the mindset of trench warfare and "by the book" tactics. Granted the British failure is eminently *understandable* in retrospect. As a matter of policy, the British government forbade its army to plan for war on the continent. With the diversions provided by the demands of empire policing, the British Army experienced difficulty in focusing on future enemies, much less in developing a broad vision of future warfare or promulgating advanced concepts across the barriers inherent in its regimental culture.

German military leaders, by contrast, had few doubts that one day they would fight Polish, French, or other continental armies; they trained relentlessly for such combat;[82] and, the general staff found the means to push Seeckt's vision of future war beyond the immediate tactical lessons of 1917-1918. Thus, the roots of German success in this particular peacetime innovation are as explicable as the roots of French and British failure. That said, however, such explanation and understanding cannot, and do not, mitigate one simple but brutal fact: the French and British armies of May 1940 failed the test of combat against a German Army that had learned to conduct mobile, armored warfare with considerable skill and competence.

Case 2: Continental Air Power

Three main factors drove the development of land-based air power in Britain and the United States during the interwar period: a desire to escape World War I's slaughter; the institutional imperatives and yearnings that arose, in the British case, in protecting air force autonomy,[83] or, in the American case, in seeking it; and, the promise and potential of technological advances in aviation. To interwar British and American "strategic-bombardment" enthusiasts, the heavy bomber held the possibility of winning future conflicts independent of armies or navies. It was this vision of air power striking directly at the enemy's industrial heart or population centers that became the focus of British and American thinking. Hindsight suggests that what was *not* accorded sufficient play in this vision was the evidence of the previous war as to the complexities, difficulties, and limitations of military power in general and air power in particular. Among other things, American and British bomber proponents substantially overestimated the accuracy and efficacy of bombing and paid inadequate attention to the need to gain air superiority over enemy territory *before* air forces could exploit the full potential of friendly air power. Even then, the effects of strategic bombing "were gradual, cumulative, and during the course of the campaign rarely measurable with any degree of assurance."[84]

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82 Even after the fall of Poland in September 1939, the French high command made no effort to provide large-unit training for the French Army (Corum, *The Roots of Blitzkrieg*, p. 205). As a result, when war came in May 1940, "a typical German Army captain or major...would have participated in more multi-divisional maneuvers than the average British or French general" (ibid.).

83 In August 1917 the War Priorities Committee, chaired by Field Marshal Sir Jan Smuts, recommended the creation of an independent air arm that would encompass both military and naval aviation in a new service. The Royal Air Force was created the following April.

84 Wesley F. Craven and James L. Cate, *The Army Air Forces in World War II*, vol. II, *Europe: Torch to Pointblank, August 1942 to December 1943* (Chicago, 1949), p. ix.

In comparison, German air power took a substantially different direction between 1918 and 1939. The more traditional, combined-arms context within which German thinking about air power evolved reflected the *Reich*'s geographic position as well as the German military's examination and institutionalization of the tactical and operational lessons of World War I air operations. The resulting German view did not ignore strategic bombing, as commentators have repeatedly asserted,[85] but rather placed that particular use of air power within a broader, combined-arms context. On one hand the Germans neglected neither air superiority nor air support of ground forces; on the other hand by 1940 the Luftwaffe also had the world's largest bomber fleet and had done more to cope with the difficulties of locating and hitting targets in bad weather or at night than any other air force.[86] As a result, the Luftwaffe was able to deal out levels of damage through independent bombing operations, such as the 1940 'Blitz' against London, that neither British nor American air forces matched until 1943. At the same time, German air power was generally more effective than its British or American counterparts in influencing the battlefield during the period 1939-1942. Nevertheless, the Luftwaffe's failure to achieve daylight air superiority over England during the Battle of Britain ended whatever hopes the Germans might have had of invading the British Isles and reinforced the inclinations of many to believe that air power was most effective when employed in combination with other forces.[87]

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[85] In the view of the American Eighth Air Force in 1945, the German high command "saw an air force as a weapon primarily for use in obtaining decisive results in ground battle" and lacked the "imagination" to "envision that the decisive battle itself might take place in the air" (Eighth Air Force and Army Air Forces Evaluation Board [European Theater of Operations], *Eighth Air Force Tactical Development: August 1942-May 1945* [England, July 1945], p. 84). Sir Charles Webster and Noble Frankland offered similar views in the British official history of the strategic air offensive against Germany (*The Strategic Air Offensive against Germany*, vol. I, *Preparations* [London, 1961], p. 125). The fact that the Luftwaffe never managed to field heavy bombers comparable to the American B-17 or the British Lancaster has undoubtedly been one of the reasons for such views. See, for example, Corum's *The Roots of Blitzkrieg*, pp. 167-168. The German Air Ministry canceled development of the four-engine Dornier Do 19 and Junkers Ju 89 in 1936 because the German aircraft industry had not been able to produce sufficiently powerful engines, not because Luftwaffe leaders like Walther Wever or Helmut Wilberg lacked imagination about the potential of strategic bombing or ignored it as a mission (Williamson Murray, *Strategy for Defeat: The Luftwaffe 1933-1945* [Maxwell Air Force Base, Alabama, 1983], pp. 8-9). In 1937, the year after Wever's death in a plane crash, the Germans began development of the He 177, which they hoped would enable them to bypass the need to develop the high-powered engines required for four-engined heavy bombers by mounting two less-powerful engines in a single nacelle. German engineers were never able to make this design work (ibid., p. 9). In retrospect, aircraft-engine technology may well have been one area in which the Versailles treaty succeeded in constraining German military developments.

[86] For example, Luftwaffe scientists began experimenting in 1939 with radio-direction systems for navigation and as an answer to the problem of bombing targets at night or in bad weather. The Knickebein blind-bombing system, first used during the Battle of Britain, was a direct result and preceded by about two years the fielding of a similar system by the Royal Air Force (Murray, *Strategy for Defeat*, pp. 16 and 20). The Germans used a version of this system (fine X-beams or X-Gerãt) on the evening of 14 November 1940 to mark the city of Coventry for a night attack that killed 554 people and seriously injured 865 (Jones, *The Wizard War*, pp. 141 and 147-151). These systems consisted of radio-direction beams broadcast from two separate locations that crossed over the target. The German bombers that attacked Coventry flew to the city down the western beams eminating around Cherbourg and used the eastern crossing beams eminating from Calais to provide timing signals for bomb release (Jones, *The Wizard War*, pp. 135-145; also, Cajus Bekker [pseudonym for Hans Dieter Berenbrok], *The Luftwaffe War Diaries* [Garden City, NY, 1968], pp. 179-180).

[87] R. J. Overy, *The Air War: 1939-1945* (New York, 1980), pp. 36-37. The Bf 109's limited range meant that German twin-engine bombers could only attack southern England if they were to have adequate fighter escort to

Senior British and American airmen, of course, drew different lessons from the Battle of Britain. Unlike the Germans, they recognized how important the full mobilization of national industrial capacity would be to the provision of the aircraft necessary for success in air.[88] But far from giving up on independent bombing in light of the Luftwaffe's failure in 1940, bomber advocates on both sides of the Atlantic promoted such an approach as the only way to strike directly at Hitler until the Allies could mount an invasion of the continent and perhaps win the war without costly land campaigns. Still, it would take time, enormous industrial resources, and the lives of thousands of airmen on both sides for the British and American air forces to realize the heavy bomber's potential, whether operating independently or in support of ground operations. In the American case, it was not until spring 1944 that U.S. strategic air forces in Europe developed the wherewithal, including long-range escort fighters and a capacity to replace heavy losses of men and equipment, to wrest daylight air superiority from the Luftwaffe over Europe, thereby making the Normandy invasion and the sustained daylight bombardment of the German heartland possible.[89] And even in early 1945, after American heavy bombers had, at last, been able to concentrate on industrial targets, the visible results were less decisive than American airmen had hoped.[90]

As for the overall *direct* effects of the Anglo-American Combined Bomber Offensive on its intended target, the German war economy, the proximate cause behind the rapid decline of German war production in early 1945 was the collapse of the German *Reichsbahn* (national railroad). As Air Chief Marshal Sir Arthur Tedder argued in late October 1944, the one "common denominator" to the entire Nazi war effort was the Reich's system of rail, road, and water communications.[91] The *Reichsbahn*'s collapse strangled the essential flow of coal on which both transportation and German industry depended, while, simultaneously, demolishing the division of

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keep losses to acceptable levels. Consequently, in the Battle of Britain the Luftwaffe could only impose on Fighter Command a rate of attrition that its commanders were willing to accept, and the Germans were never in a position to attack the Royal Air Force over the full length and breadth of its domain (Murray, *Strategy for Defeat*, p. 46).

[88] Murray, *Strategy for Defeat*, p. 56; also, Geoffrey Perret, *Winged Victory: The Army Air Forces in World War II* (New York, 1993), p. 42. In the American case it was Robert Lovett, by April 1942 the assistant secretary of war for air, who eventually tied production to strategy (*Winged Victory*, p. 141).

[89] Perret, *Winged Victory*, pp. 295-296. U.S. Eighth Air Force heavy bombers began combat operations against targets in German-occupied France on 17 August 1942; Eighth's heavies first bombed targets in Germany in late January 1943 (Roger A. Freeman, with Alan Crouchman and Vic Maslen, *Mighty Eighth War Diary* [New York, 1981], pp. 9 and 35). During the first two years of Eighth Air Force heavy bomber operations there was "nothing resembling the repeated heavy attacks on vital industrial targets that the Maxwell theorists and authors of AWPD-1 had envisaged" (Perret, *Winged Victory*, p. 325).

[90] As Arnold wrote feelingly to his senior air commander in Europe, General Carl "Tooey" Spaatz, on 14 January 1945: "We have a superiority of at least 5 to 1 now against Germany and yet, in spite of all our hopes, anticipations, dreams, and plans, we have as yet not been able to capitalize to the extent which we should. We may not be able to force capitulation of the Germans by air attacks, but on the other hand, with this tremendous striking power, it would seem to me that we should get much better and much more decisive results than we are getting now." (quoted in Wesley F. Craven and James L. Cate, *The Army Air Forces in World War II, vol. III, Europe: Argument to V-E Day, January 1944 to May 1945* [Chicago, 1951], p. 716).

[91] "Note by Air Chief Marshal A. W. Tedder...for Sir Charles Portal on Air Policy to be Adopted with a View to Rapid Defeat of Germany, 25th October 1944," Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive against Germany, vol. IV, Annexes and Appendices* (London: 1961), Appendix 25, p. 290.

industrial labor and capacity for substitution within the German war economy.[92] Ironically though, despite Tedder's sound instincts, the air attacks that destroyed this "vital" target system from October 1944 to February 1945 resulted more as a second-order consequence of actions aimed at other objectives and target systems than by conscious design.[93]

The divergent approaches to continental air power taken by the Germans, as contrasted with the British and Americans, suggest how extraordinarily difficult it was to foresee with clarity or detail the proper direction towards which to develop air power during the interwar period. To understand the choices that airmen confronted, one must consider the "lessons" that air power's role in World War I might have suggested to dispassionate observers. The four years between 1914 and 1918 saw major technological changes that transformed the airplane into a crucial component of land warfare. Moreover, the war suggested a number of tactical and operational lessons that subsequent experience would confirm.

First was the absolute requirement for aerial superiority before air forces could embark on *any other* air operations without suffering unacceptable losses. Second was the general inaccuracy of the bombing both by day and night. In September 1917 Lieutenant Commander Lord Tiverton of the Royal Naval Air Service reported that "experience has shown that it is quite easy for five squadrons to set out [at night] to bomb a particular target and for only one of those five ever to reach the objectives; while the other four, in the honest belief that they had done so, have bombed four different villages which bore little, if any resemblance to the one they desired to attack."[94] The third, and perhaps most important, lesson had to do with the role of the airplane in ground operations. By 1918 the great offensives returned some degree of movement to the battlefield; but, without the help of aircraft, particularly reconnaissance and close air support, the new tactical concepts underlying breakthroughs and exploitation would not have worked.

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92 Alfred C. Mierzejewski, *The Collapse of the German War Economy, 1944-1945: Allied Air Power and the German National Railway* (Chapel Hill and London, 1988), pp. 183-185; Ernest W. Williams, Elbridge L. Shaw, et al. United States Strategic Bombing Survey (USSBS), Transportation Division, *The Effects of Strategic Bombing on German Transportation* (Washington, DC, January 1947), *European War Report #200*, pp. 3 and 79-90. The USSBS Transportation Division's bottom line was that the consequences of the collapse of the German transportation system "were probably greater than any other single factor in the final collapse of the German economy" (ibid., pp. 3 and 90).

93 In October 1944, Tedder managed to get RAF Bomber Command to change its aiming points from German city centers to marshalling yards; and, starting in early December and continuing through the Battle of the Bulge (16 December 1944-6 January 1945), Allied bombing in support of General Omar Bradley's forces put further pressure on the Reichsbahn, as well as the river and canal system that transported about ten percent of German coal (Perret, *Winged Victory*, p. 368). Yet, as late as mid-January of 1945, most Allied air commanders and intelligence analysts still failed to comprehend the capacity for resistance, substitution, and adaptation inherent in a developed industrial economy (Mierzejewski, *The Collapse of the German War Economy, 1944-1945*, pp. 164-166 and 181-182). For a summary of the attacks on this target system from August 1944 to May 1945, as well as the effects of those attacks as they were perceived in 1945, see J. Kenneth Galbraith, Burton H. Klein, et al., USSBS, Overall Economic Effects Division, *The Effects of Strategic Bombing on the German War Economy* (Washington, DC, 1945), *European War Report #3*, pp. 5-6; also Williams, et al., *The Effects of Strategic Bombing on German Transportation*, pp. 12-16. For operational details on these attacks, as well as coverage of the Allies' internal debate over transportation as a target system in late 1944 and early 1945, see Craven and Cate, *The Army Air Forces in World War II, vol. III*, pp. 649-657 and 717-721.

94 Quoted by Group Captain R. A. Mason in "The British Dimension," *Airpower and Warfare*, ed. Alfred F. Hurley and Robert C. Ehrhard (Washington, DC, 1979), p. 32.

At the outset of war in 1914, the role of air power had approximated the intelligence gathering duties of cavalry. What intelligence aircraft provided was largely idiosyncratic and murky in nature. By 1915, however, aircraft were providing aerial photographs which were crucial in developing artillery capabilities during the remainder of the war. By 1917, air reconnaissance had become so important that the failure of French fighters to protect their reconnaissance aircraft was a major contributor to the catastrophic defeat of the Nivelle offensive—a defeat that almost resulted in the collapse of France.[95] As a result, the Germans had liaison officers in the front-line trenches to coordinate air strikes against enemy positions by use of radio as early as 1917.[96] By 1918, close air support aircraft were providing substantial support for the breakthrough battles that subsequently changed the nature of land war in the twentieth century.[97]

In most other areas, the performances of World War I air forces indicated the potential of air power in other areas. Air defense, interdiction, and strategic bombing all made their appearances in the war and achieved varying degrees of success. But promise and unrealized potential rather than mature achievement characterized the dawning applications of military aviation. At best there were hints as to what air power might achieve, particularly in terms of independent bombing operations, but mature capabilities still lay in the future.

Again it was on strategic bombing that Anglo-American airmen eventually concentrated, almost to the exclusion of all other possibilities, whereas the Germans developed a broader conception of air power and how it might solve their operational problems. How to explain this difference in approach? In the first place, Germany's continental position forced its airmen to think in terms of defending their territory on the ground as well as in the air. They could not just bomb Paris, Prague, or Warsaw if, at the same time, German ground forces lost the battle of the frontiers and the enemy-occupied Silesia or the Rhineland.

Equally important to the German approach was the fact that their airmen carried out an examination of air operations in the last war paralleling and reinforcing the exhaustive analysis of ground operations directed by Seeckt.[98] Consequently, when the Nazi regime began rearming in 1933, German airmen possessed a careful, thorough examination of the last war's actual experiences in the air. Thus, German doctrinal statements on air power—particularly those in the aerial-reconnaissance and air-support sections in "Leadership and Battle with Combined Arms" and in the Luftwaffe's 1935 doctrinal manual *Die Luftkriegsführung [Conduct of the Air War]*—rested on a solid historical foundation that the army shared as well.

This foundation produced a reasonably balanced approach to air power. The principal tasks set out for the Luftwaffe in the 1935 manual were: the attainment and maintenance of air superiority, air support of the army and the navy, attacks on enemy industry and centers of gov-

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[95] Lupfer, *The Dynamics of Doctrine*, p. 66, note 115.

[96] General der Kavallerie von Hoeppner, *Deutschlands Krieg in der Luft* (Leipzig, 1921), pp. 114-118 and 149-150.

[97] The best work on the doctrinal and tactical changes during 1917-1918 remains *Lupfer's The Dynamics of Doctrine*. Nevertheless, Lupfer underestimates the contribution of air power to these developments.

[98] The German Air Service (Luftsreitkräfte) initiated its program for studying the lessons of World War I about two weeks before Seeckt issued his 1 December 1919 directive (Corum, *The Roots of Blitzkrieg*, p. 144). The Air Service's 1919-1920 examination of World War I air operations involved eighty-three officers working on twenty-one subcommittees (ibid.).

ernment, and interdiction between front and homeland.[99] The Germans promoted no one application of air power at the expense of others. Instead, German thinking, grounded firmly on the experiences of 1914-1918, recognized the importance of achieving air superiority, underlined the crucial interdependence between ground and air forces on the modern battlefield, and suggested that emphasis or priorities among air power's various tasks should depend on local circumstances, which could vary widely from one campaign to another.

