The *Force* in US Air Force

Fodder for Your Professional Reading on the Implements of Strategy and Tactics for Conventional Air War

DR. DAVID R. METS*

Editorial Abstract: As a former editor and frequent contributor to APJ, *Dr. Dave Mets is one of our most recognized and popular authors. In another of his now famous "fodder" articles, he again offers readers an overview and recommended readings on a topic of professional interest. For this installment, he has chosen the evolution of Air Force weaponry. This is more than just a litany of technology, as Dr. Mets explores related issues of tactics, doctrine, force structure, and so forth. As weapons get smarter and we contemplate arming unmanned aerial vehicles and moving missions to space platforms, the reader should, as the title suggests, consider the very nature of what it may mean to be an air "force."*

YOU MAY HAVE noticed previous "Fodder" articles in the *Aerospace Power Journal*. In them we have sought to give you some tools to help you plan and execute your own professional reading programs. Most of them dealt with subjects unfamiliar to many air warriors/scholars and addressed new books in that field. One looked at naval aviation and another at the Pacific dimensions of World War II, based on the theory that modern airmen were more familiar with the air war against

*I wish to acknowledge the fine help I received in the preparation of this article from Lt Col Bill "Flaps" Flanagan, Lt Col Forrest Morgan, Maj Keith Kosan, and Maj Todd Harmer. The errors of fact and interpretation are wholly my own, and this article in no way represents the position of Air University, the US Air Force, or the Department of Defense.

Germany. Here, I aim to acquaint you with the most prominent conventional air weapons that are the *Force* in US Air Force and, during that process, review a new book on the development of one of the most famous aerial weapons of all time—the Sidewinder missile. Not until the 24th year of my service as a flyer was I assigned to an aircraft—the AC-130—that had any lethal weapons at all. After giving the matter some thought, I concluded that that experience may have been more typical than otherwise and thus decided to write a "Fodder" article on the weapons of airmen and their acquirement. Typical of this series, this piece concludes with a sampler of 10 books that will enhance the expertise of air warriors/scholars in the tools of their trade.

A Shoestring Primer on the Development of Air Weapons

The Era of Converted Guns and Shells

For many years after the Wright brothers first flew, air forces simply adapted the weapons of ground warfare for use in the air. That is probably not all that remarkable, given the maturity of gun and explosive technologies, common for hundreds of years. Airframe and internal-combustion-engine technologies absorbed about all the energy and money that airmen could muster. Thus, both the flexible and fixed guns of the Great War had been designed for war on the ground, and the first bombs were merely rejected artillery shells with tail fins attached. These practices continued well into World War II and beyond. The standard American gun was the 1917 Browning, and bombs differed little in principle from those of World War I.

The World War II Catalyst

The second great war in a generation provided the impetus for original thinking about weapons on both sides of the Atlantic, although standard weapons used in war often did not reflect those ideas. The Germans experimented with a variety of guided bombs and even air-to-air missiles, and the US Navy and US Army Air Forces had programs on all of the guided-weapons technologies that have since come into use, except the technology for the laser-guided bomb (LGB). On top of that, the United States reaped a great harvest of German ideas about aerial technology with its foresighted Operation Paperclip at the end of the war. The BAT, an autonomous radar-guided glide bomb, actually got some ship kills in the Pacific before the war ended.

The Morning Twilight of the Guided-Weapons Age

During the huge drawdown after the war, nuclear weapons, new electronics, and jets largely absorbed the available energy and money, leaving little for the development of conventional weapons. The Berlin airlift and Korean War demonstrated that all conflicts might not become nuclear, and, even in those years, the Navy and Air Force proceeded with developing air-to-air guided missiles. Some of the World War II guided-bomb technologies were resurrected for the Korean War, and the Navy's and the Air Force's losses to ground fire stirred a modicum of new interest in guided weapons that would yield both accuracy and standoff for crews. This brought air-to-air missiles into standard use by 1956, and the Sidewinder got its first kill in 1958.

Disappointments of the Fight above Vietnam

The Korean War also led to the development of the Bull Pup standoff air-to-surface missile, which proved unsatisfactory in several respects. The Sidewinder infrared and Sparrow radar missiles did not live up to their great expectations for several reasons. However, toward the end of the Vietnam War, electro-optical bombs and especially LGBs proved successful and instrumental in checking the North Vietnamese army in Linebacker I. We had made a beginning toward penetrating the sanctuary of darkness, and the efficiency of precision-guided munitions (PGM) also tended to swing the pendulum away from surface-to-air missiles and antiaircraft artillery back in favor of the aerial offensive.

The Maturation of Precision Guidance at Century's End

As the century waned, the Gulf War and Kosovo demonstrated that the night had indeed become the friend of the aerial offensive and that the enemy had lost the sanctuary of darkness. Laser, infrared, radar, and Global Positioning System (GPS) guidance systems all helped achieve efficiencies that would enable parallel (as opposed to sequential) attack and greatly reduce friendly casualties. Some people began to talk about deterrence via conventional PGMs instead of nuclear weapons. The advances in miniaturization and solid-state circuitry greatly improved the reliability and envelopes of both Sparrow and Sidewinder, and the fielding of the new advanced medium-range air-to-air missile (AMRAAM) permitted the West to dominate the air battle as well.

Implications for the Future

The longed-for collapse of the Soviet Union did not free us of security worries. On the contrary, it made the future less ponderable than it had been since the 1930s. The threat was perhaps less forbidding but also much less well defined, making it difficult to predict what the improvement in PGMs might mean for the future. Many people argued that the West so dominated conventional warfare that all thinking adversaries would seek asymmetric means to overcome that advantage. Guerrilla warfare and terrorism were only two of the possible methods. Too, air forces seem to have become victims of their own successes. PGMs had seemingly led to such rapid and bloodless victories that airmen worried that the expectations had now become unreasonably high—enough to paralyze the use of airpower. But others argued that the new precision allowed us to use conventional warheads to achieve objectives formerly possible only with nuclear weapons. Thus, these weapons might underwrite deterrence more effectively, in that the deterred parties could not count on the president's humanitarian reluctance to use them, as they could in the case of nuclear weapons.

The Era of Converted Guns and Shells

Lt Col Isaac Newton Lewis, US Army, first demonstrated the use of his lightweight machine gun from an American aircraft in 1912. Actually, Lewis had envisioned his weapon for use by soldiers on the move—not as an aircraft weapon—because the Maxim gun had proved too heavy for mobile infantry. The Marine Corps had adopted Lewis's gun before the outbreak of World War I, but when leathernecks arrived in France, our forces needed a lighter aircraft weapon so badly that Gen John J. Pershing required the Marines to

give it up to the Air Service. The Lewis gun went on to serve in flexible installations on practically all Allied aircraft throughout the war and well beyond, getting its last kill as a ground gun against a German V-1 buzz bomb in 1944.[1]

The story was the same for most of the fixed-gun installations on the Allied side—even among their enemies. Long before, Hiram Maxim had designed the machine gun, which, along with the steamboat, enabled the imperialistic drive that conquered Africa in the latter part of the nineteenth century. Both the Allied Vickers and the German Spandau aircraft machine guns—standard weapons on both sides—derived from the Maxim design, as did the ground guns. The latter comprised part of the technological explanation for the defensive stalemate on the ground.[2]

Similarly, bombs dropped from aircraft in World War I were at first adaptations from artillery rounds or projectiles rejected for use in ground guns. Explosive shells, an old idea, had seen a good deal of improvement since the American Civil War. In the early days, aircrews threw the weapons, now sporting fins and necessarily light, overboard.[3] Only later did they attach them to simple bomb racks or sometimes even put them in internal bomb bays. The fully mature technology for the fuzes, filler, and bomb casing did not call for intensive research and development programs for many years thereafter—especially since both the internal combustion engine and aerodynamics remained on the steep parts of their development curves, crying out for heavy investments. The late part of the Great War saw bombs especially developed for aircraft but without much serious design and testing work. One assumed that the streamlined bomb casings that emerged would greatly reduce drag but substantially increase the complexity of manufacture compared to cylindrical bomb casings. Not until after the war did anyone have time to subject them to wind-tunnel testing, which revealed that reduced drag did not compensate for increased complexity.[4] Still, the basic design called for standard explosives in a casing much simpler and less robust than that of an artillery shell, nose and tail fuzes far less robust than those in artillery, and simple tail fins. This design endured until the end of World War II, the only remaining changes involving a larger size and a stubbier shape to increase the load in bomb bays.

