Multi-Domain Suppression of Enemy Air Defense

A Monograph

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Abstract

Arms versus Armor: Multi-Domain Suppression of Enemy Air Defense, by MAJ Nathan J. Barlow, 35 pages.

The purpose of this monograph is to distill lessons from the history of air defense and airpower's efforts to penetrate those defenses. It identifies six lessons from World War I, World War II, Vietnam, Desert Storm, and modern developments by Russia and China. These six lessons inform both air and ground forces in their future efforts to conduct Suppression of Enemy Air Defense (SEAD) and penetration operations. This monograph explores the question of how the Joint Force should approach the SEAD mission and whether or not forces from the land domain should take a more significant role in penetrating ground-based air defense systems.

Contents

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Abbreviations

AAA	Anti-Aircraft Artillery
ADA	Air Defense Artillery
ADP	Army Doctrine Publication
ARVN	Army of the Republic of Vietnam
ECM	Electronic Counter Measures
EW	Electronic Warfare
Flak	Flugabwehrkanone, German for "aircraft defense cannon."
IADS	Integrated Air Defense System
IOC	Intercept Operations Center
ISR	Intelligence, Surveillance, Reconnaissance
JADC2	Joint All Domain Command and Control
MANPAD	Man-Portable Air Defense
MiG	Mikoyan and Gurevich Design Bureau
MUMT	Manned-Unmanned Teaming
NATO	North Atlantic Treaty Organization
PAVN	People's Army of Vietnam
PLA	People's Liberation Army
PLARF	People's Liberation Army Rocket Force
PMC	Private Military Contractor
RHAW	RADAR Homing and Warning
SAM	Surface-to-Air Missiles
SOC	Sector Operations Center
SEAD	Suppression of Enemy Air Defense
UAV	Unmanned Aerial Vehicle
USSR	Union of Soviet Socialist Republics

Figures

Introduction

> Americans in 1950 rediscovered something that since Hiroshima they had forgotten: you may fly over a land forever; you may bomb it, atomize it, pulverize it and wipe it clean of life−but if you desire to defend it, protect it, and keep it for civilization, you must do this on the ground, the way the Roman legions did, by putting young men into the mud.
>
> —Theodore Reed Fehrenbach, Jr., *This Kind of War*

T.R. Fehrenbach reminds us of an enduring feature of warfare. Regardless of how sophisticated and advanced our technology has become, armed conflict still requires a soldier to stand upon a piece of ground and claim it for his cause. Airpower theorists have suggested that in future wars, men and women may no longer need to confront violence in close proximity and that air means alone can achieve the ends.[1] While a pure air war remains a distant imagining, ground forces will continue to struggle forward and seize objectives with young women and men in the mud. This monograph does not suggest that airpower is unnecessary; on the contrary, it is vital. The reach and impact of air forces have become inextricable from ground maneuver and have, in recent wars, been the necessary lead of an army's attack. However, the model of air supremacy as a prerequisite for ground progress may no longer hold. The proliferation of mobile and portable air defense systems, combined with long-range strike capabilities that hazard ground forces, regardless of their location, can force ground combat to precede its air complement.

This monograph addresses how the Joint Force should conduct Suppression of Enemy Air Defense (SEAD) in the future. It considers the struggle between attacking air forces and defenders on the ground. Specifically, it discusses how advances in air defense systems have developed to a point beyond the US Air Force's capability to continue carrying the lion's share to suppress and penetrate them. In the future, the US Army may have to strike the first blows against an Integrated Air Defense System (IADS) to open the door for the US Air Force to begin the air superiority fight.

[1] Giulio Douhet, *The Command of the Air*, 2nd ed. (New York: Coward-McCann, 1942), 29.

SEAD is critical to a ground force's freedom of maneuver.[2] Prior to the reduction of an opponent's air defense assets, the enemy's air force can attack maneuvering formations at will. Airpower has been critical to modern maneuver warfare since early flyers dropped the first weapons from aircraft in the early 20th century. Air and ground defenses have advanced to the point that it is unthinkable for an army to attack without first defeating its competitor's air forces. The rapid and thorough defeat of Iraq's air defense systems and subsequent destruction of their air force was instrumental in the quick maneuver and overwhelming victory of the coalition in Operation Desert Storm.[3] The paradigm of SEAD, with the US Air Force in the lead followed by ground maneuver, was so powerful that the competitors of the United States and NATO took note and adapted. Today's Integrated Air Defense Systems (IADS) are highly networked, mutually supporting, and layered in depth.[4] These defensive networks, combined with the advent of long-range munitions, have created a multifaceted problem. IADS confound an enemy air force's ability to establish maneuver space for its ground units while long-range fires simultaneously hold these attacking forces under threat. The dual dilemmas of an advanced IADS, paired with long-range munitions, require us to consider if our current SEAD methods are sufficient.