This sort of balance about the uses of air power in future war was not evident in either the Royal Air Force or, after 1926, the U.S. Army Air Corps. The British began cooking the evidence about air operations even before World War I ended.[100] Their official history of the war in the air was more a masterpiece of propaganda to justify an independent air force rather than a realistic appraisal of the cold, harsh realities of the air war during 1914-1918. In fact, the air staff made its dismissal of history explicit as early as 1924. It argued in a memorandum from 1924 that the forces employed in attacking an enemy nation:

> can either bomb military objectives in populated areas from the beginning of the war, with the objective of obtaining a decision by moral[e] effect which such attacks will produce, and by the serious dislocation of the country, or, alternatively, they can be used in the first instance to attack enemy aerodromes with a view to gaining some measure of air superiority, and when this has been gained, can be changed over to the direct attack on the nation. The latter alternative is the method which the lessons of military history seem to recommend, but the Air Staff are convinced that the former is the correct one.[101]

As the first and only independent air force in the 1920s, the Royal Air Force (RAF) faced the problem of maintaining its independence in an era when resources were scarce and its sister services were eager to carve up the new challenger. The RAF did evolve some relatively effective capabilities to subdue the empire's native populations. But while such capabilities indicated that air power could be useful in other roles than strategic bombing, such possibilities received little attention in London. The major—almost exclusive—emphasis in the air staff lay on strategic bombing. In 1923 Sir Hugh Trenchard, chief of the air staff through most of the 1920s, made clear his preferences in discussions over a possible war with France:

> I would like to make this point again. I feel that although there would be an outcry [among British civilians in case of French air attacks on Britain], the French in a bombing duel would probably squeal before we did. That was really the final thing. The nation that would stand being

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[99] Murray, *Strategy for Defeat*, p. 8; Corum, *The Roots of Blitzkrieg*, pp. 167-168.

[100] The conclusion of RAF studies on the effect of bombing raids on German towns—written before the war was even over—was that the enemy's fighting capacity decreased "as the number of raids increased....Though material damage is as yet slight when compared with the moral[e] effect, it is certain that the destruction of 'morale' will start before the destruction of factories and, consequently, loss of production will precede material damage." Air Ministry, "Results of Air Raids on Germany Carried Out by British Aircraft, January 1st-September 30th," D.A.I., No. 5 (A.IIB, October 1918), Trenchard Papers, RAF Staff College, Bracknell, D-4.

[101] Public Record Office (PRO) AIR 20/40, Air Staff Memorandum No. 11A, March 1924.

> bombed longest would win in the end....[T]he policy of hitting the French nation and making them squeal before we did was a vital one—more vital than anything else.[102]

Given the RAF's emphasis on strategic bombing as air power's *sole* mission, what appears almost inexplicable throughout the interwar years was the RAF's lack of focus on the creation of the operational capabilities required to execute strategic bombing. As war approached and funding increased, there is no evidence that the shortfall between capabilities and mission received serious attention. It was not that there was insufficient evidence that problems existed. In May 1938 the assistant chief of the air staff admitted that "it remains true, however, that in the home defense exercise last year, bombing accuracy was very poor indeed. Investigation into this matter indicates that this was probably due very largely to failure to identify targets rather than fatigue."[103]

But, in the end, little was done. Bomber Command's efforts against German oil resources during the final months of 1940 proved so inaccurate that the Germans "were scarcely aware that their oil resources were supposed to have been the object of a systematic British assault, and, in August 1941, an investigation of Bomber Command's results at night during June and July using photography revealed that of the two-thirds of crews who claimed to have bombed their primary targets, only one-third had come within five miles of the aiming points.[104]

Unlike the Germans, who recognized the problem of finding the target at approximately the same time, the RAF made little effort to develop the technological aids for doing so in adverse weather or at night. Part of the problem was organizational. In 1937 the air staff created the Committee for the Scientific Survey of Air Offense under Henry Tizard. The hope was that the committee would do for Bomber Command what a similar committee was doing for Fighter Command. But the latter body worked directly for the head of Fighter Command, Sir Hugh Dowding, a man of great vision, leadership, and technological sophistication. The new committee on bombing, however, worked for the Air Ministry, which filtered out much of the civilian advice before it reached a command hardly enthralled with the idea of civilian input.[105]

At the same time Bomber Command established its own internal committee to examine bombing accuracy, but the evidence at the committee's disposal was scanty indeed. As the official historians suggested:

> ...the Bombing Committee had to rely on the trials at the Armament Training Camps and theoretical reasoning. But the trials provided no tests for the identification of a target. They were often made at levels which would be impossible in wartime against defended targets. They took

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[102] "Minutes of a Conference Held in the Room of the Chief of the Air Staff, Air Ministry, on 19 July 1923," Webster and Frankland, *The Strategic Air Offensive against Germany, vol. IV, Appendix 1,* pp. 66-67.

[103] PRO AIR 2/2598, Air Ministry File #541137 (1938).

[104] Max Hastings, *Bomber Command* (New York, 1979), pp. 98 and 108. D. M. Butt's statistical conclusions included even more depressing numbers for targets in Germany: against Germany as a whole, only one-fourth of the RAF bomber crews claiming to have bombed their primary targets managed to come within five miles of their aiming points; over the Ruhr the percentage claiming to have bombed within five miles fell to one-tenth ("Report by Mr. Butt to Bomber Command on his Examination of Night Photographs, 18th August 1941," Webster and Frankland, *The Strategic Air Offensive against Germany*, vol. IV, Appendix 13, p. 205). In other words, over Germany as a whole less than seventeen percent of the aircraft Bomber Command dispatched were dropping within five miles of their aiming points, and over the Ruhr this percentage was under seven percent.

[105] Webster and Frankland, *The Strategic Air Offensive against Germany*, vol. I, p. 114.

> place in daylight and good weather. There were hardly any tests as to what could be done at night or in cloudy weather. Under these conditions some squadrons were able in practice to produce a high degree of accuracy. But in the larger-scale exercises which approached more closely to war conditions, their deficiencies were exposed. When remedies were proposed, and the relative forms of bombing were discussed, it was realized that there were not sufficient data on which to found reliable conclusions....Nevertheless, the Manual of Air Tactics contained minute instructions on the various kinds of bombing, special attention being given to high level bombing in daylight. Most of this was necessarily based on theoretical reasoning since there had been so little practical experiment.[106]

In short, when war came in 1939, "Bomber Command was not trained or equipped either to penetrate into enemy territory by day or to find its target areas, let alone its targets, by night."[107]

Part of the explanation for this unfortunate situation has to do with insufficient funding that marked so much of Britain's defense effort between the wars. Nevertheless, the fact is that Bomber Command did little better in addressing the problem of finding targets even *after* the outbreak of war. What one sees is a persistent belief in doctrine irrespective of the clear warnings that contemporary exercises suggested. Moreover, in some cases, the air staff deliberately closed off avenues of technological development because of its narrow preconceptions. In early 1940, for example, Dowding suggested that it was technologically feasible to develop long-range escort fighters to accompany bomber formations. His suggestion received a curt dismissal from the Air Ministry.[108]

This doctrinal concentration almost exclusively on strategic bombing led the RAF to ignore most other aspects of air power. The air staff dismissed close air support and prepared its forces only minimally to conduct interdiction strikes. In November 1939—with the experience of Poland clearly available—the air staff argued as follows about the mission:

> Briefly the air staff view—which is based on a close study of the subject over many years[109]—is as follows: the true function of bomber aircraft in support of the army is to isolate the battlefield from reinforcement and supply [in other words interdiction], to block and delay the movement of reserves, and generally to create disorganization and confusion behind the enemy front....But *neither in attack nor in defence* [our italics] should bombers be used on the battlefield itself....All experience of war proves that such action is not only very costly in terms of casualties but is nor-

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106 Ibid., vol. I, pp. 117-118.

107 Ibid., vol. I, p. 125.

108 The Air Ministry note on Dowding's proposal for long-range escort fighters commented: "It must, generally speaking, be regarded as axiomatic that the long-range escort fighter must be inferior in performance to the short-range fighter.... The question has been considered many times, and the discussion has always tended to go in circles.... The conclusion had been reached that the escort fighter was a myth. A fighter performing escort functions would, in reality, have to be a high performance and heavily armed bomber." PRO AIR 16/1024, Minutes of the 20th Meeting of the Air Fighting Committee, held at Air Ministry, White Hall, 12.3.40.

109 How closely the air staff had studied interdiction is suggested by the criticism that Sir Archibald Wavell made after a combined RAF-army exercise in the summer of 1939. Wavell noted that the RAF had obviously given no thought to supporting ground operations and thus its pilots were incapable of performing this mission. John Connell, *Wavell, Soldier and Scholar* (New York, 1964), p. 204.

> mally uneconomical and ineffective compared with the results of the correct employment of aircraft...[110]

The attacks by British bombers against the Meuse bridges on 15 May 1940 suggest how inadequately the RAF had prepared for the interdiction mission. The raids cost 56 percent of attacking aircraft without achieving any substantial damage to the tenuous enemy links across the river.[111]

The one area where British airmen successfully innovated during the interwar period lay in the development of Fighter Command and its supporting structure. The integration of radar, communications (radio, telephone, and telegraph), aircraft identification friend or foe, a hierarchy of operations centers, an observer corps, and, not least, advanced fighters, produced the first true air-defense system. Not surprisingly, during the 1920s and the early 1930s, the RAF, with its emphasis on bombers, was inclined to minimize the potential of air defense.[112] But in the mid-1930s three crucial events occurred that enabled a viable air-defense system to emerge. First, the Air Ministry picked a particularly astute officer, Dowding, to head its research and development. He proved instrumental in encouraging development of radar by British scientists, linked it to real-world operational requirements, and set the specifications for the next generation of fighters, the Hawker Hurricane and Supermarine Spitfire.[113] Then, having lost out in the competition to become the next chief of staff, Dowding moved over to head the newly established Fighter Command. Finally, in 1937, as he took charge of his new command, the Chamberlain government reviewed defense priorities and decided to support air defense rather than air staff arguments calling for a large bomber fleet.[114]

From his assumption of command, Dowding wove the technological capabilities that British scientists had uncovered into a coherent *system* to defend Britain's air space.[115] He then

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110 PRO CAB 21/903, 18.11.39, "Bomber Support for the Army," Memorandum by the air staff; see also the letter from Admiral Lord Chadfield to Chamberlain, 15.11.39, on the RAF arguments against the provision of special units for the close air support of the army.

111 Major L. F. Ellis, *The War in France and Flanders, 1939-1940* (London, 1953), pp. 55-56.

112 Throughout the 1920s Trenchard had stressed the importance of bombers over fighters in a future air war. For example, the British air staff stated in 1924 that "as a principle...bombing squadrons should be as numerous as possible and the fighters as few as public opinion and the necessity for defending vital objectives will permit." PRO AIR 20/40, Air Staff Memorandum No. 11A, March 1924.

113 Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," Millett and Murray, "Innovation in the Interwar Period," pp. 455-470; also, Francis K. Mason, *Battle Over Britain* (Bourne End, UK, 1969), pp. 61 and 68.

114 David MacIsaac, "Voices from the Central Blue: The Air Power Theorists," *Makers of Modern Strategy: from Machiavelli to the Nuclear Age*, ed. by Peter Paret with Gordon A. Craig and Felix Gilbert (Princeton, NJ, 1986), p. 633. The decision of the Chamberlain government to back fighter defenses instead of bombers had nothing to do with military effectiveness; rather it had to do with the fact that fighters were cheaper.

115 The 1934 committee of outside experts led by Henry Tizard came upon the idea of radar in the course of investigating whether electromagnetic "death rays" could be used to boil the blood of enemy aircrews in their planes (Beyerchen, "From Radio to Radar: Interwar Military Adaptation to Technological Change in Germany, the United Kingdom, and the United States," Millett and Murray, "Innovation in the Interwar Period," pp. 457-458). When Arnold F. Wilkins showed that at five kilometers a huge amount of power would be needed just to generate a fever in an airman's body—even if the airman was not shielded by the plane's metal fuselage—Robert Watson Watt asked precisely the right question: What else might be of use in such phenomenology to the people at the Air Min-

fought the Battle of Britain in summer 1940 and inflicted the first major defeat on the German armed forces that they suffered in World War II—surely one of the great examples of successful innovation in any period. However, Dowding's case can be misleading; it is the only one in the interwar period where one individual, by his wisdom and drive,[116] was singularly responsible for carrying through major changes in a relatively short period of time. The other innovation cases during the 1920s and 1930s, as this essay argues, represented more protracted and complex processes.

American thinking about air power during the interwar years faced at least three interlocking problems. First, unlike their British counterparts, American army airmen did not emerge from World War I as an independent service. Instead, the Army Reorganization Act of 1920 established the air service as a combat arm of the U.S. Army.[117] Hence, the emphasis on strategic bombing at the expense of other missions that increasingly characterized thinking among army aviators after 1926 (the year in which the air service became the army air corps) was driven in no small part by a growing desire for independence.[118] Airmen also had unique technological needs. Still, there is a certain irony in the fact that this desire led them to emphasize strategic bombardment. Whereas British airmen under Trenchard's leadership focused single-mindedly on strategic bombing to *defend* the RAF's autonomy, American airmen, chaffing under the absence of "air mindedness" displayed by their non-flying colleagues, became more and more enthusiastic over the technological potential of the heavy bomber as a means to autonomy.

The second problem that confronted American army airmen had to do with the difficulties involved in holding on to the lessons suggested by America's limited experience with air power during World War I. Because the U.S. entered the war so late, the operational experience of U.S. airmen was not nearly as extensive as that of the British or Germans. Nonetheless, in the early 1920s the view taught at the fliers' "graduate" school showed reasonable balance between pursuit, attack, and bombardment aviation.[119] Reflecting the collective experience of Allied and German airmen, the school taught that "the primary role of the air arm was the defeat of the en-

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istry? This question led Wilkins to recall an earlier experiment in which aircraft had interfered with radio beams that were being bounced off the ionosphere, and from this recollection it was a short step to Wilkins' historic February 1935 paper "Detection and Location of Aircraft by Radio Methods" (ibid., p. 459).

116 "The war," Dowding wrote to the head of operational research at Fighter Command in November 1940, "will be won by science thoughtfully applied to operational requirements" (quoted in Derek Wood and Dereck Dempster, *The Narrow Margin: The Battle of Britain and the Rise of Air Power 1930-40* [New York, 1961], p. 170). These words reflect the unusual insight and intelligence that Dowding brought to the problem of England's air defense.

117 Lieutenant Colonel Thomas A. Fabyanic, "Strategic Air Attack in the United States Air Force: A Case Study," Air War College Report No. 5899, April 1976, p. 15.

118 "The quest for autonomy led to the advocacy of strategic bombardment, which led, in turn, to the depreciation of not only defensive pursuit aircraft but all pursuit aircraft. Bombardment and autonomy were so inextricably bound together that the questioning of bombardments by an Air Corps officer was not only impolitic but unwise." Perry McCoy Smith, *The Air Force Plans for Peace: 1943-1945* (Baltimore and London, 1970), p. 34.

119 The creation of the air service in 1920 brought about the establishment of a graduate school for its officers. The school, founded by Colonel Thomas DeWitt Milling, was originally known as the Field Officers' School and located at Langley, Virginia (Perret, *Winged Victory*, p. 24). In 1922 it was renamed the Air Service Tactical School (ibid.). When the air service became the air corps in 1926, the school underwent its final name change and became the Air Corps Tactical School (Fabyanic, "Strategic Air Attack in the United States Air Force," p. 15). Four years later, in 1931, the school was moved to Maxwell Field, Alabama (ibid.).

emy air force; secondarily, it would destroy military and industrial targets in the enemy's homeland."[120]

Starting in 1926, however, the Tactical School's doctrine implicitly accorded greater prominence to strategic bombing, a trend that persisted to the eve of World War II and beyond. The implicit character of this doctrinal shift, both in substance and in terms of its promulgation, is important to appreciate in trying to understand peacetime innovation. During the interwar years, most key officers of the U.S. Army Air Forces (USAAF) in World War II went through the Tactical School; a number also served as faculty members.[121] Originally, the Tactical School was a nine-month course that contained over 200 hours of classroom instruction on pursuit, bombardment, observation, and attack aviation; starting in 1923, the school added 130 hours of flying instruction, so that the typical day consisted of academics in the morning and flying in the afternoon.[122] Over time, first attack and then pursuit declined in significance in the teachings of the Air Corps Tactical School. That said, the strategic bombing enthusiasts who gained ascendancy at the school by the mid-1930s won the debate over the proper direction for American air power fairly:

> Theirs wasn't the only subject taught at Maxwell. And anyone at the Tactical School was free to make any argument he wanted. Even after [the fighter advocate Claire] Chennault left there were other fighter advocates, such as Earle Partridge and Hoyt Vandenberg, on the faculty. Each side put its case to the students, who were free to decide which, if either, they wanted to believe.[123]

Nonetheless, it was the bomber advocates who came to dominate the thinking of American airmen by the late 1930s. The appearance in 1935 of flying prototypes of the four-engine bomber that became the B-17 Flying Fortress aided their intellectual ascendancy substantially. Coupled with the Norden Mark XV bombsight developed by the navy, the speed, range, payload, and defensive firepower of the B-17 against the fighters then available led Tactical School bombardment instructors to argue that well-flown, well-led bomber formations could, even in daylight, penetrate *without escort* by friendly fighters and accurately bomb targets from high altitude without suffering unacceptable losses.[124] As the bombardment text for 1935 noted, "escorted fighters

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[120] Fabyanic, "Strategic Air Attack in the United States Air Force" p. 20.

[121] Ira C. Eaker, Carl Spaatz, Curtis E. LeMay, Haywood S. Hansell, Jr., and Claire E. Chennault all went through the Tactical School; Hansell the bomber advocate and Chennault the fighter advocate both taught at the school as well.

[122] Perret, *Winged Victory*, pp. 24-25.

[123] Ibid., p. 27. Attack fell by the wayside at the Tactical School with George Kenney's departure to attend the Army War College in 1931; the neglect of pursuit is often dated from Chennault's forced retirement due to chronic bronchitis in 1936 (ibid., pp. 26 and 27).

