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The absolute importance of air superiority in modern warfare is unquestionable, but the relative ease with which America currently retains air supremacy is shaping its fighter fleet. The Air Force is transitioning its fourth-generation air superiority fighter, the F-15C, out of Active Duty squadrons as the airframe ages, and it has curtailed acquisition of its fifth-generation air superiority fighter, the F-22A. Joint force fighter acquisitions are currently stove-piped in the multirole F-35. Though multirole fighters serve current conflicts well, an over-reliance on multirole aircraft, while neglecting a dedicated air superiority capability, will create a lopsided fighter force that is ill suited to counter a comprehensive enemy counter-air capability. To ensure air superiority in all possible future conflicts, the United States military must balance developing and acquiring multirole fighter aircraft with modernizing and expanding a fleet of dedicated air superiority fighters.

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MASTER OF MILITARY STUDIES

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TAKING AIR SUPERIORITY FOR GRANTED:
AMERICA'S WANING AIR DOMINANCE CAPABILITY

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OF THE REQUIREMENTS FOR THE DEGREE OF
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## Executive Summary

**Title:** Taking Air Superiority for Granted: America's Waning Air Dominance Capability

**Author:** Major William R. Kastner, United States Air Force

**Thesis:** To ensure air superiority in all possible future conflicts, the United States military must balance developing and acquiring multirole fighter aircraft with modernizing and expanding a fleet of dedicated air superiority fighters.

**Discussion:** The absolute importance of air superiority in modern warfare is unquestionable. Controlling the sky permits air forces to engage an enemy tactically and strategically with impunity while simultaneously permitting friendly ground forces to operate unhindered by a reciprocal air threat. For nearly fifteen years, the United States has maintained air superiority, if not air supremacy, during combat operations. The last American aerial victory occurred over fifteen years ago during Operation ALLIED FORCE. Since then, enemy air forces that even possessed a means to challenge America in the air chose to run or stay on the ground. Contrasted from past eras, like the Vietnam War, air supremacy is the American new normal in combat operations. The relative ease with which America currently retains air supremacy is shaping its future fighter fleet. The Air Force is transitioning its fourth-generation air superiority fighter, the F-15C, out of Active Duty squadrons as the airframe ages, and it has curtailed acquisition of its fifth-generation air superiority fighter, the F-22A. Joint force fighter acquisition is currently stove-piped in the multirole F-35. Multirole fighters serve current conflicts well, in which air superiority is unchallenged. However, an over-reliance on multirole aircraft, while neglecting a dedicated air superiority capability, will create a lopsided fighter force that is ill suited to counter a comprehensive enemy counter-air capability.

**Conclusion:** Dedicated air superiority fighters are the answer to maintaining air superiority against an enemy air force. Unless the United States military refocuses on its air dominance fleet, it risks having its air superiority capability overshadowed by its competitors and potentially its enemies.

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## Preface

As an F-15E Weapon Systems Officer by trade, I contend that the mighty Strike Eagle is the best all-around fighter in the Air Force inventory. I also concede that I would not want to go to war in the air without F-15C Eagles and F-22A Raptors providing fighter sweep. Eagle and Raptor pilots are the air-to-air experts, and their jets and their training are uncompromising in their purpose, air dominance. However, we are not in an air war, we are in a Close Air Support and Dynamic Targeting war. For years, we have fought *from* the air but not *for* the air. This has bred shortsightedness in how we maintain and modernize our fighter fleet. Air dominance fighters may seem superfluous in our current conflicts, but we will desperately require their capabilities when challenged in the air. If we wait for that challenge as the impetus to bolster our air dominance capability, it will be too late.

I would like to thank Dr. Paul Gelpi for his guidance and for helping me direct my research. His historical expertise and perspective were instrumental in framing my argument for the critical importance of capable air dominance fighters. I would also like to thank Lieutenant Colonel Micheal "Booger" Russ for his assistance in formulating my research topic and Major Rod "Brick" James, a fellow Strike Eagle brother, for "sanity-checking" the argument I put forth in this paper. Most importantly, I must thank my wife, Sarah, for her love and support in this and all of my endeavors.

## Introduction

The absolute importance of air superiority in modern warfare is unquestionable. Controlling the sky permits air forces to engage an enemy tactically and strategically with impunity while simultaneously permitting friendly ground forces to operate unhindered by a reciprocal air threat. For nearly fifteen years, the United States has maintained air superiority, if not air supremacy, during combat operations. American and coalition ground forces operate without fear of reprisal from the air. Intelligence, Surveillance, and Reconnaissance aircraft, with limited or no defensive capability, provide uninterrupted surveillance of high-value targets and over-watch of friendly forces, unfettered by air threats. Aircrew providing Close Air Support (CAS) focus almost exclusively on supporting friendly ground forces, as limited ground-borne and virtually no airborne enemy defenses threaten their aircraft.

America's combat air supremacy is a blessing to its current operations but a curse to future readiness. The last American aerial victory occurred over fifteen years ago during Operation ALLIED FORCE. Since then, enemy air forces that even possessed a means to challenge America in the air chose to run or stay on the ground. During past eras, air superiority was an expensive commodity. In today's operations, American air superiority is less an objective and more an assumption. Due to credible deterrence and incapable enemy air defense, air superiority has become more an entitlement for the American military than a costly bill that it must pay.

The relative ease with which America currently retains air supremacy is shaping its future fighter fleet. The Air Force is transitioning its fourth-generation air superiority fighter, the F-15C, out of Active Duty squadrons as the airframe ages, and it has curtailed acquisition of its fifth-generation air superiority fighter, the F-22A. Joint force fighter acquisition is currently

stove-piped in the multirole F-35. Multirole fighters serve current conflicts well, in which air superiority is unchallenged. However, an over-reliance on multirole aircraft, while neglecting a dedicated air superiority capability, will create a lopsided fighter force that is ill suited to counter a comprehensive enemy counter-air capability. To ensure air superiority in all possible future conflicts, the United States military must balance developing and acquiring multirole fighter aircraft with modernizing and expanding a fleet of dedicated air superiority fighters.

## Air Superiority

Air superiority is defined in Joint Publication 3-01, *Countering Air and Missile Threats*, as "that degree of dominance in the air battle of one force over another that permits the conduct of operations by the former and its related land, maritime, and air forces at a given time and place without prohibitive interference by the opposing force's air and missile threats."[1] Air superiority, as a broad principle, may be broken into three distinctive levels, air parity, air superiority, and air supremacy. Air parity exists when no single force exhibits a marked advantage in conducting air operations free of enemy interference. A force has air superiority when it operates without "prohibitive interference" from opposing forces, either in a general operating environment or during a specific time and/or location. An increased degree of air superiority, air supremacy exists when an air force is able to conduct operations free of "effective interference" from enemy forces. Like air superiority, air supremacy may exist as a permanent condition across the operating area in general, or it may be limited to specific locations and/or times.[2]

Air Force doctrine breaks air superiority operations into two broad categories, offensive counter air (OCA) and defensive counter air (DCA). The purpose of OCA is to "destroy, disrupt,

or degrade enemy air capabilities," including a broad swath of ground-based and airborne weapon systems, communication systems, and related infrastructure, enabling friendly use of airspace and limiting the possibility of attack from enemy air forces or missiles. The purpose of DCA is to "protect friendly forces and vital interests from enemy airborne attacks" by targeting enemy airborne assets.[3]

The doctrinal framework for counter air operations provides a multi-faceted approach to gaining and maintaining air superiority. For OCA operations, this includes attack, suppression of enemy air defenses (SEAD), fighter escort, and fighter sweep. DCA operations incorporate active measures, including air and ballistic missile defense, and multiple passive defense measures, including detection and warning capabilities as well as methods to increase survivability of potentially targeted assets.[4] While OCA and DCA operations may be accomplished by a confluence of weapon systems, this paper will focus on the capabilities of fighter aircraft in performing fighter sweep, fighter escort, and air defense to counter enemy fighters in the air.

