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"All the Missiles Work"

Technological Dislocations and Military Innovation

A Case Study in US Air Force Air-to-Air Armament
Post–World War II through Operation Rolling Thunder

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AIR UNIVERSITY

SCHOOL OF ADVANCED AIR AND SPACE STUDIES

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Foreword

When Airmen think about technology, it is typically in terms of how best to achieve military effects. This paper explores the deeper and more crucial issues of how organizations and individuals resist, embrace, and shape technological innovation. Steam-powered warships, machine guns, aircraft carriers, intercontinental ballistic missiles, and remotely piloted aircraft all threatened established practice and faced the resistance of entrenched bureaucracies and dogmatic tradition. Yet such rigidity of mind and habit contrasts with the imperative of achieving military advantage and the sparkling allure of the new, the scientific, and the powerful. Lt Col Steve Fino explores the tension between such technological skepticism and technological exuberance—a tension that "weaves itself through the fabric of US military history," with his concept of *technological dislocation*. In this light, he examines how various factors can dislocate the predicted evolutionary pathway of emerging or even established technologies and steer them in new, perhaps surprising, directions.

The development of air-to-air armament in the initial decades of the jet age provides an intriguing case study of technological dislocation. On this stage, various actors such as fighter pilots, senior leaders, institutional preferences, cutting-edge technologies, and enemy combatants played out the first scenes of aerial combat's missile age. The Air Force's inflated rhetoric on missile efficacy, based on misassumptions and technological exuberance, was punctured by the failure of missiles in actual combat. Still, the institution persisted in its belief that "all the missiles worked." Fino examines why senior leaders—some of them renowned combat pilots—clung to this fiction despite dramatic failures spotlighted in Korea and Vietnam. Nevertheless, a handful of relatively junior officers effected a dislocation from the dominant missile technology and installed an external air-to-air cannon on the F-4 Phantom, an aircraft previously exalted as a missile-only guarantor of air superiority. Their clashes with the enemy and the bureaucracy created long-lasting results and demonstrated how the concepts of technological skepticism, exuberance, and dislocation instruct military innovation. Indeed, this study provides today's leaders and strategists much needed insights into how to bring about change and create advantage in the swirling complexity of modern technology and bureaucracy.

Originally written as a master's thesis for Air University's School of Advanced Air and Space Studies (SAASS), Colonel Fino's *Technological Dislocations and Military Innovation* received the Air University Foundation's 2010 award for the best SAASS thesis on the subject of technology, space, or cyberspace. I am pleased to commend this excellent study to all who believe that

broadly informed research, rigorous argumentation, and clear expression are vital to the advancement of strategic thought and practice.

Timothy P. Schultz
Colonel, USAF, Retired, PhD
Associate Dean of Academic Affairs,
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About the Author

Lt Col Steven A. Fino graduated from the US Air Force Academy as a distinguished graduate in 1996. Following an academic assignment to the University of California–Los Angeles (UCLA), he graduated from Euro-NATO Joint Jet Pilot Training at Sheppard AFB, Texas, in 1998 and was selected to fly the F-15C Eagle. In June 2004 he graduated from the US Air Force Weapons School at Nellis AFB, Nevada. His weapons school research paper, "Achieving Air Superiority in a Gardenia Electronic Attack Environment," won top honors among the 73 graduates. His flying assignments in the F-15C included Langley AFB, Virginia; Kadena AB, Japan; Eglin AFB, Florida; and Nellis.

While at Nellis, Colonel Fino was involved in the operational testing of critical software and hardware upgrades for the F-15C Eagle. In addition to his instrumental role in developing new fourth- and fifth-generation fighter tactics for use against advanced electronic attack-equipped adversaries, Colonel Fino also worked with the F-35 Joint Strike Fighter program staff as a core pilot specializing in air-to-air tactics. Following his assignment at the School of Advanced Air and Space Studies at Maxwell AFB in 2010, Colonel Fino was stationed at the Pentagon in the Air Force chief of staff's strategic studies group, where he provided critical analysis and policy recommendations on a variety of strategic initiatives, including the joint Air Force–Navy Air-Sea Battle initiative.

Colonel Fino has flown combat missions in support of Operations Northern Watch and Southern Watch and homeland defense missions in support of Operation Noble Eagle. He has a bachelor of science degree in materials science from the USAFA, a master of science degree in materials science and engineering from UCLA, a master of science degree in operations analysis from the Air Force Institute of Technology at Wright-Patterson AFB, Ohio, and a master's degree in airpower art and science from SAASS. He is currently pursuing a PhD in engineering systems at the Massachusetts Institute of Technology.

Acknowledgments

Like the technological innovations discussed herein, this paper quickly developed a life of its own, and my attitude toward it fluctuated almost daily between skepticism and exuberance. Col Tim Schultz, SAASS commandant, dean, and trusted advisor, always provided a valuable moderating influence. Two other SAASS professors were particularly instrumental in steering me toward investigating the role of science and technology in the military: Dr. Stephen Chiabotti, who enlightened me to the science and technology historical subfield; and Dr. Michael Pavelec, who helped me transform a jumble of random ideas into a semicoherent research prospectus. Their collective efforts ensured that my foray into the annals of airpower history was satisfying and rewarding.

The superb staff at the Air Force Historical Research Agency (AFHRA) and the wonderful librarians at the Muir S. Fairchild Research Information Center at Maxwell aided my adventure. My SAASS professors—especially Dr. Hal Winton—helped refine my writing skills, while my SAASS colleagues helped hone my argumentation skills. I emerged from this 11-month program better able to conceptualize and articulate the diverse challenges facing the Air Force and our nation.

I extend special thanks to retired colonel Gail "Evil" Peck. Evil, a talented F-4 driver who flew in Vietnam, is also a gifted civilian instructor at the USAF Weapons School at Nellis. I had the pleasure (or agony) of sitting through 20-plus hours of Evil's instruction on the AIM-7 Sparrow air-to-air guided missile during my weapons school training in 2004. When I needed an authoritative source to answer my F-4 systems questions, I knew where to turn, and Evil graciously accommodated me. He also put me in touch with retired major Sam Bakke, an F-4 pilot who worked for Col Frederick "Boots" Blesse in 1967 at Da Nang Air Base, South Vietnam. Mr. Bakke provided a valuable firsthand account of the 366th Tactical Fighter Wing's internal dynamics and critical insight into the innovation process central to this thesis. Mr. Bakke in turn put me in touch with retired lieutenant colonel Darnell "D" Simmonds, an F-4 pilot who served with Col Robin Olds in the 8th Tactical Fighter Wing at Ubon, Thailand, and a member of the only F-4 crew to score two MiGs with the external gun in a single mission. I am proud to serve in the Air Force legacy that Evil, Sam, and D helped cultivate.

Finally, there is no way to adequately say "thank you" to my wife and our wonderful children. I draw my strength and motivation from their untiring patience and support. To them I dedicate this work.

Abstract

History reveals a Janus-faced, nearly schizophrenic military attitude toward technological innovation. Some technologies are stymied by bureaucratic skepticism; others are exuberantly embraced by the organization. The opposing perceptions of skepticism and exuberance that greet military technologies mirror the different interpretations of technology's role in broader society. Thomas Hughes's theory of technological momentum attempted to reconcile two of the disparate perspectives—social constructivism and technological determinism. The theory of technological dislocations advanced by this thesis is a refinement of Hughes's theory and is more reflective of the complex, interdependent relationship that exists between technology and society.

Drawing on a single, detailed historical case study that examines the development of air-to-air armament within the US Air Force, post–World War II through Operation Rolling Thunder, this paper illustrates how an unwavering commitment to existing technologies and a fascination with the promise of new technologies often obfuscate an institution's ability to recognize and adapt to an evolving strategic environment. The importance of a keen marketing strategy in outmaneuvering bureaucratic skepticism, the benefits of adopting a strategy of innovative systems integration vice outright systems acquisition, and the need for credible, innovative individuals and courageous commanders who are willing to act on their subordinates' recommendations are all revealed as being critical to successful technological innovation.

Chapter 1

Introduction

Da Nang was a mess. We shared operational use of the base with the Vietnamese and neither the previous American nor Vietnamese commander appeared to have a handle on the wide variety of problems that faced them. . . . To make matters worse, the senior officers in the wing were doing little or no flying.

—Maj Gen Frederick "Boots" Blesse, USAF

As the new deputy commander for operations at the 366th Tactical Fighter Wing (TFW), Da Nang Air Base, South Vietnam (SVN), then-colonel "Boots" Blesse, a Korean War double ace, was determined to transform his unit into a "respectable combat outfit." He and his assistant, Col Bert Brennan, hammered out new wing directives, established new traffic patterns to minimize aircraft exposure to potential ground attack, and developed new landing procedures to curb the frequent mishaps that occurred on the poorly designed and often wet Vietnamese runway. More importantly, Blesse and Brennan understood that "you can't push a piece of string" and made a pact shortly after their arrival in April 1967 that they "would be two full colonels who flew 100 missions 'Up North.' " Whereas some Air Force colonels in Vietnam tried to limit their exposure to the more dangerous combat missions, merely biding their time before rotating back home to the states after their one-year assignment, Blesse and Brennan were determined to fly "the same missions as the buck pilots."[1]

Thus, when the wing commander, Col Jones Bolt, stopped by to see Blesse on 13 May 1967, the message came as quite a shock. "We have several other missions besides the Hanoi run and I expect you to be active in them all," he informed Blesse. "You can't be going to Pack Six every day, so get back to spreading yourself around."[2] Although heartbroken, Blesse knew his commander was right. He had flown two Pack Six missions the two previous days—on one, even loitering in the target area for an extra 10 minutes "hoping to see enemy aircraft." It wasn't that Blesse was "hogging" the combat missions; he had a personal stake in the outcome of the next aerial engagement with the North Vietnamese MiGs.[3] So it was with some anxiety and much reservation that Blesse watched the next day's two flights of four F-4C Phantoms lumber off the runway at Da Nang. It was Sunday afternoon, 14 May

1967. The F-4s had a mission "Up North," and several of them were loaded with the Air Force fighter's newest air-to-air weapon.[4]

Piloting the lead aircraft—call sign Speedo 1—was Maj James Hargrove, Jr. Because he occupied the front seat of the F-4, he was the aircraft commander. In the backseat sat 1st Lt Stephen H. DeMuth. DeMuth was also a pilot, as were all Air Force F-4 backseaters during the Vietnam War, but he and the other pilots flying in the rear seat had grown accustomed to being referred to, somewhat derogatorily, as the "GIB" (guy in back). Mimicking the previous two days' missions, Hargrove's four-ship of F-4s teamed with an additional flight of four F-4s—callsign Elgin 1—to provide MiG combat air patrol (MiGCAP) cover for 19 388th TFW F-105 Thunderchief fighter-bombers from Korat Royal Thai AFB, Thailand, that were tasked with striking targets near Hanoi. The specific target that Sunday afternoon was the Ha Dong army barracks, located approximately four miles south of the capital city. After the members of Speedo flight completed their prestrike aerial refueling in the skies over Thailand and began their trek north toward Hanoi, Air Force early warning controllers alerted them to the suspected presence of enemy MiGs in the target area. The aircraft of Speedo flight assumed their tactical formation, slightly behind and 2,000 feet above the F-105 strikers, and eagerly searched the area with their state-of-the-art AN/APQ-100 radars. As the strike force neared the target, the Air Force controllers continued to warn the F-4s that MiGs were patrolling the area. Just then, the lead F-105 called, "MiG, 12 o'clock low, coming under."

Flying at 19,000 feet and more than 500 knots airspeed, offset slightly to the right of Hargrove in Speedo 1, Capt James Craig, Jr., in Speedo 3, and his GIB, 1st Lt James Talley, were the first F-4 crew to spot the MiGs, passing head-on, underneath the F-105 strikers just ahead of Speedo flight. A passing glance out the left side of the F-4 and the shimmer of silver wings against the cloudy undercast alerted Craig to two more MiGs at nine o'clock. Hargrove called for the flight to turn left, descend, and engage the enemy aircraft. Midway through the turn, Craig recognized that the "enemy MiGs" he had seen to the left were in fact friendly F-105 strikers. Pausing momentarily in disgust at his misidentification and now wondering where the earlier-spotted MiGs were, Craig resumed his visual scan of the airspace surrounding the F-105s and quickly, and this time correctly, identified four MiG-17s, split into two elements of two aircraft each, chasing down the F-105s. Communicating the observed MiG formation to the other Speedo flight members, Craig and his element mates in Speedo 4 started to maneuver into position against the trailing two MiGs. Hargrove in Speedo 1 jettisoned his cumbersome external fuel tanks and announced that his element would attack the leading two MiGs. Hargrove's

wingmen, Capt William Carey, and 1st Lt Ray Dothard in Speedo 2, jettisoned their external fuel tanks and maneuvered into a supporting position slightly aft of Speedo 1.

Speedo 1 and 2 tightened their left turns, the four American pilots straining against the rapidly increasing G-forces, and accelerated downhill toward the MiGs, hoping to position themselves at the MiGs' six o'clock before the enemy fighters could react. It was to no avail. The MiGs may have seen the white vapor trails streaming off the F-4 wingtips in the humid afternoon air, or they may have detected the characteristic black smoke spewing from the Phantom's General Electric J79 engines tracing the F-4s' maneuvers against the blue sky above.[5]

The MiGs started a hard, diving left turn toward Hargrove and his wingman, eventually passing head-on before they disappeared into the clouds behind and below the F-4s; there was no time for Hargrove to mount an attack. Frustrated, Hargrove began a climbing right turn, exchanging kinetic energy for potential energy and maneuvering away from the deadly antiaircraft artillery (AAA) that preyed on fighters caught flying too low to the ground. As the needle on the altimeter spun through 7,000 feet, Hargrove looked outside and surveyed the area. Exuberantly recounting the engagement for Blesse after he landed back at Da Nang, Hargrove described the scene: "Wall to wall MiGs, Colonel. You should have been there!"[6] Indeed, F-4 and F-105 pilot reports submitted after the mission revealed the presence of 16 MiG-17s in the skies facing Speedo flight that afternoon.[7] At this point, Speedo flight had accounted for only four.

Whereas the North Vietnamese MiGs quickly and successfully shook Speedo 1 and 2, Speedo 3 and 4's MiG prey were initially not so lucky. Craig and his wingman were able to dive on the MiGs, achieving the ideal six o'clock position from which to launch their Sparrow radar-guided or Sidewinder heat-seeking missiles. Craig pointed the nose of the F-4 at one of the MiGs and told Talley in the back seat to get a radar lock.[8] While Talley worked the radar, Craig ordered his wingman to jettison the external fuel tanks as Speedo 1 and 2 had done earlier—standard procedure to increase the F-4's performance for an imminent dogfight. Unfortunately, only one of Craig's two wing tanks fell away from the aircraft, leaving one tank partially filled with fuel still attached to the aircraft, seriously handicapping the Phantom's maneuverability and stability.

With Craig in the front seat trying desperately to jettison the remaining fuel tank and Talley in the back seat working feverishly to attain a radar lock, the MiG suddenly initiated a hard, descending 180-degree left turn toward Speedo 3 and 4. Recognizing the fleeting weapons opportunity as the MiG

rapidly approached minimum missile employment range, Craig pointed his F-4 at the turning MiG and launched a Sparrow missile despite lacking the requisite radar lock needed to accurately guide the missile to the target. The aircraft shuddered as the 12-foot missile ejected from its nesting place under the belly of the F-4, but the missile motor never fired, and it fell harmlessly to the ground as the MiG disappeared into the clouds below. Craig and his wingman began a climbing right turn, looking to escape the lethal low-altitude AAA employment zone as Speedo 1 and 2 had done earlier.

Midway through their climb, Craig visually acquired another MiG two-ship off the left side, low, in a left-hand turn. In a maneuver nearly identical to their first, Speedo 3 and 4 entered a tight, descending left turn and arrived undetected just behind the MiGs. Craig again pointed the nose of his F-4 at one of the MiGs as Talley adjusted the radar scan in hopes of achieving a radar lock on the enemy aircraft. Talley was successful this time, and from a mile away, in a left-hand turn, with the radar seemingly locked on to the target, Craig again squeezed the trigger and launched a Sparrow missile. Unfortunately, the result was the same—the missile separated from the aircraft and then promptly fell 4,000 feet to the ground. Now twice frustrated and too close to the MiGs to launch another missile, Craig and his wingman initiated a high-speed "yo-yo" maneuver to gain lateral and vertical separation from the MiGs and started searching for yet another target.[9]

Meanwhile, Speedo 1 and 2 had similarly engaged another two flights of two MiGs each, with unfortunately similar results—both of Hargrove's Sparrow missiles failed to guide, much less score a hit. After more than five minutes of intense air combat, the F-4s in Speedo flight had launched four Sparrow missiles, and none had worked as advertised—all fell harmlessly to the ground. The F-4s could ill afford to remain in the fight much longer. Well outnumbered by the MiGs, the American aircrews were losing situational awareness while quickly depleting their F-4's precious energy and maneuverability with continued attacks. Their luck was beginning to run out.

Following his last unsuccessful Sparrow missile attack, Hargrove directed his element to pursue another MiG. By turning to pursue the MiG in sight, though, Hargrove inadvertently maneuvered his element directly in front of an attacking MiG. Fixated on the MiG in front of them, Hargrove and his wingman failed to detect the two incoming enemy Atoll heat-seeking missiles launched from the MiG now behind them. Luckily, the North Vietnamese missile performance was comparable to the Americans' that day, and the missiles failed to guide toward the F-4 element. The MiG continued to press the attack, rapidly closing the range between the aircraft. Only a last-second, passing glance alerted Hargrove to the presence of the attacking MiG-17, the

front of the enemy aircraft rhythmically sparkling with muzzle flashes as the Vietnamese pilot fired his cannons at the F-4s.

As missile failures continued to frustrate the members of Speedo flight, their accompanying flight of four F-4s—callsign Elgin—led by Maj Sam Bakke and his GIB, Capt Robert Lambert, approached the target area and quickly joined the melee. Bakke in Elgin 1 selected a MiG and fired two Sidewinder missiles at it. The enemy pilot abruptly initiated a hard defensive turn and successfully outmaneuvered the American heat-seeking missiles. Observing their initial missiles defeated, Elgin 1 and 2 executed a high-speed "yo-yo" maneuver to reposition away from the turning MiG and selected another MiG-17 to attack. That MiG dove into the low clouds before Bakke could maneuver his element into a firing position.

Simultaneously, Elgin 3 and 4, flying in a supporting position slightly above the other two members of Elgin flight, caught a glimpse of another pair of MiGs rapidly closing on and firing at Bakke and his wingman. Hoping to distract the MiG pilots, Elgin 4 fired two Sidewinder missiles in quick succession, but neither missile was launched within proper parameters and both failed to guide toward the target. Elgin 3 also attempted to launch a Sidewinder missile at the attacking MiGs; that missile, despite being launched with the requisite tone and within valid launch parameters, misfired and never left the aircraft. Then, as Elgin 3 and 4 were engaging the MiGs that were attacking Elgin 1 and 2, another set of MiGs appeared and began attacking Elgin 3 and 4. Like Speedo flight, Elgin flight's luck was beginning to wear thin.

Once under attack, both Elgin 3 and 4 immediately initiated individual defensive "jink" maneuvers, but not before the MiGs' bullets passed within 15 feet of Elgin 4's crew. Fortunately, Elgin 4's maneuvers were effective; the F-4 crew successfully shook the MiG attacker and, in a remarkable stroke of good luck, ended up in perfect Sidewinder firing position behind another MiG that inexplicably flew directly in front of them. They tried to take advantage of the precious opportunity, but par for the day, that Sidewinder missile also failed to guide toward the target. The crew of Elgin 3 successfully shook an attacking MiG, and following the last unsuccessful Sidewinder missile attack by Elgin 4, the two aircraft, now both low on fuel, decided to exit the fracas. They turned south out of the target area and joined a flight of F-105s that were heading home after dropping their ordnance on the target.

Elgin 1 and 2 remained in the target area battling the MiGs. After losing sight of the second MiG that dove into the clouds, and as Elgin 3 and 4 were defending themselves from the separate MiG attacks, Bakke and his wingman observed a lone MiG in a left-hand turn a half-mile in front of and 2,000 feet above them. Bakke pointed the F-4 toward the MiG, and Lambert acquired a

radar lock. In his zeal to dispatch the MiG, Bakke squeezed the trigger three times trying to launch a Sparrow missile at the target before he realized that he was too close to the MiG to shoot.[10] Selecting idle power and slowing the F-4 opened the range between the two aircraft. Once outside of minimum missile range, Bakke launched two Sparrow missiles in quick succession at the unsuspecting MiG. The first missile failed to guide, but the second missile " 'homed in' on the target, causing an explosion and fire in the right aft wing root of the MiG-17."[11] The MiG "burst into flame and pitched up about 30 degrees, stalled out, and descended tail first, in a nose high attitude at a rapid rate into the cloud deck" below.[12] Finally, a missile worked; a MiG was destroyed, and Bakke and Lambert had earned a kill.

Bakke and his element mates had no time to celebrate. The North Vietnamese surface-to-air missile (SAM) sites surrounding the target were particularly active that day. The F-105s reported 14 observed SAM launches, one of which claimed an F-105.[13] Fortunately, the SA-2 missile launched toward Bakke's element shortly after it destroyed the MiG missed, detonating almost a mile away. Undeterred, Elgin 1 and 2 continued to attack the MiGs. They engaged another lone MiG with two Sidewinder missiles, but that MiG successfully outmaneuvered both missiles by executing a maximum-G turn.

As they broke off their unsuccessful attack and initiated a climb to higher altitude, the F-4s observed another three MiG-17s flying directly beneath them. Once more, Bakke and Lambert selected a MiG, acquired a radar lock, and fired a Sparrow missile—their last. And once more, the Sparrow missile failed to guide to the target. After separating from the aircraft, the missile veered sharply to the right and rocketed out of sight. Out of missiles, Elgin 1 tried to maneuver the element into position behind the remaining MiGs so that Elgin 2 could engage the enemy aircraft with its missiles, but the last of the remaining MiGs dipped into the clouds below before a stable firing position could be attained. The MiGs never reappeared. Elgin 1 and 2 conducted one last sweep of the target area and then turned south toward the tanker aircraft orbiting over Thailand before continuing home to Da Nang.

Bakke and Lambert's kill was not the only one that day. Immediately before Elgin 3 and 4 defensively reacted to the attacking pair of MiGs, all of the members of Elgin flight observed a "MiG-17 erupt into a ball of flame and dive, at an 80-degree angle, into the cloud shelf." About two minutes later, just prior to Elgin 3 and 4 exiting the target area, Elgin 2 and 3 observed another "MiG-17 in a 60-degree dive, at a high rate of speed, with a thin plume of white smoke trailing the aircraft."[14] Both MiGs were victims of Speedo flight and Blesse's mystery weapon.

Recall that as the members of Elgin flight entered the fight, Hargrove and DeMuth in Speedo 1 were under missile and gun attack by a rapidly closing MiG. Tightening the F-4's turn, Hargrove hoped to both avoid the MiG's bullets and cause the MiG to fly out in front of the Phantom. The tactic worked; the MiG overshot, and Hargrove, slamming the throttles into afterburner, reversed his turn direction to follow the MiG. Unfortunately, the F-4 was too slow, having sacrificed energy and speed executing the tight defensive turn, and the MiG quickly sped away from the lumbering F-4.

Speedo 1 and 2 initiated a climb and searched for other MiG targets. They found two at right, two o'clock, a half-mile away, low. Hargrove started a right turn, selected the trailing MiG in the right-turning formation, and surmised that he was in perfect position to employ the new weapon slung beneath the F-4's belly. Flying between 450 and 500 knots and only 2,000 to 2,500 feet behind the MiG, Hargrove pulled the nose of the F-4 far out in front of the MiG and squeezed the trigger. As the range collapsed inside of 1,000 feet, Hargrove could clearly distinguish the individual aluminum panels that made up the skin of the Russian-built fighter. Hargrove continued to mash down on the trigger. As the range collapsed inside of 500 feet, even more detail on the MiG became apparent. Despite continuing to accelerate toward the MiG on a certain collision course, Hargrove pressed the attack. Watching Hargrove's attack from a supporting position 500 feet behind and 1,000 feet above, slightly offset toward the left, Carey in Speedo 2 began worrying that "Speedo 1 had lost sight of the MiG-17 and would collide with him."[15]

Finally, at 300 feet separation—the point where the image of the MiG completely filled the F-4's windscreen—Hargrove observed the weapon's effectiveness. The weapon was the SUU-16 20-millimeter (mm) gun pod, and at 300 feet the impact of the individual rounds could be observed tearing holes into the MiG's thin aluminum skin right behind the canopy. "At approximately 300 feet, flame erupted from the top of the MiG fuselage. Almost immediately, thereafter, the MiG exploded from the flaming area and the fuselage separated in the area just aft of the canopy."[16]

Desperately trying to avoid the debris from the MiG erupting immediately before him, Hargrove initiated a violent, evasive maneuver to the left, inadvertently toward Speedo 2. Carey and Dothard in Speedo 2, in turn, executed an aggressive climbing turn in their own frantic attempt to avoid hitting both the MiG debris and Speedo 1. In the commotion, Speedo 1 and 2 became separated from each other, and the two fighters never successfully rejoined. Instead, Speedo 2 came upon another set of American fighters, and Hargrove in Speedo 1 directed Carey in Speedo 2 to join with the other fighters and accompany them home.

Speedo 1, now operating alone, attempted to engage an additional MiG with a Sidewinder missile, but Hargrove launched the missile when the F-4 was under too many G-forces, and it missed the target. Hargrove continued to close on the target, intending to employ the gun once again, but passing inside of 2,500 feet he realized he was out of ammunition. Rather than continue to press the attack, the crew of Speedo 1 thought better of using their sole remaining Sidewinder and elected instead to retain the missile for the long trek south to friendly airspace.

Craig and Talley in Speedo 3 also had success with the new SUU-16 20 mm gun pod that afternoon. Frustrated by two unsuccessful Sparrow launches, Craig observed two MiGs at nine o'clock low, in a left-hand turn, and immediately decided to maneuver for a gun attack. As Craig led his element in a diving left turn to engage the pair of MiGs, he noticed another lone MiG trailing the others by 3,000 feet. Craig wisely decided to switch his attack to the trailing MiG. Speedo 3 and 4 executed a barrel roll to gain better position on the trailing MiG, but, like Elgin 3 and 4, they too came under SAM fire. Similarly undeterred, Speedo 3 and 4 continued to prosecute the attack. The MiG tried to shake the chasing F-4s with a sudden reversal in turn direction, but Craig matched the maneuver perfectly and closed to within 1,500 to 2,000 feet before opening fire. Craig later reported, "I followed the MiG through the turn reversal, pulled lead, and fired a two and one-half second burst from my 20-mm cannon." His aim was spot-on. "Flames immediately erupted from his [the MiG's] right wing root and extended past the tailpipe. As I yo-yo'd high, the MiG rolled out to wings level, in a slight descent, and I observed fire coming from the left fuselage area. I initiated a follow up attack. However before I could fire, the MiG burst into flames from the cockpit aft and immediately pitched over and dived vertically into the very low undercast."[17] Shortly thereafter, Craig and his element-mate rejoined with Hargrove in Speedo 1 and together they pressed home, looking forward to the celebration that would take place later that night at the DOOM, the Da Nang officer's open mess.

Because the 366th wing commander was in Hong Kong for a meeting that fateful day in May 1967, Blesse had the pleasure of authoring the wing's daily operational summary report for Gen William Momyer at Seventh Air Force. It read: "SPEEDO Fl[igh]t: Today's success with SUU-16 on the F-4C confirms feasibility of this idea. Wing now has 14 a[ir]c[ra]ft modified and continuing modification at as rapid a pace as possible. We feel certain there will be two pilot meetings tonight. One in Hanoi, the other in the 8th Tac Fighter Wing."[18] Surprisingly, the numerous failures of the air-to-air missiles that afternoon warranted no mention in the summary report; their lackluster performance was not deemed out of the ordinary.[19]

How was it that in the dawning age of solid-state electronic radars paired with advanced air-to-air radar-guided and heat-seeking missiles, the successful combat employment of an antiquated weapons system cumbersomely mounted externally on an F-4 fighter aircraft was heralded so triumphantly by a seasoned combat fighter pilot? Surely, Air Force fighter pilots would have instead preferred, indeed demanded, the latest and most technologically advanced weaponry to help them in the life-or-death struggle that is air combat. If that technology failed to live up to advertised performance requirements, as it did on 14 May 1967 and countless times before that, then one would assume the Air Force pilots would have been up in arms, demanding the technology be quickly improved and refined. Instead, pilots like "Boots" Blesse pursued a decidedly low-tech weapon and fought to get a gun, even in bastardized form, on the F-4C.

The story then of the return of the air-to-air cannon to the F-4 Phantom provides a unique vantage point to peer into the complex interdependent relationship between technology and the US military—a relationship that historically alternates between periods of technological exuberance and technological skepticism. The theoretical lens of *technological dislocations* explains this relationship. To appreciate the theory's utility, a conceptual understanding of the foundational theories of technological change, especially Thomas Hughes's theory of technological momentum, is required and presented in chapter 2. Chapter 3 presents the theory of technological dislocations. Chapters 4, 5, and 6 describe the development of Air Force air-to-air weaponry post–World War II through Operation Rolling Thunder. This historical survey provides a useful case study to evaluate the role of technological dislocations in military history. Armed with this historical knowledge, the concept of technological dislocations can be extended to the larger context of military innovation, which is the subject of chapter 7. Collectively, a thorough understanding of the nature of technological development based on these concepts provides decision makers with the necessary tools to assess technology's influence on strategic decisions.

Notes

All notes appear in shortened form. For full details, see the appropriate entry in the bibliography. Additionally, note that portions of this thesis were used in Fino, "Breaking the Trance."

1. Blesse, *Check Six*, 117–18.
2. Ibid., 124. "Pack Six" refers to Route Package Six. To simplify command arrangements during the Vietnam War, the Navy and the Air Force subdivided North Vietnam into seven geographic regions (Route Packs One through Five, and 6A and 6B). Hanoi and the majority of lucrative North Vietnamese targets were located in Route Pack Six. Michel, *Clashes*, 38. During

a 1984 interview, Maj Gen Jones Bolt described Blesse's enthusiasm: "Boots was a pretty good troup [*sic*]; he was a little flamboyant sort of fellow; you had to keep your thumb on him. Boots wanted to fly too much." Bolt, oral history interview, 190.

3. Blesse, *Check Six*, 123.

4. PACAF Command Center, Chronological Log, 14–15 May 1967; Bakke, interview. Specifically, the aircraft flying in the #1 and #3 positions were supposed to be loaded with the new weapon. However, one of the flight's aircraft was unable to launch that afternoon due to a malfunction, and an airborne spare aircraft rolled into the Elgin 1 position. Unfortunately, there were not enough of the new weapons to equip the spare aircraft. The narrative of the 14 May 1967 mission that follows in this chapter is based on information in the Air Force Historical Research Agency (AFHRA) Aerial Victory Credit folders: AFHRA, "1967–14 May; Hargrove and DeMuth"; AFHRA, "1967–14 May; Craig and Talley"; and AFHRA, "1967–14 May; Bakke and Lambert." Each AFHRA folder contains a narrative summary and aircrew personal statements and/or memoranda to the "Enemy Aircraft Claims Board" that describe the MiG engagement.

5. Describing the characteristic F-4 smoke trail in subafterburner powers settings, one former combat F-4 pilot noted, "There were times when I could see F-4s 15 or 20 miles away due to the smoke trail—especially at a co-altitude when the F-4s were highlighted against the haze layer." Peck, e-mail.

6. Blesse, *Check Six*, 123.

7. AFHRA, "1967–14 May; Bakke and Lambert." The other F-4 flight, callsign Elgin, encountered another 10 MiG aircraft that afternoon, but based on the proximity of the two fights, there may be some overlap in the reported number of MiGs in Speedo and Elgin flights' accounts.

8. In close combat, F-4 crews generally used their radars in Boresight mode. The 8th Tactical Fighter Wing's (TFW) "Tactical Doctrine" manual described the boresight procedure: "Going to Boresight cages the radar antenna to the dead ahead position. The aircraft commander now steers to place the target within the reticle of the optical sight and places the pipper on the target. The radar target blip will appear in the pilot's radar scope 'B' sweep. The pilot then locks on to the target in the Boresight mode. Once lock-on is acquired, the system is returned to the RADAR mode to provide full system capability with auto tracking. The aircraft commander now begins to pull lead on the target by placing the target tangent to the top of the radome. . . . Upon reaching the 'in range' area, the AIM-7E should be launched." 8th TFW, "Tactical Doctrine," March 1967, 80.

9. Boyd described "the high speed yo-yo" as "an offensive tactic in which the attacker maneuvers through both the vertical and the horizontal planes to prevent an overshoot in the plane of the defender's turn. . . . The purpose of the maneuver is . . . to maintain an offensive advantage by keeping nose-tail separation between the attacker and defender." The offensive maneuver begins with an aggressive pull up into the vertical plane while rolling slightly away from the target. As the distance to the target begins to increase toward an acceptable range, the offender rolls back toward the target and initiates a descent toward the defender's extended six o'clock position. Boyd, *Aerial Attack Study*, 64–73.

10. Bakke, to 366 TFW Enemy Aircraft Claims Board. The F-4 weapons system was equipped with an "interlock" switch that when activated inhibited launching a Sparrow missile unless all of the missile firing parameters were met.

11. Ibid.

12. AFHRA, "1967–14 May; Bakke and Lambert."

13.   Message, 388 TFW to NMCC. The message noted that the pilot of the downed F-105, callsign Crab 2, was successfully recovered by rescue forces.

14.   AFHRA, "1967–14 May; Bakke and Lambert."

15.   Statement from Carey.

16.   Hargrove, to 366 TFW (DCO).

17.   Craig, to 366 TFW Enemy Aircraft Claims Board.

18.   Message, 366 TFW to 7 AF CC. Blesse's reference to the pilot meeting at the 8th TFW reflected his belief that Col Robin Olds, 8th TFW commander, would demand quick implementation of the 366th TFW's innovation within his own F-4 wing at Ubon, Thailand. In his autobiography, *Check Six*, Blesse stated that the summary report read: "We engaged enemy aircraft in the Hanoi area, shooting down three without the loss of any F-4s. One was destroyed with missiles, an AIM-7 that missed and an AIM-9 heat seeker that hit. That kill cost the US government $46,000. The other two aircraft were destroyed using the 20-mm cannon—226 rounds in one case and 110 rounds in the other. Those two kills cost the US government $1,130 and $550, respectively. As a result of today's action, it is my personal opinion there will be two pilot's meetings in the theater tonight—one in Hanoi and the other at the 8th TFW at Ubon." Blesse, *Check Six*, 124. Blesse's recollection of the summary report in *Check Six* is factually incorrect. Rather than firing an AIM-7 Sparrow followed by an AIM-9 Sidewinder that destroyed the MiG as Blesse described, Bakke is clear in his statement following the event: "I fired two Sparrow missiles while pursuing the target in a left turn. One missile did not guide and the other 'homed in' on the target." Bakke, to 366 TFW Enemy Aircraft Claims Board.

19.   Coincidentally, the Sparrow missile failures did catch the attention of the Pacific Air Forces (PACAF) commanding general, who four days later demanded "immediate analysis of AIM-7 missile failures during MiG engagements on 12, 13, 14 May 67." Message, PACAF CC to 7 AF and 13 AF, 18.

Chapter 2

Foundations of Technology

But lo! men have become the tools of their tools.

—Henry David Thoreau

On 17 January 1961, Pres. Dwight Eisenhower delivered his farewell address to the nation. Besides extending the customary thanks to Congress and offering best wishes for the next presidential administration, Eisenhower warned of two "threats, new in kind or degree," that loomed over the nation. Both concerned technology. The first admonition is well cited.

> Our military organization today bears little relation to that known of any of my predecessors in peacetime, or indeed by the fighting men of World War II or Korea.

> Until the latest of our world conflicts, the United States had no armaments industry. American makers of plowshares could, with time and as required, make swords as well. But we can no longer risk emergency improvisation of national defense; we have been compelled to create a permanent armaments industry of vast proportions. Added to this, three and a half million men and women are directly engaged in the defense establishment. We annually spend on military security more than the net income of all United States corporations.

> Now this conjunction of an immense military establishment and a large arms industry is new in the American experience. The total influence—economic, political, even spiritual—is felt in every city, every State house, every office of the Federal government. We recognize the imperative need for this development. Yet we must not fail to comprehend its grave implications. Our toil, resources and livelihood are all involved; so is the very structure of our society.

> In the councils of government, we must guard against the acquisition of unwarranted influence, whether sought or unsought, by the military-industrial complex. The potential for the disastrous rise of misplaced power exists and will persist.

> We must never let the weight of this combination endanger our liberties or democratic processes. We should take nothing for granted. Only an alert and knowledgeable citizenry can compel the proper meshing of the huge industrial and military machinery of defense with our peaceful methods and goals, so that security and liberty may prosper together.

The second warning is less well known.

> Akin to and largely responsible for the sweeping changes in our industrial-military posture has been the technological revolution during recent decades.

In this revolution, research has become central; it also becomes more formalized, complex, and costly. A steadily increasing share is conducted for, by, or at the direction of, the Federal government.

Today, the solitary inventor, tinkering in his shop, has been overshadowed by task forces of scientists, in laboratories and testing fields. In the same fashion, the free university, historically the fountainhead of free ideas and scientific discovery, has experienced a revolution in the conduct of research. Partly because of the huge costs involved, a government contract becomes virtually a substitute for intellectual curiosity. For every old blackboard there are now hundreds of new electronic computers.

The prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money is ever present—and is gravely to be regarded.

Yet, in holding scientific research and discovery in respect, as we should, we must also be alert to the equal and opposite danger that public policy could itself become the captive of a scientific-technological elite.[1]

Stephen Ambrose characterized Eisenhower's farewell speech as that of "a soldier-prophet, a general who has given his life to the defense of freedom and the achievement of peace."[2] Not all received the speech so warmly. One Air Force writer questioned Eisenhower's sincerity, commenting, "President Eisenhower . . . had his eye on a place in history as a military hero who revolted against war."[3] Walter McDougall, writing in 1985, described Eisenhower's farewell speech as eerily prescient. "It reads like prophecy now, its phrases sagging with future memories."[4] McDougall lamented that Eisenhower's warnings, regardless of their particular motivation, went unheeded. For McDougall, the burgeoning role of the military-industrial complex and an unhealthy faith in technology's unrelenting march toward "progress" fostered a technocratic ideology that quickly permeated the United States.[5]

Technological Exuberance

Nearly a decade prior to McDougall, Herbert York also called attention to the nation's fascination with technological solutions to international and domestic issues. He suggested that this attitude sprouted from the nation's unique world stature: "The United States is richer and more powerful, and its science and technology are more dynamic and generate more ideals and inventions of all kinds, including ever more powerful and exotic means of mass destruction. In short, the root of the problem has not been maliciousness, but rather a sort of *technological exuberance* that has overwhelmed the other factors that go into the making of overall national policy."[6] While York's unabashed faith in the United States' technological superiority may conjure visions of a social Darwinist argument, the idea that civilian and military

leaders can be blinkered by the promise of technology—York's technological exuberance—is consistent with the message in Eisenhower's farewell address and McDougall's observation of a United States slipping toward technocracy.[7]

The link between technology and the military can be especially profound. Merritt Roe Smith observed that the "military enterprise has played a central role in America's rise as an industrial power and . . . since the early days of the republic, industrial might has been intimately connected with military might."[8] Looking toward the future in a decidedly ethnocentric manner reminiscent of York's argument, a US Army War College report written in 2000 claimed that "the ability to accept and capitalize on emerging technology will be a determinant of success in future armed conflict. No military is better at this than the American, in large part because no culture is better at it than the American."[9] Indeed, a cursory review of popular US military history reveals the services' affinity for relying on technological solutions to ensure national security—in York's words, "a sort of technological exuberance."

