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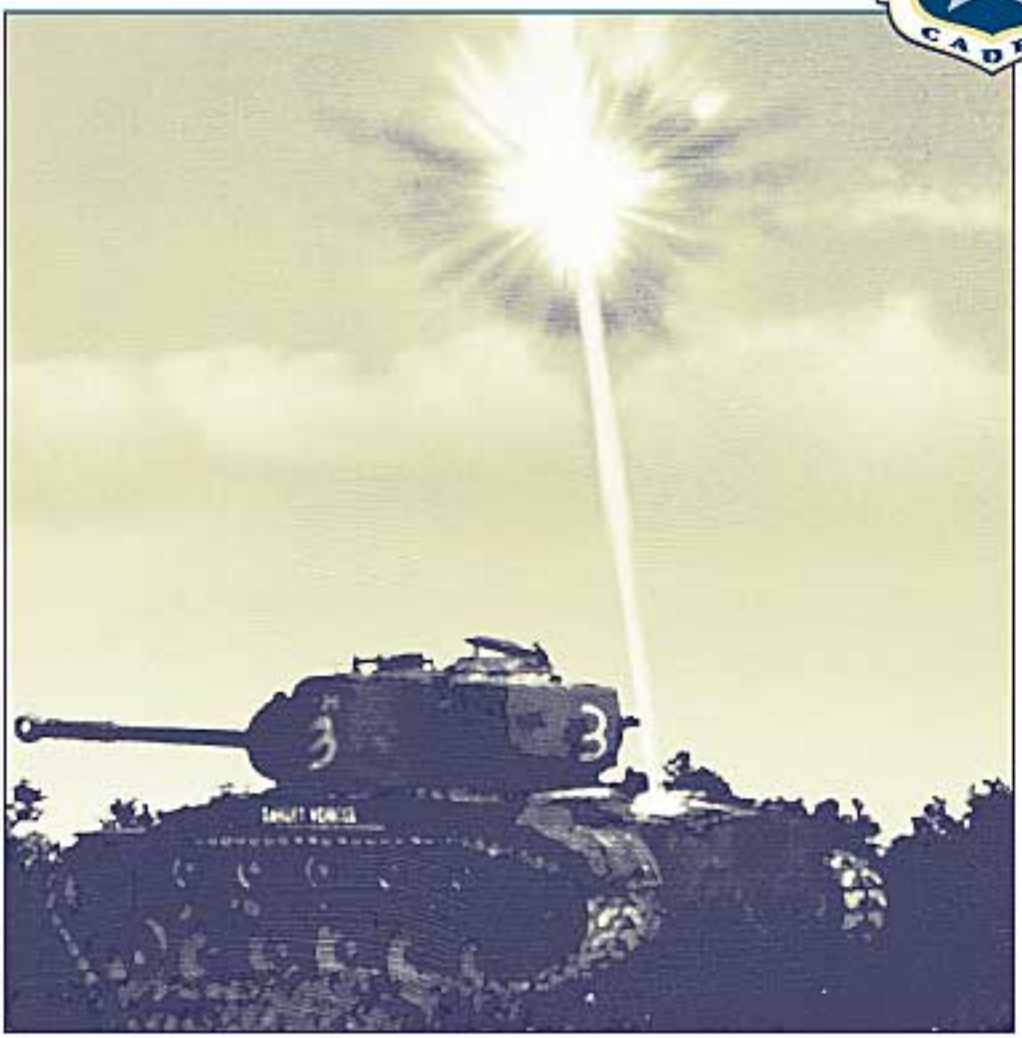

The Long Search for a Surgical Strike

Precision Munitions and the Revolution in Military Affairs

David R. Mets, PhD

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The Long Search for a Surgical Strike

Mets

Precision Munitions and the Revolution in Military Affairs

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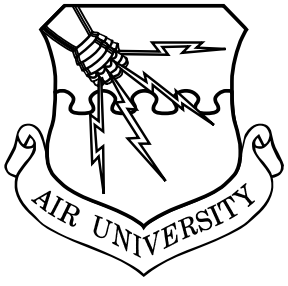

The Long Search for a Surgical Strike

Precision Munitions and the Revolution in Military Affairs

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CADRE Paper No. 12

Air University Press
Maxwell Air Force Base, Alabama 36112-6615

October 2001

Library of Congress Cataloging-in-Publication Data

Mets, David R.
The long search for a surgical strike : precision munitions and the revolution in military affairs / David R. Mets.
p. cm. -- (CADRE paper ; no. 12) — ISSN 1537-3371
At head of title: College of Aerospace Doctrine, Research and Education, Air University.
Includes bibliographical references.
ISBN 1-58566-096-5
1. Air power--History. 2. Air power--United States. 3. Precision guided munitions--History. 4. Precision guided munitions--United States. I. Title. II. CADRE paper ; 12.

UG630 .M37823 2001
359'00973--dc21 2001045987

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Foreword

Dr. David R. Mets's *The Long Search for a Surgical Strike: Precision Munitions and the Revolution in Military Affairs* is a broad, thought-provoking examination of the relationship between the advancement in conventional weapons guidance technology and the "revolution in military affairs" (RMA). He defines an RMA as *a rapid change in military technology, doctrine, and organization leading to a sweeping new way that wars are fought.* Dr. Mets then considers whether the improvement in conventional air weapons accuracy since World War II is the foundation, the main pillar, one of the principal supports, or is irrelevant to the RMA—which is said to be afoot. Clearly, the air theorists of the 1920s were fully persuaded that indeed a revolution was afoot. Equally clearly, the visions of Giulio Douhet, William "Billy" Mitchell, and the Air Corps Tactical School were no more than partially fulfilled in World War II. Dr. Mets also explores the degree to which the shortcomings of aerial weapons were responsible for the denial of their visions and the degree to which those inadequacies were overcome in the conflicts that followed. He closes with an estimate as to whether their dreams of a revolution are about to be fulfilled.

The Long Search for a Surgical Strike: Precision Munitions and the Revolution in Military Affairs is based on research conducted for a presentation at the Society of Military History, Calgary, Canada, May 2001. Some of the research was supported by a generous grant from the Center for Strategy and Technology, Maxwell Air Force Base, Alabama. This work was also facilitated by an equally generous six-month sabbatical from Dr. Mets's teaching duties at Air University's School of Advanced Airpower Studies.

The College of Aerospace Doctrine, Research and Education (CADRE) is pleased to publish Dr. Mets's timely

study as a *CADRE Paper*, thereby making it available to the Air Force and beyond.

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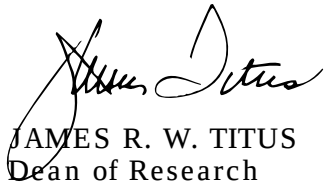

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Dr. David R. Mets (BS, US Naval Academy; MA, Columbia University; PhD, University of Denver) is a professor of technology and innovation at the School of Advanced Airpower Studies, Maxwell Air Force Base (AFB), Alabama. Prior to this position, he served six years as a civilian historian in the Armament Division at Eglin AFB, Florida. During his 30-year career in the United States (US) Navy and the US Air Force (USAF), he served tours as a navigator in strategic airlift, an aircraft commander in Strategic Air Command tankers, as a tactical airlift pilot in Vietnam, and served as the editor of the *Air University Review*—then professional journal of the Air Force. His last flying tour was as the commander of an overseas AC-130 squadron. Dr. Mets has taught at the USAF Academy at Colorado Springs and the US Military Academy at West Point and was a flight instructor in the USAF pilot school. He has published four books on national security studies and airpower and is the author of a 150-page CHECO Study on tactical airlift in Vietnam.

Preface

What is a revolution in military affairs (RMA)? What did the classical airpower theorists think? How did the revolution succeed in combat up to 1975? How did the improvement of armament technology since then affect the RMA?

These are intriguing questions. As I use RMA in this paper, it is usually founded upon a rapid military technical revolution (MTR). But very often added to that are substantial changes in doctrine and the required modifications of organization to implement that doctrine.

The classical airpower theorists—Giulio Douhet, William "Billy" Mitchell, and the teachers at the Air Corps Tactical School—believed that an RMA was indeed afoot. To consummate it, they held that engine and aircraft technology had to be further developed, that the doctrine of strategic attack against the vital centers in the enemy heartland had to be adopted, and that an autonomous organization under a centralized department of defense was needed to implement the doctrine. In general, they did not give very much attention to the needs for associated intelligence, fire control, and armament technology and may have underestimated the notion that MTRs are most often the result of new combinations of several matured technologies rather than single new inventions.

The RMA proved disappointing in practically all the wars up to 1975, and the explanations are widely varied. The airpower advocates usually blamed the failure to adopt the doctrine and to perfect the required organization. Their opponents often argued that the basic theory was fatally flawed and that autonomous airpower could not work whatever the organization and technology. For the entire period from 1903 to 1975, aerodynamic and engine technologies were on the steep parts of their development curves, whereas conventional armament technology was much more matured and—in most areas—beyond the point of diminishing returns.

Many things changed between 1945 and 1975. Among them were some advances in relatively new component technologies

that founded rapid advance in conventional armament technologies along with their fire control. These included the miniaturization of electronics, development of solid-state components, and radical improvements in computational capabilities. Also included was the maturation of radio frequency, infrared, and electro-optical sensing, as well as the discovery of laser light and its application to seekers. These advances and others ended the stagnation of conventional armament technology. Meanwhile, aircraft and engine development slowed down. The addition of new armament, command and control, and intelligence technologies to matured aviation technology resulted in a combination that yielded a great improvement in the cost-effectiveness of the aerial offensive—notwithstanding the maturation of air defense systems during the same period. The combination produced a synergy that changed the calculus of conventional war; and it was demonstrated in the Israeli operations in the Bekáa Valley, the Persian Gulf War, and the air war over Serbia. Enthusiasts called it an RMA, others called it a transformation, and still others called it a pipe dream.

The advances in the technology, the doctrine, and the organization for air offensives have caused some advocates to argue that the day of the "air alone" campaign in some circumstances has arrived. The many disappointments in the past—in addition to the usual parochial considerations—have caused many analysts to oppose the idea. My conclusion is that because of the long time involved, Benjamin Lambeth is probably correct in arguing that airpower has been transformed (rather than revolutionized) since Vietnam; and even if it cannot carry the day alone, we would be derelict in our duty as citizens not to consider the possibility of increasing use of airpower as the *supported* force and ground and sea power as the *supporting* forces. As those ideas must be a concern of the Saddam Husseins of the world, we must expect that they will attempt to avoid meeting us in conventional combat and will seek asymmetrical means to overcome us. We should also consider whether it is wise to voluntarily leave the conventional battlefield where we seem to hold a huge advantage in our

favor and weaponize space because we may find this a new playing field harder to dominate.

I express my appreciation for the support and encouragement of the men and women of the Air Armament Center at Eglin Air Force Base, Florida. I am indebted to B-2 pilot Lt Col A. Colella, F-16 pilot Maj Scott C. Long, space officer Maj Michael Smith, Col (Dr.) Thomas Keaney of Johns Hopkins University, Col Brooks Bash of the National Security Council, and Mr. Lon O. Nordeen Jr., of the Boeing Company for their excellent advice on improving this work; all its remaining flaws are my own responsibility.

Introduction

This research paper explores the relationship between the advancement in conventional weapons guidance technology and the "revolution in military affairs" (RMA) said to be afoot. It also explores whether the improvement in conventional air weapons accuracy since World War II is the foundation, the main pillar, one of the principal supports, or is irrelevant to the RMA. Clearly, the air theorists of the 1920s were fully persuaded that indeed a revolution was afoot. Equally clear, the visions of Guilio Douhet, William "Billy" Mitchell, and the Air Corps Tactical School (ACTS) were no more than partially fulfilled in World War II. This research paper explores the degree to which the shortcomings of aerial weapons were responsible for the denial of their visions and the degree to which those inadequacies were overcome in the conflicts that followed. It closes with an estimate as to whether those dreams of a revolution are about to be fulfilled.

Bernard Brodie concluded that World War II had been as complete a test of the theories as Douhet could have desired.[1] Yet, the argument goes on as to the effectiveness of the bombing campaigns of that conflict.[2] Consequently, none of the subsequent air wars has approached the completeness of the tests over Japan and Germany in the 1940s. Therefore, the concluding estimate cannot be much more than a guess.

What Is a Revolution in Military Affairs (RMA)?

There can be no doubt that Douhet and Mitchell perceived the coming of airpower as a revolutionary event. They asserted that the ultimate objective of wars had never been the defeat of the enemy armed forces but rather the destruction of the adversary's will or capability to resist our will. Although the enemy armies and navies had been the primary targets in all the centuries that had passed, they no longer were barriers blocking the route to the really vital targets of the enemy heartland. In the future the surface battle could be ignored for the first time, and aircraft could directly deliver their destructive power on the vital targets in the sanctuary of the enemy

Maj Gen Mason Patrick

General Patrick, commander of the Air Service in the American Expeditionary Force overseas in World War I, was appointed by Gen John Pershing. Three years after the First World War, General Pershing had become chief of staff of the Army and was again concerned with the turbulence in the Air Service. He recalled General Patrick from engineering work in New Orleans to once more take charge of the airmen. General Patrick then completed flight training, including the solo requirement, and successfully established his credibility with Mitchell and the rest of the airmen—his ideas were indeed quite similar to theirs.

interior. There was a little uncertainty about what were those vital targets. Air war in the new era was to be much more violent and visited upon civilians no longer perceived as noncombatants; the horror would be so much shorter than World War I had been that the total human suffering would certainly be less.[3]

Neither Douhet, Mitchell, nor ACTS were much concerned with the possibilities of air defenses nor with the technology and techniques of identifying, finding, hitting, and destroying the vital targets.[4] To them there were three main impediments to the fulfillment of the revolution. First, there was the need for further development of aircraft engine and airframe technology. Second, the acceptance of a doctrine of independent strategic bombing must be at least one of the main roles of air forces. Third, the creation of autonomous air organizations should be under the auspices of a centralized department of defense.[5]

The term *revolution in military affairs* is a mental construct, an abstraction. It is a simplification of reality, largely intended to help explain the way that change comes about and to provide something of a common vocabulary to facilitate communication among scholars and decision makers. It has spawned a huge literature in the last 20 years or so.[6] But the RMA is not reality. It is no more than an approximate depiction of it. Thus, that huge literature contains a wide variety of definitions of the term. Many of those definitions have much in common with the visions of Douhet, Mitchell, and the ACTS[7] (not to mention many others in Britain's Royal Air Force [RAF][8] and in Germany[9]). Many suggest that the usual stimulant of an RMA is a rapid and extensive change in the technology of combat. But those changes themselves are not enough for an RMA. For example, the French military technology was equal to that of the Germans in 1940, but they were defeated nonetheless. The Germans had developed a new doctrine for that technology and had built new organizations to implement those ideas effectively for the employment of the new weapons.[10]

Although there are several other possibilities, this research paper discusses that conceptual framework. The usual foundation suggests that the coming of the airplane provided the

massive technological change in a short time. The need for new doctrines was seen first in the form of the theories of the airmen, though they were not transformed into new doctrine as rapidly as had been the case with the Germans in the 1920s and 1930s.

The vision for a new organization was most nearly fulfilled in the creation of the RAF in 1918 and then its Bomber Command in 1935. The organizational changes in the United States (US) were much more hesitant. The creation of the Air Corps in 1926 and the General Headquarters (GHQ) Air Force in 1935 were seen as partial advances, as was the development of the US Army Air Forces (USAAF) after World War II had begun. In Britain the impediment was the slow development of aircraft technology. The first US four-engine bombers came out of the Boeing plants in 1935, but the RAF did not get its Sterlings, Halifaxes, and Lancasters until 1942—three years after the war had begun. The working definition of an RMA in this discussion is *a rapid change in military technology, doctrine, and organization leading to a sweeping new way that wars are fought.*

What Were the Notions of the First Airpower Advocates of RMA?

As noted, in all the centuries past, enemies had found a sanctuary behind their armies and navies. As with Czar Alexander I and his armies before Napoléon in 1812, they could retreat into the sanctuary of the interior.

Douhet, Mitchell, and the Removal of Sanctuaries?

Douhet and Mitchell and others thought a revolution had come—that the sanctuary of distance was no longer there. Aircraft could leap right over the armies and navies and go right to the vital targets in the enemy heartland. They could go there so rapidly and put bombs on their targets so quickly that the surface forces could be hardly anything more than onlookers. This was to be achieved with bigger and better bombers—a doctrine of strategic bombing directed against the vital centers in the enemy homeland and with an organization

of large bombers commanded by an airman autonomous from the surface forces.

Munitions Technology Implications of Their Theories

The visionaries of the interwar period did not entirely ignore the development of munitions or that of fire control. Douhet made some inferential leaps in his writings, especially laying out the bomb patterns in neat geometrical arrangements. This founded his estimate of the number of bombs and bombers that would be needed to bring an enemy down—but it was full of assumptions:

- Vital targets could be identified and then found.
- They could be hit from altitude.
- The bombs would have deadly effects on most of them.[11]

It is probably fair to say that Mitchell gave a little more attention to the munitions than did Douhet. He was instrumental in the development of a 2,000-pound (lb) bomb that worked well against the *Ostfriesland* in 1921, and even a 4,000 pounder that was ready for testing three or four months later.[12] But the largest bomb in the RAF inventory in 1939 was a 500 pounder.[13] The USAAF had standard bombs up to 4,000 lbs when it went to war in 1941, but they would not fit into the bomb bays of the standard bomber, the B-17. No more than two 2,000 pounders could be crammed in, and far more usually the load carried to Germany consisted of eight 500 lb weapons.[14] Their bodies had been redesigned since World War I to make them more compact for internal carriage; but the fuses, detonation chains, and explosive fillers were about the same.[15]

One of the reasons the B-17s going to Germany filled their bomb bays with 500 lb shotgun pellets rather than 2,000 lb rifle slugs was that their fire control did not turn out to have rifle accuracy.[16] Much was made of the USAAF's possession of the supersecret and precision Norden bombsight during World War II, but it seems clear that the concern had not been that great in the days of Mitchell and beyond. The Norden sight had been developed by the US Navy (USN) because of its concern with the difficulty of hitting a maneuvering ship. However, the

Artist Drawing of the B-17G Flying Fortress

The final World War II version of the B-17 was the G model shown here. It had a redesigned tail section, an upper and lower power turret with two .50-caliber guns in each, and a chin turret mounting two more such guns. About 12,000 B-17Gs were produced in World War II.

USN decided that it would have to use dive bombing to achieve that; and the USAAF took over the Norden sight almost as an afterthought to facilitate hitting the stationary vital centers of the ACTS industrial web.[17]

The way that ACTS built upon the Mitchell theories almost inevitably contained another flaw—the failure to develop a system of identifying just what those vital targets were, even if they could be hit. Those were the days of the Neutrality Acts and the Merchants of Death legislation in Congress. It would have been highly impolitic for a service trying to get increased appropriations and greater autonomy to have suggested the possibility of going back to Europe for another war. Thus, public discussion of the vital targets in Germany (or Japan) was not politically correct. This statement is not meant at all to

imply that there was no public discussion of what came to be known as strategic bombing. Again building upon the Mitchell theories, the school put a defensive cast on its musings. Instead of using the German system as its model industrial web, it used the American infrastructure.[18] The scenario often put forth was that of an enemy established on a base in the Ontario peninsula. From that base, it could reach out and touch the vast majority of nodal points in the American industrial web. Thus, the USAAF needed the B-17 Flying Fortress to enable it to go out to sea to help destroy an invading enemy before it could establish an Ontario base.[19] Or, if that base were established, then the USAAF would have to have the heavy bomb loads of the B-17 for missions we now call offensive counterair.[20] The result was that we studied the vital targets in the US northeastern industrial heartland but accumulated very little intelligence on what might have been the nodal points in the German and Japanese webs. But then what would have been the sense in building the intelligence picture of the nodal points if you did not have the following:

- the bombs that would destroy them,
- the bombardier school that could teach our flyers to hit them,
- the navigator schools to train people who could bring them to the target,
- the airplanes that could carry them thence, and
- the pilot schools that would develop the people to get them off the ground in the first place?