The hypothesis proposed is that the Joint Force should conduct future SEAD as a closely coordinated ground and air team. The US Army should resource responsive, robust, and mobile air and missile defense systems, long-range precision fires, ground-launched Anti-Radiation Guided Missiles (ARGM), and loiter munitions.[5]

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[2] US Department of Defense, Joint Staff, Joint Publication (JP) 3-01.4, *Joint Tactics, Techniques, and Procedures (JTTP) for Join Suppression of Enemy Air Defense (J-SEAD)* (Washington, DC: Government Publishing Office, 1995), I-1.

[3] Richard G. Davis, *On Target: Organizing and Executing the Strategic Air Campaign Against Iraq* (Washington, DC: Air Force History and Museums Program, 2002), 218-219.

[4] Maj Peter W. Mattes “Systems of Systems: What, Exactly, is an Integrated Air Defense System?” *The Mitchell Forum*, no. 26 (2019), 9.

[5] Joseph Trevithick and Tyler Rogoway, “Air Force to Turn Navy Air Defense Busting Missile Into High-Speed Critical Strike Weapon,” *The Drive*, 18 March 2019, accessed September 14, 2020, https://www.thedrive.com/the-war-zone/27022/air-force-to-turn-navy-air-defense-busting-missile-into-

The methodology employed is an examination of the history, theory, and doctrine of SEAD. It considers SEAD's history from World War I to the present. Countering Air and Missile Threats (Joint Publication 3-01) categorizes SEAD as a primary Offensive Counter Air (OCA) mission.[6] Its purpose is to "neutralize, destroy, or temporarily degrade surface-based enemy air defenses by destructive or disruptive means."[7] US forces developed SEAD in response to the increasing sophistication and efficacy of ground-based anti-aircraft systems and it has effectively coevolved with advances in air defense. The history of air defense in this monograph has five major sections. The first section discusses airpower development in World War I and how early air forces' increased capability opened opportunities for ground maneuver. The response to air attacks in WWI led to the creation of weapons that would hold the air arm at risk to prevent penetration during World War II.[8] WWII's combatants refined the technologies created in WWI to develop more lethal targeting systems and improved munitions for both attacking air forces and defenders on the ground. During the Vietnam War, the People's Army of Vietnam (PAVN) employed a dense combination of air defense weaponry, which required the United States to outfit and train specialized aircraft to suppress North Vietnam's defenses; this was the first instance of a dedicated SEAD capability. Next, the monograph reviews US employment of AirLand battle in Operation Desert Storm to show SEAD's effectiveness and how it provided the basis for further adaptations by other world powers to counter the doctrine in FM 100-5.[9] The fifth chapter considers Russian New Generation Warfare (RNGW), Chinese long-range missiles,

high-speed-critical-strike-weapon.

[6] US Department of Defense, Joint Staff, Joint Publication (JP) 3-01, *Countering Air and Missile Threats* (Washington, DC: Government Publishing Office, 2018), IV-9.

[7] Ibid., IV-12.

[8] Maj William Hewitt, *Planting the Seeds of SEAD: The Wild Weasel in Vietnam* (Maxwell Air Force Base: US Air Force School of Advanced Airpower Studies, 1992), 3-10.

[9] Petro G. Grigorenko, *FM 100-5: A Soviet Assessment* (Falls Church: Delphic Associates Incorporated, 1983), 64.

and the proliferation of anti-aircraft weaponry to prevent penetration. The author incorporates the evolution of SEAD theory and doctrine with historical examples to demonstrate how the competition between air forces and IADS has developed into today's highly sophisticated systems.[10] Finally, the monograph proposes a model for the ground component's future contribution in combat against a modern IADS.