The trend is particularly evident within the US Air Force. After gaining independence in 1947, the Air Force built upon its World War II image as a technologically advanced fighting force armed with an array of high-speed fighters and massive four-engine bombers. The chief of the fledgling air service, Gen Henry "Hap" Arnold, relished his opportunity to cultivate technology within the service. He described his charge as "get[ting] the best brains available, hav[ing] them use as a background the latest scientific developments in the air arms," and creating instruments "for our airplanes . . . that are too difficult for our Air Force engineers to develop themselves."[10] Having for years been constrained by the world war's unrelenting demands for immediate technological practicality, Arnold was excited to now "look ahead and set free the evangelist of technology that dwelt within him."[11] Neil Sheehan posited that Arnold "intended to leave to his beloved air arm a heritage of science and technology so deeply imbued in the institution that the weapons it would fight with would always be the best the state of the art could provide and those on its drawing boards would be prodigies of futuristic thought."[12]

Arnold had already laid the foundation by war's end. Earlier, the air chief established the Army Air Forces Scientific Advisory Group, a collection of military officers and academics led by scientific whiz Dr. Theodore von Kármán (at Arnold's behest), and tasked it with peering into the future and charting a course for Air Force technological development. The group's 33-volume report, *Toward New Horizons*, was completed in December 1945. The title of the first volume, "Science: The Key to Air Supremacy," was indicative of the report's general conclusions. Von Kármán's executive summary of the volume boldly proclaimed: "The men in charge of the future Air Forces should always

remember that problems never have final or universal solutions, and only a constant inquisitive attitude toward science and a *ceaseless and swift adaptation to new developments* can maintain the security of this nation through world air supremacy."[13] Bolstered by the promise of technology, the nascent Air Force of the 1950s marketed itself as *the* military service of the future, proudly ushering in the "Air Age" with visions of gleaming B-36 bombers soaring high across the sky, far above Soviet air defenses, ready to deliver the atomic weapons that American scientific ingenuity had bequeathed to the nation.[14]

A decade later, images of futuristic space rockets and ballistic missiles dominated the public and military consciousness. The Air Force sought to capitalize on the fascination and aggressively lobbied for a manned presence in space independent from that of the newly formed National Aeronautics and Space Administration (NASA).[15] The Air Force's vehicle, the X-20A Dyna-Soar—"a low, delta-winged spaceplane to be launched on a Titan rocket but land like an airplane"—eventually informed NASA's space shuttle designs.[16] The Air Force originally marketed the X-20A as an ideal way to quickly deliver nuclear weapons anywhere in the world. However, as the space antiweaponization movement became more entrenched, the mission of the X-20A to rain down nuclear destruction from space became untenable. The Air Force scrambled to identify a more palatable purpose for the Dyna-Soar. According to McDougall, the subsequent search for a useful application for the impressive but impractical technology was "typical [of a] big project [at the time]: demonstration of technical feasibility, privately funded research and salesmanship leading to military acceptance, extrapolation of existing technology, contrivance of plausible military missions, the savor of 'technological sweetness,' and finally the Sputnik panic."[17] McDougall's lambasting continued: "It [the X-20] was a bastard child of the rocket revolution, an idea too good to pass up, if only because it promised spaceflight without dispensing with wings or a pilot. . . . It was wet-nursed by industry and raised by the military on the vaguest of pretexts."[18] After seven years and $400 million in funding, but with the program still facing "imposing technical challenges, . . . an overly ambitious set of objectives," and an "ill-defined military requirement," Secretary of Defense Robert McNamara cancelled the program in 1964.[19]

By the late 1960s and early 1970s, the military, grasping for technological solutions that would facilitate victory in the jungles of Vietnam and Laos, became entranced with the promise of cybernetic warfare.[20] In 1969 Gen William Westmoreland predicted, "On the battlefield of the future, enemy forces will be located, tracked, and targeted almost instantaneously through the use of data links, computer assisted intelligence evaluation and automated fire control. With first round probabilities approaching certainty, and with sur-

veillance devices that can continually track the enemy, the need for large forces will be less important."[21] Within two years, Westmoreland's vision was largely realized in the jungles of Southeast Asia. Under the auspices of Igloo White, the American military deployed and maintained a system of "acoustic and seismic" sensors along the Ho Chi Minh Trail at an annual cost approaching $1 billion.[22] The sensors' signals were relayed by overhead aircraft "to the heart of the system, an IBM 360/65 computer at Nakhon Phanom Royal Thai Air Force Base." The computer-processed information enabled "real-time tracking of the truck traffic" moving into SVN.[23] Fueled by the tactical intelligence goldmine, the Igloo White system "triggered massive B-52 and fighter strikes aimed at destroying the road structure and the trucks in transit."[24] However, when North Vietnam (NVN) responded in November 1971 by deploying SAMs and fighters to counter the B-52 strikes, they rendered the technologically impressive Igloo White system impotent. The North Vietnamese counter not only curtailed the Americans' ability to act on the high-tech intelligence, but it also capitalized on the shifting "psychology of the [American] war effort" and the new emphasis "on limiting American casualties of all types, and especially avoiding the loss of highly visible assets like the B-52."[25]

In 1983 Pres. Ronald Reagan and the nation again turned to the promise of futuristic technology to provide for the national defense:

> Let us turn to the very strengths in technology that spawned our great industrial base and that have given us the quality of life that we enjoy today.
>
> What if free people could live secure in the knowledge that their security did not rest upon the threat of instant US retaliation to deter a Soviet attack, that we could intercept and destroy strategic ballistic missiles before they reached our own soil or that of our allies?
>
> I know this is a formidable, technical task, one that may not be accomplished before the end of the century. Yet, current technology has attained a level of sophistication where it's reasonable for us to begin this effort. . . .
>
> I call upon the scientific community in our country, those who gave us nuclear weapons, to turn their great talents now to the cause of mankind and world peace, to give us the means of rendering these nuclear weapons impotent and obsolete.[26]

With these words, President Reagan launched the Strategic Defense Initiative (SDI), later derogatorily nicknamed "Star Wars." SDI cultivated visions of space-based lasers and "Brilliant Pebbles" kinetic kill vehicles orbiting high above the earth's atmosphere, always in position and ready to defend the United States and its allies from Soviet ballistic missile attack. Despite the optimistic rhetoric, the SDI technology failed to materialize. However, the failure did not diminish the American military's obsession with technology. Eight years later, the world was offered a front-row seat—via CNN—to wit-

ness the impressive state of Reagan-inspired military technology during Operation Desert Storm.

The focus on high-cost and high-tech came to the forefront of the Air Force consciousness again in 2008. Facing a seemingly interminable and daunting counterinsurgency struggle in Iraq and Afghanistan, Secretary of Defense Robert Gates was aghast at the Air Force's preoccupation with acquiring more F-22 stealth fighters. In May 2008, speaking in Colorado Springs, Colorado, Gates suggested that the Air Force, by focusing on future potential "near-peer" competitors at the expense of supporting the current wars, suffered from "next-war-itis."[27] Gates's frustration was also evidenced a month prior. In a speech at Maxwell AFB, Alabama, in April 2008, Gates lamented, "I've been wrestling for months to get more intelligence, surveillance and reconnaissance [ISR] assets into the theater. Because people were stuck in old ways of doing business, it's been like pulling teeth."[28] The secretary demanded that the Air Force quickly field more ISR assets, including low-tech, expendable unmanned aerial vehicles (UAV) (later referred to as remotely piloted aircraft [RPA]). When the Air Force chief of staff and the secretary of the Air Force failed to conform to Gates's wishes, they were relieved of duty.[29]

. . . or Technological Skepticism

Secretary Gates recognized the Air Force's technological skepticism that overshadowed an otherwise blossoming UAV/RPA fleet. Several authors note the Air Force's legacy of shunning development and deployment of UAV/RPAs for a variety of reasons—some technical, but the majority organizational. For example, P. W. Singer cited one individual's assessment, "The Air Force was terrified of unmanned planes; . . . the whole silk scarf mentality."[30] Another former Defense Department analyst joked that "no fighter pilot is ever going to pick up a girl at a bar saying he flies a UAV. . . . Fighter pilots don't want to be replaced."[31] Summarizing these perspectives and characterizing the persistent nature of the Air Force's organizational culture, Singer noted that "being a fighter pilot is . . . in the Air Force leadership's organizational DNA. Given this, it is no surprise then that the Air Force long stymied the development and use of drones, letting DARPA [Defense Advanced Research Projects Agency] and the intelligence agencies take the lead instead."[32] Thomas Mahnken made a similar observation, noting that despite "considerable use" of UAVs such as the Teledyne Ryan BQM-34 Firebee during the Vietnam War, "they did not find a permanent home in the Air Force until

decades later. . . . Favored by neither the bomber nor the fighter communities, unmanned systems lacked an organizational home."[33]

It took the events of 9/11 and the developing counterinsurgency battles in Iraq and Afghanistan to overcome much of the bureaucratic resistance. Singer cited one defense contractor: "Prior to 9/11, the size of the unmanned vehicle market had been growing, but at an almost glacial pace. Thanks to battlefield successes, governments are [now] lavishing money on UAV programs as never before."[34]

The later decision to arm the UAVs also met with considerable skepticism. Mahnken noted that prior to "September 11, [2001], nobody wanted control of (and responsibility for) the armed Predator. . . . The notion of an unmanned vehicle controlled by an operator located hundreds or thousands of miles away delivering bombs in support of troops in close combat is something that would have previously been inconceivable" to both the Air Force and the Army.[35] Indeed, Singer noted that just prior to 9/11, a senior White House official was needed to resolve the disputes between the Central Intelligence Agency (CIA) and the Air Force over who would be responsible for controlling and, more importantly, funding the paltry $2 million cost of arming the Predator drones with Hellfire missiles.[36]

The story of F-22s and Predator UAV/RPAs is one recent illustration of the complex history of military technology. However, it is not unique. For all of the stories of technological exuberance, an equally rich history of technological skepticism, bolstered by organizational and bureaucratic resistance, also weaves itself through the fabric of US military history.

For example, military bureaucratic resistance stalled development of the Air Force's *raison d'être*—manned flight—for several years. In 1905, less than two years after their historic flight at Kitty Hawk, North Carolina, Wilbur and Orville Wright approached the US War Department seeking a contract to produce airplanes for the US military. Their inquiries merited no response.[37] The Wright brothers then turned to the British War Office at the suggestion of their adviser Octave Chanute, reasoning after the fact that their "invention will make more for peace in the hands of the British than in our own."[38] Those negotiations also languished. The Wright brothers, fearing piracy of their designs, returned to the United States and dismantled their aircraft; they would not fly again until May 1908.[39] In 1907, following renewed European interest in the Wright brothers' Flyer and prodding by Senator Henry Cabot Lodge, the War Department finally solicited bids for an airplane that matched the Wrights' specifications. The Wright brothers' first test flight at Fort Myer on 3 September 1908 easily surpassed the performance requirements, and the US military promptly drafted a contract.[40] It had been almost five years since the

first successful flight and three years since Orville and Wilbur first approached the US military.

Similarly, the intercontinental ballistic missile (ICBM) met with considerable skepticism within the Air Force, especially prior to the successful development of the solid-fuel Minuteman missile. Sheehan described how the Air Force ICBM emerged from the inventive imagination of Air Force colonel Bernard Schriever. At a March 1953 meeting of the Air Force Scientific Advisory Board—the latest incarnation of Arnold's earlier von Kármán–led Scientific Advisory Group—Schriever listened to nuclear weapons pioneers Edward Teller and John von Neumann explain how expected improvements in thermonuclear bomb design would, within 10 years, result in a high-yield, low-weight device. Based on the scientists' predictions, Schriever envisioned "the ultimate weapon—nuclear-armed ballistic missiles hurtling across continents at 16,000 miles per hour through the vastness of space."[41] Despite the strategic promise of the ICBM concept, the blue-sky bomber generals of the Air Staff, typified by Gen Curtis LeMay, stymied Air Force development of the missile. Sheehan attributed LeMay's "vociferous" opposition to his concern that ICBM development "would divert funds from aircraft production."[42] Characteristic of the skepticism directed toward ICBMs, LeMay once quipped, "These things will never be operational, so you can depend on them, in my lifetime."[43] By 1958 the promise of future ICBM development, embodied in the design of the Air Force's latest Minuteman missile, had surmounted General LeMay's skepticism.[44]

Technological skepticism is not limited to the future-minded, technologically dependent US Air Force. John Ellis described the almost-worldwide resistance to the machine gun that persisted for more than 30 years after its introduction in 1862. He noted that by 1892, "the machine gun [was] well-designed, relatively easy to mass produce and fairly reliable under battlefield conditions."[45] Still, most militaries passed on the technology. Attempting to explain their rationale, Ellis concluded that the majority of the officers in the world's armies were not in tune with the Industrial Revolution and, being groomed within "rigid hierarchical structures," were able to "minimize the impact of the faith in science and the machine."[46] Ellis continued, "When faced with the machine gun and the attendant necessity to rethink all the old orthodoxies about the primacy of the final infantry charge, such soldiers either did not understand the significance of the new weapon at all, or tried to ignore it, dimly aware that it spelled the end of their own conception of war. . . . For them, the machine gun was anathema, and even when their governments bought them out of curiosity, or because their enemies did, they almost totally ignored them."[47]

William McNeil located earlier evidence of technological skepticism in the development, or lack thereof, of English musketry. He noted that the "standard [English] infantry weapon," affectionately nicknamed the "Brown Bess," persisted from 1690 through 1840 "with only minor modifications."[48] McNeil attributed this technological stasis to the military's "choice between the advantages of uniformity and the cost of reequipping an entire army."[49] It chose uniformity over capability. McNeil also observed a similar conservative skepticism in an 1828 English Admiralty memorandum regarding a proposed shift from sail- to steam-powered warships; the Admirals warned, "Their Lordships feel it is their bounden duty to discourage to the utmost of their ability the employment of steam vessels, as they consider that the introduction of steam is calculated to strike a fatal blow at the naval supremacy of the Empire."[50]

As the preceding survey illustrates, instead of exhibiting a pattern of careful, rational decision making, the military's pursuit of technological innovation invites a diagnosis of organizational schizophrenia. Upon further inspection, however, a pattern emerges—revolutionary technological innovations that challenge preconceived notions of warfare such as the airplane, the ballistic missile, the machine gun, or the steamship are usually met with stubborn, bureaucratic paranoia and technological skepticism. If the resistance is overcome and the innovation is allowed to mature, the technology can be embraced by the organization and reinforced with subsequent evolutionary innovation, yielding an image of technological exuberance. This is the case with the evolutionary technologies represented by the B-36 aircraft of the 1950s, the cybernetic warfare systems developed in the 1970s, and the F-22 of the 2000s. However, technological exuberance is not strictly limited to just evolutionary technologies; it can also extend to revolutionary technologies such as the X-20 Dyna-Soar project or Reagan's SDI program.[51] This observed pattern of behavior forms a basis for Hughes's theory of technological momentum.

Technological Momentum

Hughes recognized the "complex and messy" nature of technology: "It is difficult to define and to understand. In its variety, it is full of contradictions, laden with human folly, saved by occasional benign deeds, and rich with unintended consequences. Yet today most people in the industrialized world reduce technology's complexity, ignore its contradictions, and see it as little more than gadgets and as a handmaiden of commercial capitalism and the military."[52] Confounding matters, even the term *technology* is often muddled by differing connotations. As Eisenhower noted in his 1961 farewell address,

the notion of technology was relatively new to the post–World War II world. Prior to that, what would be referred to as *technology* today might have been called "applied science," the "practical arts," or simply "engineering."[53] Hughes provided his own definition of technology—"craftsmen, mechanics, inventors, engineers, designers, and scientists using tools, machines, and knowledge to create and control a human-built world consisting of artifacts and systems."[54] There are advantages to Hughes's liberal definition of technology: it avoids the restrictive connotations of artifacts engineered solely for utility and instead recognizes processes as possible manifestations of technology.[55] Based on this understanding of technology and recognizing the historical patterns of technological evolution, Hughes purported that "massive [technological] systems . . . have a characteristic analogous to the inertia of motion in the physical world"—momentum.[56]

Hughes first coined the term "technological momentum" to describe the pattern of technological evolution that he observed in his study of the interwar German chemical industry and the exclusive contract for synthetic gasoline that materialized between the German chemical firm I. G. Farben and the nascent National Socialist regime.[57] For Hughes, the "dynamic force" of technological momentum provided an alternative to the popular "conspiracy thesis" presented at the Nuremberg trials where Farben scientists and engineers were accused of entering into a "conspiratorial alliance [with the Nazis] . . . to prepare [for] wars of aggression."[58] Hughes acknowledged that Farben's research into hydrogenation offered a means to convert Germany's vast deposits of brown coal into a more practical resource, gasoline. Hughes also acknowledged that access to indigenously produced gasoline renewed the "possibility of Germany regaining her economic and political position among the world powers." But he discounted the Nuremberg accusations that Farben directors engaged in Machiavellian-style behavior that sought to stoke a "future military market."[59] Rather, for Hughes, Farben's early commitments to developing the hydrogenation process contributed to a powerful and nearly autonomous "drive to produce and a drive to create."[60] Unfortunately for the engineers and managers at Farben, almost immediately after the investment of significant time and resources yielded a successful process, the Great Depression erased much of the world's demand for gasoline. Farben was left with "a vested interest in a white elephant."[61] Unwilling to cut their losses, the company officers sought industrial protection from Nazi officials. For Hughes, the "commitment of engineers, chemists, and managers experienced in the [hydrogenation] process, and of the corporation heavily invested in it, contributed to the momentum" that led to the arrangement.[62] In short, "the technology, having gathered great force, hung heavily upon the corporation that developed it and

thereby contributed to the fateful decision of the vulnerable corporation to cooperate with an extremist political party."[63]

Hughes refined his theory of technological momentum over the next 30 years, continuing to stress the role of technological maturation and organizational acceptance as important components of technological momentum. Describing the influence, Hughes noted, "People and investors in technological systems construct a bulwark of organizational structures, ideological commitments, and political power to protect themselves and the systems. Rarely do we encounter a nascent system, the brainchild of a radical inventor, so reinforced; but rarely do we find a mature system presided over by business corporations and governmental agencies without the reinforcement. This is a major reason that mature systems suffocate nascent ones."[64]

Hughes frequently cited examples of technological momentum within the military-industrial complex. For example, commenting on nuclear weapons, Hughes noted, "The inertia of the system producing explosives for nuclear weapons arises from the involvement of numerous military, industrial, university, and other organizations as well as from the commitment of thousands of persons whose skills and employment are dependent on the system. Furthermore, cold war values reinforce the momentum of the system."[65] According to Hughes, understanding these vested interests helps opposition to nuclear disarmament. "Disarmament offered such formidable obstacles not simply because of the existence of tens of thousands of nuclear weapons, but because of the conservative momentum of the military-industrial-university complex."[66]

Such organizational motivations are not new. An economist might characterize Hughes's technological momentum as simply a manifestation of the principle of sunk cost.[67] However, within the field of the history of technology, Hughes's theory of technological momentum provided a unique and important bridge between two opposing theories of technological change—technological determinism and social constructivism.

Technological Determinism

Henry David Thoreau poetically derided the rise of machines in everyday life: "But lo! men have become the tools of their tools."[68] Historian Lewis Mumford similarly lamented, "Instead of functioning actively as an autonomous personality, man will become a passive, purposeless, machine conditioned animal."[69] Indeed, acknowledging the increasing influence that technology exerts over humankind is, to a certain extent, dehumanizing. Nevertheless, significant historical trends have often been solely attributed to

technological development. For example, some blame Eli Whitney's cotton gin for the Civil War. They argue that Whitney's invention restored the profitability of the cotton market, thereby reinvigorating the American slavery system, which consequently caused the Civil War that resulted in the death of more than 620,000 soldiers.[70] Similarly, some suggest that the Protestant Reformation can be traced to Gutenberg's printing press and its capability to provide for the first time "direct, personal access to the word of God" to individuals outside the priesthood.[71] And Jared Diamond traced the demise of Native American cultures to animal domestication in Eurasia.[72]

Merritt Roe Smith and Leo Marx noted that "popular narratives" such as these frequently

> convey a vivid sense of the efficacy of technology as a driving force of history: a technical innovation suddenly appears and causes important things to happen. . . . The thingness or tangibility of mechanical devices—their accessibility via sense perception—helps to create a sense of causal efficacy made visible. Taken together, these before-and-after narratives give credence to the idea of "technology" as an independent entity, a virtually autonomous agent of change. . . . It is typified by sentences in which "technology," or a surrogate like "the machine," is made the subject of an active predicate: "The automobile created suburbia." "The atomic bomb divested Congress of its power to declare war." . . . "The Pill produced a sexual revolution." . . . These statements carry the further implication that the social consequences of our technical ingenuity are far-reaching, cumulative, mutually reinforcing, and irreversible.[73]

Critics of technological determinism claim that the perspective is too reductionist, marginalizing important societal and environmental influences that affect technological development. However, Nassim Nicholas Taleb suggested it is human nature to be reductionist, preferring "compact stories over raw truths."[74] According to Taleb, we suffer from the "narrative fallacy"—it is difficult for us "to look at sequences of facts without weaving an explanation into them, or, equivalently, forcing a logical link, an *arrow of relationship*, upon them."[75] Nevertheless, he noted that there is value in causal interpretation: "Explanations bind facts together. They make them all the more easily remembered; they help them *make more sense*."[76] Too often, though, the causal relationship is improperly or inadequately constructed. Understanding this human predisposition toward reductionism helps explain why the principles of technological determinism are so seductive.

Despite its reductionist nature, technological determinism appears to possess some historical veracity, as technology sometimes exerts a significant influence over society.[77] For example, it is difficult to discount the societal impact of the automobile, the computer connected to the Internet, or nuclear weapons and ICBMs. Certainly, it would be hard to pry these essential tech-

nological systems away from society or the military. In Hughes's parlance, these systems have developed substantial technological momentum. They support the technological determinists' contention that "the advance of technology leads to a situation of inescapable necessity. . . . Our technologies permit few alternatives to their inherent dictates."[78] Moore's Law, which describes the astonishing growth of the number of transistors on an integrated circuit, is a prime example of technology's "inherent dictates." Thus, according to the determinist perspective, integrated circuit technology adheres to Moore's Law, not because society demands it but because the technology naturally continues to advance at its own exponential pace.[79]

Reinforcing the technological determinist position that society does not significantly influence technological development, there is historical evidence of similar technologies emerging from disparate social environments. The development of ICBMs in both the United States and the Soviet Union is one example.[80] ICBMs emerged from both nations despite their vastly different cultural contexts—Schriever leading the US ICBM effort, and the Soviets benefiting from the technical prowess of their chief rocket scientist, Sergei Korolev.[81] Additionally, technological determinists point to Wernher von Braun's German V-2 ballistic missiles of World War II, suggesting that with the first successful V-2 missile launch, the development of future ICBMs in the United States and the Soviet Union became a foregone conclusion.[82] Accordingly, both nations stumbled into the ICBM race not based on calculated decisions but on the promise of technology. As one historian noted in decidedly deterministic language, "The United States built its missile arsenal without any agreed understanding—even within elite circles, much less among the general population—of why it was doing so."[83]

Giovanni Dosi's theory of a technological trajectory addresses the notion of technological progress's universality.[84] Despite borrowing heavily from Thomas Kuhn's social constructivist interpretation of scientific progress, Dosi's technological trajectory concept has a decidedly deterministic tone.[85] Dosi defined a *technological trajectory* as the "direction of advance within a technological paradigm."[86] He noted that these "technological paradigms have a powerful *exclusion effect*: the efforts and the technological imagination of engineers and of the organizations they are in are focused in rather precise directions while they are, so to speak, 'blind' with respect to other technological possibilities.[87] Donald MacKenzie described Dosi's technological trajectory as a "direction of technical development that is simply natural, not created by social interests but corresponding to the inherent possibilities of the technology."[88] There is also a connection between Dosi's theory of technological trajectories and Hughes's theory of technological momentum. Dosi asserted that

"once a path [of technological development] has been selected and established, it shows a *momentum* of its own, which contributes to define the directions toward which the 'problem solving activity' moves."[89]

The Social Construction of Technology

Social constructivists challenge the reductionism associated with the technological determinist interpretation of history. While MacKenzie acknowledged the deterministic connotations associated with Dosi's theory of technological trajectories, he challenged the interpretation, instead suggesting that the trajectory is propagated by social influences as a social "self-fulfilling prophecy"—"those lines of technical development that do not get pursued do not improve; those that get pursued often do."[90] Thus, for MacKenzie, socially constructed forces drive the technological trajectory, not the nature of the technology itself. Drawing on Hughes's discussion of technological momentum, MacKenzie similarly suggested that the trajectory results from people "invest[ing] money, careers, and credibility in being part of 'progress,' and in doing so help[ing] create progress of the predicted form."[91]

Hughes also acknowledged the role of societal influences in furthering a technological system, particularly when technical or organizational problems are encountered during technological development. Describing these obstacles as "reverse salients," Hughes noted, "As technological systems expand, reverse salients develop. Reverse salients are components in the system that have fallen behind or are out of phase with the others."[92] MacKenzie expanded upon Hughes's definition: "A reverse salient is something that holds up technical progress or the growth of a technological system."[93] Emphasizing the social influences implicit in reverse salients, MacKenzie noted, "System builders typically focus inventive effort, much like generals focus their forces, on the elimination of such reverse salients; they identify critical problems whose solution will eliminate them. . . . But it may not always be clear where progress is being held up, nor what should be done about it. Even with agreement on goals, . . . the nature of the obstacles to the achievement of these goals and the best means of removing them may be the subject of deep disagreement."[94]

Thus, according to the social constructivists, failure to acknowledge the "economic, political, organizational, cultural, and legal" contexts that surround technology results in an imperfect understanding of technological development.[95] "Technological development [is] a nondetermined, multidirectional flux that involves constant negotiation and renegotiation among and between groups shaping the technology."[96] Within this construct, John Law's "heterogeneous engineer" is an individual well suited to mediate between the

opposing social groups while simultaneously overcoming or circumventing technical impediments. Such individuals, Law argued, are singularly important in the development and propagation of technological systems.[97]

Just as there is evidence of technological determinism in military history, the pattern of social influences on technological development is also evident. When researching American technological innovation in the military following World War II, Thomas Mahnken concluded, "the [US military] services molded technology to suit their purposes more often than technology shaped them."[98] Similarly, the historian Williamson Murray emphasized the social influences on military technology, observing that it is the combination of "technology and potent management skills" that produces change.[99]

Sheehan's account of US ICBM development offers a prime example of a social constructivist account of military technological innovation. Within his narrative, Sheehan cast Schriever as a master strategist deftly outmaneuvering a manned bomber bureaucracy allied against him, while simultaneously surmounting an array of scientific and technological hurdles and operating within the constraints of a budget-conscious political administration wary of burdensome military expenditures.[100] Sheehan concluded that without Schriever's "intellectual bent and the foresight to see the implications for the future," the development of a US ballistic missile force would have failed.[101] Indeed, for Sheehan, the history of US ballistic missile development is a history of Schriever—a heterogeneous engineer triumphing over technical and social adversities.[102]

Like most "great man" narratives, the ICBM development story is both interesting and appealing, involving colorful individual personalities drawn together by unique and trying circumstances.[103] For example, Sheehan cited the importance of the appointment of the hard-drinking and paper-chewing Trevor Gardner as the special assistant to the secretary of the Air Force for research and development and his subsequent selection of Schriever to lead the Air Force's ICBM efforts.[104] He also cites the nontraditional yet successful efforts of the ICBM proponents to secure a National Security Council briefing in front of President Eisenhower,[105] the decision by an Air Force engineer to subvert a cruise missile program to support ballistic missile rocket engine development,[106] and even Schriever's prowess as a golfer as all being critical to the ICBM effort.[107]

According to Sheehan and the social constructivist argument, the fabric of history would have undoubtedly unfurled differently absent any one of these meetings, decisions, or personal attributes. However, the development of a Soviet ICBM force discounts Sheehan's position that without Schriever, the US Air Force's foray into ballistic missiles was destined to fail. While there is

no denying that Schriever's skills certainly influenced the quick realization of ICBM technology, it is possible that another individual could have taken up the torch, and technology would have continued marching along.

. . . And Hughes's Link between the Two

Therefore, history supports both the technological determinist and the social constructivist arguments. Hughes's theory of technological momentum steps between the two and offers an alternative to the Manichean perspectives that have unnecessarily polarized past historical analyses. For Hughes, "a technological system can be both a cause and an effect; it can shape or be shaped by society."[108] Thus, the theory of technological momentum "does not contradict the doctrine of social construction of technology, and it does not support the erroneous belief in technological determinism."[109] Hughes suggested that as technological systems acquire momentum by amassing "technical and organizational components," they exhibit a pattern of behavior that appears to be "autonomous," yielding an image of technological determinism.[110] This description, however, rests on a razor's edge. Despite Hughes's unwillingness to declare his acceptance of the tenets of technological determinism, his description of momentum still acknowledged the significant influence technology could exert on society.

Within his theory of technological momentum, Hughes credited an important role to time, suggesting that technology's influence on society, and its reciprocal, is "time dependent."[111] Granted, time itself is not sufficient for technologies to develop momentum, but it is necessary to allow technological systems to "grow larger and more complex" and to become "more shaping of society and less shaped by it."[112] Based on this observed relationship, Hughes claimed that "the social constructivists have a key to understanding the behavior of young systems; technical determinists come into their own with the mature ones."[113]

Applying Hughes's theory of technological momentum to the earlier description of the military's relationship with technological systems yields the model in figure 1. New, revolutionary technological systems like the Wright brothers' aircraft, the machine gun, and the ICBM are initially dominated by socially constructed influences and are typically frustrated by technological skepticism and bureaucratic resistance. If the skepticism is surmounted and the technological system allowed to mature over time, the technology acquires momentum and begins to exert an influence over the bureaucracy corresponding to the technological determinist position. Furthermore, mature technological systems are often reinforced by evolutionary innovation and

improvements, further adding to the momentum and the institutionalization of the technological system. While technological exuberance can exist at any stage of the development process, it typically dominates once the technology has acquired momentum.
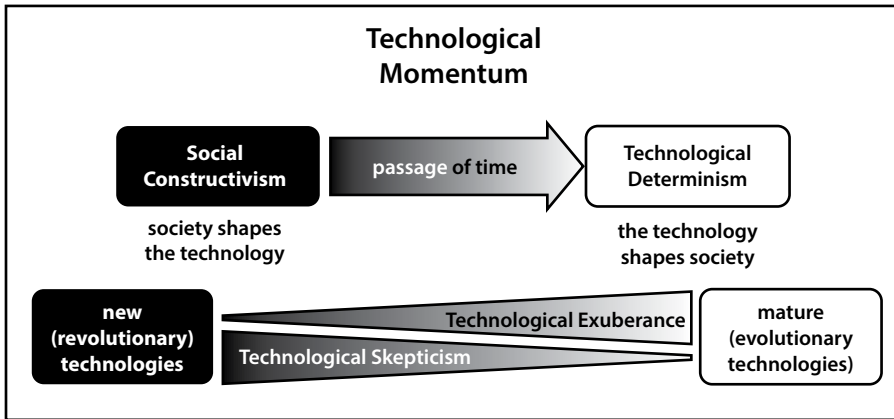
Figure 1. Technological momentum. (*Created by* the author)

While Hughes's theory of technological momentum offers hope for reconciling the discrepant deterministic and constructivist analyses of technological history, upon closer inspection it reveals itself to be also imperfect and too reductionist. Although Hughes acknowledged that the "phases in the history of a technological system are not simply sequential," his theory presumes that the transition from social constructivism to technological determinism is unidirectional.[114] His theory therefore tends to focus historical analysis on characterizing the transition from technological adolescence to maturity—from when society dominates the technology to when the technology begins to dominate society. The model of technological dislocations explored in the next chapter addresses the consequences of this limitation.

Notes

1. Quoted in Medhurst, *Dwight D. Eisenhower*, 191–92.
2. Ambrose, *Eisenhower*, 536.
3. McDougall, *Heavens and the Earth*, 230. McDougall cites Claud Witze's "How Outer Space Policy Evolved."
4. Ibid., 229.

5.   Ibid., 5, 436, and 443. McDougall defined *technocracy* as "the institutionalization of technological change for state purposes, that is, the state-funded and -managed R & D [research and development] explosion of our time." Further describing the US transition to a technocratic ideology, McDougall continued, "Technocratic *ideology* captured the country only after Sputnik, when a new willingness to view state management as a social good and not a necessary evil turned a quantitative change into a qualitative one. . . . 'Scientific' management only seduced its practitioners into thinking themselves objective" (emphasis in original).

6.   York, *The Advisors*, ix (emphasis added).

7.   Other scholars have noted the attempt to apply technological solutions to ill-defined strategic problems. Singer cited retired Marine officer T. X. Hammes: "We continue to focus on technological solutions at the tactical and operational levels without a serious discussion of the strategic imperatives or the nature of the war we are fighting. I strongly disagree with the idea that technology provides an inherent advantage to the United States." Singer deemed Hammes's comments noteworthy because of their uniqueness within the US military establishment. Singer, *Wired for War*, 213.

8.   Smith, "Introduction," 4.

9.   Singer, *Wired for War*, 238.

10.   Arnold's autobiography *Global Mission* is cited by Spires, *Beyond Horizons*, 8; and Sheehan, *A Fiery Peace*, xvi.

11.   Sheehan, *A Fiery Peace*, xvi.

12.   Ibid.

13.   Ibid., 121 (emphasis added).

14.   Barlow, *Revolt of the Admirals*, 46. Air Force general Tooey Spaatz announced in October 1945, "The aeronautical advance of the past few years has ushered in the 'Air Age.' Its primary force is Air Power. As sea-power was the dominant factor in the destiny of nations in the nineteenth century, so today the dictate is Air Power." Barlow summarized the mood of the nation's defense establishment: "air power had become the nation's dominant force" and "the first line of defense for the United States."

15.   Spires, *Beyond Horizons*, 79. According to Spires the Air Force desperately sought a manned space presence, especially after President Eisenhower's 1959 decision to transfer the manned space mission and the responsibility for developing "superbooster" rockets like the Saturn V to NASA.

16.   McDougall, *Heavens and the Earth*, 340.

17.   Ibid.

18.   Ibid., 341.

19.   Ibid.; and Spires, *Beyond Horizons*, 124–26.

20.   The principles of cybernetic warfare are discussed in Bousquet, *Scientific Way of Warfare*, 123 and 137. Bousquet characterized cybernetic warfare as "the shift from traditional notions of command to that of 'command and control,' the reduction of war to a set of mathematical functions and cost-benefit calculations susceptible to optimization through the techniques of operations research and systems analysis, and the increasing modeling and simulation of conflict." Reflective of Eisenhower's "scientific-technological elite," Bousquet noted that the cyberneticists sought to reduce "war to a complex equation to be resolved by a technoscientific priesthood." See also Lonsdale, *The Nature of War*.

21.   Quoted in Bousquet, *Scientific Way of Warfare*, 136. Bousquet also cited Paul Edwards's critique of Westmoreland's speech: it "epitomizes the 'vision of a closed world, a chaotic and dangerous space rendered orderly and controllable by the powers of rationality and technology.'"

22. Randolph, *Powerful and Brutal Weapons*, 47; and Bousquet, *Scientific Way of Warfare*, 156–57.

23. Randolph, *Powerful and Brutal Weapons*, 47; and Bousquet, *Scientific Way of Warfare*, 126. Bousquet noted that it is "not surprising that the military embraced computers as the panacea to the eternal problem of uncertainty and unpredictability on war."

24. Randolph, *Powerful and Brutal Weapons*, 47.

25. Ibid., 47–48; Bousquet, *Scientific Way of Warfare*, 157–58; and Lonsdale, *Nature of War*, 83. Critiquing the US efforts, Bousquet noted, "The North Vietnamese were being treated [by US officials] as a cybernetic system which could be steered toward the desired behavior by a selective input of information in the form of targeted aerial bombardment." By treating "the war as a purely technical problem to be solved through overwhelming application of materiel according to a scientific methodology, these [US] officials failed to grasp the sheer determination of their opponents and the extent of the success of their political strategy." Lonsdale cautioned that "unbridled confidence in the robustness of RMA [cybernetic] capabilities to countermeasures should not go unchallenged. . . . Every weapon system is countered eventually to some degree."

26. Quoted in Mahnken, *Technology and the American Way*, 150.

27. "I [Gates] have noticed too much of a tendency toward what might be called next-war-itis—the propensity of much of the defense establishment to be in favor of what might be needed in a future conflict." Shanker, "Gates Says New Arms Must Play," A18; and Walker, "Air Force Firings," 61.

28. Holmes, "Why USAF's Top Two Were Forced Out," 8.

29. Dreazen, "Gates Ousts Top Leaders," A1. Citing "a pattern of poor performance," Gates ousted the Air Force's secretary, Michael Wynne, and its chief of staff, Gen Michael Moseley, on 5 June 2008. Although the "immediate trigger for the resignations" was the accidental shipment of ballistic missile fuses to Taiwan, several Washington pundits believed the firings to be "the culmination of a broader dispute between Mr. Gates and the Air Force's leadership over the service's strategic direction. The biggest source of tension has been the Air Force's insistence on buying hundreds of expensive, state-of-the-art F-22 fighter jets . . . despite opposition from Mr. Gates who has argued that the planes aren't needed for prosecuting America's current wars."

30. Singer, *Wired for War*, 54. Robert Finkelstein's firm developed software for an unmanned F-4 Phantom target drone. Describing the evolution of the technology and the oppressive bureaucratic skepticism, Finkelstein commented, "The new software began to beat pilots consistently, and the idea grew to use it as an advanced teaching tool for fighter pilots. But it never came to be. The program was too much, too soon, and most important too good for its own sake."

31. Ibid., 252. Singer cited Andrew Krepinevich, "a former Defense Department analyst who is now executive director of the Center for Strategic and Budgetary Assessments."

32. Ibid., 253.

33. Mahnken, *Technology and the American Way*, 114; and Randolph, *Powerful and Brutal Weapons*, 194–95. Randolph described the drones' success: "During 1972 the drones flew a total of 498 missions, losing 52 aircraft. The missions targeted a total of 6,335 high-priority points for photos, succeeding with 2,543 of these."

34. Singer, *Wired for War*, 61.

35. Mahnken, *Technology and the American Way*, 202.

36. Singer, *Wired for War*, 35.

37. Morrow, *Great War*, 5. Morrow noted that the 1903 "abject failure" of Samuel Langley's $50,000 airplane project sponsored by the War Department's Board of Ordnance and Fortification "made the War Department wary of future winged projects."

38. Hughes, *American Genesis*, 101.

39. Morrow, *Great War*, 6.

40. Hughes, *American Genesis*, 100–104.

41. Von Neumann and Teller "predicted that by 1960 the United States would be able to build a hydrogen bomb that would weigh less than a ton but would explode with the force of a megaton, i.e., eighty times the power of the simple atomic or fission bomb that had blown away Hiroshima." Sheehan noted that "these two attributes were the *sine qua non* for the building of a practical intercontinental ballistic missile." Sheehan, *Fiery Peace*, 178.

42. Ibid., 223. LeMay also "predicted that the Atlas [ICBM] would turn out to be an extravagant boondoggle. It would never perform as anticipated."

43. Ibid., 412–13.

44. Ibid., 415. In 1955 LeMay stated that he would "consider the ICBM 'the ultimate weapon' worthy of inclusion in SAC's [Strategic Air Command's] inventory when one could be created with a capability of instantaneous launch and with acceptable reliability, accuracy, and yield." Three years later, after receiving the briefing on the Minuteman missile, LeMay "swung around to the three-star deputy chiefs of staff sitting in the rows behind him and asked: 'Do you agree it's a go?'"

45. Ellis, *Social History of the Machine Gun*, 16. In 1862 Richard Jordan Gatling produced a crank-operated gun that fired an impressive steady stream of 200 rounds per minute. Twenty-two years later, Hiram Maxim developed an automatic firing mechanism. By 1892 William Browning had produced a gun that used its own muzzle gasses to operate an automatic firing mechanism.

46. Ibid.

47. Ibid., 17; and Hughes, *American Genesis*, 105. Hughes noted that one irrational argument for denigrating the machine gun was that it "could not be supplied rapidly enough with ammunition in the field."

48. McNeil, *Pursuit of Power*, 142.

49. Ibid.

50. Ibid., 226.

51. Despite the revolutionary technologies associated with manned spaceflight, the X-20 Dyna-Soar could be considered an evolutionary technology, as it was envisioned as an extension of the Air Force's vision of manned aircraft delivering atomic weapons as part of a strategic bombing campaign. This contrasts with the revolutionary ICBM technological system, which dramatically changed the concept of warfare. Similarly, it is difficult to suggest that Reagan's SDI program followed an evolutionary trend—it was also revolutionary. The difference between evolutionary versus revolutionary technologies has been treated extensively in the literature: see Hughes, "Evolution of Large Technological Systems," 57 and 59; Dosi, "Technological Paradigms and Technological Trajectories," 158; Constant, *Origins of the Turbojet Revolution*, 4; and Luttwak, *Strategy*, 234–36. Hughes offered his interpretation: "Inventions can be conservative or radical. Those occurring during the invention phase are radical because they inaugurate a new system; conservative inventions predominate during the phase of competition and systems growth, for they improve or expand existing systems." Describing the rationale for technological skepticism toward revolutionary technologies, Hughes continued: "Large organizations vested in existing technology rarely nurtured inventions that by their nature contrib-

uted nothing to the momentum of the organization and even challenged the status quo in the technological world of which the organization was a leading member. Radical inventions often deskill workers, engineers, and managers, wipe out financial investments, and generally stimulate anxiety in large organizations." Dosi described the difference between " 'incremental' innovation versus 'radical' innovation" in his article. Similarly, Constant noted the importance of identifying the nature of the technological change—"the relative importance of incremental versus discontinuous or revolutionary changes"—when assessing society's reaction to the new technology. Luttwak discussed the "bureaucratic aversion to new [military] equipment that does not fit the established order of things."

52. Hughes, *Human-Built World*, 1.

53. Ibid., 2; and Smith, "Technological Determinism," 7. Smith noted that "the belief that in some fundamental sense technological developments determine the course of human events had become dogma by the end of the [nineteenth] century." However, as evident in James P. Boyd's 1899 *Triumphs and Wonders of the 19th Century* (cited by Smith), *progress* was a diffuse entity and not specifically linked to the term *technology*. "It may be said that along many of the lines of invention and progress which have most intimately affected the life and civilization of the world, the nineteenth century has achieved triumphs and accomplished wonders equal, if not superior, to all other centuries combined."

54. Hughes, *Human-Built World*, 4.

55. Examples of processes representative of technological innovation include Henry Ford's assembly line and Frederick Taylor's principle of scientific management. Similarly, the US interstate freeway system could be considered a technological innovation, despite its lack of any high-tech gadgetry.

56. Hughes, *American Genesis*, 460.

57. Hughes, "Hydrogenation," 106–32.

58. Ibid., 106. The Nuremberg charges were later dismissed.

59. Ibid., 116–17.

60. Ibid., 112.

61. Ibid., 122.

62. Ibid., 131.

63. Ibid., 131–32.

64. Hughes, *American Genesis*, 460.

65. Ibid.

66. Ibid.

67. "Sunk cost—in accounting, a cost that grows out of a past, irrevocable decision. A typical example is a fixed asset, such as a machine, that has become obsolete and whose book value therefore cannot be recovered." Ammer and Ammer, *Dictionary of Business and Economics*, 449; and Brauer and Tuyll, *Castles, Battles, and Bombs*, 78.

68. Thoreau, *Walden*, 29.

69. Quoted in Smith, "Technological Determinism," 29.

70. Smith and Marx, "Introduction," x. The Civil War death total is from McPherson: "More than 620,000 soldiers lost their lives in four years of conflict—360,000 Yankees and at least 260,000 rebels. The number of southern civilians who died as a direct or indirect result of the war cannot be known; what *can* be said is that the Civil War's cost in American lives was as great as in all of the nation's other wars combined through Vietnam." McPherson, *Battle Cry of Freedom*, 854 (emphasis in original).

71. Smith and Marx, "Introduction," x.

72. "Eurasian crowd diseases evolved out of diseases of Eurasian herd animals that had become domesticated . . . [and] played a key role in decimating native peoples." Diamond, *Guns, Germs, and Steel*, 212–13.

73. Smith and Marx, "Introduction," x.

74. Taleb, *Black Swan*, 63.

75. Ibid. (emphasis in original).

76. Ibid., 64 (emphasis in original).

77. Hughes, "Technological Momentum," 102. Hughes defined *technological determinism* as "the belief that technical forces determine social and cultural changes" and social constructivism as "presum[ing] that social and cultural forces determine technical change."