The Organizational Implications of Their Theories

The foregoing list might also have included the notion that the whole thing would have been futile in the absence of commanders who could admit the possibility of defeating the Germans without an invasion of France. But even with the reorganization of the Army ground forces, the Army air forces, and the Army service forces, at the head of things was the chief of staff—sympathetic to the airmen, but still a ground soldier for his entire adult life.[21] All of the plans always included the notion that the bombing should include features that would weaken the enemy's resistance significantly in case

Boeing P-26

The Air Corps and its tactical school have often been accused of being obsessed with strategic bombing; but the first monoplane, all-metal fighter in the world (in line service) was the Boeing P-26. It came on line in 1932, the same year as the B-10.

an invasion was necessary. George C. Marshall based his "90 Division Gamble," not on the idea that airpower would make the invasion unnecessary, but rather that the landing could be safely done with limited numbers partly because airpower was to have an equalizing effect.[22] At the other end of the world by the summer of 1945, Douglas MacArthur agreed with Marshall that if an invasion of Japan were required, it should be an Army operation and the former should command it. Here, too, air superiority was a prerequisite; and the whole purpose of starting with Kyushu instead of Honshu was to facilitate that.[23]

How Did RMA Work Out in Wars from 1939 to 1972?

The summary report—*United States Strategic Bombing Surveys (USSBS)*—concluded that airpower, not strategic airpower, had been a decisive factor (not *the* decisive factor) in

the defeat of Germany. The counterpart report for Japan asserted that the combination of blockade and strategic bombing had been decisive against Japan.[24]

Why were the qualifications—published in a report—often said to be stacked in favor of strategic airpower? Other *USSBS* reports showed that the bombs had almost always been too small. They argued that only a very tiny fraction, much smaller than prewar estimates, actually hit the targets. The summary reports and the supporting documents both argued that very often the wrong targets were attacked, and the right ones were sometimes not reattacked often enough. It was also quite clear that air defense radar so changed the equation that the bomber did not always get through with acceptable losses.[25] The defenses were much more effective than Mitchell, Douhet, and the ACTS anticipated; and the effects achieved were far from commensurate with the resulting losses of aircraft and airmen. Another major factor *USSBS* identified was that the weather had been a far greater inhibitor than anticipated.[26]

The summary reports and their supporting reports both asserted that the nighttime area attacks of the RAF had been less effective than the daytime precision attacks of the USAAF. The RAF had begun night bombing because of the huge losses Bomber Command suffered in the opening rounds. However, the German night defenses improved more rapidly than did the RAF night navigation and bomb aiming. The initial difficulty was in finding the target areas and then hitting the targets within them. Ultimately, this drove Bomber Command to attacking area targets, often cities, rather than trying to take out the nodal points. Although the nighttime accuracy improved, the defenses improved more rapidly until the Bomber Command was suffering more losses at night than the USAAF was in the daylight. The official RAF history agreed that the effects of RAF night bombing were even less commensurate with its losses than was the case with the USAAF.[27]

The interwar vision went wrong in part because of not knowing what the truly vital targets were. It was also due to the inability to find even the known targets—due to the darkness, weather, and the primitive navigation methods and training

employed. Even when the vital targets were known and found, they were very seldom hit effectively. That was partly because of the unanticipated resilience of the German economy and the targets themselves. The bombs used were almost always too small to be effective. The failure of the vision was also because the defenses were often effective in disrupting the aim. The weather often drove the USAAF over to radar fire control, which at that stage was hardly better than area bombing. All of those things also proved deficient because the peacetime professional crews had established standards of proficiency impossible to duplicate with people brought in for the duration from civilian life—the press of time was simply too great.[28]

Some of the most avid strategic bombing airmen also complained that the theory had not really been implemented. According to them, the power of the strategic offensive was much diminished by the competing requirements of the surface battles. They were distraught at having to gut the Eighth Air Force in England to send its best units as the cadre of Twelfth Air Force for the invasion of Africa.[29] The airmen complained often about the diversion away from the vital centers in the German heartland against the submarine at sea or in the pens. They also argued that the diversion of four-engine bombers to the Navy in the Pacific diluted the power of the offensive.[30] They lamented the decision to waste the strategic bombers against the French rail yards in April 1944 when they should have continued the attack on the synthetic oil plants, which was a further weakening. The airmen continued to complain that summer when the heavy bombers were again diverted to do tactical bombing, even close air support, to facilitate the Saint Lô breakout. They again lamented the diversion against the V-1 launching sites that same summer.[31]

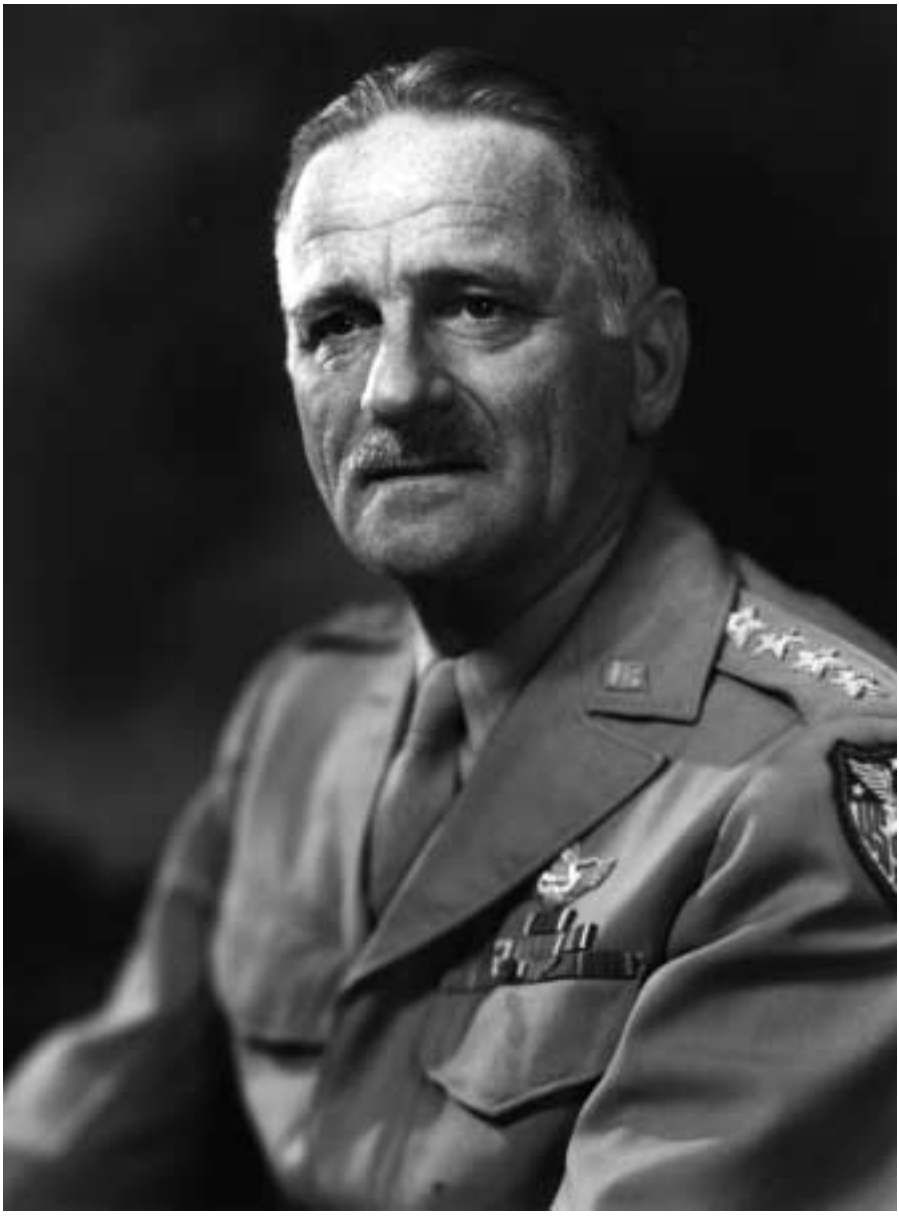
All of this was not lost on the wartime leadership. The commanding general, Henry H. “Hap” Arnold, directed that the B-29s would not be so diverted from the assault on the Japanese home islands (though in the end considerable effort was indeed given to the mining campaign against shipping). General Arnold enthusiastically pressed the development of bomb aiming radar for that airplane which made the Superfortress more accurate through the weather than the bombers had been over

Germany.[32] The German V-1 cruise missile was captured and copied in record time. It was deployed to the Philippines and was ready to go into combat even as the atomic bombs were dropped on Hiroshima and Nagasaki. The V-1 certainly was not a precision weapon—rather its guidance was very similar to that of the Kettering Bug that had been conceived in World War I.[33] All of the operational seeker systems that have come into use (except lasers) were conceived and under development in the USAAF and USN before the war ended. Some of them—such as the USN autonomous radar-guided Bat glide bomb and the visual-radio guided AZimuth ONly (AZON) free-fall bomb—actually entered into combat with some modestly encouraging results.[34]

Although the people in the Japanese and German heartlands could find no place to hide, the weather and the darkness provided them some sanctuary. German troops at Normandy had suffered mayhem along the roads in daylight, but at least they found some refuge in darkness. Months later, at the Battle of the Bulge, the *Wehrmacht* found some weather-related safety for the first six days. But when the weather cleared, that sanctuary was removed and the tide of battle reversed. Similarly, the Japanese armies found protection under the jungle canopies of the Solomons and the

B-29 *Enola Gay*

The B-29 is returning from the atomic bombing of Hiroshima, August 1945.



Gen Carl A. "Tooey" Spaatz

General Spaatz commanded the strategic air forces in the Pacific when the first atomic bomb was dropped. He became the last commanding general of the US Army Air Forces and the first chief of staff of the USAF. General Spaatz presided over the transition to a separate service and a nuclear-armed world.

Philippines and underground in Okinawa. All this had little impact on the final outcome, but the belief of the interwar theorists that the sanctuaries were gone was shown optimistic or at least premature.

Nonetheless, the ambiguous results of air combat and the conclusions in the *USSBS* were not enough to make the completion of the Mitchell RMA with reorganization a cakewalk. Notwithstanding the stalwart support of Harry S. Truman, George C. Marshall, and Dwight D. Eisenhower for an independent USAF, the interservice battle of the late 1940s was as fierce as any in our history. But in the end, the RMA was partly fulfilled with an autonomous air force (though the other services retained their own air forces) and with a national military establishment (which was far weaker than the one envisioned by Mitchell). Earlier, the USAAF had been reorganized along functional lines to include a dedicated strategic bombing organization, long known as the Strategic Air Command (SAC).[35]

Korea

The hostile nature of the unification fight and the weariness of the Berlin blockade had not at all subsided when the North Koreans invaded the South. The new autonomous air force organization was still getting its bearings, and many of its people had still not acquired new USAF uniforms. The new SAC had gotten off to a shaky beginning under the leadership of Gen George C. Kenney, and successor Gen Curtis E. LeMay was just getting its reform rolling when the Communists marched southward.[36] The USAF had not yet written its basic doctrine nor had it much adjusted its founding theories to account for the coming of the nuclear weapons, still less to respond to the early Soviet explosion of a nuclear device. The USAF was in the midst of a number of simultaneous technological revolutions that included the following:

- transitioning from reciprocating engines to jets,
- adjusting to and perfecting nuclear weapons and delivery methods,

- developing aerial refueling techniques to permit the use of jets on long-range bombers, and
- developing missile technology.

Those revolutions were being done in the wake of a demobilization—more like an implosion—that the political leadership had demanded in order to balance the budget and begin paying down the national debt that was run up during World War II.[37] The notions were strong that the United Nations (UN) would prevent future wars or that American nuclear weapons would end them in a trice—all of which would make conventional weapons (and armies and navies) irrelevant. Thus, in the five years between wars, it is not at all remarkable that little money and attention were applied to the development of conventional guided weapons. So practically all of the weapons and many of the airplanes used in Korea were left over from World War II.

Gen Curtis E. LeMay

In 1962 General LeMay was the first bomber pilot to become chief of staff of the USAF.

The First Experimental Guided Missiles Group was established at Eglin Field immediately following the war; and some of the remnants of the cadre of that great installation were still there to toy a bit with the AZON, and especially the Range and AZimuth ONly (RAZON), but little significant work was done. One of the reasons that the AZON had not been pursued more vigorously was that the developers had felt that the RAZON would be much better and was right around the corner. However, the war ended, and the funds had dried up before the latter could achieve combat ready status.[38]

Little appreciated at the time was that the cost-effectiveness calculations of World War II were rapidly becoming obsolete. The implication that the Berlin blockade was an early sign that the coming of the UN and atomic bombs did not portend eternal peace and brotherhood was not fully recognized.[39] It was still less appreciated that the nuclear weapons had done little or nothing to resolve the problems of Berlin with the USSR. President Eisenhower asserted later that his atomic threats had something to do with the satisfactory ending of the Korean War, but there is room to doubt that effect and that the outcome was indeed satisfactory. The marked unhappiness among Reserve air crews not wishing to return to combat so soon after Schweinfurt was another indication that the attrition rates of World War II were no longer acceptable—at least not for the limited interests that seemed engaged in Korea.[40]

The air superiority battle was handily won in Korea, but the attrition of ground attack aircraft to the surface defenses was very substantial given the limited stakes involved. The resilience of the North Korean and Chinese Communist armies under massive interdiction attacks greatly diminished the worth of the outcomes from the American point of view.[41]

The United States had harvested some of the advanced German weapons technology at the end of World War II. It had also undertaken the development of some air-to-air guided weapons research before Korea, but that had not yet reached fruition. The basic weapon of the air battle was the same old M-3 .50-caliber machine gun, albeit that it was now mounted in jets like the F-86 Sabre and the F-84 Thunderstreak.[42] The MiGs and the Sabres that the Americans encountered in the

Me 262

The first jet in line service (shown above) was brought into the Luftwaffe near the end of World War II. Had it appeared earlier in greater numbers, it might have defeated the strategic bombing campaign. The Messerschmitt 262 started a revolution in air superiority fighting that progressed very rapidly until Korea, when practically all of the air-to-air battle was among jets.

north had 23 millimeter (mm) cannons, but their rates of fire were so low and muzzle velocities so poor that it did not yield an advantage for the North Koreans. By a very large majority, the air-to-ground weapons were leftovers from World War II as well. Most of them were the standard 500 lb high explosive (HE) bombs, but huge numbers of the unguided rockets that were developed late in World War II were also fired. The accuracy and ranges of those weapons were so poor that the US aircraft had to come so close to the ground defenses that our losses were too great for the effects achieved. Having been designed for compact internal carriage and now delivered from the external stations on jets, the bombs were no longer adequate. The aerodynamic drag, which increased with the square of the airspeed, reduced the range of the aircraft and slowed its passage through the danger zones on low-altitude deliveries.[43] The bombs' compactness was still a virtue in the bomb bays of the B-29s.

The RAZON was brought forth for a combat test, even though it had not yet been made a standard item in the inventory. It achieved some good results, though by the 1990s it was still far from the precision and reliability standard. One of

the big difficulties was that the guidance kits still used vacuum tube electronics, and thus the reliability was low. Often the guidance would not take hold, and the wild rounds would go off in unanticipated directions. That made them too unreliable to be used in close air support (CAS) operations in the vicinity of friendly troops. The kits also required that the bombardier keep both bomb and target in sight during the fall, and that could have dangerous results for the aircrews. This radio-visual guidance through a data link required some specialized training. Before the end of the war, the guidance was adapted to some British 12,000 lb TALLBOY bombs in order to guarantee that a direct hit on a robust target would ensure its destruction.[44] However, that required special modifications to B-29s and the building of specialized loading facilities. Two airplanes were lost to what were deemed technical deficiencies in the weapon, so the tests were discontinued notwithstanding that some bridges were destroyed with many fewer sorties than would have been required with unguided weapons.[45]

At the end of the day in Korea, the enemy found a renewed sanctuary in distance—though the aircraft could have reached them anywhere in the distant sanctuary beyond the Yalu, the refuge was maintained by political factors. As with the Germans in World War II, the darkness enabled the Communists to get some sustainment forward—in their case enough to at least mount a successful defense. They were also able to find sanctuary beneath the ground on the battlefield and in railroad tunnels and elsewhere. At first, their ground defenses provided little protection; but they soon learned to disperse and to mount ground fires that gave them some relief from air attack.[46] As with Germany, the American air forces still had limited capability to attack effectively through the clouds; but the weather was somewhat less of an aid to the Communists than it had been on the northern European plain for the Germans.

Because the outcomes were so conditioned by various political factors and because the nodal points in the enemy industrial web were held to be beyond the Yalu River and out of limits, the doctrinal implications of the conflict were ambiguous. Airmen then almost universally argued that no strategic

bombing had been done in Korea because the vital centers in the USSR and Communist China had not been attacked.[47]

The implications for tactical doctrine were only a little less ambiguous. General of the Army Omar Bradley, chairman of the Joint Chiefs of Staff (CJCS), asserted that it had been a war against the wrong enemy, at the wrong place, at the wrong time. Secretary of State John Foster Dulles and Commander in Chief (CINC) Eisenhower spoke forcefully for a New Look in defense policy. It came to be known as Massive Retaliation—a nuclear response against the Soviet and Chinese heartlands, even in reaction to limited challenges—strategic bombing. They hoped this would result in balancing the suffering federal budget and at the same time preserve peace and security. The result in doctrinal terms was that strategic bombing was the main mission in the future and that the tactical air forces, the USN, and the US Army would have to play a secondary role.[48] At that time the other services accused the USAF of being obsessed with strategic nuclear bombing to the exclusion of tactical considerations (and continue to make this accusation today); yet they did everything they could to acquire a nuclear capability of their own.

Not much was done in organizational terms in the years that followed Korea. The powers of the secretary of defense were strengthened some in 1949, and then again in the late 1950s; but they remained limited. In the USAF, the organization of the operational commands remained stable throughout the Eisenhower years though the functions of research and development (R&D) were divorced from procurement when the Air Research and Development Command (later the Air Force Systems Command) and Air Force Logistics Command were established in the early 1950s.[49]

A dedicated conventional munitions R&D organization existed briefly at Eglin AFB in the wake of Korea. Known as the Air Armament Center, it disappeared soon after the Soviet launch of sputnik in 1957, which returned the focus to strategic nuclear warfare.[50] The forced draft application of the US scientific and technical capability to field an intercontinental ballistic missile (ICBM) capability at an early time left little for

the development of conventional doctrine and associated weapons.

The rivalry among the US services abated slightly in the 1950s. President Eisenhower appointed Adm Arthur Radford as CJCS immediately after the Korean War. As Eisenhower and Admiral Radford had been principal antagonists during the unification debate, that appointment can be deemed as the making of peace.[51] Four great *Forrestal*-class conventional aircraft carriers were built in the 1950s, and they were the same size as the cancelled USS *United States* was to have been. Moreover, the even larger nuclear-powered aircraft carrier, the USS *Enterprise,* was also brought into the fleet. Unlike the planned *United States,* they all had the conventional islands. Unexpectedly, the nuclear weapons were miniaturized early, making it possible to launch nuclear-armed fighter-sized aircraft from carrier decks without the abandonment of an island superstructure. These events were combined with the initial development of nuclear submarines followed by the submarine-launched ballistic missiles with nuclear warheads, which greatly enhanced the Navy's role—all well before the coming of flexible response and in the midst of the decade during which the USAF and SAC were expected to have consumed a disproportionate share of the defense budget. Though none of those five supercarriers could fit through the Panama Canal—which worked to limit their role in Vietnam (though most of them eventually got there through a long voyage around South America)—they nonetheless were important factors in conventional war fighting, which diminishes the notion of a supposed US obsession with strategic nuclear warfare.