Much theorizing addressed the use of the new airpower technology to bring about a revolution in warfare—especially to eliminate any repetition of the ordeal in the trenches. But this did not pay a great deal of attention to whether armament technology would support the theories of Giulio Douhet, Hugh Trenchard, Billy Mitchell, members of the Air Corps Tactical School, and others—due in part to factors arising from organization.

As early as 1920, the Army decided on a division of developmental labor that conditioned the way things happened for long after. Everything that remained with the aircraft, except its guns, would become the responsibility of airmen at what became Wright-Patterson AFB, Ohio—in the hands of the Air Service (later the Air Corps, Army Air Forces, and, ultimately, the US Air Force). Everything departing the airplane, plus the guns, remained with the Ordnance Department or the Chemical Service of the Army.[5] Armor-piercing bombs, another exception, remained a specialty of the Navy. This arrangement persisted until the 1960s, in large part because the leaders of the air arm had to promise Congress that unification would not lead to the Air Force's establishing a third set of arsenals and weapons factories.[6] Consequently, conventional weapons did not have an advocacy group within the Air Force establishment, and no one could make a below-the-zone promotion by becoming the service's most brilliant expert in bomb development or the like.

The World War II Catalyst

War, especially total war, tends to focus research and development on incremental change—relatively minor improvements to

weapons on hand at the outset—because major changes in weapons suites tend to radically reduce production output and, consequently, the numbers of weapons available. Thus, of all the aircraft with which the United States fought World War II, only the P-61 and the B-29 had not flown before the attack on Pearl Harbor. So, too, the Browning M-2 (and its little-changed derivative, the M-3), the standard long before the fighting began, remained so when the war ended. In fact, it soldiered on until later models of the F-86 converted to 20 mm guns at the end of the Korean War.[7] However, this affected the Allied side less than it did the Axis.

Only the aggressors can make the assumption that a conflict will be a short war. Without that assumption, both the Nazi and Japanese decisions to go to war would have been even more insane than they were. A corollary of those decisions held that any technology that could not mature in time to help in a short war would have to be put off until after the Axis had won. But the Allies had to assume that they would fight as long as it took—a war to the end. Thus, the early days emphasized numbers and only incremental change. But as the war continued, they began to draw even with the Axis and then to greatly outnumber the enemy. At that point, Gen Henry Arnold and his colleagues gave increasing attention to longer-term improvements. Although many German scientists and engineers did have innovative ideas, the weaknesses of their economic system and their grand strategy did not yield the time required to transform those ideas into standardized weapons systems. The Allied side did have the time and resources.

Neither gun nor explosive technology made really dramatic advances among the Allied technological establishments. But numerous research projects sought to solve the problem of hitting a target from altitude. The Germans and the US Navy had found a partial solution to the problem even before the war—dive-bombing. But any aircraft stout enough for that work would likely prove too limited in both bomb loadout and range. Too, diving on a target entailed flying straight down the barrels of the antiaircraft artillery, which tended to solve all four of the gunner's problems by yielding a constant azimuth and elevation and sooner or later flying into range. When it did so, it automatically solved the timing problem, since it flew right down the trajectory.

The Germans found another partial solution through standoff with precision, contriving a variety of bombs and rockets with a relatively simple guidance system. All of them needed a data link of some sort through which the bomber could transmit range and azimuth corrections. The "Fritz," a glide bomb with a flare in its tail and fins with tabs on them for steering the bomb up and down or right and left, sank the Italian battleship *Roma* in September 1943, as it attempted to surrender to the Allies. The second of the two hits, using a radio data link, set off the ship's magazine and sent it to the bottom. Correctly anticipating that the Allies would soon develop a jammer for the data link, the Luftwaffe had prepared a wire-guided version.[8] The Germans also developed a powered guided bomb with a similar radio-frequency data link but a smaller warhead—a concept not radically different from that of the Air Force's current AGM-130, although it did not contain its own seeker. Despite their innovativeness, these weapons did not go into standard use—probably because Hitler feared that the Allies would capture a dud and use that technology to increase the effect of their air superiority against Germany. Thus, he prohibited the use of the Fritz over land, where it might have done the *Wehrmacht* more good than at sea—albeit the powered bomb did achieve several kills of lighter ships before the war ended.[9] Hitler need not have worried, though, because more advanced guidance technologies were already being developed in America.

These advancements did not include the azimuth only (AZON) bomb, a free-fall weapon that had a guidance system similar to that of the Fritz. The weapon, guided through a radio-frequency data link with the

bomber, received only right and left corrections en route to the target. It had vertical stabilization but no elevators for raising or lowering the nose to affect the range, making it significantly more accurate than unguided bombs against long, narrow targets like bridges and roads. Combat tests in both Italy and the China-Burma-India theater produced encouraging results. However, the "perfect is the enemy of the good enough" phenomenon arose when developers opposed the standardization of AZON because the range and azimuth (RAZON) bomb was just around the corner, promising so much more.[10]

RAZON bore even more similarity to the Fritz than did AZON. However, in the days of vacuum tubes and mechanical gyroscopes, development could not move along fast enough to get this weapon into combat before the war ended. Sporadic attempts to improve it occurred in the late 1940s, and RAZON tested out encouragingly during the Korean War. But the reliability problem persisted. Meanwhile, many other guidance technologies underwent development in America before Hiroshima.[11]

These included systems based on infrared and radar. However, General Arnold had decided to go for the simple solution (AZON and RAZON), fearing that the more complex technologies would not be ready in time for the war at hand. The Navy did pursue radar technology to the point that its BAT—a glide bomb with a wooden airframe and autonomous radar guidance—underwent a combat test and achieved several kills against merchant ships before the war ended.[12] The problem proved a little simpler at sea than over land because of the greater contrast between the target and the background and the absence of competing false returns.[13] Still, the lack of solid-state electronics and miniaturization limited what one could do in that day. Moreover, the coming of nuclear weapons at war's end so overshadowed conventional-weapons technology that the pace slowed even more than one would expect in the aftermath of a total war. Too, for a couple of years, the West assumed that the United Nations would do it right, whereas the League of Nations had failed and war itself would become unthinkable in the foreseeable future.

Such limited gun and conventional-bomb development that had occurred in World War II came practically to a halt in the late 1940s, along with the many guidance programs. The highest-ranking airmen of the period felt that strategic bombing had been a—if not *the*—decisive factor. Some thinkers who had their doubts asserted that the intercontinental bomber, combined with the atom bomb, overcame the earlier shortcomings of the theories of the strategic bombing people and would prove decisive in future wars. Conventional bombsights, even the radar ones coming on just at the end of the war, would do for nuclear work—the lethal radius of the new bombs was so great that precision was not as vital as it had been with the high-explosive weapons. So in 1947, the combination of long-range bomber technology, the new nuclear weapon (thought deliverable only by large airplanes), and the wartime record of the air forces proved enough to sustain the doctrine of strategic bombing and therefore justify the creation of a new organization—the independent US Air Force. On the surface of things, it appeared that what we would today call a revolution in military affairs (RMA) had arisen.

In addition to its progress in weapons guidance, the United States reaped a rich technological harvest from Germany. Defeat is seldom so complete as it was for the Nazis, which enabled free access to Germany's archives and scientists at war's end. Most people know the story of our importation of the rocket scientists, and Operation Paperclip gathered a rich trove of scientific and technological information that would greatly boost aeronautical and weapons development.[14]

Current debates about RMAs often turn on questions of semantics, but many debaters would assert that the usual RMA consists of three elements. First, the implements of war would undergo a major technological change. However, that by itself would not be enough. Doctrine would have to recognize the new

technology, and then one would have to build organizations that would accommodate both the new technology and doctrine.[15] So it had taken 44 years to move from Kitty Hawk to the independent Air Force and to bring about a revolutionary new way of fighting wars: to leap right over armies and navies without defeating them to achieve victory through air attacks on the vital targets within the enemy homeland—or so went the argument.

Many people, especially in the other services, tended to deny that any revolutionary change had taken place. They argued that one still needed boots on the turf and command of the sea and that the most vital contribution of airpower in World War II was support of the land and sea forces. Germany did not collapse until after the infantry had crossed its borders, east and west. The Japanese did not throw it in until their armies and navies had suffered defeat in the field and the Soviet army had joined the fray. As regards economic factors, the submarine campaign had shut down Japanese industry before strategic bombing even started.