78. Smith and Marx, "Introduction," xii. Edgerton directly challenged the deterministic assertion by offering a "use-based" theory of technological development: "A central feature of use-based history, and a new history of invention, is that alternatives exist for nearly all technologies: there are multiple military technologies, means of generating electricity, powering a motor car, storing and manipulating information, cutting metal or roofing a building. Too often histories are written as if no alternative could or did exist." Edgerton, *Shock of the Old*, 7.

79. Kurzweil described the effects of Moore's Law: "The result is that every two years, you can pack twice as many transistors on an integrated circuit. This doubles both the number of components on a chip as well as its speed. Since the cost of an integrated circuit is fairly constant, the implication is that every two years you can get twice as much circuitry running at twice the speed for the same price. For many applications, that's an effective quadrupling of the value. The observation holds true for every type of circuit, from memory chips to computer processors." In a nod to the determinist camp, Kurzweil noted that this "remarkable phenomenon has been driving the acceleration of computing for the past forty years." Kurzweil, *Age of Spiritual Machines*, 21.

80. For a description of the US/USSR H-bomb competition, see Rhodes, *Dark Sun*, and Rhodes, *Arsenals of Folly*.

81. Sheehan, *Fiery Peace*, 405.

82. On von Braun and German V-2 rockets, see Neufeld, *von Braun*.

83. MacKenzie, *Inventing Accuracy*, 162. The remark is ironic because MacKenzie declared early in his book that he is a social constructivist. Indeed, he purports that his book is a counter to the assumption that technological determinism drove ICBM guidance system development.

84. Dosi, "Technological Paradigms," 148.

85. Kuhn challenged the notion that "scientific development" is "the piecemeal process" by which a "constellation of facts, theories, and methods" are "added, singly and in combination, to the ever growing stockpile that constitutes scientific technique and knowledge"—the interpretation that science is a naturally evolving process. In its place, Kuhn postulated that science can be divided into two phases: "normal science" operating within an established "scientific paradigm," and "revolutionary science" that evolves from investigating anomalies during "normal" scientific experiments and which yields new scientific paradigms. By addressing the social components of paradigm development and acceptance within the scientific community, Kuhn established the foundation for a socially based analysis of scientific history. Kuhn, *Structure of Scientific Revolutions*, 1–2, 10, and 84.

86. Dosi, "Technological Paradigms," 152. Besides drawing on Kuhn's notion of "paradigms," Dosi also drew a corollary to Kuhnian "normal science" by describing a "technological trajectory as the pattern of 'normal' problem solving activity (i.e., of 'progress') on the grounds

of a technological paradigm." On "normal science," see Kuhn, *Structure of Scientific Revolutions*, 24–34.

87. Dosi, "Technological Paradigms," 153 (emphasis in original).

88. MacKenzie, *Inventing Accuracy*, 167.

89. Dosi, "Technological Paradigms," 153 (emphasis added).

90. MacKenzie, *Inventing Accuracy*, 168. MacKenzie noted that economist Brian Arthur found a similar pattern of increasing returns; Arthur's discovery is explained within the context of complexity science in Waldrop, *Complexity*.

91. MacKenzie, *Inventing Accuracy*, 168. However, MacKenzie's argument does not address the possibility that people's increased investment in a particular technology is a manifestation of a particular technology exerting influence over society through technological determinism.

92. Hughes, "Evolution," 73.

93. MacKenzie, *Inventing Accuracy*, 79–80.

94. Ibid.

95. Ibid., 9.

96. Bijker, Hughes, and Pinch, "Common Themes," 13.

97. Law defined *heterogeneous engineering* as "the association of unhelpful elements into self-sustaining networks that are, accordingly, able to resist dissociation. . . . 'Heterogeneous engineers' seek to associate entities that range from people, through skills, to artifacts and natural phenomena." Law, "Technology and Heterogeneous Engineering," 114 and 129.

98. Mahnken, *Technology and the American Way*, 219.

99. Murray and Millet, *Military Innovation*, 1.

100. Sheehan, *Fiery Peace*, 139–40, 223, and 412. Gen Curtis LeMay typified the Air Force's manned bomber bureaucracy opposed to the ballistic missile. Sheehan quoted LeMay, "These things [ICBMs] will never be operational, so you can depend on them, in my lifetime." Sheehan also described LeMay as being "vociferously opposed" to the ICBM because it "would divert funds from aircraft production." While parrying LeMay's attacks, Schriever had to develop strategies to overcome problems with rocket propulsion, guidance, and delivery vehicles and operate under a tightening military budget as part of Eisenhower's "new look" strategy. Although the new look strategy's emphasis on "security with solvency" favored the purported cost benefits associated with nuclear weapons and the "intercontinental reach of LeMay's nuclear bombers" over the expense of conventional military forces, Schriever's nuclear missile capabilities were viewed as an unknown quantity and therefore a risky venture.

101. Sheehan, *Fiery Peace*, xviii. Sheehan suggested that Schriever was also bolstered by a prodigious personal charge delivered by Gen Hap Arnold to facilitate the mobilization of "science and technology into air power's service." Sheehan continued, "Whatever his reasons, [General] Arnold had summoned the right man."

102. See note 97 for a discussion of John Law's heterogeneous engineer.

103. For another example of a "great man" historical narrative, see Cherny, *Candy Bombers*, 404. Describing the individual actions of Pres. Harry Truman and Gen Lucius Clay during the Berlin Airlift, Cherny wrote: "There was never a clearer refutation of the canard that it is simply the current and not the captain that guides humanity past the shoals."

104. Sheehan noted, "Gardner had a serious drinking problem. He kept it under control during the day, although a couple of double-shot Old Forester bourbons with ginger ale, his standard portion at lunch, made him more aggressive back at the office in the afternoon." Gardner also had a penchant to tear off a corner of yellow legal pad paper, "roll it into a wad with his thumb and forefinger . . . toss it into his mouth," and "begin chewing it, all the while continuing

to listen" to the topic of discussion. Describing Schriever's selection for the job, Sheehan recounted Schriever's tentative acceptance: "I'll [Schriever speaking] take the job . . . provided I can run it—completely run it—without any interference from those nitpicking sons of bitches in the Pentagon." Sheehan, *Fiery Peace*, 197–98 and 228.

105. Ibid., 268–78, and 299. Schriever had to lobby aggressively to secure a National Security Council briefing in front of the president. Less than two months after the briefing, President Eisenhower signed NSC Action no. 1433, designating the ballistic missile "a research and development program of the highest priority above all others" to be built with "maximum urgency."

106. Ibid., 246–47. Sheehan described how Air Force lieutenant colonel Ed Hall, working at the Air Development Center, devised a strategy to "use the requirements for adequate engines for the Navaho booster [an intercontinental cruise missile then in development but destined to be cancelled] as a cover to acquire a rocket engine for an intercontinental ballistic missile." Coincidentally, Sheehan noted that this was not Hall's first time skirting Air Force regulations—Hall and a friend previously planted a fraudulent intelligence report of a massive Russian rocket engine to help ensure sufficient funding for Hall's rocket engine development office.

107. Ibid., 253 and 260. Sheehan described how part of Schriever's campaign to win over a dissatisfied superior, the "win over Tommy Power" campaign, included "arranging the schedule so that their get-togethers were also an opportunity for the general to play [golf] with a partner in top form." The campaign and the golf worked; Sheehan noted that Schriever's first fitness report signed by General Power characterized Schriever as possessing "excellent staying qualities when the going gets rough."

108. Hughes, "Technological Momentum," 112.

109. Hughes, "Evolution," 80.

110. Ibid., 76.

111. Hughes, "Technological Momentum," 102.

112. Ibid., 112.

113. Ibid.

114. Hughes identified the phases of technological system evolution as "invention, development, innovation, transfer, and growth, competition, and consolidation." Indicative of the sequential process, Hughes described "mature systems" as acquiring a "high level of momentum" that "often causes observers to assume that a technological system has become autonomous." Hughes, "Evolution," 56 and 76.

Chapter 3

Technological Dislocations

If technological determinism implies that "technical forces determine social and cultural changes" and social constructivism suggests that "social and cultural forces determine technical change," then Hughes's theory of technological momentum provides a conceptual bridge between the two opposing perspectives.[1] It also helps explain how a technology can go from being shunned to being exuberantly embraced by a bureaucratic institution. Yet, Hughes's theory requires further refinement. The alternate theory of technological dislocations addresses the limitations of Hughes's theory and provides a more useful lens with which to study the role and process of innovation within the Air Force and the military in general.

A Technological Tipping Point?

While not specifically subscribing to the technological determinist position, Hughes conceded that mature systems possessing technological momentum invite perceptions of determinism.[2] The more momentum a technological system acquires, the more it can influence society in a deterministic fashion.[3] While acknowledging "that technological momentum, like physical momentum, is not irresistible," Hughes noted that effecting change in a technological system that possessed significant momentum would require a Herculean effort directed across a "variety of its components."[4] In short, "shaping is easiest before the [technological] system has acquired political, economic, and value components."[5] According to Hughes, these "value components" tighten a technology's grip on its surrounding environment. As bureaucratic institutions devoted to the technology begin to flourish, they provide the necessary funding and procedural regimens that reinforce the technology's growing influence on society. After sufficient time, the technological system may cement itself within the society's collective psyche. One popular example of this phenomenon is the story of the gasoline-powered automobile, which, after an initially cool reception, now exerts a dominant influence on American society. Thus, within Hughes's construct, time plays a significant role in technological development. Although rarely sufficient, time is necessary for momentum to build and for technology to evolve from society-shaped to society-shaping—from social constructivism to technological determinism.[6]

Hughes's theory is conceptually convenient. However, the unidirectional evolutionary process suggested by his theory is not without complications. Specifically, if a successful technology transforms from being socially constructed to being deterministic, then that transformation should be marked by a transition point—a tipping point—that divides the two influences (fig. 2). While Hughes did not explicitly treat the notion of a discrete technological tipping point in his writings, other scholars have investigated the phenomenon.
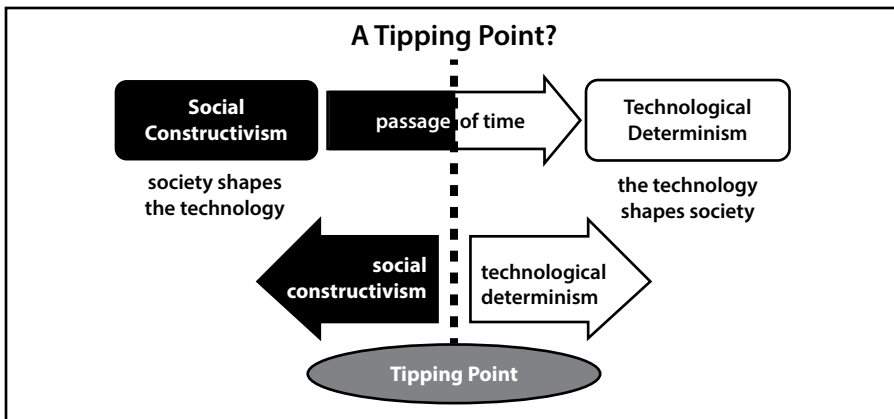
Figure 2. The putative tipping point between social constructivism and technological determinism. (*Created by* the author)

One such author, Malcolm Gladwell, used the notion of "tipping points" to describe how products and ideas spread through society. Defining a tipping point as the "dramatic moment in an epidemic when everything can change all at once," Gladwell examined, among others, the 1995 popular resurgence of Hush Puppies shoes, the almost overnight decline in New York City's crime rate in 1992, and the 1987 proliferation of low-priced fax machines.[7] Regarding the fax machine, Gladwell reported that after Sharp introduced the first low-priced fax machine in 1984, sales remained relatively flat and unimpressive for the next three years. In 1987, however, business suddenly and unexpectedly boomed. At that point, "enough people had faxes that it made sense for everyone to get a fax"; the low-priced fax machine crossed a tipping point.[8] There is a link between Gladwell's tipping point and Hughes's technological momentum. Using Hughes's parlance, in 1987 fax machines assumed sufficient technological momentum to influence a substantial segment of society

to forgo any lingering skepticism and purchase the machines; the technology began to shape society in a deterministic fashion.

Identifying when the tipping point for low-priced fax machines was crossed is relatively easy—1987. Describing the causal factors that led to the tipping point is more difficult. In fact, Gladwell provided none, other than the raw sales numbers.[9] While a more practical fax machine model, a lower unit cost, or a favorable review in a business journal may have contributed to the sudden explosion in the fax's popularity, according to Gladwell's theory of tipping points, it was not necessarily a combination of these factors, nor should it simply be attributed to a steadily growing level of acceptance. All of a sudden, something relatively minor happened, and society was profoundly affected.

The transition from society-shaped to society-shaping is rarely as black and white as Gladwell asserts. For example, during the development of the ICBM, President Eisenhower's 1955 decision to declare the ballistic missile "a research and development program of the highest priority" could be regarded as the tipping point that catalyzed future US reliance on ICBMs.[10] Similarly, LeMay's 1958 acceptance of the Minuteman ICBM and the implicit organizational legitimacy that it granted may be regarded as a more appropriate tipping point.[11] However, one could also argue that the development of US ICBMs and their consequent role in national defense strategy was assured when Schriever was selected to head Air Force ICBM development in 1954, or when Pres. Harry Truman decided in 1950 to pursue the H-bomb, or when von Braun launched his first successful V-2 rocket from Peennemünde in October 1942.[12] These examples illustrate the difficulty with trying to identify an individual technological tipping point, even retrospectively.

Thus, while Hughes's theory of technological momentum and Gladwell's theory of tipping points are plausible at a macro level, when finely applied to a specific, complex technological system like the ICBM, they quickly lose their appeal. Neither author provides adequately descriptive terminology—Hughes for the transition between social constructivism and technological determinism, Gladwell for the causal factor that manifests as the technological tipping point. Both theories are too reductionist and fail to adequately address the complex nature of technological development.

Unlike the idealized model (fig. 2), there is often no clear, time-dependent technological metamorphosis that separates a society-shaped technology from a society-shaping technology; the two forms coexist throughout the technology's lifetime.[13] This observation marks a distinct departure from Hughes's theory. Hughes stated that "a technological system can be both a cause and an effect; it can shape or be shaped by society." His interpretation was based largely on the unidirectional transition from one form to another.[14]

While Hughes acknowledged that changes can still be made even after the technology had acquired momentum, his theory fails to provide a descriptive mechanism to address those later-in-technological-life changes. Similarly, the theory of technological momentum fails to address the society-shaping influences that even a nascent technology may exert.

A more holistic appraisal of the nature of technological change suggests that technologies often begin to exert deterministic tendencies early in their development process. It also suggests that social pressures can influence technological development even after a deterministic trajectory has been realized. MacKenzie, recognizing that Hughes's artificial restriction of society's impact on mature technologies discounted the later influence of individual events and the power of historical contingency or chance, championed the latter point.[15] MacKenzie argued that it is a fallacy to suggest that a technological system is only "social up to the point of invention and self-sustaining thereafter. Its conditions of possibility are always social."[16] For example, the Cuban missile crisis reflected a social influence that reinforced the need to develop a sufficient strategic deterrent force, consequently accelerating the missile race and profoundly influencing future strategies of international brinksmanship. However, many would agree that ICBM technology had already begun to shape strategic policy in a deterministic fashion prior to October 1962.

In his zeal to emphasize the social element of technological development, MacKenzie's constructivism-based critique goes to the opposite extreme and fails to recognize the sometimes-deterministic influences of technology. As cited previously, even MacKenzie had to acknowledge that "the United States built its missile arsenal without any agreed understanding—even within elite circles, much less among the general population—of why it was doing so."[17] Collectively, these inconsistencies suggest that Hughes's theory of technological momentum—with its reliance on a seemingly discrete transition from technological adolescence and social constructivism to system maturity and technological determinism—requires refinement.

Theory of Technological Dislocations

The alternative conceptual perspective provided by the theory of technological dislocations facilitates a better understanding of the mechanisms that contribute to technological development and military innovation.[18] Rather than trying to identify and characterize a technology's transition from socially constructed to technologically deterministic, it is more useful to recognize that the two characterizations may be inextricably intertwined within a

technological system. Unlike social constructivism, the theory of technological dislocations acknowledges the potential existence of an orderly, technologically deterministic framework operating beneath the surface of popular history. And, unlike technological determinism, the theory of technological dislocations provides for the introduction of perturbations caused by changing social contexts that alter both nascent and mature technologies' otherwise logical evolutionary patterns.

The theory of technological dislocations builds upon the above discussion of Hughes's theory of technological momentum and a metaphor drawn from solid-state physics. Invoking the scientific metaphor, at the atomic level solid materials are made up of an ordered array of interlocking atoms. Frequently, though, that order is interrupted: an atom may go missing; the wrong type of atom may be inserted in the wrong place; or in some instances, a whole sheet of atoms may interpose and alter the structure (fig. 3). When the last occurs, it is referred to as a dislocation. Dislocations form whenever the developing crystalline structure is subjected to some form of stress, either nonmechanical stress caused by nonuniform heating or the presence of chemical impurities, or mechanical stress caused by physical damage.[19] Despite the disruption to the atoms immediately surrounding the dislocation, the lattice structure usually does not collapse in disarray. Rather, the structure quickly adapts and reassumes an ordered pattern, although the new structure differs slightly from the crystalline structure that existed before. This scientific metaphor helps one to better visualize the process of technological innovation and development.
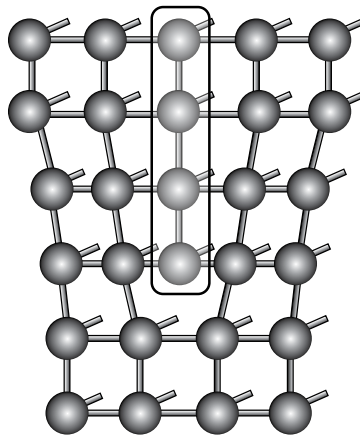

Figure 3. Edge dislocation. (*Adapted from* J. S. Blakemore, *Solid State Physics*, 2nd ed. [Cambridge: Press Syndicate of the University of Cambridge, 1960], 78.)

All but the most stringent technological determinists acknowledge the significant role socially constructed influences play in the birth of a technological system. As Hughes pointed out, fruitful technologies are rarely the product of a single "Eureka!" moment but more often result from the determined labors of a small cadre of inventors, financiers, and marketers.[20] Law similarly emphasized the distinctly social nature of an emerging technology with his concept of heterogeneous engineers and their knack for associating disparate entities to spur technological progress.[21] These collective social influences can either nurture or stymie the embryonic technology. If the social influences suppress the technology through skepticism or bureaucratic resistance, further development halts, and the technology typically withers away. But if cultivated by its surrounding social context, the budding technology may blossom.

Almost immediately, a technological trajectory develops within the emerging technological paradigm. According to Dosi, this "technological paradigm" channels the efforts of the organization in a precise direction to propagate a "technological trajectory," often to the exclusion of possible alternatives.[22] Thus, the technology quickly begins to exert a shaping influence on society. Invoking the solid-state physics metaphor, the crystalline solid begins to take shape, and additional growth aligns itself to the underlying pattern. In the military realm, the new technology begins to shape the bureaucratic institutions, either through the addition of a new directorate tasked with monitoring or promoting the new technology or the assignment of responsibility for the new technology to an existing directorate. Referencing Hughes, the technological system begins to gain momentum. However, this early trajectory and its metaphorical structural influence on society do not imply that the technology cannot thereafter succumb to bureaucratic neglect or mounting skepticism. Rather, it illustrates that nearly from its inception a technology begins to shape its surroundings in a somewhat deterministic fashion according to a logical technological trajectory.

As the technology continues to mature—as the solid crystal grows—socially induced stressors may interpose and introduce a technological dislocation, disrupting the logical technological trajectory. The dislocation jars the bureaucracy from the technological rut that previously constrained revolutionary innovation. Such stressors might include a competing alternative technology, a changed political agenda or economic environment, or a looming scientific stumbling block.[23] The magnitude of these stressors may vary. Consequently, the disruptiveness of the dislocation and the significance of the departure from the previous technological trajectory may also vary. For example, McNamara's decision to cancel the Air Force's Dyna-Soar program in 1964 effectively crushed the technological trajectory that was leading toward

an independent military-manned presence in space. Other dislocations need not be so calamitous.

Consider the effect of Sputnik on the Soviet and American space programs. Prior to the 4 October 1957 launch, both countries' space and missile programs endeavored toward a common vision made apparent by von Braun. However, immediately following Sputnik, increased political pressures in the Soviet Union and the United States resulted in an altered trajectory for both nations. In the Soviet Union, Nikita Khrushchev's insatiable demand for propaganda victories led to highly publicized launches of dubious scientific value; in the United States, public outcry invigorated American space efforts and placed a high priority on manned missions.[24] Sputnik therefore represents a technological dislocation that disrupted the US and USSR space and missile technological trajectories; it forced both nations to reconsider their preconceived notions of space-related progress and reorient their efforts.

Another advantage of the theory of technological dislocations is that it provides a conceptual basis for understanding how different technological systems can develop interdependently. Much like the three-dimensional crystalline lattice structure in the physical realm, technologies can become linked to one another in the social realm. For example, if the American and Soviet space and missile technologies are recognized to be competitive and therefore mutually reinforcing, then they can be aggregated into a broader space and missile technological system. The model of technological dislocations allows for a single dislocation like Sputnik to influence the linked technologies (fig. 4). Similarly, as the following case study will demonstrate, the Air Force's guided air-to-air missile technology can be aggregated into a broader air-to-air armament technological system comprised of the missiles and the aircraft built to carry them, and stressors associated with the American air combat experience during Vietnam can be interpreted as introducing a technological dislocation into the system.

Most significantly, the theory of technological dislocations provides a conceptual model and a practical, descriptive vocabulary that aids analysis by describing how societal influences can affect a technological system at any time during its life. There is no putative, binary tipping point that illogically separates social constructivism from technological determinism. Immature technologies may be greeted with skepticism; their supporting bureaucratic institutions may exuberantly embrace mature technologies. Throughout, socially constructed contexts, or even historical contingencies, always threaten to perturb the otherwise established technological trajectories that guide technological development.
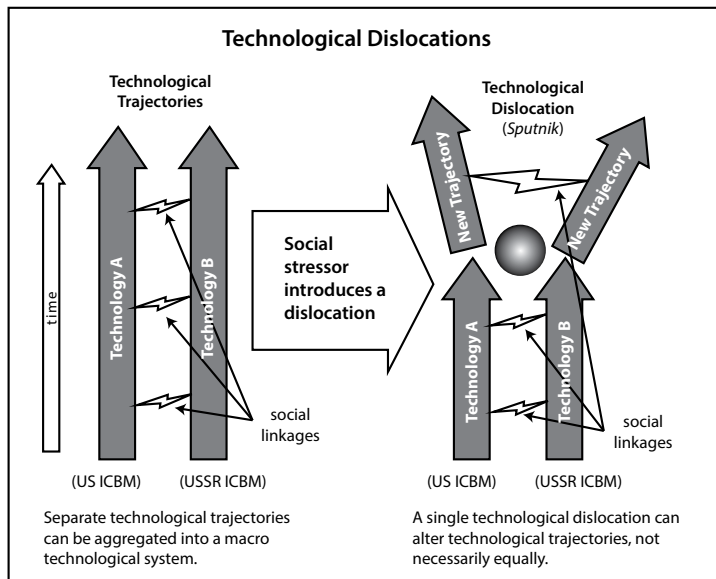
Figure 4. Technological dislocations. (*Created by* the author)

Furthermore, there can be numerous dislocations during the life of a technological system. In the ICBM example, Schriever's efforts helped garner technical and organizational legitimacy for the new technology, thereby dislocating the dominant technological trajectory that had earlier denigrated ICBMs in favor of massive fleets of manned nuclear bombers. Later, the trajectory toward more lethal ICBM targeting that spurred the development of the multiple independently targetable reentry vehicles (MIRV) encountered a dislocation in 1993 when the United States agreed to dismantle its MIRV warheads as part of the Strategic Arms Reduction Treaty II.[25] Attempting to discern the frequency and character of the numerous dislocations in the life of a technological system becomes a philosophical question of agency.

A Question of Agency

How much influence does any one individual and his or her actions have on society? Does it matter if one individual decides to ride a bike to work instead of driving a car? Can a single e-mail sent from one individual to another have important societal ramifications? Do the identities of the individuals in question matter? Certainly, one individual electing to ride a bike to work will

not cut down on pollution, but a thousand individuals making independent decisions to ride their bikes to work may. Similarly, if the US president sent the e-mail to the prime minister of Great Britain, then the e-mail would likely be considered important.

It is difficult to determine agency in real time and absent context. What is expected to have significance often does not, and what is occasionally seen as innocuous can quickly become momentous. For example, within the realm of technology, nuclear power was initially seen as a potential solution to the world's burgeoning energy demands. General Electric (GE), Westinghouse, Babcock and Wilcox, and Combustion Engineering all established nuclear reactor development facilities in the 1950s, supported and subsidized by the federal government. Reflective of the national enthusiasm, Hughes reported that "a GE executive promised a young man entering the company that within ten or twenty years the company's nuclear-power business would be larger than the entire company in the 1950s."[26] Thomas E. Murray, atomic energy commissioner in 1953, proclaimed, "The splitting atom . . . is to become a God-given instrument to do the constructive work of mankind."[27] Despite this fanfare, nuclear energy fizzled.

Conversely, when Henry Ford introduced his Model T automobile on 1 October 1908, a virulent "anti-auto mood" already pervaded the nation.[28] One author noted that "the horseless carriage's arrival [nearly a decade earlier] had left more people behind than it carried along, offering the less fortunate no choice but to watch and yearn."[29] Using slightly stronger language, a *Breeder's Gazette* from 1904 described automobile owners as "a reckless, blood thirsty, villainous lot of purse-proud crazy trespassers."[30] Nevertheless, despite the initially hostile public attitude, by 1923 Ford was producing two million cars and trucks annually.[31]

These failed predictions about nuclear energy and the automobile suggest that analysis of technological development is best conducted after the fact. Study aided by the concept of technological dislocations is no exception; it is also limited to descriptive analysis used to inform decision makers, not to accurately predict the utility and practicality of a particular technology.

Even then, determining where to draw the line between the significant and the insignificant is difficult. The clash between technological determinism and social constructivism has roots in this question of agency, as it affects the historian's interpretation of technological transformations (fig. 5). Social constructivists impart high agency to individual actions; strict technological determinists grant no agency. There clearly should be bargaining room between the two. Hughes's theory of technological momentum offered one compromise by suggesting that high agency dominated immature technologies and

low agency ruled mature technologies. The theory of technological dislocations takes Hughes's theory one step further and eliminates the purported distinction between immature and mature technologies.
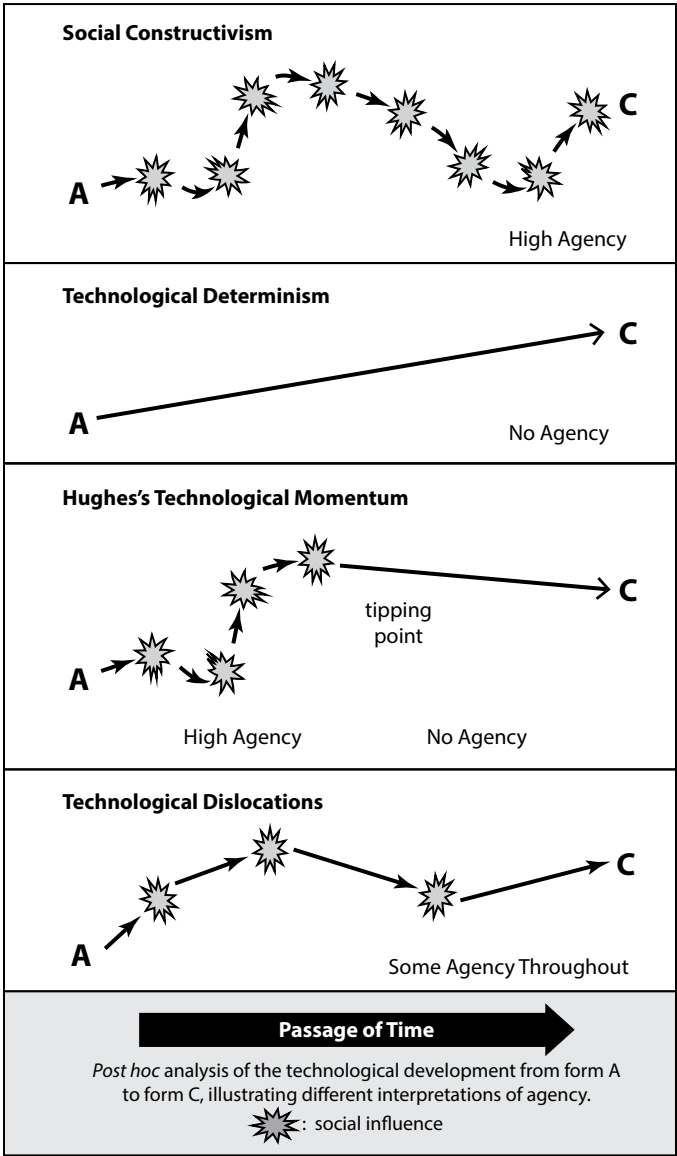

Figure 5. Historical analysis and agency. (*Created by* the author)

Issues of scale also confound the assessment of agency. "In a large technological system there are countless opportunities for isolating subsystems and calling them systems for purposes of comprehensibility and analysis," Hughes noted.[32] If historical research is narrowly focused on an individual technological system, then the level of agency imparted to particular individuals and events typically rises. For example, if studying American ICBM development, Sheehan's story of Air Force lieutenant colonel Ed Hall and the unauthorized diversion of funds from a languishing Air Force cruise missile project to help with ICBM rocket engine development are noteworthy.[33] However, if the scope of investigation addresses the role of rocketry in strategic posturing between the United States and the Soviet Union, as in McDougall's text, then Hall's actions are robbed of much of their significance—it no longer makes sense to extend agency that far down the ladder. Thus, scale and agency may be in inverse proportion—as the scale widens, agency narrows, and vice versa. Unfortunately, if neither is adequately defined, the resulting historical analysis quickly devolves into a teleological mess.

Applying the Theory of Technological Dislocations

Yet there must be some limiting principle that precludes the possibility of making a mountain out of every historical molehill. Alas, there is none, except the historian's own judgment. It is up to the historian to present a convincing analysis that portrays the past in relevant, useful terms.

In light of this objective, this author asserts that through the 1950s and 1960s, the allure of guided air-to-air missile technology entranced the Air Force. Blinded by technological exuberance, the Air Force failed to recognize that the assumptions guiding the development of its air-to-air armament were faulty. Even after those faults were laid bare by combat experiences in Korea, the Air Force continued to pursue missile and aircraft development in accordance with the dominant technological trajectory. That path demanded more complex missiles capable of targeting higher and faster-flying bomber aircraft at the expense of pursuing alternative forms of air-to-air armament optimized for different target sets.

If not for the efforts of a handful of determined individuals, the Air Force might never have introduced an air-to-air gun on the F-4 Phantom prior to the conclusion of Operation Rolling Thunder in November 1968. Furthermore, because the introduction of the old technology in an innovative fashion challenged the dominant culture within the Air Force and the prevailing technological trajectory, the new technology was initially greeted with intense

skepticism. Fortunately, the individual agents overcame this bureaucratic resistance. The resulting technological dislocation had wide-ranging implications that extend to today.

The following historical case study and the articulation of a theory of technological dislocations are not simple pedantry. By understanding how a specific technological dislocation was generated, decision makers gain insight into the nature of technological development. They also gain a contextual appreciation for the methods that historically have helped organizations dislocate the powerful technological trajectories that favor incremental evolution over truly creative and revolutionary innovation.

Notes

1. Hughes, "Technological Momentum,"102.

2. Hughes stated: "Technological systems, even after prolonged growth and consolidation, do not become autonomous; they acquire momentum. They have a mass of technical and organizational components; they possess direction, or goals; and they display a rate of growth suggesting velocity. A high level of momentum often causes observers to assume a technological system has become autonomous. Mature systems have a quality that is analogous, therefore, to inertia of motion. The large mass of a technological system arises especially from the organizations and people committed by various interests to the system." Hughes, "Evolution of Large Technological Systems," 76.

3. As technological systems "grow larger and more complex, systems tend to be more shaping of society and less shaped by it." Hughes, "Technological Momentum," 102, 112.

4. "A system with great technological momentum can be made to change direction if a variety of its components are subjected to the forces of change." Ibid., 112–13.

5. Ibid., 112.

6. Ibid., 102.

7. Gladwell identified three characteristics of social change—"one, contagiousness; two, the fact that little causes can have really big effects; and three, that change happens not gradually but at one dramatic moment. . . . Of the three, the third trait—the idea that epidemics can rise or fall in one dramatic moment—is the most important, because it is the principle that makes sense of the first two and that permits the greatest insight into why modern change happens the way it does." Gladwell, *Tipping Point*, 7 and 9.

8. Gladwell offered the cell phone revolution as another example of a tipping point: "Through the 1990s, they got smaller and cheaper, and service got better until 1998, when the technology hit a Tipping Point and suddenly everyone had a cell phone." Ibid., 12.

9. The fax machine was not a prime case study within Gladwell's book, which helps explain the omission of potential causal factors. In other sections, Gladwell offered two lessons for fomenting a tipping point: "Starting epidemics requires concentrating resources on a few key areas. . . . The Band-Aid solution is actually the best kind of solution because it involves solving a problem with the minimum amount of effort and time and cost." Second, because "the world—much as we want it to—does not accord with our intuition," those "who are successful at creating social epidemics do not just do what they think is right. They deliberately test their intuitions. . . . What must underlie successful epidemics, in the end, is a bedrock belief that

change is possible, that people can radically transform their behavior or beliefs in the face of the right kind of impetus." Ibid., 255–59.

10. Quoted in Sheehan, *A Fiery Peace*, 299. President Eisenhower's decision was articulated in NSC Action no. 1433 following a National Security Council briefing given by von Neumann and Schriever.

11. Ibid., 415. One of the officers that briefed General LeMay in 1958 on the Minuteman Missile Program recollected that LeMay was captivated by the "massiveness of the scheme. The thought of hundreds and hundreds of rockets roaring out of silos was LeMay's vision of how to frighten the Russians and then to reduce the Soviet Union to cinders if it did come to nuclear war."

12. Ibid., 195; Rhodes, *Dark Sun*, 401–2; and Neufeld, *Von Braun*, 137.

13. Law referenced Edward Constant's notion of coevolution as "an attempt to grapple with the interrelatedness of heterogeneous elements and to handle the finding that the social as well as the technical is being constructed." Law, "Technology and Heterogeneous Engineering," note 5.

14. Hughes, "Technological Momentum," 112.

15. MacKenzie, *Inventing Accuracy*, 79–80; and Hughes, "Evolution," 73. While Hughes's concept of "reverse salients" offers some redress to the criticism, the notion of correcting "laggard components" implicit in the description of a reverse salient discounts the other opportunities for social influences to alter technological systems that have otherwise established momentum.

16. MacKenzie, *Inventing Accuracy*, 4.

17. Ibid*.,* 162.

18. The term *theory* is used in the social science construct. Martel's exploration of the different interpretations of theory in the political science and international relations realm provides a basis for the present discussion of the theory of technological dislocations: "For [David] Easton, theory should also provide 'guidance to empirical research' by serving as an 'incentive for the creation of new knowledge.' . . . For Brecht, theory is 'one of the most important weapons in the struggle for the advance of humanity,' because correct theories permit people to 'choose their goals and means wisely so as to avoid the roads that end in terrific disappointment.' . . . The real test of a theory, for international relations theorist Hans Morgenthau, is for it to be 'judged not by some preconceived abstract principle or concept unrelated to reality, but by its purpose: to bring order and meaning to a mass of phenomena which without it would remain disconnected and unintelligible.'" Martel, *Victory in War*, 90–92. Jervis offered a similar interpretation: "A theory is necessary if any pattern is to be seen in the bewildering and contradictory mass of evidence." Jervis, *Perception and Misperception*, 175.

19. Blakemore, *Solid State Physics*, 78–80; Campbell, *Science and Engineering of Microelectronic Fabrication*, 17–18; and West, *Solid State Chemistry*, 320 and 340–55. This type of dislocation is known as an *edge dislocation*—"one of the planes of atoms terminates, resembling a knife blade stuck part way into a block of cheese." For information on dislocation formation in semiconductor crystals grown for electronics applications, see Swaminathan and Macrander, *Materials Aspects of GaAs*, 57–61 and 450–56.

20. Hughes, "Evolution," 57.

21. "'Heterogeneous engineers' seek to associate entities that range from people, through skills, to artifacts and natural phenomena. This is successful if the consequent heterogeneous networks are able to maintain some degree of stability in the face of the attempts of other entities or systems to dissociate them into their component parts." Law, "Heterogeneous Engineering," 129.

22. Dosi, "Technological Paradigms," 147–62.

23. An example of an alternative technology is the introduction of steam power into the sail-powered British Navy in the early nineteenth century; see McNeil, *Pursuit of Power*, 226. Eisenhower's "New Look" defense policy and the resultant shift from a large Army and Navy towards a leaner defense establishment reliant upon Air Force nuclear bombers illustrate the effects of a changing political and economic agenda on military technology; see Barlow, *Revolt of the Admirals*. On the role of scientific obstacles or "presumptive anomalies," see Constant, *Origins of the Turbojet Revolution.*

24. McDougall, *Heavens and the Earth*, 205, 249, and 295. McDougall described the implications of NSC-5918, "U.S. Policy on Outer Space," signed by the president on 12 January 1960: "It was therefore the American objective, among others, 'to achieve and demonstrate an overall U.S. superiority in outer space without necessarily requiring U.S. superiority in every phase of space activities.' To minimize Soviet psychological advantages, the United States should select and stress projects that offer the promise of obtaining a demonstrably effective advantage, and proceed with manned spaceflight 'at the earliest practicable time.'" Concerning the Soviet approach to space, McDougall first cites Khrushchev's memoirs: "Of course, we tried to derive the maximum political advantage from the fact that we were the first to launch our rockets into space." He then notes, "But [Khrushchev's] quest for 'maximum political advantage' led to the espousal of a 'party line' that not only hindered rapid and rational development of [Soviet] space technology but encouraged a dangerous deception in military policy as well. . . . [Khrushchev's] radical error was hyperbole, for he plotted the Soviet curve in the Space Age as hyperbolic, when it in fact was parabolic. After straining upward on a dizzy slope, Space Age communism slowed, then arced downward . . . to a premature end."

25. MacKenzie, *Inventing Accuracy*, 214–16; and Schmemann, "Summit in Moscow," A1.

26. Hughes, *American Genesis*, 439.

27. Ibid., 441.

28. Brinkley, *Wheels for the World*, 114.

29. Ibid., 113.

30. Ibid., 114–15. Woodrow Wilson, then president of Princeton University and within seven years president of the United States, characterized the automobile as "a picture of the arrogance of wealth, with all its independence and carelessness."

31. Hughes, *American Genesis*, 208. Similar false starts have been observed in the scientific community. When Martin Fleischmann and Stanley Pons announced that they had achieved cold fusion in 1989, news reporters heralded the discovery as an astounding scientific accomplishment. However, efforts to reproduce the experiment flopped, and the story is now but an inglorious footnote in scientific history. Browne, "Fusion in a Jar," C1; and Browne, "Physicists Debunk Claim," A1. Conversely, the discovery of C60 went largely unnoticed but has since spawned the nanotechnology craze that dominates university laboratories today. "Soccer Ball Molecules," C9.

32. Hughes, "Evolution," 55. However, Hughes warned that in "isolating subsystems, . . . one rends the fabric of reality and may offer only a partial, or even distorted, analysis of system behavior."

33. Sheehan described how Air Force lieutenant colonel Ed Hall, working at the Air Development Center, devised a strategy to "use the requirements for adequate engines for the Navaho booster [an intercontinental cruise missile then in development but destined to be cancelled] as a cover to acquire a rocket engine for an intercontinental ballistic missile." Sheehan, *Fiery Peace*, 247.

Chapter 4

Rise of the Missile Mafia

There will be a gun in the F-4 over my dead body.

—Gen William Momyer, USAF

Like Gen Hap Arnold before him, Gen William Momyer was a technology zealot. Serving as director of operational requirements for the Air Force from 1961 to 1964, Momyer was in a unique and powerful position to define the role of technology in the Air Force, especially after the Kennedy administration decided to revitalize the nation's nonnuclear force structure. Momyer's purview extended to the development of Air Force air-to-air armament, both the guided missiles and the aircraft designed to carry and employ them. In this position, one Air Force officer noted that Momyer had "just one feeling . . . and that was to exploit technology to its fullest; . . . if it didn't fly faster or higher, [it was] a step backwards."[1] In a 1977 interview, Maj Gen Frederick "Boots" Blesse described Momyer's particular affinity for missile technology.

> General Momyer, bless his heart, was one of the fuzzy thinkers in that [air-to-air missiles] area. He was in Requirements in the Pentagon. He was determined that the missile was the name of the game, guns just did not have any part in anything from then on. . . . In fact, I went to see General Momyer when he was a full colonel, I was a major at the time, in early 1953 or 1954. His statement to me was, "You goddamn fighter pilots are all alike. You get a couple of kills with a gun and you think that the gun is going to be here forever. Why can't you look into the future and see that the missile is here and the guns are out? There is no need for a gun on an airplane anymore."

> I said, "But Colonel Momyer, it is like a guy who has a pistol or it is like a guy who has a rifle fighting against another guy who has a knife. Now if you had a knife and a rifle and you threw the knife away, and you were fighting this guy near a phone booth, obviously the best weapon would be the rifle. However, if he somehow got you inside the phone booth, you would be in deep serious trouble. And that is what the gun is, the gun is the knife in the phone booth. It is for close-in protection. The missile goes off and does not even arm itself for about 1,500 feet. Now I am talking about a range within 2,000 feet; when you get to turning, you are inside that range and you cannot get away. The first guy who turns away is going to get knocked down. You just need to have a gun for those close-in times."