The Air Armament Center of the 1950s did not exist long enough to do much with conventional weapons development. But under Army and Navy auspices, some work did continue. The Air Force developed the AIM-4 Falcon during the 1950s for air-to-air battle, but the most successful work in that realm was done by the Navy at China Lake. That was to be expected because the kamikazes at the end of World War II clearly demonstrated the vulnerability of aircraft carriers and other surface ships. The imminent appearance of guided air-to-surface missiles and bombs portended the arrival of truly fearless

USS *Forrestal*

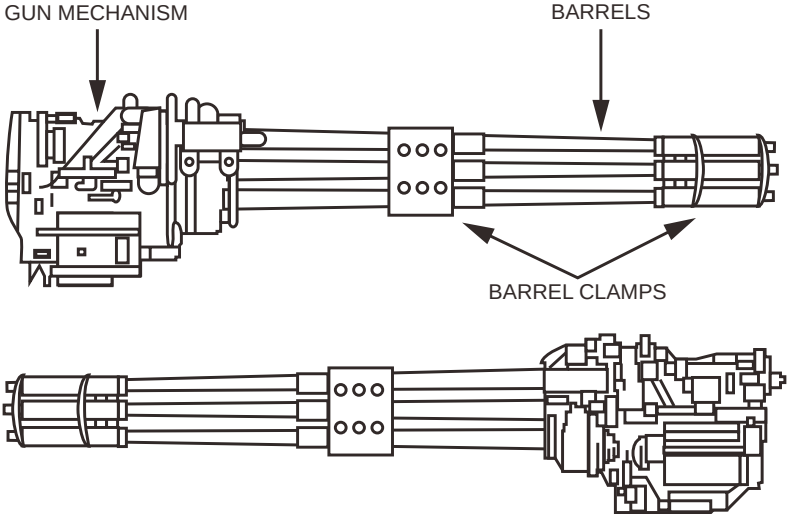
This ship came on line in 1955 and has a displacement of 60,000 tons empty, about the same as planned for the never constructed USS United States. Unlike the United States's design, however, the Forrestal had an island instead of a flush deck. In the interim, nuclear weapons had been so miniaturized and catapults so improved that they could be carried off ships in smaller fighter-sized aircraft than in 1949.

kamikazes.[52] Thus, the development of an effective fleet air defense was imperative. The result was the standardization of the AIM-9 Sidewinder infrared (IR) and the AIM-7 Sparrow semiactive radar missiles that are both—much improved—still in use by both the USAF and the USN as well as in air forces of many other nations.[53] Both those missiles received their initial operational capability (IOC) in 1956, and the Sidewinder scored the first missile kills in history in Chinese Nationalist service aboard F-86s in the Quemoy–Matsu crisis of 1958.[54] There was much talk of a revolution in the air superiority battle during the late 1950s.

But the progress in conventional air-to-ground weaponry was not remarkable in the 1950s. The standard HE bombs

were improved by giving them new shapes to reduce the drag when externally carried.[55] This work was done as per the agreements made during the development of the National Security Act of 1947.[56] General-purpose bombs remained in the Army's province and resulted in the M-117 750 lb bomb and the M-118 3,000 lb weapons.[57] The Navy also developed low drag bombs (low compared to World War II weapons) for external carriage in various sizes up to 2,000 lbs, now known as the Mark (Mk) series. All these bombs received their IOCs about 1960. The Army's Ordnance Department also remained in charge of gun development, which resulted in one of the greatest conventional weapons in history—the M-61 Gatling gun. It continues in standard use throughout Air Force, Navy, and foreign air arms. A derivative is being included in the new F-22 that differs only in the barrels, which have been made lighter than those in the standard gun. The Gatling gun received its IOC in 1958 aboard the F-104 and the F-105.[58]

With the development of the Bullpup guided missile, the USN responded to the losses suffered in ground attacks in Korea. The Bullpup was made standard in both the Navy and the Air Force before Vietnam. A rocket-powered weapon, the



Artist Drawing of the M-61 Gatling Gun

Bullpup and its guidance were similar in principle to that of the RAZON. The pilot visually tracked the weapon on its way to the target by watching the flare in its tail and guided it into its aim point with the controls in his cockpit. The warhead was small, and it was not a launch-and-leave weapon. The crew had to provide guidance the entire time until impact, which meant that they had to steer the airplane on a steady course toward the target throughout.[59]

In the end, the Korean War had not stimulated dramatic changes in technology, doctrine, or organization. But President Eisenhower recognized from the beginning that the United States would not enjoy its nuclear monopoly—or even hegemony—for long and that massive retaliation would be perishable. The USSR approached nuclear parity soon after the decade ended. That meant that even if the United States could have ever depended upon massive retaliation to deter limited and unconventional wars, the reconstitution of a more balanced defense arrangement must come with that nuclear parity—unfortunately, ending US balanced budgets for many years to come.

Vietnam

It has been a cottage industry among scholars to bash the United States and the USAF for being unprepared for the guerrilla war in Vietnam. To some extent, in the Air Force case, these critics have been bashing the USAF for doing what it was told to do by a succession of American presidents; and the criticism has been administered largely by the very elements of the ideological spectrum most committed to civilian supremacy over the military. Much of that criticism has been delivered without any indication as to what might have been a better policy, strategy, or weapons development program. Also scarce is recognition of the fact that nuclear deterrence did not fail. Equally rare is any recognition that throughout history weapons have very often, if not usually, been used in ways not at all envisioned by their developers. Our great battleship fleet of the 1930s did yeoman service as antiaircraft platforms and in fire support for amphibious landings but never found the

second Jutland or Trafalgar for which it had been designed.[60] Our remarkable fleet boats of the 1930s submarine force had been designed for battle fleet support, but they did their best work in unrestricted submarine warfare against Japanese merchant shipping. Not only did their designers fail to envision that but it actually was against the law as expressed in the Washington treaties of 1922![61] The fact that the F-105 was not optimal for fighting guerrillas or even for bombing North Vietnam is not that remarkable. It is equally unsurprising that the Douglas Skyraider happened to be better suited for counterinsurgency operations, notwithstanding that it had been originally designed for war at sea as a combination torpedo bomber and dive bomber.[62] Obviously, torpedoes have little utility in guerrilla warfare in the jungles!

Arguably, the cost-effectiveness equation for the American air forces had worsened even since Korea. The leadership had informed us that Korea had been the wrong war against the wrong enemy and that there would be no more Koreas. Yet here was another enemy on the Asian mainland even more unfamiliar to us. The Communist onslaught had obviously slowed since Czechoslovakia had fallen in 1948. Deterrence and containment seemed to be working, and the memories of a total war world were fading. The political unity of the Franklin D. Roosevelt and Dwight D. Eisenhower years was a dim memory. A racial crisis had been approaching ever since the desegregation of the armed forces in the late 1940s and of the Little Rock, Arkansas, schools in the mid-1950s. The election of 1960 had been very close. President John F. Kennedy had suffered a severe blow to his prestige (and reelection prospects) with the Bay of Pigs fiasco in 1961, and it was not altogether restored with the Cuban missile crisis in 1962.

Thus it can be argued that with only limited hope for firm public support, the United States entered the Vietnam conflict without having made any sweeping changes in its air doctrines, technology, and organization. Though the jets were more advanced than the Sabre, their armament had not kept pace. The bombers were still controlled by SAC, as they had been during Korea. The tactical forces consisting of fighters, tactical airlift, reconnaissance, and others were organized as

they had been in the early 1950s. Those based in the United States were still under the command of Tactical Air Command (TAC), and the ones overseas reported to the area CINC—usually a Navy admiral or an Army general. The tankers still belonged to SAC; and even when tankers and bombers were deployed overseas to places such as Guam or Thailand, they still were under the operational control of the CINC in Omaha. Similarly, the intertheater airlifters remained under the control of the commander of the Military Airlift Command (MAC)—which had been named the Military Air Transport Service at the time of Korea.

The theory and doctrine conditioning the organization and employment of airpower had remained fairly stable since World War II. If the United States became involved in a general war, then SAC would conduct attacks on the vital centers in the industrial web of the enemy heartland—increasingly with nuclear weapons. At lower levels of war, the tactical air forces should be operating under a centralized command at the theater level and their priorities normally should be air superiority, interdiction, CAS, reconnaissance, and tactical airlift. That operational control was the same as it had been since 1943.[63]

The Cold War was at its height, but the USSR was approaching nuclear parity; and that was an even greater concern than it had been in President Truman's day. The ground-based air defenses on the Communist side had been improved significantly, but that had not yet been demonstrated in full-blooded combat. However, in 1960 the downing of Francis Gary Powers's U-2 over Russia by a surface-to-air missile (SAM) had been a portent of things to come. Communications had improved some since Korea, but the greatest advances were still ahead. The US population had gained almost universal access to television, which greatly vivified and accelerated its acquisition of news about the war.

The air war in Vietnam was a disappointment to the airmen and their countrymen alike. Clearly, our military effort did not coerce the enemy into doing our will—to permit the existence of an independent and noncommunist South Vietnam. There is still not much of a consensus as to why the military forces in general and the air forces in particular failed to bring this

about.[64] Though the enemy losses were far greater than those of the United States, the Communists proved much better able to sustain them. There are a host of hypotheses that attempt to explain the outcome.[65] Many of them have nothing to do with airpower.

- Some say the United States was attempting the impossible, as Vietnamese nationalism and xenophobia could never have been overcome.
- Others argue that external support from the USSR and China was decisive.
- Still others assert that America was never defeated on the battlefield, but rather some combination of effective Communist propaganda, weakness of US civilian morale, and journalistic sensationalism undermined the effort.

Even those factors related to airpower are ambiguous in their significance, and little consensus has developed. There is alleged to be a rather widespread belief inside the military that the gradual application of airpower was to blame. It deprived the air instrument of some of its chief virtues: shocking power, surprise, speed, and flexibility. It gave the enemy the time they needed to import and develop an integrated air defense system (IADS) when, instead, a sudden and sustained massive attack would have coerced them before they could have reacted. The cautious way that the administration of President Lyndon B. Johnson approached the application of airpower is variously described as necessary to avoid World War III or foolish by depriving airpower of the revolutionary potential that Mitchell and Douhet anticipated. The vital nodes in the industrial web were not beyond the physical reach of airpower; rather, they were placed in a Soviet and Chinese sanctuary by political factors, rightly or wrongly. Those ideas were not universally held by those in uniform, but they were popular. Certainly, there was a case for constraint in a nuclear-armed world. But the Cuban missile crisis of that era seemed to suggest some value in a gradual escalation; and, more recently, the Kosovo campaign suggests that coalition warfare may now be the wave of the future and a gradualist approach may be inevitable there.[66]

At a lower level of concern, the Vietnam War suggested the following as possible lessons for the future of air war:

- The air superiority battle remains paramount but has grown to be more complicated now, and the ground elements must be taken more seriously than they were by Mitchell and Douhet.
- The new complexity of the air superiority battle has increased the requirement for support aircraft like fighter escort and suppression of enemy air defenses airplanes.
- The need for support aircraft increasingly diminishes the number of shooters available to deliver ordnance, reducing airpower's virtue of being able to quickly bring mass to bear anywhere in the theater.
- There is a synergy among the air-to-air, SAM, antiaircraft, and command and control (C^2) elements of the IADS.
- Low-altitude delivery of nonprecision bombs increases accuracy and losses as well.
- Delivery of nonprecision ordnance at night or in bad weather is difficult and not very accurate for fighter aircraft.
- Darkness and weather do not do much to protect striking forces against the radar-aimed parts of the IADS.
- The performance of air-to-air missiles was disappointing, and the gun was proven still necessary in the air battle for close-in combat.
- The radar-guided air-to-air missile was particularly disappointing—partly because of its complexity of use, partly because of its mechanical unreliability, and partly because of restrictive rules of engagement.
- Aircraft and weapons are often used for purposes other than those intended during their design.
- Multimission platforms or weapons are unlikely to be optimal in any of their missions.
- Bombing accuracy from long-range platforms is much improved over Korea, even in weather and at night, but still suffers from occasional stray rounds.
- Precision-guided munitions (PGM) may increase shooter effectiveness so as to compensate to some degree for increased resources devoted to support aircraft.

- PGMs are not effective in adverse weather with restricted visibility.
- Designators with an IR or low-light level television capability can give laser-guided bombs (LGB) a night capability.
- The long-held airmen's ideal of centralized control of airpower at the theater level by a coequal airman had been a part of doctrine since 1943 and was still far from realization.
- The way that the bombers and tankers were retained under SAC control contradicted USAF doctrine for centralization and tended to undermine its arguments with the other services.
- The doctrine for strategic attack was widely condemned by Vietnam specialists, but its defenders claim that it was not at all tested as with the Korean experience—the true industrial web nodes were off limits for attack in the USSR and China.
- Airpower began to undermine the enemy sanctuary of darkness; but the sanctuaries of jungle cover, weather, and political-cultural restraints remained significant.

Change after Vietnam

At the end of the day, though, the technical, doctrinal, and organizational lessons of the war in Southeast Asia remained ambiguous.[67] The outcomes were affected by so many political, cultural, and fortuitous factors besides airpower that the lessons were not all that clear. However, defeat usually is more of a stimulus for change than is victory.[68] In the decade or so after the war, major attempts to change were made in all the services. Additionally, there was a general aversion to any notion of any more Vietnams; and the military began to refocus its attention on a possible North Atlantic Treaty Organization (NATO) war in Europe between massed armed forces.

For airpower, little change came to its published doctrine in the years after Vietnam.[69] The need to be prepared for unconventional war was clear enough, and that was reflected in the evolution first of Twenty-Third Air Force and its later transfor-

mation into Air Force Special Operations Command. Its headquarters was built at Hurlburt Field, Florida; and a joint organization dedicated to the work—the US Special Operations Command—was founded at MacDill AFB, Florida. Generally, special operations forces in Vietnam had adapted old weapons and technologies to their mission, and that tradition continued after the war. Helicopters and several variants of the C-130 were employed and developed, and some unique smaller items of equipment were also acquired.

As for tactical airpower, the disappointments in the air battle in Vietnam and Army complaints about the inutility of high-performance fighters in the CAS role also led to change. More specialized platforms were developed for both roles. The F-15 was optimized for air superiority, and the new A-10 was dedicated almost wholly to the CAS role. The A-10 was designed for heavy loadouts, with great protection and a long loiter time. Its only air-to-air weapon was the short-range IR Sidewinder. This meant that it would have little utility at all in the air battle, and even its potential for deep attacks in interdiction would be limited.[70] At the same time, a third aircraft was developed that had both air-to-air and air-to-ground functions. That was the F-16; and its design certainly favored the former role, which made it formidable in the air battle but limited its loadout in the ground attack role and even its range for deep interdiction missions.[71] A contemporary but secret development was the design and building of the F-117. The hope here was that it would be invisible or less visible to enemy radar, and thus the need for supporting aircraft for strike packages would again be radically reduced.

The A-10's main weapon, the GAU-8 30 mm cannon with its complementary tank-killing ammunition, was created first; and the airplane was developed around it—one of the rare cases where the weapon drove the design of the platform.[72] Electro-optical (EO) weapons had been employed in Vietnam in the form of the Navy's Walleye bomb and the Air Force's homing bomb system. Both had been effective under the right conditions but were difficult to use and expensive. Though the LGBs did not get much media attention when they were first used inside South Vietnam nor even during Linebacker I, the

earliest versions were cheap and very effective. From the beginning, they produced very good accuracy even from medium altitudes—though the early versions were a bit cumbersome to use in the delivery.[73] They had to have either the service of a target designator on the ground or the help of another airplane orbiting the target with its onboard designator. Unfortunately, the designation had to be continued until the time of impact; and that could be dangerous whether the designator was on the ground or in the air. In the air—though the shooter could depart as soon as the bomb was released—the buddy or designator aircraft would have to fly a predictable arc around the target until the time of impact. On the ground, the man with the designator would have to keep the target in his line of sight for the entire time of fall—which could mean keeping his head in the line of sight of people at the target. Still, the results were spectacular, especially in Linebacker I in "I" Corps;[74] but they were masked somewhat by the national trauma through which we were passing at the time.

Though the public was relatively unaware of the potential huge economies entailed in even the earliest PGMs used in Vietnam, those weapons made a substantial impression inside the services.[75] That led to two successive programs for the further improvement of the LGBs and the perfection of the EO and IR seekers.[76] The former were kits used to modify the standard general purpose bombs, as were the television and IR seekers used in the GBU-15 free-fall weapon and the air-to-ground missile (AGM) rocket-powered variant, AGM 130. Both are mated with 2,000 lb bombs, as are some of the LGB seeker kits—guided bomb units (GBU)—GBU-10/27. There are also laser guidance kits for the standard 500 lb free-fall bomb (GBU-12). Similar seeker technologies were also applied to a launch-and-leave guided missile—the Maverick AGM-65—that had a wide application on A-10s, F-16s, and other platforms with a ground attack role. The Maverick comes in an EO, an IR, or a laser-guided variant; and though its warhead is smaller than those of most guided bombs, it is optimized for armor penetration. It is a launch-and-forget weapon, and the primary mode of operation for both the GBU-15 and the AGM-130 also permits a similar usage as well.[77] The Maverick is

F-4 Phantom

The standard USAF fighter by the end of the Vietnam War was the F-4 Phantom. It had originally been designed by the Navy as a fleet defense fighter without a gun. In an effort to increase commonality among services, Secretary of Defense Robert McNamara insisted that the USAF use it also; and he would not permit a redesign to include an internal gun. The combat results ultimately established the necessity of the weapon; and by war's end, the E model was coming on line with an M-61 20 mm Gatling gun.

rocket-powered and yields a modicum of standoff in low-altitude attacks—as do the LGBs by virtue of the momentum of high-speed release and their airfoils.

The implications of these weapons' technical advance for airpower doctrine and organization did not receive a great deal of attention in the public media prior to the Persian Gulf War. But, in general, they portended great improvements in accuracy and some gain in standoff delivery capability. That meant fewer losses per target destroyed, perhaps far fewer—maybe of revolutionary proportions. It also meant far fewer shooters could achieve the same damage as larger non-PGM strike forces, or the same number could do far more accurate damage. It also suggested that improved precision would frequently eliminate the need for reattack. Also, even at that early day, airlift was often viewed as the limiting factor in distant campaigns; and the perfection of PGMs suggested that there

might be large economies ahead in the logistical system. Even before the Gulf War, some airpower advocates, such as Col John A. Warden III, thought the technological improvements after Vietnam might portend the fulfillment of the visions of Douhet and Mitchell—they might enable an "air only" campaign to succeed under certain circumstances.[78]

Yom Kippur War, 1973

The Arab–Israeli War of 1973 occurred just months after the United States had agreed to remove its ground forces from Vietnam and in return recovered its prisoners from the North Vietnamese. The Israeli Air Force (IAF) had dominated its enemies in all the past wars, had recently been reequipped with US aircraft, and had long been benefiting from technology transfer from America.[79] However, the results from the short war in October 1973 caused much hand-wringing everywhere. The Arabs, using an unfamiliar strategy and new missile technologies for both antitank and air defense purposes, imposed grave losses on the Israelis in the opening days. Though their US friends had been coping with SAMs for some years past, the IAF was nonetheless caught unprepared.

The air battle was not the problem. Rather the losses fell mostly to the ground-based defenses, especially the missiles. The SA-2s and SA-3s with which the IAF had been contending for many months were responsible for many of the losses. However, the Arabs had received some additional assets from their Soviet sponsors that were new to the Israelis: the handheld SA-7 IR SAM and the SA-6 mobile system. Similarly, the land battle featured wire-guided light antitank missiles that worked mayhem on the Israeli armored formations.

Many of the analyses immediately following the war claimed that it portended the end of the blitzkrieg, for the pendulum had swung heavily in the direction of the defense both in the air and on the ground. A single, half-trained infantryman could now kill a multimillion dollar airplane or tank with impunity with a cheap missile. But even at the time, there were competing interpretations. Anwar Sadat lamented that he would have won a great victory if the Israelis had not benefited

from the import of Maverick missiles (the few that arrived came too late to have any significant effect on the battle).[80] In the end, the Israeli combined arms offensive succeeded in surrounding the Egyptian Third Army; and it looked as though that Arab force was about to be annihilated when the superpowers stepped in to shut down the war.

At that point the lessons were uncertain, and most analyses were biased by the prejudices of the analysts. But when the Falklands War and the Israeli Bekáa Valley operations occurred nine years later, it appeared that the 1973 requiem for offensive airpower had been premature. The IAF had found methods to suppress the Syrian ground defenses, and the air battle over Bekáa was a one-sided slaughter using mostly air-to-air missiles. The British surface naval forces suffered very serious losses to Argentine airpower; and, but for the failure of many bombs to explode on impact with the ships, they might well have been much worse. The British by then had an all-aspect version of the Sidewinder aboard their Harriers, but the Argentines were still equipped with the older version of the AIM-9 requiring stern shots and some French and Israeli missiles that were better—but not as good as—the AIM-9L. Four years later, a raid was made on Libya in response to terrorism, with impressive results and the loss of only one airplane—but it was only a one-time attack on an unalerted enemy.[81] Thus, as had been the case with the 1930s combats in Spain and China, there was enough ambiguity in the experiences of foreign armed forces that the message for doctrinal and organizational change in America was unclear.

Meanwhile, the reaction to the frustrations of Vietnam also stimulated doctrinal change in the US Army, which had an impact on the USAF.[82] The Army refocused its attention to the problems of a possible NATO war, sought ways to fight with inferior numbers, and perhaps even win without having to use nuclear weapons. To some extent, this was also driven by known Soviet doctrinal and organizational changes themselves designed to bring about early victory in a nuclear context—hopefully without suffering the ravages of a nuclear exchange. The US Army felt that the West would have to gain leverage out of its technological advantage. It could not hope

to win a force-on-force engagement given the perceived huge numerical advantages enjoyed by the Warsaw Pact forces.