Although the doctrine of the new US Air Force insisted that strategic bombing alone could decide outcomes and that the new Strategic Air Command would prove decisive, the other services argued that the decision would have to come on the ground and sea. An air campaign could not win alone; furthermore, it could act decisively not as the supported force but only as a supporting element. The Truman and Eisenhower administrations both seemed to accept the Air Force version of things, but plenty of reasons existed to doubt that an RMA had really occurred.[16]

The Morning Twilight of the Guided-Weapons Age

The same generation that fought World War II fought in the Korean War—and used the same weapons for the most part. Air Force doctrine remained theory since it had not yet appeared in print, and the course of the war did not much resemble the way airmen in the late 1940s had envisioned conflict. The Berlin blockade and the Korean War began to cast doubt on the notion of the universal utility of atomic bombs. Rather, Korea seemed a tactical conflict, with B-29s having difficulty finding targets that even resembled the ones envisioned by theorists at the Air Corps Tactical School in the 1930s. The presence of seasoned veterans in the United Nations fighter forces enabled the domination of the air battle. The pilots had new jets, to be sure, but they made all their kills with the same guns that had armed World War II aircraft.[17]

We deployed guided RAZONs and TARZONs—12,000-pound Tall Boy bombs employing RAZON guidance technology—to Korea for combat tests, and developers saw reason for optimism although many operators thought them more troublesome than beneficial. Still dependent upon vacuum-tube technology, they were not very reliable. We dropped 30 TARZONs on Korean bridges during the war and several times took out a bridge with only one round. However, we lost two B-29s in the process, probably due to deficiencies in bomb design, and terminated the combat tests.[18]

Because Gen Omar Bradley and many others considered the Korean War an aberration, it did nothing much to undermine the administration's and the Air Force's focus on nuclear strategic bombing. The USSR had exploded a nuclear device in 1949, which caused a great hullabaloo, but we still had good reason to doubt the Communists' ability to deliver such weapons upon the American homeland. The one-sidedness of Korean air battles did not produce much action in weapons development, but considerable losses to ground fire for both the Air Force and Navy stimulated a desire to develop some standoff and additional accuracy in conventional weapons. Still, the greater part of the emphasis remained on intercontinental nuclear war (or deterrence) until the onset of the 1960s.

Because of the lack of radical change in either conventional-armament technology or tactical air doctrine, not many organizational revisions occurred in the 1950s. The overall

structure remained stable, although the powers of the secretary of defense saw some enhancement in 1949 and 1958. The Navy's conventional-armament research and development occurred in large part at the Naval Ordnance Test Station at China Lake, California, while the Ordnance Department of the US Army performed bomb and gun development for the Air Force.

A major change occurred in the Air Force in 1950. Researchers had expressed dissatisfaction with the unification of procurement and research and development functions under Air Materiel Command, arguing that supply people tended to dominate and repress innovation. The dollar value of supply operations, much higher than that of research and development, led to a focus on maximum productivity and, consequently, to incremental change. The researchers had their way in 1950 and got their own major command, the Air Research and Development Command, which focused most of its work on strategic air war, but some went on in the tactical realm as well.[19] One manifestation of that came in the airlift business with the acquisition in the 1950s of hundreds of C-124s and C-130s, both having major Army support functions but neither having much to do with nuclear war. As for conventional weapons, when sputnik went up, an attempt to establish an armament center at Eglin AFB, Florida, quickly aborted to allow the better concentration of financial and human resources on strategic-missile development.[20]

That did not completely end the development of conventional armament, though, because the Army brought one of the greatest aircraft guns in history—the M-61 Gatling gun—into operation in 1958, installing it as standard equipment in both the F-104 and F-105, both of which came on the line that year.[21] Toward the end of the Eisenhower administration, the Army Ordnance Department, still in charge of bomb development, also brought a new low-drag bomb series on the line: the 750 lb M-117 and the 3,000 lb M-118, both designed for external carriage on fighter bombers. The Navy also brought a low-drag bomb series onto the line at about the same time in the Mk-80 series, with 500 lb and 2,000 lb versions for Air Force use.[22]

Notwithstanding all the focus on strategic attack, air-to-air weapons enjoyed some important progress in the 1950s, the usual rationale pointing out that we would need these new weapons against hordes of enemy bombers coming across the North Pole. But the resulting weapons led the way into the missile age and proved adaptable to tactical air warfare. Ron Westrum has recently published a book on the most legendary of these weapons—the AIM-9 Sidewinder—and the organization that built it—the Naval Ordnance Test Station at China Lake.[23]

A Harvard graduate with a PhD in sociology from the University of Chicago and a professor at Eastern Michigan University, Ron Westrum worked for 13 years on his volume (*Sidewinder: Creative Missile Development at China Lake* [Annapolis: US Naval Institute Press, 1999]). He has written two other books—one on complex organizations and the other on sociology and society—both of which are out of print and neither of which is in the Air University Library. Westrum has also written a number of articles for periodicals. The Sidewinder volume depends heavily upon interviews, most of them concentrated among the veterans of China Lake. Thus, an oral-history purist might complain that his use of this material is on the uncritical side. Certainly, we cannot expect anyone to have immediate command of the complete literature on science, technology, and innovation—much less cite it in a single book—but Westrum clearly is erudite in his own field.

Organized along chronological lines, *Sidewinder* almost wholly addresses the development rather than the employment of this missile. It also advocates the decentralization of innovation so as to permit "technology push," which allows ideas to bubble up from below rather than come only in response to demand from above.

According to Westrum, the Sidewinder is a classic case of technology push, having emerged from a freewheeling community of

scientists and engineers in the 1950s—the golden years at China Lake. Encouraged to think freely, these people could work on things they considered useful, as well as on projects assigned from above. In such an environment, the Sidewinder project moved along rather swiftly. Because of the absence of a surrounding community and because everyone, including civilians, lived on the base in government quarters, they all knew each other in a far less formal setting than in larger, more established organizations. Too, the isolation of the desert community had the effect of magnifying the impact of personality and leadership.

On first glance, it might appear that Westrum worships Bill McClean, one of the China Lake leaders. If he does, then he has plenty of company. Born in 1914 and brought up and educated in California, where he graduated from the California Institute of Technology, William B. McClean worked on fuzes, among other things, at the Bureau of Standards during World War II until he moved to China Lake in 1945. By 1954 he had become technical director of the Naval Ordnance Test Station and had his finest hours during the ensuing decade, culminating in 1958 with President Eisenhower's awarding him a special gold medal for achievement in the creation of the Sidewinder. According to Westrum and many reports, McClean not only produced many ideas himself, but also was not too proud to quickly adopt those from other sources. He inspired free thinking and burned countless hours of midnight oil—luring many others to do the same.[24] Although we often tend to overrate the influence of individuals on institutions, that probably does not apply to McLean. Perhaps when he left the scene in 1967, his absence had more to do with the perceived decline of China Lake than with any of the other factors Westrum cites.

The simplicity of the Sidewinder—one of its beauties—makes it cheaper to buy in numbers, smaller and lighter than many similar weapons, and more reliable and easier to maintain than complex mechanisms. This simplicity also makes for easy adaptation to new airplanes as they come along. Further, its operation does not depend upon extensive equipment aboard the aircraft or upon complex launching procedures. Thus, the

The simplicity of the Sidewinder—one of its beauties—makes it cheaper to buy in numbers, smaller and lighter than many similar weapons, and more reliable and easier to maintain than complex mechanisms.