> The response to that was, "There will not be any close-in times because you will die long before you get to the missile [*sic*]." I said, "That is if the missile works, sir." He said, "All the missiles work."[2]

Momyer's faith in missiles proved to be without basis during Vietnam, as aptly illustrated in the dismal performance of Speedo and Elgin flights' missiles on 14 May 1967. However, Momyer was not alone in his faith in missiles, nor was he the first to promote the promise of long-range air-to-air missiles in future air combat. His attitude was reflective of a common one-dimensional understanding of future air combat that would be fought primarily against Soviet bomber aircraft and the trend toward technological exuberance that underpinned Air Force weapons decisions in the 1950s and 1960s. During that period, the Air Force's embrace of air-to-air missiles established a technological trajectory that subsequently exerted a deterministic influence on Air Force weapons development, blinding Air Force leaders to potential alternatives in the character of future conflicts and the technologies required for success therein.

Air-to-Air Missile Development

The Air Force's fascination with high-speed, air-to-air guided missiles blossomed during the closing stages of World War II. The Airmen of the Army Air Forces, intrigued by the performance of German V-1 and V-2 missiles, sought to apply the developments in modern rocketry to the emerging "air-to-air combat problem" presented by faster, higher-flying aircraft.[3] Beginning in 1948, students at AU's Air Tactical School (ATS) at Tyndall AFB, Florida, received a one-hour lecture on the armament problem. The lesson's stated purpose was to "acquaint the student with the need for air-to-air guided missiles and with some of the problems associated with their development and operational use."[4] The lesson plan focused on two issues.

The first was "the effect of the high speed on the pilot."[5] While newer, faster aircraft subjected the pilot to the increased physiological stresses of higher altitude flight and greater G-forces, the lesson focused instead on the cognitive limitations the pilot would encounter in the faster-paced environment. In this new age, the Air Force determined most of its pilots would be unable to autonomously process information quickly and accurately enough to complete an air-to-air intercept to a position from which they could employ existing weapons.[6]

The second issue of jet-age air combat was characterized by the limited effectiveness of air-to-air cannon technology at high airspeeds. "New 50 caliber machine guns can fire 1,000 to 1,200 rounds per minute with a muzzle velocity of 2,700 feet per minute, but the range at which the average pilot can expect to obtain telling hits is very short. In fact, even using the A-1 [gun] sight,

he will still have to get within 800 yards of the target to obtain hits. . . . The way aircraft are being built these days," the lecture continued, "it would be a very lucky round indeed that might destroy another ship."[7] Consequently, only air-to-air guided missiles offered the prospect of "enabl[ing] a pilot to stand off at least 10,000 feet away and fire at a target with fatal results to that target."[8]

Summarizing the promise of the new missile technology, the lesson concluded, "As presently visualized, the missile has the following advantages over armament now mounted in our aircraft:

1. Much longer effective range
2. Controllable all the way to the target
3. Powerful enough to insure a kill."[9]

By the time the ATS lesson was introduced in April 1948, the Air Force already had gathered valuable air-to-air missile experience. The first Air Force air-to-air missile, the JB-3, boasted a massive 100-pound warhead, a top speed of 600 miles per hour, a range of five to nine miles, and an ability to attack aircraft at altitudes of up to 50,000 feet.[10] Designed by Hughes Aircraft according to a January 1945 Army Air Forces contract, the missile, nicknamed "Tiamet" after the "goddess in Assyrian-Babylonian mythology," was guided toward the target by an internal FM radar homing device.[11] Ironically, the first Tiamet launch occurred on 6 August 1945—the same day the United States ushered the world into the atomic age, which would consequently place a greater premium on an aircraft's ability to defend the nation from future higher and faster Soviet bombers threatening atomic attack. However, according to Air Defense Command's (ADC) *History of Air Defense Weapons, 1946–1962*, "none of the first ten [Tiamet] missiles tested showed much promise," and the "very cumbersome" 625-pound missile—"essentially a 100-pound bomb with wings"—was terminated in September 1946.[12] The Air Force instead rededicated and accelerated its efforts toward acquiring a more "'practical' air-to-air missile that could be developed within two years."[13]

One ADC historian described the ensuing effort: "Missile development contracts sprouted like spring flowers immediately after the war."[14] Several contracts were issued, including two separate contracts each for a fighter-launched missile (to attack bombers) and a bomber-launched missile (to attack fighters). However, when President Truman drastically curtailed the national defense budget, the windfall in missile spending quickly evaporated and the newly independent Air Force allowed several contracts to wither and die in 1947–48.[15] By the end of 1948, only two Air Force air-to-air missile contracts remained: Ryan's Firebird missile, designed for use by fighter air-

craft; and Hughes Aircraft's Falcon missile, designed for use by bomber aircraft.[16] Further budgetary pressure led to the realization that the "distinction between bomber-launched missiles and fighter-launched missiles had blurred to the point where the two were interchangeable," and the Air Force adapted its contracts to reflect the need for only a single air-to-air missile that would enable "use as an offensive weapon for interceptor aircraft and for defensive use by bombers."[17] Finally in April 1949, the Air Force terminated Ryan's Firebird program and devoted all of its air-to-air missile funds and energy to Hughes's Falcon missile program.[18]

The first version of the Falcon missile was radar-guided.[19] It relied on the interceptor aircraft to use its fire-control radar to illuminate the target aircraft. Once the missile was launched, the seeker within the GAR-1 Falcon sensed the radar energy reflected off the target, measured the relative change in line-of-sight between the missile body and the radar reflections, and steered itself using hydraulic servos that actuated its control fins to zero-out the relative changes in line-of-sight to create a collision intercept. These principles of radar guidance allowed the interceptor to launch the missile in any weather condition—even if the interceptor pilot could not see the target—and from any direction (aspect) relative to the target.[20] However, it also required the interceptor aircraft's radar to remain locked to the target while the missile was in the air—easy against a large nonmaneuvering target but exceedingly difficult against a small maneuvering one. Therefore, successful GAR-1 employment demanded flawless performance from both the interceptor radar and the missiles. It proved to be a high and often unachievable standard.

The ambitious project was also hampered by continued bureaucratic skepticism and technical difficulties. Despite being the sole Air Force air-to-air missile project, funding for the Falcon continued to deteriorate, the victim of tightening defense budgets and bureaucratic coffer scavenging to fund the Air Force's focus on strategic bombing. In 1949 the Air Force set aside a puny $200,000 emergency fund for the program, lest all development work be halted if the program's funds completely disappeared.[21] Funding was eventually restored, but the influx of money did little to address the performance failures plaguing the missiles.

The weapons system was extremely complex. The missile relied on 72 notoriously unreliable radio vacuum tubes; the interceptor aircraft's radar relied on countless more.[22] Persistent technical problems resulted in numerous production delays, forcing Hughes to slip the promised delivery date for the missile from June 1954 to October 1954 and finally to August 1955.[23] The first GAR-1 Falcon-equipped squadron of F-89H Scorpion aircraft was not de-

clared operational until March 1956, almost two years after the first scheduled delivery date.[24]

Hughes addressed some of the performance limitations of the GAR-1 missile with its follow-on version, the GAR-1D. Notably, the GAR-1D increased the missile's performance against high-altitude targets from a 50,000-foot maximum target altitude to 60,000 feet.[25] The GAR-1D, however, did not remarkably improve the reliability of the GAR-1. ADC's *History of Air Defense Weapons* recorded, "Although the F-89H and F-102A and the GAR-1D missiles, which were their primary armament, were available to ADC in appreciable quantities by the end of 1956, the missiles were not usable at that time. While the fire control systems (R-9 and MG-10) designed for use in connection with the Falcon missile were far from reliable, the missiles themselves also failed to live up to expectations."[26] For example, the Air Force Weapons Center in Yuma, Arizona, determined that "37.5 percent of the Falcons in storage failed to meet operational standards upon initial inspection. A later check showed another 16.5 percent to be unfit for use. Firing tests resulted in a large proportion of near misses even when the fire control system was operating normally."[27]

Based in part on these failures, the Air Force removed the GAR-1D missiles from its operational inventory in January 1957. The missiles returned to service six months later after Hughes corrected some of the deficiencies.[28] Reminiscing about the difficulties associated with early guided missile development, Fred Darwin, then executive secretary of the Department of Defense's Guided Missiles Committee, lamented, "Day-by-day, then with increasing acceleration, I became convinced of something I considered important: THESE THINGS WILL NEVER BE OPERATIONALLY USEFUL. Even Should We Make Them Perfect."[29]

Hughes's infrared-guided (heat-seeking) variant of the Falcon, the GAR-2, suffered from an equally tumultuous development process. The GAR-2 missile was initiated in November 1951 and Air Force officials hoped the GAR-2 missile would complement the radar-guided GAR-1.[30] Indeed, the GAR-2 offered multiple advantages over the GAR-1. According to a 1956 Air Force evaluation report, the "GAR-1B [GAR-2] can be used at lower levels (no ground clutter); against multiple targets (it will select a target); and it has greater accuracy since the missile homes on a point source of heat rather than seeing the entire target. Additional advantages are that it is a passive seeker, it is immune to electronic countermeasures, and it can be launched with less specialized fire control equipment."[31]

Unfortunately, the GAR-2 and its improved variant, the GAR-2A, performed miserably during low-altitude tests conducted in 1959.[32] Neverthe-

less, a "single success after universal failure" during the testing buoyed the Air Force's and Hughes's "hopes that something might, after all, be done to make the GAR-2A useful at low altitudes."[33] In this instance, the optimism was deserved; Hughes successfully designed an improved infrared guidance unit and solved many of the low-altitude guidance problems.[34] By 1961 the GAR-2A provided the primary punch for the F-102A and served as secondary armament on the F-101B.[35]

As Hughes struggled to work the kinks out of its guided missile systems, the Air Force hedged and looked toward unguided rockets as an interim air-to-air armament solution. Ironically, the Air Force turned to the Army's Ordnance Department for a viable system. The Army obliged and began transforming the German World War II two-inch R4M unguided rocket into a "2.75-inch spin-stabilized rocket expected to have a range of about 2,000 yards."[36] Although very different from the 10,000-yard range the Air Force desired, the Army's 2.75-inch folding-fin aerial rocket (FFAR) promised to help "increase interceptor firepower until the guided missiles were ready."[37]

However, the effectiveness of the unguided rockets was questionable. "In a case famous at the time [in 1956], two F-89s equipped with a total of 208 rockets fired all of them, but failed to shoot down an F6F Hellcat drone that had drifted off course and was threatening to crash on Los Angeles. [The wayward drone] eventually ran out of fuel and crashed harmlessly. The rockets did more damage. Several started brushfires, and one errant missile hit a pickup truck in the radiator but failed to detonate."[38] Unguided rockets were still in use as air combat armament in 1961, but confidence in their utility remained low. One Marine Corps pilot remarked, "The plan was to fire a salvo of four 19-shot pods on a 110-degree lead-collision course, with a firing range of 1,500 feet. Whether or not we would have hit anything on a regular basis is a matter for conjecture, but I think not."[39]

Hughes continued to improve the Air Force's Falcon guided missiles, eventually developing an upgraded GAR-1D radar-guided missile, designated the GAR-3, and an enhanced GAR-2 infrared-guided missile, designated the GAR-4. Announcing the development of the GAR-3 in 1958, the *New York Times* described the new missile as having "a longer, higher, and deadlier reach than that of any other air-to-air missile." In the same article, Roy Wendahl, vice president of Hughes's airborne systems group, claimed that the GAR-3 could "climb far beyond the altitude capabilities of the interceptor and destroy an enemy H-bomber in any kind of weather."[40]

In 1961 the Air Force reclassified its missile programs, and the GAR-1 through 4 Falcon missile designations were subsumed under the AIM-4 label.[41] Besides now sharing a common designation, the family of Falcon mis-

siles also shared a notorious deficiency. Because the missiles were specifically designed to be paired with the F-102A Delta Dagger under the new aircraft-missile weapon system construct, the missile's dimensions were restricted by the size of the F-102A's internal weapons bay. After allotting space within the missile body for the complex and bulky array of vacuum radio tubes needed for missile guidance, there was disappointingly little room left for the missile warhead and fusing assembly, rendering the Air Force's desire for "a kill even from a one-hundred-foot miss" laughable.[42] Instead of a 300-pound missile warhead, the Air Force eventually settled on Hughes's puny 2.8-pound warhead, later increased to a whopping five pounds.[43] To detonate the Falcon's miniscule warhead, the missile relied on a contact fuse mounted on the leading edge of the missile fins, which meant that the missile had to hit the target to explode.[44]

Like the Air Force, the Navy also pursued development of both radar- and infrared-guided air-to-air missiles for its fighter aircraft. And like the Air Force, the Navy's guided missiles were initially greeted with technological skepticism. William McLean, overseeing the Navy's Sidewinder guided air-to-air missile program while working at the Naval Ordnance Test Station at China Lake, California, described the constraints they encountered:

> Every time we mentioned the desirability of shifting from unguided rockets to a guided missile, we ran into some variant of the following list of missile deficiencies:
>
>> Missiles are prohibitively expensive. It will never be possible to procure them in sufficient quantities for combat use.
>>
>> Missiles are impossible to maintain in the field because of their complexity and the tremendous requirements for trained personnel.
>>
>> Prefiring preparations, such as warm-up and gain settings required for missiles, are not compatible with the targets of surprise and opportunity which are normally encountered in air-to-air and air-to-ground combat.
>>
>> Fire control systems required for the launching of missiles are complex, or more complex, than those required for unguided rockets. No problems are solved by adding a fire control computer in the missile itself.
>>
>> Guided missiles are too large and cannot be used on existing aircraft. The requirement for special missile aircraft will always result in most of the aircraft firing unguided rockets.[45]

The Navy's radar-guided missile, the Sparrow, evolved from a 1947 contract with Sperry Gyroscopic Laboratory. Sperry's Sparrow I saw limited fleet use beginning in September 1952; widespread deployment throughout the fleet began in May 1954.[46] However, because of design limitations in the Sperry missile, the Navy pursued two alternate versions of the Sparrow:

Douglas Aircraft's Sparrow II and Raytheon's Sparrow III. A series of missile fly-offs between the three versions led to a 1957 Navy decision to award its future contracts exclusively to Raytheon and its Sparrow III design.[47] Unlike Sperry's beam-rider missile, which steered its control fins to keep the missile in the center of a radar beam pointed at the target aircraft, Raytheon's Sparrow III relied on a semiactive seeker that guided the missile body toward radar energy reflected off the target, similar to the guidance system used by the Air Force's radar-guided Falcon.[48] The Sparrow, never designed to be carried internally in a particular aircraft, was significantly larger than the Falcon, measuring 12 feet in length compared to the Falcon's six feet, and packed a considerably larger wallop with a 65-pound warhead.[49] The Navy set sail with the Sparrow III in July 1958.[50]

The Navy's infrared missile, the Sidewinder, was developed in-house by engineers at China Lake. Despite being denied the level of resources devoted to radar-guided missiles, the Sidewinder beat the Sparrow to the fleet by almost two years, becoming operational in 1956.[51] The genius of the Sidewinder lay in its relative simplicity. Whereas the Air Force's infrared Falcon missile variant required 19 technicians just to maintain the missile's test equipment, which in turn occupied 40 feet of wall space, the Navy designed the Sidewinder for the harsh and cramped conditions on an aircraft carrier.[52] Moreover, the Sidewinder generally performed better than the Falcon. The disparities were too great to ignore, and in 1957 the Air Force reluctantly decided to co-opt the Navy's Sidewinder project.[53]

In contrast to the Air Force's Falcon missiles that relied solely on a contact fuse to detonate the warhead, the Navy's Sparrow and Sidewinder missile designs incorporated both a contact and a proximity fuse. Thus, even if the Navy missile did not hit the target, if the missile flew close enough to it, the warhead would still detonate, hopefully causing enough damage to disable the enemy aircraft. However, the addition of a proximity fuse necessitated a greater minimum firing range—approximately 3,000 feet of separation between the interceptor and the target—to preclude the possibility of the missile inadvertently fusing off the launching aircraft. At the time, few pilots recognized that the minimum ranges of the missiles roughly corresponded to the maximum effective range of existing aircraft cannons.[54]

The poor reliability of the Air Force's Falcon missiles and the greater minimum ranges of the Navy's Sparrow and Sidewinder missiles were not the only limitations of the new air-to-air missiles. Launching a radar-guided missile entailed a time-consuming and complex procedure involving multiple switch actuations and dial manipulations to configure the aircraft radar, acquire the target with the radar, and select and launch the appropriate missile.[55] After

launch, the pilot had to ensure that the radar remained locked on the target to provide the constant radar illumination that the missile required for guidance. Loss of the radar lock resulted in the missile veering wildly off course. Furthermore, early aircraft fire-control radars had difficulty acquiring and tracking targets that operated below the interceptor and close to the ground due to a problem known as *ground clutter*—the radar could not distinguish the low-altitude target aircraft from the terrain features on the ground.[56]

Infrared missiles had their own set of limitations. Whereas infrared missiles did not require a radar lock, they did require the pilot to maneuver the interceptor aircraft into a small 30-degree cone directly aft of the target.[57] This was the only region where the infrared seeker on the missile could observe and track the target's hot jet exhaust; outside of the cone, the missile was incapable of detecting the target's heat source. To defeat a heat-seeking missile prior to launch, the enemy only had to aggressively turn the aircraft to keep the interceptor aircraft outside of the cone. Under the same premise, a similarly aggressive turn could also defeat a Sidewinder missile already in flight.[58]

Although Air Force and Navy officials recognized many of these limitations, they were not deemed significant in the next anticipated conflict. Air Force and Navy officials expected pilots to have ample time to acquire the targets, actuate switches, and maneuver their aircraft into position to employ a radar-guided missile or, if necessary, an infrared-guided missile. Few challenged these assumptions during missile testing. Rather than conducting missile tests against small, maneuverable, fighter-like aircraft, both services concentrated the majority of their air-to-air missile testing on intercepting high-flying, nonmaneuvering targets, reflective of their anticipated combat against massive formations of large Soviet bombers en route to attack western Europe and the United States. There was no need to worry about targeting the Soviet fighters that might accompany the bombers to the target because there would not be any fighters; they did not have sufficient fuel for the bomber-escort mission. Similarly, the majority of US fighters faced the same fuel limitations and would be unable to escort American bombers to their targets within the Soviet Union. Logic therefore suggested that American interceptor aircraft need only be concerned with attacking high-flying, nonmaneuvering Soviet bomber aircraft.

This general assessment of the threat was clearly reflected in the Air Force's decision to acquire nuclear-armed air-to-air unguided rockets and guided missiles for its interceptor aircraft. Having determined that "existing and programmed armament [was] deficient" and cognizant of the need for weapons that would "assure a high degree of kill probability," on 31 January 1952 ADC issued a requirement for a nuclear interceptor missile capable of "cut[ting] a

wide swath of destruction through a formation of enemy bombers."[59] However, at that time, no nuclear warhead existed that was small enough for use in a fighter-interceptor missile. ADC reissued its requirement on 23 March 1953 and stressed the urgent need for a "lightweight atomic warhead of lowest possible cost with yields within the range of 1–20 KT [kilotons]."[60] The Joint Chiefs of Staff (JCS) approved development of a nuclear-armed air-to-air rocket a year later, and the MB-1 Genie, an unguided rocket complete with nuclear warhead, was test fired by an F-89J Scorpion in July 1957 over the desert north of Las Vegas, Nevada.[61] Partly because the unguided MB-1 did not fit within the F-102A internal weapons bay, but also reflective of the Air Force's fascination with guided missiles, the Air Force ordered Hughes to develop a nuclear variant of the Falcon, the GAR-11, which was test fired without a warhead on 13 May 1958.[62]

From its inauspicious beginnings as the JB-3 Tiamet in 1946, the air-to-air guided missile underwent a major technological transformation in the ensuing 15 years, overcoming much of the early bureaucratic skepticism and its "rhetoric of denial."[63] Although still suffering from significant employment limitations and questionable reliability, by the time of the Korean War armistice in 1954, guided missiles were considered up to the task of inflicting considerable damage on the ominous hordes of Soviet bombers should the opportunity present itself. Reinforcing that assessment, the Air Force elected to remove the guns from its interceptor versions of the F-86 (F-86D),[64] the F-89 (F-89D),[65] the F-94 (F-94C),[66] and its newly designed F-102A interceptor.[67]

Gun development continued within the service until 1957, but only in an air-to-ground context and only for aircraft designed for fighter-bomber applications such as the F-100 Super Sabre, the F-101 Voodoo, and the F-105 Thunderchief. The GE 20 mm M61 Vulcan Gatling gun, capable of firing 6,000 rounds per minute, armed the Thunderchief.[68]

For its air-to-air armament, the Air Force focused exclusively on developing its guided missiles—optimized for attacking large, nonmaneuvering aircraft—despite its experiences in the Korean War struggling to wrest air superiority from a determined foe armed with small, maneuverable MiG fighters.[69] For example, the Air Force's 1957 post-Korea requirements for the F-106, a follow-on to the F-102A, addressed the need for "carry[ing] one MB-1 air-to-air atomic rocket and four GAR-3/GAR-4 Falcons, launchable in salvo[s] or in pairs."[70] Reflecting the opinion of the day, Secretary of Defense McNamara reportedly quipped, "In the context of modern air warfare, the idea of a fighter being equipped with a gun is as archaic as warfare with bow and arrow."[71]

The Phantom II

In light of this fixation on guided missiles, it is not surprising that the Navy's F-4 Phantom II (then designated the F4H-1F), once deemed the "classic modern fighter of the free world" by aviation historian and former Smithsonian Air and Space Museum director Walter Boyne, entered the fleet in December 1960 bristling with missiles but missing an internal cannon.[72] Originally proposed to the Navy as a follow-on to the F3H Demon in September 1953, McDonnell Aircraft's design morphed several times during the next two years as the Navy waffled between requesting a fighter-interceptor and an aircraft optimized for ground attack.[73] During the attack-aircraft phase, McDonnell reengineered the F4 design into the AH-1, a twin-engine, single-seat aircraft armed with four 20-mm Colt Mark-12 guns or 56 two-inch unguided rockets.[74] However, in April 1955 the Navy finally announced that it would pursue acquisition of a two-seat, all-weather, fighter-interceptor. McDonnell responded and began manufacturing several F4H-1 test aircraft, which eventually evolved into the F4H-1F version destined for fleet use.[75]

After settling on a fighter-interceptor design, the Navy had to address the aircraft's armament requirements. A series of Sparrow missile tests conducted in August 1955 convinced Navy engineers "that missiles provided a better interception system than a combination of cannon and aircraft."[76] In short, the F-4 engineers believed that "guns were . . . a thing of the past, . . . [and] guided missiles were the wave of the future," and they quickly moved to incorporate the missiles and the necessary accompanying fire-control radar equipment into the aircraft design.[77]

Still, the transition to an all-missile configuration took several design iterations. Initially in 1955, the Sparrow missiles were added only as a supplement to the already planned cannon and rockets. Less than a year later, Navy engineers designated Raytheon's Sparrow III missile the aircraft's primary weapon. By 1957 the internal cannon was completely removed from the F-4 design.[78] According to Marshall Michell III, the "lack of a cannon did not appear to unduly disturb the F-4 aircrews; in fact, many supported it."[79] Glenn Bugos described the rationale behind the armament decision:

> There were four main reasons for dedicating the F4H-1 to guided missiles. First, the missiles were lighter than the cannons they replaced. Second, they were much cheaper than aircraft, which, if carrying cannons or rockets, would need to get more dangerously close to the enemy. Third, self-guided missiles reduced the workload of the aviators, who simply pushed a button in response to symbols on a computer screen rather than engaging in the extensive dogfighting maneuvers needed with cannons or rockets, though the aviators saw this as being de-skilled by the missiles. Finally, the use of guided missiles

allowed a more flexible reconstruction of the F4H-1's interception system. . . . Unlike rockets or cannons, there was an electromagnetic umbilical cord between the Sparrow III in flight and the F4H-1. This meant McDonnell engineers could decide which tasks—how much guidance or speed—should be built into the missile and which built into the aircraft, and how these tasks should be shifted between the aircraft and the missile as the technologies changed.[80]

Contrary to popular lore, McNamara did not mandate that the Air Force adopt the Navy's F-4. The Air Force by October 1961 had already expressed interest in acquiring an Air Force version of the Navy F4H-1, which they would label the F-110 Spectre, the next designation in the Air Force's century series of fighters.[81] But the secretary of defense did pressure the Air Force to cancel its next version of the F-105, the F-105E, in favor of procuring additional Navy Phantoms for Air Force use. Emphasizing commonality and cost effectiveness, McNamara also urged the Air Force to accept the new Navy fighter with little modification.[82] Finally, the secretary, "preoccupied with standardization of things both technical and nomenclatural," demanded that the services accept a common designation for the aircraft. Thus, the Navy's F4H-1 test aircraft became F-4As, the F4H-1F production aircraft became Navy F-4Bs, and the Air Force's F-110 aircraft became Air Force F-4Cs.[83]

Modifications of the Navy's F-4B for Air Force use as the F-4C were limited to enhance "the notion of commonality and . . . [maintain] the program schedule."[84] The Air Force requested only seven changes: (1) an improved radar display; (2) an autonomous inertial navigation system (INS) similar to the type installed in Strategic Air Command (SAC) bombers; (3) a larger oxygen supply to support transoceanic flights; (4) a refueling receptacle compatible with Air Force boom-equipped aerial refueling aircraft; (5) a cartridge-based engine-starting system for use at remote locations without adequate ground support; (6) larger, softer main landing gear tires to better distribute the aircraft's weight on concrete runways (vice the Navy's steel carrier decks); and (7) a full set of flight controls for the rear cockpit.[85] The lack of an internal cannon and the aircraft's total reliance on air-to-air missiles was not an item of concern for most Air Force procurement officials despite recognizing the variety of missions—ranging from ground attack to counterair—the Air Force expected its newest multirole fighter aircraft to perform.[86]

As the Air Force F-4C began to materialize, a handful of determined officers tried to alert the Air Force leadership that the decision to forego a gun that could complement the guided missile armament hinged on faulty assumptions. However, they met stiff resistance. According to Maj Gen John Burns, the prevalent attitude within the Pentagon at the time was that aircraft guns were "anachronisms, throwbacks to earlier, bygone days, . . . that the day

of the gun was gone, and that the day of the maneuvering fighter was gone, and that air combat would consist entirely of a radar detection and acquisition and lock-on, followed by a missile exchange."[87]

Working at the Pentagon in Air Force Operations as a colonel in the early 1960s, Maj Gen Richard Catledge recounted his Pentagon experience with the antigun sentiment and Momyer:

> I realized this two-star, General "Spike" Momyer[,] ran the Air Staff—very strong-minded individual, very knowledgeable individual, who did his homework on everything. . . . It was his belief and his concept that future airplanes would not have guns in them. There was no need for guns. I couldn't believe this when I came across it in the Pentagon.
>
> So I built a flip chart briefing, with my convictions, why we needed guns, more for air-to-air than for air-to-ground. . . . Anyway, I found it was an uphill fight. That every colonel, every major, in requirements, whose business I was getting into, believed as their boss did. So I really went uphill.
>
> I built my chart, got my ducks all lined up, and went to my boss, [Major General] Jamie Gough, and gave him that briefing. He said, "Well, it's a good story, . . . [but] you are going to have to run this by Spike Momyer, and I'm not going with you." . . .
>
> So I went up, got the appointment, put my stand in front of his [Momyer's] desk, and started in telling him why we needed guns in airplanes. Well at one point in this—he stopped me several times and gave me a few words on why we did not, and [that] essentially missiles had taken over. Missiles had taken over for air-to-air . . . and other kinds of munitions [had taken over] for air-to-ground, so there really was no need [for obsolete guns].
>
> Well, I thought I had a pretty good argument, but [I] didn't convince him. I remember he'd beat on his table and say, "There will be a gun in the F-4 over my dead body." That was his attitude.[88]

The Air Force's first YF-4C prototype was delivered on 27 May 1963, 65 days ahead of schedule. On 1 August 1964, the 558th Tactical Fighter Squadron of the 12th TFW at MacDill AFB, Florida, conducted a "limited evaluation . . . to determine the practical capabilities, deficiencies, and limitations of the F-4C aircraft."[89] Unfortunately, air-to-air testing was a "relatively low test project priority." Of the 46 scheduled Sparrow shots, only 17 sorties were flown and, of those, only four successfully launched the test missile. All four test launches were later "termed non-productive" due to failure of the telemetry scoring system. No Sidewinder missiles were launched during the test. Despite the inconclusive findings, the evaluation report was optimistic, declaring, "The F-4C [air-to-air] delivery capability is somewhat apparent."[90] The Air Force F-4C entered operational service at MacDill AFB on 20 November 1963, armed with Navy Sparrow III radar-guided and Sidewinder infrared-guided missiles but no gun.[91]

The effects of the Air Force's fascination with guided missiles began to manifest in another area—aircrew training. One aviation historian accused the Air Force of placing "more emphasis on its capital equipment throughout the late 1950s and 1960s than it did on preparing its pilots for aerial combat."[92] Indeed, Blesse characterized the Air Force between 1956 and 1963 as being dominated by an overriding and unhealthy concern for aircraft safety: "Safety became more important than the tactics, more important than gunnery, more important than anything. Safety was king."[93] For example, following two Phantom training accidents, Tactical Air Command (TAC) imposed strict limits on aircraft maneuvering, relegating the F-4 crews "to train for aerial combat using a flight regimen confined to unrealistically high airspeeds and low angles of attack."[94]

Many senior Air Force leaders justified the tight restrictions on air-to-air training because they believed there was no need to practice aggressive aircraft maneuvering for an intercept mission that would only entail taking off, climbing to the altitude of the Soviet bomber targets, selecting the appropriate missile, and pulling the trigger.[95] This idealistic vision of air combat extended to the Navy. One Navy pilot reminisced, "F-4 squadrons, being state-of-the-art in equipment and doctrine, seldom bothered with 'outmoded' pastimes such as dogfighting. Besides, they had no guns and consequently felt little need to indulge in ACM [air combat maneuvering]."[96]

Thus, at the beginning of the 1960s, technological exuberance for air-to-air missiles exerted a profound influence over the Air Force. Fascination with the promise of air-to-air guided missile technology, optimized to defend the nation from Soviet nuclear bombers, blinded Air Force leaders to the shift in Soviet strategy from manned bombers to ICBMs. Even after intelligence assessments confirmed the Soviet strategic swing, Air Force leaders failed to adapt their vision of future air combat to the new strategic context. They deemed the missile technology "too promising to discard" and continued to focus missile development against the preexisting target set.[97] The assumption that the missiles would attack large, high-flying, nonmaneuvering targets went unchallenged.

American missile technology and American pilots were "expected to dominate air combat" upon entering the Vietnam War.[98] In the words of Momyer, "All the missiles work."[99] Unfortunately, the reality in the skies over Vietnam did not match the rhetoric.

Notes

1. Hildreth, oral history interview, 29.

2. Blesse, oral history interview, 59–60. There is a discrepancy in Blesse's narrative. Blesse states that he confronted then-colonel Momyer in 1953–54, but this would have been prior to Momyer's assignment at the Pentagon. It is possible that Blesse encountered Momyer in the specified period while Momyer was serving on the Air War College faculty at Maxwell AFB, Alabama, and Blesse was assigned to the Fighter Gunnery School at Nellis AFB, Nevada. Blesse provided no further clarification on the meeting's timing elsewhere during the interview. In a touch of irony, Blesse and Momyer would meet again to discuss the practicality of installing guns on fighter aircraft; as the 366 TFW deputy commander for operations, Blesse needed the Seventh Air Force commander, Momyer, to approve his proposed aircraft modification.

3. McMullen cited the influence of the German V-1 and V-2 weapons on American air-to-air missile development. The 1948 ATS lesson plan described the "air-to-air combat problem": "At present, it would appear that our faster aircraft . . . may be fine to carry a pilot from one point to another in a great hurry but may be of little or no use in air-to-air combat." McMullen, "History of Air Defense Weapons"; and ATS lecture manuscript, "Air-to-Air Guided Missiles," 1.

4. ATS, "Air-to-Air Guided Missiles," 1.

5. Ibid.

6. Ibid. The lesson plan used the following example of an air-to-air intercept to illustrate the geometric problem: "The B-45 flying at 500 miles per hour is travelling south. The P-51 [propeller-driven aircraft] and P-88 [jet-powered aircraft] flying 450 miles per hour and 677 miles per hour respectively are flying north about one mile west of the B-45 flight path. When these two fighters sight the bomber, it is two miles away. Now let both fighters attack using a curve of pursuit. Both will fly so that the acceleration on the pilot never exceeds 4 Gs. The P-51 flies around and may be able to get in a short burst at fairly long range. If the pilot miscalculated slightly, he will never come within firing distance of the B-45. The P-88 will find itself several miles from the B-45 when it has arrived at the same heading as the bomber. It will be unable to fire a single round and will be practically out of identifying sight of the bomber. Had the P-88 been an aircraft flying at 1,200 miles per hour, the problem would be even more acute. At this speed, the radius of curvature becomes 4.63 miles. When the 1,200 miles per hour aircraft comes to the same heading as the bomber, it will be 8.26 miles to the east of where the B-45 was originally and about four miles astern. Therefore, as aircraft speeds rise, it will become more and more difficult for fighters to attack other aircraft."

7. Ibid., 2. There is an interesting parallel between Edward Constant's notion of a *presumptive anomaly* that led to the turbojet revolution and the presumed necessary shift from cannon to missile armament predicated by the same turbojet revolution. Constant proposed, "Presumptive anomaly occurs in technology, not when the conventional system fails in any absolute or objective sense, but when assumptions derived from science indicate either that under some future conditions the conventional system will fail (or function badly) or that a radically different system will do a much better job. No functional failure exists; an anomaly is presumed to exist; hence presumptive anomaly." Constant, *Origins of the Turbojet Revolution*, 15. In this instance, the scientific limitations associated with gunpowder and bullets were presumed to limit their effectiveness in the jet-age future. The limitations of guns in air combat can also be interpreted as an example of Hughes's notion of a "reverse salient"—a laggard system component that "holds up technical progress." Hughes, "Evolution of Large Technological Systems," 73; and MacKenzie, *Inventing Accuracy*, 79–80.

8. ATS, "Air-to-Air Guided Missiles," 2.

9. Ibid.

10. Wildenberg, "A Visionary Ahead of His Time," 6.

11. Ibid.; and ATS, "Air-to-Air Guided Missiles," 4.

12. McMullen, "History of Air Defense Weapons," 12. The ATS lecture stated, "The project [JB-3] was cancelled when it was decided that the missile no longer met the requirements of an air-to-air missile because it was too large in size and lacked sufficient maneuverability." ATS, "Air-to-Air Guided Missiles," 4.

13. Wildenberg, "A Visionary Ahead of His Time," 6.

14. McMullen, "History of Air Defense Weapons," 44. Illustrative of the relative importance granted to advanced armament following the war, "item three on the revised [1947] AAF [Army Air Forces] priority list specified the need for 'greatly improved defense armament for bombers,' and [the recommendation] that the bomber launched air-to-air missile should proceed on a high priority." Wildenberg, "A Visionary Ahead of His Time," 8.

15. Wildenberg, "A Visionary Ahead of His Time," 8; and Cherny, *Candy Bombers*, 231. For example, Truman demanded that the military limit its spending to an inflexible $15 billion for fiscal year (FY) 49.

16. McMullen, "History of Air Defense Weapons," 47.

17. Ibid.; and Wildenberg, "A Visionary Ahead of His Time," 8.

18. McMullen, "History of Air Defense Weapons," 88.

19. Hughes's family of Falcon missiles underwent several changes in designation during its almost 40-year life. Initially, the Air Force assigned aircraft type designations to its guided missiles; as an interceptor missile, the Falcon missile became the F-98. However in 1955, the Air Force changed its missile designations to use a GAR (guided air rocket) prefix, and the radar-guided Falcon became known as the GAR-1 (alternate versions of the Falcon became the GAR-2, GAR-3, and GAR-4). In 1963 under the secretary of defense's direction, the services standardized the nomenclature, adopting the AIM (air intercept missile) prefix for guided missiles, and the Falcon family of missiles assumed the AIM-4 designation. Windelberg, "A Visionary Ahead of His Time," 8.

20. Air Research and Development Command (ARDC), *Evaluation Report*, 2.

21. McMullen, "History of Air Defense Weapons," 88–89.

22. Westrum, Sidewinder, 28.

23. McMullen, "History of Air Defense Weapons," 157 and 277.

24. Ibid., 277.

25. Ibid., 284; and ARDC, *Evaluation Report*, 1–2. The follow-on GAR-3 also raised the acceptable aircraft to launch a missile from Mach 1.3, based on the F-102, to Mach 2.0, based on the Air Force's faster F-106.

26. McMullen, "History of Air Defense Weapons," 278; and ARDC, *Evaluation Report*, 8, 12. The ARDC report prophetically warned that "a chain is not stronger than its weakest link and even though the missile itself may be highly reliable, the fire control system, because of its complexity, may cause trouble." The sentence's reference to a "highly reliable" missile is suspect. The report later noted, "The probability of hit for each missile is 0.25 giving a 0.578 probability of hit for a salvo of three missiles."

27. McMullen, "History of Air Defense Weapons," 278; and Holloman Air Development Center, *Test Report on GAR-1*, 5. The 29 October 1956 test performance report alerted that "out of 48 missiles launched from 1 January 1956 until 1 September 1956, only seven intercepted their target."

28. McMullen, "History of Air Defense Weapons," 278–80.

29. Westrum, *Sidewinder*, 34 (emphasis in original).

30. McMullen, "History of Air Defense Weapons," 280.

31. ARDC, *Evaluation Report*, 2. The 1956 report referred to the GAR-2 infrared missile as the GAR-1B. The missile changed designations on 1 March 1956, shortly before the report's release. The evaluation report also reflected the Air Force's dominant vision of air combat against fleets of invading Soviet bombers. Curiously absent from the assumed advantage that the infrared missile "will select a target" was the criteria that the missile actually guide toward the target that it was fired against; apparently, any target would do, and there would supposedly be plenty of them in the sky. *Ground clutter* occurs anytime the radar is pointed below the horizon; radar energy reflected off the ground often masks the target return. Stimson, *Introduction to Airborne Radar*, chapter 22.

32. McMullen, "History of Air Defense Weapons," 283.

33. Ibid., 284.

34. Ibid.

35. Ibid.

36. Ibid., 47.

37. Ibid., 88.

38. Westrum, *Sidewinder*, 30.

39. Ibid.

40. "New Missile Ready," 11.

41. Wildenberg, "A Visionary Ahead of His Time," 8.

42. Westrum, *Sidewinder*, 28.

43. Ibid.; and ARDC, *Evaluation Report*, 1.

44. ARDC, *Evaluation Report*, 1–2. Additionally, the small size of the warhead meant that its effects on the target would be negligible unless the missile hit the target.

45. Westrum, *Sidewinder*, 32.

46. Ibid., 44; and Bugos, *Engineering the F-4 Phantom II*, 78–79.

47. Westrum, *Sidewinder*, 44–45.

48. Ibid.; and Bugos, *Engineering the F-4 Phantom II*, 79. Bugos elaborated on the design limitations of Sperry's Sparrow I: "The missile homed and maneuvered best when the fins were in the x position, but it carried and launched best with the fins in the + position. However, just that one-eighth of a turn disrupted the gyros. Also, the pilot had to power up the homing head as long as he suspected enemy aircraft nearby, causing reliability problems. Furthermore, beam riding presented a problem whenever the launch aircraft and the target aircraft maneuvered relative to each other. The missile intercepted the changing beam as a curve rather than as a new direct route between itself and the target, and it spent its thrust following that curve."

49. Michell, *Clashes*, 15; ARDC, *Evaluation Report*, 1; and Westrum, *Sidewinder*, 44–46.

50. Westrum, *Sidewinder*, 132.

51. Ibid., 130.

52. Ibid., 138–39; and ARDC, *Evaluation Report*, 12. The 1956 evaluation report was prophetic, noting, "This complex weapon system [the Falcon] will require large numbers of trained airmen." According to Westrum, the Sidewinder's ruggedness was illustrated in dramatic fashion during a Navy demonstration of the Sidewinder for Air Force representatives at Holloman AFB, New Mexico, 12–16 June 1955. Asked by Hughes's engineers if they wanted to store their Sidewinder test missiles in a temperature- and humidity-controlled room with the Falcon test missiles, the Navy engineers shrugged and instead elected to store their missiles "on a mattress in the bed of a pickup truck."

53. Westrum, *Sidewinder*, 161, 176–78, and 186–87. The Air Force initially adopted the Navy's AIM-9B version but then elected to develop subsequent versions of the Sidewinder

independent of the Navy. During Vietnam, F-4 pilots like Maj James Hargrove, pilot of Speedo 1 on 14 May 1967, lobbied hard to discard the Air Force's AIM-9E missiles in favor of the Navy's AIM-9D. During an interview on 19 September 1967, Hargrove commented, "The A[IM-]9D is something that we could probably have like within a couple of weeks, if we made the decision to get it, and it would give us a lot better missile capability for close-in fighting like we're doing up there with MiGs." Hargrove, oral history interview, 15. Bugos compared the Sidewinder with the Sparrow, noting, "The Sparrow III was a high-cost solution to relieving dogfighting duties. . . . But its complex radar made the Sparrow expensive and unreliable. At twice the cost, its success rate in test flights was half that of Sidewinder." Bugos, *Engineering the F-4 Phantom II*, 89.

54. "It was not noticed that the minimum range of the missile was the beginning of the effective envelope of aircraft cannon, which were more effective the closer the range." Michell, *Clashes*, 16.

55. Poor cockpit design and complex armament switchology plagued the F-4 design. Lt Col Steve Ritchie, an Air Force Vietnam war ace, derided the F-4's "cockpit arrangement—particularly the positioning of the master arm and several other vital switches." Ritchie, "Foreword," 6. Anderegg described F-4 pilots' attempts to improve functionality in the cockpit: "Some pilots went to their crew chief and asked for a piece of the stiff plastic tubing the maintenance troops used to take oil samples from the engines. The pilot would then cut a two-inch length of the tubing and slip it over the missile select switch. . . . [That way], if [the pilot] quickly needed a [different type of missile], he could swat the plastic tubing down with his left hand." Anderegg, *Sierra Hotel*, 12.

56. Michell, *Clashes*, 15; see note 31 for information on ground clutter.

57. Ibid., 13. Early AIM-9s did not use a cooled infrared seeker; later versions did, enabling better target discrimination and tracking. The AIM-9 also suffered from severe employment restrictions—the interceptor had to be flying at less than 2-Gs when the missile was launched or the missile would fail to guide. Westrum, *Sidewinder*, 177; and Davies, *USAF F-4 Phantom II*, 18.