How the Joint Force will conduct future SEAD operations is critical to how the services will integrate and cooperate when faced with future IADS. Modern IADS pose a significant barrier to future air and, by implication, ground operations. The employment of ground to air weapons by both nation-states and non-state actors exacerbates the problem of IADS disintegration. It dramatically increases the level of combat power required to conduct SEAD and penetration of enemy-held territory. The use of Stinger missiles by Afghan mujahedin in the Soviet-Afghan war and the more recent shootdown of Malaysian Airline's flight MH17 over Ukraine are examples of how these systems' proliferation has gone beyond strict use by established armies. In future wars, both sides may face a contiguous IADS and an un-networked air defense employed by irregular forces. Joint Forces must develop multiple options to defeat these systems and expand their approach to maximize flexibility and enable both air and ground forces to pose numerous threats to an opponent defended by both an IADS and independent ground to air weapons.

Chapter 1: A New Domain

The development of airborne weapons inspired the need for counter-air tactics and systems. The opening of what we today call the air domain added a third dimension to what had previously been a grounded experience in conflict. As armies scrambled to develop tools to deal with attacks from above, the free hand that flight provided inspired military leaders such as Giulio

[10] Col Joseph Speed and Lt Col Panagiotis Stathopoulos, “SEAD Operations of the Future.” *The Journal of the Joint Air Power Competence Centre*, ed. 26 (Spring/Summer 2018): 38-43, accessed 29 July 2020, https://www.japcc.org/portfolio/journal-26/.

Douhet and William Mitchell to imagine a future where airpower reigned supreme. On the ground after the Great War, the apparent vulnerabilities of formations, lines of communication, bases, and cities drove the British to combine and improve existing technologies into the first Integrated Air Defense System (IADS) by 1939. The arms race between offense and defense had opened a new front that would require daring and invention on both sides to keep pace with war's changing character.

The earliest military uses for aircraft centered around reconnaissance tasks and spotting targets for artillery strikes. While not a direct threat in themselves, reconnaissance pilots proved their worth. The aerial observation of Russian formations allowed the Germans to mass at Tannenberg and achieve victory, despite being outnumbered. The desire to maintain surprise led maneuvering armies to reach for solutions to prevent airborne observation. The most effective protection against air reconnaissance was the machine gun-armed fighter plane. The first use of fighter aircraft was in an air-defensive role.[11]

The airplane's weaponization happened within a decade of Wilbur Wright's demonstration at Le Mans in 1908.[12] Although it did not have a decisive effect during the Great War, the airplane's potential for disrupting ground forces was recognized and pursued. The new invention rapidly developed from a reconnaissance tool and artillery spotter to a direct threat to opposing ground and air forces. The giant R-planes and Gothas of the German bombing effort signaled that future war could see massive attacks directed at breaking infantry formations and interrupting lines of communication.[13] The industrialization of aircraft production and the bombers' proven capability to strike behind enemy lines forced armies to look to the skies as a

[11] Reg Grant, *Flight: 100 Years of Aviation* (New York: Dorling Kindersley, 2002), 70-72.

[12] Ibid., 20, 72-73.

[13] Raymond Fredette, *The Sky on Fire: The First Battle of Britain 1917-1918* (Tuscaloosa: The University of Alabama Press, 1991), 8.

threat and caused them to develop countermeasures. With both sides seeking ways to break the western front's stalemate, air forces represented a new hope.

Bomber formations had a significant effect on the evolution of warfare.[14] The Zeppelin Staaken R.VI "R-plane" and the smaller Gotha bombers were both employed to strike London with the R-plane capable of deploying with a bomb load up to 4,000 pounds.[15] Air raids on the warring homelands contributed to the developing theory of strategic bombing. The new weapons made direct attacks on the will and passions of an enemy population a reality.[16] The bombing runs on London and Paris proved that specialized weaponry to counter the air threat had become necessary.

Early ground-based anti-aircraft weapons were simple and initially amounted to not much more than artillery pieces modified to shoot higher and broader angles.[17] These ground systems were recognized as necessary but did not have the desired efficiency. Sound-detection, searchlights, optical range-finders, and mechanical fuses improved kill rates from 11,600 rounds per kill in 1915 to near 4,000 rounds per kill in 1918, but this was far from adequate for reducing the impact of air raids on the homeland.[18] These shortcomings in defensive technologies opened the door for a one-sided concept of aerial combat as a purely offensive tool.

Explicit theories of airpower and air defense did not appear until after the war. Giulio Douhet is credited as one of the earliest thinkers to publish on the subject. He landed squarely in the offensive camp and gave short shrift to the future of anti-aircraft efforts. He went so far as to claim that anti-aircraft guns' future development was a waste of energy and that nations should

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[14] Raymond Fredette, *The Sky on Fire: The First Battle of Britain 1917-1918*, 13.