Sidewinder reached its initial operating capability in 1956 and got its first kill in 1958 aboard a Chinese Nationalist F-86.[25]

When the new missile went to war in earnest, in Vietnam, it proved a little disappointing—even with a kill ratio far higher than that of all other air-to-air missiles. Designed to attack nonmanuevering bombers, the Sidewinder nevertheless lent itself to improvements that would make it more suitable for use against agile, very fast fighters. Because first-generation seekers could only lock onto the hot exhausts of jets, the attacker would have to maneuver his plane into a narrow cone behind the target before he could get a lock-on signal. A maneuvering target varied the shape of the cone in weird ways. Too, an alert enemy could see Sidewinder smoke at a long distance and could possibly outturn the missile as it closed in. Flares could spoof early versions, which sometimes would home in on the sun or hot spots on the ground, rather than the target. Ultimately, scientists solved all of these problems so that the later models—the AIM-9L and AIM-9M—proved far superior and had much better kill records in the Falklands conflict, the Bekaa Valley fighting, and the Gulf War than did their predecessors in Vietnam.[26] The current AIM-9X program seeks to develop the missile even further by employing thrust vectoring and helmet-mounted sights to close gaps that

have developed with the latest Russian and Israeli missiles. Those innovations, together with much wider gimbal limits, yield a new and impressive off-boresight capability (the ability to shoot at something not directly ahead of the airplane).[27]

Westrum laments, however, that China Lake is not what it used to be. He doesn't go into some of the other worthy programs developed there in the golden era: Walleye electro-optical bombs and Shrike antiradiation missiles, among others. But, relying heavily on the memories of the China Lake veterans of those days, he complains that constraints imposed by rules and regulations and centralized control have bureaucratized the place and made it far less adventurous than before. The genius of the old leadership is not quite so apparent lately. It has become more a supporter of innovative research done elsewhere (in industry) than the developer of major weapons on its own.

Undoubtedly, the golden age produced good work, China Lake benefited from good leaders, and we recognize the Sidewinder as one of the most successful weapons in American history. Yet, the skeptic might wonder whether the author is unduly swayed by the sentiments of the veterans of yesteryear. Similar things happen in other organizations and technologies. The original LGB is a case in point. With Eglin AFB and Texas Instruments doing the work, the first versions were a great leap forward—and so were the second. But by the time we got around to Paveway III, the most obvious improvements had already been made, and further advances did not yield so much gain despite costing somewhat more. In other words, we had reached the point of diminishing returns. More than likely, that sort of thing may have changed China Lake more than any diminishment in imagination or leadership.

Notwithstanding the inevitable limitations of any single book, *Sidewinder* is a useful tome, and the air warrior/scholar would profit from reading it. Westrum could hardly have written the whole story of China Lake in one volume, and he would have been hard put to better place the story in its larger context by expanding his research into arenas concerning Washington, foreign policy, and the other military services. This book is a worthy contribution to the sparsely populated area of serious research into the history of conventional weapons.

Disappointments of the Fight above Vietnam

The apparent ease of victory in the air-superiority battle over Korea had made both the American public and airmen complacent. Accident rates in World War II and for a decade afterwards were horrific indeed. Something had to be done. The flying-safety programs of the American services had their effect: flying F-15s today is much safer than flying B-25s in the early 1950s. We can thank better flying discipline for this achievement—but apparently at a cost of diminishing the quality of air-to-air training in the fighter world before Vietnam. Specifically, commanders of the late 1950s and beyond became so fearful of accidents that they imposed unrealistic restrictions on training for air combat.[28]

To some degree, the experience of the Navy F-8 Crusader squadrons, which came away with the best air-to-air record of all units engaged in the struggle for command of the air, supported that notion. That is, because the Crusaders had no other mission, their training program focused on the air-to-air battle. The fact that the F-8's weapons included only internal guns and Sidewinder missiles may also have had something to do with it.[29]

Some of the literature of the late 1950s enthusiastically endorsed the potential of missiles. One article asserted that if a pilot came back to claim a gun kill, he would have failed to apply his missile weapon properly—otherwise, he would have certainly killed his enemy long before he got into gun range.[30] But it did not turn out that way in combat. For many reasons, both the radar missiles and the heat seekers had very low kill ratios—about one kill out of 10 for the radar Sparrow and

US air forces are amply equipped with cluster bombs loaded with a wide variety of submunitions and mines. Shown here are standard dispensers ready for loading onto an F-111 in the Gulf War. They often come with proximity fuzes that open the dispenser at some altitude to release a host of small submunitions over a wide area—so many, in fact, that even a very small dud rate can leave a dangerous residue. This sometimes leads both the public and the media to oppose their use. (Photo courtesy of Col Mason Carpenter, USAF)

close to two out of 10 missiles fired for the infrared Sidewinder. These figures were skewed somewhat because pilots sometimes fired two missiles at one target, fearing that the unreliablity of one or the other's electronic components would deny them the kill. Also, they sometimes launched weapons when they knew they were outside the firing limits to make their enemies turn—friendly fighters could then catch up with them by cutting them off and shoot them down with guns. In any event, because of the missiles' disappointing performance, some people proposed improving their technology or building specialized air-to-air combat training ranges and loosening the rules for that training in both the Navy and, later, the Air Force.[31]

Air-to-ground attack in Vietnam was also disappointing. Clearly, the interdiction campaign did not shut off the flow of goods to the south, but the Army expressed more satisfaction with the close air support (CAS) it received in Vietnam than in earlier wars.[32] Probably, this had little to do with the technological quality of the weapons used for the purpose.[33] Aircraft used unguided bombs during most of the war and experienced difficulty acquiring targets under the jungle canopy. This problem would have persisted even had they found it easier to identify targets in the jungle or under the protection of darkness.

The Bull Pup missile, available from the beginning of the war, featured guidance very similar to that of the RAZON. The pilot would visually track the flare in the tail of the missile and send orders correcting its course through a radio data link. But the pilot had to fly the missile and the airplane at the same time and keep both pointing at the target during the weapon's time of flight—no easy feat when flying down the gun barrels of an alerted and angry enemy. Too, the small warhead did not do much damage even when it scored a hit.[34] China Lake managed to get the Walleye electro-optical weapon into service by 1967, but the bombing halt prevented it from having an important effect.[35]

Meanwhile, the people at Eglin had been working with a new phenomenon—laser light. By 1967 they had developed a weapon, much simpler and cheaper than Walleye, that could be guided precisely upon a spot of laser light reflected off a target. Combat testing with kits on standard Mk-82 500 lb and M-117 750 lb bombs in the spring and summer of 1968 showed clear promise of a radical improvement in bombing accuracy—and at a relatively low price. By 1972 the testers had gone back to Eglin and adapted their laser-guidance kits to Mk-84 2,000 lb and M-118 3,000 lb bombs so that the new precision could work mayhem on the North Vietnamese Easter Offensive in 1972. The kits cost less than $10,000 apiece and brought huge economies that repaid their price many times over. Too, infrared sensors aboard AC-130s, OV-10s, and F-4s could point laser designators so that the combination began to remove the enemy's sanctuary of darkness.[36]

However, those things did not have much effect on tactical doctrine then or in the following decade and a half before the Gulf War. But airmen's traditional preference for the offensive had received a boost because PGMs had begun to swing the balance away from ground-based defenses in favor of the aerial offensive. The "shooters" had become so much more efficient at hitting targets that the burden of supporting forces in the way of numerous fighter escorts and suppression of enemy air defenses (SEAD) aircraft became much less onerous than it had been for most of the war.

The Maturation of Precision Guidance at Century's End

In the years following the Linebacker operations in the Vietnam War, the chief combat experiences included the October War of 1973 as well as the Falklands campaign and the Bekaa Valley fighting of 1982. Those experiences seemed to strongly indicate that missiles had become the dominant weapons of the air war—that technology had overcome the limitations of the Vietnam struggle. Guns had made all of the kills in the Arab-Israeli War of 1967, whereas both guns and missiles had registered kills in the October War. But missiles enabled practically all of the air-to-air victories in the Bekaa Valley and Falklands fighting. The rules of engagement for radar missiles were less restrictive than they had been in Vietnam, and missile reliability had increased enormously. Improvements to the Sidewinder made it practically an all-aspect weapon that pilots could fire in head-on attacks. Although other factors contributed to the outcomes in both the Bekaa Valley and the Falklands, the air-to-air missile clearly had come of age.[37]

A few Maverick missiles made it to the Israeli forces in 1973, but, notwithstanding President Anwar Sadat's claim that these were what defeated him, they came so late and in so few numbers that they could not have made much of a difference. So PGMs did not have much of an effect then.[38] However, the British used some with good effect in the Falklands war, and they played an even more prominent role in the Bekaa Valley fighting. Although still too early to claim predominance for PGMs in the ground battle, it seemed clear enough that the balance was changing.

American tactical air doctrine had not changed very much prior to the Gulf War, notwithstanding the progress made in both air-to-air and air-to-surface weapons. It remained largely the same as it had in the 1943

version of Field Manual 100-20, *Command and Employment of Air Power:* air superiority came first, usually followed by interdiction, and finally CAS, except in the case of a ground emergency. After his forces had provided for all those things, the commander could turn to reconnaissance and tactical airlift. He would have to command in a centralized way at the theater level and be colocated with a coequal ground commander. Those ideas, in fact, dated all the way back to Mitchell in the 1920s, if not to World War I itself.