## History's Lessons

Air superiority is the historical "prerequisite to success," permitting friendly forces uncontested access to the air for airborne operations and freedom of movement for land and sea operations.[5] A testament to the importance of this concept and American capability in accomplishing the same, no American ground forces have suffered attack from the air since the Korean War.[6] Such a statistic may indicate that the United States long ago solved the air superiority equation. If the United States is to maintain such a statistic, it cannot forget or ignore historical lessons.

` The Korean War and the Vietnam War provide the most relevant lessons for modern air combat. The Korean War saw the advent of jet-versus-jet air-to-air combat, and the Vietnam War introduced guided air-to-air missiles into aerial combat. Further, these two conflicts present the latest wars in which an enemy credibly challenged American air superiority in protracted air-to-air battles. More importantly, lessons learned in Korea and subsequently re-learned in Vietnam illustrate universal principles regarding air-to-air combat: Through superior training and equipment, fighter pilots must be capable of effectively engaging the enemy in visual air combat maneuvers.

The first jet-versus-jet combat and victory occurred on November 8, 1950, when First Lieutenant Russell Brown shot down a MiG-15 with his F-80 over the Yalu River.[7] However, the battles between MiG-15s and F-86s largely characterize the battle for air superiority over Korea, with the first F-86 victory over a MiG-15 claimed by Lieutenant Colonel Bruce Hinton on December 17 of the same year.[8] By comparative attrition, Americans and their F-86s emerged the victors against the Koreans, Chinese, and Soviets flying MiG-15s. By the end of the war, F-86 pilots shot down 792 MiG-15s. Out of a total 224 recorded F-86 losses during the Korean War, approximately 100 were attributed to air-to-air combat,[9] resulting in an approximate 8:1 kill ratio. Historian Xiaoming Zhang notes that the methods by which the Soviet and American air forces awarded aerial victories likely inflated the American kill ratio. Fighting over enemy territory required Americans to rely to a greater degree on gun camera footage when determining aerial victories; the Soviets contended that only 75% of MiGs seen being hit through gun camera footage actually crashed.[10] The Soviet air force, in fact, claimed a kill ratio of 7.9:1 from November 1950 through December 1951, though that ratio declined to 1.9:1 by 1953. The

Chinese, however, claimed a kill ratio of only 1:1.42. Overall, though, Zhang notes a more recent study that indicates an overall kill ratio of 2:1, in favor of United Nations forces.[11]

Whether by 8:1 or 2:1, the marked success of United Nations air forces versus Communist air forces was due to a mix of aircraft and pilot superiority. In the case of the F-86 versus the MiG-15, data and perspectives vary regarding the superior aircraft. Historian Kennet P. Werrell notes that the MiG, "outperform[ed] the F-86 almost to the end of the war."[12] Indeed, the MiG-15bis had a thrust-to-weight ratio of 0.60:1, compared to the 0.45:1 for the F-86A, permitting faster acceleration and a significant advantage in rate of climb.[13] The F-86E that entered service in 1951 possessed improved handling characteristics with hydraulic flight controls and stabilators (fully moveable horizontal stabilizers, instead of fixed stabilizers with elevators), but a new engine, which provided a 12 percent increase in thrust, was not introduced until the F-86F went into service in 1952.[14] In terms of armament, the MiG-15 carried a 37mm cannon and twin 23mm cannons, compared to the six .50 caliber machine guns carried by the F-86.[15] Despite less potent firepower, American F-86s were equipped with gunsights superior to those of the MiG-15. In 1951, the U.S. Air Force began fitting F-86s with advanced automatic range-finding gunsights employing the APG-30 radar. Though maintenance problems with the APG-30 soured the gunsight's reputation among pilots, Werrell notes statistical analysis that shows that pilots opened fire at longer ranges, fired 18 percent fewer shots, and improved hit probability at ranges beyond three hundred feet using the new gunsights.[16] By comparison, MiG-15 pilots operated with a gunsight based on World War II technology, optimized for British .303 caliber machine guns, not the MiG's cannons, inducing inaccuracy at higher speeds. Furthermore, differing trajectories between the MiG's 37mm cannon and 23mm cannons proved

problematic for aiming, with some F-86 pilots reporting 23mm shells missing them high while 37mm shells simultaneously missed low.[17]

Traded advantages in performance and weapon systems may have leveled the playing field between the F-86 and the MiG-15, but pilot training and proficiency were the Americans' undoubted advantages in achieving air superiority over Korea. Zhang notes that at the start of the Korean War, many American pilots were veterans of World War II with 1,000 flight hours. By comparison, many Chinese pilots had fewer than 100 hours.[18] Attempts by the People's Liberation Army Air Force (PLAAF) in 1950 to train with more experienced Soviet pilots were mostly unsuccessful. In early combat missions combining veteran Soviet pilots with inexperienced Chinese pilots, the Chinese pilots could not keep up with the Soviets' tactics and maneuvers. Further, the Soviet pilots had difficulty communicating with the Chinese pilots due to language barriers.[19] Zhang notes that Chinese pilots did improve nominally with experience, with a kill ratio of 1:1.46 between September 1951 and May 1952 improving to 1:1.42 by October 1952. Though this was only a minor increase in victories, it also accompanied a nearly 50 percent decrease in flying mishaps, indicating an improvement in airmanship.[20] Simultaneous with the gradual increase in Chinese proficiency, Soviet proficiency decreased, as previously noted, as the Soviets sent lesser-experience pilots to the war in 1952 and 1953.[21] As Werrell notes, as opposed to flying a superior aircraft, American pilots attributed their success in Korea to better tactics, leadership, and pilots than the Koreans, Chinese, and Soviets.[22]

If the over-arching lesson of the air war in Korea was that superior training permitted air superiority, the American military misapplied this lesson during the air war over Vietnam. The American military's primary misconception lay in the nature of future air-to-air combat following the Korean War. Pilots fought air-to-air engagements over Korea exclusively within

visual range, as MiG-15s and F-86s were fitted with cannons and machine guns, respectively. By Vietnam, however, the U.S. Air Force and Navy's front-line fighter, the F-4, carried the AIM-7D Sparrow, a semi-active radar missile with a range of 25 miles.[23] The American military employed AIM-7 missiles with the viewpoint that modern fighters would merely act as high-speed interceptors that would be required to target high-flying bombers, a situation in which only air-to-air missiles would be effective.[24] Indeed, the F-4 was originally designed and manufactured without an internal gun and lacked a gun capability entirely until the introduction of the SUU-16A 20mm externally-mounted gun pod in 1965 and, in 1967, the incorporation of an internal 20mm cannon in the F-4E.[25] Missile reliability issues and tactics employed by the Vietnam People's Air Force (VPAF) soon disproved the theory that modern air-to-air combat had transitioned to strictly long-range missile shots. A 1969 report of missile effectiveness, directed by Captain Frank Ault of Naval Air Systems Command, indicates that, out of approximately 600 air-to-air missiles fired in 360 engagements between June 1965 and September 1968, combat performance indicated "a probability of achieving about one kill for every ten firing attempts."[26] Of the two missiles the F-4 employed, the AIM-7 and the AIM-9 infrared-guided missile, the AIM-7 was less reliable, forcing attacking pilots into the visual range required for AIM-9 employment.[27] In cases where the AIM-9 failed as well, gun-less F-4 crews found themselves out of options. In one account, having unsuccessfully fired all of their missiles and without a gun, Colonel Robin Olds and First Lieutenant William Lafever resorted to rolling in behind MiG-17s in the Hoa Loc traffic pattern simply to frighten the MiG pilots.[28]