In America the soldiers developed the notion that the Soviets could be defeated by disrupting the scheduled reinforcements on the part of the second and third echelon Warsaw Pact forces sent to exploit the breakthroughs achieved by the Communist first echelon. The NATO first line forces would engage and hold the Warsaw Pact first echelon along the front. Meanwhile the West's forces would use their technological advantages for a deep attack upon the reinforcing echelons. That was to disrupt them so as to skew the entire enemy schedule and lead to confusion and defeat without generating the necessity for NATO to use its nuclear weapons. Much of this thought was originated at the US Army Training and Doctrine Command (TRADOC) headquartered at Fort Monroe, Virginia, neighboring the USAF TAC at Langley AFB, Virginia. TRADOC saw the deep attack being carried out principally by the air forces—at least for the time being—and called the scheme AirLand Battle. The TAC leadership, at least initially, thought the notion was a good one.

During this same period in Europe, in NATO circles similar ideas were developing under the rubric of follow-on-forces attack. The idea of disrupting the time line of the follow-on forces to enable winning in spite of being outnumbered was the same.[83] But the TRADOC idea had focused the planning and execution at the *corps* level, with the corps commanders being the lords of battle. NATO looked upon the scheme as being centered at the *theater* level. The difference rang alarm bells in some USAF circles because the AirLand Battle seemed a step back toward Kasserine and the fragmentation of the control of airpower among the various ground commanders. The new Army interest in deep attack also made some Air Force folks uncomfortable because the soldiers had been denigrating the potential of interdiction since the beginning of time. The appearance of long-range, ground-based fires on the technological horizon seemed to portend an Army effort to grab another chunk of the Air Force turf. Thus it happened that though TAC signed agreements incorporating the AirLand

Battle idea, the notion never got written into Air Force doctrine in general.

By the mid-1980s Congress got around to doing something in the hope of clarifying the command practices for future theater wars. It generally strengthened the role of the CJCS and the area CINCs and more closely confined the work of the service chiefs to the functions of training and equipping their forces for employment by those CINCs. It also seemed to provide a partial step in the direction long favored by the airmen as to the C^2 of airpower: centralized at the theater level and controlled by an airman coequal to the land and sea commanders. The Goldwater–Nichols Act also recommended that CINCs appoint a joint force air component commander (JFACC) and that he be chosen from the service with the preponderance of air assets engaged.[84] Just as electronic advances had enhanced the development of PGMs, they also facilitated the improvement of gathering information and of unifying C^2 at the theater level. The improvement in electronics also facilitated the development of space assets that could provide sensors for information, help with weather forecasting, greatly facilitate precise navigation, and improve worldwide communications.[85]

Those, then, were the airpower technological, doctrinal, and organizational changes that took place before the Warsaw Pact and the USSR collapsed and the Gulf War appeared in close succession.

War and Technology in the 1990s: Has the Last Sanctuary Been Closed?

The Cold War ended abruptly and the United States had not even begun to explore the required policy, strategy, doctrinal, or organizational changes when Saddam Hussein marched into Kuwait and threatened to go farther.

Gulf War, Weather Sanctuary, and Concrete Sanctuary

The coalition that was developed to oppose Iraq's move toward domination of the oil supply was blessed with a good deal of time to plan and deploy its response.[86] When combat was fi-

nally initiated, the result was so pleasing, swift, and complete that it surprised even the most optimistic planners. The coalition won the air superiority campaign in a trice; the air-to-air battle itself did not last long. Practically all of the coalition's few aircraft losses fell to the ground elements of the enemy IADS, and that had been effectively suppressed by the third day through both lethal and nonlethal means. In the years that had passed since the end of the Vietnam War, electronic news reporting had developed still further so as to have instant worldwide coverage. It was emplaced in Baghdad when the war began and was able to return impressive video images of the character of the strategic part of the air attack. The air campaign ran several weeks before the CINC, US Army general H. Norman Schwarzkopf, launched the ground assault. The ground portion of the campaign was over in four days and brought the analysts out in droves explaining that the proof was at hand that the Douhet/Mitchell revolution was finally consummated or denying that was so.[87]

Many technological advances made since Vietnam had an effect. One was that space technology had greatly advanced facilitating a much better picture of what was going on for the commanders on the coalition side. It also gave accurate and timely weather forecasts and greatly improved navigation (by Global Positioning System [GPS]) for some vehicles of every description, and even for the foot soldiers. The technologies for deployment were not much changed since Vietnam; and though the striking force was made up of new jets, their advance had not been as great as the one made between, for instance, World War II and Vietnam.

There were some new weapons guidance technologies in place in the GBU-15 and antiradiation missiles (ARM), but their principles of operation were not much different from those employed in their predecessors in Vietnam. In any case, by far the greater part of the PGMs employed were the LGBs and Mavericks—the former of which had been extensively used in Linebacker I in 1972. Their utility was much better noted this time because of the great electronic news coverage in Baghdad, which yielded some spectacular combat footage. Even at that, only about 10 percent of the bombs dropped

were guided weapons. But is was clear enough that at times the weather was still a potential sanctuary from air attack, even from PGMs.

Practically all of the kills made in the short air battle were the result of PGMs, but the missiles used were later models of the same AIM-9 Sidewinders and AIM-7 Sparrows that had armed our forces in Vietnam. The air-to-ground part of the air superiority battle was facilitated by one new technology in a major way: the F-117 stealth aircraft had come on the line.[88] It was used against some of the most dangerous C^2 nodes in the enemy defense system, and the combination of its stealth with the two LGBs it carried proved devastating.[89] According to some estimates, one F-117 could achieve in one sortie what was achieved with a striking force of 300 B-17s in World War II—a change of potentially revolutionary proportions. In the words of Gen Buster C. Glosson:

> Air power advocates have long dreamed of a day when the weapon, platform, and willingness to use them properly would come together to make air power a decisive force. Today, those dreams are reality. One need only look back to our raids on Schweinfurt, Germany, in World War II to see how dramatically precision weapons have enhanced our capabilities over the last 50 years. Two raids of 300 B-17 bombers could not achieve with 3,000 bombs what two F-117s can do with only four. Precision weapons have truly given a new meaning to the term *mass*.[90]

No F-117s were lost, even though theirs were the most dangerous targets assigned. The new high-speed antiradiation missile (HARM) also facilitated the air-to-ground part of the air superiority effort. It was much faster than the antiradiation weapons used in Vietnam; and even when the enemy knew a HARM had been launched, it yielded him much less time to shut down his radar than theretofore (ARMs home in on radar emissions).[91] Those lethal methods were supplemented by the nonlethal jamming efforts of various platforms such as the Navy's EA-6 and the Air Force's EF-111. The consequence was that though all of the coalition losses save perhaps one were to the surface defenses, they were nonetheless minimal compared to Vietnam and the Yom Kippur War—and especially to World War II.

The doctrinal dimensions of the air war in the Gulf were of some consequence. One argument was stimulated between

the Army and the Air Force that probably emerged from the AirLand doctrines of the former. The corps commanders had jurisdiction of the placement of the fire support coordination line (FSCL), which had marked the border between CAS and interdiction—or between Army and Air Force turf—for many years past. Detailed coordination with the ground commander was required for any air strikes inside the FSCL, whereas the air commander could conduct his operations outside the line in an unhampered way.[92]

That coordination had worked well ever since World War II. But now, in the rapidly moving four-day ground battle, it led to some difficulty. Formerly the FSCL had been set at the outer limit of the field artillery range, a limited distance. But in the years since Vietnam, new ground technologies in the multiple launch rocket system, helicopters, and potentially in the new ground launched missile systems (Army Tactical Missile System) greatly increased the range of organic fire support systems available to the ground commander. He was thus tempted to project the FSCL out much farther than theretofore. This happened in the closing hours of the ground campaign and, according to the airmen, excluded them from attacking fleeing Republican Guard units—many of which wound up escaping.[93]

Another of the traditional Air Force doctrinal issues stimulated a good deal of debate as a result of the Gulf War. Since the beginning of World War II, the airmen had been urging that airpower be commanded by an airman in a centralized way at the theater level. The air commander was to be colocated with the ground commander and was to be equal to him. Neither force was to be subordinate to the other. As noted, the Goldwater–Nichols Act in 1986 had provided a legal basis for this though it did not mandate that the joint force commander adhere to the ideal.[94] In the Gulf War, a JFACC was established in the person of Air Force Lt Gen Charles A. Horner; and his air operations center produced the daily air tasking order (ATO). Everything that flew over the landmass in the area of operations (AO) was required to be listed on that ATO. General Horner and many other airmen argued that the airmen's ideal for centralized command had finally been realized. Not all air-

men agreed, and many in the Navy and Marine Corps did not. One of the reasons was that there was such a huge force of airplanes available that the hard choices that would have had to have been made in a time of aircraft scarcity had not been necessary. The resulting theater organization resembled that envisioned in the Goldwater–Nichols Act; but General Schwarzkopf acted as his own land force component commander, and that was said to have made the various components unequal.[95]

Another thing made possible by the great abundance of coalition airpower was what has come to be called parallel attack in the writings of Warden and later in Air Force Doctrine Document 1, *Air Force Basic Doctrine*.[96] The idea is that from the beginning, airpower has usually been condemned to a sequential attack—that it first had to mass all the power available in the counterair mission to gain air superiority. Only after that was achieved could it turn to the other missions. However, by the time of the Gulf War, the combination of ample numbers of aircraft and the new efficiency of PGMs so reduced the number of sorties needed to destroy a target that new options were thus opened. Now, according to Warden and others, it was possible to undertake the various tasks of airpower simultaneously. One could conduct the counterair, interdiction, CAS, and strategic attack missions at the same time. The result would not be the dispersion of one's forces and the violation of the principle of mass. Rather, it was to be the accomplishment of massing firepower in time—hitting multiple centers of gravity at the same time. That would create synergies that would greatly increase enemy shock and confusion. As an antithesis to gradualism, the idea was highly appealing to many airmen.[97]

As noted, the weather during the Gulf War was far worse than it had been in that region for a number of years, which inhibited the effectiveness of the PGMs then available. The Iraqis also found another sanctuary that was not altogether new—a cultural or humanitarian one. One example was the civilian deaths suffered in the bombing of the Al Fidros bunker, a military installation temporarily being used as a bomb shelter for noncombatants. Saddam Hussein effectively

used the incident—together with his access to the West's electronic media—to shock public opinion to the point that further attacks in Baghdad were prohibited for most of the rest of the war.[98] Additionally, when he found that his concrete aircraft shelters were no protection for his air force, he sent many of the survivors into another sanctuary: Iran. That, in effect, was a functional kill for the coalition because the Iraqis never got them back.[99] Some of the remnants were parked near monuments and other civil structures, which formed cultural sanctuaries.

In earlier days, the Vietnamese found sanctuaries for some elements of their IADS by deploying them along dikes, near hospitals, or in villages. The coming of PGMs was to make the physical task of destroying such targets without collateral damage less difficult than theretofore, but the penalties for *any* collateral damage in lost public and neutral support steadily grew as the century waned.

In the euphoria that we enjoyed at the end of the Gulf War, the president said we had finally overcome the Vietnam War syndrome. Many airmen argued that the visions of the pioneers of the 1920s had finally been fulfilled. The ideal of centralized control had been consummated. The potential for precision would not only make the penalties of collateral damage less but also induce such economies that parallel attack would become more feasible. It might also considerably reduce the size of the logistical tail and diminish the time necessary to deploy and to bring sufficient shock on the enemy to cause him to do our will. It might even enable an air alone campaign in some circumstances.[100] Whether it was the strategic attack or the tactical operations that had brought that about is not easy to determine. But the fact remains that the air campaign had reduced the enemy to the point where the ground battle lasted only four days, and the whole war cost the United States only 148 service people killed in action.[101] But there were gnawing concerns that with all our information and precision attack advantages, we had been unable to master the threat of theater ballistic missiles. The weather sanctuary remained, and many argued that the results should not be taken as the wave of the future. Though concrete shelters and

underground bunkers were put at risk by new penetrating bombs, going underground could still provide some refuge.[102] Even with the bad weather, the desert environment and relatively good climate were ideal for air campaigns and would seldom be seen again.

Organizational Change after the Gulf War

Some air reorganization was in the wind before the Gulf War but did not come to fruition until afterwards. The heyday of SAC was in the distant past. There had been questions about the fragmentation of combat airpower since the days of Billy Mitchell, and even at the time of the creation of SAC, TAC, and the Air Defense Command. The coming of the ICBMs and the sea launched ballistic missiles (SLBM) caused a gradual transition from reliance on bombers to dependence upon missiles for deterrence. The Navy role with the SLBMs had long been an obvious inducement toward the creation of a joint organization. Finally, the collapse of the USSR reduced the relative importance of nuclear deterrence in national security planning.

The disappearance of the Soviet Union and the end of the Cold War were important factors leading to organizational change in another way. The American people had been laboring under heavy defense expenditures and frequently unbalanced federal budgets ever since 1938. The end of the Cold War greatly reduced their fear of general war. It also stimulated their desire to gain a peace dividend, balance the national accounts, begin paying down the national debt, and apply funding to other important social needs. Thus, any consolidations and reductions in the numbers of headquarters would facilitate those desires.

One of the consolidations was the reunification of the R&D function with the procurement role. The original splitting of those functions occurred in the early 1950s and was done on the notion that the R&D funding would always be so much less than that for procurement and supply that the officers in charge of the latter would always dominate the Air Materiel Command. The argument was that such dominance would be certain to limit the Air Force to incremental change and con-

demn it to unimaginative developmental programs. On the other hand, it did create two commands where one had existed theretofore and thus increased the overhead. The reunification was achieved under the name of Air Force Materiel Command, which is headquartered at Wright–Patterson AFB, Ohio.[103]

The notion that underlay the creation of GHQ Air Force in 1935 was that combat airpower was inherently indivisible. Were it commanded in a fragmented way, its full shocking power could never be realized. The GHQ AF briefly lived under the name of Air Combat Command (ACC) before the onset of World War II.[104] But during World War II, airpower was seldom controlled in a unified way. Often the RAF model of functional commands was followed—usually a bomber command, a fighter command, a coastal command, a training command, and perhaps a service command. In the RAF case, airpower was under unified command only at the ministerial level.

After World War II, just before the creation of the USAF, the USAAF reorganized for a peacetime role. In 1946 strategic attack, strategic defense, and tactical airpower were split into their respective functional commands. So it remained until 1992 when they were all reunified into an ACC led from Langley AFB.[105] Still, the ACC function is mainly to train and equip air forces for employment by the area CINCs. The bomber force was only a shadow of its former self, and that was a part of the reason the command wound up at Langley, where TAC had been situated. Another part of the reason was that the remaining nuclear deterrence functions were placed under a new joint command, the United States Strategic Command; and it needed a home, which was found at Offutt AFB, Nebraska—formerly the location of SAC headquarters. But that created a problem with finding a home for SAC's tankers. They were often discounted as combat aircraft, and thus it was thought inappropriate to put them in ACC. Rather, the name of MAC was broadened to Air Mobility Command (AMC); and the tankers were transferred to its control, which would be exerted from Scott AFB, Illinois.[106] These name changes and functions were more stimulated by political change than by technology.

Changes in Air Technology after the Persian Gulf War

There was little change in the technology of aircraft in the aftermath of the Gulf War, and the Kosovo campaign was fought with largely the same types of aircraft. The B-2 bomber was indeed used over Kosovo for the first time in combat,[107] and its stealth and massive bomb load combined with one more improvement in conventional munitions technology might tempt one to say that the last sanctuary has been closed: the bad weather refuge.[108]

Allied Force, AMRAAM, JDAM, JSOW, and Weather Sanctuary

The improvement was really a combination of conventional guidance and space technology advances. The GPS system had matured more since the Gulf War, and a technology pro-

B-2 Spirit

In 1999 this bomber was first used in combat over Serbia with the GPS/INS bombs with very good results. The joint direct attack munition used there was the 2,000 lb size, but there are now programs under way to adapt the guidance to the 500 lb weapon so that each sortie could hit more than the 16 targets possible with the 2,000 pounders.

gram that antedated it was transitioned into line weaponry. Both the joint direct attack munition (JDAM) and the joint standoff weapon (JSOW) programs achieved their IOCs before NATO attacked Slobodan Milosevic's Serbia.[109] Both are launch-and-leave weapons, though each can receive GPS updates after launch. By 1999 JDAM had been certified for operation only aboard the B-2, though it was in the process of being qualified on practically all American air-to-ground aircraft. On the B-2, however, the plane's radar systems permit the correcting of the GPS coordinates of targets—thereby increasing JDAM accuracy over that achieved on other aircraft. The results were spectacular in that the JDAM attacks were launched against Serbian targets from a USAF base in Missouri and continued even when the weather had grounded all other attack aircraft. The bombing was done through the clouds and yet yielded highly accurate results.

The JDAM and JSOW use similar guidance systems that are not dependent upon visual, IR, or radar acquisition of the target if its coordinates are known. Both these systems are guided first by an inertial measurement unit (IMU) that can bring them very close to the target. They also have a relatively simple GPS receiver so that they can receive accuracy updates to their IMUs during their time of fall to the target. The JDAM is a tail kit that is fitted to the standard 2,000 lb US bombs stored in huge numbers all over the world, and kits are being developed for smaller sized bombs as well. In terms of the usual PGM costs, they are exceedingly cheap and thus are being acquired in huge numbers. The two great advantages of the JDAM and the JSOW are their low cost and their ability to hit a target through the clouds, at night, or through smoke or other obscuration. They also do not require designation, and thus the launch crews can move on to other things or drop additional weapons. The disadvantage of both weapons is that in some applications, though not as much in the B-2, they require good intelligence on the exact location of the target. JSOW costs substantially more than JDAM, but it is still relatively economical compared to the usual PGM with the same standoff capability.[110] It has a set of folding wings that enable it to glide a considerable distance and still hit a target through

Joint Standoff Weapon

the weather with the same accuracy as the JDAM. Being presently unpowered and lacking a seeker with large data processing requirements, it is more economical by far than the usual cruise missile, or even the AGM-130 (which has a much larger radar cross section, higher drag, and a bigger warhead than JSOW). JSOW is not a mere attachment to a standard weapon. Rather, it has a weapons bay which—in its earliest version—carries a number of the standard submunitions normally delivered with a munitions dispenser, which sometimes requires that the delivery aircraft make a closer approach to the target.[111]

It is well established in the historiographical literature that the "want of a nail" single causation explanations of military technical revolutions (MTR) are very seldom correct. This is also true of the perceived RMA at hand. Arguably, it is based on far more than the coming of stealth and air-to-ground precision weapons. By the turn of the century, the last several combats (Yom Kippur War, Falklands War, Bekáa Valley, the Gulf War, and the air war over Serbia) all suggest that there has been a radical improvement in the West's ability to conduct the air-to-air battle since Vietnam. In part, this has been based on the improvements in the Sidewinders and Sparrows of that day to make them more reliable, easier to use, and less easy to evade. In part, it has arisen from much improved C^2 with the coming of the airborne warning and control system, as well as aircraft optimized for the air battle (F-15C). In addition, just after the end of the Gulf War, new precision weapons

came on the line in the form of the advanced medium range air-to-air missile (AMRAAM).[112] The Sparrow was roughly in the same range category, but it was not a fire-and-forget weapon. Its launching crew had to direct it toward its target all the way up to impact. In turn, the crew could not begin evasive maneuvers or attacks on additional enemies until the missile reached its target; and the relatively slow speed of the Sparrow and its visible smoke trail made it conceivable that an alert enemy could avoid it.