[124] Perret, *Winged Victory*, p. 28; Fabyanic, "Strategic Air Attack in the United States Air Force," p. 30; and, MacIsaac, "Voices from the Central Blue," p. 634. The development of U.S. civil aviation during the interwar years, which was encouraged by governmental subsidies as well as the long distances involved in flights across the United States, resulted in important technical innovations in navigation, power plants, and aircraft design for civil aircraft. The B-17, the world's first true strategic bomber, exploited technologies that had largely developed in the civilian sector. See in particular the chart on American airline development in Maurer Maurer, *Aviation in the U.S. Army, 1919-1939* (Washington, DC, 1987), p. 438. The contrast between the predominant German civilian airliner of the 1930s, the Ju 52, and the predominant American airliner, the DC-3, suggests how differently civil aviation devel-

will neither be provided nor requested unless experience proves that bombardment is unable to penetrate such resistance alone."[125]

Along with this confidence in the defensive capabilities of heavy bombers went a faith in the bomber's effectiveness against targets. The chapter on bombing accuracy and probabilities in Maxwell's 1939 tentative manual, "Delivery of Fire from Aircraft," argued that one could quantify the question of how large a bomber force would be necessary to destroy a given target with "a reasonable assurance of success" while avoiding overkill.[126] Such assurance rested on the application of probability and statistics to peacetime experience on bombing ranges. Necessary and even ground breaking as this sort of analytic work was, subsequent events indicate that it had the unfortunate consequence of encouraging the belief that through statistical methods and probability theory one could quantify the important aspects of bombing and then predict its effects against the enemy.

The heady mixture of faith in air power's future, confidence in the technical superiority of American bombers, and "mathematical assurance" as to the efficacy of bombing created an atmosphere that gave disproportionate weight to vision and "scientific" calculations over firsthand combat experience. Instead of a careful study of foreign wars, which might have questioned the plausibility of doctrinal tenets such as unescorted, daylight bombing in airspace defended by enemy fighters and antiaircraft artillery (AAA)—or the ease with which air attacks could destroy target systems—bomber proponents either disregarded combat experience in Europe or interpreted it in light of American doctrinal preferences.

This assessment may seem harsh. But it is difficult to reach any other judgment in light of later events. When American airmen, some of whom were to lead the army air forces after Pearl Harbor, went to England in 1940 to study European air war at firsthand, their reports doubted that British or German experiences applied to U.S. forces:

> ...for all its ferocity, the Battle of Britain could not duplicate the sort of air battle that the American air planners had in mind. As a result, the concrete "lessons" simply did not materialize. True, both German and British bombers proved vulnerable to fighters, but then they were medium bombers, poorly armed and flying at relatively low altitude....American bombers were much better armed and they would be flying at high altitude.[127]

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oped in the two nations due to local circumstances such as the much longer distances between the West and East Coasts of the United States compared with those between European cities. The American airliners needed longer ranges which, in turn, promoted the development of more powerful engines.

125 Quoted in Fabyanic, "Strategic Air Attack in the United States Air Force," p. 31.

126 Air Corps Board, "Delivery of Fire from Aircraft," Part One, "Precision Bombing," chapter IV, "Bombing Accuracy and Probabilities," 10 June 1939, Alfred F. Simpson Historical Research Center, 167.86-4, Maxwell AFB, Alabama, p. 1. This manual contains, among other things, a clear definition of "Circular Error Probable" (CEP) and charts for determining the number of independently aimed bombs that would need to be dropped to have various probabilities of hitting the target. The manual also states that "a large proportion of individual bombardment objectives will be destroyed if hit by one properly selected size of bomb" (ibid., p. 2). As Fabyanic has pointed out, the Tactical School's assumption that proper bomber formations could permit unescorted penetration was incompatible with the assumption that each bomb would be independently aimed ("Strategic Air Attack in the United States Air Force," pp. 37-38).

127 Major General Haywood S. Hansell, Jr., *The Air Plan That Defeated Hitler* (Atlanta, 1972), pp. 53-54.

A further point that the British airmen pressed on American observers was that, in any event, a long-range, high-performance fighter was technically impossible.[128] As a result, when the Air War Plans Division revised its August 1941 estimate of the air requirements for defeating Germany in August 1942, it concluded that it was "...*perfectly feasible to conduct precise bombing operations against selected precision targets, from altitudes of 20,000 to 25,000 feet, in the face of antiaircraft artillery and fighter defenses* [italics in original]."[129] This conclusion reflected a continuing conviction that heavily armed bombers in proper formations could penetrate without escorts and not incur unacceptable levels of attrition.[130]

This conviction was highly optimistic. At the time written, Bomber Command was largely (but not entirely) bombing at night after concluding that "the only way in which daylight bombing could achieve reasonably accurate results without...incurring prohibitive casualties, was by the provision of fighter cover."[131] Yet, on 20 October 1942, Brigadier General Ira Eaker, now commander of Eighth Bomber Command, whose bombers had begun flying missions against occupied France with heavy RAF fighter escort, wrote to Arnold in Washington:[132]

> You have probably been asked whether it is feasible to bomb objectives in Germany by daylight without fighter cover. I am absolutely convinced that the following measures are sound....*Three hundred heavy bombers* can attack any target in Germany by daylight *with less than four per cent losses.* A smaller number of bombers will naturally suffer heavier losses. [Italics added.][133]

Several aspects of Eaker's assurance warrant comment. First, the basic doctrinal belief conveyed in this 20 October 1942 letter was no anomaly. It reflected Eaker's honest and deeply held conviction. During October he reiterated this conviction to both his immediate superior in England, General Carl Spaatz, and to Arnold in Washington, DC.[134]

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[128] James Parton, *"Air Force Spoken Here" General Ira Eaker and the Command of the Air* (Bethesda, MD, 1986), pp. 123-124. Also see, William R. Emerson, "Operation POINTBLANK: A Tale of Bombers and Fighters," *The Harmon Memorial Lectures in Military History, 1959-1987*, ed. Harry R. Borowski (Washington, DC, 1988), pp. 452-453; and, Fabyanic, "Strategic Air Attack in the United States Air Force," pp. 65 and 69.

[129] As quoted in Fabyanic, "Strategic Air Attack in the United States Air Force," p. 65. For purposes of estimating force or munitions requirements, the use of probability and statistics to estimate the numbers of bombers required to destroy various targets was unavoidable. But extending these kinds of calculations to cover the defensive viability of bomber formations against a determined enemy was a different matter altogether. However valuable the reliance on numbers that grew up at the ACTS may have been for force planning, its extension to combat outcomes against a reactive adversary proved a mistake.

[130] Parton, *" Air Force Spoken Here"*, p. 124.

[131] Webster and Frankland, *The Strategic Air Offensive against Germany*, vol. I, pp. 448-449.

[132] On Eighth Bomber Command's first heavy bomber mission on 17 August 1942, twelve B-17s were shepherded to Rouen and back by 108 Spitfires (Perret, *Winged Victory*, p. 246; Freeman, *Mighty Eighth War Diary*, p. 9). At this point, Spaatz and Eaker were both convinced that "once they could mount raids with large numbers of B-17s the bombers would have such massed firepower they would be able to defend themselves on the deepest raids into the Third Reich" (Perret, *Winged Victory*, p. 246).

[133] Quoted in Bernard Boylan, "Development of the Long-Range Escort Fighter," USAF Historical Study No. 136, Air University, September 1955, pp. 68 and 265.

[134] Parton, *"Air Force Spoken Here"*, pp. 190-191; Fabyanic, "Strategic Air Attack in the United States Air Force," p. 125.

Second, despite mounting operational evidence to the contrary, Eaker not only persisted in this conviction for another year, but felt compelled, in no small part due to pressure from Arnold in Washington and the British in the United Kingdom, to put the lives of his bomber crews on the line to test the theory's validity once and for all.[135] In October 1943, Eighth Air Force's bomber and bomber crew strength finally reached sufficient numbers for Eaker to dispatch the "magic number" of 300 or more heavies against targets deep in Germany. That is precisely what he proceeded to do over the course of six deep-penetration missions flown during the twelve days of 2-14 October.[136] On the last mission in this series, Eighth made its second attack on the ball-bearing plants at Schweinfurt; it lost sixty B-17s over enemy territory in that attempt. Including those bombers written off, the six deep-penetration missions cost Eighth 198 heavy bombers—roughly 37 percent of its operational strength at the time; ignoring wounded and dead airmen in aircraft that survived the trip back to England, 166 crews totaling 1,651 American airmen went down over enemy territory—nearly 40 percent of the command's average effective combat-crew strength.[137]

Such aircraft and crew losses represented levels of attrition that Eighth could simply not sustain. The morning after the second Schweinfurt, Eaker reversed his long-standing position on unescorted bombers in a cable to Arnold. He requested, among other things, additional P-38 Lightnings and P-51 Mustangs, as well as auxiliary drop tanks to extend the ranges of all escort fighters.[138] While the level of attrition sustained by Luftwaffe fighters opposing these raids was severe, USAAF hopes of conducting unescorted, daylight precision bombing of German targets ended in October 1943.[139] This outcome reconfirmed the implication of World War I combat experience that control of the air represents an essential prerequisite to *all other applications* of air power.

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[135] In fact, Eighth Bomber Command's early missions did not provide encouraging data for the proposition that unescorted, deep-penetration bomber missions with acceptable losses were possible (Fabyanic, "Strategic Air Attack in the United States Air Force," pp. 68-73).

[136] "Overstatements made to sell bombardment in the 1935-38 period committed Air Corps leaders to a fixed view on how to execute the strategic mission." Smith, *The Air Force Plans for Peace: 1943-1945*, p. 33.

[137] Freeman, *Mighty Eighth War Diary*, pp. 120-133; Craven and Cate, *The Army Air Forces in World War II*, vol. II, pp. 849-850; and, "Statistical Summary of Eighth Air Force Operations: European Theater, 17 August 1942—8 May 1945." Eighth's overall loss rate as a percentage of the 2,014 heavy-bomber sorties dispatched against German targets for the missions of 2, 4, 8, 9, 10, and 14 October 1943 was 9.8 percent, more than double the 4 percent upper limit Eighth Air Force leaders believed putting up 300 or more bombers at a time would guarantee. Worse, the losses per mission escalated dramatically over the course of these six missions as the Germans reacted to the deep-penetration raids. On the second Schweinfurt mission of 14 October, German defensive measures included large-scale use for the first time of rockets fired from beyond the bombers' effective machine-gun range to break up formations, concentrating attacks on one bomb group at a time, and aggressively pressing home head-on fighter attacks (Craven and Cate, *The Army Air Forces in World War II, vol. II*, p. 699). Line bomber crews who participated in unescorted, deep-penetration missions like the second attack on the ball-bearing plants at Schweinfurt have tended to remain puzzled and bitter right down to the present day. See, for example, Elmer Bendiner, *The Fall of Fortresses: A Personal Account of the Most Daring—and Deadly—American Air Battles of World War II* (New York, 1980), pp. 227-239; also George C. Kuhl, *Wrong Place! Wrong Time! The 305th Bomb Group & the 2nd Schweinfurt Raid: October 14, 1943* (Atglen, PA, 1993), pp. 247-250.

[138] Parton, *"Air Force Spoken Here"*, pp. 315-316.

[139] Murray, *Strategy for Defeat*, p. 226.

Finally, the conviction that the aggregate defensive firepower of 300 or more heavy bombers could keep daytime losses to enemy fighters under 4 percent was tantamount to a belief that combat outcomes in aerial warfare are as predictable and calculable as the earth's tides or lunar eclipses were to Isaac Newton when the first edition of his *Principles of Natural Philosophy* appeared in 1686. This implicit faith in the ability of statistical methods and probability theory to render bombing operations predictable has identifiable roots in things like the bombing manuals developed at the Tactical School during the interwar period. Nonetheless, the present authors do not think that either late-twentieth-century physics or military history supports such "linear," mechanistic view of combat processes.[140] As Clausewitz observed, war involves interaction between two opposing sides, and "the very nature of interaction is bound to make it unpredictable."[141] Reformulated in the language and concepts of late-twentieth-century dynamics, the thrust of Clausewitz's insight is that nonlinearity and unpredictability—which can be identified with his unified concept of general friction (*Gesamtbegriff einer allgemeinen Friktion*)[142]—lie at the heart of *all* combat interactions in the real world.

This nonlinear view of combat processes contrasts sharply with the more mechanistic view embedded in the theory of strategic air attack that emerged at the Air Corps Tactical School (as well as within Bomber Command).[143] The assumption of linearity in the thinking of U.S. bomber advocates was not confined to narrow issues like bomber invincibility or estimates on the number of independently aimed bombs required to achieve an 80 or 90 percent probability of destroying a

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140 Regarding physics, we concur with Gregory Chaitin's observation that "classical physics really did have randomness and unpredictability at its very core"—notwithstanding Newton's hopes and Simon Pierre de Laplace's firm beliefs to the contrary (G. J. Chaitin, "Undecidability & Randomness in Pure Mathematics" in G. J. Chaitin, *Information, Randomness & Incompleteness: Papers on Algorithmic Information Theory* [Teneck, NJ, 2d ed. 1990], p. 307). The demonstration of nonlinearity in the so-called three-body problem of classical physics was, arguably, Henri Poincaré's deepest discovery (Stewart, Does *God Play Dice?*, pp. 66-72). Note, too, that gathering more data, or processing it faster, cannot and will not eliminate the kind of structural nonlinearity Poincaré discovered.

141 Clausewitz, *On War*, p. 139. We emphasize interaction because interaction is a form of feedback, and, in the simplest mathematical examples of nonlinear systems, it is the amplification of feedback over the course of repeated iterations that gives rise to nonlinearity or chaos. Perhaps the simplest example is the logistic mapping or quadratic iterator. For those interested in this example who are uncomfortable with mathematics, we recommend John Briggs and F. David Peat, *Turbulent Mirror: An Illustrated Guide to Chaos Theory and the Science of Wholeness* (New York, 1989), pp. 53-65; for those interested in a more rigorous treatment, see Peitgen, Jürgens, and Saupe, *Chaos and Fractals*, chapter 11, pp. 585-653.

142 Carl von Clausewitz, Vom Kriege, ed. Werner Hahlweg (Bonn, 1991), p. 265. Regarding the constituents of general friction, Clausewitz wrote: "We have identified danger, physical exertion, intelligence, and friction as the elements that coalesce to form the atmosphere [Atmosphäre] of war, and turn it into a medium that impedes activity. They allow themselves therefore in their restrictive effects once again to be united under the unified concept of general friction." (ibid.). The second sentence in this passage has been translated somewhat more literally than one finds on page 122 of Howard and Paret's 1976 English translation of *On War*. In more general terms, Clausewitz characterized friction as "the only concept that more or less corresponds to the factors that distinguish real war from war on paper" (Clausewitz, *On War*, p. 119).

143 British bomber proponents, like their American counterparts, were also inclined to presume that the results of strategic attack were quantifiable and predictable. For example, in 1939 RAF Bomber Command estimated that if it concentrated attacks on nineteen power plants and twenty-six coking plants in the Ruhr, "they could be put out of action in a fortnight by 3,000 sorties with a loss of 176 aircraft, and Germany's war-making power reduced almost to a standstill" (Webster and Frankland, *The Strategic Air Offensive against Germany, vol. I*, p. 97).

given target. After the breakout from Normandy, American heavy bombers in Europe were able to focus far heavier and more sustained blows on the German war economy than had been possible previously.

Yet, by late October 1944, it seemed clear that the offensive had not decisively affected reequipment of German armies, a conclusion that received ample confirmation from subsequent developments as well as postwar evidence.[144] German production of tanks actually rose in December 1944 and, that same month, the Luftwaffe was numerically larger than it had ever been.[145] Worse, the supposedly defeated Luftwaffe rose in sufficient strength on 2 November 1944 for the Eighth Air Force commander, General James Doolittle, to worry that the enemy might still be able to bring "down 100 American bombers on any deep penetration of the Reich."[146]

When the Germans then surprised the Allies with a ground attack through the Ardennes, it became painfully clear that the recuperative powers of the German war economy in the face of strategic bombing were far greater than Tactical School theorists had imagined—or, for that matter, than the most pessimistic expectations of Anglo-American air commanders and their staffs in late 1944. Consequently, it appears that Anglo-American efforts between the wars not only failed to develop the requisite capabilities, but neglected fundamental aspects of real war as opposed to war on paper. Despite the cautions and caveats rightly offered by J. A. Dewar, J. J. Gillogly, and M. L. Juncosa against jumping from their 1991 demonstration of nonlinearity in a very simple *mathematical* model of combat to the conclusion that nonlinearity is also a feature of real war, we are persuaded on historical grounds that combat interactions are—and have always been—nonlinear and unpredictable.[147] In our judgment, the profound difficulties that the Allies encountered in predicting how a system as adaptable as the German economy would react to strategic air attack offers an instructive illustration of what the interwar strategic bombardment theorists missed.

We suggested in the first part of this case study that the German approach to land-based air power in the interwar period largely rested mainly on three things: previous combat experience with air power (World War I), the actual prospects that German armed forces confronted in the late 1930s, and lessons learned from foreign conflicts such as the Spanish Civil War.[148] We also argued that German airmen placed air innovation within a broader context of the operational goals of the army as well as the Luftwaffe, which resulted in a more balanced approach than the Anglo-

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144 Craven and Cate, *The Army Air Forces in World War II, vol. III,* p. 649.

145 Ibid., vol. III, pp. 649 and 663.

146 Ibid., p. 661.

147 Dewar, Gillogly, and Juncosa, "Non-Monotonicity, Chaos, and Combat Models," p. vi. While Dewar, Gillogly, and Juncosa analyzed extremely simplified Lanchesterian models of combat, their models were nevertheless "rich" enough to incorporate a very rudimentary kind of "human" interaction between the two sides by allowing Red or Blue to call on reinforcements as a function of the current state of the battle (ibid., pp. 5 and 12). It turns out to be precisely this sort of interaction that induces structural nonlinearity or unpredictable "misbehavior" (ibid., p. 42). The reason for the extreme simplicity of their models was, of course, so that other potential sources of misbehavior—roundoff/precision problems, time-step granularity, and feedback effects from delayed reinforcements—could be ruled out.

148 The basic lessons that the Germans drew from the Spanish Civil War were: first, that "strategic" bombing was going to be more difficult than many thought; second, that bombing accuracy was also going to be a major problem; and, third, that close air support would often have an important role to play in ground operations.