In addition to problems presented by less-than-capable missiles, the VPAF's adaptive MiG-21 tactics forced F-4s into close-range visual engagements. Using Ground-Controlled Intercepts (GCI), MiG-21 pilots would attempt to maneuver low and undetected to convert and

intercept F-4s from a stern aspect, after which they could employ their AA-2 infrared-guided missiles.[29] Variations of this tactic included flying silver-painted MiG-21s at high-altitude in an attempt to distract F-4 pilots from a low-flying camouflaged-painted MiG-21 working in coordination to achieve an unobserved intercept on the F-4s.[30] The 8th Tactical Fighter Wing discovered a similar MiG tactic in 1967, when two of its F-4s were shot down by two MiG-21s that approached undetected at low altitude and climbed quickly to attack in a visual engagement from the F-4s' stern.[31] Although American airmen showed up to the Vietnam air war expecting and trained for long-range missile fights, actual air-to-air combat due to American weapons and VPAF tactics devolved back to dogfighting. As Colonel Olds stated regarding air combat in Vietnam, "Perhaps the biggest lesson Clobber College over there taught us is that dogfighting today is surprisingly like our experience in World War II and Korea."[32]

The lessons of air-to-air combat in Vietnam were not lost on the United States Air Force (USAF) and Navy, both as the war progressed, and continuing into the remainder of the Cold War. As one recommendation from the Ault Report was comprehensive training in air combat maneuvers (ACM), the Navy started The U.S. Navy Post Graduate Course in Fighter Weapons Tactics and Doctrine, more commonly known as "TOP GUN." Originally a four-week course, with three weeks of air-to-air and one week of air-to-ground combat training, the complexity of air-to-air combat resulted in the school dropping air-to-ground training and later extending the course to five weeks.[33] Intending to produce ACM experts to, in turn, instruct their fleet squadrons, TOP GUN ultimately improved Navy kill ratios from 3.7:1 in 1968 to 13:1 when air-to-air combat resumed over Vietnam in 1972.[34] Though later to the game, the Air Force established an aggressor squadron in 1972 to provide realistic air-to-air combat training for its Fighter Weapons School. By 1975, it was also conducting RED FLAG, an exercise designed to

simulate air combat for junior pilots, pushing them through their first ten critical "combat" sorties in a training environment.[35] Having recognized the value of air-to-air combat skills, specifically dogfighting and ACM, America prepared through the remainder of the Cold War for another air battle against Soviet pilots that never came to fruition. However, American airmen were more than prepared to fight the Iraqi Air Force during Operation DESERT STORM.

In the domain of air-to-air combat, Operation DESERT STORM proved an overwhelming victory for American airpower. Entering the war, the United States was leery of Iraq's air superiority capabilities. Baghdad had seven times the concentration of air defense artillery as Hanoi did during the Vietnam War.[36] Additionally, the Iraqi Air Force was equipped with a capable array of fighter aircraft, including the MiG-29, [37] a fourth-generation fighter and a peer to the F-15 in performance capability. Nonetheless, in the fight for air superiority, the American and coalition air forces proved vastly superior to the Iraqi Air Force. If anything, the Iraqi Air Force hardly allowed coalition fighters a chance to prove themselves. One American fighter pilot observed an Iraqi MiG-29 roll in front of a second MiG-29, which immediately shot the other down. Further, after this fratricidal mistake, the offending MiG-29 pilot then rolled and pulled his aircraft into the ground.[38] Anecdotally, the Iraqi Air Force was shooting itself out of the sky, but American and coalition air forces were also cleaning house. The Iraqi Air Force ultimately lost 35 aircraft to coalition fighters during DESERT STORM, with 16 credited to F-15s and two to F-18s.[39] Further, not a single coalition fighter aircraft was lost to an air-to-air engagement.[40] So effective were American and coalition fighters versus Iraqi fighters in air dominance, that Saddam Hussein hangared his air force, hoping to preserve it for a later resurgence.[41] When coalition strike aircraft began targeting the Iraqi jets in their protective shelters, the Iraqi Air Force took to the skies again, but his time to flee to Iran.[42] The degree of

the Iraqi Air Force's defeat was so absurd, U.S. Air Force Colonel John McBroom, 1st Tactical Fighter Wing Commander, commented, "If somebody were going after my hometown, I'd [fight] a little harder."[43]

## The F-22: The Air Superiority Fighter without a Fight

The fall of the Soviet Union and overwhelming victory in the skies over Iraq quite possibly made America's air superiority fighters a victim of their own success. A RAND publication, *Trends in the Global Balance of Airpower*, completed in 1995, supported the United States Air Force's planned "fighter procurement holiday," assessing that it could halt fighter procurement for a decade or more, following a significant Cold War procurement effort in the 1980s. The same report noted, however, that doing so would inevitably result in increased unit costs for future fighters as production slowed.[44] Both conclusions foreshadowed the problems that would ultimately plague the F-22 Raptor program.

In 1991, the Air Force chose the F-22 from two competing prototypes as its next air superiority fighter. The engineering, manufacturing, and development (EMD) phase began in 1991, with initial operating capability (IOC) originally set for 2001.[45] Developed by Lockheed Martin in a bid for the Air Force's Advanced Tactical Fighter program, the F-22A was intended to counter the Cold War threat of Soviet airpower by meeting requirements to "[find] and [destroy] high-priority enemy interceptors, standoff jammers, and large, offensive attack formations." Specific air superiority threats that the United States faced from the Soviet Union at the time included the MiG-29 and the Su-27.[46] The Cold War purpose of the F-22A in a post-Cold War Air Force immediately hampered acquisition, with initial planned production cut from 750 to 648 in the first year of the jet's EMD phase.[47] As personnel and acquisition cuts

continued, the F-22A survived due to staunch advocates such as General Michael Low, Commander of Tactical Air Command, and General Merrill McPeak, the Air Force Chief of Staff. It also survived at the expense of two other fighter programs, the joint Air Force/Navy A/F-X and the Air Force Multirole Fighter. As a result, Lockheed Martin tacked on multirole capability to the F-22A, modifying the aircraft design to carry two GBU-32 1,000 lb. Joint Direct Attack Munitions (JDAM). (A later upgrade included the capability to employ the GBU-39 Small-Diameter Bomb.) Nonetheless, iterative reductions continued in planned F-22 acquisition, reaching a trough of 183 in 2004, when Presidential Budget Directive 753 directed production curtailment by FY2008.[48]

The F-22 program's troubles were rooted in cost and the perceived lack of a credible adversarial air threat. In 1991, the total estimated cost of the F-22 program was $99.1 billion, with $19.5 billion slated in total development costs, averaging a production unit cost of $122.8 million.[49] By 1996, estimated development costs of the F-22 increased to $22.4 billion. Having already decreased planned acquisition, and concerned about increasing program costs, Congress limited production costs to $43.4 billion, for a total estimated program cost of $65.8 billion. This limitation transitioned acquisition from a requirement-based program to a cost-capped program.[50] By the time production funding terminated in 2008, the Air Force had convinced Congress to purchase an additional four F-22s, for a final production run of 187 aircraft.[51] Of the 187 jets, 179 were production aircraft, six were production representative test vehicles, and two were EMD aircraft.[52] The 2010 final Selected Acquisition Report for the F-22 program calculated the total cost of the F-22 procurement program was $67.3 billion, with a per-aircraft cost of $369.5 million, in 2010 dollars.[53] Adjusting for inflation, each F-22, in 2010 dollars, cost

$172.9 million more than the average production unit cost calculated in 1991 for a planned production run of 648 aircraft.[54]

Cost overrun and production delays[55] were only part of the problem facing the F-22. In 1994, General McPeak labeled the F-22 program as "probably the single most important [acquisition] program" for the Air Force, testifying before Congress that "stealth and precision" were principle requirements for maintaining air superiority in the future.[56] Working against the argument for a large fleet of fifth-generation fighters, however, was the end of the Cold War and the dissolution of the Soviet air threat for which the F-22 was originally developed. Further, the events of September 11, 2001, and the resulting Global War on Terror further pulled financial and strategic support from a strong dedicated air-to-air combat capability.