AMRAAM made many improvements. It is much lighter and can be carried aboard most of the F-16s in the inventory, of which there were many which could not handle the weight nor the radar requirements of the Sparrow. In one of its modes of operation, the AMRAAM has an active radar. That is to say, it can "paint" the target with its own radar transmitter. This makes it possible for the launching fighter to begin his escape or another attack before impact. In contrast, the Sparrow only has a receiver. AMRAAM has a higher speed than Sparrow, which gives the enemy less time to evade it; and it has less of a smoke trail, which makes it less likely that an enemy will discover he is under attack until it is too late.[113]

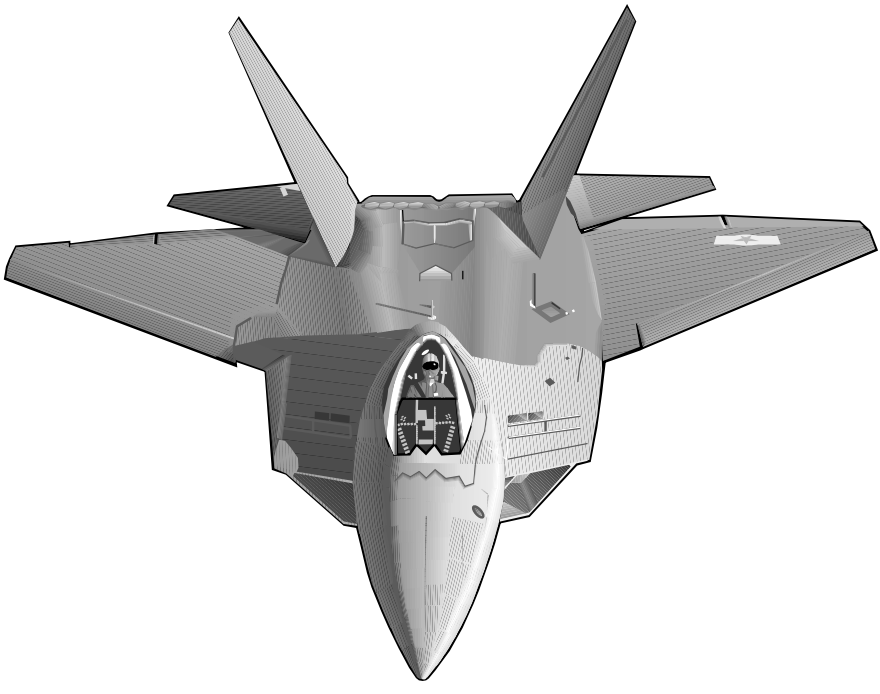
The Western capability for the close-in fight has also been improved since the Gulf War. In the American case, this has come about in small part by the design of improved ammunition for the standard air-to-air gun, the M-61. That design has improved the muzzle velocity with the effect of flattening the trajectory while at the same time reducing the time the enemy aircraft has to get out of harm's way. But atop that improvement has been the design of a new version of the Sidewinder, the AIM-9X. That, too, has a higher velocity and less smoke than its predecessors. It also has a new control system that enables it to turn more sharply, thereby reducing the enemy's chance to escape by way of violent maneuvers. Like its immediate predecessors, the AIM-9X is simpler to use than its Vietnam ancestors because it is an all-aspect weapon. This means that the attacker no longer has to maneuver into a narrow cone astern its victim to get a lock on. Rather, the Sidewinder now can attack from the beam or ahead of the target. A further improvement is also on the horizon for some of

Advanced Medium Range Air-to-Air Missile

The advanced medium range air-to-air missile (AMRAAM—AIM-120) on an F-16. The weapon achieved its initial operational capability in 1991 and scored its first kill in 1992.

the US air-to-air fighters: the helmet mounted sight. The pilot will no longer have to maneuver his jet so as to get his target into his heads up display (HUD) on the cowling. Rather, all of the HUD information will now be projected onto the visor of his helmet so that he will not even be required to look forward to his cowling. He will be able to slave the seeker in the AIM-9X to the sight on his helmet and to launch it at whatever he is looking at—within the field of regard of the seeker. That means saving of precious seconds consumed in maneuvering and the ability to launch off-boresight shots at targets on the beam—and potentially even some behind the beam.[114]

Added to those weapon improvements are still others in C^2 and situational awareness, in addition to the design of a successor to the F-15C as a dedicated air-to-air plane. The new craft—the F-22—has stealth, improved agility, and supercruise (the ability to sustain supersonic flight without the use of fuel-guzzling afterburners)—all of which promise to combine with the weapons improvements to further widen the West's advantage in the air-to-air part of the air superiority battle.[115] Given the weakness of the Russian economy and its R&D base in the last 10 years, it seems doubtful that the improvements on the ground-based defenses have kept up with the combinations cited above—but, as always, only all-out battle could prove that point.



Artist Drawing of the F-22 Raptor

The USAF F-22 depicted above is the latest technology development designed first to sustain command of the air. An air-to-ground capability is being added to increase its versatility. A complementary program is afoot to develop the "small diameter bomb" that will fit into its weapons bay and yet have the precision and improved explosive filler to give it the same potency as much larger weapons. Its stealth—in most circumstances—should give it the first shot advantage over nonstealthy aircraft, which has usually been decisive in past aerial battles. Atop that it has a sustained supersonic capability without the use of afterburners, which aims to reduce the time it would be vulnerable to the ground defenses.

The Remaining Humanitarian Sanctuary and Doctrinal Implications

Airpower began to remove the sanctuary of distance a long time ago. In the United States, Professor Thaddeus Lowe's balloons began to diminish the Confederate ability to hide from prying Union eyes as long ago as 1862.[116] The addition of airplanes to the lighter-than-air capability of reconnaissance and spotting was a major factor in denying World War I enemies an

offensive potential by peering into their rear areas to prevent undetected massing of troops.[117] By World War II, the offensive capabilities of airpower brought lethal firepower far into the enemy homeland to further close the sanctuary of distance. Gerd von Rundstedt's troops could still find some protection from airpower during the darkness of short nights as they fled across France in 1944 and 1945. The *Wehrmacht* found some safety under the clouds for the first six days of the Battle of the Bulge. Also, the combination of the inaccuracy of the bombs and the pain inflicted on the air offensive by the defenses limited the shock put on enemies. The North Koreans and the Chinese enjoyed the same sanctuaries up to 1953, but the refuge of darkness began to disappear for enemies during the Vietnam War. By the time of the Gulf War, the curtain of the night had been removed—in fact, the darkness had become the friend of offensive airpower. But Saddam Hussein's soldiers could still find a little safety underground or behind the clouds and smoke.

Neither clouds nor darkness helped Milosevic's Serbia much because by then these elements made no difference to JDAM or JSOW. His people could still find a little shelter behind cultural and humanitarian sanctuaries and some protection beneath soil or concrete in a limited war world. They also proved expert at using decoys and camouflage to help them hide—at some cost in time and mobility. But the increasing application of precision to conventional weapons was working to diminish that protection.

Organizational Implications

It would certainly be presumptive to argue that PGMs had brought the revolution envisioned by Douhet and Mitchell and their followers to full flower. RMAs in the past have almost always been the result of a new combination of relatively mature technologies, not a single radical new invention.[118] In the absence of stealth, the B-2 would have been highly vulnerable in Allied Force, and its 16 JDAMs might all have gone for naught. Even with stealth, the B-2 crews could not have hit their targets with that kind of regularity without the combining of in-

ertial measurement technologies with those provided by space-based navigation systems.

There are predictions far and wide suggesting that because countermeasures such as radar have always been found in the past, a counter to stealth might be just around the corner. There is a regular refrain regarding the possibility of jamming GPS, thereby preventing transition to a full-blooded doctrine of air-only coercion. Accordingly, to reorganize our national security around airpower alone would require a superhuman act of foresight—or a foolhardy one. Those who can remember the rapid disappearance of the US isolationist world during the afternoon of 7 December 1941 would never again want to put our national eggs into that single basket. Yet the advice of Rear Adm James Winnefeld and Dr. Dana J. Johnson certainly seems worth contemplating.

Perhaps the combination—of air refueling, long-range airpower, superior information, precision and accurate guidance, stealth and superior defense suppression, and increased standoff—is enough to cause us to at least consider the possibility that an airpower-based RMA has occurred. On the other hand, it would be imprudent to conclude that air-only solutions apply in all instances. With that much said, many historians would still cringe at the use of the word *revolution*, especially since the greater part of a century has passed since the days of Douhet and Mitchell. But in my own opinion, Benjamin Lambeth's choice of *Transformation* for the title of his new book is not too much.[119]

I would further argue that the great improvements in conventional weapons since 1945 have changed the cost-effectiveness calculations in favor of the aerial offensive. This change has been dramatic enough since the discovery of laser light in 1958 that I would argue that PGMs are a main pillar of that transformation. Two cautions are necessary. First, Vietnam showed us that being prepared for one kind of larger war did not automatically mean that we were also prepared for a smaller conflict of another sort. The potential adversaries know that and will surely be reluctant to challenge the United States in another Desert Storm. Second, we so dominate the conventional battlefield that we should carefully consider

whether we should deliberately change the arena by weaponizing space, where it might be more difficult to establish and sustain a commanding advantage on a new battlefield.

Notes

1. Bernard Brodie, *Strategy in the Missile Age* (Princeton, N.J.: Princeton University Press, 1965), 73.

2. Gian P. Gentile, *How Effective Is Strategic Bombing? Lessons Learned from World War II to Kosovo* (New York: New York University Press, 2001).

3. David MacIsaac, "Voices from the Central Blue: The Airpower Theorists," in *Makers of Modern Strategy: From Machiavelli to the Nuclear Age,* ed. Peter Paret (Princeton, N.J.: Princeton University Press, 1986), 624–30; Brodie, 98; Williamson Murray and Allan R. Millett, *A War to Be Won: Fighting the Second World War* (Cambridge, Mass.: Belknap Press, 2000), 304; and Lee Kennett, "Strategic Bombardment: A Retrospective," in *Case Studies in Strategic Bombardment,* ed. R. Cargill Hall (Washington, D.C.: Air Force History and Museums Program, 1998), 623. The idea that bombing could reduce human suffering by shortening wars antedates both Mitchell and Douhet for it was voiced by Capt William Crozier, US Army, at the Hague Conference of 1899.

4. William "Billy" Mitchell, lecture, Army War College, 24 November 1922, Curricular Archives file no. 240-49, US Army Military Institute, Carlisle Barracks, Pa., hereinafter referred to as Mitchell's lecture; Giulio Douhet, *The Command of the Air*, trans. Dino Ferrari (1942; new imprint, Washington, D.C.: Office of Air Force History, 1983), 9; and Brodie, 71–144. In his lecture, General Mitchell said "some improvement has been made in antiaircraft artillery. However, as I said before, we care little for antiaircraft artillery." In *The Command of the Air,* Douhet stated that "the airplane has complete freedom of action and direction; it can fly to and from any point of the compass in the shortest time—in a straight line—by any route deemed expedient. Nothing man can do on the surface of the earth can interfere with a plane in flight, moving freely in the third dimension. All the influences which have conditioned and characterized warfare from the beginning are powerless to affect aerial action." The ideas of Douhet may be received directly from his book or indirectly from Brodie.

5. Alfred F. Hurley, *Billy Mitchell: Crusader for Air Power* (1964; reprint, Bloomington, Ind.: Indiana University Press, 1975); and William Mitchell, *Winged Defense: The Development and Possibilities of Modern Air Power—Economic and Military* (1925; reprint, New York: Dover Publications, 1988). Hurley is considered the authority on Mitchell as is Mitchell himself in *Winged Defense.*

6. Adm William A. Owens, US Navy (USN), retired, "The Emerging System of Systems," US Naval Institute (USNI) *Proceedings,* May 1995, 35–39; idem, "It's Time for the Revolution," USNI *Proceedings,* April 2000, 90–92; Bill Toti, "Stop the Revolution; I Want to Get Off," USNI *Proceedings,* July 2000,

30–33; Andrew F. Krepinevich, "Cavalry to Computer," *National Interest,* Fall 1994, 30–42; idem,"Forging a Path to a Post-Nuclear U.S. Military," *Issues in Science and Technology,* Spring 1997; Michael E. O'Hanlon, *Technological Change and the Future of Warfare* (Washington, D.C.: Brookings Institution Press, 2000); idem, "Can High Technology Bring U.S. Troops Home?" *Foreign Policy,* Winter 1998/99, 72–87; Thomas C. Hone, "Jackie Fisher's Revenge," USNI *Proceedings,* February 2000, 82–86; Steven Metz, "The Next Twist of the RMA," *Parameters,* Autumn 2000, 40–54; Eric R. Sterner, "You Say You Want a Revolution (in Military Affairs)?" *Comparative Strategy,* October–December 1999, 297–309; Colin S. Gray and John B. Sheldon, "Space Power and the Revolution in Military Affairs: A Glass Half Full?" *Airpower Journal,* Fall 1999, 23–39; on-line, Internet, available at http://www.airpower.maxwell.af.mil/airchronicles/apj/apj99/fal99/gray.html; Williamson Murray, "Clausewitz Out, Computer In: Military Culture and Technological Hubris," *National Interest,* Summer 1997, 57–65; Lawrence Freedman, *The Revolution in Strategic Affairs,* Adelphi Paper 318 (New York: Oxford University Press, 1998); Thomas A. Keaney and Eliot A. Cohen, *Revolution in Warfare? Air Power in the Persian Gulf* (Annapolis, Md.: USNI Press, 1995); Michael J. Mazarr, Jeffrey Shaffer, and Benjamin Edrington, "The Military Technical Revolution," in *American Defense Policy,* ed. Peter L. Hays, Brenda J. Vallance, and Alan R. Van Tassel, 7th ed. (Baltimore, Md.: Johns Hopkins University Press, 1997); and Robert Tomes, "Revolution in Military Affairs—A History," *Military Review,* September–October 2000, 98–102. These are samples of that huge literature.

7. Peter R. Faber, "Interwar US Army Aviation and the Air Corps Tactical School: Incubators of American Airpower," in *The Paths of Heaven: The Evolution of Airpower Theory*, ed. Phillip S. Meilinger (Maxwell Air Force Base [AFB], Ala.: Air University Press, 1997), 183–238.

8. Phillip S. Meilinger, "Trenchard, Slessor, and Royal Air Force [RAF] Doctrine before World War II," in *The Paths of Heaven,* ed. Meilinger, 41–78.

9. James S. Corum, *The Roots of the Blitzkrieg*: *Hans von Seeckt and the German Military Reform* (Lawrence, Kans.: University Press of Kansas, 1992), 151–59; and Richard Muller, *The German Air War in Russia* (Baltimore, Md.: Nautical and Aviation Publishing, 1992), 149–88.

10. Among those using such a concept are Steven M. Kosiak, "U.S. Fighter Modernization: An Alternative Approach," *Issues in Science and Technology Online,* Spring 2000, 8, on-line, Internet, 25 April 2001, available at http://www.nap.edu/issues/16.3/kosiak.htm; and Dr. Elinor Sloan, "Canada and the Revolution in Military Affairs: Current Response and Future Opportunities," *Canadian Military Journal,* Autumn 2000, 1–2, on-line, Internet, 25 April 2001, available at http://www.journal.dnd.ca/vol1/no3_e/revolution_e/rev1_e.html.

11. Brodie, 73.

12. US Army, Air Service, Headquarters First Provisional Air Brigade, Langley Field, Va., "Armament Report," 8 August 1921, copy at USAF

Historical Research Agency (AFHRA), file no. 248.222-89; Mitchell's lecture, 9; and Maj T. D. Milling, report, "The Air Service Tactical School," Langley Field, Va., 1924, copy in files of History Office, Air Armament Center, Eglin AFB, Fla., file no. 25A-1-15. Major Milling relates some experiences in the bombing tests. The school had not yet migrated from Langley to Maxwell AFB, Ala., to become the Air Corps Tactical School (ACTS); and instruction was suspended for the duration of the tests. The officers of the school became a part of the nucleus of the First Provisional Air Brigade, which conducted the Air Service part of the tests. During his lecture Mitchell speaks also of some of the bomb research that the First Provisional Air Brigade did in preparing for the bombing tests.

13. Neville Jones, *The Beginnings of Strategic Air Power: A History of the British Bomber Force, 1923–39* (London: Frank Cass, 1987), 66.

14. Edward Jablonski, *Flying Fortress: The Illustrated Biography of the B-17s and the Men Who Flew Them* (Garden City, N.Y.: Doubleday, 1965), 315.

15. C. M. Green, H. C. Thomson and Peter C. Roots, *The United States Army in World War II,* vol. 3, *The Ordnance Department,* pt. 1, "Planning Munitions for War" (Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1955), 422, 452–55; Harry C. Thomson and Lida Mayo, in *The United States Army in World War II,* vol. 3, *The Ordnance Department,* pt. 2, *Procurement and Supply* (Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1960), 119–21; and US Air Force (USAF), Air Command and Staff College (ACSC), *Air Weapons* (Gunter Air Station, Ala.: Extension Course Institute, 1957), 1–2.

16. Lt Col Robert A. Colella, interviewed by author, 9 May 2001, Maxwell AFB, Ala. The joint direct attack munitions (JDAM) used by the B-2 in the Kosovo campaign all had 2,000-pound warheads, which allowed the delivery of 16 on different targets on every trip; since then, given the accuracy developed by the new tail kits, the USAF has moved to develop a 500-pound version of JDAMs so as to enable the delivery of even more rifle shots than were possible in 1999.

17. Thomas Wildenberg, *Destined for Glory: Dive Bombing, Midway, and the Evolution of Carrier Airpower* (Annapolis, Md.: USNI Press, 1998), 219–20; and Stephen Lee McFarland, *America's Pursuit of Precision Bombing, 1910–1945* (Washington, D.C.: Smithsonian Institution Press, 1995). McFarland traces the history of the Norden bombsight development, and Wildenberg traces the origins of the Norden bombsight development and the adoption of dive bombing for the sake of hitting a maneuvering ship.

18. William A. Borden, "Air Bombing of Industrial Plants," *Army Ordnance,* I, November–December 1920. Borden's early ideas are similar in some ways to those prominent at the ACTS a decade and a half later and even some on incendiary weapons often associated with the name of Gen Curtis E. LeMay and the fire bombing of Japan a quarter century afterwards.

19. In the abstract a fortress is a defensive system, and that name for the aircraft was originally chosen to suggest its defensive character.

20. Mitchell's lecture, 23; Faber, 219–21; and Robert T. Finney, *History of the Air Corps Tactical School, 1920–1940*, USAF Historical Study 100 (Maxwell AFB, Ala.: USAF Historical Division, Air University, 1955). Usually the idea of the vulnerable triangle subject to bombing from an Ontario base is attributed to the ACTS, but Gen Billy Mitchell referred to the notion in this lecture.

21. Haywood S. Hansell Jr., *The Air Plan That Defeated Hitler* (Atlanta, Ga.: Higgins–MacArthur/Longino and Porter, 1972), 94–95, 112.

22. Russell F. Weigley, *Eisenhower's Lieutenants: The Campaign of France and Germany, 1944–1945* (Bloomington, Ind.: Indiana University Press, 1981), 12–19.

23. Murray and Millett, 509–10; Thomas B. Buell, *The Quiet Warrior: A Biography of Admiral Raymond A. Spruance* (Annapolis, Md.: USNI Press, 1987), 396; E. B. Potter, *Nimitz* (Annapolis, Md.: USNI Press, 1976), 378–81; Gerhard L. Weinberg, *A World at Arms: A Global History of World War II* (Cambridge, U.K.: Cambridge University Press, 1986), 882; and Ronald H. Spector, *Eagle against the Sun: The American War with Japan* (New York: Vintage, 1985), 540–44.

24. *The United States Strategic Bombing Surveys [USSBS], Summary Report: European War, Pacific War* (1947; reprint, Maxwell AFB, Ala.: Air University Press, 1987), 37, 106.

25. Bernard and Fawn M. Brodie, *From Crossbow to H-Bomb* (Bloomington, Ind.: Indiana University Press, 1962, 1973), 207–8. The Brodies show that the Navy was working on radar in Washington from 1935 and demonstrated it aboard ship before the war; the Army tested radar for antiaircraft guns and for aircraft warning by 1939 as well, but little thought had so far been given to the implications for air defense and for long-range bombing before World War II.

26. Maurer Maurer, *Aviation in the U.S. Army, 1919–1939* (Washington, D.C.: Office of Air Force History, 1987), 69–84; and *USSBS, Summary Report*, 37–40, 108–13. The comments on the ACTS and Mitchell in this essay are not meant to convey any notion that they were totally preoccupied with strategic bombing. Mitchell, especially in his earlier writings, was arguing for balanced air forces, and the US Army air arm contained a dedicated tactical support group throughout the interwar period—the 3d Attack Group based at Barksdale Field, La., for the greater part of the period. It was one of three operational groups, and the others also contained attack airplanes. There was an attack course in the curriculum of the ACTS throughout the interwar period, and numerous attack aircraft were designed and produced during that period. The first monoplane in US service was the Curtiss A-8 of 1928, some time before the monoplane P-26 and B-10 appeared.

27. Dudley Saward, *Bomber Harris: The Story of Marshal of the Royal Air Force, Sir Arthur Harris* (Garden City, N.Y.: Doubleday, 1985), 221.