[15] Ibid., 46-52.

[16] Carl von Clausewitz, *On War*, ed. and translated by Michael Howard and Peter Paret (Princeton: Princeton University Press, 1976), 89.

[17] Kenneth Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell Air Force Base: Air University Press, 2005), 1.

[18] Werrell, *Archie to SAM*, 3.

invest in independent air forces.[19] Given his experiences and the state of air defense weapons at the time, it is clear why he arrived at this conclusion.

The offensive advantage of the airplane was well established by 1918. Reconnaissance, fighter, and bomber aircraft had all proved their worth. Airpower, despite its immaturity, had confirmed its impact. Early bombing efforts and nascent anti-aircraft tactics struggled to provide their respective sides the advantage, with technological superiority landing squarely on the side of the attacker. Commanders, theorists, and the public saw flight as the future and invested themselves in aviation. To the soldiers in the trenches, military aircraft represented another new threat among the growing number of lethal tools on the battlefield. The machine gun, poison gas, tanks, and airplanes combined to create a titanic shift in offensive capability. Airpower had proven itself a force to be reckoned with, and ground maneuver needed to adapt or die. As the "War to End All Wars" ended, military leaders took advantage of the pause to increase their strengths and mitigate their weaknesses. One weakness of the defense was the bomber's ability to "always get through."[20]

The flyer's indomitable outlook of the airplane's ability to penetrate any defensive efforts was the predominant assumption following WW I. Leading airpower personalities Giulio Douhet and Brigadier General William "Billy" Michell advocated for independent air-forces dedicated to the attack. The sinking of the battleship *Ostfriesland* in 1921 solidified the bomber's offensive superiority, firmly establishing the seriousness of the bomber threat and the need to develop credible air defenses.[21] The nation which most embraced the need for improved protection was Britain.

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[19] Douhet, *The Command of the Air*, 55.

[20] Fredette, *The Sky on Fire: The First Battle of Britain 1917-1918*, 244.

[21] Roger Miller, "Billy Mitchell: Stormy Petrel of the Air," *1903-2003 FLIGHT: The 100th Anniversary*, Commemorative Edition (Washington, DC: Office of Air Force History, 2004), 32-33.

The bombings of London between 1914-1918 left an indelible mark on British politicians and war leaders' psyche. The crude efforts at homeland defense against Germany's air attacks had proven ineffectual, and as aircraft became ever more lethal, leaders in Parliament found the elevated risk unacceptable. Fully believing in an air force's ability to destroy their nation, Henry Tizard and Air Chief Marshall Hugh Dowding accepted the challenge of thinking bigger about stopping the bomber.[22] Henry Tizard was a civilian chemist and advisor to the British Air Ministry. Hugh Dowding, who would later become the first commander of the Royal Air Forces (RAF) Fighter Command, was a leader in the RAF's research and development arm. Tizard's scientific approach combined with Dowding's organizational skills to operationalize the first Integrated Air Defense System (IADS) by 1939, the most concerted effort in the interwar period, to stop the bomber from getting through.

Air Marshall Dowding integrated the Tizard Committee's refinement of Radio Detection and Ranging (RADAR) with belts of observers stationed along the British coastline. These technical and human sensors reported to a hierarchy of command and communications posts that decided what response to take and notified anti-aircraft gun emplacements and the newly minted pursuit squadrons of the RAF's Fighter Command.[23] The Dowding system focused all of its efforts on the essential tasks of sensing inbound aircraft, predicting their flight path, and communicating targetable information to the appropriate Anti-Aircraft Artillery and Fighter Command squadrons. It had to accomplish this feat within four minutes to enable aircraft to scramble in time to intercept.[24]

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[22] Austin Duncan, "Innovation Determinants of the World's First Integrated Air Defense System," *Real Clear Defense*, May 03, 2018, accessed 16 September 2020, https://www.realcleardefense.com/articles/2018/05/03/innovation_determinants_of_the_worlds_first_integrated_air_defense_system_113402.html.

[23] "The Battle of Britain," RAF 100 Schools Project, The Historical Association, accessed 17 September 2020, https://www.raf100schools.org.uk/resource/40/the-battle-of-britain-and-radar.

[24] Ibid., 5.

The RAF's investment in Fighter Command and the Dowding System set the stage for the Battle of Britain, the first instance where an attacking air force had to consider the suppression of an air defense network. The Battle of Britain between July and October of 1940 would be the first real competition between an IADS and the seemingly unstoppable bomber.