58. Capt John R. Boyd noted that the attacker's task became more difficult "when employing [an] AIM-9B [Sidewinder] against a maneuvering target, [because] the cone not only diminishes in size, it also changes in shape." Boyd, "Aerial Attack Study," 42

59. McMullen, "History of Air Defense Weapons," 158.

60. Ibid., 290. For comparison purposes, the atomic bomb dropped on Hiroshima detonated with the force of 12.5 kilotons. Rhodes, *Making of the Atomic Bomb*, 711.

61. Schaffel, *Emerging Shield*, 234; and McMullen, "History of Air Defense Weapons," 294. The Joint Chiefs of Staff set 1 January 1957 "as the target date for air defense forces to become operational with nuclear weapons." According to Schaffel, "To prove the weapon safe for air defense over populated areas, several volunteers stood directly below the detonation in the Nevada desert."

62. McMullen, "History of Air Defense Weapons," 294–96.

63. "The rhetoric of denial seemed to provide powerful arguments against wasting time on the expensive and complicated guided missiles for use in air-to-air combat." Westrum, *Sidewinder*, 32.

64. Knaack, *Post–World War II Fighters*, 69. The F-86D, which became operational in April 1953 more than two years behind schedule, shared only a common wing design with its predecessor of Korean War fame. The F-86D relied on "interception radar and associated fire-control systems" that "could compute an air target's position, guide the fighter on to a beam-

attack converting to a collision course, lower a retractable tray of 24 rockets (2.75-inch [Navy-designed] Mighty Mouse, each with the power of a 75-mm shell) and within 500 yards of the targets fire these automatically in salvos."

65. Ibid., 83–97. After several production fits, the Air Force elected to replace the 20 mm nose-mounted cannon armament of the F-89C with "104 2.75-inch folding-fin aerial rockets (FFAR), carried in permanently mounted wing-tip pods" in the follow-on F-89D, which became operational on 7 January 1954. In March 1954 during the F-89D production run, the Air Force elected to modify the F-89 wingtip pods to incorporate 42 standard FFARs and six Falcon missiles. The modified aircraft became the F-89H. The final model of the F-89 earned a new designation, the F-89J, based solely on the significance of its armament—"two Douglas-built, unguided, air-to-air MB-1 Genie [nuclear-armed] rockets."

66. "The success of the F-94C's all-rocket armament hinged on rocket accuracy and interceptor performance reliability. The F-94C and its rockets had neither." Ibid., 108.

67. Ibid., 159. The F-102, originally dubbed the "'1954 Interceptor' for the year it was expected to become operational," was specially designed to combat the expected speed and altitude capabilities of new Soviet intercontinental jet bombers. The aircraft did not enter operational service until April 1956. The F-102 was the first aircraft developed under the weapons system concept, which married the development of the aircraft and its accompanying Falcon armament into a weapon system, thereby theoretically ensuring that each component retained compatibility with the other components. As noted earlier, this imposed significant size constraints on the F-102's Falcon missiles.

68. Mets, "Evolution of Aircraft Guns," 225–26; and Michel, *Clashes*, 11 and 158. Michel noted that the Air Force "stopped the development of guns for fighter aircraft in 1957 (fortunately not until after the M-61 Vulcan was developed)."

69. According to Thomas Hone, the faster-paced, jet-powered air combat over Korea confirmed the Air Force's armament worries of the late 1940s: "Air-to-air combat in Korea was different than in World War II. Jet fighters approached, engaged, and disengaged at much higher speeds. Firing opportunities were brief and fleeting. Neither the MiG nor the Sabre (but especially the MiG) had armament or gunsight suited to this cascading, turbulent form of combat. As a result, losses on both sides were lower, given the number of aircraft sortied, than during comparable battles in World War II." Hone, "Korea," 496. Unfortunately, the Air Force failed to adapt based on its experiences. Maj Gen Emmett O'Donnell's statement to Congress in 1951 aptly summarized the prevalent attitude within the Air Force during the Korean War: "I think this is a rather bizarre war out there, and I think we can learn an awful lot of bad habits in it." Crane noted, "Perceived success provides little incentive for improvement, and because of this confidence [following the Korean War] and SAC's focus on general war, most of the lessons about airpower in limited wars were lost or deemed irrelevant. They would have to be relearned again, at high cost, in the skies over Vietnam." Crane, *American Airpower Strategy*, 60, 170.

70. Knaack, *Post–World War II Fighters*, 210.

71. Michel, *Clashes*, 16.

72. Boyne, *Phantom in Combat*, 10.

73. Ibid., 32; and Bugos, *Engineering the F-4 Phantom II*, 1.

74. Bugos, *Engineering the F-4 Phantom II*, 24.

75. Ibid., 25.

76. Ibid., 27–28.

77. Boyne, *Phantom*, 32; and Bugos, *Engineering the F-4 Phantom II*.

78.   Bugos, *Engineering the F-4 Phantom II*, 27–28.

79.   Michell, *Clashes*, 13.

80.   Bugos, *Engineering the F-4 Phantom II*, 3 and 28.

81.   Knaack, *Post–World War II Fighters*, 333.

82.   Enthoven and Smith, *How Much Is Enough?*, 263; Thornborough, *USAF Phantoms*, 11; Bugos, *Engineering the F-4 Phantom II*, 120; Crane, *American Airpower Strategy*, 172; and Hannah, *Striving for Air Superiority*, 30. Multiple interpretations of the Air Force's F-4 procurement decision exist. Enthoven and Smith noted that, "the [Defense] Secretary's decision in 1962 to stop the F-105 and to procure the Navy's F-4 for the Air Force—over the strong official objections of the Air Force—was based on a cost-effective analysis." Thornborough suggested that McNamara "brought pressure on the Air Force" to select the F-4 over the F-105; such a decision would "maintain US service modernization rates while capitalizing on longer production runs and lower joint-service lifecycle costs to reduce unit prices and keep the budget watertight," which were key McNamara priorities. However, Bugos characterized the acquisition decision as being informed more by Air Force analysis than by secretary of defense meddling. Bugos described the F-4/F-105 fly-off in November 1961 at Nellis AFB, Nevada, and the subsequent decision process: "The two aircraft performed equally well, and the choice once again became a matter of policy. Several considerations added up in the Phantom's favor. First, the Air Force also needed a fast, low-flying aircraft for tactical reconnaissance. The F-4 flew low and fast, and, once McDonnell removed the APQ-72 radar, the Air Force could add lots of cameras, radars, and other sensors. . . . Second, [President] Kennedy was increasing the number of nuclear warheads in the Air Force inventory, and General William Momyer . . . thought TAC could only compete, politically, with the Strategic Air Command if TAC flew a fighter like the F-4 that could also drop nukes. Most importantly, Lt General Gabriel Dissoway, the deputy chief of staff for Programs and Requirements at Air Force Headquarters, praised the Phantom's flexibility for the cost." The identity crisis and insecurity gripping TAC at the turn of the decade stemmed from a SAC-dominated Air Force bureaucratic structure. Crane noted that TAC's focus "primarily on nuclear strikes in support of NATO was a sure way to garner budget support and force structure in the national security environment of the mid-1950s, but it skewed the focus of USAF tactical airpower away from limited and conventional wars. [General] Weyland and his TAC successors struck a Faustian bargain with the atomic Mephistopheles, transforming the organization into a 'junior SAC.' " Hannah quoted from Caroline Ziemke's PhD dissertation, "In the Shadow of the Giant: USAF Tactical Air Command in the Era of Strategic Bombing, 1945–1955": "By the late 1950s, the command [TAC] perceived itself primarily as an extension of nuclear deterrence—a sort of massive retaliatory capability on the regional rather than global level. Other missions, especially air-ground and air-air operations, fell into neglect as TAC became an increasingly specialized strike command. Like Dorian Grey, TAC had sold its soul in exchange for vitality, and in Vietnam, the world got a look at its aged and decrepit conventional structure." Hannah described the repercussions: "By becoming a miniature version of SAC, TAC entered the air war in Vietnam with aircraft that were ill suited for aerial combat with the small, highly maneuverable MiG fighters."

83.   Bugos, *Engineering the F-4 Phantom II*, 2.

84.   Ibid., 121.

85.   Ibid., 122–23; and Thornborough, *USAF Phantoms*, 11.

86.   Knaack, *Post–World War II Fighters*, 265. The multirole mission of the Air Force F-4, "covering the entire tactical mission—close air support, interdiction, and counter air"—was detailed in Specific Operational Requirements 200, dated 29 August 1962.

87. Burns, oral history interview, 3.

88. Catledge, oral history interview, 31–32.

89. History, 12th Tactical Fighter Wing, vol. 1.

90. TAC, *F-4C Limited Evaluation*, 55–59. The evaluation report noted that the disparity between the number of sorties flown and the number of missiles launched was due to "aircraft or target problems."

91. Knaack, *Post–World War II Fighters*, 266. Early requirements for the F-4C to support the Air Force's AIM-4 Falcon missile were dismissed to avoid delaying production.

92. Hannah, *Striving for Air Superiority*, 94.

93. "The fuzzy thinkers thought that was great. [In their minds,] it was a hell of a lot better to fly three hours with drop tanks than it was to fly an hour and 20 minutes in a very productive mission that involved doing a lot of different things with the airplane." Blesse, oral history interview, 61–65.

94. Hannah, *Striving for Air Superiority*, 95.

95. Michel, *Clashes*, 160. Additionally, because the Air Force used the F-4 for both air-to-air and air-to-ground missions, its crews had to be qualified and trained for both. As a result, air-to-air training, especially training emphasizing dogfighting skills, was virtually nonexistent.

96. Hannah, *Striving for Air Superiority*, 97.

97. "By the time intelligence assessments revealed the Soviet ICBM emphasis in the early 1950s, most air-to-air missile programs were well on their way. The technology was too promising to discard." Westrum, *Sidewinder*, 29.

98. Michell, *Clashes*, 13.

99. Blesse, oral history interview, 59–60.

Chapter 5

The Gun Resurrected

We were voices in the wilderness in those days.

—Maj Gen John Burns, USAF

In 1963, as the specter of air combat over Vietnam grew, the Air Force hurriedly organized an internal assessment of its aircraft capabilities for a nonnuclear, limited war. Completed in January 1964, the resulting secret report, *Project Forecast*, concluded that the majority of the Air Force's tactical fighter fleet was unprepared and ill-equipped for the pending conflict. The one ray of hope lay in the Air Force's newest fighter, the F-4C, which, according to the report, "has an equal or better capability than present interceptors against the same air targets. . . . In addition, the F-4C [is] useful against fighter and recce [reconnaissance] aircraft."[1] The first engagements between the USAF F-4Cs and the North Vietnamese MiG-17s in 1965 seemed to confirm the enthusiastic assessments trumpeted in *Project Forecast*. Unfortunately, the report proved exceedingly optimistic. Over the next three years, the gross inadequacies of the Air Force's air-to-air missile armaments in modern, fighter combat would become all too apparent, as would the Air Force's penchant for technological exuberance.

Early Air Combat

After a grueling transpacific flight, 18 F-4C aircraft from the 555th Tactical Fighter Squadron (TFS), 12th TFW, MacDill AFB, Florida, touched down on the southwestern edge of Okinawa on 10 December 1964.[2] As the first F-4Cs to deploy to the Pacific region, the members of the "Triple Nickel" squadron were tasked with "establish[ing] transoceanic deployment procedures and test[ing] aircraft maintainability" for the Air Force's barely one-year-old weapons system "away from the luxuries of home."[3] The deployment paved the way for the bevy of F-4s that would eventually provide almost 30 percent of the tactical aircraft fleet in Southeast Asia (SEA) in 1968.[4] That influx began in earnest in April 1965 when the 15th TFW's 45th TFS, also from MacDill, sent 18 of its F-4C aircraft to Ubon Royal Thai AFB, Thailand.[5] Over the next year, the number of F-4Cs in theater would increase more than tenfold, from 18 in 1965 to 190 by the end of 1966. The Air Force concentrated its F-4s at

three bases: the 8th TFW at Ubon; the 12th TFW at Cam Ranh AB, South Vietnam; and the 366th TFW at Da Nang AB, South Vietnam.[6]

The USAF F-4C Phantom II first drew MiG blood on 10 July 1965.[7] On that day, a flight of four 45th TFS F-4Cs engaged and destroyed two MiG-17s who were harassing a flight of F-105 Thunderchiefs attempting to attack the Yen Bai ordnance and ammunition depot 30 miles outside Hanoi.[8] In what the Phantom flight lead, Maj Richard Hall, later described as "a schoolbook exercise," the F-4Cs, armed with the standard complement of four Sparrow and four Sidewinder missiles each, fired eight Sidewinder missiles at the two MiGs during the four-minute engagement.[9] The next day back in Thailand, each victorious two-person F-4 crew was awarded a Silver Star; the aircrews from the accompanying F-4s received Distinguished Flying Crosses.[10]

Although Hall's confident assessment of the engagement did not address it, American missile and aircraft performances that afternoon were far from perfect. In one aircraft piloted by Capts Kenneth Holcombe and Arthur Clark, the violent maneuvering during the engagement caused their radar to fail, instantly rendering their Sparrow missiles worthless for the remainder of the flight. Additionally, two of their four Sidewinder missiles failed to launch when fired. Fortunately, the remaining two Sidewinders did function properly and brought down a MiG: one missile "produced a large fireball at or slightly to the right of the MiG"; the other "detonated slightly to the right of the MiG."[11]

Capts Thomas Roberts and Ronald Anderson, flying in an accompanying F-4, had a similarly frustrating experience. Their first Sidewinder "streaked past the [enemy's] tail and detonated four to six feet from the left wing tip." However, the MiG kept flying, "rolling slowly to the left in a bank." Flustered, Roberts "hastily" launched a second Sidewinder missile without a valid missile tone (a growl in the aircrews' headsets indicating that the missile had acquired the target); it also "proved ineffective." Roberts's third Sidewinder "tracked well and exploded just short of the MiG's tail," but because he "saw no debris emitting from the aircraft," he launched his last Sidewinder missile. Roberts and Anderson could not observe their last missile's flight path because they came under AAA fire that forced them to initiate aggressive defensive maneuvers.[12]

This first F-4C versus MiG-17 engagement foretold many of the problems the F-4C fleet would face in the coming years: unreliable electronic equipment, faulty missiles and imprecise weapons employment (e.g., firing a Sidewinder without acquiring a valid tone), and the difficulty of engaging a MiG while also defending against ground-based air defenses like AAA and SAMs.[13] Yet the engagement also validated, in some Air Force leaders' minds, earlier

appraisals that the 1950s-era Soviet-built MiGs were no match for the Americans' modern F-4C fighter.

One problem that drew attention that day was the significant impact of the United States' restrictive rules of engagement (ROE) governing the F-4C weapons system and its aircrews. To reduce the possibility of airborne fratricide, aircrews were required to positively identify their target before firing a missile. Unfortunately, Air Force fighters such as the F-4C lacked reliable means to do so electronically, thereby often necessitating a visual identification of the suspected enemy aircraft.[14] Writing after Vietnam, General Momyer, who served as the Seventh Air Force commander responsible for all tactical air operations in Southeast Asia during the war, described the ROE's impact: "The necessity for a visual identification of the enemy hindered successful shoot-downs by reducing the frequency of opportunities for employing, for example, the Sparrow. . . . We forfeited our initial advantage of being able to detect a MiG at thirty to thirty-five mile range and launch a missile 'in the blind' with a radar lock-on from three to five miles. Many kills were lost because of this restriction."[15] A *New York Times* article detailing the 10 July 1965 engagement reported that most F-4 pilots "were not too happy with the requirement for visual identification . . . [but] that they preferred this to shooting down one of their own aircraft by mistake."[16]

Pilot reports and interviews after the July engagement also alluded to the F-4's need for better short-range armament. Whereas the North Vietnamese MiG adversaries, often armed solely with air-to-air cannons, had earlier proven the continued viability of the gun in jet combat, several members of the victorious 10 July 1965 F-4 flight dismissed the combat potential of a gun on the F-4. For example, Holcombe warned that adding a gun to the F-4 "will just get people into trouble" by tempting aircrews to get dangerously "low and slow" with the MiGs.[17] Holcombe's concerns echoed the conclusions of the Air Force's 1965 Feather Duster program, which warned that trying to outmaneuver the smaller MiG aircraft was an F-4 air combat "no-no."[18] Thus, instead of entertaining the potential of an antiquated-but-proven-effective system, many aircrews longed for better, more advanced missiles that would allow them to exploit the F-4's overwhelming thrust advantage and high-speed capability when attacking the more maneuverable MiGs at close range.

The next nine months following the July shoot-down witnessed only sporadic MiG activity as the North Vietnamese Air Force retooled the country's air defense system. Central to the upgrade were new ground-controlled intercept (GCI) procedures to vector their MiG-17 and recently acquired and more sophisticated MiG-21 fighters into favorable positions against US aircraft and the deployment of large numbers of SAMs such as the SA-2 across

the theater.[19] The new arrangement proved formidable. The United States did not claim another MiG until mid-April 1966. By then, the MiGs had claimed four more US fighters and had harassed numerous F-105 fighter-bombers, forcing them to jettison their ordnance while defensively reacting to the attacking MiGs. Additionally, the North Vietnamese SAMs levied a heavy toll on the American fighters.[20]

The next F-4C MiG kill occurred on 23 April 1966; four F-4Cs engaged four MiG-17s and destroyed two of them after firing seven missiles—five Sparrows and two Sidewinders. Reminiscent of the missile problems that frazzled the F-4C aircrews on 10 July 1965, of the five Sparrows launched one was fired inside its minimum range, two missiles' motors never ignited after launch, one guided but missed the target, and one hit and downed a MiG. Of the two Sidewinders launched, one was fired without a valid tone, and the other hit and destroyed the second MiG.[21]

In the F-4C's first two successful engagements, four MiGs were downed at a cost of 15 missiles. Of the 15 missiles fired, four failed to launch properly (27 percent), and three were launched outside of parameters (20 percent). But those numbers only accounted for missile shots during engagements that resulted in a kill. For example, that same day—23 April 1966—two F-4Cs were dispatched to intercept a pair of MiG-21s en route to attack an orbiting Douglas EB-66 electronic jamming aircraft. Unfortunately, the two F-4Cs came up empty-handed, but not for lack of effort; the two Phantoms fired a total of six Sparrow and Sidewinder missiles against the MiGs to no avail.[22]

Despite the missiles' lackluster performance in these and other engagements, the earlier antigun sentiment expressed by Holcombe persisted. One of the pilots from the successful 23 April engagement commented, "The need for [an] F-4 gun is overstated, although it would be of value if it could be obtained without hurting current radar and other systems performance. If you are in a position to fire [the] gun, you have made some mistake. Why, after a mistake, would a gun solve all [your] problems? Also, having a gun would require proficiency at firing, extra training, etc. [We] have enough problems staying proficient in [the] current systems. If the F-4 had guns, we would have lost a lot more [F-4s], since once a gun duel starts, the F-4 is at a disadvantage against the MiG."[23]

Missile performance was markedly better three days later when Maj Paul Gilmore and 1st Lt William Smith scored the Air Force's first MiG-21 kill. Gilmore fired three Sidewinders at the MiG. His first Sidewinder severely crippled the MiG, and the pilot ejected from the aircraft. However, Gilmore thought that the first missile had missed the target and, not seeing the pilot eject, repositioned and fired another missile; that second missile clearly

missed the target. "After missing twice," Gilmore explained, "I was quite disgusted. I started talking to myself. Then I got my gunsights on him and fired a third time. I observed my [Sidewinder] missile go directly in his tailpipe and explode."[24] As a *New York Times* article describing the combat noted, "It was only then that Major Gilmore's wingman, who had temporary radio failure, was able to radio him that the first missile had hit and that the pilot had ejected and parachuted."[25] Following the kill, the two F-4Cs attempted to engage a second MiG-21, but Gilmore's last Sidewinder missile missed the target, and now low on fuel, Gilmore's flight of F-4s decided to return home.[26]

Air Force leaders greeted Gilmore's MiG-21 victory with enthusiasm. Early analyses concluded that the F-4 was at a significant disadvantage relative to the modern Soviet MiG-21. The Southeast Asia Counter-Air Alternative (SEACAAL) study, forwarded to the secretary of the Air Force a few weeks later on 4 May 1966, predicted that the Air Force "should expect to lose three F-4s for each MiG-21 . . . shot down."[27] The results from Gilmore's 26 April engagement seemed to refute that analysis. It also proved that, while side-by-side comparisons of aircraft energy-maneuverability diagrams could help inform American pilots of where their aircraft were expected to perform best against the MiG fighters, actual air combat was too fluid to draw definitive categorizations.[28] Aircrew experience, area radar coverage, environmental factors, and chance all played a significant role in dictating who would return home to paint a star on the side of his or her aircraft.

As MiG activity increased during the remainder of April and May 1966, several American pilots continued to follow the Feather Duster advice and tried to avoid entering a turning engagement with the MiGs. However, sometimes during the course of an engagement, attacking MiGs could force the F-4 pilots to defend themselves with a series of aggressive, defensive turns. In these situations, the Phantom crews had no choice but to discard the approved combat solution.

Despite this emerging combat reality, many pilots let their faith in missile technology and published tactics color their opinions of air-to-air armament. Most continued to categorically dismiss the potential value of a gun on the F-4. Following a successful engagement on 29 April 1966 in which an F-4C downed a MiG-17 with a Sidewinder missile, one Air Force pilot commented, "It would be undesirable and possibly fatal for an F-4 to use a gun in fighting with a MiG because the MiG is built to fight with guns and the F-4 is not."[29]

However, attitudes began to change a month later. According to Michel, "By the end of May, Air Force F-4 aircrews reported losing much of their confidence in the Sparrows."[30] Additionally, several F-4 aircrews reported that

many times in combat they could have dispatched an enemy MiG with a gun, if only they had had one.[31]

Because the F-4C did not have a gun, nor were there any plans to add a gun to the platform, the Air Force focused its efforts on improving the "poor" performance of the F-4's missile armament.[32] The uninspiring combat results were difficult to ignore. From April 1965 through April 1966, the primary armament of the F-4, the AIM-7 Sparrow—the weapon that had guided the aircraft's design and development—had accounted for only one kill, downing a MiG-17 on 23 April 1966.[33] To address the problem, the Air Force appointed a special team of Air Force and F-4/Sparrow specialists to travel to SEA to personally review the weapon system's combat performance and "recommend the required actions necessary to enhance success of future Sparrow/Sidewinder firings." Unfortunately, the team concluded that even "assuming proper maintenance of both aircraft and missiles, the probability of kill with the Sparrow can be expected to be low."[34] The team found that during the period from 23 April to 11 May 1966, Air Force F-4Cs fired 13 AIM-7s (and tried to fire an additional three which never left the aircraft) to down a single MiG—a 6 percent hit rate.[35] Whereas some failures could be attributed to faulty missile maintenance and aircraft loading or improper pilot performance, the team noted that "four of the Sparrows launched during the period 23–24 April were fired under ideal conditions and missed" for inexplicable reasons.[36]

In spite of these compelling anomalies, the Air Force remained committed to its dominant paradigm and deployed the newest version of the AIM-7, the AIM-7E, to the theater in mid-1966. Unfortunately, the new version did not appreciably improve the combat statistics, adding only one more victory to the F-4's tally by the end of 1966.[37]

The Sidewinder's performance was markedly better—a 28 percent hit rate over 21 shots in April and May 1966—but still less than what aircrews had expected based on earlier, euphoric test reports that had predicted a 71 and 68 percent hit rate for the Sparrow and the Sidewinder, respectively.[38] Additionally, aircrews complained about the Sidewinder's restrictive launch envelope, both relative to the target's position, range, and angle-off, and the 2-G limit when launching the heat-seeking missile. One frustrated Air Force pilot, Maj Robert Dilger, quipped in a July 1967 interview, "The Sidewinder—this is the AIM-9B—totally hopeless in the air-combat environment. It's a reliable missile and it will work most of the time. It has a good Pk, probability of kill, if launched within its parameters. Well, the trouble is you can't launch it in the ACT [air combat tactics] environment within its parameters. It's always going to be out-G'd, just about; so the only thing that we can do with a Sidewinder

is use it as a scare tactic or if the MiGs don't know we're there."[39] Not all pilots shared Dilger's opinion. While acknowledging the missile's restrictive launch envelope, MiG-killer Maj William Kirk of the 433rd TFS concluded, "It's a damn fine little missile if you can get the thing launched under the right parameters."[40]

The problem was that the Sparrow and Sidewinder missiles were neither designed nor tested for fighter-versus-fighter combat. They were designed to shoot down high-altitude, nonmaneuvering, bomber-type targets.[41] Sidewinder engineers never envisioned a requirement to attack small, low-altitude, maneuverable fighters. Sparrow engineers counted on their missile being launched, in Momyer's words, "in the blind," with the target still three to five miles away.[42] The 8th TFW's *Tactical Doctrine* manual, dated 1 March 1967, called pilots' attention to the disparity between the anticipated F-4 combat environment and 1967 reality in Vietnam:

> The F-4C/APQ-100/APA-157 weapons control system and associated armaments, the AIM-9B and the AIM-7E, are designed to be employed in a non-maneuvering environment using close control. This close control coupled with the long ranges of the armament provide an element of surprise and thus a high probability that the target will be in a non-maneuvering state. Further, the system was designed more as a defensive rather than an offensive system. *The chances of employing the system in this manner in SEA are very remote.*

> The system as employed in SEA is in an offensive role in the enemies [*sic*] environment. Therefore, the enemy has the advantages since he can employ radar and fighters in defense against the F-4C system. The enemy knows more about us than we know of him in this type of environment. The F-4C now becomes the hunted as well as the hunter. Further, due to saturation in the battle areas, visual identification is necessary prior to armament launch. In order to positively identify the target, the F-4C must move into visual acquisition range and the chances are very good that the enemy will see the F-4C at the same time, since the enemy has knowledge of approaching aircraft through ground radar control. Once the attackers' presence is known to the enemy, it becomes a battle of aircraft maneuvering for advantageous firing position.[43]

The Air Force's decision to limit aircrews to a single 100-mission tour unless they volunteered for a second also began to take its toll on the F-4C's combat performance. As the Vietnam War dragged on, the personnel policy created an insatiable appetite for fighter aircrews. Responding to the demand, the Air Force "simply lowered standards, brought in more students, and graduated more pilots from pilot training."[44] The Air Force allowed, and then eventually required, pilots with little or no tactical fighter experience to transition to fighter aircraft like the F-4 and fly a combat tour.

Regardless of prior tactical experience or lack thereof, new Phantom pilots completed a six-month training program at a replacement training unit

(RTU). However, air-to-air combat training at the RTU was limited; aircrews had to be trained for every potential F-4 mission, including basic skills such as how to take off and land the aircraft, in only six months. The Air Force's "corporate belief that air combat maneuvering among inexperienced pilots would lead to accidents," combined with the dominant culture that prioritized safety over training, also thwarted efforts to prepare the new aircrews for actual, ongoing air-to-air combat.[45] Navy pilot and Vietnam-ace Randy "Duke" Cunningham characterized the Air Force's aircrew training program as "an out-and-out crime."[46]

The F-4 units in SEA felt the effects. One Air Force pilot commented in July 1967, "Some of our pilots are terrific. I mean they're really top drawer, aggressive, well-trained, well-motivated people. Some of our pilots fall short of these standards, and part of the problem [is] that—through no fault of their own, in a lot of cases—they just don't have the background. [An] 80-hour training course like they get in the RTU program, if they have no previous fighter time, fighter background, fighter tactics, is just not quite enough to bring them up to par."[47]

Despite declining aircrew proficiency and the shortcomings in armament, the F-4C was performing remarkably well in air combat against the MiGs. The first 18 months of combat saw only four F-4Cs lost due to MiG action out of 69 total F-4C losses. In return, the F-4Cs downed nine MiG-17s and five MiG-21s.[48] One Air Force pilot summed up the F-4C's early performance: "With no gun and two types of missiles whose reliability was about ten percent, you'd have to rate the F-4C's abilities as a fighter as low. Still, I'd take that F-4 ride into Hanoi over the F-105 any day!"[49]

More deadly than the MiGs, though, was the heavy concentration of ground defenses the North Vietnamese hid around their lucrative target areas. With mounting losses to SAMs and AAA threatening the Air Force's ability to attack targets in NVN, in October 1966 the Air Force responded by deploying the QRC-160 electronic countermeasures (ECM) jamming pod, which was designed to confuse the enemy SAM and AAA fire-control radars.[50]

Initially, the ECM pods were loaded on the F-105 fighter-bombers so that they could attack heavily defended targets. "But after the F-105s started carrying the [ECM] pods," a 31 December 1966 SEACAAL report stated, "the [accompanying] F-4s', having neither jamming nor warning equipment, began to suffer unusually heavy losses to SA-2s. As a consequence, the F-4s were restrained from flying into SA-2 areas—which were also the MiG areas—until protective equipment was available." The report noted that the North Vietnamese quickly took advantage of the F-4s' absence—"MiG activity has surged this past month and they have enjoyed appreciable success in harassing our aircraft."[51]

Still, the SEACAAL report was optimistic. "Adaptor pylons [to mount the ECM pods] have been airlifted to SEA so that by 1 January 1967, some F-4s can also be pod equipped." But, reflective of the true Catch-22 situation, the report's next sentence read, "The pods are in short supply at present so they can be used on F-4s only by taking them off F-105s."[52] The aircraft shared the valuable pod resources, relying on special formations that maximized ECM protection for all flight members, until production could catch up with demand, which occurred in mid-1967.[53] As the Air Force scrambled in 1966 to deal with the emerging SAM and AAA threat, it also renewed its efforts to address the poor performance of the F-4's air-to-air armament.

A Focus on Technical Solutions

Michel described the air-to-air results of Rolling Thunder as a "Rorschach test for the US Air Force and Navy." True to the test, "the two services drew almost exactly the opposite conclusions from their battles with the MiGs." Whereas the Navy "decided that lack of training was the problem," which led to the establishment of their famed Top Gun Fighter Weapons School in 1969; the Air Force, gripped by the promise of technology, "looked at its losses to MiG-21s . . . and decided that the problem was a technical one."[54] The Air Force consequently went to great lengths to address the technical deficiencies of its missiles and its aircraft.[55]

The Air Force, in partnership with the Navy, first sought to improve Sparrow performance. Their initial answer was the AIM-7E Sparrow, which entered the fray in mid-1966. Sporting only minor improvements over the earlier AIM-7D, the AIM-7E failed to address many of the Sparrow's shortfalls. The next AIM-7 version, the AIM-7E-2, was introduced in August 1968. Hailed as the "dogfight Sparrow," Air Force and Navy officials believed the new AIM-7E-2 missile would provide the necessary edge for F-4 aircrews in the tight-turning, high-G, close-range air-to-air engagements that typified combat in the skies over Vietnam. Boasting a "minimum-range plug" that "(in theory) gave the AIM-7E-2 a minimum range of 1,500 feet instead of 3,000 feet, better fusing, and better capability against a maneuvering target," the missile saw only limited use and contributed no additional MiG kills before Rolling Thunder ended three months later.[56] Renewed MiG action in 1971 provided the missile with another opportunity to prove itself, but ultimately the missile failed to live up to the hype. During the course of the Vietnam War, 281 AIM-7E-2 missiles were fired, yet the missiles scored only 34 kills—a dismal 12 percent success rate.[57]

Whereas the Air Force and Navy elected to address the Sparrow's faults collectively, albeit without notable success, the Air Force abandoned the Navy's efforts to improve the Sidewinder in favor of readying its own AIM-4D Falcon, offspring of the 1960s' Hughes GAR-4 air-to-air missile.[58] Accompanying the Air Force's new D-model variant of the F-4 Phantom to the 8th TFW at Ubon in late May 1967, the AIM-4D, although promising better combat performance against fighter aircraft, was not well received by the aircrews. First, the missile retained its 1950s' contact-only fusing system and small warhead. Second, in a horrible misunderstanding of the nature of fighter-versus-fighter air combat, engineers designed the Falcon with only enough cooling supply for two minutes of operation. Compounding matters, "the sequence of switches to start the coolant flow was complicated," and once started, "the coolant flow to the seeker head . . . could not be stopped."[59] Hence, if the missile was not launched two minutes after it was first armed and cooled, then it became a "blind, dead bullet—derisively called the 'Hughes Arrow'—which had to be carried home and serviced before it could be used again."[60] Thus, "the F-4D pilot had a choice: either arm the AIM-4D early in the engagement and hope he would get a chance to use it within the next two minutes, or wait and try to remember to arm it after the fight began and when there was a target available. In a turning dogfight where shot opportunities were fleeting, such restraints on a missile clearly were unacceptable."[61]

In a postwar interview, Brig Gen Robin Olds, World War II ace and former 8th TFW commander credited with 16 air-to-air victories, derided the Air Force's AIM-4D Falcon missile:

> They gave us another weapon called the AIM-4 Falcon built by Hughes for air defense and my only comment on that weapon was that it was no good. It was just no good. In assuming that everything worked just as advertised, which it seldom did, the missile had only 2 ¾ pounds of unsophisticated explosive in it, and it had a contact fuse so the missile had to hit what you're aiming at for this little firecracker to go off. . . . Too many times, time and time again, the missile would pass right through the hottest part of the exhaust plume of the MiG-17 which is about a 12-foot miss and that and, you know, five cents will get you a bad cup of coffee.
>
> Secondly, its launch parameters were much too tight, not as advertised, but as changed once they got the things to the theater. Then they sent in the wire and said what your minimum firing range was under altitude, overtake, G conditions. And it turned out that if you were at 10,000 feet in a 4 G turn, the minimum altitude at which that weapon was any good was 10,500 feet. The maximum range of the little son-of-a-b_ _ _ _ was 12,000 feet or something on that order.
>
> So it's just no good. I mean, maybe, if one of the MiGs would be very accommodating and sort of hold still for you out here, you know, that would be fine. . . . There may have been some occasions, when yes, you could use it, but I never ran into one. In summary,

I didn't like the AIM-4. I don't think it's worth a d_ _ _. Nor do I think it has any growth potential.[62]

Less than three months after the Falcon's introduction to the theater, officers at Pacific Air Forces (PACAF) informed Headquarters USAF in Washington, DC, that it intended to replace the AIM-4D Falcons on its F-4Ds with AIM-9B Sidewinders. The process was more complicated than simply slapping the old Sidewinder missiles back on the aircraft; the F-4D had to be rewired to accept the new, old missiles.[63] The F-4D units would have preferred to upgrade to the Navy's new Sidewinder missile; but instead of modifying its missile rails to accept the Navy's AIM-9D, the Air Force—smacking of technological hubris—elected to design its own Sidewinder, which became the AIM-9E. Development delays ensured the AIM-9E would not reach the theater until after Rolling Thunder concluded, and even then its performance was significantly lacking relative to the Navy's AIM-9D.[64]

In addition to addressing the limitations of its air-to-air missiles, the Air Force addressed some of the problems inherent in the F-4C airframe. Unable to make many design changes to the Navy's F-4 early in the program, the Air Force quickly began drafting requirements for an updated, Air Force–tailored F-4 Phantom. In 1964 the Air Force, working through the Navy, issued a contract to McDonnell Aircraft for a new F-4D.[65] Stemming from the Navy's original F-4 fighter-interceptor configuration, the majority of the Air Force's proposed changes were intended to bolster the F-4's multirole capability. For example, by installing a new "GE AN/ASG-22 servoed Lead Computing Optical Sight Set (LCOSS), which replaced the old, fixed, manually depressed gunsight, and the AN/ASQ-91 automatic Weapons Release Computer System (WRCS)," the F-4D was able to perform "a brand new radar-assisted visual bombing mode known as 'dive-toss,' which increased bombing accuracy and crew survivability in one fell swoop."[66] Engineers also addressed some of the F-4's air-to-air deficiencies, although not all of the changes were successful—aptly illustrated by the AIM-4D debacle. Additionally, engineers designed the LCOSS gunsight with an available air-to-air mode, but since the F-4D lacked an internal gun, the capability went unappreciated and unused when the new Phantom model reached combat in May 1967.

Rhetoric and Reality Converge

By mid-1966, the Air Force finally began to acknowledge North Vietnam's inconvenient refusal to adhere to the American idealistic vision of air combat upon which the Air Force's entire fleet of air-to-air missiles had been built. A

PACAF *Tactics and Techniques Bulletin* discussing "F-4C Fighter Screen and Escort," dated 14 July 1966, noted that since the ideal F-4 engagement— "obtain[ing] long range radar contacts and establish[ing] an optimum attack position within the launch envelope for AIM-7 firing"—was often unachievable, "close-in fighting may become necessary."[67] The report issued by the summer 1966 Heat Treat Team—the Air Force and F-4/Sparrow contractor team tasked with improving missile reliability—echoed the apparent inevitability of close-in maneuvering during MiG engagements and the lack of a viable short-range weapon: "The MiG/F-4C encounters thus far have resulted in close-in maneuvering engagements. Missiles were intentionally fired out of designed parameters in hopes of achieving a 'maybe' hit since guns were not available for the close-in maneuvering."[68] The 31 December 1966 SEACAAL report noted, "The lack of guns on the F-4 is considered one of the factors for the low kill rate in the MiG encounters."[69] Most tellingly, by mid-1966, Air Force mission debriefings implied that North Vietnamese pilots were starting to exploit the disparity in short-range weapons, especially the "'safe zone'— the approximately one-half mile in front of a Phantom created by the lack of a cannon."[70] And, there was no longer any denying that, when push came to shove, the cannon on the F-105 Thunderchief was proving effective.[71] The pressure to equip the Air Force's newest fighter with a 1950s-era gun was reaching a crescendo.

According to Bugos, "as early as October 1963, the Air Force's TAC had suggested an F-4E version, with a built-in gun, to fly as a tactical strike fighter." He also noted, "Air Force pilots anticipated more situations where a gun would be useful."[72] One of those officers was Catledge, the then-colonel who had set up his flip charts in front of Momyer and pleaded for a gun in the F-4. Undeterred by Momyer's brush-off, Catledge persisted and eventually secured funding for a podded gun system.[73]

Another gun proponent was Col John Burns. Tasked in 1964 with helping develop requirements for the Air Force's next-generation F-X fighter, Burns and the other members of the group recommended a new fighter design. The group also suggested "the installation of an internal gun in the F-4, because we became concerned that we [the Air Force] were putting too much reliance on missiles alone."[74] In a 1973 interview, Burns described the advantages of the gun:

> There is only one countermeasure to a gun and that is better performance in the gun platform. . . . . If you've got superior air combat maneuvering performance and you've got a gun—you stick the gun in the guy's ear. There is no countermeasure for that.
>
> So our view, then, was that relying on missiles alone was a serious mistake, which means that you don't need the synergism of a very fine and superior air combat vehicle that

gave you the performance bedrock, and the avionics system to exercise that performance through a *complete and proper complementary set of armaments: radar missiles, IR missiles, and a gun. . . .* We were voices in the wilderness in those days.

. . . We had OST—Office of Science and Technology—and the President's Scientific Advisory Committee all over our backs, and in 1965, arguing about why we don't just put a better radar and better missiles in the F-4. . . . [But by April 1966,] there were many, many [MiG] engagements, and the capabilities and serious limitations of missiles were very amply demonstrated. . . . From then on, the things that we argued about—sanctuaries, maneuvering performance, *the need for guns as well as missiles*—seemed very well demonstrated over North Vietnam.[75] (emphasis added)

On 18 October 1966 the Pentagon announced its intention to purchase "99 improved Phantom jets equipped for the first time with a built-in gun and designed to give the United States clear superiority over Russian-made MiG-21s in Vietnam."[76] Based on a more detailed press release issued the following month, the *New York Times* proclaimed that the "new model of the McDonnell Phantom fighter plane recently ordered by the Air Force will incorporate some new features as a result of lessons learned in the air over North Vietnam and Laos." Leading the discussion of the aircraft improvements was the description of "a 20-mm internally mounted gun with a rate of fire of 6,000 rounds a minute [which] will complement the plane's missile capability and should give it superiority in both long-range action and close combat." Later, the article outlined the combat-demonstrated requirement for the gun: "While the Phantom has the performance and weapons to stay out of range of the MiG[-21] and shoot it down, it is often difficult in a few seconds at high speeds to maneuver into firing position. The lack of internally mounted guns has sometimes meant the escape of a MiG. Although the United States missiles outrange the Soviet missiles, the Sidewinder and Sparrow cannot be fired from close in; they will not 'arm' in time to detonate."[77]

The new F-4E was to be armed with the GE M61 20-mm Vulcan Gatling gun, the same gun that had equipped the F-105D in the 1950s and that had been produced in podded form due in part to Catledge's advocacy within the Pentagon.[78] Bugos noted that "integrating this gun into the Phantom airframe, however, caused considerable problems."[79] Lacking space within the airframe, McDonnell officials decided to lengthen the nose of the F-4 and mount the gun on its underside. Because the nose also housed the aircraft's sensitive electronics, including the already finicky radar, McDonnell and GE had to design a special system of shock mounts to isolate the equipment from the 100-G instantaneous vibrations that rattled the jet when the gun began firing its six rounds per second.[80] Aviation historians Anthony Thornborough and Peter Davies described an additional complication: "The original gun muzzle

shroud configuration . . . did not dissipate gun gasses adequately, frequently resulting in heart-palpitating engine flame-outs. And, without engine power, the sleek F-4 shared the same flying characteristics as a brick."[81]

The other major planned air-to-air improvement for the F-4E was a radical new radar system that boasted of an unparalleled ability "to filter out ground clutter at low level so that moving targets, such as a fleeting, low-level MiG, would be picked out and presented as a clear, synthesized target symbol."[82] Unfortunately, Hughes's Coherent-on-Receive Doppler system (CORDS) outpaced the capability of premicrochip electronics, and the radar system failed to sufficiently mature in time. The Air Force cancelled the CORDS program on 3 January 1968. The CORDS decision put the whole F-4E program in jeopardy; when the F-4E was originally conceived, the Air Force determined that if CORDS failed to materialize in a timely fashion, the F-4E program would be scrapped and the procurement of the F-4D model extended.[83] Fortunately, the Air Force elected to continue F-4E development using an alternative, but less advanced, AN/APQ-120 radar set.