In the case of the Navy, we have seen that the organization of aircraft-armament development has had more or less a continuous history at China Lake (and other places) since World War II at the latest. We also noted that, for a short time in the 1950s, a dedicated aircraft nonnuclear-armament unit existed at Eglin AFB, but it disappeared in 1957. However, by 1964 the responsibility for bomb development had migrated from the Army to the Air Force, and the requirements of the Vietnam War further contributed to the need for organizations to handle that responsibility. Founded in 1964 at Eglin, one such organization, Detachment 4 of the Research and Technology Division of Air Force Systems Command at Wright-Patterson AFB, would eventually become the Air Force Armament Laboratory and now the Armament Directorate (at Eglin) of the Air Force Research Laboratory, also at Wright-Patterson.[39]

At about the same time, a special unit of the Aeronautical Systems Division of Wright-Patterson was established at Eglin AFB. Known as Detachment 5, it evolved into the Armament Development Test Center, the Armament Division, and finally the Munitions Systems Division.[40] Thus, the Air Force again had an organized and dedicated unit that could become the advocate for the development of advanced munitions.

Like all wars, the Gulf War of 1991 was unique. By then, precision guidance in weapons for both the air battle and the one on the ground had become so prominent that many people began to think that doctrinal change would have to follow. The air battle ended in a trice, again with practically all of the kills falling to missiles. The combination of jamming, lethal SEAD, and stealth seemed to have brought the threat from surface-to-air missiles under control. Although the addition of the powered AGM-130 and the GBU-15 television and infrared guided bombs had enhanced the inventory of air-to-ground weapons, laser-guided weapons available at the end of the Vietnam War accounted for the lion's share of precision attack. But the forward-looking infrared radar (FLIR) and low-altitude navigation and targeting infrared for night (LANTIRN) equipment made the LGBs as usable in the darkness as in the daytime. Combined with stealth, they removed the night sanctuary of the enemy and made darkness the friend of the aerial offensive.[41] The victory over Saddam Hussein was so quick and so painless that some people began to assert that important doctrinal changes would have to come soon.

Precision guidance, along with the many other technological advances affecting airpower, now required doctrinal change, which in turn would demand organizational changes as well.

The attack on Schweinfurt, Germany, in 1943 seemed to teach us that we would always have to achieve air superiority first before airpower could turn to its other missions. During the Gulf War, people began to say that the PGMs made each sortie so much more effective that we might look beyond sequential to parallel attack. Having to use hundreds of bombers to reliably hit one target made a sequential (step-by-step) campaign mandatory. But the fact that one shooter could now take out multiple targets made it feasible to undertake strategic attack and interdiction campaigns simultaneously (in parallel) with the

struggle for air superiority. According to the most enthusiastic airmen, this also made it practical to so change doctrine that airpower could sometimes become the supported force while armies and navies assumed the supporting role. Sometimes, they said, airpower alone could achieve national objectives.[42]

Precision guidance, along with the many other technological advances affecting airpower, now required doctrinal change, which in turn would demand organizational changes as well. Many airmen said it was time for the other services to recognize the validity of the central control of airpower at the theater level. It was time, too, for the Army and Navy to concede the wisdom of sometimes having an airman serve as the geographical commander in chief. But many people in the other services were not ready to make such concessions. Boots on the turf and command of the sea had to remain the primary considerations, even though everyone admitted that air superiority was important, even essential, to all other operations. Some of them argued that the Gulf War had been a fluke, a nontest. The terrain and climate, so favorable to airpower, and the enemy's ineptitude made the whole thing meaningless. Any strategy would have won in those conditions.[43] Besides, the argument went on to assert that the degree to which the bad weather in the Gulf had inhibited the air campaign proved that airmen still did not have a handle on that sanctuary. One could not count on the air campaign to protect the other forces and assist them in the ground battle because changes in the weather could shut down or severely limit air operations.

Insofar as conventional air armament is concerned, the reaction to the Gulf War's "lessons" seemed more rapid than usual. It had long been understood that weather could inhibit the effective use of all the precision weapons in the inventory. Even before the Gulf War, at Eglin AFB, an inertially aided munitions program had promised simplicity, economy, and a way to overcome weather limitations. Outgrowths of Operation Desert Storm included the joint direct attack munition (JDAM) program, which had received a boost from the combat experience. The idea entailed providing a relatively simple kit consisting of an inexpensive inertial measurement unit (IMU), a GPS receiver, and a tail-control unit, all of which mounted on standard 2,000 lb bombs already in the inventory in large numbers.[44] By the time of the Kosovo campaign, JDAM had already entered low-rate initial production and had received certification for use aboard the B-2. The Air Force became the lead service in that development.

Meanwhile, the Navy led a contemporary program using similar principles to develop the joint standoff weapon (JSOW), a bit more complex than JDAM because of its folding wings and its ability to carry submunitions to a target from a range considerably greater than that of JDAM. In any event, the latter carries only unitary warheads, whereas JSOW will not have one until it reaches a later phase of development.[45]

Because neither of the weapons has a terminal seeker, neither can achieve the same degree of precision as an LGB, a GBU-15, or a Maverick. But the requirements demanded of the development called for 10-meter accuracy—rather good for a 2,000 lb warhead (the JSOW's is about 1,000 lb). Because both depend on guidance from an IMU corrected for drift by GPS, aircraft can drop them through the clouds with good assurance that they will impact within 30 feet of the target.

Although we used only a few JSOWs in the Kosovo campaign, B-2s dropped the JDAM in considerable numbers and with great success. By the time of the Kosovo fighting, the unit cost of the kits had gone down to about $18,000, so the Air Force and Navy could purchase them in large numbers. Thus, we have made a very substantial start on one of the Gulf War problems—penetrating the weather sanctuary.[46] As things stand at the end of the Balkans fighting (assuming that it has ended), some limitations exist. Both JSOW and JDAM depend upon good real-time target-location intelligence, and once they leave the airplane, they become autonomous—without a human in the loop. That situation compli-

cates the bomb-damage-assessment problem and in some situations carries a risk of collateral damage.[47]

The air-to-air weapons of the Gulf War seemed more than adequate, and by the time of Kosovo, we had added AMRAAM, which increased the West's advantage in the air battle. Although Israel and Russia both possessed short-range infrared missiles combined with helmet-mounted sights, those technologies were not available to the enemy over Serbia. The dominance of the air-to-air battle turned out to be as complete in the Balkans as it had been in the Gulf War.

Did the Gulf War affect US Air Force doctrine in response to the combat experience with the new conventional-weapons technology? The 1992 version of basic doctrine appeared after the war but had been completed before the fighting began. We might take that as a baseline at the end of the cold war. The Air Force Doctrine Center, set up in the aftermath of Desert Storm, has produced a set of doctrine manuals, including basic doctrine, counterair, counterland, and countersea, among others—all attractive, well scrubbed, and easy to use. They mention some things associated with the 1991 war, such as parallel attack, but do not emphasize them to the point of reflecting a major change in doctrine. The basic elements seem about the same as they have been since the 1920s, although the vocabulary differs somewhat, as does the framework for their presentation. Perhaps that is as it should be. Ideally, doctrine should concern the eternal truths—the generic things that, hopefully, would apply to all cases. Strategy, on the other hand, is optimized for the particular case at hand and is thus much more perishable than doctrine.

As pointed out above, most people consider the Gulf War unique, and it would be reckless to base "eternal verities" on a sample size of one. Since wars, blessedly, do not occur frequently, inferences drawn from them and made into elements of doctrine can change only slowly. In some ways, one may say that the Kosovo campaign doubled our sample size, albeit still very inadequately. Does it reinforce any of the armament "lessons" of the Gulf War? Perhaps. It certainly suggests that PGMs are important and destined to become more so. It also adds to the evidence that, at least for now, the night sanctuary for the adversary is no more. Kosovo confirms the difficulty of acquiring mobile targets such as Scud missile launchers and of destroying them. It confirms that the air-to-air part of the air superiority campaign is well in hand but that the SEAD portion of counterair perhaps needs more work. Airborne SEAD assets need replenishment, and the Serbs' tactics of avoiding radio-frequency emissions suggest that we need a weapon that does not depend on radiation for guidance to hit ground-based defenses.[48] Some air enthusiasts argue in favor of a place in doctrine for air-alone campaigns, but one finds the notion hard to sustain with Kosovo evidence. Not only does it represent just a sample of one, but also the evidence as to why Slobodan Milosevic quit remains too ambiguous to make the assertion at this point. Maybe Kosovo does reinforce the idea that airpower can sensibly become the supported force in some conflicts.