American emphasis on strategic bombing.[149] It is possible at this juncture to push this line of analysis further and observe that, in the German and American cases, the differences in their approaches reflected different assumptions about the fundamental nature of combat processes. The 1933 *Truppenführung* expressed a decidedly Clausewitzian view of the essential nature of combat interactions. Consider this passage from its introduction:

> Situations in war are of unlimited variety. They change often and suddenly and only rarely are from the first discernible. Incalculable elements are often of great influence. The independent will of the enemy is pitted against ours. Friction and mistakes are of every day occurrence.[150]

In much the same vein, the Luftwaffe's basic doctrinal manual underscored that "the nature of the enemy, the time of year, the structure of the [enemy] nation, the character of the [enemy] people, as well as one's own military capabilities" would determine air power's role in a future war.[151] These views are decidedly at odds in their assumptions about the underlying nature of war, with those manifest in Air Corps Tactical School bombardment theory or AWPD-1.

The contrast between German and Anglo-American efforts to develop land-based air power also highlights how resistant doctrinal beliefs—especially visionary ones—can be to empirical data, including actual combat experience. If the experience of U.S. airmen before and during World War II is any guide, doctrinal beliefs are almost impervious to countervailing evidence when those beliefs bear on institutional autonomy or existence, however justified those ends might be.

In turn, this insight raises the issue of how important the intellectual atmosphere in which peacetime military innovations occur is to success. Without some institutional process or consensus on the importance of subjecting doctrinal tenets, theoretical conclusions, and quantitative effectiveness calculations to *honest* evidentiary tests, it appears all too easy for military organizations to follow their hopes and dreams into catastrophe. A further implication of the different directions in which German and Anglo-American air power developed between the wars is that none of the three air forces were fully, or even adequately, prepared for the full gamut of prospective missions at the outset. The Germans had certainly prepared more thoroughly in 1939-1940 than their adversaries to employ air power to influence the outcome of land operations. The Luftwaffe's bombing of French forces in and around Sedan on the afternoon of 13 May 1940 offers a good example of the flexibility that the Luftwaffe had built into its bomber and dive-bomber forces.[152]

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149 However, interservice cooperation between the Luftwaffe and the German navy remained virtually nonexistent throughout the history of the Third Reich. Thus, the RAF's postwar assessment that the Luftwaffe's "main role" during World War II had been "to annihilate enemy air power and then to give the army maximum support" was reasonably close to the mark (*The Rise and Fall of the German Air Force: 1933-1945*, p. 49).

150 Truppenführung, trans. of Part 1, U.S. Army Report No. 14,507, 16 March 1936, p. 1. The explicit reference in this passage to friction and mistakes being a constant feature of military operations obviously reflects a Clausewitzian outlook.

151 *Die Luftkriegführung* (Berlin, 1935), paragraph 11.

152 Doughty notes that the Luftwaffe's aerial assault on 13 May 1940 sapped the will of French defenders by disrupting the fire of numerous artillery batteries and providing immediate fire support (*The Breaking Point*, p. 137). Besides accompanying escort fighters, II FliegerKorps put 310 bomber and 200 dive-bomber sorties into this effort;

It is also true that, in late summer and fall 1940, the Germans utilized their bomber forces with reasonable effectiveness in a strategic-bombing role, at least in comparison to the capabilities of the RAF or the USAAF at that time. R. V. Jones, a crucial figure in British scientific intelligence during World War II, and the man who single-handedly uncovered the secrets of the Germans' *Knickebein* radio-direction system (for bombing targets at night or in poor weather) and its successors, has noted that without British countermeasures: "Not only could there have been many more Coventrys, but [Field Marshal Ernst] Milch's aim of knocking out our aero-engine factories might have been achieved."[153]

Still, in the early years of World War II, the knock-out blow from the air feared by many on both sides failed to materialize.[154] In this sense, *none* of the major air forces we have examined—not the Luftwaffe, the RAF, or the USAAF—were adequately prepared, prior to early 1944, to carry out strategic-bombing operations aimed at achieving air superiority over enemy territory without concurrent ground operations to overrun the enemy territory in question. Further, even for the Allies, the destruction of an enemy's war economy by independent bombing did not prove feasible until late 1944, if not early 1945. Both points suggest that the independent use of nonnuclear air power against the heartland of an enemy nation to achieve political ends was far harder to achieve than most airmen realized or imagined during the interwar years, even in their most pessimistic moments.[155]

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these attack sorties were also supplemented by StG 77 from VIII FliegerKorps (Bekker, *The Luftwaffe War Diaries*, pp. 118-119).

153 Jones, *The Wizard War*, p. 180. By June 1940, the Rolls Works in Derby that produced Merlin engines for the Spitfire and Hurricane fighters was arguably one of the more important targets in England, and, in July, Hermann Göring concluded that destroying the RAF and its supporting aero-engine industry could give the Germans air superiority over Britain (ibid., pp. 103 and 104). For Jones' initial wartime report on the Knickebein system, see PRO AIR 20/1623, Air Scientific Intelligence Report No. 6, "The Crooked Leg," 28.6.40. The British began concerted jamming of Knickebein in mid-September 1940 when the Luftwaffe shifted to night bombing; it took a couple months for the Germans to appreciate the countermeasures (ibid., pp. 127 and 129-130). In principle, a German bomber flying Knickebein should have been able to hit a target of about one square mile (ibid., p. 129). Since the Germans had other systems in train, countering Knickebein was the first round in the "battle of the beams," and Jones' assessment was that the British were less successful in the second against the X-system, which they started jamming in October 1940 (ibid., pp. 138, 152, and 161). In principle the "fine-beam" X-system was more accurate, but even Kamp Gruppe 100 was never able to get more than a few bombs on pin-point targets (ibid., p. 142).

154 Overy, *The Air War: 1939-1945*, p. 26.

155 This conclusion can certainly be supported at the target-system level. Consider, for example, the USSBS' assessment of bombing's effectiveness against German anti-friction bearings: "It proved more difficult to put factories out of operation than had been foreseen. The susceptibility of machine tools to damage was not very great; fire proved more effective than blast. Stocks of raw material and semi-finished bearings could not be harmed irrecoverably. Finally, even hits on vital processes were not sufficient to put a whole plant out of commission, as had been expected....Vigorous production measures, dispersal from the large centers of production to numerous small plants, the construction of underground plants, the bomb proofing and erection of blast walls around vital machinery, and the rapid repair or replacement of damaged or destroyed machinery and equipment, enabled production to return to adequate levels before the cushion provided by stocks and the shortening of the pipeline between producer and user plants had ceased to exist....The Germans were thus able to make good their boast, 'Es ist kein Gerät zurück geblieben weil Wälzlager fehlten' (No equipment has been held up because of a shortage of bearings)." USSBS, Equipment Division, The German Anti-Friction Bearings Industry (Washington, DC, 2d ed. January 1947), European War Report #53, pp. 1-2.

While the air power historian David MacIsaac was certainly on solid ground when he suggested in 1986 that the initial American theory of strategic air attack developed at the Tactical School, "with its overriding emphasis on economy of force artfully applied, cannot be dismissed as...fantasy," combat experience revealed many theoretical shortcomings.[156] Those weaknesses that MacIsaac catalogued included:

> (1) the unstated assumption that precise intelligence regarding enemy targets would be available; (2) a prevailing tendency to magnify expected capabilities derived from designs still on the drawing boards, at the same time minimizing the likely effects of limiting factors—not the least of which would prove to be the impact of weather conditions on flying operations; (3) a pattern of looking at parts of the problem at the expense of the whole, a form of reductionism surely not limited to air power theorists, but one leading to a concentration on means rather than ends, running parallel with a tendency to confuse destruction with control, and at the same time reducing strategy to a targeting problem; and (4) a gross over-estimate of the self-defending capacity of bomber aircraft against a daring and dedicated defending air force.[157]

It is not at all obvious that the passage of a half century since World War II has yet ameliorated some of the difficulties and complexities inherent in air power. Major General Haywood Hansell, who taught at the Tactical School in the 1930s and was involved in all of the major American planning efforts for the daylight bombing of Germany (AWPD-1, AWPD-42, and the 1943 CBO plan), wrote after the war that "weather was actually a greater hazard and obstacle than the German Air Force."[158] In the aftermath of the Desert Storm air campaign (17 January-28 February 1991), (then) Major General Buster Glosson, who not only was the chief air planner for the campaign but commanded all U.S. Air Force fighter units in Saudi Arabia during its execution, made much the same observation: "Weather absolutely beat us down!...[It] was our Number One problem."[159]

As for the structural problem of understanding how target systems selected for attack actually function, the nature and vulnerability of the Iraqi nuclear program was as much of an enigma to Coalition air commanders, planners, and intelligence analysts to the end of Desert Storm as the nature and vulnerability of the German war economy seems to have been to most Allied air commanders, planners, and intelligence analysts during 1943-1945.[160]

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156 MacIsaac, "Voices from the Central Blue," p. 635.

157 Ibid., p. 635.

158 Hansell, *The Air Plan That Defeated Hitler*, p. 121.

159 Interview, Gulf War Air Power Survey with Major General Buster C. Glosson, 14 April 1992, Pentagon, Washington, DC, personal notes taken by Barry D. Watts. Examination of F-117 "no drops" and "misses" attributed to weather, particularly during the first and sixth weeks of the campaign, confirms Glosson's assessment that weather was a major impediment to Coalition strike operations (Barry D. Watts and Thomas A. Keaney, *Part II: Effects and Effectiveness in Gulf War Air Power Survey, vol. II, Operations and Effects and Effectiveness* [Washington, DC, 1993], pp. 387-389). Over the course of 1,299 combat sorties, F-117 pilots reported 442 no drops or misses due to weather.

160 Ibid., pp. 314-317 and 327-330; also, Michael Eisenstadt, *Like a Phoenix from the Ashes? The Future of Iraqi Military Power* (Washington, DC, 1993), Washington Institute Policy Paper No. 36, pp. 92-93. We can see no clear indication in the United States Strategic Bombing Survey's overall report on the effects of strategic bombing against the German war economy that John Kenneth Galbraith's Overall Economic Effects Division grasped the

Nevertheless, there is another side to the inherent difficulties and complexities of applying air power directly to the economic heart and will of an enemy state. On the one hand, the *direct* effects that British and American airmen sought from the strategic air offensive proved more elusive and less calculable than was anticipated between the wars. On the other hand, the pursuit of these objectives had important *indirect* effects which are overlooked. Burton Klein, assistant director of the Economics Effects Division of the Strategic Bombing Survey, noted in 1959 that: "From 1942 to the first half of 1944 [German] expenditures on air defense armaments—defensive fighter planes and their armaments, antiaircraft weapons, and ammunition—nearly tripled, and at the time of the [Normandy] invasion amounted to about one third of Germany's entire munitions output."[161]

Similarly, German records suggest that the V-1 and V-2 programs were motivated by the conviction of Nazi leaders that, to sustain popular morale, they needed to retaliate against Britain for the damage that Allied bombing was inflicting on the Reich.[162] Yet, while Allied bombing and other countermeasures prevented the V-weapons from affecting the course of the war militarily, the opportunity cost just for the production of these weapons was estimated by the USSBS as the equivalent of 24,000 fighter aircraft.[163] Given *indirect* economic distortions on the scale of the

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pivotal role in German war production of the "coal/transport nexus" described in Mierzejewski's 1988 *book The Collapse of the German War Economy, 1944-1945*. As recently as 1981, Galbraith remained adamant that German war production had expanded under the direct bombing of weapons plants, and that attacks against oil and transportation only had military, as opposed to economic, effects (John Kenneth Galbraith, *A Life in Our Times: Memoirs* [Boston, 1981], p. 226). Nevertheless, the USSBS transportation report concluded that between May 1944 and January 1945, the direct and indirect effects of Allied attacks on transportation accounted for 50-60 percent of the decline in German economic output, and, by March 1945, "most of the chaos" that gripped the German economy "was traceable...to the disaster which overtook the transportation system" (Willams, et al., *The Effects of Strategic Bombing on German Transportation,* pp. 3 and 90). Similar discrepancies regarding the economic effects of transportation attacks exist between the USSBS' overall report for the European theater and the final conclusions of the transportation division. The former only credited the transportation failure of late 1944 and early 1945 as causing precipitous decline in civilian production, which was described as not being a proximate cause of military collapse (Franklin D'Olier, Henry C. Alexander, et al., USSBS, Office of the Chairman, Over-all Report (European War) [Washington, DC, 30 September 1945], European War Report #2, p. 38). By contrast, the transportation report concluded by endorsing Dr. Hans Kehrl's back-of-the-envelope estimate that in the first quarter of 1945, 90 percent of the production losses not due to loss of territory could be attributed to the direct and indirect effects of the transportation collapse (Willams, et al., *The Effects of Strategic Bombing on German Transportation*, p. 90). The reason for this discrepancy is not hard to discern: whereas the principal report of Galbraith's division, like the overall USSBS report on the European theater, was published in late 1945 and never updated, the Transportation Division's principal report did not appear until January 1947.

161 Burton H. Klein, *Germany's Economic Preparations for War* (Cambridge, Massachusetts, 1959), pp. 232-233; James G. Roche and Barry D. Watts, "Choosing Analytic Measures," *The Journal of Strategic Studies*, June 1991, p. 181.

162 Murray, *Strategy for Defeat*, p. 300.

163 USSBS, Military Analysis Division, V-Weapons (Crossbow) Campaign (Washington, DC, 1947), European War Report #60, pp. 35 and 36. This conservative estimate assumed that the production cost of one fighter equaled five V-1s or one-third of a V-2 (ibid.). USSBS researchers concluded that the Germans produced about 30,000 V-1s and 6,000 V-2s by the end of the war. To give some idea of the economic magnitude of 24,000 fighter aircraft, the Germans produced 17,065 aircraft in 1942 and 93,326 in 1944 (Galbraith, Klein, et al., USSBS, *The Effects of Strategic Bombing on the German War Economy,* Appendix Table 101, p. 276). The USSBS estimate for the economic resources consumed by V-weapon production omits research and development, launch-site construction, and other costs. A more recent estimate for the entire long-range weapon program suggests that it may have cost

Germans' investments in antiaircraft air defenses and long-range weapons, the perseverance of American and British airmen in pursuing independent bombing clearly paid dividends that affected the outcome of war. Thus, while the prewar objective of directly defeating enemy forces and destroying the enemy's will to resist was only achieved by combined operations, it is still difficult to escape the conclusion that Allied pursuit of strategic bombing "was an important factor in explaining victory in the war as a whole."[164]

Coming back to peacetime innovation, the American effort to develop precision bombardment into a strategic weapon is particularly useful in underscoring the practical difficulties of innovation under conditions of technological, fiscal, institutional, and geostrategic uncertainty. Factors as subtle as a proclivity toward reductionism or inadequate attention to potential enemy responses can lead to seemingly small distortions or shortfalls in emerging capabilities that, over time, may have very large and lasting consequences for how well or poorly the new way of fighting fares in actual combat. This pattern can be seen in the contrast between German and British experiences in developing armored, mobile warfare during 1918-1939. It also persists in the final example of innovation we shall examine.

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the Reich an amount equal to a quarter of the cost of the U.S. Manhattan Project that built the first atomic bombs and, relative to the size of the German economy, imposed "a burden on the Third Reich roughly equivalent to that of the Manhattan Project on the United States" (Michael J. Neufeld, *The Rocket and the Third Reich: Peenemünde and the Coming of the Ballistic Missile Era* [New York: 1995], p. 273).

[164] Overy, *The Air War: 1939-1945*, p. 205.

Case 3: Carrier Aviation

Our final case study of peacetime military innovation is the development of carrier aviation during the interwar period.[165] In retrospect, the American experience appears to have been one of incremental evolution from battleship gunfire to carrier aircraft as the primary offensive means of defeating opposing fleets. The U.S. Navy's development of carrier aviation in the interwar period also provides an instance of relatively successful peacetime innovation. That success was contingent on organizational interactions and processes through which the naval aviation community reached technological decisions about the kinds of carriers and carrier aircraft it would need.

In contrast, the Royal Navy's failure to develop carrier capabilities comparable to those of the U.S. and Japanese navies represents, a case of flawed, if not failed, innovation, especially in light of the British lead in 1918. At the close of World War I, the Royal Navy possessed "a fleet of nearly a dozen carriers of one sort or another at a time when no other naval power had even one."[166] Indeed, by the end of 1918 the British fleet even included the newly commissioned (but not yet operational) HMS *Argus*, whose fully flush deck made her the first true aircraft carrier.[167] Additionally, during World War I the British had accumulated considerable operational experience with carriers and naval aviation.

This experience encompassed the operation of carriers as part of the main battle fleet as well as employment in independent attacks against targets ashore. The first carrier air raid in history, the attack on the Cuxhaven Zeppelin base near Wilhelmshaven by seven British seaplanes from three improvised "carriers" in the Heligoland Bight, took place on Christmas Day 1914.[168] But, despite the lead conferred by nearly four years of wartime carrier operations and develop-

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165 Our decision to concentrate mainly on the Americans and British obviously neglects the Japanese. We chose not to explore the Japanese experience in any depth for two reasons. First, compared to the American and British cases, the primary source material on the development of carrier aviation by the Japanese between the world wars is still rather thin—especially in English. Second, the Japanese acquired most of their carrier-aviation technology from foreign sources, and were so obsessed during the interwar period with the tactics of "out-ranging" the U.S. Navy's battleships in a decisive fleet engagement, that they never developed a clear vision of fast carriers as a substitute for battleships (Commander James R. FitzSimonds, "The Development of Japanese Naval Air Power," internal memorandum, OSD/Net Assessment, 30 June 1994, pp. 2-3). For a discussion of out-ranging, see Rear Admiral Yôichi Hirama, "Japanese Preparations for World War II," *Naval War College Review*, Spring 1991, pp. 72-74.

166 Geoffrey Till, "Adopting the Aircraft Carrier: The British, American, and Japanese Experiences," Allan R. Millett and Williamson Murray, "Innovation in the Interwar Period," p. 308. Given the loss of HMS Campania on 5 November 1918, the Royal Navy appears to have had the following carriers at the close of World War I: Furious, Argus, Vindictive, Nairana, Pegasus, Vindex, Ark Royal, Manxman, Engadine, Empress, and Riveria (Norman Friedman, *British Carrier Aviation: The Evolution of the Ships and Their Aircraft* [Annapolis, MD, 1988], pp. 47 and 90). These vessels ranged from early seaplane carriers, such as Empress and Riveria, to Ark Royal, the first ship largely designed and built as an aircraft carrier, and Argus, the first flat-deck carrier (ibid., pp. 29, 30, and 65).