In the shadow of the Global War on Terror, Air Force leadership continued to argue for increased F-22 acquisition. In 2008, before the Air Land Subcommittee of the Senate Armed Services Committee, Lieutenant General Daniel Darnell testified that, by 2024, the Air Force would have a fighter gap of 800 aircraft.[57] Senator John McCain countered this argument during a Senate floor statement in July of 2009. Senator McCain suggested that the concerns surrounding a "fighter gap" were unfounded, insofar as they assumed that the United States would fight unilaterally and not as part of a coalition. He cited the Air Force's Combat Air Force restructure plan as a more cost-effective solution—halting F-22 procurement at 187, modernizing "newer or more reliable" legacy fighters, such as the F-15 and F-16, and purchasing less expensive new aircraft, specifically noting the F-35. Perhaps more significantly, Senator McCain contended that the Department of Defense needed to focus on irregular warfare, "and the F-22 is not a key program for improving those capabilities." He further quoted then Secretary of Defense Robert Gates as saying, "the reality is we are fighting two wars, in Iraq and

Afghanistan, and the F-22 has not performed a single mission in either theater."[58] In a 2008 speech to journalists, Secretary Gates summarized his view of military development and acquisition writ large: "I have noticed too much of a tendency towards what might be called Next-War-it-is—the propensity of much of the defense establishment to be in favor of what might be needed in a future conflict."[59]

With the Cold War over and the Global War on Terror at the forefront of national military operations, the F-22 practically fell to the wayside as America's front-line insurer of air superiority. What was originally to be a 750 aircraft replacement fleet for the F-15, ended up as a 187 aircraft supplement to fourth generation fighters. The last F-22 rolled off the assembly line in Marietta, GA on December 13, 2011, before Lockheed Martin shuttered production.[60]

**Basics Principles of Air-to-Air Combat and the need for an Air Dominance Fighter**

The F-22A may be an aircraft for the "Next War," which is to infer that the United States may never fully exploit its capabilities. Indeed, the only combat weapons employed from the F-22 were bombs dropped in support of operations against Islamic State militants.[61] The F-22A also missed years of combat in Iraq and Afghanistan. At the outset of both conflicts, the F-22A was not yet IOC, and the United States and its coalition partners very quickly established and maintained air supremacy over both countries. The Raptor never had an enemy air force to fight.

That F-22 development and acquisition became so controversial and contentious overshadows two of the jet's strongest capabilities as a dedicated air superiority fighter: power and maneuverability. Colonel John Boyd, then a Major, developed the Energy-Maneuverability (E-M) Theory in 1962, with the help of a civilian engineer, Thomas Christie. The theory centers on an aircraft's specific energy—total energy divided by weight. The equation that he developed

calculates an aircraft's specific energy, or $P_s$, by subtracting an aircraft's drag from its thrust, dividing by aircraft weight, and multiplying the result by the aircraft's velocity. The equation allowed Boyd to make comparative analyses of aircraft performance based on energy bleed rates under G and an aircraft's ability to maintain or re-gain energy based on thrust, drag, and weight.[62] Today, $P_s$ curves serve as the basis for comparative performance between fighter aircraft. During within visual range (WVR) combat, E-M theory holds that an aircraft that can turn tighter (small turn radius), turn faster (high turn rate), and do so losing the least amount of energy will hold the advantage in a dogfight. This is because the aircraft that can do all of these will be able to achieve a weapons employment solution prior to an adversary doing so. For Boyd, this meant that a fighter needed to have a high thrust-to-weight ratio and "lots of wing" (a significant capability for producing lift) for maneuvering into a weapons engagement zone.[63]

The F-22's power and maneuverability allow it to dominate in WVR air-to-air combat, but beyond visual range (BVR) capability is equally important for modern air superiority fighters. Although Boyd scoffed in the 1960s when the Air Force wanted a Mach 2 fighter,[64] high altitude supersonic flight capability plays a crucial role, along with sensor capability, in modern BVR aerial combat. Maximum speed in BVR engagements maximizes F-Pole, the distance from a fighter to its target at missile impact. By launching a missile while maintaining a higher airspeed and a higher altitude, a fighter is able to increase the kinematic range of the missile, and therefore F-Pole, versus an adversary fighter.[65] Due to its power, the F-22 excels in this capability as well.

## Multirole as an Air Superiority Substitute

With the closing of the F-22 production line, the F-35 remains the only fifth-generation fighter in production, though not fully mission capable.[66] Though modern in terms of technology, the F-35 is not an air superiority fighter, but a multirole fighter,[67] a discriminator that carries serious ramifications for its capability in air-to-air combat. Doctrinally, multirole aircraft can perform any mission assigned to an air-to-air fighter. Joint Publication (JP) 3-01, *Countering Air and Missile Threats*, states that both air-to-air (air superiority) and multirole fighters may conduct fighter sweep, escort, and missions to intercept enemy aircraft, in both an offensive counter air (OCA) or defensive counter air (DCA) role.[68] In some cases, multirole aircraft may even serve an air-to-air and air-to-ground purpose simultaneously, executing a self-escort role.[69]

Though partially designed for and capable of executing air-to-air missions, multirole fighters create a conundrum of tactics and aircraft capability. Tactically, when executing a self-escort mission, multirole fighters risk sacrificing mission objectives. In self-escort, the multirole fighter fulfills two to three OCA tasks. One of these roles is always fighter sweep. Additional roles will include air-to-ground missions, which, based on weapons load-out and aircraft capability, may include interdiction or suppression of enemy air defenses (SEAD). In a self-escort role, the multirole fighter's primary mission is always its air-to-ground mission. Conducting a fighter sweep into enemy airspace *not* to employ air-to-ground ordnance on enemy targets is counterintuitive and runs contrary to exploiting air superiority as a means to target enemy forces and resources on the ground. However, engaging enemy aircraft in air-to-air combat, particularly within visual range (WVR), will likely require jettisoning air-to-ground ordnance to improve maneuverability, thereby negating the multirole fighter's primary mission.

Therefore, integrating dedicated air superiority fighters into strike packages is essential for ensuring the success of OCA missions in a contested environment.