Have combat experience, technological advances, and new doctrine manuals resulted in organizational change? True, about the time of the Gulf War, organization for the employment of Air Force airpower radically changed. We concentrated combat airpower into one command—Air Combat Command (except for airpower assigned to a new joint command—US Strategic Command—and to the Air Force's Special Operations Command). But that did not arise from either the Gulf War or the improvement in munitions. It was afoot earlier than that, and the notion dates all the way back to the General Headquarters (GHQ) Air Force of 1935.[49] About the same time, the organization for conventional-weapons development also changed. First, the reforms of 1950 became undone with the merger of Air Force Systems Command with Air Force Logistics Command to form a new Air Materiel Command—which reunited the research and development function with the procurement apparatus. But

this, too, arose from sources other than the Gulf War and improvement in armament technology. Rather, the rationale held that it would simplify the process and make for more efficiency—and reduce the force structure. At the same time, the Munitions Systems Division at Eglin was abolished, and its functions rolled back into the Aeronautical Systems Division (later Center), an arrangement that lasted only a short time—until 1998. Then the armament-development function again departed the Aeronautical Systems Center, moving back to Eglin under a new command, the Air Armament Center, which had responsibilities for armament development beyond those assigned to the Munitions Systems Division. Possibly, we can attribute this one change to the performance of PGMs in the Gulf War and to their rising importance to air warfare.

Implications for the Future

Secretary of Defense William Cohen and Department of Defense acquisition chief Jaques Gansler argue that perhaps it is time to reduce our emphasis on platforms and to increase emphasis on smart weapons. It is hard to argue with that point. No American can regret the absence of combat casualties in Kosovo. Were that emphasis to increase and continue, we probably would need more exact intelligence. Less clear is the argument that gradualism is bad. Many military people came out of the Kosovo experience asserting that, in comparison to the Gulf War, it proved that Instant Thunder is the way to go. But it also seems clear that the United States will usually have to operate in coalitions in order to retain the legitimacy that comes from the approval of international organizations. That being the case, we need consensus to achieve unity, and the consequent delays probably will mandate a more gradual approach to targeting than many airmen would like.

Since the end of the Gulf War, many people have asserted that smarter adversaries than Saddam will not confront a Western coalition in a conventional battle but will employ asymmetrical means.[50] To some extent, it appears that the Serbs got the message, keeping their integrated air defense system from emitting and using it as sort of a force in being. They also mixed civilians amongst their military convoys—an idea as old as the hills. The Vietnamese certainly used it up until the spring of 1972, when they launched a conventional campaign.

The implications of that tendency probably need more study. Certainly, it is better to have PGMs in an asymmetrical contest than not to have them. Long-term efforts have attempted to devise a means of finding targets in a guerrilla context under jungle canopy, and current studies seek to identify the special-munitions requirements of urban warfare. Here, too, precision is much to be desired.

The United States has long had an edge in cluster weapons, the use of which some people oppose—especially mines. Area weapons have less accuracy than PGMs by definition. Are there political means of protecting that advantage? Are there technical means of overcoming the difficulty? Or must we plan our campaigns without the use of these effective weapons? Can potential adversaries use the "Cable News Network effect" to neutralize our huge inventory of these expensive and efficient weapons? Have airmen become the victims of their own successes? Both the Gulf War and Kosovo proved so economical in terms of our own casualties and in collateral damage to enemy civilians that they may have caused the public to have unrealistic expectations that we cannot meet next time. Do we have a public-affairs policy that can overcome that problem? The technical means of avoiding losses and collateral damage has improved so much since Vietnam that the region of diminishing returns may not be far off. How can we change our developmental and employment doctrines to diminish these difficulties?

If our cluster munitions are becoming less usable because of public opinion, perhaps our other conventional weapons, especially PGMs, are becoming more important to US and world security. Paul Nitze, a doyen of strategic thought, has written that perhaps the time is

coming when we can base our deterrence upon strategic conventional weapons instead of nuclear missiles and bombs.[51] He argues that we may have needed our nuclear weapons in deterring Soviet nuclear forces, but they have had little utility in dealing with various regional adversaries. Rather, some of the latter have sensed that the very destructiveness of nuclear weapons inhibited our president's choice of using them—the humanitarian cost was simply too high. Thus, these adversaries acted against our interests with impunity. However, Nitze now wonders if the potency of long-range precision attack will bring us closer to using such PGMs to deter adversaries other than major nuclear powers.

Conventional weapons have become so precise and destructive that they can do many of the things that heretofore resided only within the capabilities of nuclear bombs and missiles. So, Nitze argues, because of their precision and ability to limit collateral damage, we might possibly use them with far less inhibition than has been the case with the nukes. Thus, because of their greater usability, perhaps strategic conventional precision weapons can serve to deter regional powers bent on acting against our wishes. Nitze does hedge to the extent that we would have to maintain our dispersed and potent nuclear formations because it will be a long time before our conventional weapons could take out a major nuclear arsenal. However, the rising utility of strategic conventional weapons could conceivably lead to a less threatening world. Perhaps, then, the use of the B-2/JDAM combination is only an indicator of things to come.

We end this article by providing a starter list of books for your professional reading program—a particularly difficult feat in this area. The libraries are full of published works on nuclear weapons, airplanes, engines, strategic missiles, and whatnot. But precious few discuss conventional bombs, guns, and missiles, and still fewer relate their technologies to doctrine and organization for development or employment. To develop in-depth expertise, the reader certainly would have to turn to unpublished material and periodical literature. Thus, more so than is usually the case, the sampler that follows is not a definitive bibliography but only a starter list for the generalist air warrior/scholar. □

A 10-Book Sampler on the *Force* in US Air Force

Two for an Overview

Ideas and Weapons: Exploitation of the Aerial Weapon by the United States during World War I by Dr. Irving B. Holley Jr. New Haven, Conn.: Yale University Press, 1953.

Not dedicated to conventional armament but a classical reading on the process of developing weapons and the doctrine and organization to go with them.

Winning the Next War: Innovation and the Modern Military by Stephen Rosen. Ithaca, N.Y.: Cornell University Press, 1991.

Not about the special area of conventional aircraft weapons but dedicated to the process of innovation in weapons development and other areas. Every air warrior/scholar should know this book.

Eight for Greater Depth

The Evolution of the Cruise Missile by Kenneth P. Werrell. Maxwell AFB, Ala.: Air University Press, 1985.

Recent and authoritative.

International Missile and Spacecraft Guide by Frederick I. Ordway III and Ronald C. Wakeford. New York: McGraw-Hill, 1960.
Quite dated now but contains good material on the guidance research that went on for bombs and missiles in World War II.

Aircraft Armament by Louis Burchiss. New York: Aerosphere, Inc., 1945.
A comprehensive treatment of the standard air-to-air and air-to-ground armaments of World War II.

The Illustrated Encyclopedia of Aircraft Armament: A Major Directory of Guns, Rockets, Missiles, Bombs, Torpedoes and Mines by Bill Gunston. New York: Orion Books, 1988.
A coffee-table book but generally accurate and fairly comprehensive.

Air Warfare in the Missile Age by Lon Nordeen. Washington, D.C.: Smithsonian Institution Press, 1985.
Covers more than just conventional weapons but contains accurate and interesting information on them. After updating it, Smithsonian will republish it very soon.

The Ordnance Department: Planning Munitions for War by C. M. Green, H. C. Thomson, and Peter C. Roots. The United States Army in World War II: The Technical Services (series). Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1955.
Deals with munitions in general but has authoritative material on air weapons. The scholar should certainly be aware of this model official history, one of many volumes in the US Army's "Green Book" series on World War II.

The Gatling Gun: 19th Century Machine Gun to 21st Century Vulcan by Joseph Berk. Boulder, Colo.: Paladin Press, 1991.
Since the M-61 arms all our fighters in the Air Force and Navy (except the F-117), the scholar should be familiar with this book.