167 Friedman, *British Carrier Aviation*, pp. 67-68. In September 1916, the British achieved success in making arrested landings with an Avro 504 biplane equipped with a hook; it appears to have been these experiments that encouraged the decision to complete the liner Conte Rosso as the carrier flat-deck Argus (ibid., p. 61).

168 Ibid., p. 32. The improvised carriers that conducted the Christmas 1914 raid were Engadine, Riveria, and Empress. All three were troop carriers modified to carry small numbers of seaplanes. For flight operations, the seaplanes were lowered into the water using cranes.

ment, the British entered World War II with only four first-line carriers (plus three obsolescent ones); their carrier aircraft were markedly inferior in numbers and quality to those of the Americans and Japanese; and, most crucially, even first-line British carriers of 1939 could not generate pulses of aircraft striking power comparable to those attainable from Japanese and, especially, American front-line carriers.[169] Explaining this curious turn of events will be an important part of this case study. As will become evident, one cannot satisfactorily explain the poor technical choices made by the British concerning carriers and carrier aircraft during the interwar period either by the more complex strategic and economic circumstances that confronted Britain, or as a particularly unfortunate run of bad luck.[170]

American naval interest in aviation predated World War I. In 1900, realistic ranges for gunfire between capital ships of the line were in the vicinity of 1,500 yards and, even at those ranges, accuracy under combat conditions remained well under ten percent.[171] By the end of World War I, practical battle ranges for battleships extended tenfold to some 15,000 yards.[172] During this period gunfire accuracy also improved by two, if not three, orders of magnitude due to the innovation of continuous-aim fire by William S. Sims.[173] This rapid expansion in the range and accuracy of large naval guns against ships capable of high sustained speeds hinged on developing reliable and accurate means of fire control.

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169 Till, "Adopting the Aircraft Carrier," pp. 314, 322, 340, and 357-358; Friedman, *British Carrier Aviation*, pp. 18-19.

170 The fact that many of the technical decisions about carriers and carrier aircraft made by the British between the two world wars appear quite sensible when placed in historical context should not obscure the fact that they were later shown to have been wrong. Till's recent argument that the British, Americans, and Japanese were all three "reasonably successful" in developing carrier aviation during the interwar years, and that "one can trace specific failures to apparently minor technical errors and problems," obscures this fundamental point (Till, "Adopting the Aircraft Carrier," p. 364). For example, the tacit British decision not to adopt deck parks can be seen as having been altogether rational given the Royal Navy's circumstances and the state of technical knowledge at the time. Nonetheless, it imposed "very severe limits" on British carrier aircraft and, arguably, was "the single most important British interwar naval air decision" (Friedman, *British Carrier Aviation*, p. 11).

171 During the war with Spain in 1898, for example, Admiral George Dewey's ships had fired 5,859 shells and achieved only 142 hits, for a hit rate of 2.4 percent (David F. Trask, "William Sowden Sims: The Victory Ashore," *Admirals of the New Steel Navy*, ed. James C. Bradford [Annapolis, MD, 1990], p. 285).

172 Norman Friedman, Thomas C. Hone, and Mark D. Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy: Military-Technical Revolutions, Organizations, and the Problem of Decision," draft report for the Director of Net Assessment, Washington, DC, 14 July 1994, p. 40.

173 "In 1899 five ships of the [U.S.] Atlantic Squadron fired five minutes each at a lightship hulk at the conventional range of 1,600 yards. After twenty-five minutes of banging away, two hits had been made on the sails of the elderly vessel. Six years later one naval gunner made fifteen hits in one minute at a target 75 by 25 feet at the same range—1,600 yards; half of them hit in a bull's-eye 50 inches square." (Morison, *Men, Machines, and Modern Times*, p. 22). Sims learned all there was to know about continuous-aim fire from Admiral Sir Percy Scott while both were serving on the China station, Sims as a junior officer and Percy as the commanding officer of HMS Terrible (ibid., pp. 27-28). Sims tried to interest the Bureaus of Ordnance and Navigation in this innovation to no avail. In 1902, after he wrote directly to President Theodore Roosevelt, Sims was brought back to Washington and installed as Inspector of Target Practice, a post he held through the remaining six years of the administration (ibid., p. 31). When Sims departed that post in 1908, he was universally acclaimed as the man who taught the navy how to shoot.

It was this immediate tactical problem of fire control that convinced then Lieutenant (jg) (later Admiral) John H. Towers even before World War I of “the need to get into the air;” his experience in 1910 as a gunfire spotter on the USS *Michigan*, whose 12-inch guns could reach over the horizon, led him to see aircraft as a means of providing accurate long-range gunfire.[174] By early 1911, Captain Washington Chambers and Curtiss pilot Eugene Ely had demonstrated that aircraft could take off and land on a ship.[175] In February 1913, Rear Admiral David W. Taylor, the new chief of the Bureau of Construction and Repair, approved construction of a wind tunnel in the Washington Navy Yard so that his staff “could begin systematic experiments in aerodynamics” resembling the work in hydrodynamics already being done in the Yard’s towing tank.[176] During August 1913, the navy’s General Board reported to Secretary of the Navy Josephus Daniels that a “complete and *trained* air fleet” had become “a necessary adjunct” to the navy.[177] And, in 1914, the navy detailed J. C. Hunsaker to participate in establishing the first graduate degree program in aeronautical engineering in the United States at the Massachusetts Institute of Technology.[178] Thus, by 1914 senior naval leaders had come to see aviation as a “required adjunct to fleet operations” and had taken steps to ensure that their service would be at the forefront of aviation progress.[179]

This sense of naval aviation’s growing importance for future war at sea covered a range of possible aircraft uses. By 1912 Lieutenant Commander Henry C. Mustin, an expert in naval gunnery and early naval aviator, realized that battleship and battle-cruiser gunfire, effectively controlled by aircraft, could potentially win a fleet engagement in a matter of minutes.[180] He not only

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174 Friedman, Hone, and Mandeles, “The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy,” pp. 39-40. The USS Michigan was the first American dreadnought battleship.

175 Charles M. Melhorn, *Two-Block Fox: The Rise of the Aircraft Carrier 1911-1929* (Annapolis, MD, 1974), p. 8. The makeshift system Ely used to land his aircraft on the Pennsylvania on 18 January 1911 “incorporated the basic elements of a modern arrested landing system: hook, wire, deaccelerating assist, and barrier” (ibid.). Shortly after this successful experiment, however, Chambers became enamored with seaplanes and was still championing them over aircraft carriers for wheeled naval aircraft as late as 1930 (ibid., p. 9).

176 Friedman, Hone, and Mandeles, “The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy,” p. 46.

177 William R. Braisted, “Mark Lambert Bristol: Naval Diplomat Extraordinary of the Battleship Age,” *Admirals of the New Steel Navy*, ed. James C. Bradford (Annapolis, MD, 1990), p. 334.

178 Clarke van Vleet and William J. Armstrong, *United States Naval Aviation: 1910-1980* (Washington, DC, 1981), NAVAIR 00-80P-1, p. 9.

179 Friedman, Hone, and Mandeles, “The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy,” p. 52. In the years between the war with Spain and World War I, two communities within the USN—regular line officers, on the one hand, and technical officers from the bureaus of Ordnance, Steam Engineering, and Construction and Repair, on the other—promoted and managed the transformation of the service’s technology. Innovations during this period included steam turbines, long-range guns, fire-control calculators, submarines, signals intelligence, and the shift from coal- to oil-fired ship propulsion (ibid., p. 43). In the context of all these technological changes, it is hardly surprising that the U.S. Navy embraced aviation as well.

180 Aerial spotting allowed accurate battleship gunfire to extend well beyond the visual horizon. By 1922, for example, effective battleship gunfire had extended from 20,000 to 24,000 yards with the aid of spotter aircraft (Norman Friedman, *U.S. Aircraft Carriers: An Illustrated Design History* [Annapolis, MD, 1983], p. 33). When the Japanese battleship Yamato was launched in 1940, her 18.1-inch guns could reach out to 40,000 meters (Yôichi Hirama, “Japanese Preparations for World War II,” p. 73).

began to advocate aircraft-carrying ships, but also seems to have been "the first U.S. Navy officer to see clearly that the striking power of aircraft at sea *could and would* equal that of the battleship."[181] Mustin's early leap from employing aircraft to direct battleship gunfire against fast-moving ships to using them to deliver ordnance—which he may have made as early as 1914—illustrates how hard it is to pinpoint the precise origins of carrier concepts. What does seem clear is that, by 1914-1915, three distinct concepts had arisen within both the British and American navies:

> One concept was to use carrier-based aircraft to attack land targets. Under this concept, the carrier was just a forward airfield. It did not work in concert with, or form an integral part of, a whole fleet. Another concept was that the carrier, though part of a larger fleet, was nonetheless an auxiliary to existing weapons such as the battleship. Under this concept, carrier aircraft scouted, drove off enemy scouts, and directed the gunfire of heavy ships. Yet another, different (and revolutionary) concept was that of the carrier and its aircraft as the centerpiece of a long-range striking force—the new battle line, so to speak.[182]

During World War I, British carrier operations emphasized the first two roles: land attack and fleet support. The reason lay in interlocking technical problems that required solutions to develop effective carriers, aircraft, and weapons capable of attacking battleships. The numbers of aircraft that World War I carriers could generate remained limited, and the aircraft themselves were not capable of delivering ordnance with much potential to sink capital ships.

The most promising aircraft weapon for such strikes at the beginning of war was the high-speed torpedo.[183] Its promise led the Royal Navy to concentrate the initial "carrier" efforts on torpedo-carrying floatplanes that specially modified ships could carry to within striking distance of the target.[184] While the British achieved some success during 1915 against Turkish shipping in the Sea of Marmara by using fourteen-inch (810-pound) torpedoes delivered from floatplanes, they needed heavier weapons to sink, rather than damage capital ships.[185] But the drag and weight associated with seaplane floats so limited aircraft performance that the British could not lift larger torpedoes until they had shifted to wheeled aircraft. Not until 1918 did the Royal Navy field sufficient quantities of wheeled aircraft, the Sopwith Cuckoo, with the performance to carry the 18-inch (1,000-pound) torpedo needed for a mass strike on the German fleet in its base.[186]

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181 Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," pp. 49-50 and 203.

182 Ibid., pp. 174-175.

183 The Whitehead torpedo is perhaps best characterized as a "ram with reach" (Wayne P. Hughes, Jr., *Fleet Tactics: Theory and Practice* [Annapolis, MD, 1986], p. 62). The possibility of marrying the airplane and the torpedo was recognized early in the development of naval aviation. In the United States, Rear Admiral Bradley Fiske, USN, was granted a patent on his proposal to use the airplane as a delivery vehicle for the torpedo in 1912 (Melhorn, *Two-Block Fox*, pp. 10-11).

184 Friedman, *British Carrier Aviation*, p. 26.

185 Ibid., pp. 37, 41, and 49.

186 Ibid., p. 41. Even then, the "lightweight" 18-inch torpedo only contained 170 pounds of explosives and would have been questionable against capital ships.

The use of sea-based aircraft to attain air superiority over the fleet also led the Royal Navy from floatplanes to wheeled aircraft over the war's course. While the British used floatplanes initially, once the Germans began employing relatively high-flying Zeppelins to shadow the Grand Fleet, the 1917 aircraft committee quickly made the anti-Zeppelin mission a first priority of shipborne aircraft operating with the fleet.[187] Since only wheeled fighters like the Sopwith Pup had the performance to intercept Zeppelins, this mission, too, led to the conclusion that the Royal Navy needed the capability to recover high-performance, wheeled aircraft at sea.[188]

In turn, employment of wheeled aircraft at sea required more than floatplane carriers. The British required ships with flight decks for the launch and recovery of aircraft. HMS *Furious*, initially designed with a "flying-off" deck only, was modified in 1918 to include a "flying-on" deck to permit recovery of wheeled aircraft.[189] Unfortunately, the ship's split-deck configuration with a truncated central superstructure did not permit safe recovery of aircraft, while the flush-deck *Argus* was still undergoing trials as the war ended.[190]

Not surprisingly, British wartime experience prompted the Americans to give serious thought to the future of aviation. In 1919, how aggressively the U.S. Navy should pursue such development became a major issue for the General Board.[191] As early as 1916, American appreciation for the growing importance and utility of aircraft in the war prompted Congress to authorize creation of separate navy and navy reserve flying corps.[192] That same year, the navy also negotiated its first aircraft production contract with Glenn Curtiss.[193] By the end of the war, British experience with naval aircraft in such roles as land attack and fleet support, as well as the Royal Navy's development of specialized ships, provided further motivation for Americans to press ahead. However at the end of 1918, U.S. naval opinion was not unanimous as to how best to proceed. Conservatives, including the chief of naval operations, saw the capital ship as the decisive element of naval warfare; aviation could provide reconnaissance and over-the-horizon spotting,

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187 Ibid., p. 48.

188 Melhorn, *Two-Block Fox*, pp. 15-16.

189 The air turbulence from the bridge structure of Furious made landing on her rear deck "almost as hazardous as ditching in the sea," and Furious remained a one-shot carrier (Geoffrey Till, *Air Power and the Royal Navy: 1914-1945, A Historical Survey* [London, England, 1979], p. 62). In her justly famous Tondern raid of 19 July 1918, for instance, Furious launched seven Sopwith Camels which flew 80 miles to find, bomb, and destroy Zeppelins L54 and L60 in their shed; but five of the aircraft were forced to fly on to neutral Denmark while the two that returned to the ship ditched alongside rather than attempt to land on the carrier (H. A. Jones, *The War in the Air: Being the Story of the Part Played in the Great War By the Royal Air Force,* vol. VI [London, 1937], pp. 365-367).

190 Friedman, *British Carrier Aviation*, pp. 27, 55-56, 61-62, and 67.

191 The General Board was a group of senior flag officers who, during the interwar period, advised the Secretary of the Navy on "naval building programs, naval arms limitations, and such other policy matters as the secretary might refer to them" (Braisted, "Mark Lambert Bristol: Naval Diplomat Extraordinary of the Battleship Age," *Admirals of the New Steel Navy*, p. 356).

192 Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 51.

193 Van Vleet and Armstrong, *United States Naval Aviation: 1910-1980*, p. 15.

but was only a support element for the battle line—a not unreasonable view at the time.[194] Opponents of the conservative position ranged from outspoken aviation advocates like Admirals Sims and William F. Fullam, who foresaw the carrier as an agent of revolutionary change in naval warfare, to less radical proponents who, while convinced that the aircraft carrier was indispensable to future naval operations, stressed the carrier's importance in support of the naval gun.[195] Thus, when the General Board convened in January 1919, the fundamental question was not whether to adapt aviation to naval purposes, but how best to do so and at what pace.[196]

The uncertainties were immense. What, for example, was the proper air vehicle? Was it the dirigible, the floatplane (whether launched from battleships or carried by a seaplane tender), or wheeled aircraft operating from a flush-deck carrier like HMS *Argus*? If the answer was the latter, were the frail planes then available really capable of supplanting light cruisers as the "eyes of the fleet?" Looking further ahead, could carrier aircraft acquire, as some foresaw, the capability to sink capital ships? The General Board, lacking aviation expertise, heard testimony from a wide range of witnesses with experience and knowledge and its hearings lasted into autumn 1919. While most witnesses were naval officers, the board also heard from army Brigadier General William Mitchell, who had just returned from France where he had coordinated employment of 1,480 aircraft in support of American ground forces during the battle of St. Mihiel.[197]

The board's conclusion in 1919 was that aircraft had become an essential arm of the fleet. Hence, it recommended to Secretary of the Navy Josephus Daniels that the navy undertake a broad program of peacetime development to establish a naval air service "capable of accompanying and operating with the fleet in all waters of the globe."[198] On that basis, Daniels dropped his earlier opposition to construction of an aircraft carrier. When several influential military figures, including Billy Mitchell, also testified in favor of the aircraft carrier, Congress followed suit. The Naval Appropriations Act passed in 1919 contained a number of provisions important to the de-

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[194] Melhorn, *Two-Block Fox*, pp. 30-31.

[195] After his retirement, Fullam began to argue in forums such as the New York Herald that naval air power would eventually drive dreadnoughts and battle cruisers from the sea (Rear Admiral W. F. Fullam, "Battleships and Air Power: Provisions Must Be Made in Future for Protection from Above," *Sea Power*, December 1919, p. 274). Melhorn, *Two-Block Fox*, pp. 31-32.

[196] Melhorn, *Two-Block Fox*, pp. 32-33. Melhorn notes that the General Board "had already made a tentative commitment to the aircraft carrier when it convened" (ibid., p. 32).

[197] Alfred H. Hurley, *Billy Mitchell: Crusader for Air Power* (Bloomington, IN, 1975), pp. 35-36. Mitchell's initial testimony before the Navy General Board in spring 1919 emphasized the need for wheeled fighters and carriers that could operate independently of the rest of the fleet, and was relatively compatible with the views of naval aviators (Melhorn, *Two-Block Fox*, pp. 40-41). Later testimony from Mitchell before congressional committees, however, began to emphasize more and more the need to unify all aviation in a separate air force on the British model, a position that clearly threatened the desires of USN officers to retain control over their own aviation.