The first F-4E entered operational testing on 3 October 1967 while the CORDS program was still in turmoil. Further production delays and requirements revisions delayed the F-4E's deployment to SEA until November 1968. Additional aircraft problems slowed the influx of the newer Phantoms, such that by mid-1971 only 72 F-4Es were in-theater.[84]

Air Force pilots yearned for the F-4E's arrival.[85] Kirk commented, "Eventually we're going to have the E-model airplane with the internal gun. That's the answer. That's obviously the answer. I think the Air Force has learned its lesson. We'll never build another fighter without an internal gun. I'm convinced of that, or at least I hope to God we don't."[86] General Olds had a slightly different perspective, "Putting the gun in the F-4E doesn't automatically make out of that aircraft an air superiority fighter. You haven't changed that airplane one damn bit except now you've made a fighter out of it from what the F-4 was before; sort of a fish or fowl thing."[87]

Ironically, for all the Air Force's development efforts, the F-4E's gun would eventually account for only 12 percent of the total number of MiGs downed by 20-mm fire by the end of the Vietnam War. The jury-rigged gun system developed at Da Nang in May 1967 was responsible for more than double that figure.[88]

Notes

1. *Project Forecast*, IV–9. In drawing their conclusion, the *Project Forecast* team emphasized the long-range detection and engagement capability of the F-4 and its Sparrow and Side-

winder missiles: "The F-4C equipped with the APQ-100 radar and Sparrow missiles is now entering the operational inventory. This radar has an 85 percent probability of detection of a five square meter target at 34 miles and the same probability against a 10 square meter target at 45 to 50 miles. The attack course provided by the fire control system is a lead pursuit course; in practice, however, a constant bearing course is flown, with a conversion to a pursuit course shortly before reaching the firing range. This aircraft also carries the GAR-8 [Sidewinder] in-frared missile. . . . This system has a good area defense capability (the purpose for which it was designed), and it also has a capability for fighter-to-fighter combat."

2. History, 12th Tactical Fighter Wing, vol. 1, 19. As part of the Lima-Mike tasking, the 555th TFS launched 24 F-4Cs (20 primary and 4 spare aircraft) from MacDill AFB, Florida, on 8 December 1964. After a brief stopover at Hickam AFB, Hawaii, 20 aircraft (18 primary and two spare aircraft) launched toward Okinawa.

3. Thornborough and Davies, *Phantom Story*, 92.

4. Hone, "Southeast Asia," 521.

5. History, 15th Tactical Fighter Wing, vol. 1; Thornborough and Davies, *Phantom Story*, 92; and Hone, "Southeast Asia," 521. The JCS-directed deployment, Two Buck, began on 4 April 1965.

6. Hone, "Southeast Asia," 521 and 524. The 12th TFW moved to Cam Ranh in November 1965, and the 8th TFW set up shop at Ubon in December 1965. The 366th TFW eventually established itself at Da Nang in March 1966.

7. Futrell, *Aces and Aerial Victories*, 4–5. NVN MiG-17s scored the first aerial victories of the war. On 4 April 1965 MiG-17 fighters, armed only with air-to-air cannons, successfully shot down two "heavily loaded F-105's orbiting over the target waiting for their turn to attack." The MiG-17s sped away before the F-100 escort fighters could even the score. The first F-4 victories of the war went to the Navy's F-4Bs when they downed two MiG-17s with Sparrow missiles on 17 June 1965.

8. Ibid., 22–25.

9. "Maj. Richard Hall . . . said the downing of the MiG-17's was almost a schoolbook exercise because the two United States aircraft were able to turn inside their slower but highly maneuverable enemies for the kill with heat-seeking Sidewinder missiles." "Pilots Describe Downings of MiG's," 3.

10. Futrell, *Aces and Aerial Victories*, 25–26.

11. Ibid., 24–25.

12. Ibid., 25.

13. Peck, e-mail; Bugos, *Engineering the F-4 Phantom II*, 134; and AFHRA, "1965–10 July; Holcombe and Anderson." (Each AFHRA Aerial Victory Credit folder contains a narrative summary and aircrew personal statements and/or memoranda to the "Enemy Aircraft Claims Board" that described the MiG engagement. Hereafter, unless otherwise indicated, the cited information came from the narrative summary within the AFHRA folder.) Electrical problems plagued the early F-4Cs, especially in SEA. One former combat F-4 pilot, Peck, described the electrical problems: "Sometimes weird and unexpected things happened for either no reason at all or one thing happened when another thing was directed. By this, I mean things falling off the jet unexpectedly or when a different station was commanded to release." According to Bugos, Air Force and McDonnell engineers later determined that the heat and humidity in Southeast Asia were causing the potting compound used "to seal the backs of [electrical] wire-bundled connectors from water and motion . . . to revert to a viscous, tarry gum. . . . Each F-4 had six hundred potted connectors," all of which eventually had to be replaced, requiring over "$40,000

and two thousand man-hours per aircraft." Further illustrative of the equipment problems encountered on 10 July 1965 (in addition to Holcombe and Clark's radar failing during the engagement), one aircrew reported that their radar operation was degraded, and another aircrew reported that their radar failed to operate in search before finally shutting down altogether during the flight. The aircraft whose radar failed to search also encountered radio problems that prohibited the two pilots in the aircraft from communicating with each other. On a more humorous note, following the engagement one of the pilots suggested, "An ash tray would be desirable in [the] F-4."

14. For example, although the MiGs on 10 July were detected at a range of 33 miles, by the time the F-4s could positively visually identify the aircraft as hostile MiG-17s, they were too close to employ their Sparrow missiles. AFHRA, "1965–10 July; Holcombe and Anderson."

15. Momyer, *Airpower in Three Wars*, 156.

16. "Pilots Describe Downings," 3.

17. AFHRA, "1965–10 July; Holcombe and Anderson." Not every member of the 10 July flight agreed with Holcombe's assessment; Captain Anderson (Captain Roberts's GIB) commented that he "would like [an] internal gun."

18. Davies, *USAF F-4 Phantom II*, 9; and Michel, *Clashes*, 19. To derive air combat lessons, the Air Force's Feather Duster program pitted F-4Cs against Air National Guard F-86H Sabres simulating the smaller MiG-17 fighters. The test program "showed the folly of getting 'low and slow' in a turning fight" with the MiG. Michel summarized the Feather Duster conclusions: "Overall, the Feather Duster tests suggested some rather pessimistic projections about US fighter performance against the MiG-17 and another, more advanced Soviet fighter, the MiG-21, which the North Vietnamese was expected to receive soon. The final report said that both MiGs would out-turn and generally outperform all US fighters at 0.9 Mach and below, and, the slower the speed, the greater their turn advantage against the F-4 and F-105."

19. Futrell, *Aces and Aerial Victories*, 26; and *Project Red Baron II*, 8–9.

20. "During this period, American crews shot down five MiGs, while four fighters were lost to the enemy's aircraft." Futrell, *Aces and Aerial Victories*, 26.

21. AFHRA, "1966–23 April; Cameron and Evans." The narrative noted, "The flight had prebriefed to fire missiles on the identification pass even though there was little probability of aircraft making the identification getting a hit. Past history had been that the MiGs were always on the offensive, and any action that could be taken to put them on the defensive would be beneficial to the F-4C flight." Ultimately, three missiles—two Sparrows and one Sidewinder—were launched with known low probability of hit on the head-on identification pass. The cumbersome nature of the F-4C cockpit was aptly illustrated in the ensuing dogfight. One of the pilots noted, "When the MiG aircraft selected afterburner after my first missile firing, I attempted to select HEAT on my missile panel to fire an AIM-9B Sidewinder. My inertial reel [seatbelt] was locked and I had difficulty releasing the inertial lock so I could reach the panel and change the switch. Since the MiG was starting to evade, I elected to remain in the radar position and fire another AIM-7D Sparrow."

22. Davies, *USAF F-4 Phantom II*, 11.

23. AFHRA, "1966–23 April; Cameron and Evans." The Navy experienced similar issues with its missiles. However, the use of F-8 Crusader aircraft in the air-to-air role to escort the F-4B fighters, which were primarily tasked with performing strike missions, mitigated some of the negative effects. Although it lacked a radar and therefore the capability to employ the Sparrow missile, the F-8 was designed to be an air-to-air fighter and was armed with Sidewinder missiles and four 20-mm Colt Mark 12 cannons. More importantly, the F-8 crews were able to focus

their attention on air-to-air combat and routinely practiced the "type of dogfighting that became the norm over North Vietnam." The results were telling; by the end of the Vietnam War, the F-8 boasted the highest MiG kills per engagement, leading Michel to conclude, "The F-8 pilots were the best air-to-air pilots in the theater during Rolling Thunder." Michel, *Clashes*, 11 and 161.

24. Futrell, *Aces and Aerial Victories*, 28–29.

25. "US Flier Says 2," 3.

26. Futrell, *Aces and Aerial Victories*, 29.

27. PACAF, SEACAAL, iii, I–5; and Hiller, SEACAAL, 2. The assumption that air combat would take place above 30,000 feet altitude gave an advantage to the MiG-21. A follow-up SEACAAL report published on 31 December 1966 noted that this assumption was incorrect; in fact, the majority of air combat occurred below 20,000 feet, a regime where the F-4 enjoyed a slight advantage over the MiG-21. A PACAF briefing at HQ USAF in Washington, DC, concluded that the May 1966 SEACAAL report had an ulterior motive: The "study was devoted to providing a rationale for striking the [North Vietnamese] airfields. The [first SEACAAL] study emphasized—quite correctly—the rapid growth of the NVN Air Force, the gun defenses, the SA-2s, and the GCI system. It painted the MiGs not only as a threat to our strike aircraft over NVN but also to our bases in SVN."

28. Michel, *Clashes*, 20. The initial comparisons were based on US fighters whose performance was thought to match the MiGs'; more accurate relative comparisons "would have to wait until the US had real MiG-17s—and especially real MiG-21s—to test."

29. AFHRA, "1966–29 April; Dowell and Gossard." Two Sidewinders were fired during the engagement. The first was fired outside of parameters to distract the MiG from prosecuting an attack on an F-4 in the flight. The next Sidewinder fired "went up the tail of [the] MiG, exploded, [and the] pilot ejected with [the] aircraft on fire and corkscrewing." As the flight egressed the area, they encountered another MiG. The F-4s launched two more Sidewinders, but the missiles were fired at too great a range and failed to down the second MiG.

30. Michel, *Clashes*, 43. One pilot's comments recorded after shooting down a MiG-17 on 30 April 1966 confirm Michel's assessment: "Confidence in Sparrow was low at this point; there had been 13 firings with no hits in the previous week." AFHRA, "1966–30 April; Golberg and Hardgrave."

31. One pilot commented that he "didn't think [the] Sparrow could ever have been used in this encounter because all [the] attacks were diving at the ground and were never in the proper range band." Another noted, "After the initial attack . . . [we] were never able to achieve the necessary conditions for an ideal missile attack. The nearness to the ground negated much of the missile effectiveness." Within the flight, two pilots noted that an F-4 gun would have been valuable, commenting that "a gun would have been useful—could have gotten into gun range," and "an internal gun could have been used very effectively in this environment." AFHRA, "1966–29 April; Dowell and Gossard." Following an engagement on 30 April, another pilot commented, "A gun would be nice in the F-4C as long as it was clearly understood that it was only a weapon of last resort. Soviet fighters are more capable than US aircraft inside gun range." AFHRA, "1966–30 April; Golberg and Hardgrave." Still another F-4 pilot remarked after an engagement on 16 September 1966, "[An] air-to-air weapon with close range [is] required, down to 1,500 to 1,000 feet. Could have used a gun in several instances." AFHRA, "1966–16 September; Jameson and Rose."

32. "The overall performance of the guided missiles system has proven to be poor. Many missiles either would not fire or, once fired, failed to guide and function correctly." PACAF, SEACAAL, H-12.

33. AFHRA, "1966–23 April; Cameron and Evans." Even though the Sparrow proved successful in this instance, the pilot stated that we wanted to launch a Sidewinder but were unable to reach the missile selector switch during the intense engagement. See n21 for the pilots' description of the engagement.

34. PACAF, "F-4C Fighter Screen," 10. Extracts from the Heat Treat team's SEA trip report were distributed as an attachment to the article.

35. Ibid., 6; and Davies, *USAF F-4 Phantom II*, 17.

36. PACAF, "F-4C Fighter Screen," 6. In an Air Force interview conducted after the war, Brig Gen Robin Olds alluded to the difficulty of maintaining the F-4 radar, critical to Sparrow success. "We had to continually keep the radars peaked and when you're flying a bunch of airplanes—those that are available to you—an average of 85 to 90 and sometimes more airframe hours—hours of utilization, per bird, per month—this turnaround rate is pretty high and you just don't have time to peak up all the little systems with all the exactness that it takes to make this system [the Sparrow] work well." General Olds, oral history interview, 68–69.

37. Michel, *Clashes*, 150.

38. Ibid., 43 and 156.

39. Dilger, oral history interview, 25–26.

40. Kirk, oral history interview, 3. Olds, former 8th TFW commander, echoed Kirk's assessment in a later interview, "Sidewinder. A wonderful little weapon. Limited tactically, yes. Its fire cone was somewhat limited. 2½ Gs, certain range, a minimum range. . . . However, it was reliable, it was simple to maintain. . . . And . . . it was lethal. . . . I was personally quite happy with the Sidewinder." General Olds, oral history interview, 69–70.

41. Davies noted that "pre-war tests [were] held in ideal conditions at high altitude against non-maneuvering targets." Davies, *USAF F-4 Phantom II*, 19.

42. Michel, *Clashes*, 156–58; and Momyer, *Airpower in Three Wars*, 156.

43. Eighth TFW, "Tactical Doctrine," March 1967, 78 (emphasis added). Close control occurs when an individual fighter is directed against an individual target via precise vectors provided by either a ground- or air-based radar operator.

44. Michel, *Clashes*, 163.

45. Ibid., 165.

46. Cunningham remarked, "When I went into combat I had over 200 simulated dogfights behind me. By way of comparison, in Da Nang, I met an Air Force C-130 pilot who had just transitioned to F-4s. He went through a total of 12 air combat training flights, then he was going up North to fights MiGs! I considered this situation an out-and-out crime." Hannah, *Striving for Air Superiority*, 89.

47. Dilger, oral history interview, 6–7.

48. Davies, *USAF F-4 Phantom II*, 16. One MiG kill occurred when the MiG pilot flew into the ground while trying to evade an F-4 attack.

49. Ibid. The pilot also described the F-4C's problems in combat: "We were having a tussle fighting 1950s-era MiGs. The only real advantage we had was to accelerate out of the fight. I'd trade that for turn performance any day. Turning with a MiG-17 was suicidal. You could do pretty well turning with a MiG-21, but he was so small that it was tough keeping him in sight. We were twice the size of the MiGs and had that big smoke trail [from our engines]."

50. Michel, *Clashes*, 62; and *Project Red Baron II*, B-3. The increase in SAM activity earned notice in the *Red Baron II* report's chronology of Rolling Thunder. On 5 July 1966, "NVN missile crews launch[ed] an estimated 26-28 SA-2s at USAF aircrews" in what was then the most prolific SAM activity to date. The NVN beat that number four months later, when it launched

94 SA-2s at aircraft on 19 November 1966. The SAM attacks could be lethal, but luckily the pods proved effective. Michel noted, "In 1965, the SAMs shot down one aircraft for every 16 SAMS fired; in 1966 it dropped to about one kill for every thirty-three missiles fired, then decreased to one kill per fifty in 1967 as pods came into general use, and in 1968 it took more than 100 missiles to bring down an Air Force aircraft."

51. PACAF, SEACAAL, iv, V-6. The report noted that the loss of three F-4s to SA-2s "in less than two weeks" prompted the F-4 flight restriction into SA-2 areas.

52. Ibid., V-6. Taking the pods off the F-105s and putting them on the F-4s formed the basis for the famed Operation Bolo mission on 2 January 1967. Led by Col Robin Olds, 8th TFW commander, "14 flights of F-4Cs, 6 flights of F-105 Iron Hand SAM suppressors, and 4 flights of F-104 covering fighters departed from Ubon and Da Nang and converged on Hanoi. . . . The plan was to have them [the F-4Cs] imitate the F-105s and so draw NVAF [North Vietnamese Air Force] MiGs out for a dogfight. Though the force from Da Nang was forced to turn back because of poor weather, the 'bait' from Ubon was challenged by MiGs from Phuc Yen. . . . Three flights from the 8th TFW downed seven MiG-21s 'within 12 minutes of combat.'" Hone, "Southeast Asia," 536.

53. "By mid-1967, [the Air Force] had enough [pods] to equip all strikers and most escorts." Michel, *Clashes*, 121.

54. Ibid., 181 and 186. See Wilcox, *Scream of Eagles*, for a discussion of the Navy's Top Gun training program.

55. Michel, *Clashes*, 120–21 and 163. The failure to address aircrew training concerns would continue to plague the Air Force throughout the war. Cycling pilots through combat after 100 missions put a strain on the pilot inventory and limited the Air Force's ability to collectively garner and apply combat experience to future tactical missions. Michel noted that one Air Force report concluded that the aircrew policy ensured "the Air Force wound up 'fighting seven one-year wars instead of one seven-year war.'" The Navy elected to "not limit the number of combat missions an aircrew could fly over North Vietnam and, since a Navy aircrew's tour of duty on a Pacific Fleet carrier was about three years, it was normal to make two or three cruises to Vietnam during that time." It was "a two-edged sword. While Navy aircrews became very experienced, . . . Navy combat losses over North Vietnam nevertheless were high; soon the pilot supply began to dwindle, forcing the survivors to participate in more combat cruises— which affected their morale."

56. Ibid., 182; and *Project Red Baron II*, 13. The report noted that only one AIM-7E-2 launched before Rolling Thunder concluded.

57. Michel, *Clashes*, 279. The Navy's Sparrow employment statistics matched those of the Air Force.

58. Ibid., 156; and Westrum, *Sidewinder*, 177. The Navy pressed on and developed the AIM-9D. The AIM-9D sported a redesigned gyro optical system, which improved its ability to track a maneuvering target, and a new, cooled lead sulfide target detector cell for more sensitive and discriminate heat-source tracking. The problem with the new detector was that it required high-pressure nitrogen gas to cryogenically cool it to minus 196°Celsius (77 Kelvin). Lacking sufficient room within the missile body to store the nitrogen gas, Navy engineers elected to redesign the missile rail so that it could store a bottle of nitrogen gas and pipe it to the missile seeker. This design allowed the missile to cool for almost four hours.

59. Michel, *Clashes*, 110.

60. Thornborough and Davies, *Phantom Story*, 110.

61. Michel, *Clashes*, 110.

62. General Olds, oral history interview, 70–74. Olds's opinion of the AIM-4D Falcon never changed. In his posthumously published memoirs, Olds commented, "By the beginning of June, we all hated the new AIM-4 Falcon missiles. I loathed the damned useless things! I wanted my Sidewinders back." Olds, *Fighter Pilot*, 314.

63. Michell, *Clashes*, 111. The USAF *Red Baron II* report concluded that the AIM-4's "performance was degraded due to design limitations, tactical restrictions, and complexity of operation." The AIM-4D was in combat for 10 months before the transition back to the AIM-9B Sidewinder was completed. During that period, "49 firing attempts were made . . . resulting in four MiG-17s and one MiG-21 being downed." Fifty-five percent of the missiles were fired outside of parameters. *Project Red Baron II*, 13.

64. Michel, *Clashes*, 111; and Hargrove, oral history interview, 14. Hargrove, an Air Force pilot who had the benefit of serving with the Navy on a 30-day exchange assignment, described the benefits of the Navy's AIM-9D relative to the Air Force's AIM-9B: "It's [the Navy's AIM-9D] a much better missile. It has better G capability, it has a better look angle, . . . has a better close-in range, so I think the Air Force is definitely missing a big point in not getting the A[IM-]9D."

65. Knaack, *Post–World War II Fighters*, 273.

66. Thornborough and Davies, *Phantom Story*, 108. Thornborough and Davies described the dive-toss method: "Having rolled down, or 'popped up' on to the target heading at the pre-planned altitude, the pilot selected weapons, stations, and fuses . . . and then lined up on the target, wings-level, for the dive-bomb run. In the back seat, the GIB . . . [had only] to lock the radar on to the top of the ground return line, which by then would be moving down the vertex as the pilot entered the dive, 'ready for pickle.' Once accomplished, the radar boresight line (RBL) was lined up with the pilot's gunsight LCOSS 'pipper.' Jiggling into position, usually at an altitude where the necessity for jinking was less problematic, the pilot centered the servoed 'pipper' on the target and pressed and held the firing (bomb release) trigger, thereby telling the WRCS to ingest and hold the radar-generated slant-range information to target, which it used automatically to compute the moment for optimum weapons release (also drawing on computed variables derived from the INS [inertial navigation system] and central air data system). Still keeping the button pressed, . . . the pilot pulled back on the stick up out of the dive and the WRCS, sensing when all the release parameters had been met, sent a signal at the speed of light to the bomb ejector racks (which responded lazily by comparison), to deposit the bombs on target. Bombing patterns could be initiated at least 2,000 feet higher than when employing manual 'down the chute' procedures, keeping them out of small-arms fire." As testimony to the value of the system, Olds, commenting on the F-4 in general, described the new F-4D system: "And that dive toss worked very well. Very, very, well indeed. It improved our bombing accuracy tremendously." General Olds, oral history interview, 78.

67. PACAF, "F-4C Fighter Screen," 3.

68. Ibid., 8.

69. PACAF, SEACAAL, H-14. The report continued: "Making an ID pass places a restriction on the effective use of missiles. In addition, where missiles have been unsuccessful, these attacks might have been followed with an effective gun attack if the F-4 had been equipped with a gun and lead computing sight."

70. Michel, *Clashes*, 105–6; and Blesse, *Check Six*, 121. The Air Force's 1968 *Red Baron I* report, cited by Michel, concurred with the pilots' assessments. Studying 29 F-4 versus MiG engagements, the report concluded that "in 23 of the engagements the F-4s had cannon-firing opportunities, and often the lack of a cannon appeared to have cost a kill. [Furthermore,] the study concluded that in approximately half of the 29 engagements, North Vietnamese fighters

benefitted from the F-4's inability to shoot them at close range, and that even if the only effect of the cannon was to keep the MiGs from getting close, it would help because then the MiG would be in the missile envelope." Blesse noted, "The slower MiG-17s quickly learned of our poor maneuverability and established the procedure of using the tight turn as a defensive haven. We had no gun and couldn't turn with them, so unless we could get a long-range missile shot, they were quite safe. At low altitude the missiles had little success. We needed the gun to be able to take that shot at them and break up their defensive haven."

71. Futrell, *Aces and Aerial Victories*, 118–19; and Michel, *Clashes*, 106. Although significantly outclassed in an air-to-air sense by the MiG-17, by the end of 1966 the F-105 had dispatched five MiG-17s with its 20-mm Vulcan cannon. Additionally, Michel noted that, in the event an F-105 was shot down, the accompanying F-105s often used their cannon "to strafe approaching North Vietnamese to protect the crew until a rescue helicopter arrived."

72. Bugos, *Engineering the F-4 Phantom II*, 158.

73. "What I [Catledge] was proposing was to put guns in the F-4, and the only way to do it since they were already in production was to pod one. . . . If we could sell the program, someday down the line they would go into production airplanes. . . . So we spent the money, and we podded the gun. The change in concept came about. We got them into production, and the F-4 came out as the F-4E." Catledge, oral history interview, 32.

74. Burns, oral history interview, 3. The F-X program evolved into the F-15 program. Burns also noted, "This was before the experience of Southeast Asia bore these things out, I might add."

75. Ibid., 17–18 (emphasis added).

76. "Air Force Orders New Jet Fighter," 9.

77. "US Jets Will Reflect Lessons," 3.

78. Mets, *Evolution of Aircraft Guns*, 225–26; and Catledge, oral history interview, 32.

79. Bugos, *Engineering the F-4 Phantom II*, 158.

80. Thornborough and Davies, *Phantom Story*, 114.

81. Ibid. The muzzle problem was not corrected until "an elongated Midas IV shroud" was developed and flight-tested in April 1970.

82. Ibid., 113.

83. Knaack, *Post–World War II Fighters*, 278–80.

84. Ibid., 280.

85. Bugos noted that the introduction on an internal gun to the F-4E "added flexibility in planning and was a powerful ideological statement that Air Force pilots were less missile system managers than gunfighters, capable of dogfighting and strafing ground units like their predecessors in other wars." Bugos, *Engineering the F-4 Phantom II*, 159.

86. Kirk, oral history interview, 7.

87. General Olds, oral history interview, 77.

88. Futrell, *Aces and Aerial Victories*, 118–25 and 157. Aircraft 20 mm gunfire accounted for 40 of the USAF's 137 MiG kills during the Vietnam War. The F-4E contributed one MiG-19 and four MiG-21s to that tally. In contrast, the podded gun system initially put into service at Da Nang for the F-4C and F-4D tallied 10 MiGs, with an 11th MiG shared between an F-105F and an F-4D.

Chapter 6

An Interim Solution

I gnash my teeth in rage to think how much better this wing could
have done had we acquired a gun-carrying capability earlier.

—Brig Gen Robin Olds, USAF

In early 1915 a French pilot, aided by his mechanic Jules Hue, affixed a set of steel deflectors to the propeller of his Morane-Saulnier L monoplane and took off in search of German aircraft operating over the western front. Despite saddling the already fragile aircraft with additional weight, the inelegant propeller-mounted steel plates were critical to mission success. Without them, Roland Garros would have shot off his own propeller blades when firing his Hotchkiss machine gun, which he mounted directly in front of the cockpit and squarely behind the spinning prop. The innovation, although certainly unorthodox, worked. In a three-week period, the Frenchman claimed three German airplanes.[1]

More than 50 years later, American pilots of the 366th TFW at Da Nang AB, South Vietnam, slowly meandered around their F-4C Phantom—a machine constructed of advanced metals and capable of speeds in excess of 1,600 miles per hour, which stood in stark contrast to Garros's earlier, fabric-covered machine that maxed out at a blistery 70 miles per hour—and wondered how they would accomplish a similar feat. They also succeeded.

In both instances, a tactical innovation, born of necessity and resourcefulness in the field, made its appearance with little fanfare, but had startling repercussions on the future of air combat. Although the 366th's innovation would by war's end contribute to less than one-thirteenth of the total number of Air Force MiG kills during the Vietnam War, their leap backward to what was thought to be an antiquated form of aircraft armament actually heralded a renewed era in aerial combat that has continued into the twenty-first century.[2]

The Tool at Hand

Spurred by Catledge's efforts at the Pentagon, in 1964 the Air Force began developing an external housing that could hold the GE 20 mm M61 Vulcan cannon, a six-barrel and 6,000-rounds-per-minute Gatling gun then installed on the F-105 Thunderchief fighter-bomber.[3] The resultant SUU-16/A gun pod, powered by a ram-air turbine (RAT) and the aircraft's electrical system,

weighed over 1,700 pounds, contained 1,200 rounds of ammunition, and measured 16 feet long.[4]

Air Force Systems Command's Air Proving Ground Center began testing the SUU-16/A on the F-4C in summer 1965. Alternately installing the gun pods on the F-4C's centerline station under the belly of the aircraft and in pairs beneath each wing, the test investigated the effectiveness of the F-4C/SUU-16 combination in a close air support role attacking enemy personnel and vehicles. After the test began, Air Force engineers also decided to study the gun pod's utility in an air-to-air role.[5]

The August 1965 test report concluded that multiple successful air-to-ground firings justified use of the SUU-16/A for close air support missions; the report was less enthusiastic about the gun pod's air-to-air potential. The first three of six air-to-air test missions were deemed unsuccessful when the F-4C did not score a single hit on the target. Aircrews struggled to identify an appropriate aiming reference, and the lack of an accurate air-to-air gunsight was cited as one of the major deficiencies of the system. To help compensate for the poor gunsight, the report recommended "that tracer ammunition be used while employing the F-4C/SUU-16/A combination in an air-to-air situation whenever possible." Despite the limited air-to-air testing and the known deficiencies, the report concluded, "The F-4C/SUU-16/A combination provides a *limited* air-to-air capability."[6]

Based on the demonstrated air-to-ground potential of the SUU-16 system, the Air Force pursued procurement. SUU-16/As began arriving in SEA in April 1967, with initial pods directed to the 366th TFW at Da Nang.[7] Two rationales contributed to the selection of Da Nang. First, because of Da Nang's location in northern South Vietnam, the 366th performed a large number of in-country and near-border missions, including the close-air-support mission for which the pod was tested.[8] Second, the 8th TFW at Ubon, Thailand, was scheduled to receive its first F-4Ds in about a month. In addition to having a lead-computing air-to-air gunsight, the F-4D also had the capability to carry a new gun pod, the SUU-23/A.

The SUU-23 boasted two improvements over its SUU-16 predecessor: the gun was powered not by a RAT but by muzzle gasses, and it had a sleeker design, which theoretically reduced drag and fuel consumption.[9] Despite its better aerodynamics, one former F-4 pilot still lamented, "With the open-ended gun barrels and blast deflector on its front ends, the [SUU-23 gun] pod was indeed cruel to the Phantom II's slipstream and its fuel consumption."[10]

The extra weight and drag associated with the gun pod, and the expected consequent decrease in aircraft maneuverability and increase in fuel consumption, led many pilots to doubt its utility in combat.[11] Aircrews assumed

they had to wait for the recently announced F-4E with its internal cannon before they would enjoy a combat-effective gun.

The Gunfighters

"Boots" Blesse knew about employing the gun in air-to-air combat. A two-tour, 123-combat-mission Korean War veteran, Blesse downed 10 North Korean aircraft—nine jet-powered MiG-15s and one propeller-driven LA-9—with his F-86 Sabrejet's six 0.50-inch Colt-Browning M-3 machine guns.[12] Returning to the states in late 1952, Blesse reported to the Air Force's gunnery school at Nellis AFB, Nevada, forerunner to today's USAF Weapons School. While there, Blesse published a popular tactics manual, *No Guts, No Glory*.[13] Also while he was at Nellis, Blesse's aerial gunnery prowess was publically highlighted when he took first place in all six individual events at the USAF Worldwide Gunnery Meet in 1955, an unprecedented accomplishment.[14] After completing National War College in 1966, Blesse volunteered for service in Vietnam, specifically at Da Nang. When the members of the 366th TFW learned that their new deputy commander for operations would be Blesse, they knew that he would play a pivotal role in improving the wing's lackluster tactical performance.[15] Blesse wouldn't have much time.

Shortly after Blesse's arrival at Da Nang in April 1967, Pres. Lyndon Johnson for the first time authorized strikes against both Hanoi's electric power system and North Vietnamese military airfields.[16] North Vietnam responded by ramping up the number of MiG sorties, which prompted the Air Force to dedicate more F-4s to MiGCAP missions to protect the F-105 fighter-bombers.[17] The 366th TFW at Da Nang and Olds's 8th TFW at Ubon were assigned the extra escort missions.[18] Prior to that, the 366th TFW had been executing almost exclusively air-to-ground missions. In fact, when Blesse arrived he bemoaned, "there wasn't anyone in the outfit who had ever fought an enemy aircraft except me."[19] The wing desperately needed a quick refresher on air-to-air tactics, and Blesse went to work providing it, at times even calling upon his 12-year-old *No Guts, No Glory* tactics manual.[20]

Much of the wing's focus was on the F-4's air-to-air armament. As a Korean War air-combat veteran, Blesse had a unique appreciation for the nature of air combat and the "complementary" roles for both missiles and guns in a jet fighter:

> I had felt for years we went the wrong direction in the Air Force when we decided guns no longer were necessary. This was "the missile era," they said. I was told by some pretty high-ranking officers I was wrong, but my experience in Korea seemed to tell me other-

wise. Missiles don't always work, they had limiting parameters under which they could be fired, they were ballistic (no guidance) for several hundred feet after launch, they didn't arm immediately, and, in general, left a great deal to be desired. In addition, from an operational standpoint, you could be surprised while attacking another aircraft and find yourself in a tight turning battle. High Gs and tight turns are not ideal parameters for firing a missile, and besides, range between aircraft decreases rapidly under those conditions and you could easily find a gun a far more useful weapon. An internal gun also provides a capability at all times for targets of opportunity on the ground. For all these reasons, I found the missile and gun complementary weapons, not weapons that were in competition with each other.[21]

Blesse reasoned that the wing, now tasked with additional MiGCAP missions in NVN and receiving the first of several SUU-16 gun pods, "could take that SUU-16 gun to Hanoi and increase our air-to-air capability."[22] One former 366th pilot recalled that Blesse, pointing to an F-4, once exclaimed, "All I want to do is get a gun on there. . . . I don't care if we have to . . . wire a . . . 38-caliber pistol with a string to it, that's what we'll need against those MiGs!"[23] While it did not require such drastic measures, introducing the SUU-16 to F-4 air-to-air combat was nonetheless easier said than done.

Blesse assigned the task of integrating the SUU-16 onto the F-4C for air-to-air employment to the wing's elite weapons section.[24] The first problem the officers encountered was where to hang the gun pod on the aircraft. The F-4 had two pylons attached to the underside of each wing. The outermost wing pylons could carry either a 370-gallon external fuel tank or air-to-ground ordnance (including the SUU-16/23). The innermost wing pylons could carry either two AIM-9 (or on the F-4D, two AIM-4D) missiles or additional air-to-ground ordnance, but not external fuel tanks. The centerline pylon suspended from the belly of the aircraft could carry a larger, 600-gallon external fuel tank or an array of air-to-ground ordnance, including the SUU-16/23. The F-4's four Sparrow missiles were carried underneath the aircraft's fuselage in specially designed, recessed missile stations. During F-4 air-to-air missions early in the war, the preferred configuration included two 370-gallon external fuel tanks, a tank suspended from each outermost wing pylon; four Sidewinder missiles, two attached on either side of the innermost wing pylons; four Sparrow missiles nestled along the belly of the aircraft; and often a 600-gallon fuel tank attached to the centerline of the aircraft. The extra fuel provided by the three external fuel tanks allowed the F-4s to maximize their flight time patrolling the target area.[25] Also, the configuration was symmetric, offering maximum aircraft stability in-flight.

However, the introduction of the external ECM pod on the F-4 in early 1967 required a change to the preferred aircraft configuration. The ECM pod, necessary for aircraft defense against the escalating SAM threat, relied on spe-

cial wiring that was only available in the outermost wing pylon, a position normally reserved for a 370-gallon external fuel tank. Consequently, the approximately 190-pound ECM pod was mounted on the outermost right wing pylon.[26] Loaded on the opposite pylon was the 370-gallon external fuel tank, which weighed almost 2,400 pounds when full. The 600-gallon fuel tank was carried on the centerline as before, and the Sidewinders and Sparrows likewise maintained their prior positions on the aircraft.

The resultant configuration was far from symmetrical, and it forced the F-4 to fly in a notoriously unstable configuration. Colonel Bolt, the 366th TFW commander at the time, later exclaimed that in that configuration, "Well, the airplane flew sideways! It used up a lot of gas, and it was dangerous."[27] Colonel Olds, the 8th TFW commander, offered a similar appraisal: "When they originally wired the airplane, they put the ECM pod on the right outboard pylon. This put us into a terrible, horrible configuration. . . . You had to carry a 600-gallon centerline tank . . . and your other external tank, your 370-gallon left outboard tank, hanging way out here, in [sic] the outside of the wing, with nothing to balance it on this side. . . . Takeoff was very exciting."[28]

Prior to the arrival of the ECM pods, Olds and others requested that the Air Force address the pending aircraft configuration issue, hoping Air Force engineers would modify the F-4 so that the ECM pod could be hung from an inboard wing pylon. The Air Force's response was disconcerting, "We were told it would take some 12 to 14 hundred man-hours per aircraft to modify our F-4s."[29]

The 366th's weapons section therefore faced a dilemma. On MiGCAP missions, the SUU-16 had to be mounted on the centerline pylon; otherwise, it would be extremely difficult to aim at the MiG target. However, the F-4 could not afford to sacrifice the extra fuel provided by the 600-gallon tank usually mounted on the centerline, especially when the necessary ECM pod precluded the possibility of loading a 370-gallon fuel tank on the right outermost wing pylon. The only solution was to devise a way to move the ECM pod to the inboard pylon in a manner that did not require excessive time or maintenance effort.

Later described by the wing's historian as working under the premise, "You know it can't be done, so now tell us how to do it," a team of pilot tacticians and aircraft maintenance personnel finally developed a solution.[30] Fortunately, it was both inexpensive and relatively easy to implement. Crediting the genius to a particular chief master sergeant, the 366th wing commander later described the proposed fix: "All he did was build a simple harness with two cannon plugs on it and tie it in to the nuclear armament system."[31] After having confirmed the design's potential, wing personnel performed a limited

number of pylon and ECM pod modifications so that they could test the new configuration.

Based on these in-house tests, the weapons section concluded that the pod did not appreciably degrade the F-4's performance and maneuverability as once thought.[32] The tests also illustrated that the most effective gun-carrying configuration was to load the flight and element lead aircraft, flying in the #1 and #3 positions, with the SUU-16 gun pod on the centerline, two 370-gallon external fuel tanks on the outermost wing pylons, the ECM pod on the innermost right wing pylon, two Sidewinders on the innermost left wing pylon, and two of the four Sparrow missiles on the aircraft's belly. Although there was still room for four Sparrows, the reduced fuel supply based on substituting the 370-gallon fuel tank for the typical 600-gallon fuel tank and the increased drag associated with the SUU-16 pod led the tacticians to recommend that two of the Sparrow missiles be downloaded to reduce aircraft weight and drag.[33] The wingmen, flying in the number 2 and number 4 positions, retained the previous asymmetric ECM pod configuration and all eight missiles—four Sparrows and four Sidewinders.[34] This allowed the wingmen to carry the larger 600-gallon centerline fuel tank, providing them with more fuel for the mission, which they typically burned trying to maintain formation with the lead aircraft.[35]

Having developed a viable configuration to carry the gun, the 366th's weapons section turned its attention to establishing the procedures to employ the gun in combat. The lack of a lead-computing air-to-air gunsight on the F-4C seriously degraded the gun's effectiveness. Blesse described the wing's expedient solution:

> We decided we could make do with the fixed sight that was installed. With no lead computer, it was useless to put the pipper (aiming dot) on the enemy aircraft because the rounds fired would all end up behind the target. The . . . gun we carried had a very high rate of fire. So high, in fact, that the rounds that came out of this single gun would strike the [target] aircraft only about eight inches apart at 2,000 feet range. We figured, if you put the pipper on the target, then moved it forward about twice as far as you thought necessary before you began to fire, you would over-lead the target. The procedure then was to begin firing as you gradually decreased your amount of lead. This would allow the enemy aircraft to fly through your very concentrated burst. Wherever hits occurred, the rounds stitched through the wing or cockpit area like a sewing machine. Clusters of 20mm rounds striking close together would weaken the wing or whatever it hit, and the violent air and G forces would tear it off the aircraft.[36]

Olds later noted that the procedure entailed "wasting a lot of bullets, but all you need is a few of them to hit and down he goes."[37] Using this imprecise-but-best-available procedure was also thought to take advantage of the other-

wise adverse effects on bullet dispersion caused by the gun vibrating on the mounting pylon when it was fired.[38]

With the background research done, Blesse was ready to approach Momyer, Seventh Air Force commander, seeking permission to modify the 366th's entire fleet of F-4Cs. Blesse described the meeting:

> Charts and all, I parked myself in the general's outer office and awaited my turn. Finally the door opened and "Spike" Momyer appeared. With him was Colonel Robin Olds, commander of the 8th Tac[tical] Fighter Wing at Ubon. General Momyer, seeing me waiting and remembering the subject, turned to Robin Olds and invited him to hear my briefing.

> So, with my select audience of two, I laid out our ideas, our test results, our method of compensating for the lack of a computing gun sight, and our ideas for air-to-ground use of the gun. It was magnificent, I thought—innovative, thorough, concise. I was quite happy with myself as General Momyer reflectively turned to Colonel Olds and said, "What do you think of that idea, Robin?"

> Olds then proceeded to blow me out of the water, hull and all, with the simple statement, "General, I wouldn't touch that with a ten-foot pole!" . . . I was stunned.

> General Momyer was more kind. "You and I talked about this a few years ago, Boots, and I didn't think much of the idea then. Maybe things are a little different now, I'm not sure. I think you have a hole in your head but go ahead with your gun project and keep me informed."

> It wasn't the whole-hearted support I was shooting for but at least we could go on with it.[39]

Additional configuration testing at the 366th on 3–4 May 1967 focused on evaluating the ECM pod's performance when mounted on the inboard pylon. The subsequent message to Momyer on 5 May 1967 reported:

> 100 percent successful electronic emissions all applicable altitudes and attitudes. Twenty-six man-hours involved [in the aircraft modification]. . . . ALQ-71 [ECM] pod modification makes possible SUU-16 gun installation [on] centerline station for use in Package Six.

> *This Wing has lost minimum seven kills in the past ten days because of a lack of kill capability [against targets] below 2,000 feet altitude and inside 2,500 feet range. . . .*

> SUU-16 can be carried without degradation of aircraft performance. . . .

> Your HQ has 120,000 rounds of 20mm tracer ammo enroute to Da Nang, which we will use on one to eight basis in our ammo load. With a fixed sight, this tracer of utmost importance both for sighter burst and deflection shooting.

> *It is interesting to note we are dusting off deflection shooting info published early WW II and Korea for our Mach 2 fighters. . . .*

> Request authority to continue modification for entire 366th fleet.[40]

Momyer granted the request. Six days later the 366th sent a message to the top aircraft maintenance officer at Seventh Air Force, courtesy-copying Thirteenth Air Force in the Philippines and the two other F-4 wings in SEA (the 8th TFW at Ubon and the 12th TFW at Cam Ranh), outlining the modification procedures and justification in greater detail: "This modification allows the carriage of the SUU-16 gun pod, the only air-to-air weapon that can be employed against very low altitude aircraft. The need for the modification became apparent after a number of pilots reported unsuccessful results after engaging the MiG-17. In all cases, the main reason was the very low altitude the MiG attained after engagement. This station [366th at Da Nang] proposes to add an ECM capability to the right inboard pylon. . . . The aircraft wiring changes are merely a splice made with existing aircraft wiring. The inboard pylon is modified to add one connector. . . . The modification in no way affects the present ECM capability nor any other system on the a[ir]c[ra]ft."[41]

The following day, Blesse and Maj Bob Dilger, a member of the wing's weapons section that had worked on the gun project, took off for a mission "Up North," their F-4Cs toting an ECM pod on the right inboard wing pylon and a SUU-16/A on the centerline—"the first gun-equipped Phantoms into Pack Six."[42] Two days later, the tireless efforts of Blesse and the other members of the 366th TFW, as well as earlier efforts by Catledge and Burns at the Pentagon, finally came to fruition.