28. Marshall L. Michel III, *Clashes: Air Combat over North Vietnam, 1965–1972* (Annapolis, Md.: USNI Press, 1997), 164–65; and Wayne Thompson, *To Hanoi and Back: The U.S. Air Force and North Vietnam*,

1966–1973 (Washington, D.C.: Smithsonian Institution Press, 2000), 288. This is a continuing concern. The reason why the USAF was so successful in the Korean air battles was that it still had World War II experienced fighter pilots in its ranks who were still young enough for combat. However, that kind of experience was no longer available in Vietnam; and that was one of the reasons for disappointing results there. The peacetime training programs were then beefed up to reduce the difficulty, and neither the Persian Gulf War nor the air war over Serbia lasted long enough to exhaust our supply of well-trained people.

29. Hansell, 257.

30. Ibid.

31. This is not to imply that all those diversions were bad. Clearly, the submarine campaign was near enough to success that everything conceivable had to be done to defeat it. They could not know in advance that the attacks on the submarine pens or the shipyards building the U-boats were to be futile. Also, the bombing of the V-1 launching sites was a waste of bombs, and the Germans knew it. They continued to build the concrete launching ramps even after they had decided on other means to launch the V-1 precisely because they were attracting bombs that otherwise might have gone to downtown Germany. Again, the political impact of the V-1s that were hitting London was so great that in the absence of the knowledge about the launchers, everything possible had to be attempted. The so-called diversion to Africa turned out to yield much greater gains than the airmen (or George Marshall) anticipated.

32. Kenneth P. Werrell, *Blankets of Fire: U.S. Bombers over Japan during World War II* (Washington, D.C.: Smithsonian Institution Press, 1996), 195–201.

33. Kenneth P. Werrell, *The Evolution of the Cruise Missile* (Maxwell AFB, Ala.: Air University Press, 1985, 1996), 12–17.

34. US Army Air Forces (AAF), AAF Board, Orlando, Fla., "Controlled Missiles," Project no. GP 5, 29 October 1943, copy in Technical Library, Eglin AFB, Fla., file no. 2416, 1–7; and Albert B. Christman and J. D. Gerrard-Gough, *History of the Naval Weapons Center, China Lake, Calif.*, vol. 2, *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), 277–79.

35. Herman S. Wolk, *Planning and Organizing the Postwar Air Force, 1943–1947* (Washington, D.C.: Office of Air Force History, 1984), 147.

36. Harry R. Borowski, *A Hollow Threat: Strategic Air Power and Containment Before Korea* (Westport, Conn.: Greenwood Press, 1982). Borowski is considered the authority on the early years of Strategic Air Command.

37. Donald E. Wilson, "The History of President Truman's Air Policy Commission and Its Influence on Air Policy, 1947–1949" (PhD diss., University of Denver, 1978), 3–30; and USAF, "Report of the Chief of Staff of the United States Air Force to the Secretary of the Air Force," 30 June 1948,

10–13. Copy in Air University Library, Maxwell AFB, Ala. This report shows that the AAF discharged more than 400,000 people in October 1945, greater than the entire strength that the USAF planned for 2001.

38. USAF, Aberdeen Proving Ground, Aberdeen, Md., "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.

39. Roger G. Miller, *To Save a City: The Berlin Airlift, 1948–1949* (Washington, D.C.: Air Force History and Museums Program, 1998).

40. Stephen Ambrose, *Eisenhower*, vol. 2, *The President* (New York: Simon and Schuster, 1984), 52; on the discontent among Reservists see Doris M. Condit, *History of the Office of the Secretary of Defense*, vol. 2, *The Test of War, 1950–1953* (Washington, D.C.: Office of the Secretary of Defense, 1988), 491.

41. Notwithstanding the great kill ratios in the air-to-air battle, the larger fight for air superiority was not a pushover. The USAF suffered very substantial losses to ground defenses, and the B-29s could not fly except at night along the Yalu.

42. Robert F. Futrell, *The United States Air Force in Korea, 1950–1953*, 2d ed. rev. (Washington, D.C.: Office of Air Force History, 1983), 244–53, 696–98. The M-2 of World War II was the standard, and the .50 calibers in the F-86 through its E model were the M-3. The action in the M-3 was practically the same as that in the M-2—the principal difference being in the barrel, which had a liner that was much superior. The main benefit was in logistics, as one could use the M-3 barrels for many more missions than the M-2; but it did permit a higher rate of fire and a slower deterioration of accuracy resulting from barrel wear. The M-2 was tested first in 1917 and was standard for many years. The USAF stuck with the gun for a long time because of its superior armor piercing incendiary ammunition.

43. USAF, ACSC, *Air Weapons*, 1–2.

44. Dr. William S. Coker, "The Extra-Super Blockbuster," *Air University Review*, March–April 1967, 61–68; "Big Bombs," *Impact*, June 1945, 46–48; and Marshal of the RAF Sir Arthur Harris, *Bomber Offensive* (London: Collins, 1947), 44, 58, 59, 77, 82, 237–53. During World War II, the British did more development of larger bombs precisely because their aircraft were capable of carrying them. That, in large part, was driven by the frustrations of the submarine war wherein it seemed impossible to conquer the U-boats on the high seas. It did not seem feasible to cut them off at the source in the shipyards while they were under construction. Yet the Germans built concrete slips for the submarines in the French ports that were too stout for the largest conventional bombs, even when they did achieve direct hits. This led to the development of blockbusters like the 12,000 lb TALLBOY and the GRAND SLAM of 22,000 pounds. The crisis was past before the RAF was ready to use them against the sub pens, but they managed to penetrate the concrete when so used; and the giant weapons also succeeded in finally getting the *Tirpitz* in a Scandinavian fjord. Later the United States adapted the TALLBOY for use as the TARZON guided bomb with some success against

Korean bridges; see also Harris, on the British underestimate of both the size of the bombs that would be effective and on the merit of incendiary weapons plus the wartime development of the weapons and tactics to adjust to that misestimation.

45. USAF, Aberdeen Proving Ground, Aberdeen, Md., "Operational Suitability Tests of the TARZON Air-to-Surface Guided Missile," 13 August 1951. Copy in Technical Library, Eglin AFB, Fla., file no. 5999.

46. Futrell, 474.

47. Ibid., 195.

48. Ambrose, 172–73.

49. Michael H. Gorn, *Vulcans Forge*: *The Making of an Air Force Command for Weapons Acquisition (1950–1985)* (Andrews AFB, Md.: Office of History, Headquarters Air Force Systems Command [AFSC], 1985), 3–17; and Albert Misenko and Phillip Pollack, *Engineering History from McCook Field to the Aeronautical Systems Division* (Wright–Patterson AFB, Ohio: History Office, Aeronautical Systems Division, 1978), 23–29. In the 1990s the argument had come full circle and Air Force Logistics Command and AFSC merged again—still at Dayton, Ohio, under the old name of Air Force Materiel Command (AFMC).

50. USAF, AFMC, "Air Materiel Armament Test Center, January 1949 to 30 June 1950." Copy at AF Development Test Center, Eglin AFB, Fla., file no. 25b. Even at this early date, the intent was clear: "the basic reason and idea for the Center was to give the Air Force complete and direct control over the armament program and to speed up armament development, making test proved equipment ready for installation in production aircraft at the earliest possible date"; and Maj Gen Richard C. Coupland, briefing to the Scientific Advisory Board, 12 July 1949, wherein he described the concurrent development model and lamented that armament as a part of the systems approach tended to be neglected. Copy in files of History Office, Air Armament Center, file no. 25-N-4-8.

51. Warren A. Trest, "View from the Gallery: Laying to Rest the Admiral's Revolt of 1949," *Air Power History*, Spring 1995, 16–29.

52. Albert N. Garland and Howard M. Smythe, *United States Army in World War II*, vol. 2, *The Mediterranean Theater of Operations, Sicily and the Surrender of Italy* (Washington, D.C.: Chief of Military History, 1965), 532–33; Charles H. Bogart, "German Remotely Piloted Bombs," USNI *Proceedings*, November 1976, 62–68. The Italian battleship *Roma* was sunk in September 1943 by two Luftwaffe Fritz guided bombs employing guidance systems not very different from that of the RAZON.

53. Semiactive radar missiles have a radar receiver and a control system that guides them toward the source of the radar energy. That means that the aircraft radar has to continue bouncing the radar signal off the enemy aircraft until the time of impact. Some of the newer missiles, like the AIM-120, have active radars—that is, they can be launched at a target and they have their own radar transmitters as well as receivers. At some point in their trajectories, their own radar transmitters will start "painting" the target; and

thus they will home on the energy reflected back from their own radar signals. That means that the launching aircraft can leave as soon as the missile is on its way (in one mode of its operation, at least).

54. Bill Gunston, *The Illustrated Encyclopedia of Aircraft Armament*: *A Major Directory of Guns, Rockets, Missiles, Bombs, Torpedoes and Mines* (New York: Orion, 1988), 55; Frederick I. Ordway and Ronald C. Wakeford, *International Missile and Spacecraft Guide* (New York: McGraw–Hill, 1960), 34–35; Ron Westrum, *Sidewinder: Creative Missile Development at China Lake* (Annapolis, Md.: USNI Press, 1999), 208; and Capt Robert Thor, "GAR-8," *Fighter Weapons Newsletter,* June 1958, 29–30. Thor comments on the early notion the new missiles were so good that admitting a gun kill would be a sign of incompetence on the part of the pilot. Westrum gives an exhaustive treatment of the Sidewinder.

55. Robert Futrell, *The United States Air Force in Korea, 1950–1953* (Washington, D.C.: Office of Air Force History, 1983). Futrell is the authority by a wide margin on the air war in Korea. During the infancy of the jet age, there was a retrogression of sorts. The early jet engines were slow to accelerate and, unlike the reciprocating engines, they did not develop their optimum power at the lower altitudes. Thus, their payloads were often less than those of the older aircraft. Too, as the drag of the bombs goes up with the square of the airspeed, the penalty on the jets was higher than it may seem at first; but they did have the virtue of flying through the ground fire danger zone in less time than required by the Mustangs, Corsairs, and Skyraiders. But then the latter, especially the Skyraiders, had payloads that were so much larger that they had to make fewer trips into the danger zones to get the same effect.

56. Gen Carl A. Spaatz, memorandum to all major commands and all staff sections, Headquarters Army Air Forces, 1 April 1947, with attached testimony on Senate bill 758, 63–88, copy in Air University Library; Maj John S. Hardy, "Development of Conventional Fighter Weapons" (thesis, ACSC, Maxwell AFB, Ala., June 1967); and Lt Col Kenneth Rasmussen, report, "The Munitions of Airpower in Southeast Asia, 1964–69," AFHRA file no. K239.0370-2 (Maxwell AFB, Ala.: Corona Harvest Project Office, Aerospace Studies Institute, Air University, January 1970), 5. Hardy had been a test pilot at Eglin AFB, Fla., prior to attending ACSC and, among other things, 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 for the work. Rasmussen's report complains that one of the reasons for shortfalls in both acquisition and shipping of munitions was the by-then traditional dependence of the Air Force on the other services for its weapons development and supply.

57. "Aircraft Armament Division Notes," *Army Ordnance*, March–April 1921, 290; and "Aircraft Armament Division Notes," *Army Ordnance*, May–June 1921, 360–6l. From the early 1920s, it was established that the Ordnance Department would be responsible for the development of guns as well as all the armament items that left the aircraft (e.g., bombs and am-

munition). The Air Service would be responsible for all the equipment that stayed with the airplane (e.g., bombsights and bomb racks) except the guns. The Chemical Service was responsible for chemical weapons, flares, and incendiaries. The Navy was responsible for armor-piercing bombs. This persisted well after the Air Force was founded until the I-2000 penetrator bomb was developed in the 1970s and the GAU-8 30 millimeter (mm) weapon was developed for the A-10 in the same decade.

58. 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, "Development of Conventional Fighter Weapons," 2; even the World War II inventory was made usable aboard the F-100 and the fighters of the late 1950s by the redesign of the tail fin to reduce the drag and increase the reliability of their safe separation from the aircraft, USAF, ACSC, *Air Weapons*, 9; US Navy, Bureau of Naval Weapons, "Free-Fall Nonnuclear Ordnance RDT&E Program," 9 September 1960, 2, shows that the Mk 80 series was ready for action even before the election of 1960 and the coming of flexible response with the Kennedy administration; Capt Martin J. Loftus, "Tactical Non-Nuclear Weapons," in *Fighter Weapons Review*, June 1964, 20–28, speaks of both the M-117/M-118 and the Mk 80 series as being standard on USAF fighters—the date being before the passage of the Gulf of Tonkin Resolution. He notes that the AN series of World War II bombs was still in the inventory and said that 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. In a 1962 study, R. S. Titchen and P. E. DePoy, (U), "Conventional Ordnance for Aircraft Use 1962–67," Interim Research Memorandum, Operations Evaluation Group, Washington, D.C., 8 January 1962, show that the Bullpup guided missile, the ROCKEYE shaped-charge submunition, the WALLEYE TV bomb, and the Shrike antiradiation missile (ARM) were either in development or in the inventory before either the frustrations of Vietnam or the impact of flexible response can have stimulated the services into action.

59. W. C. Richert, *The World's Missile Systems* (Pomona, Calif.: General Dynamics, 1975), 50–53.

60. Daniel McNeil, "Technology, History and the Revolution in Military Affairs," *Canadian Military Journal*, Winter 2000–2001, n.p., on-line, Internet, available at www.journal.dnd.ca/vol1/no4_e/ronald_e/ronald1_e.html, 24 April 2001.

61. Thomas Hugh Buckley, "The United States and the Washington Conference, 1921–1922" (PhD diss., Indiana University, 1961), 178. The prohibition of attacks on noncombatant shipping without warning and provision for the safety of the merchant crews and passengers had been embedded in the treaty at the insistence of the United States.

62. John W. R. Taylor, *Combat Aircraft of the World from 1909 to the Present* (New York: Paragon, 1969), 492.

63. Daniel R. Mortensen, "The Legend of Laurence Kuter," in *Airpower and Ground Armies: Essays on the Evolution of Anglo-American Air Doctrine*,

1940–1943, ed. Daniel R. Mortensen (Maxwell AFB, Ala.: Air University Press, 1998), 93–145. Mortensen discusses the origins of Field Manual 100-20 in 1943.

64. Among the many interpretations of airpower in the Vietnam War are Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam* (New York: Free Press, 1989); Thompson, n.p.; Michel, n.p.; John Schlight, *The War in South Vietnam: The Years of the Offensive, 1965–1968,* The United States Air Force in Southeast Asia series (Washington: Office of Air Force History, 1988); and Adm U. S. G. Sharp, *Strategy for Defeat: Vietnam in Retrospect* (Novato, Calif.: Presidio Press, 1978)

65. Peter Braestrup, *Big Story: How the American Press and Television Reported and Interpreted the Crisis of Tet in 1968 in Vietnam and Washington* (New Haven, Conn.: Yale University Press, 1983). Braestrup presents an interesting case study on the subject.

66. Michael Ignatieff, "The Virtual Commander: How NATO Invented a New Kind of War," *New Yorker,* 2 August 1999, 33–35, explores Gen Wesley K. Clark's travails in that area; Lt Gen Michael C. Short, NATO air commander, came out of the campaign with a disdain for the gradual application of airpower; however, the chief of staff of the Air Force, Gen Michael E. Ryan, hedges on the issue, John G. Roos, "Effects Based Operations: US Air Force Chief Assesses a Decade of Transformation," *Armed Forces Journal International,* March 2001, 70; General Clark defended it in Crawley, "Clark Explains Choices," 25; and he also defended it in interview, Gen Wesley K. Clark with Col Mason Carpenter, USAF, Washington, D.C., 6 November 2000.

67. Col Walter Kross, *Military Reform: The High-tech Debate in Tactical Air Forces* (Washington, D.C.: National Defense University Press, 1985). A "military reform" debate grew out of the Vietnam and Yom Kippur Wars, among other things, and the two sides are generally divided into "low-tech" and "high-tech" schools. The limitations of weather on tactical airpower have been a major concern for both schools and remained a sanctuary for enemy ground forces even as it had been during the first six days of the Battle of the Bulge in 1944. Colonel Kross gives a convenient summary of the debate from the high-tech viewpoint.

68. Stephen Peter Rosen, *Winning the Next War: Innovation and the Modern Military* (Ithaca, N.Y.: Cornell University Press, 1991), 250, 252. Rosen makes it clear enough that neither defeat nor budgetary plenty are essential to military reform, though ample time is a factor.

69. Johnny R. Jones, *Development of Air Force Basic Doctrine, 1947–1992* (Maxwell AFB, Ala.: Air University Press, 1997); and Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force,* vol. 1, *1907–1960,* and vol. 2, *1961–1984* (Maxwell AFB, Ala.: Air University Press, 1989). The USAF has published editions of its basic doctrine in 1953, 1954, 1955, 1959, 1964, 1971, 1975, 1979, 1984, 1992, and 1997.

70. "USAF's Air Support Role to Change, *Jane's Defence Weekly,* 11 June 1988, 1158; John D. Morrocco, "Pentagon to Review Air Force Study Supporting Modified F-16 for CAS Role, *Aviation Week and Space*

Technology, 31 October 1988, 30; Maj Pat A. Pentland, "Close Air Support—A War Fighting Role," *Armed Forces Journal International*, September 1988, 92–96; "Operation Desert Storm: Initial Lessons Learned," *Aviation Week and Space Technology*, 18 February 1991, 40–55; and Paul Mann, "Mammoth Air/Ground Assault Defeats Iraq in Gulf War," *Aviation Week and Space Technology*, 4 March 1991, 20–22.

71. Christopher Chant, *Encyclopedia of Modern Aircraft Armament* (Wellingsborough, Northamptonshire, U.K.: Stephens, 1988), 161, on the F-15 and 112 on the F-16; "Filling the Missing Link," *Jane's Defence Weekly*, 13 April 1991, 606–9; and Maj Gerald R. Volloy, "Red Flag in Perspective," *USAF Fighter Weapons Review*, Spring 1979, 2–5.

72. Dale M. Davis, report, "Historical Development Summary of Automatic Cannon Caliber Ammunition: 20-30 Millimeter," file no. AFATL-TR-84-03 (Eglin AFB, Fla.: Air Force Armament Laboratory, January 1984), 24–53. The only other use of the technology is in a gun pod (GPU-5A) containing a 30 mm weapon with fewer barrels than the GAU-8, which is also built by General Electric. It uses the same ammunition, and it gives many of the aircraft in the inventory the tank-killing capability of the A-10's 30 mm ammunition through the carriage of the pod on external stations. The F-4 came to the USAF on the insistence of Secretary of Defense Robert S. McNamara; and though Tactical Air Command wanted it modified to include a gun, McNamara refused it. Rather, a gun pod was developed for a 20 mm Gatling weapon and carried aboard the center line station of Phantoms until combat had shown the necessity of a gun and the E model was redesigned to include an internal M-61 20 mm.

73. USAF, 7AF/DOA, Working Paper, "Pave Way Utility and Cost Effectiveness in SEA," file no. AFATL 68-1605 (Eglin AFB, Fla.: Technical Library, 15 September 1968); and Peter DeLeon, report no. R-1312-1-PR, *The Laser-Guided Bomb: Case History of a Development* (Santa Monica, Calif.: RAND, 1974).

74. South Vietnam had been divided into four corps areas and assigned roman numerals. Orally, all were commonly referred to by number. For example, the area around Saigon was called "Three Corps (III Corps)"; but the northernmost one was the exception called "Eye Corps (I Corps)."

75. Col Thomas Keaney, USAF, retired, E-mail to author, 21 May 2001. Colonel Keaney argues that the development of the laser-guided bomb was not at first pressed as hard as it might have been because some USAF officers thought it would be impractical against the Warsaw Pact ground defenses. The requirement to loiter over the battlefield to lase the target until impact was thought to be an inhibitor and an argument in favor of building the precision into the airplane and not the weapon—where it also could be used repeatedly.

76. AFSC, AD, 3246th Test Wing, report, "GBU-22/B and GBU-24/B Low-level Laser Guided Bombs [LGB] Development Test and Evaluation," (Secret), file no. AD-TR-R-84-20 [hereinafter cited as TW, LGB DT&E] (Eglin AFB, Fla.: Technical Library, 1984), 13 (data extracted is unclassified); AFSC,

AD, Directorate of Systems Safety, report, "Safety Study Report of the Low Level Laser Guided Bomb, GBU-22/B, GBU-24/B," 20-5, file no. AD-E8000 [hereinafter cited as AD, LGB Safety] (Eglin AFB, Fla.: Technical Library, December 1982), 791.