[198] Van Vleet and Armstrong, *United States Naval Aviation: 1910-1980*, p. 38. One event that seems to have helped the development of a consensus within the USN favoring carriers was the success achieved by a novice airborne spotter in coaching the gunfire of the Texas to an average error of only sixty-four yards, many times better than was done by ship's spotters (Melhorn, *Two-Block Fox*, p. 37). Commander van Tol has speculated, however, that the public testimony of senior champions like Mitchell, Fullam, and Sims may have been even more decisive in pushing the USN to make a strong institutional commitment to develop carrier aviation (Commander Jan van Tol, "Historical Innovation: Carrier Aviation Case Study," OSD/NA memorandum, 27 June 1994, p. 4).

velopment of naval aviation, the most important of which was conversion of the collier *Jupiter* into an aircraft carrier, later commissioned as the USS *Langley*.[199]

Over the next six years, a series of interwoven events and developments set the course for American naval aviation during the interwar period. These developments occurred in four basic areas: (1) key individuals like Sims and William Moffett attained bureaucratic positions from which they promoted and influenced development of naval aviation; (2) aviation emerged as a recognized and separately funded enterprise within the Department of the Navy; (3) changes in the external environment modified development of U.S. naval aviation; and, (4) an *ad hoc* institutional process emerged for answering both conceptual and technical questions about how best to proceed in developing carriers and carrier aircraft. Sims had received appointment as president of the Naval War College in January 1917. After President Woodrow Wilson declared war on the Central Powers, Sims received a call to Washington "to represent the U.S. Navy in Great Britain," which he did during 1917-1918 with the same energy, skill, and intolerance for those who disagreed with him that he had displayed during his efforts to reform naval gunnery.[200] At the war's conclusion, he successfully maneuvered to return to the Naval War College, where he remained until retirement in 1922. When Sims returned to Newport in December 1918, he was an outspoken proponent of the notion that carriers would revolutionize naval warfare. He immediately began adapting war gaming at the war college into a tool to educate naval officers by providing surrogate decision-making experience in naval warfare; his tactical games "contributed substantially to the development of ideas about how to employ the aircraft carrier."[201] Ultimately, Newport's war gaming became a key element in the institutional process by which the U.S. Navy worked out answers to fundamental issues that confronted all navies in developing carrier aviation beyond the Royal Navy's achievements through 1918.

The other officer who achieved a key bureaucratic position from which to shape naval aviation was, of course, Moffett. A line officer who endorsed the philosophy of worldwide American maritime expansion, Moffett lived through the bitter resistance of line officers to absorbing engineers into their own ranks—a traumatic experience that lasted from the war with Spain to the beginning of World War I.[202] Moffett did not take aviation seriously until the war in

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199 Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 58.

200 Trask, "William Sowden Sims: The Victory Ashore," *Admirals of the New Steel Navy*, pp. 282, 286, and 289.

201 Peter P. Perla, *The Art of Wargaming: A Guide for Professionals and Hobbyists* (Annapolis, MD, 1990), p. 71. During 1919-1922 Sims oversaw the further development of two kinds of games at the Naval War College: strategic games, based on naval charts containing symbols for forces, which focused overwhelmingly during the interwar period on exploring the major problems posed by a Pacific war between the U.S. and Japan; and, board maneuvers, which were tactical games, played on a specially inscribed wooden table with three-minute time steps, designed to compare the value of different tactical formations, offensive and defensive techniques, and force mixes (ibid., pp. 71-75). While the tactical gaming materially aided naval aviation, its dominance by the Fire Effects System, which assessed damage from naval shellfire, tended to give many naval officers "a false sense of comfortably paced, discretely phased combat" which did not prepare them well for the "mayhem of the close-in clashes of the Solomons where forces rapidly approached each other at point-blank ranges, and ships' combat lives were measured in minutes" (ibid., p. 76).

202 Clark G. Reynolds, "William A. Moffett: Steward of the Air Revolution," *Admirals of the New Steel Navy*, ed. James C. Bradford (Annapolis, MD, 1990), pp. 374 and 376; also, Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 43. Moffett served under Captain Alfred

Europe demonstrated the usefulness of airplanes and he himself became involved, as commander of the Great Lakes Naval Training Station near Chicago, in satisfying the navy's pressing need for aviation mechanics in 1918.[203] When Moffett received command of the battleship *Mississippi* in December 1918, he had a turret ramp installed to launch scout planes to spot the fall of shells. In May and June of 1920, spotter planes under Captain Henry Mustin and Commander John Towers proved so effective in gunnery exercises that the *Mississippi* achieved "scores so high that they almost equaled those of all the other battleships combined."[204]

Following his tour in command of the *Mississippi*, Moffett left the West Coast on 9 December 1920 with orders to report to the Navy Department. Enroute to Washington he stopped in Illinois where he renewed links with industrialists like William K. Wrigley and J. Ogden Armour.[205] Wrigley had by then become prominent in the Republican party, and Moffett, at Mustin's urging, asked Wrigley to recommend himself to lead naval aviation; Wrigley delightedly agreed as did President Warren Harding, and in March 1921 Moffett relieved Captain Thomas Craven as director of naval aviation.[206] Congress passed legislation establishing a Bureau of Aeronautics (BuAer) as a flag-rank billet on 12 July 1921, and Harding nominated Moffett to be the first BuAer chief within a week of signing the legislation.[207] Moffett became BuAer on 26 July 1921. While the job was nominally a four-year assignment, he exploited his political connections to receive two additional four-year terms as BuAer and successfully rebuffed attempts to send him to sea or to shunt him off to the General Board.[208] As a result, Moffett remained chief of BuAer from his original appointment in July 1921 until his death in the crash of the dirigible *Akron* in April 1933.

During Moffett's long tenure at BuAer, his contributions to American naval aviation during the interwar period were many. Four bear mentioning. First, his bureaucratic skill and political connections were crucial in heading off Mitchell's efforts to create a unified air force on the model of the Royal Air Force, as well as in securing adequate funding for naval aviation through his political connections. Moffett set out to bind naval aviators to the navy, rather than see them

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Thayer Mahan's command aboard the protected cruiser Chicago in 1893-1895, and went to the Naval War College in summer 1896 during Mahan's last tour.

203 Reynolds, "William A. Moffett: Steward of the Air Revolution," p. 377. It was during his tour as commander of the Great Lakes Naval Training Station that Moffett developed an especially close relationship with the chewing-gum magnate William K. Wrigley.

204 Ibid., p. 378.

205 William F. Trimble, *Admiral William A. Moffett: Architect of Naval Aviation* (Washington, DC, 1994), p. 65.

206 Reynolds, "William A. Moffett: Steward of the Air Revolution," p. 378. While Reynolds certainly suggests that Moffett energized his political connections in order to replace Craven and become the first head of the Bureau of Aeronautics, Steve Rosen has cited documentary evidence that the senior leaders of the navy genuinely believed at the time that Moffett was the best man for the job (*Winning the Next War,* p. 77).

207 Trimble, *Admiral William A. Moffett*, p. 80.

208 Reynolds, "William A. Moffett: Steward of the Air Revolution," p. 380; also Trimble, *Admiral William A. Moffett*, pp. 150-151 and 193-195. Moffett's successor as chief of BuAer was Ernest J. King, who would serve as chief of naval operations during World War II (*Admiral William A. Moffett*, p. 273).

subsumed into a unified air force as had happened to the Royal Naval Air Service with creation of the RAF in 1918; he ultimately prevailed in early 1926.[209]

Second, while Moffett's technological choices were not always correct (as his ill-fated enthusiasm for airships proved), his long-term commitment to air-cooled, radial engines proved crucial to the fielding by the eve of World War II of rugged, reliable, high-wing-loaded aircraft with the performance to engage land-based fighters on relatively equal terms and the structural strength to withstand the G-forces involved in dive bombing.[210] Third, under Moffett's leadership naval aviation took the risks necessary to experiment as to what would work and what would not.[211] Finally, like Sims at the Naval War College, Moffett involved BuAer in the institutional process by which the naval aviation community thought through the fundamental problems of realizing the potential of naval air power.

The bureaucratic emergence of naval aviation began with establishment of BuAer in July 1921. When Moffett relieved Craven as the director of naval aviation in March 1921, aviation matters were "split up into ten divisions or bureaus of the Navy Department," each of which was "a law unto itself."[212] Creation of a separate bureau provided Moffett the opportunity to bring order to what had arguably been chaos. Further, following BuAer's establishment the navy began to make disproportionately large investments in naval aviation. From 1922 to 1928, naval appropriations dropped from $537 million to $358 million, a decline of 33 percent; nevertheless, from 1923 to 1928, appropriations for naval air grew from $14.7 million to $25 million, an increase of more than 70 percent.[213] Finally, Moffett and his allies made naval aviation an attractive career

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209 Melhorn, *Two-Block Fox*, p. 73; Trimble, *Admiral William A. Moffett*, pp. 156-166; Reynolds, "William A. Moffett: Steward of the Air Revolution," p. 384; and, Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 208. 1925 closed with the aviation board headed by Dwight W. Morrow coming out strongly in favor of the continued independence of naval aviation, as well as Billy Mitchell being found guilty by an army court-martial of the charges that resulted from his public accusation of "incompetency, criminal negligence and almost treasonable administration of our national defense by the Navy and War Departments" in the wake of the 30 August 1925 loss at sea of a PC-9 attempting to fly from San Francisco to Hawaii and the 3 September 1925 crash of the navy airship Shenandoah (Trimble, *Admiral William A. Moffett*, pp. 160 and 165-166).

210 Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," pp. 108, 177, and 192-193; also, Melhorn, *Two-Block Fox*, p. 99. The American development of air-cooled, radial engines permitted aircraft like the Grumman F4F-4 to have substantially higher wing loadings than, for example, the Japanese Zero, which achieved biplane maneuverability in a comparatively fragile airframe that even lacked armor for the pilot (Thomas C. Hone and Mark D. Mandeles, "Interwar Innovation in Three Navies: U.S. Navy, Royal Navy, Imperial Japanese Navy," *Naval War College Review*, Spring 1987, pp. 77-78). Melhorn has emphasized the importance of air-cooled radial engines in the emergence of dive bombers as genuine ship killers due to the much greater accuracy of dive versus level bombing (*Two-Block Fox*, pp. 110-111).

211 An example is Moffett's decision not to penalize naval aviators who lost carrier aircraft through honest mistakes, thereby giving them leeway to learn through trial and error (Melhorn, *Two-Block Fox*, p. 146, note 21). As a 1927 BuAer manual on aircraft tactics put it, "Risk is never to be avoided" (Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 107).

212 Trimble, *Admiral William A. Moffett*, p. 76.

213 Ibid., pp. 278-279. The budget category "Aviation, Naval" included "all direct appropriations for aircraft and engine procurement and maintenance, operations, and the miscellaneous services under the Bureau of Aeronautics' authority" (ibid., p. 168). A similar pattern can be seen in personnel. By 1929 the U.S. Navy overall had 1,500

for the service's "best and brightest." By the mid-1920s Moffett had secured the authority "to draw the best graduates of the Naval Academy into aviation."[214] More importantly, building on the Morrow Board's recommendation in 1925 that the command of flying activities, including command of aircraft carriers and naval air stations, be the preserve of qualified aviators, Moffett provided career paths for flying officers that led to command at sea.[215] Thus, he integrated aviators into the line navy, much as had occurred at the beginning of the century with engineers.

The importance of the latter achievement is perhaps best appreciated in comparison with what occurred with the British and Japanese navies during the interwar years. The Japanese chose to rely primarily on enlisted aviators rather than officers. By 1941, approximately 90 percent of Imperial Japanese pilots were enlisted compared to only 20-30 percent in the United States Navy.[216] This choice limited upper mobility for Japanese aviators who best understood the growing potential of naval aviation during the 1930s. The British ran into a similar problem, but for different reasons. In April 1918, the British Army and naval air arms separated from their services and combined to form the RAF. As a result, the Royal Navy lost nearly 55,000 officer and enlisted personnel of the Royal Naval Air Service and their accumulated experience.[217] Although the navy formed a Fleet Air Arm in 1924 (albeit under dual control with the RAF) and thinking about naval aviation did not altogether cease in the Admiralty during the interwar years, the 1918 transfer of personnel effectively denuded the Royal Navy of the personnel needed to formulate and execute sound policies, secure the best equipment, develop an institutional process for thinking through conceptual and technical problems in carrier aviation, or even win friends in high places.[218]

Changes in the external environment also affected development of U.S. naval aviation during the interwar years. In contrast to the fate that befell the British, American naval aviators ulti-

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fewer men than it had had in 1923, but naval aviation had grown by some 6,750 men over the same period (Melhorn, *Two-Block Fox*, p. 95).

[214] Hone and Mandeles, "Interwar Innovation in Three Navies," p. 74; Trimble, *Admiral William A. Moffett*, pp. 198-199. Admiral R. E. Coontz recommended that all Naval Academy graduates be given a course in aeronautics, and that the majority of graduates who qualified for aviation training be assigned to flight school upon graduation (Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 109).

[215] Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 82; Melhorn, *Two-Block Fox*, p. 98. Congress ordained in June 1927 that only aviators could command carriers and naval air stations in the U.S. Navy (Till, *Air Power and the Royal Navy* p. 45). A subtle problem regarding the integration of naval aviators into the USN during the interwar years was that, due to the high attrition they were expected to suffer in wartime, the navy needed to train so many of them that they threatened to crowd out surface line officers for promotion. As Steven Rosen has noted, the problem "was ameliorated by a system in which aviators could go into the navy reserve in peacetime, to be activated in time of war" (Rosen, *Winning the Next War*, p. 77).

[216] FitzSimonds, "The Development of Japanese Naval Air Power," p. 8.

[217] Till, *Air Power and the Royal Navy*, pp. 30 and 116-117.

[218] Ibid., pp. 40 and 111. "More to the point, the transfer of the [Royal] Navy's first generation of flyers into the RAF meant that there were hardly any aviators senior enough to command the big carriers. Whereas in 1926 the US Navy had one vice-admiral, three rear-admirals, two captains and 63 commanders who received flying pay, the Royal Navy had only one rear-admiral and a few commanders and junior captains by the start of the Second World War." (ibid., p. 45).

mately succeeded in fending off the efforts to unify American air power under an independent service. The U.S. Navy was less successful, however, in avoiding the impact of naval arms control. Starting in late 1920, Senator William E. Borah began pushing for arms limitations to stem what he saw as a fast-developing arms race in capital ships among the major powers; Borah believed that limiting naval construction would reduce tensions between the powers and lessen tax burdens on all.[219] Harding called for an international conference on naval construction on 12 July 1921.[220] The result was the Washington Naval Treaty, signed in Washington on 6 February 1922 by representatives of the United States, the British Empire, France, Italy, and Japan. The treaty established tonnage ratio of 5-5-3 for the capital ships of Britain, the United States, and Japan, respectively, and a lesser figure for France and Italy; the same 5-5-3 ratio set overall tonnage limits for aircraft carriers of 135,000-135,000-81,000 tons, while limiting new carriers to 27,000 tons with the exception that each nation could build two carriers of not more than 33,000 tons by converting existing or partially constructed ships.[221]

How did the Washington Naval Treaty affect the carrier programs of the British, American, and Japanese navies? As of early 1919, the Royal Navy's plan was to retain four old seaplane carriers—*Vindex*, *Nairara*, *Pegasus*, and *Vindictive* (totaling some 17,000 tons displacement)—and modify or complete four others—*Furious*, *Argus*, *Eagle*, and *Hermes* (more than 71,000 tons).[222] By the time of the Washington naval conference, *Argus* had joined the fleet, but *Eagle* was not yet completed, and *Hermes* and *Furious* were delayed into 1924 and 1925 respectively.[223] In subsequent years, the British proved reluctant to abandon their investment in *Argus*, *Hermes*, and *Eagle.* Thus the Royal Navy failed to build replacement carriers even though *Argus*, *Hermes*, and *Eagle* were too slow to keep up with the fleet and, collectively, could only operate a total of forty-eight aircraft.[224] Further, since the British had no large-hull, fast battle cruisers under construction for conversion to carriers, the best they could do was to convert two World War I light cruisers, *Courageous* and *Glorious*, which offered hulls in the vicinity of 23,000 tons.[225]

In contrast, both the Americans and Japanese had large-hulled battle cruisers under construction at the time of the treaty, and each converted two hulls into aircraft carriers: the U.S.

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[219] Melhorn, *Two-Block Fox*, p. 63.

[220] Harding's call for a naval arms-control conference came as the highly publicized bombing tests off the Virginia capes by navy and army aircraft to explore the vulnerability of naval combatants to aerial bombing began. These tests began on 21 June 1919 when twelve bombs from Navy F5Ls sunk the German submarine U-117; they culminated on 21 July with the sinking of the battleship Ostfriesland following the delivery of eleven 1,000- and 2,000-pound bombs from army aircraft (Van Vleet and Armstrong, United States Naval Aviation: 1910-1980, pp. 49-50).

[221] Ibid., p. 51.

[222] Till, *Air Power and the Royal Navy*, p. 64.

[223] Ibid., p. 65.

[224] Ibid., pp. 66 and 71.

[225] Friedman, *British Carrier Aviation*, p. 106; Till, *Air Power and the Royal Navy*, p. 65. Till's view is that the British decision in the early 1920s to opt for larger numbers of smaller carriers in the 20-23,000 ton range was "probably correct" seems hard to sustain in light of World War II carrier operations, especially in the Pacific. Regardless, it does seem clear that this sort of tradeoff was terribly difficult to make fifteen to twenty years before the four major carrier engagements of 1942—the battles of the Coral Sea, Midway, the Eastern Solomons, and the Santa Cruz islands—provided empirical evidence on the issue.

Navy's *Lexington* and *Saratoga*, and the Japanese *Kaga* and *Akagi*.[226] In retrospect, carriers of this size were crucial to World War II carrier operations. Ships like *Lexington* and *Saratoga*, had difficulty from the outset staying under the treaty limit of 36,000 tons.[227] Consequently, they were not only large enough to accommodate the heavier, higher performance naval aircraft of World War II, but could operate those aircraft in far greater numbers than the carriers of the Royal Navy.[228] Indirectly, therefore, the Washington Naval Treaty constrained the British more than the Americans and Japanese, at least partially as a result of the early lead in naval aviation that the Royal Navy had achieved during the last war.[229]

To appreciate the often-subtle but cascading effects of the fact that the British were stuck with carriers displacing 23,000 tons or less, one needs to consider the institutional process that emerged within the U.S. Navy for answering fundamental questions about how best to proceed in carrier and aircraft development. The first American carrier, the converted collier *Langley*, was not commissioned until March 1922 and did not join Aircraft Squadron Battle Fleet as a second-line combat ship until December 1924.[230] Initially, therefore, American thinking about carrier operations and requirements rested on the experience of others. The alternative that Admiral Sims provided at this stage consisted of simulations at the Naval War College in Newport, Rhode Island. What Sims and his war gamers developed, particularly in their tactical simulations, was a systematic analytic device for exploring naval aviation's potential.[231]

One of the insights that emerged from Newport's games in the early 1920s was the realization that the tactical dynamics of offensive carrier operations differed fundamentally from battleship engagements. When battle lines of dreadnoughts engaged, the fires of the two sides came more or less in steady streams, and each side could redirect or concentrate its "stream" of fire on the enemy's surviving ships as the engagement progressed. Anticipating the attrition equations of Frederick W. Lanchester for warfare under "modern" conditions (that is, with long-range fire

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[226] A modernization clause in the Washington Naval Treaty in fact permitted Lexington and Saratoga to approach 36,000 tons displacement (Friedman, *U.S. Aircraft Carriers*, p. 43). Inevitably, however, the displacement of these ships grew over time.