After the members of Speedo flight landed at Da Nang following their 14 May 1967 mission, they were mobbed by their compatriots, including Blesse, before being hustled into the intelligence section to debrief the first-ever F-4 air-to-air gun engagements.[43] During the debrief, the flight members praised the SUU-16 "as a very good gun" and "a very good system." Captain Craig from Speedo 3 commented, "The kills with the gun . . . could not have been made with a missile." Maj Hargrove from Speedo 1 reminded his debriefers that he "never had a chance to shoot the SUU-16 air-to-air before this encounter," and added that although he "would like to have had a lead-computing [gun] sight," the use of "tracers [in the future] . . . will help a lot."[44] The message traffic describing the engagement sent across the theater late that night noted, "All members of Speedo [flight] spoke praise for the SUU-16 gunnery system. We think the results speak for themselves."[45]

In a later interview, Hargrove described the combat in more detail: "I opened fire at about 2,000 feet, and he [the North Vietnamese MiG pilot] still—right away—he didn't break, and I guess he probably saw my muzzle flashes with the smoke, and didn't know what that crazy pod was underneath anyway, but he did break at, oh, a thousand feet or so. He broke hard, . . . but it was too late now. I cut him in half with the gun. But had he known, of

course, that I had the gun, he would have maneuvered differently. But without the gun—in the fight that we were in—I don't see how I possibly could have gotten a MiG without slowing down and exposing myself considerably more than is smart to do."[46] Hargrove also reportedly chuckled, "I'll bet they [the North Vietnamese] had a tactics meeting at Kep (NVN air base) that night."[47]

Following Speedo flight's successes, news of the 366th and the F-4/SUU-16 weapons combination spread rapidly throughout the Air Force. At 0250 on 14 May 1967, local Hawaii time (17 hours behind Da Nang), the PACAF command center logged the first message about the 366th's engagements, reporting Elgin flight's MiG kill:

> 0250   <u>MiG Shoot Down</u>. 366TFW OPREP-3/011 reports that Elgin Flight, F-4C's, MIG CAP, saw 6 MiG-17s and Elgin Lead shot down one with a Sparrow. AFCP [Headquarters, Air Force Command Post] notified. [48]

Thirteen minutes later, the second message from the 366th arrived:

> 0303   <u>Two MiG-17s Shot Down by F-4Cs</u>. 366 TFW Msg OPREP-3/010 reports that Speedo Flight, while escorting strike flight against Ha Dong Army Barracks, engaged at least 10 MiG-17s and shot down two of them using the SUU-16 gunpods. AFCP notified.[49]

Those initial messages were followed up by more detailed ones approximately four hours later.

> 0715   <u>MiG Shootdown, Elgin Flight</u>. 366 TFW Msg Fastel 448 is detailed report of Elgin Flight engaging MiGs. Comment by pilots indicate [*sic*] that the SUU-16 would have been more effective against the MiG-17s than any of their missiles.[50]

By 1030 interest in the message traffic, as well as some confusion, extended to Washington:

> 1030   <u>SUU-16 Pods</u>. Col Dunn (AFCP) requested information as to which F-4C MiGCAP aircraft were equipped with SUU-16 pods. Lt Col Hartinger (7AFCC [Seventh Air Force Command Center]) stated that Elgin lead and #3, and Speedo Lead and #3 were equipped with the gun pods. However, Elgin Lead aborted and the spare aircraft was not gun pod equipped. Elgin Lead did shoot down one MiG with a missile

and Speedo Lead and #3 each downed a MiG with 20-mm. Passed to AFCP.

1145   <u>Speedo Flight MiG Kills</u>. 366 TFW OPREP-3/Ch1, DTG 14/1800Z May 67, is narrative of the two MiG-17 kills by Speedo flight (4 F-4C MiGCAP against JCS [target] 31). The flight expended 4XAIM-7s and 1XAIM-9, all duds. Both kills were with 20mm cannon.[51]

Two hours later, Seventh Air Force and the PACAF command center were still trying to alleviate confusion surrounding the 366th's exploits:

1345   <u>Configuration for Carrying SUU-16 (20-mm Pod)</u>. Colonel Hartinger (7AFCC) stated two fuel tanks are carried outboard, a QRC-160 pod on the right inboard, two AIM-9s on the left inboard, and the SUU-16 pod carried on the centerline. A minor modification was required to allow the QRC-160 pod to be carried on the right inboard station.[52]

While messages buzzed back and forth between the 366th TFW, Seventh Air Force, Headquarters PACAF, and Headquarters USAF, Blesse received an irate phone call from the 8th TFW commander at Ubon. Responding to Blesse's daily operational summary that quipped, "There will be two pilot meetings tonight. One in Hanoi, the other in the 8th Tac Fighter Wing," Olds shouted into the receiver, "What the hell are you trying to do, you crazy bastard! Don't you realize what kind of a position this puts me in?"[53] Nevertheless, by the end of the month, the 8th TFW had begun modifying its F-4Cs and newly arriving F-4Ds according to the 366th-developed procedures.[54] The 8th downed its first MiG with the 20-mm gun pod on 24 October 1967.[55] The aircraft commander, Maj William Kirk of the 433rd TFS, would later enthusiastically characterize the gun pod as "the finest thing that was ever invented."[56]

As news of the engagement continued to spread, Momyer urged the 366th to send a message to the chief of staff of the Air Force, which they did on 18 May 1967. "Subj[ect]: MiG Engagement Supplement to 366TFW OPREP-3//012 [Speedo flight] . . . . The missiles were fired at minimum ranges and maximum allowable G forces. The missiles were fired at low attitudes and against a cloud background. Upon observing the futility of trying to maneuver for an optimum missile attack, which is virtually impossible against an enemy aircraft that is aware of an attacker's presence, the pilot shot a MiG down using the 20-mm cannon."[57] Two months later, Blesse was in Washington, DC, briefing the Senate Preparedness Investigating Committee and the

secretary of defense, touting the gun as "one of our most versatile and effective weapons."[58]

Since arriving at Da Nang, "Boots" Blesse had wanted a nickname for the wing. For example, Olds's boys at the 8th TFW were known as the "Wolfpack." After May 1967, the 366th's prowess with the SUU-16 had earned them one. Their insignia became a "little guy in a black full-length coat wearing tennis shoes and a very large black hat"—the McDonnell Aircraft Company's cartoon Phantom—"carrying a SUU-16 gun pod." Their nickname became "the Gunfighters."[59]

Assessment

The 366th's official wing history from the period recorded that "the desirability of a 20-mm Gatling gun in air-to-air combat was, in large measure, an expression of the limitations of air-to-air missiles."[60] By the end of Rolling Thunder, Blesse's innovation accounted for almost one-third of the wing's air-to-air victories, a significant tally considering the 366th resumed its primary air-to-ground missions after only six weeks of MiGCAP taskings.[61] By the end of the war, the gun on the Air Force's F-4C/D/E aircraft had accounted for 15 and a half of the Air Force's 137 kills.[62] Once deemed an antiquated armament system not worthy of further development in 1957, the gun had proven its value in air combat once again.

The combat results achieved by the external cannon, and a small jab from Blesse in his 14 May 1967 daily operational summary, swayed initial skeptics like Olds.[63] During one interview, Olds characterized the gun pod as "a very, very fine weapon and a very accurate one."[64] In a separate, earlier interview, Olds commented, "Now the old gun—the Vulcan M-61 Gatling gun we've got—is an outstanding development. . . . It's a good close-in weapon. I gnash my teeth in rage to think how much better this wing could have done had we acquired a gun-carrying capability earlier."[65] Other Air Force officers also took note. One report issued after the war concluded, "At low altitude, the air-to-air ordnance which afforded the highest kill probability was the cannon."[66]

Momyer was not so easily convinced, though, as evidenced by his writings after the war. Acknowledging in his book *Air Power in Three Wars* that "the low kill rates for missiles may also be explained in part by the fact that the AIM-7 was designed as an antibomber weapon," Momyer sounded like Gen Emmett O'Donnell of Korean War fame when he next wrote, "The different circumstances of the wars in Korea and the Middle East [referring to the1973 Arab-Israeli War] . . . prevent us from making responsible judgments about

the relative quality of pilots or equipment [during Vietnam]. . . . Both political and technological factors tended to depress our kill ratio in Vietnam, with political constraints being probably the most significant factor."[67]

Other documentation reveals Momyer's continued faith in the promise of advanced air-to-air missile technologies. In a 1975 Corona Harvest memorandum, Momyer urged, "There must be a major increase in kill potential of air-to-air missiles employed to what was obtained in Vietnam. More effort is needed in the development of a new radar and dogfight missile that has a capability of kill between seventy and eighty percent."[68] An earlier 1974 memorandum similarly concluded, "The final dogfight phase [of air combat] should be optional."[69] Still, despite emphasizing the primacy of guided missiles in air-to-air combat, Momyer came to recognize the complementary value of an air-to-air gun mounted in, or on, a fighter aircraft, and he urged the Air Force to procure a "new air-to-air gun."[70]

The decision to load an external gun on the F-4C/D and build one into the new F-4E reflected a growing appreciation that, despite the continued promises of the air-to-air missile proponents, air combat could not be reduced to simple missile exchanges at long range. Consequently, aircrews needed better air-to-air training. After surveying the Air Force's air-to-air engagements in Vietnam through 1968, the *Red Baron II* report reached a similar conclusion: "History has shown that the aircrew that is most likely to excel is the one that is the most highly trained. Without adequate training, the capabilities and limitations of the fighting platform are neither recognized nor used effectively."[71] The report recommended that "tactical aircrews . . . be provided improved (quantity and quality) ACM [air combat maneuvering] training," which helped spur the Air Force's Red Flag and Aggressor training programs in 1975.[72]

Ultimately, the persistent efforts of determined Air Force officers like Blesse, Burns, and Catledge triumphed over the Air Force's penchant for technological exuberance, embodied in its untenable embrace of poorly performing air-to-air missile technologies and the contexts they informed. In doing so, the gun advocates had to overcome the bureaucraticism and unjustified optimism that had jaded the Air Force's opinions of three interrelated technological systems—the airframe, the armament, and the aircrew training process—that collectively proceeded according to a circular logic trail gone bad:

> Missiles were better suited to shoot down jet aircraft than guns. Jet aircraft were therefore built without guns. Aircrews were therefore trained to shoot down jet aircraft using missiles. Because aircrews were trained to shoot missiles and not guns, the Air Force had to develop better mis-

siles, not guns. Because the Air Force was building better missiles, it needed better aircraft to shoot those missiles, and so on.

Each technological system or process developed according to a technological trajectory, and each reinforced the other. It was not until a few determined individuals began questioning the predicating assumptions—was a Soviet bomber the most likely target? could missiles and guns actually be complementary weapons? and could aircrews be trained to employ both types of armament?—that the Air Force's technological blinkers were finally removed.

The impact is still felt today. Aircrews continue to conduct air-to-air training in the skies north of Nellis AFB during Red Flag exercises, and the newest Air Force fighters, the F-22A Raptor and F-35A Lightning II, are both equipped with internal cannons.[73] Finally, the history of the Air Force's air-to-air armament through Rolling Thunder provides a valuable case study to examine the nature of military innovation.

Notes

1. Morrow, *Great War in the Air*, 91–92.
2. Futrell et al., *Aces and Aerial Victories*, 157. The 366th's innovative solution for employing the podded gun on the F-4C/D eventually accounted for 10 of the USAF's 137 MiG kills during the Vietnam War. (Additionally, an F-4D and F-105F shared a 20-mm gun kill.) In contrast, the F-4E's gun contributed only five MiGs to the tally.
3. Michel, *Clashes*, 102.
4. Mehserle, *Capability of the F-4C Aircraft*, 2.
5. "After the test was started, an additional objective was added, this being a demonstration of the SUU-16/A weapon in the air-to-air role." Ibid., 1.
6. Ibid., 35–36 (emphasis added). In contrast to the paltry six air-to-air missions flown, the test included 67 air-to-ground missions.
7. Davies, *USAF F-4 Phantom II*, 30.
8. Thornborough and Davies, *Phantom Story*, 105.
9. Thornborough, *USAF Phantoms*, 101; Davies, *USAF F-4 Phantom II*, 30; and Thornborough and Davies, *Phantom Story*, 107.
10. Davies, *USAF F-4 Phantom II*, 31.
11. Bakke, interview. Air Force pilots actively reinforced this perception. Retired major Sam Bakke recalled that one Saturday while he was at Nellis AFB, Nevada, for F-4 weapons training, he and his flight commander flew a demonstration flight for "a civilian official of influence" who was flying in the back seat of an accompanying F-4. Bakke's F-4 was loaded with the SUU-16 and two external fuel tanks, the accompanying F-4 with the civilian carried only the two external tanks. Bakke described the flight: "We pulled up side-by-side to demonstrate . . . how the aircraft underperformed when you had extra weight in the centerline area—to imprint on him [the civilian official] that we needed an internal gun."
12. Blesse, *Check Six*, 73–76. Blesse's last kill coincided with his last mission in Korea. While flying back to base after an otherwise uneventful mission, Blesse's flight of F-86s was jumped by a flight of four MiGs. Although the F-86s were low on fuel and, more importantly,

the MiGs were out of range, Blesse's young wingman mistakenly turned to defend himself and was unwittingly exposed to the MiGs' attacks. Blesse turned to help his wingman and engaged one of the attacking MiGs, allowing the young pilot to escape. Unfortunately, in the process of shooting down the MiG, Blesse's F-86 ran out of fuel, and he had to eject off the North Korean coast. He was rescued a short time later by an American air-sea rescue plane and was quickly ordered back to the United States, lest the Air Force risk losing one of its leading MiG killers in combat.

13. Ibid., 87; Blesse, *No Guts, No Glory*, ii and iv; and "Maj Gen Frederick C. Blesse Biography." In the foreword to *No Guts, No Glory*, Col George L. Jones, commander of the 359th Combat Crew Training Group (Ftr) at Nellis AFB, Nevada, described the manual as a "clear presentation of a way of flying and a pattern of thought essential to the fighter pilot for survival and victory in air-to-air combat." In the preface, Blesse stated that his goal was to help "produce a pilot who is aggressive *and* well trained." Affirming the manual's popularity, Blesse's official Air Force biography noted that his "book [*No Guts, No Glory*] has been used as a basis of fighter combat operations for the Royal Air Force, Marines, Chinese Nationalist, Korean Air Force, and US Air Force since 1955. As recently as 1973, 3,000 copies were reproduced and sent to tactical units in the field."

14. Blesse, *Check Six*, 91. Blesse's claims are confirmed by his official Air Force biography.

15. Bolt, oral history interview, 187–89. Assuming command one month before Blesse's arrival, the 366th TFW commander, Col Jones Bolt, later described his assessment of the wing's poor morale and lackluster tactical performance: "I was never so disillusioned and low in my life as I was when I got to that base [Da Nang] and took a look around. It was really bad. The morale of the people and the *esprit de corps* were just nonexistent. . . . Their loss rates were high, both at night and in the daytime. Their loss rate up in Route Pack I was atrocious." Bolt attributed some of the substandard performance to the relative inexperience of the deputy commander for operations prior to Blesse: "The guy that was the DO was a newly promoted colonel, B-57 [Canberra, a twin-engine, light bomber built in 1953] pilot. This doesn't work. The guy was hardly current in the F-4."

16. Hone, "Southeast Asia," 537.

17. "The number of air engagements during recent strikes against JCS numbered targets is indicative of the increasing MiG threat to our forces. Attacks against the remaining jet capable fields . . . are considered necessary at this time to further harass and disrupt the MiG air defense capability. . . . [Targets] should be attacked by larger forces in order to saturate the defenses." Message, 300055Z APR 67, CINCPAC to JCS.

18. Michel, *Clashes*, 99.

19. Blesse, *Check Six*, 125; and *Project Red Baron II*, 10. The relative decline in aircrew combat experience cited by Blesse was also noted in the *Red Baron II* report: "The average experience level of aircrew during the early part of the war was relatively high. By the end of the USAF air-to-air activity in March 1968, this experience level had been sharply lowered. . . . This lessening of experience resulted from the replacement of 'old heads' by recent UPT [undergraduate pilot training] graduates and pilots with ADC [Air Defense Command] and ATC [Air Training Command] backgrounds, or otherwise lacking tactical aircraft experience."

20. Ibid.; and "Historical Data Record," 2. Blesse's recollections are confirmed by the 366th TFW's monthly historical report for the period 1 April 1967 to 1 May 1967: "Commander[']s Conclusion: The bombing of MiG airfields in and around Hanoi has brought the MiGs up in force and confronted this Wing with a new and interesting mission. Intense training, individual squadron briefings on air-to-air fighter tactics by the Director of Operations [Blesse], and

several new ideas to improve the Wing's air-to-air capability all have played their part in changing the personality of the Wing."

21. Blesse, *Check Six*, 120. During one interview, Blesse characterized the limitations of air-to-air missiles: "Show me a missile that is good and I will throw my guns away, but I have not seen any good ones yet. They still require about 1,500 feet, just to arm. I am not interested in something in that range. I don't want a dead area, dead range in there." Blesse, oral history interview, 79.

22. Blesse, *Check Six*, 120.

23. Bakke, interview.

24. Blesse, *Check Six*, 120. Blesse named the following individuals as having "earned their pay and then some experimenting with the gun: Lt Col Fred Haeffner, Majors Jerry Robbinette, Ed Lipsey, Bob Dilger, Sam Bakke, and Captains Bob Novak, Skip Cox, Jim Craig." Of the eight officers recognized by Blesse, four would claim a MiG during the tour; one (Craig) used Blesse's innovation in doing so. Futrell et al., *Aces and Aerial Victories*, 127–31 and 157.

25. During the premission aerial refueling, all of the F-4's fuel tanks, both internal and external, would be filled. En route to the target, the F-4 would burn the fuel in the external tanks first. That way, if the F-4 needed to engage a MiG, the aircrew could jettison the empty (or almost empty) external fuel tanks and still have sufficient internal fuel to fight the MiG before returning home, via a postmission aerial refueling. Less external fuel capacity resulted in the F-4 burning its limited internal fuel supply earlier in the mission, consequently decreasing its available on-station time in hostile airspace.

26. General Olds, oral history interview, 22. Olds cites the 190-pound weight of the ECM pod.

27. Bolt, oral history interview, 195.

28. Olds described the configuration's effect on takeoff: "Now that was a lovely little takeoff configuration, like, maybe, full right rudder as soon as you broke ground." General Olds, oral history interview, 22 and 74–75.

29. Colonel Olds, oral history interview, 43.

30. History, 366th Tactical Fighter Wing, vol. 1, 2.

31. Bolt, oral history interview, 195–97; General Olds, oral history interview, 76; and Bakke, interview. Bolt's recollection of the events is suspect. Seventeen years after his assignment to the 366th, General Bolt claimed almost exclusive credit for the wing's tactical innovations: "I went down to the armament shop and I said, 'Chief, we've got to do something about this configuration on the airplane. Do you think you can rig up a wiring harness where we can put that ECM pod on the left or right inboard station and drop off two of the Sidewinders so we will just have two Sidewinders on the other side and still have the radar-guided missiles but will have the two outboard tanks? Then we don't have to fool with that big old centerline tank.' . . . He said, 'I don't know; let me try. I haven't thought about it.' I said, 'See if you can do it. I'll check back with you later in the day.' I went back down that afternoon. He said, 'I got one made; it will work.' All he did was build a simple harness with two cannon plugs on it and tie it in to the nuclear armament system, which the regulations say you can't touch, so don't ask anybody—just go ahead and do it [*sic*]. If you ask anybody, all they can tell you is no. We put that thing on. I said, 'Okay, take the airplane and configure it. I will fly it tomorrow against our radar sites . . . and we will see if it works like it is supposed to.' So I flew it and it worked great, so we reconfigured all our airplanes. We only had two Sidewinders rather than the four. I said, 'We've got to counter that someway. The only way I know to do it is to put the gun on the centerline.' We got the airplane configured right now [*sic*], and the gun on the centerline will be all right.

The gunsight left a lot to be desired in that F-4C. . . . I said, 'I think if we can get behind the MiGs, and we can, we don't really need a gun sight. We can hit him. We can put every tenth round with tracers in there. We can hit him without a gun sight.' " While flattering, the interview's narrative does not agree with Blesse's own narrative in *Check Six*, the 366th Wing's official history from the period in question, or the secondary sources such as Davies and Thornborough. A review of the message traffic also reveals discrepancies and lends more credence to Blesse's narrative. (Even Blesse's narrative, though, contains inaccuracies; see note 42, this chapter, and note 18 in Chapter 1.) This historical interpretation was affirmed during an interview with Bakke, one of the officers in the 366th TFW weapons section in 1967, who stated, "If it was anybody [who deserves credit for putting the SUU-16 on the F-4 for air-to-air], . . . I'd give . . . 100 percent of the credit to 'Boots' Blesse." Olds's after-the-fact recollection of the events is also suspect, as he failed to credit the 366th TFW for devising the wiring solution: "So, it was because of this dadgone [ECM] pod that we were having trouble with the gun and the reason is because you had to hang the gun on the centerline, see. But we had to put the 600-gallon tank on the centerline. It was a mess, so finally we rewired the airplane using the nuke circuitry that's in the bird and were able to put power to the pod on the right inboard pylon, then put the tank back on the right outboard, . . . and then you could hang the gun pod or bombs [on the centerline]." Still, Bolt's self-aggrandizing interpretation of the events possesses some merit because he succinctly and accurately described the technical solution.

32. Bakke, interview. According to Bakke, this was the other major hurdle to gaining pilot acceptance of the pod's combat utility.

33. History, 366th Tactical Fighter Wing, vol. 1, 4; and Dilger, oral history interview, 12. Dilger, one of Blesse's troops working in the 366th tactics section, noted that the new configuration "was capable of out-flying our all-missile configuration." Eventually, the wing resumed loading all four Sparrow missiles on the aircraft, even with the SUU-16 gun pod, as based on aircraft configuration data reported in AFHRA, "1967-22 May; Titus and Zimer." From the outset, the 8th TFW loaded four AIM-7s with the SUU-16/23 gun pod; their December 1967 "Tactical Doctrine" manual listed the "normal fragged configuration of the F-4 performing escort and/or 'sweep' missions" as "4 x AIM-7 Sparrows; 4 x AIM-9 Sidewinders or 3 x AIM-4 Falcons; 1 x QRC-160 or ALQ-71 ECM Pod; 600 Gal Centerline fuel tank or SUU-16/23 Gun Pod; 2 x 370 Gal Outboard fuel tanks." 8th TFW, "Tactical Doctrine," December 1967, 106. The aircraft configuration from the 5 June 1967 engagement verifies this standard 8th TFW configuration, as did former 8th TFW F-4 pilot, Lt Col (ret.) Darrell "D" Simmonds. AFHRA, "1967-5 June; Raspberry and Gullick"; and Simmonds, interview.

34. Although each wingman carried eight missiles, they were rarely able to employ them during combat. The Air Force flew a fluid four/fighting wing formation that assigned primary responsibility for shooting down enemy fighters to the flight or element lead and relegated the wingmen to simply covering the lead aircraft. In contrast, the Navy flew a loose deuce formation that afforded the wingman greater freedom of action and a shared responsibility for offensive missile employment. Michel, *Clashes*, 169–72.

35. Blesse, *Check Six*, 121.

36. Blesse offered his opinion as to how the F-4C came to be manufactured without an adequate gunsight: "After the extremely capable A-1C radar computing gun sight we used 15 years earlier in Korea, it was difficult to understand how we could find ourselves in this situation. Fuzzy thinkers were sure guns no longer were useful in combat, and in some cases even had them removed from the aircraft and destroyed. It was a disease. They pulled guns out of the F-86F and F-104 to name a couple and—what was worse—left them out of new aircraft in the

design stage. Without guns, who needs a gun sight—and that's how our predicament came about." Ibid.

37. Colonel Olds, oral history interview, 42.

38. Bugos, *Engineering the F-4 Phantom II*, 157; and Michel, *Clashes*, 103.

39. Blesse, *Check Six*, 123. Olds's less than enthusiastic response contradicts his previously cited opinion of the gun. Davies noted that in a later personal interview with Olds, "his reservations still held." Davies then quoted Olds at length: "The gun pod wasn't so much a speed penalty as an object of increased drag, and therefore increased fuel consumption. But that wasn't my objection to the gun pod. I refused to carry it for three basic reasons: 1) It took the place of five or six 750-pound bombs; 2) Only my older and more experienced fighter pilots had ever been trained in aerial gunnery, to say nothing of air-to-air fighting. There were perhaps a dozen of them in the 8th TFW; 3) I had no intention of giving any of my young pilots the temptation to go charging off to engage MiG-17s with a gun. They would have been eaten alive. Instead, they fought the MiGs the way I taught them, and I might say they did so with notable success. They learned that there were times to fight and there were times to go home and come back the next day." Davies, *USAF F-4 Phantom II*, 31. Olds's trepidations regarding inadequate pilot training were also evident in his memoir: "I really had to argue with myself about my own desire to carry a gun. I knew I could hit anything I shot at but was damned sure I didn't want to tempt my men to engage a MiG-17 in an old-fashioned dogfight or give them the urge to go down in the mountain passes in Laos to strafe a stupid truck. In either case, I would have lost bunches of them. We needed guns, no doubt about it, but we needed pilots trained to use them even more." Olds, *Fighter Pilot*, 317.

40. Message, C10697, 366 TFW to 7 AF (emphasis added). "Package Six" referred to route package six. See note 2 in chapter 1 for a brief discussion of the Route Pack arrangement in Vietnam.

41. Message, DCO00148, 366 TFW to 7 AF.

42. Blesse, *Check Six*, 123; and Michel, *Clashes*, 104. Blesse stated that the mission took place "around the first week in May." However, other sources, including the previously cited message traffic, suggest that the mission actually occurred on 12 May 1967. Michel came to a similar conclusion, "The podded cannon finally was brought into combat on May 12." The SUU-16 project was well received within the wing. In his squadron monthly history report, 1st Lt John Frazier of the 390th TFS reported, "During May, 390th aircraft were the first in the wing to be modified to carry the ECM pod on an inboard . . . pylon, . . . thus giving the F-4C the capability of carrying two external 370[-gallon] wing tanks as well as a SUU-16 20-mm cannon on the centerline station. This has been a much looked for modification." Frazier, "Historical Summary."

43. AFHRA, "1967-14 May; Hargrove and DeMuth." Carey and Dothard in Speedo 2 did not make it back to Da Nang with the rest of their flight; they ran low on gas, missed their aerial refueling rendezvous, and had to recover at Nakhon Phanom Royal Thai AFB.

44. Ibid.; AFHRA, "1967-14 May; Craig and Talley."

45. Message, 141800Z MAY 67, 366 TFW to NMCC. The message describing Elgin flight's engagement concluded with a similar assessment, "ELGIN Lead, [#]2 & [#]4 all feel that the SUU-16 would have been much more effective against the MiG-17s than any of their missiles." Message, 141410Z May 67, 366 TFW to NMCC.

46. Hargrove, oral history interview, 22–23. A "break" is an aggressive defensive turn away from an attacking fighter.

47. History, 366th Tactical Fighter Wing, vol. 1, 5.

48. PACAF Command Center, Chronological Log, 13-14 May 1967. It was later assessed that Elgin flight faced 10 MiGs that afternoon, not the six originally reported. See note 7 in Chapter 1.

49. Ibid.

50. PACAF Command Center, Chronological Log, 14–15 May 1967. Recall that Elgin 1 was not armed with the SUU-16 gun pod because it was a spare aircraft. See note 4 in chapter 1.

51. Ibid.

52. Ibid., 2.

53. Blesse, *Check Six*, 125. See note 18 in chapter 1 regarding the daily operational summary report's wording. The actual message, not Blesse's recollection, has been cited.

54. As the first in-theater wing to accept the new F-4Ds equipped with the lead-computing gunsight, the 8th TFW did not have to rely on the 366th's primitive aiming techniques.

55. Futrell et al., *Aces and Aerial Victories*, 120–21. Maj William Kirk and 1st Lt Theodore Bongartz flew the F-4D. Their prize was a MiG-21, Kirk's second kill of the war.

56. Kirk, oral history interview, 6. Although he quickly added, "It's too bad it's not internal. It's too bad we have to hang it externally; it's extra drag, extra weight, but we're willing to sacrifice that." The gun pod's air-to-air combat utility was solidified in the minds of the 8th TFW pilots on 6 November 1967 when Capt Darrell "D" Simmonds and 1st Lt George McKinney, Jr., downed two MiG-17s with the pod in less than two minutes. During the engagement, Simmonds, leading Sapphire flight, expended fewer than 500 rounds while destroying the two MiGs. During the second gunshot, Simmonds closed to within 400 feet of the MiG before it exploded. Too close to maneuver away from the disintegrating MiG, Simmonds ended up flying through the fireball. By the time of Simmonds's engagement, there were enough gun pods to equip all the F-4D escort fighters with SUU-23 gun pods. AFHRA, "1967-6 November; Simmonds and McKinney."

57. Message, DCO00157, 366 TFW to CSAF.

58. The SECDEF briefing transcript read, "Our low altitude capability was improved by a field modification here at Da Nang. This modification allowed us the carriage of the 20-mm cannon on cover missions. The gun has exceeded our expectations. We fly all missions to Package VI, including strike missions, with the gun." Responding to one of McNamara's questions, Blesse noted that the gun "is one of our most versatile and effective weapons, air-to-ground and air-to-air, in spite of the lack of a computing sight capability." Message, 191633Z JUL 67, CSAF to PACAF.

59. Blesse, *Check Six*, 126.

60. History, 366th Tactical Fighter Wing, vol. 1, 4.

61. Futrell et al., *Aces and Aerial Victories*, 118–22; Blesse, *Check Six*, 125; and Dilger, oral history interview, 11–13. During that period, the 366th shot down five aircraft with AIM-7s, three aircraft with AIM-9s, and four aircraft with the 20 mm gun and caused one MiG to crash while trying to defend itself against a 366th F-4 attack. Dilger described the 366th's combat results with the gun during a 6 July 1967 interview: "The gun right now has been engaged five different times, and we shot down four MiGs with it. Four out of five is a very good answer, and the man that missed was not—he's never fired a gun before in his life, and his tactics were so gross that you couldn't expect the gun to have done him a good job. But the people that employed the gun properly did very well with it."

62. Futrell et al., *Aces and Aerial Victories*, 157. An F-4D and F-105F shared one kill.

63. Blesse, *Check Six*, 123. Recall that Olds warned Momyer not to allow Blesse and the 366th TFW to continue pursuing employment of the SUU-16 in an air-to-air role. See note 39 this chapter for Olds's later-stated rationale.

64. Olds, like others, would have preferred to have an internal gun. He added, "It's beautiful but still it's an appendage. No fighter should be built without a gun in it. That's basic and then anything else you can add is just Jim Dandy with me." General Olds, oral history interview, 76.

65. Colonel Olds, oral history interview, 42–43.

66. *Project Red Baron II*, 19.

67. Momyer, *Airpower in Three Wars*, 158; and Crane, *American Airpower Strategy in Korea*, 60. Crane cites Air Force major general Emmett O'Donnell's 1951 Congressional testimony, "I think this is a rather bizarre war out there, and I think we can learn an awful lot of bad habits in it." One of the political restrictions which Momyer was referring to was the requirement "for positive visual identification before the pilot could open fire." Momyer more clearly articulated his concern in an earlier Corona Harvest memorandum: "We should, therefore, be cautious about the lessons derived from these limited combats [in Vietnam]. Most certainly, relative performance of aircraft could be judged and restricted conclusions on air-to-air tactics could be deduced, but one should not try to extrapolate these limited experiences in generalizing about the character of an air war in Europe where thousands of fighters would be involved." Momyer to Ellis, "Corona Harvest (Out-Country Air Operations)," 4. Corona Harvest was the Air Force's and AU's comprehensive study of airpower in SEA. Momyer, then retired, was hired in April 1974 as a paid consultant by the vice chief of staff of the Air Force, Gen Richard Ellis, to review the studies and to provide summary memorandums and recommendations for each of the Corona Harvest volumes. Cunningham, "Spike," 123–24. Hone agreed with Momyer's assessment of the political restrictions, although Hone offered a better appraisal of their effect on the air war during Vietnam. Hone emphasized, "The conflict [in the skies over North Vietnam] was between two systems, one of which was hampered by politically motivated constraints. In North Vietnam, the Vietnamese constructed a multifaceted, mutually supporting system of air defense. The burden was on US forces to penetrate it because they were never allowed to totally destroy it. . . . Vietnam was not a conflict of fighter-on-fighter but of offensive systems against defensive systems." Hone, "Southeast Asia," 555.

68. Momyer to Ellis, "Corona Harvest (USAF Operations against North Vietnam)," 4.

69. Momyer continued, "To accomplish this requirement, airborne radar will require extensive improvement in range, resolution, and reliability." Momyer to Ellis, "Corona Harvest (Out-Country Air Operations)," 24.

70. Momyer to Ellis, "Corona Harvest (USAF Personnel Activities)," 4.

71. *Project Red Baron II*, 17. The report also noted that "as the war progressed, the USAF aircrew population with prior tactical experience was diluted over 50 percent; the average in-aircraft time also decreased by a similar proportion. Conversely, the enemy's tactical experience level most probably increased over time. As a result, the USAF loss rate went up, while the NVN's went down; that is, 3.0 MiGs lost per USAF aircraft lost, decreased to 0.85 MiGs per each USAF loss."

72. Ibid., 21; Hannah, *Striving for Air Superiority*; and Skinner, *Red Flag*. The *Red Baron II* report continued, "Aircrews must have extensive initial and continuation ACM training. This training should include instruction on enemy capabilities and limitations. Realistic training can be gained only through thorough study of, and actual engagements with, possessed enemy aircraft or realistic substitutes."

73. The F-22A uses a lighter-weight version of GE's M-61 20 mm Vulcan cannon, the same gun built into the F-4E, the F-15, and the F-16. The Air Force version of the F-35 joint strike fighter (JSF) will sport the Air Force's first new fighter-gun design in almost 50 years. The Navy's version of the F-35, however, does not carry an internal gun.

Chapter 7

Military Innovation

C'est l'ancien qui nous empêche de connaître le nouveau.

—Auguste Comte

The human tendency to focus on singular concepts—old or new, intellectual or technological—often obfuscates the broad perspective critical to recognizing evolving strategic contexts. It also impedes timely and innovative adaptation to an emerging situation. While not necessarily more susceptible to this tendency than other institutions, the American military is nevertheless affected more profoundly by it, particularly within the technological realm. Countless volumes have probed the nature of military innovation, seeking a better description of it so that leaders can cultivate a more responsive and flexible organization ready to adapt to the ever-changing conditions of war. Extending the theory of technological dislocations and the Air Force air-to-air armament case study to the larger context of military innovation aids this endeavor.

The Role of Cognitive Consistency

In *Strategy in the Missile Age*, Bernard Brodie chided 1950s' American defense officials' narrow-minded approach to national strategy in the emerging thermonuclear age. Identifying the undue influence of an "intellectual and emotional framework largely molded in the past," Brodie noted that the American military profession was not only unwilling, but also largely unable to comprehend that the proliferation of nuclear weapons rendered many of their hallowed principles of war obsolete and irrelevant.[1] Brodie observed, "We have been forced to revise our thinking about weapons; but unfortunately there is not a comparable urgency about rethinking the basic postulates upon which we have erected our current military structure, which in fact represents in large measure an ongoing commitment to judgments and decisions of the past."[2] Based on his assessment, Brodie called upon August Comte's adage, *"C'est l'ancien qui nous empêche de connaître le nouveau"* (It is the old that prevents us from recognizing the new).[3]

History, however, demonstrates that the reciprocal of Comte's adage can also be true—the *new* can sometimes prevent us from recognizing the *old*. David Edgerton alluded to this phenomenon in his description of "use-based

history," noting that the history of technology is often written as though there were no alternatives to a given technology. This dominant perspective ignores the reality that "there is more than one way to skin a cat, to fight a war, to generate energy. Yet, these alternatives are often difficult to imagine, even when they exist."[4] Fascination with technology and a generally uncritical "assumption that the new is clearly superior" often skews judgment of an emerging technology's feasibility and practicality.[5] For example, Edgerton noted that Hitler's obsession with developing the technologically advanced V-2 rocket drained valuable German resources from more practical and potentially more fruitful wartime enterprises.[6] A similar pattern was revealed in the previous case study when the American Air Force's fascination with guided air-to-air missile technology biased its assessment of the combat utility of guns on future fighter aircraft.

Robert Jervis explored these limitations of human cognition within the strategic realm. He noted that an individual's desire to maintain *cognitive consistency* leads to a "strong tendency for people to see what they expect to see and to assimilate incoming information to preexisting images."[7] Whereas this pattern of obstinacy is not new to human history, Jervis was unique in his assertion that this "closed-mindedness and cognitive distortion" takes place at the decision maker's subconscious level.[8] Furthermore, not only does the desire for cognitive consistency restrict individuals to usually studying at most "only one or two salient values" when formulating a strategy, it also entices decision makers to continue pursuing a particular strategy despite evidence that may suggest the policy is ill-conceived and inappropriate.[9] Jervis concluded, "Expectations create predispositions that lead actors to notice certain things and to neglect others, to immediately and often unconsciously draw certain inferences from what is noticed, and to find it difficult to consider alternatives."[10] These inflexible schemas, whether focused on the old or the new, manifest as an inability to effectively innovate.[11]

This tendency is especially pronounced in military organizations. Citing Dean Pruitt, Jervis noted that the more extreme the perceived significance of a schema, the less flexible it becomes. Commitment—"the degree to which [a] way of seeing the world has proved satisfactory and has become internalized"—plays an important role when matters of national security, and consequently choices of life and death, are considered.[12] Moreover, because the real-world opportunities for the military's schemas to be tested are fortunately infrequent, the organization's commitment to its schemas tends to become institutionalized within military culture.[13] Historian Michael Howard described the military's plight: "For the most part, you have to sail on in a fog of peace until the last moment. Then probably, when it is too late, the clouds lift

and there is land immediately ahead; breakers, probably, and rocks. . . . Such are the problems presented by 'an age of peace.'"[14]

> Bureaucratic norms and the human need to maintain cognitive consistency, exacerbated by the high stakes associated with national security and the relatively rare data set made available by active warfare, reveal themselves in the dialectical perception of both the technological exuberance and technological skepticism of the American military. Dominant technologies are embraced while alternative technologies, especially revolutionary ones, are shunned. Initially, the Navy preferred battleships to aircraft carriers; the Army preferred cavalry to tanks and aircraft, and single-firing rifles to machine guns; and the Air Force preferred bombers to ICBMs and manned aircraft to unmanned aircraft.[15]

However, the dominant technology need not be the old technology. Indeed, as the preceding case study illustrated, the introduction of a proven-but-assumed-antiquated technology like the air-to-air cannon can also be greeted with technological skepticism. A technological innovation need only diverge from the established technological trajectory to draw the wary eye of the constituency it potentially threatens.

Technological Innovation as Military Innovation

Technological innovation does not always equate with *military* innovation. As Brodie observed, technological innovations in aircraft-delivered nuclear weapons did not induce a corresponding and necessary innovation in American military strategy; military leaders simply incorporated the new *means* into the same *ways* and *ends* equation.[16] Nevertheless, while technology clearly does not dictate strategy, a complex interdependent relationship exists between the two.

Reflecting on this link between technology and military strategy, Colin Gray noted, "Technology, as weaponry or as equipment in support of weaponry, does not determine the outbreak, course, and outcome of conflicts, but it constitutes an important dimension [of strategy]."[17] Howard drew a similar conclusion. Reminiscent of Carl von Clausewitz's trinity of war, Howard believed that strategy "progresses . . . by a sort of triangular dialogue between three elements in a military bureaucracy: operational requirement, technological feasibility, and financial capability."[18] Similarly observing the role of technology and finances within strategy, Brodie asserted, "Strategy in peacetime is expressed largely in choices among weapons systems . . . [and] the military budget is always the major and omnipresent constraint."[19] Jervis likewise acknowledged the strong influence technology can have on military strategy: "The adoption of one weapon . . . often requires changes in other

weapons, in tactics, and—in some cases—in strategies and interests."[20] These interpretations all support the assessment that technology and strategy are somehow linked, but the disparity between the individual observations suggests the linkage is amorphous, bound in historical context, and not easily discernible.

For example, one scholar relied heavily on Jervis and organizational theory to support his view of military innovation. Barry Posen observed that "innovations in military doctrine will be rare because they increase operational uncertainty." Posen purported that two powerful catalysts could nevertheless force the military to adapt: military defeat and civilian intervention. Furthermore, he observed that the two catalysts were linked: "Failure and civilian intervention go hand in hand. Soldiers fail; civilians get angry and scared; pressure is put on the military."[21] However, due to their relative unfamiliarity with military doctrine, civilians usually required a military compatriot to provide the necessary specialized knowledge—a "maverick" like Billy Mitchell, Hyman Rickover, or "Bony" Fuller.[22]

While Posen's research was clearly focused on innovation at the doctrinal level, his evidentiary base established a clear link between technological innovation and military innovation. For example, Posen cited the British air defense system of 1940 as "one of the most remarkable and successful military innovations of the pre-atomic machine age."[23] However, whereas this British military innovation was obviously reliant upon the coupling of technological developments in radar and fighter aircraft, the key innovation catalyst according to Posen was the timely intervention of a civilian-military maverick team composed of Henry Tizard, Thomas Inskip, Prime Minister Stanley Baldwin, and Air Chief Marshall Sir Hugh Dowding.[24] The team, cognizant of the changing strategic context of the 1930s when others were not, forced the Royal Air Force to shift its focus from procuring offensive strategic bombers to developing the Chain Home radar system and the corresponding fighter defenses that later proved invaluable during the Battle of Britain.[25]

Posen therefore urged future civilian leaders to actively engage with the military in matters of strategy: "Civilians must carefully audit the doctrines of their military organizations to ensure that they stress the appropriate type of military operations, reconcile political ends with military means, and change with political circumstances and technological developments."[26] Without this civilian intervention, Posen claimed that the military bureaucracy would prefer "predictability, stability, and certainty" over innovation, at potential great cost to national security.[27]

Writing seven years after Posen, Stephen Rosen offered a different assessment of military innovation. While both Posen and Rosen agreed on the im-

portance of developing an appreciation for changes within the strategic environment and overcoming bureaucratic resistance, Rosen vehemently disagreed with the primacy Posen granted to civilian intervention, even labeling Posen's theory a "*deus ex machina*."[28] Rosen viewed the process of military innovation as being far more complex, and consequently, he elected to parse innovation into three more manageable subsets: peacetime, wartime, and technological. Identifying different operative mechanisms within each category, Rosen determined:

> Peacetime innovation has been possible when senior military officers with traditional credentials, reacting not to intelligence about the enemy but to a structural change in the security environment, have acted to create a new promotion pathway for junior officers practicing a new way of war.