In addition to the possibility of mission failure through weapons jettison, multirole fighters suffer from decreased chances of survivability versus enemy air-to-air fighters. The F-15E Strike Eagle is a perfect example of this principle. America's premier interdiction fighter, the Strike Eagle is capable of employing most air-to-air and air-to-ground weapons in the United States inventory. Yet, the degree of capabilities that the Strike Eagle brings to the battlefield is also its greatest hindrance as a fighter aircraft. The Strike Eagle is a "Jack of all trades, master of none."[70] A close sibling of the F-15 Eagle, the Strike Eagle has conformal fuel tanks that increase range, hard points that increase weapons payload, and targeting and navigation pods that permit day and night precision strike. While similarly capable as an air superiority fighter beyond visual range of adversary aircraft, the Strike Eagle's added air-to-ground capability proves a significant liability within visual range.[71] After jettisoning air-to-ground ordnance during a self-escort mission and even when specifically configured for an air-to-air mission, the Strike Eagle is still at a significant disadvantage in maneuverability against most other fourth generation fighters.

The principles stated above hold true for the F-35 as well. The F-35 is a multirole fighter. While acknowledging its fifth-generation capabilities, it is not a mission-specific air superiority fighter. Like the F-15E and the F-16 that it will replace in the Air Force, the F-35 accomplishes multiple missions and will naturally have concessions in its air-to-air capability. From the perspective of BVR air-to-air combat, the F-35 is only capable of Mach 1.6.[72] By comparison, the F-22 and the F-15, the Air Force's fourth-generation air dominance fighter, are both capable of Mach 2 plus, with the F-22 capable of "super cruise" (maintaining level

supersonic flight without the use of afterburner).[73] While advanced sensors[74] may allow the F-35 to better detect targets at range, its lower top speed physically limits the kinematic range of its BVR missiles when compared to the F-22 or the fourth-generation F-15. An additional restriction to the F-35's BVR capability is its missile payload. The F-35 is only capable of carrying four AIM-120 Advanced Medium-Range Air-to-Air Missiles (AMRAAMs) internally. Hard points on its wings permit carriage of two additional missiles, at the expense of stealth capability.[75] By comparison, the F-22 carries six AIM-120s, in addition to two short-range AIM-9s, all internally. The F-15 carries eight missiles as well, with four AIM-120s, and a variable configuration of four additional missiles, either AIM-120s or AIM-9s. Hence, even when configured for purely air-to-air missions, the F-35 has half to two thirds of the BVR capability of the F-15 and F-22, respectively, in terms of missile carriage.

The F-35 also lacks sufficient capability in WVR air-to-air combat, where maneuverability and energy management are crucial requirements for killing and survival. In a comparative study of technical data, the F-35A showed slower acceleration, a lower thrust-to-weight ratio, and greater wing loading than the F-16, the aircraft it will replace in the United States Air Force Inventory. The F-35C showed similar results when compared with the F/A-18, the aircraft that it will replace in the United States Navy, with the exception of lower wing loading than the F/A-18. (The study also compared the F-35B to the AV-8B that it will replace, though the AV-8B lacks significant air-to-air capability.)[76] On a very basic level, comparative data indicates that the F-35A and F-35C are deficient in energy management capability, when compared to the fourth-generation aircraft that they will replace, and the F-35A is also deficient in turn performance to the F-16. In another indication of poor energy management capability, the study notes that, following testing in 2012, the energy sustainment capability of all three F-35

variants was downgraded from initial ratings, the most significant being the F-35A, which dropped from a 5.3G to a 4.6G sustained turn capability.[77] In simple terms, this indicates that the F-35 will sustain a lower turn rate and larger turn radius than initially specified.

Dogfighting performance is relative to an adversary and much more nuanced than simple comparisons of thrust, weight, and wing loading. A January 2015 report by an F-35 test pilot, however, supports that the F-35 exhibits performance characteristics that are inferior to the F-16 that it will replace. In a basic fighter maneuvers (BFM) engagement against an F-16, the pilot noted, "the F-35A remained at a distinct energy disadvantage for every engagement." Adding to the disparity in BFM performance, the F-35A was "clean" (absent of external stores), and the F-16 was configured with two external fuel tanks, creating a significant increase in drag.[78] Lockheed Martin was dismissive about the test pilot's remarks, stating that the specific aircraft flown was the second F-35 airframe produced, a test platform not equipped with mission systems software, stealth coating, or the equipment necessary to allow the pilot a high off-boresight missile capability with helmet cueing.[79] Though a helmet-cued weapons capability is advantageous in a dogfight, energy deficiency is disproportionally disadvantageous, particularly in a protracted engagement. Further, advanced sensors and stealth technology serve their greatest advantage during BVR engagements. In contrast, during WVR engagements, energy management and maneuverability serve as factors determining advantage.[80] The results of this singular instance employing the F-35 in BFM are anecdotal. However, they indicate that the F-35A, despite an abundance of advanced technology, is not readily superior, or perhaps even equal, in dogfighting performance capability to the aircraft that it will replace.

## Jack of All Trades: The Air-to-Air Training Problem

Most discussion about air superiority surrounding fifth-generation aircraft focuses on *aircraft* capability. Less discussed is a related but critical issue that is difficult to quantify, the effect of aircrew air-to-air combat training and proficiency. The Korean War demonstrated that superior training and experience in air-to-air combat yields impressive ratios of victories to defeats, even when aircraft closely match each other in performance capability. Experience in Vietnam demonstrated that a lack of training and proficiency yields a greater risk of air-to-air defeats, even when employing aircraft with generally superior capabilities to the enemy. These lessons were not lost on the United States military; TOP GUN and the USAF Weapons School (formerly the USAF Fighter Weapons School) programs continue. Specific and comprehensive air-to-air training elements are still present in fighter qualification training syllabi and continuation training requirements. However, with F-22 acquisition curtailed, an aging fourth generation fleet of F-15s, and the F-35 as the only fifth-generation fighter in production, fewer pilots will fly air superiority fighters and therefore fewer pilots will specialized in air superiority training and tactics.

Fighter aircrew are required to maintain proficiency in air-to-air combat training, regardless of platform. A basic tenet of multirole capability is the ability to perform air-to-air missions, in addition to air-to-ground missions. However, unlike pilots of air superiority fighters, aircrew of multirole fighters conduct air-to-air training in conjunction with training for various air-to-ground tasks. A comparison of United States Air Force training and proficiency requirements for mission qualification training illustrates this point. For mission qualification, an F-15C pilot must perform sorties focused on Aircraft Handling Characteristics (AHC), Basic Fighter Maneuvers (BFM—dogfighting), Air Combat Maneuvers (ACM—two-versus-one

element offensive and defensive air-to-air combat), Air Combat Tactics/Defensive Counter Air (ACT/DCA—minimum of two-versus-two intercept scenarios), and ACT/Air Sovereignty (air policing intercept procedures and visual identification). F-22A pilots have very similar requirements, with the addition of unopposed air-to-ground elements during their AHC sortie and an additional sortie combining pre-planned opposed air-to-ground attacks and unopposed time-sensitive targeting, to account for its limited air-to-ground capabilities.[81] By comparison, in addition to AHC, BFM, ACM, and ACT, F-15E aircrew must accomplish Basic Surface Attack (BSA—weapons delivery procedures and strafe under varying attack profiles), Airborne Interdiction (AI—opposed pre-planned air-to-ground attacks), and Dynamic Targeting/Close Air Support (DT/CAS). Likewise, F-16 pilots, in addition to AHC, BFM, ACM, and ACT, must accomplish AI, CAS, and SEAD. F-35 mission qualification requirements dictate the same, but remove the ACM requirement.[82] For multirole fighter aircrew, as compared to air-to-air fighter pilots, training sorties and flight hours must be apportioned to retain proficiency in air-to-ground missions, which, as previously mentioned, are the priority missions for multirole fighters. As such, employing a multirole fighter in an air-to-air role accepts not only concessions in aircraft performance but also in aircrew training and proficiency. Far more effective air superiority fighters are those dedicated air superiority platforms, like the F-15C and F-22A, with pilots who have focused their training solely on air-to-air combat.