U.S. Naval Weapons: Every Gun, Missile, Mine, and Torpedo Used by the U.S. Navy from 1883 to the Present Day by Norman Friedman. Annapolis: Naval Institute Press, 1982.
Contains much still-relevant material and has a short but very good section on nonnuclear aircraft armament.

One for Good Measure

From Crossbow to H-Bomb by Bernard and Fawn Brodie. Bloomington, Ind.: Indiana University Press, 1973.
Has a far larger scope than the subject of this article, but it is a classic, though dated. The modern professional should be familiar with it.

Notes

1. James J. Hudson, *Hostile Skies: A Combat History of the American Air Service in World War I* (Syracuse, N.Y.: Syracuse University Press, 1968), 135, footnote.

2. Ibid.; and George W. Chinn, *The Machine Gun*, vol. 1 (Washington, D.C.: Government Printing Office [hereinafter GPO], 1951), 314–15, 284.

3. Benedict Crowell [assistant secretary of war for munitions in World War I], *America's Munitions, 1917–1918* (Washington, D.C.: GPO, 1919), 300–305; and C. M. Green, H. C. Thomson, and Peter C. Roots, *The Ordnance Department: Planning Munitions for War,* The United States Army in World War II: The Technical Services (Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1955), 452.

4. S. R. Stribling, "Bombs and Bomb Fuzes," *Army Ordnance* 9 (March–April 1929): 329–34.

5. "Aircraft Armament Division Notes," *Army Ordnance* 1 (March–April 1921): 290; and "Aircraft Armament Division Notes," *Army Ordnance* 1 (May–June 1921): 360–61.

6. Gen Carl A. Spaatz, memorandum to all major commands and staff sections, Headquarters Army Air Forces, no subject, 1 April 1947, with attached testimony on Senate Bill 758, pp. 63–88, in box 266, Spaatz Papers, Manuscripts Division, Library of Congress; and Maj John S. Hardy, "Development of Conventional Fighter Weapons" (thesis, Air Command and Staff College, Maxwell AFB, Ala., June 1967). Hardy, who had been a test pilot at Eglin AFB, Fla., prior to attending Air Command and Staff College, speaks of the Air Force approach to doing its research, development, and testing of armament via contract, as opposed to the Navy's use of in-house resources. See also Lt Col Kenneth Rasmussen, "The Munitions of Airpower in Southeast Asia, 1964–69" (Maxwell AFB, Ala.: Corona Harvest Project Office, Aerospace Studies Institute, January 1970), US Air Force Historical Research Agency, Maxwell AFB, Ala., file no. K239.0370-2, p. 5. Rasmussen points to the traditional dependence of the Air Force on the other services for weapons development and supply as one of the reasons for shortfalls in both the acquisition and shipping of munitions. See also US Air Force Systems Command, Munitions Systems Division, "History of the Munitions Systems Division/Air Force Development Test Center, 1 October 1989–30 September 1990," vol. 1, 17–22 (copy in History Office, Air Force Development Test Center [AFDTC], Eglin AFB, Fla.). This history gives an overview of the progress or lack of progress in the Air Force's armament acquisition after World War II.

7. John W. R. Taylor, ed., *Combat Aircraft of the World from 1909 to the Present* (London: Paragon, 1969), 540–41; and Marcelle Size Knaack, *Encyclopedia of US Air Force Aircraft and Missile Systems,* vol. 1, *Post–World War II Fighters, 1945–1973* (1978; new imprint, Washington, D.C.: Office of Air Force History, 1986), 53–66. After the 20 mm M-39 tested unsatisfactorily aboard late-model F-86Fs in Korea, the airplanes were retrofitted with .50-caliber M-3s. The F-86H, the first Air Force fighter with the 20 mm standard, did not come on the line until after the Korean War.

8. Albert N. Garland et al., *The Mediterranean Theater of Operations: Sicily and the Surrender of Italy,* United States Army in World War II (Washington, D.C.: Chief of Military History, 1965), 532–33; Charles H. Bogart, "German Remotely Piloted Bombs," US Naval Institute *Proceedings* 102 (November 1976): 62–68; and Alfred Price, *Luftwaffe: Birth, Life and Death of an Air Force* (New York: Ballantine, 1969), 106–7.

9. Werner Baumbach, *The Life and Death of the Luftwaffe* (New York: Ballantine, 1960), 104–8; Bogart, 62–68; and Price, 106–7.

10. US Army Air Forces, "Controlled Missiles," Project no. GP 5 (Orlando, Fla.: US Army Air Forces Board, 29 October 1943), copy in Technical Library, Eglin AFB, Fla., no. 2416, 1–7.

11. James Phinney Baxter III, *Scientists against Time* (Boston: Little, Brown, 1946), 198–99; and Wesley Frank Craven and James Lea Cate, eds., *The Army Air Forces in World War II,* vol. 6, *Men and Planes* (1955; new imprint, Washington, D.C.: Office of Air Force History, 1983), 258–59.

12. There is a splendid sample of the BAT in the Naval Air Warfare Center's museum at China Lake, California.

13. Albert B. Christman and J. D. Gerrard-Gough, *History of the Naval Weapons Center,* vol. 2, *The Grand Experiment at Inyokern* (Washington, D.C.: Naval History Division, 1978), 277–79.

14. Linda Hunt, *Secret Agenda: The United States Government, Nazi Scientists, and Project Paperclip, 1944–1990* (New York: St. Martin's, 1991).

15. See, for example, Michael O'Hanlon, "Can High Technology Bring the Troops Home?" *Foreign Policy,* Winter 1998/1999, 72–89; and Eric R. Sterner, "You Say You Want a Revolution in Military Affairs?" *Comparative Strategy* 18 (October–December 1999): 297–308. For an authoritative, recent treatment, see Lawrence Freedman, *The Revolution in Strategic Affairs,* Adelphi Paper 318 (New York: Oxford, 1998). For a more skeptical view, see R. L. DiNardo and Daniel J. Hughes, "Some Cautionary Thoughts on Information Warfare," *Airpower Journal* 9 (Winter 1995): 69–77.

16. One of the best books in the huge literature on the debates among the services in the late 1940s is Jeffrey G. Barlow's *Revolt of the Admirals: The Fight for Naval Aviation, 1945–1950* (Washington, D.C.: Naval Historical Center, 1994).

17. The most authoritative book on the Air Force's role in the Korean War is Robert Frank Futrell's *The United States Air Force in Korea,* rev. ed. (Washington, D.C.: Office of Air Force History, 1983). For the naval dimension of that war, see the aviation chapters in Malcolm W. Cagle and Frank A. Manson's *The Sea War in Korea* (New York: Arno, 1980).

18. US Air Force, Air Proving Ground Deputy for Operations, Eglin AFB, Fla., "An Interim Report on Air Proving Ground and Other Experimental Activities in Support of Korean Operations," 5 September 1951, copy in Air Armament Center/HO files, no. 25A-1-2; US Army Air Forces, Air Proving Ground, "Operational Suitability Tests of the Tarzon Air-to-Surface Guided Missile," 13 August 1951, 320–22 (copy in Technical Library, Eglin AFB, Fla., no. 5999); and Futrell, 320–23.

19. Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force, 1907–1960,* vol. 1 (Maxwell AFB, Ala.: Air University Press, 1989), 276–78; and US Air Force, Air Force Systems Command, Armament Division/HO, Eglin AFB, Fla., to Armament Division scientific advisor, letter, subject: Mission Study of the Armament Division, 3 August 1984, with one attachment (copy on file at Air Armament Center/HO, Eglin AFB) (hereinafter Mission Study).

20. US Air Force, Air Proving Ground, "The Proving Ground's Role in the Air Force Missile Development Program," 1 December 1957 (copy at Air Armament Center/HO, file no. 25A-1-1).