> Wartime innovation, as opposed to reform, has been most effective when associated with a redefinition of the measures of strategic effectiveness employed by the military organization, and it has generally been limited by the difficulties connected with wartime learning and organizational change, especially with regard to time constraints.

> Technological innovation was not closely linked with either intelligence about the enemy, though such intelligence has been extremely useful when available, or with reliable projections of the cost and utility of alternative technologies. Rather, the problems of choosing new technologies seem to have been best handled when treated as a matter of managing uncertainty.[29]

Rosen's catalysts share one common attribute—all require a keen perception of the evolving strategic context. Whether adapting to "a structural change in the security environment," new measures to assess "strategic effectiveness," or technologies pursued to help mitigate uncertainty within the changing strategic context, all of Rosen's mechanisms are hobbled by the frequently obstinate nature of bureaucracies and individuals' search for cognitive consistency.

Other scholars treating military innovation have typically offered variations on the above themes. Owen Coté, Jr., suggested that interservice conflict "can act alone and independently to cause innovative military doctrine."[30] John Nagl focused his research on the military's organizational culture, concluding that an "institutional learning" environment was key to successful innovation, especially during wartime.[31] Barry Watts and Williamson Murray borrowed heavily from Rosen when they concluded, "Without the emergence of bureaucratic acceptance by senior *military* leaders, including adequate funding for new enterprises and viable career paths to attract bright officers, it is difficult, if not impossible, for new ways of fighting to take root within existing military institutions."[32] Allan Millet's study of innovation during the interwar period successfully linked Posen's "civilian intervention," Rosen's

"measures of strategic effectiveness," and Coté's "interservice conflict" into a single assessment: "History . . . does demonstrate a relationship between strategic net assessment and changes in military capability. . . . [It] demonstrates the importance of civilian participation in the process of change at two levels, political and technological. Both levels of interaction are important, not the least because they compensate for interservice and intraservice friction. Innovators need allies in the civilian political and technological establishments as well as patrons within their service."[33]

Howard offered his own assessment of military innovation in 1973, more than a decade before Posen published his study. Indeed, Posen's argument seems a reflection of Howard's earlier observation: "One may need a dynamic force of exceptional quality administered from outside the profession to cut through . . . arguments, and with a possible irrational determination, give the order 'You *will* do this.'" Howard also foresaw the potential negative effects technological and bureaucratic complexity would have on innovation. He continued: "It becomes increasingly difficult as warfare becomes more complex, as the bureaucracy becomes more dense, as the problems become harder, for anybody to credibly emerge and impose his will on the debate in this basically irrational manner. Thus, as military science develops, innovation tends to be more difficult rather than less."[34] Howard's observation affirms the critical role knowledgeable and credible individuals play in spurring innovation and, if necessary, disrupting the established technological trajectory.[35] These individuals are well suited to effect technological dislocations.

Technological Dislocations

Critics may contend that the preceding air-to-air case study is too narrowly focused and the innovation too minor to derive worthwhile conclusions regarding the nature of technological innovation, much less military innovation. True, air-to-air gun technology existed on other Air Force aircraft, and rather than threatening the Air Force's pilot constituency, the F-4/SUU-16 technology in effect bolstered the idolization of heroic pilots who generations earlier valiantly dueled over the western front. In addition, the innovation, being relatively inexpensive and requiring little modification to the existing aircraft, did not demand significant capital or resource expenditure. For all these reasons, adding a gun to the Phantom should have been a relatively simple task; even if the bureaucracy was not eager to adopt the innovation, it should have at most been indifferent to it. It was not. The addition of an air-to-air gun on the F-4C was opposed by not only the corporate bureaucracy,

but also by many of the practitioners themselves, including combat veterans like Olds. Why?

The paradigm and resultant technological trajectory that shaped this Air Force attitude can be traced back to the first experimental Tiamat guided missile launched in the closing days of World War II. Despite the missile's failure to meet expectations, the Air Force quickly became enamored with the prospect of arming its newest, high-speed jet fighters with advanced, radar- and infrared-guided air-to-air missiles. Initially, the nascent technology had its share of skeptics within the bureaucracy. Facing severe reductions in the postwar defense budget, Air Force officials slashed initial missile funding in favor of the Air Force's higher-priority strategic bomber fleet. While there were some rare missile successes that helped soften bureaucratic resistance, the skepticism that threatened the early missile programs was largely overcome only when the missile proponents linked their technology to the Air Force's dominant strategic assumption and its organizational self-image.

The Air Force of the 1950s marketed itself as *the* technologically minded service. Armed with impressive fleets of high-flying bomber aircraft, the Air Force promised to deliver the newest products of the nation's technological wizardry—its growing nuclear arsenal—on the Soviet Union the moment the president gave the order. However, this vision of future war also required the Air Force to prepare to thwart any Soviet attempts to deliver the same. Within this strategic context and persuaded by the incontrovertible laws of intercept geometry, as well as the ceaseless demand for ever-greater firepower, the Air Force demanded better and faster fighters with longer-range and more destructive armament that could quickly dispatch the Soviet hordes.[36] It demanded guided air-to-air missiles.

As Soviet bomber aircraft capabilities rapidly improved during the 1950s and 1960s, the Air Force responded in kind. American F-86s gave way to F-102s and F-106s, the last of which was capable of sprinting at greater than Mach 2 to intercept Soviet bombers flying nearly 10 miles high. During this period, fighter and air-to-air missile development fell into a rut that channeled future acquisitions in an unchallenged and nearly autonomous fashion. There were improvements in missile design—GAR-1s gave way to GAR-1Ds, then GAR-3s; and GAR-2s eventually transitioned to GAR-4s—but the technological paradigm and the resultant technological trajectory constrained revolutionary, innovative thinking. Incremental technical progress substituted for a conscious evaluation of the evolving strategic context, thereby reinforcing a self-deluding perception that American technological prowess would dominate future conflict. Few Air Force leaders questioned the assumption that the fighters and their missiles would only be required to destroy large, high-flying,

nonmaneuvering Soviet bomber aircraft. Even when the assumption proved invalid in the skies over Korea, the demand for cognitive consistency allowed the Air Force to disregard its tactical air-to-air experience in favor of its preferred strategy and its dominant technological trajectory.

Compounding matters, as the missiles spread through the Air Force in the decade prior to Vietnam, technological skepticism gave way to overconfidence and technological exuberance. Lackluster test performance, even against the narrowly focused, bomber-aircraft target set, did not dissuade Air Force leaders from equipping their newest fighter interceptors exclusively with missiles. Guns were seen as archaic, and the methods and techniques for employing them were considered irrelevant in future air combat that would be characterized by long-range missile attacks against unsuspecting enemy aircraft. As such, many senior Air Force leaders deemed continued air combat maneuvering training unsafe and an unnecessary risk to Air Force aircraft. Subjected to a bureaucracy enamored with the promises of missile technology and captivated by its strategic assumptions, pilots' dogfighting skills quickly atrophied.

When the glaring deficiencies in American air combat capability were finally realized in the opening months of Vietnam, the Air Force scrambled to develop technological solutions. It launched numerous studies, including the 1966 Heat Treat Team, but no viable solution readily emerged.[37] The technological paradigm that contributed to many of the deficiencies continued to dominate Air Force thinking; proposed solutions such as the AIM-4D Falcon and the AIM-7E-2 Dogfight Sparrow largely conformed to the already-established technological trajectory. Unfortunately, like their predecessors, the new weapons arrived late and failed to live up to the overhyped expectations. When the Air Force finally broke free from its technological rut and recognized the complementary value of a gun on a fighter, aircrews were instructed to wait patiently for the F-4E.

For Blesse at Da Nang in April 1967, that was unacceptable. Luckily, he benefitted from Catledge's earlier advocacy of the SUU-16 podded gun system. Although Catledge desired an F-4 air-to-air gun capability, his decision to instead market his podded gun solution as an air-to-ground weapon successfully avoided the ire of the air-to-air missile mafia that dominated the Air Force's requirements cadre. He believed that continued manufacturing of the gun, even in podded form, would ensure that it could one day be resurrected in an air-to-air role when conditions demanded. Without Catledge's tireless advocacy and ingenious work-around solution, Blesse would have lacked the critical tool necessary to introduce his technological dislocation.

As a heterogeneous engineer, Blesse proved adept at integrating assumed-disparate components into a practical solution.[38] His ad hoc innovation combining the F-4C and the SUU-16 gun pod for air-to-air combat against the North Vietnamese MiGs was in many ways a precursor to today's concept of "recombinative technology."[39] By utilizing off-the-shelf technologies and integrating them in an unforeseen way and with a minimal level of effort, Blesse was able to leverage existing technologies to fill a capabilities void. Shortfalls in the integration, such as the lack of a lead-computing gunsight in the F-4C, were identified, and procedures were developed to mitigate the negative effects. Blesse's cobbled-together F-4/SUU-16 weapons system was not a perfect solution; the F-4E was a better one. However, Blesse's innovation provided a low-cost, effective, and, most importantly, timely solution that the F-4E could not offer.

The story of Blesse and the 366th TFW's mating of the SUU-16 gun pod to the F-4 for air-to-air combat highlights the significant potential of unit-initiated tactical innovation. Granted, Blesse's innovation did not affect the strategic outcome of the Vietnam War, but it did have a dramatic impact on the Air Force's culture, acquisition requirements, and operations well into the twenty-first century. All Air Force fighter aircraft since the Vietnam War have been equipped with both missiles and guns, and today's Air Force fighter pilots routinely practice their dog-fighting skills.

Blesse's innovation also demonstrates the fragility of innovation born at the unit level. Certainly, Blesse's renowned credibility as a tactician and a Korean War ace helped disarm his commanders' skepticism. However, if the Da Nang wing commander, Bolt, or the Seventh Air Force commander, Momyer, had deemed Blesse's project too risky to personnel, equipment, or reputation, they could have simply ordered the project to be abandoned. Blesse would have had little recourse. Surprisingly, had Olds been in command, the program probably would have been terminated.

Therefore, Blesse's technological innovation aptly illustrates the important role that commanders, even those at a relatively low level, play in military and technological innovation. By nature of the military hierarchy, these individuals exert considerable influence on the military's ability to innovate. Their significance is magnified by the fact that the individuals least likely to be gripped by the dominant technological paradigm and thus more open to investigating alternatives typically reside at the lower ranks. But, because bypassing the chain of command is frowned upon, a single supervisor can sound the death knell for an otherwise promising innovation. As Jervis pointed out in his discussion of cognitive consistency, the supervisor's decision need not even be malicious.[40]

The standard military response in these situations has been to wait out the opposition, knowing that eventually all commanders move on or retire. However, waiting can complicate matters as it gives more time for the existing technology to build momentum and the bureaucracy to become even more resistant to change. Catledge's method of disarming the opposition by masking the true intention of the innovation provides one strategy, albeit an ethically questionable one, for innovating in spite of bureaucratic resistance.

The historical case study of the F-4-gun system also affirms the difficulty in identifying a discrete tipping point and its causal factors in a complex technological system befuddled by competing historical interpretations. A strong case can be made that efforts to reintroduce guns to fighter combat reached a tipping point at Da Nang in 1967. However, when dissecting the historical evidence, identifying a *single* causal factor that led to the tipping point is too reductionist and woefully inadequate. While Blesse stands at the forefront, Catledge was also certainly integral to the innovation; without his efforts, guns might not have been ready for the F-4E, and a podded gun would certainly not have been ready for the F-4C/D. Additionally, a variety of other social influences prodigiously aligned themselves at Da Nang in April and May 1967—for example, arrival of the SUU-16 gun pods, President Johnson's decision to attack the more valuable NVN targets, the consequent surge in MiG activity, the decision to assign additional MiGCAP sorties to the 366th TFW, and a receptive Momyer. All contributed to the dislocation in one way or another.

Thus, like Schriever with the American ICBM, Blesse shares credit for his innovation with others. But, also akin to Schreiver's role in ICBM development, it was Blesse's unique credibility and his heterogeneous engineering skills that allowed him to associate these varied influences into a practical solution. In doing so, Blesse successfully introduced a socially constructed dislocation, disrupting the deterministic technological trajectory that, for more than two decades, had been constraining Air Force air-to-air armament design.

The preceding case study did not validate the individual innovation catalysts as described by Posen, Rosen, or Coté. Although some might consider Blesse a military maverick based on his unwavering zeal for guns, Blesse's innovation did not require his pairing with a civilian official to garner bureaucratic acceptance as Posen suggested was necessary. Rosen's model of innovation also fails to adequately explain the 366th TFW's innovation. Granted, the Air Force recognized a substandard level of effectiveness in its missiles, but the institution's solution was to wait for the F-4E, not to load the SUU-16 onto the existing F-4C/Ds for use in air combat. Coté's model of innovation like-

wise falls short. Although the history of guided-missile development is colored by varying degrees of interservice rivalry between the Air Force and Navy, especially with regard to the Air Force's AIM-4D Falcon and the Navy's AIM-9D Sidewinder, there is little evidence to suggest that interservice rivalry encouraged the Air Force to develop the F-4E or spurred the 366th TFW to develop the F-4C/SUU-16 procedures.

It is possible that Posen's, Rosen's, and Coté's models of innovation apply only to innovation in doctrine. If true, then a significant theoretical gap exists in describing the influential mechanisms that spur innovation at the tactical and technical level. The lack of a suitable model at this level does not diminish its importance. Often, tactical innovations can have operational repercussions. It is also feasible that innovation at the tactical level could bubble up to the strategic level, although regrettably Blesse's innovation did not affect the strategic outcome of the Vietnam War.

The model of technological dislocations and the notions of competing technological skepticism and technological exuberance within a military organization help fill this theoretical void. While the proposed model lacks specific technological forecasting ability, it offers a method of conceptualizing and describing innovation at all levels, including the tactical. It also provides a vocabulary that describes the intermingling of society's influence on technology and vice versa, stimuli that continue throughout the life of a technological system. Furthermore, by identifying those key contingencies in history where a dominant technological trajectory is dislocated, the theory of technological dislocations focuses research to better inform scholars and practitioners of the relative merits of specific innovation strategies.

From this vantage point, the different innovation mechanisms described by Posen, Rosen, Coté, and others can be more accurately assessed. Absence of any of these specific catalysts does not diminish their potential analytic utility in another historical example. Their absence merely reaffirms the observation that the history of technology and the assessment of society's influence on it and vice versa are complex and open to varied interpretation.

This particular case study illustrated the value of keen marketing in outmaneuvering bureaucratic skepticism and the benefits of adopting a strategy of innovative systems integration vice outright systems acquisition, particularly when time is critical. Success or failure of this type of technical, tactical innovation hangs on the decisions of individual commanders. Thus, the review of Air Force air-to-air missile development, post–World War II through Rolling Thunder, leads to the conclusion that absent credible, innovative individuals and courageous commanders willing to act on their subordinates' recommendations, the military will regrettably tend to plod along according to a

technological trajectory, reinforced by a bureaucracy skeptical of technologies that threaten it and overconfident in existing technologies that reinforce it. This constitutes an important lesson for the future.

Lesson for the Future

The Air Force, by continuing to market itself as a technology-minded service, is particularly susceptible to the allure of technological exuberance and the potential trap of an unchallenged technological trajectory. One current example of this trend is the Air Force's continued enthusiasm for stealth technology.

Initially secreted in a *black* program, the radical F-117 stealth fighter was spared much of the bureaucratic skepticism that often stymies emerging revolutionary technologies.[41] After proving its worth during Desert Storm, stealth technology quickly became the dominant theme guiding future Air Force aircraft design.[42] In October 1991, Gen Merrill McPeak, the Air Force chief of staff, proclaimed that "it will be very difficult for the Air Force to buy ever again another combat aircraft that doesn't include low-observable qualities."[43]

Unfortunately, stealth technology is expensive, and the Air Force's nascent stealth programs of the 1990s, such as the B-2 bomber and the F-22 fighter, languished because of it.[44] In particular, acquisition problems, cost overruns, and claims that "the F-22 represents technological overkill" that is "irrelevant to the wars of today" plagued the $65 billion F-22 Raptor program.[45] Amidst the criticism over the two-decade-long Raptor program, the Air Force pared its requests from 740 aircraft to 381, and then to 243. It reluctantly settled on only 183.[46]

The Air Force's next stealth fighter, the F-35 Lightning II, is now experiencing similar cost overruns and production delays that doomed the earlier F-22. Touted as "the future centerpiece of the US military's approach to waging war in the skies," the massive F-35 program developed "a troubling performance record," according to then-secretary of defense Robert Gates.[47] Despite facing a per-aircraft cost rocketing upwards of $100 million and a production delay extending beyond two years, defense officials remain committed to the program.[48] In February 2010 Gates announced that there were "no insurmountable problems, technological or otherwise, with the F-35. . . . We are in a position to move forward with this program in a realistic way."[49]

The Air Force has chained its future to F-35 success. In their support of the decision to halt F-22 production, former Air Force secretary Michael Donley and former chief of staff Gen Norton Schwartz jointly endorsed the F-35 and

affirmed its exigency to the Air Force's future, proclaiming, "Much rides on the F-35's success, and it is critical to keep the Joint Strike Fighter on schedule and on cost."[50] Unfortunately, failure to do just that now burdens the service with what one scholar termed "the single greatest threat to the future Air Force's strategic viability," one that "risks bleeding the Air Force white over the next twenty years."[51]

While the problems associated with F-35 development are disconcerting, the Air Force's apparent refusal to reexamine the stealth aircraft's strategic utility is more alarming. Few deny the importance of maintaining a sizable fleet of stealth fighters (F-22A) and stealth fighter-bombers (F-35A) to deter potential conflict with a near-peer competitor (and if deterrence fails, to be victorious in combat). However, the simple, repeated chorus that all Air Force fighters require stealth technology does not suggest that a careful strategic assessment has been performed. An all-stealth fighter fleet would certainly simplify contingency planning. Likewise, it would be far simpler to maintain a fighter fleet that consisted of only two types of fighter aircraft. But what is the opportunity cost to other capabilities and requirements? Furthermore, what happens if a potential adversary develops a counter to American stealth technology? Even as stealth technology was introduced to the world in dramatic fashion during Desert Storm, Airmen and scholars noted that the United States would not enjoy this product of technological mastery forever.[52]

The Air Force appears reluctant to address these mounting fiscal constraints and shifting strategic contexts. Granted, the Air Force must revitalize its aging fleet. However, in its strategy to do so, the Air Force seems trapped in a technological trajectory that has yet to be sufficiently stressed and, if necessary, dislocated. Just as an Air Force armed with 740 F-22s became absurd as the strategic environment evolved during the 1990s, an Air Force equipped with more than 1,700 F-35s defies logic today. Yet the Air Force continues to demand a full inventory of stealthy F-35s at the expense of procuring, or even considering procuring, lower-cost alternatives such as the latest F-15 Silent Eagles or F-16 Block 60s that could complement a smaller, more cost-effective inventory of advanced stealth-fighter aircraft. Echoing these concerns, one independent study concluded, "The F-35 represents a classic 'middle-weight' capability—excessively sophisticated and expensive for persistent strike operations in the benign air environment of the developing world and most irregular warfare operations, yet not capable enough to contribute effectively to a stressing campaign against a nation employing modern anti-access/area-denial defenses."[53]

The Air Force's current, single-minded focus on a vision of future air combat and its dogged pursuit of the tools deemed necessary for that air war's

conduct seem eerily reminiscent of Air Force attitudes toward air-to-air guided missiles in the 1950s and 1960s. Air Force officials must guard against the seduction of a promising but unchallenged and contextually bankrupt technological trajectory, lest we one day find the world's premiere air force ill-equipped to face the nation's future adversaries. The assumption that new technology is always better than old technology is not always valid. Boots Blesse and the 366th TFW "Gunfighters" proved it.

Notes

1. "One of the barriers . . . is the general conviction, implicit throughout the whole working structure and training program of the military system, that strategy poses no great problems which cannot be handled by the application of some well-known rules or 'principles' and that compared with the complexity of tactical problems and the skills needed to deal with them, the whole field of strategy is relatively unimportant. . . . The professional officer, stimulated always by the immediate needs of the service to which he devotes his life, becomes naturally absorbed with advancing its technical efficiency and smooth operation. . . . It is therefore hard for the professional soldier to avoid being preoccupied with means rather than ends." Brodie, *Strategy in the Missile Age*, 391 and 11–17.

2. Ibid., 408.

3. Ibid., 391. Brodie could have also cited Machiavelli, as Rosen did: "There is nothing more difficult to carry out, nor more doubtful of success, nor more dangerous to handle, than to initiate a new order of things. For the reformer has enemies in all those who profit by the old order, and only lukewarm defenders in all those who would profit by the new order. . . [because of] the incredulity of mankind, who do not truly believe in anything new until they have had actual experience of it." Rosen, *Winning the Next War*, 1.

4. "A central feature of use-based history, and a new history of invention, is that alternatives exist for nearly all technologies: there are multiple military technologies, means of generating electricity, powering a motor car, storing and manipulating information, cutting metal or roofing a building. Too often histories are written as if no alternative could or did exist." Edgerton, *Shock of the Old*, xiii and 7.

5. Ibid., 8.

6. Ibid., 17. Edgerton noted that the resources Germany allocated toward development of its anemic V-2 rocket forces could have produced 24,000 fighter aircraft. While an impressive statistic, Edgerton's argument does not consider the fact that Germany did not have a pilot force capable of manning that many aircraft. A more telling statistic is that for every one enemy civilian killed in the V-2 rocket attacks, German officials sacrificed two laborers developing the V-2 and building its underground production facilities.

7. Jervis, *Perception and Misperception*, 117.

8. Ibid.

9. Jervis noted that often "inconsistent premises are used to support a conclusion." Additionally, Jervis asserted that in their search for cognitive consistency, "decision makers are purchasing psychological harmony at the price of neglecting conflicts among their own values and are establishing their priorities by default." Ibid., 137–40.

10. Ibid., 145.

11. Ibid., 201; and Jullien, *A Treatise on Efficacy*. According to Jervis, "If commitment to an image inhibits the development of a new one, those who are most involved in carrying out policies guided by the old image will be the least able to innovate." Jullien attributed this inflexibility to a Western way of thinking.

12. "The flexibility of an image seems to be an inverse function of the extremity of its level. The higher the level of trust or distrust, the lower its flexibility." Jervis, *Perception and Misperception*, 195–96.

13. Schein, "Defining Organizational Culture," 373–74. Schein defined an organization's culture as "a pattern of shared basic assumptions" that guide individual perceptions, thoughts, and behaviors within the organization.

14. "The greater the distance from the last war, the greater become the chances of error in this extrapolation. Occasionally, there is a break in the clouds: a small-scale conflict occurs somewhere and gives you a 'fix' by showing whether certain weapons and techniques are effective or not; but it is always a doubtful fix." Howard, "Military Science," 4. Howard provided an example later in the lecture: "After 1918 we [the British] did little better. We had a navy which absurdly underrated the effectiveness of air power. We had an air force which equally absurdly overrated it." Howard's analogy is an adaptation of Carl von Clausewitz's popular "fog of war" adage: "The general unreliability of all information presents a special problem in war: all action takes place, so to speak, in a kind of twilight, which like fog or moonlight, often tends to make things seem grotesque and larger than the[y] really are." Clausewitz, *On War*, 140.

15. See earlier discussion in Chap. 2, 20–21, regarding the Air Force's response to ICBMs and unmanned aircraft and the Army's response to machine guns. On the Navy's response to aircraft carriers, see Reynolds, *Fast Carriers*, and Hone, Friedman, and Mandeles, *American and British Aircraft Carrier Development*. On the Army's response to armored tanks, see Johnson, *Fast Tanks*.

16. "It is therefore hard for the professional soldier to avoid being preoccupied with means rather than ends." Brodie, *Strategy in the Missile Age*, 17. For an example of military innovation conducted largely independent of a corresponding technological innovation, see Thomas G. Mahnken's discussion of the Army's AirLand Battle doctrine. Mahnken, *Technology and the American Way*, 127–31.

17. Gray, *Modern Strategy*, 37. Technology constitutes one of Gray's 17 dimensions of strategy.

18. Howard, "Military Science," 5; and Clausewitz, *On War*, 89. Clausewitz's trinity of war is "composed of primordial violence, hatred, and enmity, which are to be regarded as a blind natural force; of the play of chance and probability within which the creative spirit is free to roam; and of its element of subordination, as an instrument of policy, which makes it subject to reason alone."

19. Brodie, *Strategy in the Missile Age*, 361. Brodie's chapter was aptly titled, "Strategy Wears a Dollar Sign."

20. Jervis, *System Effects*, 22.

21. Posen, *Sources of Military Doctrine*, 54–55 and 57.

22. Ibid., 57; Howard, "Military Science," 5; and Jervis, *Perception and Misperception*, 199. Howard alluded to the importance of "military mavericks": "Therefore the problem of encouraging and rewarding original thinkers—men like Bony Fuller who have insights of near genius into the nature of their profession and the problem of war but who do not combine these insights with other professionally desirable qualities—presents genuine problems of a kind which

laymen tend to underrate." Jervis likewise asserted, "Within the military, those who propose major innovations are often outside the mainstream of the profession."

23. Posen, *Sources of Military Doctrine*, 175.

24. Ibid., 171–73; and Beyerchen, "From Radio to Radar," 265–99. Tizard chaired the Committee for Scientific Study of Air Defense; Inskip was the minister of coordination for defense; Dowding was the head of the Royal Air Forces' Fighter Command.

25. Overy, *Battle of Britain*.

26. Posen, *Sources of Military Doctrine*, 241.

27. Ibid., 46.

28. "Failure in war has not been necessary or sufficient for peacetime innovation. . . . Civilian intervention is an appealing *deus ex machina* that might explain innovation in peacetime military bureaucracies. But observations of the difficulties civilian leaders, up to and including the president of the United States, have had in bending the military to their desires should again lead us to be cautious." Rosen, *Winning the Next War*, 9–10.

29. Ibid., 251.

30. Coté, "Politics of Innovative Military Doctrine," 13.

31. Nagl, *Learning to Eat Soup*.

32. Watts and Murray, "Military Innovation in Peacetime," 409 (emphasis in original).

33. Millett, "Patterns of Military Innovation," 336 and 359.

34. Howard, "Military Science," 6 (emphasis in original).

35. Rosen and Posen echo Howard's requirement for credible innovators. In Posen's model, the military maverick provides the necessary credibility; in Rosen's theory, senior officers choose to extend their credibility to junior officers. Posen, *Sources of Military Doctrine*; and Rosen, *Winning the Next War*.

36. In this vein, Air Force missile armament development reached a pinnacle with the GAR-11, the nuclear-armed version of the Falcon guided air-to-air missile.

37. PACAF, "F-4C Fighter Screen," 10. The 1966 Heat Treat team's findings were discussed in chapter 5. The team of Air Force and industry specialists concluded that even "assuming proper maintenance of both aircraft and missiles, the probability of kill with the Sparrow can be expected to be low." As Michel highlighted, the Navy's efforts to improve pilot training and experience were regrettably not aggressively pursued within the Air Force, another illustration of the Air Force's inability to break free from the constraints of its technological paradigm. Michel, *Clashes*, 181–86.

38. To review, John Law suggested that "'heterogeneous engineers' seek to associate entities that range from people, through skills, to artifacts and natural phenomena. This is successful if the consequent heterogeneous networks are able to maintain some degree of stability in the face of the attempts of other entities or systems to disassociate them into their component parts." Law, "Technology and Heterogeneous Engineering," 129.

39. Hasik, *Arms and Innovation*.

40. Jervis, *Perception and Misperception*, 117.

41. Schmitt, "Stealth Technology," A5. An October 1991 *New York Times* article noted that the F-117 program suffered serious setbacks, including the crashes of two early prototypes and the first production aircraft. In the article, Air Force general Joseph Ralston was quoted as saying, "The way things are conducted today, a successful program like the F-117 would have been cancelled."

42. "Fifty F-117s made up only 2.5 percent of the US combat planes deployed in the [Desert Storm] operation, but they attacked 31 percent of the targets on the first day of the air war." Kaplan, "General Credits Air Force."

43. Schmitt, "Stealth Technology," A5.

44. Ibid. B-2 bomber production was halted after only 15 aircraft, at a cost of $865 million apiece. Maj Gen Stephen B. Croker ascribed stealth's high cost not to "the physics of stealth, but the problems of producibility." He noted that the B-2 had to be constructed within tolerances of 1/10,000th of an inch.

45. Wayne, "Air Force Jet Wins Battle," C1; and Dilanian and Brook, "Raptor in Dogfight," B1. A July 2006 Government Accountability Office (GAO) report stated, "The F-22 acquisition history is a case study in increased cost and schedule inefficiencies."

46. Donley and Schwartz, "Moving beyond the F-22," A15; and Bender, "President Wins on Defense," A1. The Air Force secretary and chief of staff penned the Air Force's response to the mounting pressure threatening the F-22 program. After the Senate voted 58 to 40 to halt F-22 production in July 2009, Pres. Barack Obama praised the decision: "Every dollar of waste in our defense budget is a dollar we can't spend to support our troops, or prepare for future threats, or protect the American people. . . . Our budget is a zero-sum game, and if more money goes to F-22s, it is our troops and citizens who lose."

47. Whitlock, "Gates to Major General," A4; and Hedgpeth, "GAO Analyst Says Cost Overruns," A13. With the Department of Defense planning to acquire nearly 2,400 aircraft, the F-35 is the largest and most expensive acquisition program in US history. Its "troubling performance record" led Gates in February 2010 to fire the Marine general charged with managing the F-35 program.

48. Hedgpeth, "Price Tag for F-35 Jets," A4; Hedgpeth, "GAO Analyst Says Cost Overruns," A13; and Rolfsen, "Despite Problems."

49. Hedgpeth, "Price Tag for F-35 Jets," A4. However, others have noted, "The secretary of defense reluctantly supports this program because he has no alternative. . . . The [Joint Strike Fighter] is like a sweater. . . . You pull any thread, like pushing back on full-rate production, and things can fall apart very quickly." International participation in the program—nine US allies have staked a future on the F-35—further complicates domestic decision-making.

50. Donley and Schwartz, "Moving beyond the F-22," A15.

51. Ehrhard, *Air Force Strategy*, 88.

52. "Soviets Can Detect Stealth Bomber"; and Schmitt, "Stealth Technology," A5. Returning from an eight-day official visit to the Soviet Union in October 1991, Gen Merrill McPeak, Air Force chief of staff, responded to reporters' questions regarding the long-term viability of the then-embroiled B-2 stealth bomber. McPeak answered, "By the way, I expect that certain parts of their [Soviet] air defense setup would be able to detect the B-2 today, so we don't have to wait ten years." He quickly qualified his remarks, "No one has ever said that the B-2 is invisible or immortal. What we've argued is that it is a very hard target to shoot down, and I expect that'll still be true ten years from now." A few days later, a senior military specialist at the Library of Congress noted, "The ability to keep stealth technology sacrosanct over a protracted period of time will be nil."

53. Ehrhard, *Air Force Strategy*, 87.

Chapter 8

Conclusion

*While decision-makers do not learn most from reading about history
. . . they may learn best from these sources.*

—Robert Jervis

History reveals a Janus-faced, nearly schizophrenic military attitude toward technological innovation. On the one hand, there is an image of a military wedded to technology, aptly evidenced during the cybernetic and chaoplexic revolutions in military affairs of the 1960s and 1980s. On the other hand, there is a competing and equally vivid image of a military institution frustratingly slow to adapt to technological change.[1] Stories of obstinate bureaucratic resistance stymieing promising new technologies such as the British steamship in the 1800s, the American airplane in the 1900s, or the Air Force's unmanned aircraft entering the 2000s are but a few examples of the latter image.[2] Careful historical analysis, however, divulges a pattern in which revolutionary technologies that threaten bureaucratic constituencies are often shunned in favor of evolutionary technological improvements that bolster the organizational culture. Because of its prominent techno-savvy self-image, this trend is especially pronounced in the Air Force.

The Wright brothers' aircraft was originally greeted with significant bureaucratic skepticism. Less than 60 years later, the institution's exuberance for its manned, strategic bomber fleets jaded its assessment of promising alternative technologies such as the ICBM.[3] In a similar pattern, but occurring over a much shorter period, the Air Force transitioned from questioning the combat capabilities of its new air-to-air guided missiles to relying exclusively upon them in air combat.

This pattern of alternating skepticism and exuberance can have a deleterious effect on strategic decision making. Entering the self-proclaimed "Air Age" of the 1950s, Air Force leaders were entranced by visions of gleaming B-36 bombers soaring high across the sky, armed with the atomic weapons that American scientific wizardry had bequeathed to the nation.[4] However, this fascination with technologically advanced bombers largely bankrupted the nascent service's capability to perform more limited, tactical action. When the Korean War revealed this failure in strategic planning, Air Force leaders simply dismissed the experience as an anomaly and continued to pursue the gadgetry that reinforced their interpretation of the strategic environment.[5]

The Air Force followed a similar pattern during Vietnam. Despite the failure of its air-to-air guided missiles in combat against the small North Vietnamese MiG fighters, the Air Force remained enthralled with the missiles' technological potential. Rather than investigating alternative technologies such as the assumed-anachronistic air-to-air cannon, the Air Force bureaucracy focused its efforts on developing a new generation of more complex missiles, such as the AIM-4D Falcon, that were unfortunately just as ineffective. In both the Korean and Vietnam Wars, the Air Force's exuberant embrace of the dominant technology and wary assessment of potential alternatives clouded its strategic vision.

A parallel to this historical phenomenon within the social science realm informs the current discussion. Social constructivists suggest that society shapes technology; technological determinists contend that technology shapes society. Thomas Hughes attempted to enjoin the two interpretations into a comprehensive theory of technological momentum. Unfortunately, his effort failed to address the contextual nuances and historical contingencies that often intervene in technological development. While suggesting that technologies can be both shaped by society and shaping of society, Hughes unfortunately drew an artificial and time-dependent distinction between the two that is unrepresentative of reality.[6]

Incorporating Giovanni Dosi's descriptions of technological paradigms and technological trajectories, the theory of technological dislocations attempts to close the conceptual gap between Hughes's theory and reality.[7] Rather than suggesting that a discrete tipping point divides social influences from technologically deterministic influences, or skepticism from exuberance, the theory of technological dislocations facilitates a more holistic historical appreciation. Technological systems are born of social influences, but the technology quickly begins to exert a deterministic influence on society in the form of a technological paradigm. Within that technological paradigm, a trajectory develops that guides further technological progress. However, that same technological paradigm and the corresponding trajectory can constrain revolutionary, innovative thinking as the bureaucracy becomes bound by its dominant technology. Compounding matters, the incremental, nearly autonomous evolutionary technical development that takes place according to the technological trajectory is often misconstrued as innovative, responsive adaptation. Using Michael Howard's analogy, when the "fog of peace" finally lifts, the disparity is revealed.[8] Even then, exuberance for the dominant technology can continue to exert a profound influence on an organization's decision makers.

A technological dislocation is therefore required to jar the bureaucracy from its technological rut. The catalysts that converge to affect the dislocation and the mechanisms by which it alters the dominant technological trajectory are contextually dependent. Posen, Rosen, and Coté all offered slightly different assessments of military and technological innovation, focusing on civilian influence, strategic assessment, and interservice rivalry, respectively.[9] However, the evidence from the preceding study of Air Force air-to-air armament did not support any of these individual interpretations. Rather, the case study suggested its own influential mechanisms; namely, the importance of keen marketing, innovative systems integration, and credible, innovative individuals and courageous commanders willing to act on their subordinates' recommendations.

While the technological dislocation model does not grant decision makers the power to pre-identify critical technologies, it does offer them a tool to analyze past technological development and extract appropriate lessons for future application. One of the advantages of the theory of technological dislocations is that it accommodates a variety of influential mechanisms in the description of how technological innovation occurs. In fact, the particular method of interposing a dislocation into a technological trajectory is not especially important; the strategies suggested earlier by Posen, Rosen, and Coté retain their relevance.

The more significant value of the technological dislocations model lies in its ability to facilitate decision makers' understanding of the obstinate nature of bureaucratic institutions, despite superficial appearances to the contrary. Bureaucracies will exuberantly innovate, but without a technological dislocation to jar them from their preferred technological trajectory, the incremental technical progress they cultivate only yields an illusion of thoughtful strategic reflection and adaptation.

A careful review of history provides the decision maker with a unique appreciation for the role of technological dislocations in organizations. It also forms a bank of lessons that, appreciating their contextual nuances, can be drawn upon when required. Citing Jervis, "While decision-makers do not learn most from reading about history, . . . they may learn best from these sources."[10]

Technological progress is not a substitute for strategic analysis. Unfortunately, the allure of the *new* often clouds accurate assessment of a technology's feasibility and practicality. The Air Force has succumbed to technological exuberance in the past, and the pattern continues today with the F-35. To counter these ill effects, Airmen and civilians alike must challenge the Air Force's strategic assumptions guiding its technological acquisitions. If neces-

sary, they must be ready to introduce a technological dislocation. Air Force leaders in turn must be open to such criticism and potential disruption. Recognizing and removing the technological blinkers that obscure strategic vision provide a vital first step in conducting a meaningful strategic dialogue.

Unlike Goethe's Faust, who was at the last moment spared eternal demise, the Air Force's future should not rely solely on the angels of providence.[11] When tempted by a technological Mephistopheles, the Air Force should instead embrace well-reasoned foresight and open strategic dialogue. Choose well, Air Force.

Notes

1. Bousquet, *Scientific Way of Warfare*, 33–34. Bousquet defined cybernetic warfare as a "self-proclaimed 'science of communications and control'" that "promised to manage chaos and disruption through self-regulating mechanisms of information feedback" in war. General Westmoreland's battlefield of the future (see note 21, chapter 2) was reflective of the cybernetic way of warfare and was largely realized in the Igloo White program during Vietnam. Conversely, Bousquet linked the "principles of chaos and complexity (referred to together as chaoplexity)" and the notions of "non-linearity, self-organization, and emergence" into the term *chaoplexic* warfare. He suggested that, based on their advocacy of technologies that would enable the self-synchronization of forces without additional command and control mechanisms, netcentric warfare proponents subscribed to the chaoplexic vision of warfare. Both the military cyberneticists and the chaoplexists heralded a revolution in military affairs. See Lonsdale, *Nature of War in the Information Age*.

2. McNeil, *Pursuit of Power*; Morrow, *Great War in the Air*; and Singer, *Wired for War*. McNeil discussed the British resistance to the steamship; Morrow outlined the Army's resistance to the Wright Flyer; and Singer provided a rich narrative of the Air Force's resistance to unmanned drone aircraft.

3. Sheehan, *Fiery Peace*.

4. Barlow, *Revolt of the Admirals*, 46. Air Force general Tooey Spaatz announced the arrival of the "Air Age" in October 1945.

5. Crane, *American Airpower Strategy*, 60. Recall Air Force major general Emmett O'Donnell's testimony to Congress in 1951: "I think this is a rather bizarre war out there [in Korea], and I think we can learn an awful lot of bad habits in it."

6. "A technological system can be both a cause and an effect; it can shape or be shaped by society." Delineating the difference, Hughes continued, "The social constructivists have a key to understanding the behavior of young systems; technical determinists come into their own with the mature ones." Hughes, "Technological Momentum," 112.

7. Dosi, "Technological Paradigms," 152–53. Dosi defined a technological trajectory as the "direction of advance within a technological paradigm." He also noted that "technological paradigms have a powerful exclusion effect: the efforts and the technological imagination of engineers and of the organizations they are in are focused in rather precise directions while they are, so to speak, 'blind' with respect to other technological possibilities."

8. Howard, "Military Science," 4.

9. Posen, *Sources of Military Doctrine*; Rosen, *Winning the Next War*; and Coté, "Politics of Innovative Military Doctrine."

10. Jervis, *Perception and Misperception*, 246.

11. Goethe, *Faust*.

Abbreviations

AAA	antiaircraft artillery
AAF	Army Air Force
ACM	air combat maneuvering
ACT	air combat tactics
ADC	Air Defense Command
AFHRA	Air Force Historical Research Agency
AFRI	Air Force Research Institute
AIM	air intercept missile
ARDC	Air Research and Development Command
ATS	Air Tactical School
AU	Air University
CIA	Central Intelligence Agency
CORDS	Coherent-on-Receive Doppler System
DARPA	Defense Advanced Research Projects Agency
ECM	electronic countermeasure
FFAR	folding-fin aerial rocket
FY	fiscal year
GAO	Government Accountability Office
GAR	guided air rocket
GCI	ground-controlled intercept
GE	General Electric
GIB	guy in back
ICBM	intercontinental ballistic missile
INS	inertial navigation system
ISR	intelligence, surveillance, and reconnaissance
JCS	Joint Chiefs of Staff
kt	kiloton
LCOSS	Lead Computing Optical Sight Set
MiGCAP	MiG combat air patrol
MIRV	multiple independently targetable reentry vehicle

ABBREVIATIONS

mm	millimeter
NASA	National Aeronautics and Space Administration
NVN	North Vietnam
OST	Office of Science and Technology
PACAF	Pacific Air Forces
R&D	research and development
RAT	ram-air turbine
RBL	radar boresight line
recce	reconnaissance
ROE	rule of engagement
RPA	remotely piloted aircraft
RTU	replacement training unit
SAASS	School of Advanced Air and Space Studies
SAC	Strategic Air Command
SAM	surface-to-air missile
SDI	Strategic Defense Initiative
SEA	Southeast Asia
SEACAAL	Southeast Asia Counter-Air Alternative
SVN	South Vietnam
TAC	Tactical Air Command
TFS	Tactical Fighter Squadron
TFW	tactical fighter wing
UAV	unmanned aerial vehicle
UCLA	University of California, Los Angeles
WRCS	Weapons Release Computer System

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