### Stealth: Operating in an Anti-Access/Area-Denial (A2/AD) Environment

Just as the F-35 will not suffice as the air superiority fighter of the future for its lack of energy and maneuverability, fourth-generation air superiority fighters, such as the F-15C, will not suffice due to a lack of survivability. In testimony before Congress as the Chief of Staff of

the Air Force, General Merrill McPeak stated, "If we want to defend United States airspace, the F-15 will work fine. But I do not know where we are going to have to go in the year 2010 and have this fight. What I do know is I want to fight over *his* guys—not over *my* guys—and that is what air superiority means to us, and that is really why we need the F-22."[83] Though the air war that General McPeak used as his example never materialized, the principle regarding stealth capability holds true today. When operating over friendly territory, air superiority fighters are not vulnerable to enemy air defense systems. In such an environment, a stealth capability is a useful tool in gaining a tactical advantage over an enemy fighter that one is attempting to intercept. However, lacking a stealth capability, as is the case with the F-15C, does not place one's survival at great risk when fighting defensively over friendly territory. The F-15C's radar and AIM-120s provide adequate BVR capability against most adversary fighters, and it is adequately powerful and maneuverable to kill and survive versus the same fighters when WVR.

The same will not hold true in Joint Forcible Entry operations against a state with a robust anti-access/area-denial (A2/AD) capability. With the United States' strategic refocusing to the Asia-Pacific, China's capabilities in this regard are of particular concern. A 2015 Department of Defense report on Chinese military power states, "Within 300 [nautical miles] of China's coast, China has credible Integrated Air and Missile Defense (IADS) that relies on robust early warning, fighter aircraft, and a variety of SAM systems as well as point defense primarily designed to counter adversary long-range airborne strike platforms."[84] In terms of surface-to-air missiles (SAMs), China possesses indigenous CSA-9s and Russian-produced SA-10s and SA-20s. Additionally, China has contracted with Russia to purchase Russian SA-X-21bs, with a range of approximately 250 miles.[85] Its SA-10 and SA-20 systems are capable of engaging fighter aircraft in excess of 100 miles.[86]

Independent of the probability of going to war with China, if the United States is to prepare for potential Joint Forcible Entry Operations in the region, it must consider the highly capable "double-digit" SAM threat that China possesses. From an offensive counter air perspective, both strike and escort aircraft entering China's missile engagement zones will require stealth for survivability. In a 2003 comparative study of fighter capabilities for future conflicts, Lieutenant Colonel Devin Cate noted that the F-22's survivability against advanced SAMs was "superb" and that the F-35's survivability, though less than the F-22's was, "excellent," in both cases due to the respective stealth and electronic countermeasure capabilities of each aircraft. By comparison, his study assessed the F-15C and F-15E as "insufficient" in survivability.[87] Though seemingly obvious, for forcible entry operations into a country equipped with modern IADS, America's most suitable fighters are the F-22 and the F-35. Stated differently, the United States has, to date, produced only 179 fully mission capable fighter aircraft capable of operating in an A2/AD environment.

## Fighter Threats to American Air Superiority

Russia and China are both attempting to surpass the United States' capability in air superiority fighters. Russia continues to produce Flankers, the Su-27 and its variants, a fourth-generation competitor to the F-15. China produces its own copy of the Su-27, the J-11, under license from Russia.[88] In a comparative assessment of Chinese versus American air superiority capability, RAND noted that China has increased its fourth-generation fleet from 24 aircraft in 1996 to currently over 700.[89] Specifically, the Chinese air force currently fields 287 Flanker variants (including J-11s), 240 J-10s, 236 J-8s, and 906 J-7s.[90] Further, China and Russia are both developing fifth-generation stealth fighters that will compete with the F-22. In January

2011, China test flew a prototype of its J-20 fifth-generation fighter during a visit from then Secretary of Defense Robert Gates in an apparent flaunt of its developing military technological capability.[91] The new aircraft could enter service by 2018.[92] Russia is cooperating with India in the development and production of the the T-50 PAK-FA, its stealth fighter, and plans to procure 55 aircraft by 2020.[93]

Bridging the gap between fourth-generation capability and fifth generation development, Russia is also producing the Su-35, an aircraft that manufacturer Sukhoi has dubbed its "4++ generation" aircraft.[94] Russia currently has 48 Su-35s, with plans to purchase 50 additional jets. China is also contracting to purchase 24 Su-35s.[95] In his comparison of air superiority fighters, Lieutenant Colonel Cate notes a British Aerospace and British Defense Research Agency simulation comparing the capabilities of the Su-35 to western air superiority fighters. Though the F-22 bested the Su-35 in simulation 10:1, the F-15C suffered a predictive loss ratio of 1.3:1.[96]

Compared to China and Russia, the United States still leads in fifth-generation fighter capability and capacity. It is important to note, however, that the balance of capability may easily shift. As previously noted, the advanced A2/AD capabilities of China (and Russia, as well, as the designer and manufacturer of many of those systems) has the ability to negate America's fourth-generation fighters' survivability, leaving the F-22 and F-35 as the most (and arguably only) capable fighters for conducting forcible entry operations in either country. The F-35, as previously discussed, is not suited for air-to-air combat versus Sino-Russian fourth generation and "4++" generation fighters, leaving the role of air superiority in such operations solely to the F-22. Though currently outmatching fifth- and fourth-plus-generation Chinese fighters, the F-22 will also have to contend with the 700 plus Chinese fourth-generation fighters

that will operate with impunity in China's IADs. The United States may currently hold the upper hand in technology, but may lose to overwhelming swarms of Chinese fourth-generation fighters.

## Conclusion

The United States must posture itself to gain and maintain air superiority in any future conflict. Recent history paints that as a potentially easy task. The break-up of the Soviet Union and the end of the Cold War effectively ended the prospect for the large, prolonged air wars witnessed in Korea and Vietnam. The first real test of American air superiority following the Cold War, Operation DESERT STORM, was a blowout for American airpower…or was it just a flop for the Iraqis? Regardless, for the time, America was well prepared.

As the American military prepares for future air wars, it must take into account new considerations as well as old principles. In the Vietnam War, missiles proved simply another weapon for air-to-air combat, not a transformative technological advancement that eliminated the dogfights witnessed in the Korean War. So too, modern technology only adds to and does not fundamentally change air-to-air combat. Weapons, such as the AIM-120, that have a true BVR capability, allow killing beyond visual range but will not address every scenario that allows fighters to close to within visual range. Stealth, while an effective tool against BVR detection and a defense against modern SAMs, is also irrelevant in a dogfight. America's modern air superiority fighters must be capable of employing BVR, but they also must be capable of, and their pilots must be trained to, kill and survive in air combat maneuvers.

Active engagement with an enemy air force, or a near-term threat of the same, is not requisite for maintaining a credible dedicated air superiority capability. Waiting for such a time—the "next war"—to bolster America's air superiority capability is unwise. Emergent

adversaries will assess their chance of gaining air superiority against America's capability to prevent them from doing so. American air dominance capability that is stagnant or waning in the face of increasing adversary capability invites challenges. Challenges invite escalation. Escalation invites conflict. To prevent challenges to air superiority, America must maintain a credible deterrent force.