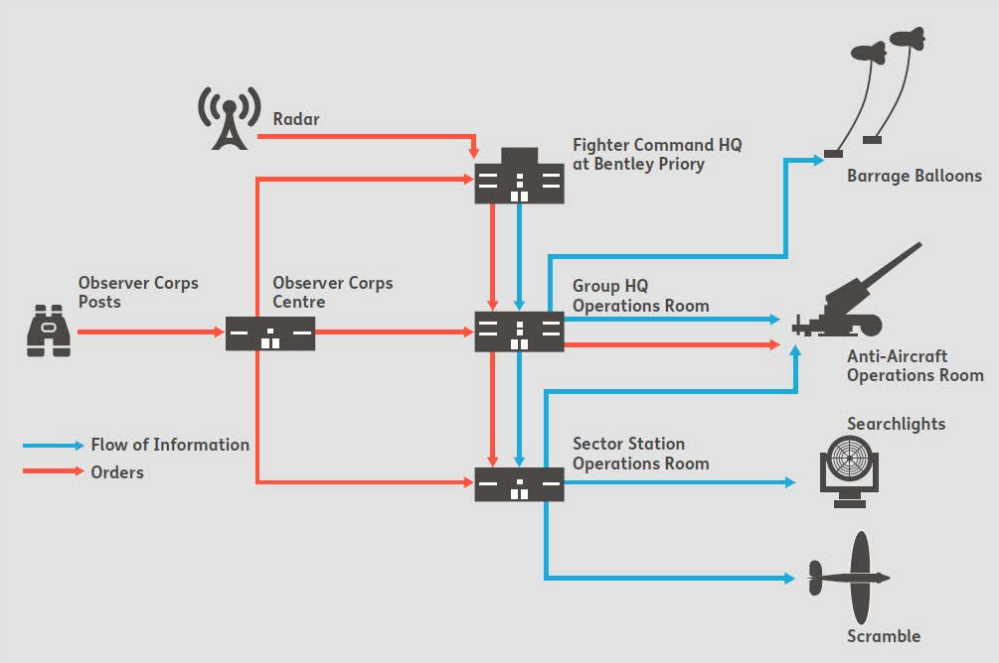

Figure 1. The Dowding System. "The Battle of Britain," RAF 100 Schools Project, The Historical Association, accessed 17 September 2020, https://www.raf100schools.org.uk/activity/11/2-the-battle-of-britain-radar.

Operation Eagle began on 11 August 1940. Operation Eagle was the Luftwaffe's attempt to achieve Hitler's guidance in *Fuehrer Directive 16* to subdue the British air force and clear the way for Operation Sea Lion to execute an amphibious invasion of the British Isles. The Luftwaffe initially attacked the RADAR sites of the island's new shield. However, due to an imperfect understanding of how the system worked, they shifted focus to command nodes and population centers.[25] The German failure to understand the RADAR network's importance caused them to

[25] Lt Col Randy McCanne and LTC Greg Olson and CDR Dario Teicher, *Operation Sea Lion: A Joint Critical Analysis* (Norfolk: Joint Forces Staff College, 2002), 25-26.

shortchange their emphasis on this critical vulnerability and bought Fighter Command time to attrit their attackers and maintain command of the air.[26] The failure of Operation Eagle to achieve air supremacy caused the cancelation of Operation Sea Lion. Britain's investment in the RAF Fighter Command and the Dowding IADS had paid off. Air Marshall Dowding had proven that ground defense could stymie an airpower attack.[27]

Early Lessons

The Dowding IADS and Operation Eagle's lesson was that detection and prediction of the attacker by a well-organized IADS could defeat an air force. The Battle of Britain represented a tipping point in the competition between offense and defense. The days of high-flying bomber incursions that struck with impunity were gone. Accounting for a target's air defenses was now a requirement, and merely amassing a larger number of aircraft than your opponent was no longer enough to gain Douhet's "command of the air." As is true today, numerical and technological superiority was not a guarantor of victory, and robust defense systems required the application of multiple and sustained dilemmas to reduce them.

RADAR provided an effective means for identifying, tracking, and predicting the routes of attacking aircraft, but defenders were still in the process of developing effective engagement methods. It was clear that close coordination was critical. The Dowding System had created some efficiencies; however, the supporting weapons systems were not much more than adaptations of tools from the trenches. Attackers learned that avoiding detection was mandatory for effective bombing and that their opponents could not just be ignored and overflown. Airpower had to expand its expertise towards countering networked ground fire systems. The Germans' failure to defeat the British defenses showcased the importance of understanding how an IADS components

[26] Joe Strange, *Centers of Gravity and Critical Vulnerabilities* (Quantico: Marine Corps University, 1996), 84.