77. Edward L. Korb, ed., *The World's Missile Systems* (Pomona, Calif.: General Dynamics, 1982), 138–42; Maj Scott Long, interview, 6 May 2001. Similar in that once a Maverick is launched, there is nothing further the crew can do about it so they might as well leave the area. In the case of the GBU-15 or AGM-130, the weapon can be more properly called a "launch-and-leave" because though the crew need not tarry to guide them, it can still affect their trajectories through the data link. Thus, the crew can get on its way out of the area, but still is in contact with the weapon and can either perfect its aim as it gets nearer the target or divert it away from a target suddenly determined to be undesirable—all the while continuing the escape of the launch aircraft. Alternatively, the weapon can be left on its own to proceed to the original aim point.

78. John A. Warden III, *The Air Campaign: Planning for Combat* (Washington, D.C.: National Defense University Press, 1988), 39.

79. Brereton Greenhous, "The Israeli Experience," in *Case Studies in the Achievement of Air Superiority*, ed. Benjamin F. Cooling (Washington, D.C.: Center for Air Force History, 1994), 578–82; and Nadav Safran, "Trial by Ordeal: The Yom Kippur War, October 1973," *International Security*, Fall 1977, 130–62.

80. Anwar Sadat, *In Search of Identity: An Autobiography* (New York: Harper and Row, 1978), 263.

81. Lon O. Nordeen, *Airpower in the Missile Age* (Washington, D.C.: Smithsonian Institution Press, 1985), 201–6; Matthew M. Hurley, "The Bekáa Valley Air Battle, June 1982: Lessons Mislearned?" *Airpower Journal*, Winter 1989, 60–70; Nick Kerr, "The Falklands Campaign," *Naval War College Review*, November–December 1982), 14–21; Lt Comdr Robert E. Stumpf, US Navy, "Air War with Libya," USNI *Proceedings*, August 1986, 42–47; "U.S. Demonstrates Advanced Weapons Technology in Libya," *Aviation Week and Space Technology*, 21 April 1986, 18–20; David M. North, "Air Force, Navy Brief Congress on Lessons from Libya Strikes," *Aviation Week and Space Technology*, 2 June 1986, 63; and Benjamin F. Schemmer, "AFJ's Dart to USAF Leadership for 'Antique Ordnance' was 180 Degrees Off Course," *Armed Forces Journal International*, June 1986, 67–68.

82. Harold R. Winton, "An Ambivalent Partnership: US Army and Air Force Perspectives on Air-Ground Operations, 1973–90," in *The Paths of Heaven: The Evolution of Airpower Theory*, ed. Phillip S. Meilinger (Maxwell AFB, Ala.: Air University Press, 1997), 399–441. Meilinger provides an articulate and authoritative discussion of the development of Army doctrine and the Air Force–Army doctrinal relationships during the post–Vietnam period.

83. Maris McCrabb, "The Evolution of NATO Air Doctrine," in *Paths of Heaven*, ed. Meilinger, 458–60.

84. Rear Adm James A. Winnefeld, US Navy, retired, and Dr. Dana J. Johnson, *Joint Air Operations: Pursuit of Unity in Command and Control, 1942–1991* (Annapolis, Md.: USNI Press, 1993), 100–101; and Stephen J. McNamara, *Air Power's Gordian Knot: Centralized versus Organic Control* (Maxwell AFB, Ala.: Air University Press, 1994), 122.

85. Keaney and Cohen, 48–49; and Michael R. Gordon and Bernard E. Trainor, *The Generals' War: The Inside Story of the Conflict in the Gulf* (Boston, Mass.: Little, Brown & Co., 1995), 205–26, 473–74. Keaney and Cohen do make the point that the bomb damage assessment in the Gulf War was far from perfect, and we had little success in determining the launching locations of the Scuds in time to destroy them or their launchers.

86. Richard P. Hallion, *Storm Over Iraq: Air Power and the Gulf War* (Washington, D.C.: Smithsonian Institution Press, 1992); and Richard M. Swain, *Lucky War: Third Army in Desert Storm* (Fort Leavenworth, Kans.: US Army Command and General Staff College Press, 1994). Hallion provides an Air Force point of view on the MTR during the Gulf War, and Swain provides an argument written from an Army perspective.

87. Col John D. Waghelstein, "Some Thoughts on Operation Desert Storm and Future Wars," *Military Review*, February 1992, 80–83.

88. The designation of the F-117 is "fighter," but it does not have an air-to-air function; and in other times it would have been classified as a bomber.

89. Kosiak, 9.

90. Lt Gen Buster C. Glosson, USAF, "Impact of Precision Weapons on Air Combat Operations," *Airpower Journal*, Summer 1993, 4–10, on-line, Internet, available at http://www.airpower.maxwell.af.mil/airchronicles/apj/glosson.html. (I know that there were more skeptical treatments of this issue published afterwards, but even the most skeptical estimates indicated an order of magnitude improvement over the Schweinfurt experience.)

91. Keaney and Cohen. It is reported that early in the Gulf War the HARM shooters were coming back to base without having fired their weapons, and only five coalition aircraft were lost to radar surface-to-air missiles during the war.

92. R. Kent Laughbaum, *Synchronizing Airpower and Firepower in the Deep Battle* (Maxwell AFB, Ala.: Air University Press, 1999). Laughbaum provides an authoritative discussion of the topic from an airman's point of view.

93. Rick Atkinson, *Crusade: The Untold Story of the Persian Gulf War* (Boston, Mass.: Houghton Mifflin Co., 1993), 470–71; and Gordon and Trainor, 429, 477.

94. Lt Col Michael O'Halloran, USMC, E-mail to author, 21 May 2001. To some extent, in the context of theater war, debates about equality among component commanders may be somewhat sterile. The Goldwater–Nichols Act makes it quite clear that the joint force commander is in complete control, and equality is whatever he wants it to be. I am indebted to Colonel Halloran for this insight.

95. McNamara, 124; Swain, 28; and Edward C. Mann, *Thunder and Lightning: Desert Storm and the Airpower Debates* (Maxwell AFB, Ala.: Air University Press, 1995), 178–80.

96. Air Force Doctrine Document 1, *Air Force Basic Doctrine*, September 1997, 29.

97. John A Warden III, "The Enemy as a System," *Airpower Journal*, Spring 1995, 40–55; 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.

98. Keaney and Cohen, 222–23.

99. Ibid., 48–54.

100. Winnefeld and Johnson, 171.

101. Almost 10 percent of them died when a single aircraft, an AC-130 with its crew of 14, was shot down.

102. John D. Morrocco and David A. Fulghum, "USAF Developed 4,700 lb Bomb in Crash Program to Attack Iraqi Military Leaders in Hardened Bunkers," *Aviation Week and Space Technology*, 6 May 1991, 67. The authors speak of the great effect of the I-2000 (BLU-109) on shelters though more was needed for the deep command bunkers. The bomb in the title is the GBU-28, with its warhead made from an artillery barrel and produced in very short order during the Gulf War. Two were dropped from an F-111 in the closing moments with good effects.

103. History, USAF Development Test Center, 1 October 1990–30 September 1991, vol. 1, 10.

104. Maurer Maurer, *Aviation in the U.S. Army, 1919–1939* (Washington, D.C.: Office of Air Force History, 1987), 325–31; Jeffery S. Underwood, *The Wings of Democracy: The Influence of Air Power on the Roosevelt Administration* (College Station, Tex.: Texas A & M University Press, 1991), 59–61; and Haywood S. Hansell Jr., "Harold L. George: Apostle of Air Power," in *Makers of the United States Air Force*, ed. John L. Frisbee (Washington, D.C.: Office of Air Force History, 1987), 82–83.

105. Gen George Lee Butler, "Disestablishing SAC: Reprint of an Official Speech Presented to the Air Force Historical Foundation," *Air Power History*, Fall 1993, 4–11; and Kennett, 631.

106. Richard K. Smith, *75 Years of Inflight Refueling: Highlights, 1923–1998* (Washington, D.C.: Air Force History and Museums Program, 1998), 76.

107. ABC News.com, "B-2 Sees First Combat," 24 March 1999, n.p., online, Internet, available at sections/world/DailyNews/bomber990324.html; John A. Tirpak, "With Stealth in the Balkans," *Air Force Magazine*, October 1999, 23–28; and Rebecca Grant, *The B-2 Goes to War* (Arlington, Va.: Iris Press, 2001). The success of the B-2 in the face of former skepticism is a main theme of Grant's book.

108. For an early but authoritative analysis of the air war over Serbia campaign, see Barry Posen, "The Air War in Kosovo," *International Security*, Spring 2000; Alan Stephens, "Kosovo: Or the Future of War," *Asia–Pacific*

Defence Reporter, June–July 1999, 18–19, leans toward the airpower advocates on the conflict; the many more skeptical views include Grant T. Hammond, "Myths of the Air War over Serbia: Some 'Lessons' Not to Learn," *Aerospace Power Journal,* Winter 2000, 79; Milan Vego, "Wake-Up Call in Kosovo," USNI *Proceedings,* October 2000, 66–70, wherein he is concerned that the United States may be becoming too reliant on smart weapons technology and remarks upon the degree to which alliance politics conditioned detailed strategic and targeting choices; Earl H. Tilford, "Operation Allied Force and the Role of Air Power," *Parameters,* Winter 1999–2000, 4; for the official version, Ministry of Defence, United Kingdom, "Kosovo An Account of the Crisis: Initial Lessons Learned," 15 December 1999, n.p., on-line, Internet, available at http://www.mod.uk.news/kosovo/account/lessons.htm; and Secretary of Defense William S. Cohen and Chairman of the Joint Chiefs of Staff Gen Henry H. Shelton, "Joint Statement on the Kosovo After Action Review," *Defense Link,* 14 October 1999, n.p., on-line, Internet, available at http://www.defenselink.mil/news/Oct1999/b10141999_bt478-99.html. To indulge in a sin often committed by airmen from Mitchell forward, if one makes a linear extrapolation of General Glosson's 300:1 ratio cited above, then one might assert that the B-2 carries sixteen 2,000 lb bombs with but two crew members compared to two such bombs and one crewman on the F-117. Thus, if the F-117 is 300 times as effective as the B-17 in World War II, then in terms of bombs, the B-2 would be 24,000 times as effective as were bombers in the Schweinfurt raid—or in terms of crew members, 12,000 times! The skeptic will immediately observe that we built about 12,000 B-17s and 18,000 B-24s in World War II, but only 21 B-2s have been ordered so far. There are so many slips twixt cup and lip that quantifying the change is near impossible and a little ridiculous, but perhaps the notion that there has been a very massive one is not an unreasonable assumption.

109. Bill Sweetman, "Scratching the Surface: Next Century Air-to-Ground Weapons," *Jane's International Defense Review,* July 1997, 55–63; Stacey Evers in November 1997 reported that the unit cost would be about $18,000 and that the program, then in low rate initial production, would be delayed in going to full rate production until some design flaws revealed in testing were overcome, "Experts Count Costs to Fix JDAM Design Flaws," *Jane's Defence Weekly,* 5 November 1999, 6. In November 1997 it was reported that the first joint standoff weapons (JSOW) were deployed aboard the aircraft carrier USS *Nimitz* in the Persian Gulf even though they had not achieved their initial operational capability and were still in a low rate of initial production. The versions deployed were said to be the ones containing combined effects munitions particularly useful against air defense sites, "Nimitz Is Carrying Latest Stand-off Weapon," *Jane's Defence Weekly,* 19 November 1997, 4.

110. Lon O. Nordeen Jr., E-mail to author, 24 May 2001, puts the approximate costs at $200,000 to $300,000 for the JSOW, $30,000 for the JDAM kit, and around $50,000 for LGB guidance kits, though the lattermost cost about twice as much if they have an inertial measurement capability.

111. Maj Scott C. Long, interviewed by author, Maxwell AFB, Ala., 7 May 2001; Bill Sweetman, "Scratching the Surface," 57; "USAF Plans Inertial Dispenser Selection This Month," *Jane's International Defense Review*, January 1997, 10; and USAF, Headquarters Air Combat Command/DRPW, "Final Operational Requirements Document, Wind Corrected Munitions Dispenser," 23 September 1994. The inventory munitions dispenser (TMD for tactical munitions dispenser) can be launched from fairly high altitudes, but its standard dispersion with some degree of wind effects can reduce the accuracy of the delivery of its submunitions of various types. The JSOW will permit launches from longer ranges and high altitudes with accuracy derived from its combination of inertial and Global Positioning System (GPS) guidance. Another new weapons program also reduces the errors when dispensers are released at higher altitudes: the wind-corrected munitions dispenser. It adds an inertial kit to the inventory dispensers at modest cost. Though it does not include a GPS receiver, the inertial feature will nonetheless remove most of the wind effect during the time of fall.

112. "Eglin's AMRAAM Joins the War," *Northwest Florida Daily News*, 22 February 1991, 3; and Mark Hewish, Anthony Robinson, and Gerarde Turbe, "Air-to-Air Missiles," *International Defense Review*, August 1990, 871–77.

113. Air Force History and Museums Program, "Hughes AIM-120 AMRAAM," n.d., n.p., on-line, Internet, available at http://www.wpafb.af.mil/museum/arm/arm10a.htm; and John Pike, "AIM-120 AMRAAM Slammer," n.d., n.p., on-line, Internet, available at www.fas.org/man/dod-101/sys/missile/aim-120.htm.

114. Brad Harlow, "Missile Systems," *Aerospace America*, December 1999, 49; Linda de France, "AIM-9X Scores with Accuracy, Capability, High Hit-Rate," *Aerospace Daily*, 3 October 2000; and Christian Lowe, "High-Tech Helmet to Cut Targeting Times 90 Percent," *Defense Week*, 18 September 2000, 1.

115. Bill Sweetman, "The Progress of the F-22 Fighter Program," *Jane's International Defense Review*, Quarterly Report, no. 1, 1997. Another development is the effort to develop the small smart bomb at 250 pounds with such accuracy that it will have the same effect in some situations as the 2,000-pound LGB, yet six of them will fit in the F-22 weapons bay.

116. Juliette A. Hennessy, *The United States Army Air Arm: April 1861 to April 1917* (1958; reprint, Washington: Office of Air Force History, 1985), 1–10.

117. The best short treatment of airpower in World War I is Lee B. Kennett, *The First Air War: 1914–1918* (New York: Free Press, 1991); on the origins of the demand for air superiority, see Maj William Mitchell, Aviation Section, Signal Corps, memorandum to Chief of Staff, American Expeditionary Force, 12 June 1917, in *The U.S. Air Service in World War I*, vol. 2, *Early Concepts of Military Aviation*, ed. Maurer Maurer (Maxwell AFB, Ala.: AFHRA, 1978), 108.

118. Robert Perry, "The Interaction of Technology and Doctrine in the USAF," in *Air Power and Warfare: The Proceedings of the 8th Military History Symposium, United States Air Force Academy, 18–20 October 1978*, ed. Alfred

F. Hurley and Robert C. Ehrhart (Washington, D.C.: Office of Air Force History, 1978), 386; and Rosen, 258.

119. Benjamin S. Lambeth, *The Transformation of American Air Power* (Ithaca, N.Y.: Cornell University Press, 2000). Lambeth presents his view arguing that there has been a transformation in the potency of airpower since the frustrating experiences in Vietnam. I share Michael O'Hanlon's cautionary note in his *Technological Change and the Future of Warfare* (Washington, D.C.: Brookings Institution Press, 2000), 31, to the effect that RMAs can sometimes make things worse not better, and that sometimes the ones who create the RMA are not the ones who benefit from it.

Bibliography

Books

Ambrose, Stephen. *Eisenhower.* Vol. 2, *The President.* New York: Simon and Schuster, 1984.

Atkinson, Rick. *Crusade: The Untold Story of the Persian Gulf War.* Boston, Mass.: Houghton Mifflin Co., 1993.

Borowski, Harry R. *A Hollow Threat: Strategic Air Power and Containment Before Korea.* Westport, Conn.: Greenwood Press, 1982.

Braestrup, Peter. *Big Story: How the American Press and Television Reported and Interpreted the Crisis of Tet in 1968 in Vietnam and Washington.* New Haven, Conn.: Yale University Press, 1983.

Brodie, Bernard. *Strategy in the Missile Age.* Princeton, N.J.: Princeton University Press, 1965.

Brodie, Bernard and Fawn M. *From Crossbow to H-Bomb.* Bloomington, Ind.: Indiana University Press, 1962.

Buell, Thomas B. *The Quiet Warrior: A Biography of Admiral Raymond A. Spruance.* Annapolis, Md.: US Naval Institute (USNI) Press, 1987.

Chant, Christopher. *Encyclopedia of Modern Aircraft Armament.* Wellingsborough, Northamptonshire, U.K.: Stephens, 1988.

Christman, Albert B., and J. D. Gerrard–Gough. *History of the Naval Weapons Center, China Lake, Calif.* Vol. 2, *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.

Clodfelter, Mark. *The Limits of Air Power: The American Bombing of North Vietnam.* New York: Free Press, 1989.

Condit, Doris M. *History of the Office of the Secretary of Defense.* Vol. 2, *The Test of War, 1950–1953.* Washington, D.C.: Office of the Secretary of Defense, 1988.

Corum, James S. *The Roots of the Blitzkrieg*: *Hans von Seeckt and the German Military Reform*. Lawrence, Kans.: University Press of Kansas, 1992.

Douhet, Giulio. *The Command of the Air*. Translated by Dino Ferrari. 1942. New imprint, Washington, D.C.: Office of Air Force History, 1983.

Faber, Peter R. "Interwar US Army Aviation and the Air Corps Tactical School: Incubators of American Airpower." In *The Paths of Heaven: The Evolution of Airpower Theory*. Edited by Phillip S. Meilinger. Maxwell Air Force Base (AFB), Ala.: Air University Press, 1997.

Finney, Robert T. *History of the Air Corps Tactical School, 1920–1940*. USAF Historical Study 100. Maxwell AFB, Ala.: USAF Historical Division, Air University, 1955.

Freedman, Lawrence. *The Revolution in Strategic Affairs*. Adelphi Paper 318. New York: Oxford University Press, 1998.

Futrell, Robert Frank. *The United States Air Force in Korea, 1950–1953*. Rev. ed. Washington, D.C.: Office of Air Force History, 1983.

Garland, Albert N., and Howard M. Smythe. *United States Army in World War II*. Vol. 2, *The Mediterranean Theater of Operations, Sicily and the Surrender of Italy*. Washington, D.C.: Chief of Military History, 1965.

Gentile, Gian P. *How Effective Is Strategic Bombing? Lessons Learned from World War II to Kosovo*. New York: New York University Press, 2001.

Gordon, Michael R., and Bernard E. Trainor. *The Generals' War: The Inside Story of the Conflict in the Gulf*. Boston, Mass.: Little, Brown & Co., 1995.

Gorn, Michael. *Vulcans Forge: The Making of an Air Force Command for Weapons Acquisition (1950–1985)*. Andrews AFB, Md.: Office of History, Headquarters Air Force Systems Command (AFSC), 1985.

Grant, Rebecca. *The B-2 Goes to War*. Arlington, Va.: Iris Press, 2001.

Green, C. M., H. C. Thomson, and Peter C. Roots. *The United States Army in World War II*. Vol. 3, *The Ordnance Department*. Pt. 1, "Planning Munitions for War."

Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1955.

Gunston, Bill. *The Illustrated Encyclopedia of Aircraft Armament: A Major Directory of Guns, Rockets, Missiles, Bombs, Torpedoes and Mines*. New York: Orion, 1988.

Hallion, Richard P. *Storm over Iraq: Air Power and the Gulf War*. Washington, D.C.: Smithsonian Institution Press, 1992.

Hansell, Haywood S., Jr. "Harold L. George: Apostle of Air Power." In *Makers of the United States Air Force*. Edited by John L. Frisbee. Washington, D.C.: Office of Air Force History, 1987.

———. *The Air Plan That Defeated Hitler*. Atlanta, Ga.: Higgins–MacArthur/Longino and Porter, 1972.

Harris, Marshal of the RAF Sir Arthur. *Bomber Offensive*. London: Collins, 1947.

Hennessy, Juliette A. *The United States Army Air Arm: April 1861 to April 1917*. 1958. Reprint. Washington, D.C.: Office of Air Force History, 1985.

Hurley, Alfred F. *Billy Mitchell: Crusader for Air Power*. 1964. Reprint, Bloomington, Ind.: Indiana University Press, 1975.

Jablonski, Edward. *Flying Fortress: The Illustrated Biography of the B-17s and the Men Who Flew Them*. Garden City, N.Y.: Doubleday, 1965.

Jones, Johnny R. *Development of Air Force Basic Doctrine, 1947–1992*. Maxwell AFB, Ala.: Air University Press, 1997.