Dedicated air superiority fighters are the answer to maintaining air superiority and deterrence against an enemy air force. Though the United States is currently superior in technology, training, and inventory to every enemy and competitor, the tables can quickly turn. America has closed its production line for fifth-generation air superiority fighters, while China and Russia continue development of their fifth-generation and fourth-plus-generation fighters. Lessons from F-22 and F-35 development demonstrate that a new fighter will take ten to fifteen years to field, from EMD to IOC. A shrinking fleet of fourth-generation air superiority fighters and a capped F-22 inventory also means a shrinking cadre of dedicated air-to-air fighter pilots, which, like aircraft production, will take time to recapitalize. Unless the United States military refocuses on its air dominance fleet, it risks having its air superiority capability overshadowed by its competitors and potentially its enemies.

## Notes

[1] Joint Chiefs of Staff, *Countering Air and Missile Threats*, JP 3-01 (Washington. DC: Joint Chiefs of Staff, March 23, 2012), I-2.

[2] Curtis E. LeMay Center, *Counterair Operations*, Air Force Doctrine Annex 3-01 (Maxwell AFB, AL: Curtis E. LeMay Center for Doctrine Development and Education, October 27, 2015), 2.

[3] Curtis E. LeMay Center, *Counterair Operations*, Air Force Doctrine Annex 3-01, 4.; Joint Chiefs of Staff, *Countering Air and Missile Threats*, JP 3-01, I-2.

[4] Joint Chiefs of Staff, *Countering Air and Missile Threats*, JP 3-01, I-3.

[5] Joint Chiefs of Staff, *Countering Air and Missile Threats*, JP 3-01, I-2.

[6] Mackenzie M. Eaglen and Lajos F. Szaszdi, "The Growing Air Power Fighter Gap: Implications for U.S. National Security," *Backgrounder* no. 2295 (Jul 7, 2009), www.heritage.org/Research/NationalSecurity/bg2295.cfm, 1.

[7] Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea* (Annapolis: Naval Institute Press, 2005), 1.

[8] Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 2.

[9] Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 221.

[10] Xiaoming Zhang, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea* (College Station: Texas A&M University Press, 2002), 203.

[11] Xiaoming Zhang, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea*, 201-203.

[12] Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 65.

[13] Douglas C. Dildy and Warren E. Thompson, *F-86 Sabre vs MiG-15: Korea 1950-53* (Oxford: Osprey Publishing, 2013), 29.

[14] Kenneth P. Werrell *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 24.

[15] The United States Air Force conducted combat tests of four F-86Es and six F-86Fs equipped with 20mm cannons beginning in 1952 under the Gun Val program. The cannons created excess weight, allowed for the carriage of fewer rounds, suffered from maintenance problems, and caused compressor stalls in the F-86. Though the Air Force decided to equip the F-86H with the 20mm cannons, Air Proving Ground Command determined Gun Val was unsuitable for combat in 1953. Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 21-23; Douglas C. Dildy and Warren E. Thompson, *F-86 Sabre vs MiG-15: Korea 1950-5*, 29.

[16] Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 28-33.

[17] Douglas C. Dildy and Warren E. Thompson, *F-86 Sabre vs MiG-15: Korea 1950-53* (Oxford: Osprey Publishing, 2013), 28.

[18] Xiaoming Zhang, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea*, 100.

[19] Xiaoming Zhang, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea*, 105-106.

[20] Xiaoming Zhang, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea*, 205.

[21] Xiaoming Zhang, *Red Wings over the Yalu: China, the Soviet Union, and the Air War in Korea*, 202.

[22] Kenneth P. Werrell, *Sabres over MiG Alley: The F-86 and the Battle for Air Superiority in Korea*, 79.

[23] Peter Davies, *F-4 Phantom II vs MiG-21: USAF & VPAF in the Vietnam War* (Oxford: Osprey Publishing, 2008), 22.

[24] Jerry Scutts, *Wolfpack: Hunting MiGs over Vietnam* (New York: Warner Books, Inc., 1988), 29.

[25] Jerry Scutts, *Wolfpack: Hunting MiGs over Vietnam*, 58; Davies, Peter, *F-4 Phantom II vs MiG-21: USAF & VPAF in the Vietnam War*, 25.

[26] "Report of the Air-to-Air Missile System Capability Review, July – November 1968," 1969, Department of the Navy, Naval History and Heritage Command, http://www.history.navy.mil/research/histories/naval-aviation-history/ault-report.html, Section I, Para A.

[27] Jerry Scutts, *Wolfpack: Hunting MiGs over Vietnam*, 58; The AIM-9B Sidewinder had a range of 2.6 miles. Peter Davies, *F-4 Phantom II vs MiG-21: USAF & VPAF in the Vietnam War*, 22.

[28] Lou Drendel, …*And Kill MiGs: Air to Air Combat in the Vietnam War* (Warren, MI: Squadron/Signal Publications, Inc., 1974), 11.

[29] Peter Davies, *F-4 Phantom II vs MiG-21: USAF & VPAF in the Vietnam War*, 34.

[30] Lou Drendel, *…And Kill MiGs: Air to Air Combat in the Vietnam War*, 20.

[31] Jerry Scutts, *Wolfpack: Hunting MiGs over Vietnam*, 74.

[32] Robin Olds, quoted in Jerry Scutts, *Wolfpack: Hunting MiGs over Vietnam*, 100.

[33] Lou Drendel, *…And Kill MiGs: Air to Air Combat in the Vietnam War*, 30.

[34] Ronald McKeown, TOP GUN Commanding Officer, quoted in Lou Drendel, *…And Kill MiGs: Air to Air Combat in the Vietnam War*, 30.

[35] Richard Hallion, *Storm over Iraq: Air Power and the Gulf War* (Washington: Smithsonian Institution Press, 1992), 31-32.

[36] Richard Hallion, *Storm over Iraq: Air Power and the Gulf War*, 169.

[37] Richard Hallion, *Storm over Iraq: Air Power and the Gulf War*, 146.

[38] Richard Hallion, *Storm over Iraq: Air Power and the Gulf War*, 175.

[39] Richard Hallion, *Storm over Iraq: Air Power and the Gulf War*, 175, 194.

[40] Richard Hallion, *Storm over Iraq: Air Power and the Gulf War*, 195.

[41] Richard Hallion, *Storm over Iraq*, 193.

[42] Richard Hallion, *Storm over Iraq*, 195.

[43] John McBroom, quoted in Richard Hallion, *Storm over Iraq*, 194.

[44] Christopher J. Bowie, Kirninder Braich, Lory Arghavan, Marcy Agmon, and Mary Morris, *Trends in the Global Balance of Airpower* (Santa Monica, CA: RAND, 1995), 46.

[45] The YF-22, developed by Lockheed Martin, was chosen over the YF-23, developed by Northrop Grumman due to "better capability at lower cost." Christopher J. Niemi, "The F-22 Acquisition Program," *Air & Space Power Journal* 26, no. 6 (Nov 2012): 53-82, 56, http://search.proquest.com/.

[46] Christopher J. Niemi, "The F-22 Acquisition Program," 55.

[47] Christopher J. Niemi, "The F-22 Acquisition Program," 56; Jeremiah Gertler, *Air Force F-22 Fighter Program*, CRS Report for Congress RL31673 (Washington, DC: Congressional Research Service, July 11, 2013), 7, https://www.fas.org/sgp/crs/weapons/RL31673.pdf.

[48] F-22 planned production was decreased to 442 following the 1993-released Bottom Up Review. The May 1997 Quadrennial Defense Review reduced F-22 planned acquisition further to 339 aircraft. Christopher J. Niemi, "The F-22 Acquisition Program," 58, 61.