21. The same gun arms all US fighters today except the F-117. The F-22 carries a modified version of the M-61.

22. In 1967 Maj John S. Hardy lamented the slow development of armament but cited both the 20 mm M-39 (in the F-100 and F-5) and the M-61 (in all other current and subsequent US fighters) as exceptions. Hardy, 2. Redesign of the tail fin to reduce drag and increase the reliability of safe separation from the aircraft made even the World War II inventory usable aboard the F-100 and fighters of the late 1950s. US Air Force, Air Command and Staff College, *Air Weapons* (Gunter AFB, Ala.: Extension Course Institute, 1957), 9. One report shows the Mk 80 series ready for action even before the election of 1960 and the coming of the doctrine of Flexible Response with the Kennedy administration. US Navy, Bureau of Naval Weapons, "Free-Fall Nonnuclear Ordnance RDT&E [Research, Development, Test & Evaluation] Program," 9 September 1960, 2. Capt Martin J. Loftus speaks of both the M-117/M-118 and the Mk 80 series as being standard on US Air Force fighters before the passage of the Tonkin Gulf Resolution. He does note the presence of the AN series of World War II bombs in the inventory; when carried on fighters, they had to be used with the new low-drag conical fins rather than the World War II box-type fins. "Tactical Non-Nuclear Weapons," *Fighter Weapons Review,* June 1964, 20–28. In a 1962 study, R. S. Titchen and P. E. DePoy show that the Bull Pup guided missile, Rockeye shaped-charge submunition, Walleye TV

bomb, and Shrike antiradiation missile were either in development or in the inventory before the frustrations of Vietnam or the impact of Flexible Response could have stimulated the services into action. "Conventional Ordnance for Aircraft Use, 1962–67," interim research memorandum, Operations Evaluation Group, Washington, D.C., 8 January 1962.

23. Now known as the Naval Air Warfare Center, Weapons Division.

24. In addition to the many citations Westrum provides, see also US Navy, Naval Air Warfare Center Weapons Division, "Introduction," in *Collected Speeches of Dr. William B. McClean* (China Lake, Calif.: Weapons Division, 1993), v–vi; and J. D. Gerrard-Gough and Albert Christman, *The Grand Experiment at Inyokern: Narrative of the Naval Ordnance Test Station during the Second World War and the Immediate Postwar Years* (Washington, D.C.: Naval History Division, 1978), 290–93.

25. US Navy, *Collected Speeches*, vi, footnote 3.

26. For more information on the operational dimension of the Sidewinder experience, see Marshall L. Michel III, *Clashes: Air Combat over North Vietnam, 1965–1972* (Annapolis: Naval Institute Press, 1997); or Lon Nordeen, *Air Warfare in the Missile Age* (Washington, D.C.: Smithsonian Institution Press, 1985).

27. Maj Todd Harmer, USAF, Maxwell AFB, Ala., interviewed by author, 28 February 2000.

28. Michel, 172, 181–85, 277–78; and Maj Gerald R. Volloy, "Red Flag in Perspective," *USAF Fighter Weapons Review*, Spring 1979, 2–5.

29. Barrett Tillman, *MiG Master: The Story of the F-8 Crusaders*, 2d ed. (Annapolis: Naval Institute Press, 1990), 62–71.

30. Robert Thor, "GAR-8," *Fighter Weapons Newsletter*, June 1958, 29–30.

31. Nordeen, 40–49, 74–78.

32. John Schlight, *The War in South Vietnam: The Years of the Offensive, 1965–1968* (Washington, D.C.: Office of Air Force History, 1988), 290–95; and John J. Sbrega, "Southeast Asia," in Benjamin Franklin Cooling, ed., *Case Studies in the Development of Close Air Support* (Washington, D.C.: Office of Air Force History, 1990), 469.

33. Although general-purpose bombs did not change much in principle from those used in the Korean War, progress in submunitions and cluster weapons helped with CAS. Harmer interview.

34. Delbert Corum et al., *A Tale of Two Bridges*, vol. 1, USAF Southeast Asia Monograph Series (Washington, D.C.: GPO, 1976), 34–35.

35. Nordeen, 31.

36. Peter DeLeon, *The Laser-Guided Bomb: Case History of a Development*, R-1312-1-PR (Santa Monica, Calif.: RAND, June 1974).

37. Brereton Greenhous, "The Israeli Experience," in Benjamin Cooling, ed., *Case Studies in Air Superiority* (Washington, D.C.: Office of Air Force History, 1994), 586–96; Nadav Safran, "Trial by Ordeal: The Yom Kippur War, October 1973," *International Security* 2 (Fall 1977): 130–62; Nordeen, 201–6, chaps. 8 and 9; Matthew M. Hurley, "The Bekaa Valley Air Battle, June 1982: Lessons Mislearned," *Airpower Journal* 3 (Winter 1989): 60–70; and Nick Kerr, "The Falklands Campaign," *Naval War College Review* 35 (November–December 1982): 14–21.

38. Anwar el-Sadat, *In Search of Identity: An Autobiography* (New York: Harper & Row, 1978), 261, 263.

39. Mission Study.

40. DeLeon, 6–8; and Mission Study.

41. The best single volume on the Gulf War is Thomas A. Keaney and Eliot A. Cohen's *Revolution in Warfare? Air Power in the Persian Gulf* (Annapolis: Naval Institute Press, 1995). Also very useful is James A. Winnefeld and others' *A League of Airmen: U.S. Air Power in the Gulf War*, MR-343-AF (Santa Monica, Calif.: RAND, 1994). Beyond that, the literature is huge—much of it very parochial.

42. Perhaps the most articulate arguments along those lines are those of John Warden in *The Air Campaign: Planning for Combat* (Washington, D.C.: National Defense University Press, 1988); idem, "The Enemy as a System," *Airpower Journal* 9 (Spring 1995): 40–55; and idem, "Air Theory for the Twenty-first Century," in *Challenge and Response: Anticipating US Military Security Concerns*, ed. Karl P. Magyar (Maxwell AFB, Ala.: Air University Press, August 1994), 311–32, among others.

43. Col Harry Summers, US Army, Retired, in *A Critical Analysis of the Gulf War* (New York: Dell, 1992), 95–116 and 199, is direct enough in his argument that a considerable segment of the Air Force had the conceit to think that it could win the war alone, and that the Iraqis still had some initiative until President Bush brought in the armored forces to settle the issue. Lt Col Price T. Bingham, USAF, Retired, in "Let the Air Force Fight Future Land Battles," *Armed Forces International*, August 1993, 42, argues that the "Chairman and the Joint Chiefs must concede . . . that, contrary to the US Army's AirLand Battle Doctrine, during Desert Storm, deep operations, not close operations, bore the 'ultimate burden of victory or defeat.' "

44. Edward J. Walsh, "Air Force, Navy Precision Weapons Pack Power in Economical Packages," *National Defense* 81 (May/June 1997): 34–35; and US Air Force, Headquarters Air Combat Command/DRPW, "Final Joint CAF and USN Operational Requirements Document for Joint Direct Attack Munition," 23 August 1995.

45. William S. Cohen, "Report of the Quadrennial Defense Review," May 1997, 40; Roy Braybrook, "Not-Too-Close Encounters of the Air-to-Ground Kind," *Armada International* 20 (February/March 1996): 36; Clifford Beal, "Bolt from the Blue: Stand-Off Weapon Developments," *International Defense Review*, August 1992, 757–62; idem, "Bolt from the Blue: Part 2," *International Defense Review*, December 1992, 1173–80; Heinz Hilgendorf, "Are Stand-Off Air-to-Ground Weapons a Necessity?" *Military Technology*, June 1993, 57–62; Eric H. Biass, "The Guided Dispenser: The Ultimate Attack Weapon," *Armada* 15 (August/September 1991): 6–14; John D. Morrocco, "Navy Primed for JSOW Critical Design Review," *Aviation Week & Space Technology*, 27 February 1995, 48; and US Air Force, Air Combat Command, "Air Combat Command Operational Concept for the Joint Standoff Weapon," 28 March 1994.

46. William S. Cohen, US Department of Defense, Report to Congress, Kosovo/Operation Allied Force, After-Action Report, 14 October 1999, 86–96.

47. Ibid.

48. Robert Wall, "SEAD Concerns Raised in Kosovo," *Aviation Week & Space Technology*, 26 July 1999, 75.

49. In fact, about the time of Pearl Harbor, the name *GHQ Air Force* briefly evolved to *Air Combat Command*, although it soon changed again to *Eighth Air Force*. By that time, though, most people thought that the Eighth represented just one of many to come.

50. Freedman, chap. 3.

51. Paul H. Nitze, "Is It Time to Junk our Nukes?" *Washington Quarterly* 20 (Summer 1997): 1–5; on-line, Internet, 22 June 2000; available from http://webnf1.epnet.com/fulltext.asp-ASP=KNGNGHHDFJHJODGBLDNEGLEC?resultSetId=00000000&hit

Num=8&booleanTerm=Paul%20and%20Nitze&fuzzyTerm=&got

oFT=true.