Jones, Neville. *The Beginnings of Strategic Air Power: A History of the British Bomber Force, 1923–39*. London: Frank Cass, 1987.

Keaney, Thomas A., and Eliot A. Cohen. *Revolution in Warfare? Air Power in the Persian Gulf*. Annapolis, Md.: USNI Press, 1995.

Kennett, Lee. "Strategic Bombardment: A Retrospective." In *Case Studies in Strategic Bombardment*. Edited by R. Cargill Hall. Washington, D.C.: Air Force History and Museums Program, 1998.

Korb, Edward L. *The World's Missile Systems*. Pomona, Calif.: General Dynamics, 1982.

Kross, Col Walter. *Military Reform: The High-tech Debate in Tactical Air Forces*. Washington, D.C.: National Defense University (NDU) Press, 1985.

Lambeth, Benjamin S. *The Transformation of American Air Power*. Ithaca, N.Y.: Cornell University Press, 2000.

Laughbaum, R. Kent. *Synchronizing Airpower and Firepower in the Deep Battle*. Maxwell AFB, Ala.: Air University Press, 1999.

MacIsaac, David. "Voices from the Central Blue: The Airpower Theorists." In *Makers of Modern Strategy: From Machiavelli to the Nuclear Age*. Edited by Peter Paret. Princeton, N.J.: Princeton University Press, 1986.

Mann, Edward C., III. *Thunder and Lightning: Desert Storm and the Airpower Debates*. 2 vols. Maxwell AFB, Ala.: Air University Press, 1995.

Maurer, Maurer. *Aviation in the U.S. Army, 1919–1939*. Washington, D.C.: Office of Air Force History, 1987.

Mazarr, Michael J., Jeffrey Shaffer, and Benjamin Edrington. "The Military Technical Revolution." In *American Defense Policy*. Edited by Peter L. Hays, Brenda J. Vallance, and Alan R. Van Tassel. 7th ed. Baltimore, Md.: Johns Hopkins University Press, 1997.

McCrabb, Maris. "The Evolution of NATO Air Doctrine." In *The Paths of Heaven: The Evolution of Airpower Theory*. Edited by Phillip S. Meilinger. Maxwell AFB, Ala.: Air University Press, 1997.

McFarland, Stephen Lee. *America's Pursuit of Precision Bombing, 1910–1945*. Washington, D.C.: Smithsonian Institution Press, 1995.

McNamara, Stephen J. *Air Power's Gordian Knot: Centralized versus Organic Control*. Maxwell AFB, Ala.: Air University Press, 1994.

Meilinger, Phillip S. "Trenchard, Slessor, and Royal Air Force Doctrine before World War II." In *The Paths of Heaven: The Evolution of Airpower Theory*. Edited by Phillip S. Meilinger. Maxwell AFB, Ala.: Air University Press, 1997.

Michel, Marshall L., III. *Clashes: Air Combat over North Vietnam, 1965–1972*. Annapolis, Md.: USNI Press, 1997.

Miller, Roger G. *To Save a City: The Berlin Airlift, 1948–1949*. Washington, D.C.: Air Force History and Museums Program, 1998.

Misenko, Albert, and Phillip Pollack. *Engineering History from McCook Field to the Aeronautical Systems Division*. Wright–Patterson AFB, Ohio: History Office, Aeronautical Systems Division, 1978.

Mitchell, William "Billy." *Winged Defense: The Development and Possibilities of Modern Air Power—Economic and Military*. 1925. Reprint. New York: Dover Publications, 1988.

Mortensen, Daniel R. "The Legend of Laurence Kuter." In *Airpower and Ground Armies: Essays on the Evolution of Anglo–American Air Doctrine, 1940–1943*. Edited by Daniel R. Mortensen. Maxwell AFB, Ala.: Air University Press, 1998.

Muller, Richard. *The German Air War in Russia*. Baltimore, Md.: Nautical and Aviation Publishing Co., 1992.

Murray, Williamson, and Allan R. Millett. *A War to Be Won: Fighting the Second World War*. Cambridge, Mass.: Belknap Press, 2000.

Nordeen, Lon O. *Airpower in the Missile Age*. Washington, D.C.: Smithsonian Institution Press, 1985.

O'Hanlon, Michael E. *Technological Change and the Future of Warfare*. Washington, D.C.: Brookings Institution Press, 2000.

Ordway, Frederick I., and Ronald C. Wakeford. *International Missile and Spacecraft Guide*. New York: McGraw–Hill, 1960.

Perry, Robert. "The Interaction of Technology and Doctrine in the USAF." In *Air Power and Warfare: The Proceedings of the 8th Military History Symposium, United States Air Force Academy, 18–20 October 1978*. Edited by Alfred F. Hurley and Robert C. Ehrhart. Washington, D.C.: Office of Air Force History, 1979.

Potter, E. B. *Nimitz*. Annapolis, Md.: USNI Press, 1976.

Richert, W. C. *The World's Missile Systems*. Pomona, Calif.: General Dynamics, 1975.

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

Sadat, Anwar. *In Search of Identity: An Autobiography*. New York: Harper and Row, 1978.

Saward, Dudley. *Bomber Harris: The Story of Marshal of the Royal Air Force, Sir Arthur Harris*. Garden City, N.Y.: Doubleday, 1985.

Schlight, John. *The War in South Vietnam: The Years of the Offensive, 1965–1968*. The United States Air Force in Southeast Asia series. Washington, D.C.: Office of Air Force History, 1988.

Sharp, Adm U. S. G. *Strategy for Defeat: Vietnam in Retrospect*. Novato, Calif.: Presidio Press, 1978.

Smith, Richard K. *75 Years of Inflight Refueling: Highlights, 1923–1998*. Washington, D.C.: Air Force History and Museums Program, 1998.

Spector, Ronald H. *Eagle against the Sun: The American War with Japan*. New York: Vintage, 1985.

Swain, Richard M. *Lucky War: Third Army in Desert Storm*. Fort Leavenworth, Kans.: US Army Command and General Staff College Press, 1994.

Taylor, John W. R. *Combat Aircraft of the World from 1909 to the Present*. New York: Paragon, 1969.

Thomson, Harry C., and Lida Mayo. In *The United States Army in World War II*. Vol. 3, *The Ordnance Department*. Pt. 2, "Procurement and Supply." Washington, D.C.: Office of the Chief of Military History, Department of the Army, 1960.

Thompson, Wayne. *To Hanoi and Back: The U.S. Air Force and North Vietnam, 1966–1973*. Washington, D.C.: Smithsonian Institution Press, 2000.

The United States Strategic Bombing Surveys Summary Report: European War, Pacific War. 1947. Reprint. Maxwell AFB, Ala.: Air University Press, 1987.

Underwood, Jeffery S. *The Wings of Democracy: The Influence of Air Power on the Roosevelt Administration*. College Station, Tex.: Texas A & M University Press, 1991.

US Air Force. Air Command and Staff College (ACSC). *Air Weapons*. Gunter Air Station, Ala.: Extension Course Institute, 1957.

Warden, John A., III. *The Air Campaign: Planning for Combat*. Washington, D.C.: NDU Press, 1988.

———. "Air Theory for the Twenty-first Century." In *Challenge and Response: Anticipating US Military Security Concerns*. Edited by Dr. Karl P. Magyar et al. Maxwell AFB, Ala.: Air University Press, August 1994.

Weigley, Russell F. *Eisenhower's Lieutenants: The Campaign of France and Germany, 1944–1945*. Bloomington, Ind.: Indiana University Press, 1981.

Weinberg, Gerhard L. *A World at Arms: A Global History of World War II*. Cambridge, U.K.: Cambridge University Press, 1986.

Werrell, Kenneth P. *Blankets of Fire: U.S. Bombers over Japan during World War II*. Washington, D.C.: Smithsonian Institution Press, 1996.

———. *The Evolution of the Cruise Missile*. Maxwell AFB, Ala.: Air University Press, 1985, 1996.

Westrum, Ron. *Sidewinder: Creative Missile Development at China Lake*. Annapolis, Md.: USNI Press, 1999.

Wildenberg, Thomas. *Destined for Glory: Dive Bombing, Midway, and the Evolution of Carrier Airpower*. Annapolis, Md.: USNI Press, 1998.

Winnefeld, Rear Adm James A., US Navy (USN), retired, and Dr. Dana J. Johnson. *Joint Air Operations: Pursuit of Unity in Command and Control, 1942–1991*. Annapolis, Md.: USNI Press, 1993.

Winton, Harold R. "An Ambivalent Partnership: US Army and Air Force Perspectives on Air-Ground Operations, 1973–90." In *The Paths of Heaven: The Evolution of Airpower Theory*. Edited by Phillip S. Meilinger. Maxwell AFB, Ala.: Air University Press, 1997.

Wolk, Herman S. *Planning and Organizing the Postwar Air Force, 1943–1947*. Washington, D.C.: Office of Air Force History, 1984.

Computer Network, Briefing, Lecture, and Memorandums

ABC News.com. “B-2 Sees First Combat.” On-line. Internet, 24 March 1999. Available from http://abcnews.go.com/sections/world/DailyNews/ bomber990324.html.

Air Force History and Museums Program. “Hughes AIM-120 AMRAAM.” On-line. Internet, n.d. Available from http://www. wpafb.af.mil/museum/arm/arm10a.htm.

Coupland, Maj Gen Richard C. Briefing. Scientific Advisory Board, 12 July 1949. Copy in files of History Office, Air Armament Center, file no. 25-N-4-8.

Kosiak, Steven M. “U.S. Fighter Modernization: An Alternative Approach.” *Issues in Science and Technology Online*. Spring 2000. On-line. Internet, 25 April 2001. Available from http://www.nap.edu/issues/16.3/kosiak.htm.

Ministry of Defence, United Kingdom. “Kosovo An Account of the Crisis: Initial Lessons Learned.” On-line. Internet, 15 December 1999. Available from http://www.mod.uk/newskosovo/account/lessons.htm.

Mitchell, William “Billy.” Lecture. Army War College, 24 November 1922. Curricular Archives file no. 240-49, US Army Military Institute, Carlisle Barracks, Pa.

Pike, John. “AIM-120 AMRAAM Slammer.” On-line. Internet, n.d. Available from http://www.fas.org/man/dod-101/sys/missile/aim-120.htm.

Spaatz, Gen Carl A. Memorandum to all major commands and all staff sections. Headquarters Army Air Forces, 1 April 1947. Copy in Air University Library, Maxwell AFB, Ala.

Titchen, R. S. and P. E. DePoy, (U). “Conventional Ordnance for Aircraft Use 1962–67.” Interim Research Memorandum, Operations Evaluation Group. Washington, D.C., 8 January 1962.

Manual

Air Force Doctrine Document 1. *Air Force Basic Doctrine*, September 1997, 29.

Newspaper Items

"Eglin's AMRAAM Joins the War." *Northwest Florida Daily News*, 22 February 1991.

France, Linda de. "AIM-9X Scores with Accuracy, Capability, High Hit-Rate." *Aerospace Daily*, 3 October 2000.

Periodicals and Journals

"Aircraft Armament Division Notes." *Army Ordnance*, March–April 1921.

"Aircraft Armament Division Notes." *Army Ordnance*, May–June 1921.

"Big Bombs." *Impact*, June 1945.

Bogart, Charles H. "German Remotely Piloted Bombs." USNI *Proceedings*, November 1976.

Borden, William A. "Air Bombing of Industrial Plants." *Army Ordnance*, I, November–December 1920.

Butler, Gen George Lee. "Disestablishing SAC: Reprint of an Official Speech Presented to the Air Force Historical Foundation." *Air Power History*, Fall 1993.

Coker, Dr. William S. "The Extra-Super Blockbuster." *Air University Review*, March–April 1967.

"Experts Count Costs to Fix JDAM Design Flaws." *Jane's Defence Weekly*, 5 November 1996.

Glosson, Lt Gen Buster C. "Impact of Precision Weapons on Air Combat Operations." *Airpower Journal*, Summer 1993. On-line. Internet. Available from http://www.maxwell.af.mil/ airchronicles/apj/glosson.html.

Gray, Colin S., and John B. Sheldon. "Space Power and the Revolution in Military Affairs: A Glass Half Full?" *Airpower Journal*, Fall 1999. On-line. Internet. Available from http://www.airpower.maxwell.af.mil/airchronicles/apj/apj99/fal99/gray.html.

Hammond, Grant T. "Myths of the Air War over Serbia: Some 'Lessons' Not to Learn." *Aerospace Power Journal*, Winter 2000.

Harlow, Brad. "Missile Systems." *Aerospace America*, December 1999.

Hewish, Mark, Anthony Robinson, and Gerarde Turbe. “Air-to-Air Missiles.” *International Defense Review*, August 1990.

Hone, Thomas C. “Jackie Fisher’s Revenge.” USNI *Proceedings*, February 2000. *Foreign Policy*, Winter 1998–99.

Ignatieff, Michael. “The Virtual Commander: How NATO Invented a New Kind of War.” *New Yorker*, 2 August 1999.

Kerr, Nick. “The Falklands Campaign.” *Naval War College Review*, November–December 1982.

Krepinevich, Andrew F. “Cavalry to Computer.” *National Interest*. Fall 1994.

———. “Forging a Path to a Post-Nuclear U.S. Military.” *Issues in Science and Technology*, Spring 1997.

Loftus, Capt Martin J. “Tactical Non-Nuclear Weapons.” *Fighter Weapons Review*, June 1964.

Lowe, Christian. “High-Tech Helmet to Cut Targeting Times 90 Percent.” *Defense Week*, 18 September 2000.

Mann, Paul. “Mammoth Air/Ground Assault Defeats Iraq in Gulf War.” *Aviation Week and Space Technology*, 4 March 1991.

McNeil, Daniel. “Technology, History and the Revolution in Military Affairs.” *Canadian Military Journal*, Winter 2000–2001. On-line. Internet, 24 April 2001. Available from http://www.journal.dnd.ca/vol1/no4_e/ronald_e/ronald1_e.html.

Metz, Steven. “The Next Twist of the RMA.” *Parameters*, Autumn 2000.

Morrocco, John D., and David A. Fulghum. “USAF Developed 4,700 lb Bomb in Crash Program to Attack Iraqi Military Leaders in Hardened Bunkers.” *Aviation Week and Space Technology*, 6 May 1991.

Murray, Williamson. “Clausewitz Out, Computer In: Military Culture and Technological Hubris.” *National Interest*, Summer 1997.

“Nimitz Is Carrying Latest Stand-off Weapon.” *Jane’s Defence Weekly*, 19 November 1997.

North, David M. “Air Force, Navy Brief Congress on Lessons from Libya Strikes.” *Aviation Week and Space Technology*, 2 June 1986.

O'Hanlon, Michael E. "Can High Technology Bring U.S. Troops Home?" *Foreign Policy*. Winter 1998/99.

"Operation Desert Storm: Initial Lessons Learned." *Aviation Week and Space Technology,* 18 February 1991.

Owens, Adm William A., USN, retired. "The Emerging System of Systems." USNI *Proceedings,* May 1995.

———. "It's Time for the Revolution." USNI *Proceedings,* April 2000.

Pentland, Maj Pat A. "Close Air Support—A War Fighting Role." *Armed Forces Journal International,* September 1988.

Posen, Barry. "The Air War in Kosovo." *International Security*, Spring 2000.

Roos, John G. "Effects Based Operations: US Air Force Chief Assesses a Decade of Transformation." *Armed Forces Journal International,* March 2001.

Safran, Nadav. "Trial by Ordeal: The Yom Kippur War, October 1973." *International Security*, Fall 1977.

Schemmer, Benjamin F. "AFJ's Dart to USAF Leadership for 'Antique Ordnance' Was 180 Degrees Off Course." *Armed Forces Journal International,* June 1986.

Sloan, Dr. Elinor. "Canada and the Revolution in Military Affairs: Current Response and Future Opportunities." *Canadian Military Journal,* Autumn 2000. On-line. Internet, 25 April 2001. Available from http://www.journal.dnd.ca/vol1/no3_e/revolution_e/rev_e.html.

Stephens, Alan. "Kosovo: Or the Future of War." *Asia–Pacific Defence Reporter,* June–July 1999.

Sterner, Eric R. "You Say You Want a Revolution (in Military Affairs)?" *Comparative Strategy,* October–December 1999.

Stumpf, Lt Comdr Robert E., USN. "Air War with Libya." USNI *Proceedings*, August 1986.

Sweetman, Bill. "Scratching the Surface: Next Century Air-to-Ground Weapons." *Jane's International Defense Review*, July 1997.

———. "The Progress of the F-22 Fighter Program." *Jane's International Defense Review,* Quarterly Report, no. 1, 1997.

Thor, Capt Robert. "GAR-8." *Fighter Weapons Newsletter,* June 1958.

Tilford, Earl H. "Operation Allied Force and the Role of Air Power." *Parameters,* Winter 1999–2000.

Tirpak, John A. "With Stealth in the Balkans." *Air Force Magazine,* October 1999.

Tomes, Robert. "Revolution in Military Affairs—A History." *Military Review,* September–October 2000.

Toti, Bill. "Stop the Revolution; I Want to Get Off." USNI *Proceedings,* July 2000.

Trest, Warren A. "View from the Gallery: Laying to Rest the Admiral's Revolt of 1949." *Air Power History*, Spring 1995.

"U.S. Demonstrates Advanced Weapons Technology in Libya." *Aviation Week and Space Technology,* 21 April 1986.

Vego, Milan. "Wake-Up Call in Kosovo." USNI *Proceedings*, October 2000.

Volloy, Maj Gerald R. "Red Flag in Perspective." *USAF Fighter Weapons Review,* Spring 1979.

Waghelstein, Col John D. "Some Thoughts on Operation Desert Storm and Future Wars." *Military Review*, February 1992.

Warden, John A., III. "The Enemy as a System." *Airpower Journal,* Spring 1995.

Reports

Davis, Dale M. Report. "Historical Development Summary of Automatic Cannon Caliber Ammunition: 20–30 Millimeter." File no. AFATL-TR-84-03. Eglin AFB, Fla.: Air Force Armament Laboratory, January 1984.

Milling, Maj T. D. Report, "The Air Service Tactical School." Langley Field, Va., 1924. Copy in files of History Office, Air Armament Center, Eglin AFB, Fla., file no. 25A-1-15.

Rasmussen, Lt Col Kenneth. Report. "The Munitions of Airpower in Southeast Asia, 1964–69." AFHRA file no. K239.0370-2. Maxwell AFB, Ala.: Corona Harvest Project Office, Aerospace Studies Institute, Air University, January 1970.

US Air Force. Aberdeen Proving Ground, Aberdeen, Md. "Operational Suitability Tests of the TARZON Air-to-Surface Guided Missile," 13 August 1951. Copy in Technical Library, Eglin AFB, Fla., file no. 5999.

———. Aberdeen Proving Ground. "The Proving Ground's Role in the Air Force Missile Development Program," 1 December 1957. Copy at Air Armament Center/History Office, file no. 25A-1-1.

———. AFMC. "Air Materiel Armament Test Center, January 1949 to 30 June 1950." Copy at AF Development Test Center, Eglin AFB, Fla., file no. 25b.

———. Headquarters Air Combat Command/DRPW. "Final Operational Requirements Document, Wind Corrected Munitions Dispenser," 23 September 1994.

———. "Report of the Chief of Staff of the United States Air Force to the Secretary of the Air Force," 30 June 1948. Copy in Air University Library, Maxwell AFB, Ala.

US Army Air Forces (AAF). AAF Board, Orlando, Fla. "Controlled Eglin Missiles." Project no. GP 5, 29 October 1943. Copy in Technical Library, Eglin AFB, Fla., file no. 2416.

US Army, Air Service. Headquarters First Provisional Air Brigade, Langley Field, Va. "Armament Report," 8 August 1921. Copy at USAF Historical Research Agency, file no. 248.222-89.

Unpublished Papers

Buckley, Thomas Hugh. "The United States and the Washington Conference, 1921–1922." PhD diss., Indiana University, 1961.

Hardy, Maj John S. "Development of Conventional Fighter Weapons." Thesis, ACSC, Maxwell AFB, Ala., June 1967.

Wilson, Donald E. "The History of President Truman's Air Policy Commission and Its Influence on Air Policy, 1947–1949." PhD diss., University of Denver, 1978.

The Long Search for a Surgical Strike

Precision Munitions and the Revolution in Military Affairs

Air University (AU) Library / AU Press

Chief Editor
Hattie D. Minter

Copy Editor
Rita B. Mathis

Book Design and Cover Art
Daniel Armstrong

Composition and Prepress Production
Vivian D. O'Neal