[227] The Washington Naval Treaty also permitted the 33,000-ton limit for the one-time conversion of two cruisers to be exceeded by another 3,000 tons for additional protection such as deck armor and underwater blisters (Friedman, *U.S. Aircraft Carriers*, p. 43).

[228] Ibid., pp. 48-49.

[229] To say that the Washington Naval Treaty ultimately constrained the British more than the Americans or Japanese in development of effective carrier aviation between the two world wars is not to say that the treaty significantly constrained the development of carrier aviation overall. Jan van Tol has noted that the Washington Naval Treaty reduced the investments that the American, British, and Japanese navies might otherwise have made in battleships (Commander van Tol, "Historical Innovation: Carrier Aviation Case Study," p. 6). So if battleships had not been constrained, all three navies might have ended up with less to invest in naval aviation than they ended up with under the treaty.

[230] Garth L. Pawlowski, *Flat-Tops and Fledglings: A History of American Aircraft Carriers* (New York, NY, 1971), pp. 19 and 20. Langley, not even able to keep up with battleships, was never more than an experimental carrier, and did not figure in tonnage limitations of the Washington Naval Treaty because she was in existence in 1921 (Friedman, *U.S. Aircraft Carriers*, p. 37). Only with the passage of the Vinson-Trammell Act in 1934 did Langley count in the total carrier tonnage the U.S. was allowed under law (ibid.).

[231] Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," pp. 64-65 and 73.

weapons),[232] three naval officers—J. V. Chase, Bradley A. Fiske, and Ambroise Baudry—depicted the cumulative results of a dreadnought battle between fleets of differing strengths in terms of a “square-law” relationship.[233]

Simply stated, this relationship suggested that, all other things being equal, the effectiveness of opposing forces in inflicting attrition on each other equaled the square of their respective fighting power at any point in the engagement.[234] If a battle of annihilation occurred between two battleship lines in which one possesses twice the fighting power (for example, twenty battleships versus ten), the numerically superior side would annihilate its opponent at a cost of approximately 17 percent of its initial force (roughly three battleships lost and one damaged in return for destroying all ten of its opponent’s ships).[235] By comparison, if the attrition in such a contest instead followed the “linear” relationship Lanchester postulated that the superior side could still defeat the smaller, but would lose ten battleships in sinking ten of the enemy’s.

Tactical gaming at Newport in the early 1920s indicated that carrier strikes came in discrete pulses of combat power rather than in continuous streams, and that the effectiveness of such pulses on the enemy was a linear function of the number of aircraft that attacking carriers could launch in a given pulse or strike.[236] Hence, the fundamental measure of offensive carrier effectiveness was the number of aircraft it could launch for a given mission.

This insight had far-reaching implications for the development of American naval aviation. It suggested that in fleet engagements striking first with carrier aircraft conferred enormous advantages; in addition, it indicated that to gain air superiority over the enemy fleet, the initial object of carrier strikes should be the enemy’s carriers.[237] On the size of carrier air wings and their operation, Newport’s tactical gaming underlined not only that the more planes a carrier could take

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[232] Lanchester’s so-called “laws of war” postulated two distinct relationships—his “linear” and “square” laws—between casualties, force ratios, and defeat in tactical engagements, depending on whether the opposing sides are armed with “ancient” weapons such as swords, or with “modern long-range” weapons like rifles (F. W. Lanchester, *Aircraft in Warfare: The Dawn of the Fourth Arm* [London, 1916], pp. 40-41). Lanchester was a British automotive engineer, and he used differential equations to describe the differing effects of superior numbers on attrition depending on whether ancient hand weapons or modern fire weapons were being used by the opposing sides.

[233] Hughes, *Fleet Tactics*, p. 66.

[234] For a relatively simple derivation of the square-law relationship, see Hughes, *Fleet Tactics*, pp. 35-36. The attrition model assumes that both sides choose to fight to the death, which is not what occurred in the 1916 Battle of Jutland.

[235] Ibid., p. 69. This result assumes a salvo model of the engagement. If a “continuous fire” Lanchester model is used, the numerically superior side will annihilate the other after only losing about 13 percent of its initial fighting power rather than 17 percent.

[236] Friedman, Hone, and Mandeles, “The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy,” p. 73. As Hughes has demonstrated, the carrier battles that occurred in the Pacific during World War II confirm that the dynamics of offensive carrier operations are driven by a pulse of air power. See *Fleet Tactics*, pp. 94-101. The one notable difference between war-college theory and operational practice in 1942 was that both American and Japanese naval aviators assumed, before as well as during much of World War II, that a strike by a single carrier air wing could sink two or three enemy carriers (ibid., pp. 94-95, 104, and 109). In reality, a strike by an American or Japanese carrier air wing in 1942 seems at best to have only been capable of sinking or disabling a single carrier.

[237] Commander van Tol, “Historical Innovation: Carrier Aviation Case Study,” p. 7.

to sea, the better, but that lowering aircraft launch, recovery, and on-board handling times was the crux of effective carrier air operations.[238]

Perhaps the most important ramification of such ideas was that they fed into an interactive, evidence-driven institutional process that involved the General Board, the Bureau of Aeronautics, war planners in the office of the chief of naval operations, active aviators in the fleet, and, through annual exercises, the fleet itself. One can see a striking example of this interplay and feedback in the experiments with the USS *Langley* conducted by Captain (later Admiral) Joseph M. Reeves. Reeves began the senior officers' course at Newport in fall 1923; after graduation he became head of the Tactics Department where he supervised the 1924-25 games; in summer 1925 he completed the aviation observer course at Pensacola and then received appointment as Commander, Aircraft Squadrons, Battle Force.[239] At that time, the *Langley* was the navy's only carrier, and it was to improving the aircraft operations on the *Langley* that Reeves turned his attention in late 1925.[240]

Having learned from Newport simulations that the number of aircraft a carrier could get into the air was crucial, Reeves shortened aircraft launch and recovery times, and increased the number of planes operating off the *Langley*. By August 1926, *Langley* had acquired a crash barrier to prevent recovering aircraft (whose tail hook had missed the arresting cables) from crashing into aircraft that had already landed, the "deck-park" practice of moving aircraft from one end of the flight deck to the other for launch or recovery was in operation, and *Langley*'s crew could launch aircraft every fifteen seconds and recover them every ninety seconds.[241] In one year, Reeves increased *Langley*'s aircraft complement from fourteen aircraft to four combat squadrons capable of operating forty-eight aircraft in combat.[242] In addition, *Langley*'s pilots had begun experimenting with dive bombing, which quickly demonstrated its accuracy for attacking ships that were underway.[243]

238 Operational experience would eventually show that, for the U.S. carrier operations, "the central issue was the size of a single deckload strike the flight deck could accommodate" (Friedman, *U.S. Aircraft Carriers*, p. 47). This formulation presumes the practice of deck parks, meaning that carrier operations were conducted using the aircraft on the flight deck. This practice required effective crash barriers during recovery, and moving recovered aircraft to the rear of the flight deck in order to initiate another launch. "Arguably the single most important British interwar naval air decision was a tacit one: not to adopt deck parks." (Friedman, *British Carrier Aviation*, p. 11).

239 Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," pp. 80-81. The observers course constituted catch-up training on aviation and flying for senior officers who were not pilots. Moffett originally established it when Billy Mitchell tried to block Moffett's appointment to head BuAer on the grounds that Moffett was not a qualified aviator. "Moffett simply set up an 'aviation observer' course at Pensacola, completion of which would qualify him as an 'aviator,' and had himself ordered to the course" (Melhorn, *Two-Block Fox*, p. 69).

240 *Lexington* and *Saratoga* did not join the U.S. fleet until 1928.

241 Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 85.

242 Ibid., pp. 90-91.

243 Ibid., p. 92. While the accuracy of dive bombing emerged during the 1920s, it was not until the 1930s that dive bombers could carry bombs large enough to be true ship killers. "In 1929, the F8C-4, used as a bomber, was powered by a 450 hp. engine, had a gross weight of 4,020 lbs., flew at 146 mph and had a range of 720 statute miles carrying two 100-lb. bombs. The SBC-4 of 1937 had, in comparison, a 950 hp. engine, a gross weight of 7,632 lbs., a maximum speed of 237 mph, and a range of 590 statute miles carrying a 1,000 lb. bomb. The monoplane SBD-2 of 1941 could carry 1,200 lbs. of ordnance 1,100 miles." (ibid., p. 105).

Many things flowed from these innovations. Reeves' success in increasing the numbers of aircraft the *Langley* could launch at a time generated empirical data that fed back into the rules governing subsequent war games at Newport. Moffett then capitalized on Reeves' early success to generate support for a five-year, 1,000-airplane program that allowed BuAer to pursue specialized carrier aircraft—fighters, spotters, dive bombers, etc.—rather than multipurpose aircraft.[244] Finally, by the time *Lexington* and *Saratoga* went to sea for Fleet Problem IX (held off Panama during 23-27 January 1929), the fleet had extended the deck-park concept to include refueling and rearming on the flight deck itself, and *Saratoga* boasted an air wing of 110 airplanes with 100 pilots.[245]

These complex interactions exemplify the institutional process for developing carrier aviation within the navy during the immediate postwar years. While the process may not have been entirely objective—few, if any, institutional processes ever are—it was based primarily on experimentation and evidence, as well as accepted by those involved in naval aviation. Initially, simulations explored concepts and new ways of fighting that the navy could not test with its existing equipment. As the first carriers and carrier aircraft became available, broad insights such as the realization of how important it was to maximize the number of aircraft that carriers could launch became linked to specific technical problems such as finding ways to recover aircraft without the need to move each aircraft below deck before the next could land.

From these linkages flowed a series of technical choices in carriers, their aircraft, and related equipment. In hindsight, the four carrier battles of 1942 in the Pacific largely validated these choices. Granted, the processes by which the navy made its choices were seldom smooth or straightforward. Linking conceptual thinking about the future to specific technical choices in the present is seldom easy. Nor would it be accurate to imply that these processes enabled American naval aviators during the 1920s to see the future more clearly or in greater detail than their British or Japanese counterparts. Even on the eve of the Japanese attack on Pearl Harbor, it seems doubtful that U.S. naval leaders foresaw the aircraft carrier's ascendance any more clearly than *Wehrmacht* leaders recognized the full implications of the *Blitzkrieg* on the eve of the May 1940 campaign. Nevertheless, the U.S. Navy did develop institutional arrangements for testing visions of the future, and those arrangements were, for the most part, based on using experimentation and evidence that connected conceptual thinking with specific technical choices.

The fundamental point about the Royal Navy's efforts to develop carrier aviation during the period is that the British had no such institutional processes.[246] It was not so much that the British in the interwar period failed to recognize that carrier effectiveness depended on the number of airplanes that they could launch. Rather, as the only navy with carrier combat experience, British naval officers presumed that the relatively small numbers of aircraft they could generate

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244 Ibid., pp. 91-93.

245 Ibid., p. 95. Fleet Problem IX is generally viewed as the first real test by the U.S. Navy of multiple carriers launching significant numbers of aircraft (ibid.). The climax of this exercise came when *Saratoga*, commanded by Reeves, left the main force of battleships and, accompanied by one light cruiser, made a high-speed run from the west and launched a seventy-plane strike against the locks of the Panama Canal from a range of 140 miles (ibid., p. 96). This strike, however, was not part of the original plan for the exercise and seems to have come about simply because the destroyer screen for *Saratoga*'s battleship escort did not have the fuel to stay with her (ibid.). Nevertheless, after Fleet Exercise IX, carriers "were accepted as fleet units" (ibid., p. 97).

246 Ibid., p. 121.

any one time represented the best that anyone could do. Admiralty assessments of U.S. carrier developments during the 1930s indicate that the British discounted, if not disbelieved, American claims about the numbers of aircraft operating at one time from U.S. carriers.[247]

Consequently, the British were content to stay with smaller carriers in the 20-23,000-ton range, which constrained storage for aviation fuel regardless of the number of aircraft carried; they failed to adopt deck parks and preferred to stow aircraft not engaged in flight operations in the hangar deck; without effective catapults or arresting gear throughout most of the period (even though the Royal Navy had originally invented both), the launch and recovery of their carrier aircraft required more space than American operations and further constrained the number of aircraft on deck; the Royal Navy chose armored decks and antiaircraft guns rather than defensive fighters as the best way to defend their carriers from air attack and maximize the number of strike aircraft they could take to sea;[248] they ignored dive bombing until late in World War II; and, they stayed with low-performance, multipurpose, multi-seat planes to keep landing and takeoff speeds below sixty knots.[249] Virtually all these technical choices were to one degree or another flawed, individually and even more so in their cascading, cumulative effects. With each step down a path that started with trying to keep planes "hangared" below flight deck except during launch and recovery, the British found it harder and harder to strike out in new directions.

Again, one can argue that, starting with the formation of the RAF, the Royal Navy was virtually prohibited from maintaining the institutional processes that might have produced better decisions and technical choices. Still, given the absence of such arrangements, as well as the bureaucratic and technical trappings that they would have entailed, it seems difficult to maintain that so many bad choices were simply a matter of bad luck. The British failure to push carrier aviation as far as the Americans and Japanese in spite of their early lead resulted primarily from the ab-

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[247] Ibid., p. 143. In a 4 October 1928 letter, Reeves noted that he had hidden the Langley's true aircraft complement from Vice Admiral Fuller of the Royal Navy (ibid., p. 94, note 133). In 1928 Reeves ordered the Langley's captain to board forty-two aircraft, three times her normal complement, for fleet exercises off Hawaii; since the British could not operate more than twelve aircraft from a carrier at that time, it was not surprising that the British refused to believe that Langley could operate with even twenty-four (Rosen, *Winning the Next War*, p. 71). Documentary evidence that the British did not appreciate as late as 1935 how large the operating complements of U.S. carriers had become can be found in the foreign developments section of the Royal Navy's annual "Progress in Tactics" during the 1930s, especially in the 1935 edition. Friedman still recalls a conversation he had with a British naval constructor that revealed this individual had still not grasped, some decades after its combat use during World War II, the American notion of a deck park (Friedman, telephone conversation with Barry D. Watts, 4 January 1995).

[248] The issue of armored carriers is particularly difficult to assess. Japanese and American carriers proved, as the British had foreseen, so vulnerable in 1942 that, after the battle of the Santa Cruz Islands in October, both sides were reduced to a single surviving carrier and their naval air wings had suffered grievous attrition (Hughes, *Fleet Tactics*, p. 100). The situation in the Pacific by 1944 was considerably different—at least on the American side. By sorting out air tactics and adding anti-air warfare ships and weapons (including the variable-time or proximity fuse), the defensive capabilities of U.S. fast carrier task forces became quite formidable (Hirama, "Japanese Naval Preparations for World War II," pp. 78-79). Consequently, what "had been a battle to sink carriers in 1942 had become a battle to destroy aircraft" by 1944 (Hughes, *Fleet Tactics*, p. 102).

[249] Commander van Tol, "Historical Innovation: Carrier Aviation Case Study," pp. 14-15; Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," pp. 147, 149-152, and 154-155.

sence of systematic, rigorous, evidentiary-based processes for testing visions and linking them to sound technical decisions about carriers and their aircraft.

Implications for the Next Military Revolution

The question with which we began was: Especially during the twentieth century, what have been the fundamental technological, operational, and organizational factors that, during times of peace, give rise to fundamental changes in how future wars are fought? Our underlying aim was to identify, based on an examination of certain aspects of the historical record on innovation during the years 1918-1939, some of the specific actions, bureaucratic tactics, and strategies that senior current American defense officials today, whether military or civilian, might consider to facilitate and foster innovation in the years ahead. The motivation for both question and purpose was the *hypothesis* that we are now in the early stages of a period in which advances in precision weaponry, sensing and surveillance, computational and information-processing capabilities, and related systems will trigger substantial changes in future wars, changes at least as profound and far reaching as the combined-systems "revolutions" of the interwar period. Having examined three instances of such peacetime innovations in some detail, what implications can one draw?

To begin with, one must never lose sight of the impact contingency often has on successful innovation. Sometimes the historical cards that military institutions are dealt increase the odds against successful innovation. In the interwar period, the British army's deep-rooted regimental system and disdain for the serious examination of the last war certainly stacked the odds against development and adoption of mobile armored warfare. Yet despite these odds, the British army managed to conduct enough experimentation with tanks by 1926 to assist substantially the German deployment of armored formations in the mid-1930s. But having moved towards defying the odds, contingency then intervened. When the chief of the imperial general staff, Lord Milne, offered command of the experimental armored unit to Britain's most experienced tank advocate, J.F.C. Fuller turned the assignment down because he, as a lieutenant colonel, had not received everything that he wished. Thereafter, Fuller became more and more of an ideologue whose strident advocacy of an ill-tank army served to keep British innovation with armor outside of the mainstream of the army.

A similarly contingent turning point came for the British with the signing of the Washington Naval Treaty in early 1922. Because the Japanese and the Americans were struggling to catch up with the Royal Navy in capital ships, each had two large battle-cruisers under construction at that time, whereas the British, for reasons that reached back to their pre World War I dreadnought competition with the Germans did not.[250] For the Americans and Japanese, the conversion of these hulls to aircraft carriers, as permitted by the treaty, not only made economic sense, but gave their navies large-deck carriers whose displacements exceeded those the British elected to stay with during most of the interwar period by approximately 10,000 tons.