[49] Christopher J. Niemi, "The F-22 Acquisition Program," 56.

[50] Christopher J. Niemi, "The F-22 Acquisition Program," 62.

[51] Christopher J. Niemi, "The F-22 Acquisition Program," 63.

[52] Jeremiah Gertler, *Air Force F-22 Fighter Program*, 8.

[53] Jeremiah Gerlter, *Air Force F-22 Fighter Program*, 9.

[54] Using the Bureau of Labor Statistics CPI Inflation Calculator (http://www.bls.gov/data/inflation_calculator.htm), $122.8 million dollars in 1991 had the same purchasing power as $196.6 million in 2010.

[55] Initial Operating Capacity (IOC) was initially scheduled for 2001. The F-22 ultimately reached IOC in December 2005. Christopher J. Niemi, "The F-22 Acquisition Program," 56; Jeremiah Gertler, *Air Force F-22 Fighter Program*, 16-17.

[56] Christopher J. Niemi, "The F-22 Acquisition Program," 57, 59.

[57] Mackenzie M. Eaglen and Lajos F. Szaszdi, "The Growing Air Power Fighter Gap: Implications for U.S. National Security," *Backgrounder* no. 2295 (Jul 7, 2009), 2, www.Heritage.org/Research/NationalSecurity/wm2539.cfm.

[58] John McCain, "Floor Statement of Senator John McCain of F-22 Aircrafts" (speech, United States Congress, Washington, DC, July 14, 2009). transcript, http://www.mccain.senate.gov/public/index.cfm/speeches?ID=7a17feb9-d56e-db2b-13a8-a712b544c59a.

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[60] Jeremiah Gertler, *Air Force F-22 Fighter Program*, 2.

[61] As of Jul 9, 2015, F-22s employed 270 bombs over approximately 60 target areas in Iraq and Syria. Lolita C. Baldor, "F-22 Raptor Ensures other War-Fighting Aircraft Survive over Syria," *Military.com*, Jul 21, 2015, http://www.military.com/daily-news/2015/07/21/f22-raptor-ensures-other-war-fighting-aircraft-survive-syria.html.

[62] Robert Coram, *Boyd: The Fighter Pilot who changed the Art of War* (Boston: Little, Brown and Company, 2002), 141-148.

[63] Robert Coram, *Boyd: The Fighter Pilot who changed the Art of War*, 204.

[64] Robert Coram, *Boyd: The Fighter Pilot who changed the Art of War*, 227.

[65] Robert L. Shaw, *Fighter Combat: Tactics and Maneuvering* (Annapolis: Naval Institute Press, 1985), 51-52.

[66] The United States Marine Corps declared initial operational capability (IOC) for the F-35B in July 2015. The United States Air Force is scheduled to declare the F-35A IOC in August 2016. The United States Navy plans to declare the F-35C IOC in August 2018. Megan Eckstein, "Marines Declare Initial Operations Capability on F-35B Joint Strike Fighter," *USNI News*, 31 Jul 2015, http://news.usni.org/2015/07/31/marines-declare-initial-operational-capability-on-f-35b-joint-strike-fighter; "F-35 Initial Operational Capability," 2013, Headquarters, United States Navy, United States Marine Corps, and United States Air Force, Report to Congressional Defense Committees, Public Law 112-239, Section 155.

[67] The United States Air Force lists the F-35A as a multirole fighter. "F-35A Lightning II Conventional Takeoff and Landing Variant," U.S. Air Force Fact Sheet, April 11, 2014, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/478441/f-35a-lightning-ii-conventional-takeoff-and-landing-variant.aspx

[68] Joint Chiefs of Staff, *Countering Air and Missile Threats*, JP 3-01,IV-17, IV-18, V-4.

[69] Joint Chiefs of Staff, *Countering Air and Missile Threats*, JP 3-01, IV-18.

[70] The author is an F-15E Weapon Systems Officer. One of his early instructors would use the well-known phrase, "Jack of all trades, master of none," as a quip that the aircraft's expansive capability and assigned missions prevented specialization and therefore expertise in any single mission set.

[71] Author's experience as an F-15E Weapon Systems Officer, having fought with and against F-15Cs in training sorties.

[72] "F-35A Lightning II Conventional Takeoff and Landing Variant," U.S. Air Force Fact Sheet, April 11, 2014.

[73] "F-22 Raptor," U.S. Air Force Fact Sheet, September 23, 2015, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104506/f-22-raptor.aspx; "F-15 Eagle," U.S. Air Force Fact Sheet, March 14, 2005, http://www.af.mil/AboutUs/FactSheets/Display/tabid/224/Article/104501/f-15-eagle.aspx.

[74] The Air Force F-35 fact sheet describes the F-35's sensor suite as "a host of next-generation technologies" that will "provide the pilot with unsurpassed situational awareness, positive target identification, and precision strike in all weather conditions." "F-35A Lightning II Conventional Takeoff and Landing Variant," U.S. Air Force Fact Sheet, April 11, 2014; Specifics of the F-35's sensor suite are classified.

[75] Bill French and Daniel Edgren, "Thunder without Lighting: The High Costs and Limited Benefits of the F-35 Program," *National Security Network*, August 2015, 8, http://nsnetwork.org/report-f-35-thunder-without-lightning/.

[76] Bill French and Daniel Edgren, "Thunder without Lighting: The High Costs and Limited Benefits of the F-35 Program," 4.

[77] Bill French and Daniel Edgren, "Thunder without Lighting: The High Costs and Limited Benefits of the F-35 Program," 4-5.

[78] Bill French and Daniel Edgren, "Thunder without Lighting: The High Costs and Limited Benefits of the F-35 Program," 5-6.

[79] Sean Gallagher, "F-35 project team says bad dogfight report 'does not tell whole story,'" *Ars Technica* July 1, 2015, http://arstechnica.com/informationtechnology/2015/07/f35projectteamsaysdogfightreportdoesnottellwholestory.

[80] Energy management, as a principle, is a pilot's measured use of an aircraft's kinetic and potential energy, trading either or both in order to maneuver. An aircraft's thrust-to-weight ratio and aerodynamic drag affect energy management capability.

[81] The F-22 possesses an air-to-ground capability. From the author's experience integrating F-15Es and F-22s in training, F-22 pilots primarily execute an air superiority role.

[82] US Department of the Air Force. *F-15—Aircrew Training*. Air Force Instruction 11-2F-15, Vol. 1, September 7, 2010, 21-22; US Department of the Air Force. *F-15E—Aircrew Training*. Air Force Instruction 11-2F-15E, Vol. 1, March 31, 2011, incorporating Change 1, March 6, 2014, 21-25; US Department of the Air Force. *F-16—Pilot Training*. Air Force Instruction 11-2F-16, Vol. 1, April 20, 2015, 18-19; US Department of the Air Force. *F-22A—Aircrew Training*. Air Force Instruction 11-2F-22A, Vol. 1, May 19, 2006, 19-21; US Department of the Air Force. *F-35—Aircrew Training*. Air Force Instruction 11-2F-35A, Vol. 1, September 13, 2010, 17-18.

[83] Christopher J. Niemi, "The F-22 Acquisition Program," 59.

[84] "Military and Security Developments Involving the People's Republic of China 2015," 2015, Department of Defense, Office of the Secretary of Defense, RefID: D-117FA69, 35.

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[92] "Military and Security Developments Involving the People's Republic of China 2015," 36.

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