250 In 1905 the Royal Navy determined to trump the German naval buildup by constructing the Dreadnought. By so doing they provided themselves with a cushion of quantitative superiority that played a significant role in their domination of the High Sea Fleet throughout World War I. But that naval superiority (over all the world's navies) also led the British into a situation where they had no battle-cruisers under construction in 1922. Hence British innovation was substantially constrained by the available platforms -- a situation very much the result of their intelligent response to an earlier threat.

At the same time, the British decision in 1922 to stick with converting cruisers in the vicinity of 23,000 tons made economic sense but started the Royal Navy down a long path that, by 1939, would leave it far behind the Americans and Japanese. As a reviewer of this essay has suggested, the contingent nature of these decisions should not be taken to imply that the British Admiralty after 1922 down played carriers, failed to see their value, or "made systematic errors" regarding their development. What it does suggest though, is that even when a military service does a "lot of things right most of the time, just a temporary failure in finance or policy or thought for the space of a few years can create major difficulties for innovation."[251]

The evidence suggests, first of all, the importance of developing visions of the future. Military institutions not only need to make the initial intellectual investments to develop visions of future war, but they must continue agonizing over such visions to discern how future wars might differ from the last due to changes in military technology and weaponry, national purposes, and the international security environment. As the above cases also attest, any vision of future war is almost certain to be vague and incomplete rather than detailed and precise, much less predictive in any scientific sense. Nevertheless, without the intellectual effort and institutional commitment to develop and evolve a vision of future war, military institutions will almost certainly fail to take the first halting steps toward peacetime innovation. Furthermore, commitment to any particular institutional vision by senior leaders tends to have long-lasting consequences, whether for good or ill. Seeckt's post-World War I vision of mobile warfare by a highly professional, well-trained, well-led army illustrates how long-lasting and powerful the choice of a sound vision of future warfare can be.

Vision, however, is not enough to produce successful innovation. One's view of future conflict must also be balanced conceptually and well connected to operational realities. The Germans' development of *Blitzkrieg* during the interwar period connected with a broader goal of developing mobile warfare within the specific strategic context of a continental power with potential adversaries on two fronts. The broad goal of sea control played much the same role in the U.S. Navy's development of carrier aviation between 1918 and 1941.[252] In the second case dive bombers with the striking power to kill capital ships did not emerge until late in the 1930s, and even in 1944 the big guns of the battleships still dominated naval engagements at night.[253] So the state of technology certainly affects the pace of change.

By comparison the strategic bombing theories developed in the United States and Britain between the wars somehow lost the balance (or intimate connection with operational reality) that the overarching goals of mobile warfare and sea control provided soldiers and sailors in developing *Blitzkrieg* and carrier aviation. The exact source of the difference is hard to pinpoint. But whatever the precise cause or causes, it was surely entwined with the airmen's belief that, because bombing could directly attack the means and morale of the enemy state, strategic air attack constituted "a new form of warfare," whose "sphere of activity" was literally above and beyond that of

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[251] Comment by Cambridge University Press' reader for this manuscript.

[252] As David Mets has noted, command of the sea was the first goal for the U.S. Navy throughout the interwar period; it was the means of achieving that goal—battleship guns or carrier aircraft—that underwent transformation, and the USN was prudent not to bet on aircraft prematurely (David R. Mets, "The Influence of Aviation on the Evolution of Naval Thought," unpublished draft, School of Advanced Airpower Studies, Maxwell AFB, Alabama, 22 November 1994, p. 20).

[253] Hughes, *Fleet Tactics*, p. 105. In 1927, for example, the USS Colorado and her sister ships, using air spotters, were firing very accurately over the horizon out to ranges of 29,000-32,000 yards (Friedman, Hone, and Mandeles, "The Introduction of Carrier Aviation into the U.S. Navy and the Royal Navy," p. 93).

armies and navies.[254] At least during the interwar years, this imbalance blinded bomber proponents to the considerable difficulties of successfully executing independent strategic air operations against a resourceful and determined enemy.

The second reasonably straightforward implication of our historical cases concerns the unavoidable necessity of bureaucratic acceptance to successful peacetime innovation. Visionaries like J. F. C. Fuller or Admiral Fullam certainly had their places in goading the military institutions they sought to reform to reconsider accepted ways of doing business. But the complexity and high technological content of modern warfare indicates that one or two vocal visionaries will not suffice to bring about far-reaching, combined-systems innovations on which we have focused in this essay. Without the emergence of bureaucratic acceptance by senior *military* leaders, including adequate funding for new enterprises and viable career paths to attract bright officers, it is difficult, if not impossible, for new ways of fighting to take root within existing military institutions.

Bureaucracies, by their very nature, "are *not* supposed to innovate,"[255] and changes in weaponry do portend, as Elting Morison has noted, changes in military "societies." Consequently, it seems unlikely that any handful of visionaries, however dedicated and vocal, have much chance of forcing military institutions to adopt fundamentally new ways of fighting without the acquiescence or grudging cooperation implied by emerging bureaucratic recognition and acceptance. Even in Seeckt's case, it was undoubtedly crucial to the *persistence* of his reforms within the *Reichswehr* that he ensured that his successor was of like mind on the need for a highly trained army and the importance of pursuing mobile warfare.[256]

As a corollary to the importance of bureaucratic acceptance among senior military leaders, the dynamics evident in the case studies suggest that the potential for civilian or outside leadership to *impose* a new vision of future war on a reluctant military service whose heart remains committed to existing ways of fighting is, at best, limited. A recent case in point can be seen in the steadfast refusal of the institutional air force to accept the critique of high-technology weaponry mounted by "military reformers" such as Franklin C. Spinney, William S. Lind, and John R. Boyd during the 1980s.[257] There is, however, another aspect to the inherent difficulties of reforming

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[254] Webster and Frankland, *The Strategic Air Offensive against Germany*, vol. I, pp. 6-8.

[255] Rosen, *Winning the Next War*, p. 2.

[256] Corum, *The Roots of Blitzkrieg*, p. 176. "Seeckt was dismissed as Reichswehr commander in October 1926 for initiating a political controversy: He had invited a Hohenzollern prince to attend the fall maneuvers. To ensure that his policies would be carried on...Seeckt arranged for General Heye, chief of the Truppenamt and a supporter of...Seeckt's policies, to be appointed commander after him." (ibid.).

[257] For the U.S. Air Force's side of this debate, see (then Colonel) Walter Kross, *Military Reform: The High-Tech Debate in Tactical Air Forces* (Washington, DC, 1985). For the reformers' side of what was often termed the "quality-quantity" debate, see Franklin C. Spinney, *Defense Facts of Life: The Plans/Reality Mismatch*, ed. James Clay Thompson (Boulder, CO, 1985). In retrospect, one of the ironies of this debate would appear to be that Richard Cheney, who was a congressional supporter of the military reformers' views on Capitol Hill in the mid-1980s, later became the defense secretary on whose watch the 1991 Persian Gulf war occurred, a war which USAF leaders saw as broadly vindicating their investments in advanced systems like precision-guided weapons and low-observables technology. As then Chief of Staff General Merrill McPeak noted in the immediate aftermath of Desert Storm, "Stealth, in combination with precision-guided munitions, I think, has certainly the potential to revolutionize warfare" ("Transcript of McPeak Briefing on Air Force Air Power in the Iraqi War," *Inside the Air Force*, 22 March 1991, p. 16). Key air force figures in the planning and execution of the Desert Storm air campaign, including General Charles Horner (the Joint Forces Air Component Commander during the war), have made much the same point ("Can Bombing Win a War?," NOVA television show #2002, Journal Graphics transcript, 19 January 1993 [air date], pp. 1 and 6-7).

military institutions from the outside, whether by strident critics like Liddell Hart or by civilian leaders like service secretaries. If "outsiders" do entertain serious hopes of changing military institutions, their best chance for long-term success lies in "encouraging" bureaucratic acceptance by such means as changing officer career paths or creating organizations like the Bureau of Aeronautics.

Third, institutional processes for exploring, testing, and refining conceptions of future war—in the specific sense of linking those inherently imprecise and ever-evolving visions to concrete decisions over time about new military systems, operational concepts, doctrines, and organizational arrangements—are literally a *sine qua non* of successful military innovation in peacetime. Especially in the case of what we have termed *combined-systems innovations,* the critical issue is achieving a better "fit" between hardware, concepts, doctrine, and organizations than do one's prospective adversaries. Furthermore, to have any real chance of beating the competition demands some evidentiary-driven process such as the German Army and the U.S. naval aviation community created after World War I.

Such a process, in turn, hinges crucially on what we would loosely term the "intellectual atmosphere" of the military societies involved. A litmus test for any military institution confronted with the need for substantive peacetime innovation is a willingness to examine past military experience with something approaching the degree of objectivity, candor about shortcomings (or, even, outright failures), and openness to radical ideas that characterized the *Reichswehr* under Seeckt.

By way of underscoring this conclusion, several points are worth noting about the willingness of the American military to subject its performance in the Persian Gulf War to such scrutiny.

- First, the U.S. military conducted no comprehensive battlefield survey of the territory occupied by Coalition forces on 1 March 1991.

- Second, while the U.S. Air Force in general, and former Secretary of the Air Force Donald Rice in particular, deserve much praise for the Gulf War Air Power Survey's thorough examination of the air campaign, the institutional air force has leaned toward ignoring some of the messier, less convenient aspects of what the survey uncovered, just as the founding fathers of the U.S. Air Force largely ignored the surprisingly parallel findings of the U.S. Strategic Bombing Survey concerning air power's strategic efficacy against Nazi Germany and Imperial Japan.[258] It should be discomforting to observe that a 1993 Defense Science Board panel concluded that reluctance of the air force and navy to make the needed investments in precision-guided weapons and associated target-engagement systems may be one of the lessons most conspicuously "not learned" from the Persian Gulf War.[259]

- Third, there does not appear to be *any* precedent in the entire history of the American military for subjecting past combat experience to the kind of merci-

[258] Smith, *The Air Force Plans for Peace: 1943-1945*, pp. 25-26.
[259] Office of the Under Secretary of Defense for Acquisition and Technology, "Report of the Defense Science Board Task Force on Tactical Air Warfare," November 1993, cover memorandum, p. 1.

less institutional scrutiny manifest in the German examination of World War I under Seeckt.

- Finally, as the case of Anglo-American theories of strategic bombardment underscores, the adverse consequences of military theories unchecked by evidence, or based on a fundamental misunderstanding of combat processes, can be extremely costly in both blood and treasure when put to the test of combat.

To push the third of these four points a bit further, the organizational process of testing visions of future war at sea based on experimentation and evidence that emerged in the U.S. naval aviation community during the early 1920s cannot be attributed to the navy as a whole. One of the more poignant demonstrations of this observation is the ineffectiveness of American submarines during the early years of World War II that stemmed from inadequacies in both torpedoes and submarine skippers. What is most striking about the problems with the Mark XIV torpedo and the Mark VI exploder is how reluctant the bureaucracy responsible for those devices was to admit even the possibility of design defects despite the accumulation of combat experience in the Pacific indicating that something was extraordinarily wrong with either the torpedo, the fuse, or both. By the end of March 1942, "almost every Pearl Harbor submariner who had fired a torpedo in anger" believed one or both of these devices to be defective.[260] It turned out there were three major design defects in this weapon, but it was not until August 1943—*twenty-one months* into the Pacific war—that the navy, with little help from the engineers finally isolated and solved all three design flaws. Worse, each defect had to be first discovered and fixed *in the field*, in all cases "over the stubborn opposition of the Bureau of Ordnance."[261]

As for the "skipper problem," even though the American submarine commanders who began the Pacific war were both Annapolis graduates and "a handpicked, highly qualified group...by peacetime standards," almost 30 percent had to be relieved "for unfitness, or lack of results, during 1942," and another 14 percent in 1943 and 1944.[262] What these problems suggest is that the naval aviation community's praiseworthy process for testing visions of future carrier warfare did not extend to all parts of the navy during the interwar years. We emphasize this point not for the sake of criticizing the interwar navy, but to underscore how fragile and isolated the *ad hoc* processes by which BuAer, the Newport war gamers, the General Board, the fleet, and war planners in the CNO's office tested a vision of carrier operations in the 1920s and 1930s was. One suspects that without explicit and forceful nurturing by senior flag officers, the kind of narrow-mindedness evident in the Bureau of Ordnance over torpedoes is, and will be, the rule rather than the exception.

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260 Clay Blair, Jr., *Silent Victory: The U.S. Submarine War against Japan* (New York, NY, 1975), p. 216.
261 Ibid., p. 439.
262 Ronald H. Spector, *Eagle against the Sun: The American War with Japan* (New York, NY, 1985), pp. 481-482. While the reasons for the "skipper problem" were many, the bottom line was that many officers who had been perfectly satisfactory in peacetime were shown, by the test of combat, to lack "the combination of nerve, judgment, and calculated recklessness needed in a successful submarine commander" (ibid., p. 130; see also Blair, *Silent Victory*, pp. 199-201). As the 1933 *Truppenführung* rightly observed: "In war, character outweighs intellect. Many stand forth on the field of battle who in peace would remain unnoticed." (*Truppenführung*, U.S. Army Report No. 14,507, p. 1).

The other aspect of organizational processes for testing visions of future war that bears underscoring is the paramount importance of empirical evidence. One could argue that, in a process or structural sense, the institutional arrangements for examining visions of the future that emerged at the Air Corps Tactical School during the 1930s were every bit as admirable and sound as those evident in the *Truppenamt* during Seeckt's tenure, or within the American naval aviation community during Moffett's era at BuAer.

Yet, based on the ruthless test of World War II combat,[263] the latter two processes seem to have been discernibly more realistic and successful than the first. Why? The main difference we can see in the case studies is, once again, openness to real-world evidence. The Germans preserved their World War I combat experience and built on it with further experimentation that gave due attention to the difficulties, frictions, and nonlinearities of actual combat. The many strategic mistakes that the Germans subsequently made in their prosecution of World War II—starting with their failure to prepare Germany's economy for prolonged war or even incorporate mass-production and managerial control techniques—largely offset the realism they displayed in developing the *Blitzkrieg*, but these mistakes should not blind us to what they got right and why.

Similarly, American naval aviators were reasonably successful in substituting war games, fleet exercises, day-to-day flight operations from carriers, and related experimentation with the technical aspects of operating carriers and their aircraft for direct combat experience. But in the case of the Air Corps Tactical School, unchecked vision and pure theory increasingly took precedence over the unruly realities, nonlinearities, and the messiness of actual combat. The difference was a subtle one, yet of critical importance nonetheless when one considers some of the shortcomings that emerged during World War II bombing operations.

A related hypothesis—and we offer it as no more than that—is that military organizations which have trouble being scrupulous about empirical data in peacetime may have the same difficulty in time of war. The RAF's failure before and during the early years of World War II to deal with the problems of locating targets, much less accurately bombing them, would appear to be a graphic instance of this sort of intellectual "bad habit" carrying over from peacetime to wartime.

The last major implication that emerges from the three cases concerns the complex way in which contingency pervades peacetime military innovation. On the one hand, chance, luck, nonlinearity, and pure serendipity are part and parcel of the process.[264] An early lead, or having triumphed in the last conflict, by no means guarantees success in coping with the sort of fundamental changes in future wars that now appear to lie just over the temporal horizon, just out of clear view. On the other hand, the case studies also suggest that the role of chance by no means implies that peacetime innovation is tantamount to a series of random rolls of the dice. The appearance of a Dowding, Moffett, or Seeckt in the right place at the right time is hard to count upon, as is the decision of a Sims to return to an intellectual post such as the Presidency of the Naval War College after serving as the U.S. Navy's representative to Great Britain. But these kinds of "happenstance" events, once they occur, tend to have long-term consequences for peacetime innovation.

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263 As R. V. Jones observed, "...war is different from peace: in the latter fallacies can be covered up more or less indefinitely and criticism suppressed, but with the swift action of war the truth comes fairly quickly to light..." (*The Wizard War*, p. 139).

264 Admiral William Owens succinctly captured this aspect of peacetime innovation when he noted, during the first of a series of OSD/NA "innovation workshops" held in the Pentagon in late 1993, that "innovation is a crap shoot."

A metaphor for this aspect of innovation suggested by Andrew Marshall is that of walking into a gambling casino for an evening at the crap tables. Chance is clearly involved, but over any extended period of time, the house has a large advantage. Finding individuals with the capabilities of a Dowding or a Seeckt, willingly supporting them for the long haul, making emergent areas of military capability founded on new weapons or operational concepts attractive to the brightest career officers available, and encouraging evidentiary-driven institutional processes as a basis for making technical choices, changing doctrine, and evolving new organization arrangements for future combat are unquestionably among the things likely to confer a similarly large advantage to the American military in the decades ahead.

This conclusion further suggests that genuine innovation, like democratic government, is unlikely to be a tidy process—much less one that can be tightly or centrally controlled by senior defense managers. Indeed, attempts to eliminate the inherent messiness—including the tendency for adaptation to proceed in fits and starts[265] —may be one of the surest ways to kill innovation. At the same time, however, senior leaders who do manage to choose a fruitful vision of future war during periods of fundamental change in how wars are fought can certainly set the basic direction for long-term innovation. In fact, judging on the basis of the major turnarounds achieved by Ford in the 1980s and Chrysler in the early 1990s, major shifts in how military organizations envision future war are possible in a relatively few number of years, even though full maturation of the new way of fighting may still take a decade or two. And, if senior leaders also manage to inculcate the requisite intellectual atmosphere and institutional processes within the military societies involved, then they will greatly enhance the chances for long-term success.

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[265] Recent research on how a sampling of U.S., European, and some successful Japanese companies have adapted to technological change suggests that such adaptation occurs in fits and starts: there is an initial, intense burst of adaptive activity followed by longer periods of relatively stable, routine use as participants return to more regular production and day-to-day tasks (Marcie J. Tyre and Wanda J. Orlikowski, "Exploiting Opportunities for Technological Improvement in Organizations," *Sloan Management Review*, Fall 1993, pp. 13-14). One major reason for this episodic pattern seems to be that there are limits to how much change people endure within a given period of time while neglecting the continuous fire fighting needed just to maintain normal operations (ibid., p. 23). We see no reason to suppose that military innovation during peacetime will exhibit a fundamentally different pattern over time.