[27] McCanne, Olson, and Teicher, *Operation Sea Lion: A Joint Critical Analysis*, 5-10.

functioned. It was not enough to attack those components in isolation; a systematic approach would be necessary.

Chapter 2: Doubling Down

Air defenders of World War II built upon the paradigms established during the interwar period. Defensive improvements came from new combinations of existing technologies instead of original capabilities. RADAR-aimed guns and mechanical fuses increased target acquisition and accuracy. Attackers responded by employing physical and electronic measures in the form of bundles of aluminum strips called chaff, code-named "Window," and airborne electronic RADAR jamming called "Carpet," but made few advances that directly countered the ground fire threat.[28] The sum of these technological re-combinations was that although defenses could not completely stymie the bomber, a minimal investment in new defensive technologies, relative to aircraft and crew costs, significantly reduced offensive effectiveness.[29]

RADAR was the foundational system of the defender's paradigm of sensor aimed ground weapons. The Dowding system established the technology's reliability, and both the Allies and Axis powers capitalized on it. RADAR served as the central concept for an effective defense against air attack as the only technology capable of vectoring weapons onto unseen targets. Improvements in RADAR transitioned it from a wide area early warning tool to an integrated target acquisition and aiming system that helped ground crews to accurately engage attacking aircraft at night or in adverse weather conditions.[30] RADAR aiming was only half of the equation. Projectile performance needed to match target acquisition. The addition of proximity

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[28] Army Air Forces (AAF) Evaluation Board in the European Theatre of Operations, *Tactics and Techniques Developed by the United States Tactical Air Commands in the European Theatre of Operations* (Washington, DC: Government Publishing Office, 1945), 6, 7, 14, 18-20.

[29] Werrell, *Archie to SAM*, 58.

[30] "General of the Flak Artillery Walter von Axthelm describes Flak development," interview by Combined Services Detailed Interrogation Centre (CSDIC), *German flak: Report 321/1945* (London: CSDIC, 1945), 50.

fuses to anti-aircraft projectiles made them approximately five times more effective.[31] Emerging technologies hinted at the future. The German "V" weapons were an indicator of the future paradigm in projectile technology, self-guiding weapons. Although the war ended before the V weapons could reach their full potential, the German Air Force tested its first V-1 in December of 1942 and showed that guided missiles were a real possibility for future warfare.[32]

Allied Air Forces responded by developing and sharing techniques for minimizing anti-aircraft fire and increasing their coordination with ground forces. The Air Ground Coordination Party (AGCP) was a critical development that presaged the intimate relationship between air and ground forces. The AGCP arose from the need to gain efficiencies between Corps and Division headquarters and tactical air forces. The AGCPs supported many mission types, but the Army Air Forces evaluation board for the European Theatre noted that AGCPs should rely extensively on artillery for target marking and counter-battery fire against enemy anti-aircraft assets.[33] This advice contrasts with the rudimentary guidance the board provided to fighter bombers when faced with flak fire, which is for the first flight to strafe the anti-aircraft positions in the hopes of discouraging the enemy gunners from engaging.[34] The challenge that WWII pilots faced was that anti-aircraft positions were very difficult to identify and target. Simultaneously, RADAR provided anti-aircraft soldiers an effective tool for locating and firing on incoming attackers. The advantage lay with the defenders. Major Frank Landes, the 8th Infantry Divisions Air Ground Coordination Party Officer (AGCPO), illustrated the effectiveness of Flak in his report on the battle of Brest. Depicted in the right-hand section of Figure 2, Major Landes effectively showed the impact that German Flak had against the 9th Air Force. The high percentage of 9th Air Force

[31] Werrell, *Archie to SAM*, 17-18.

[32] M.C. Helfers, *The Employment of V-Weapons by the Germans During World War II* (Washington, DC: Office of the Chief of Military History, 1954), 10.

[33] Army Air Forces (AAF) Evaluation Board, *Tactics and Techniques*, 18-20.

[34] Ibid., 14.

losses to Flak indicated that a more deliberate approach to attacking objectives defended by anti-aircraft weapons was warranted, and specialized weapons, tactics, and coordination would be needed in the future to combat the increased threat from the surface.

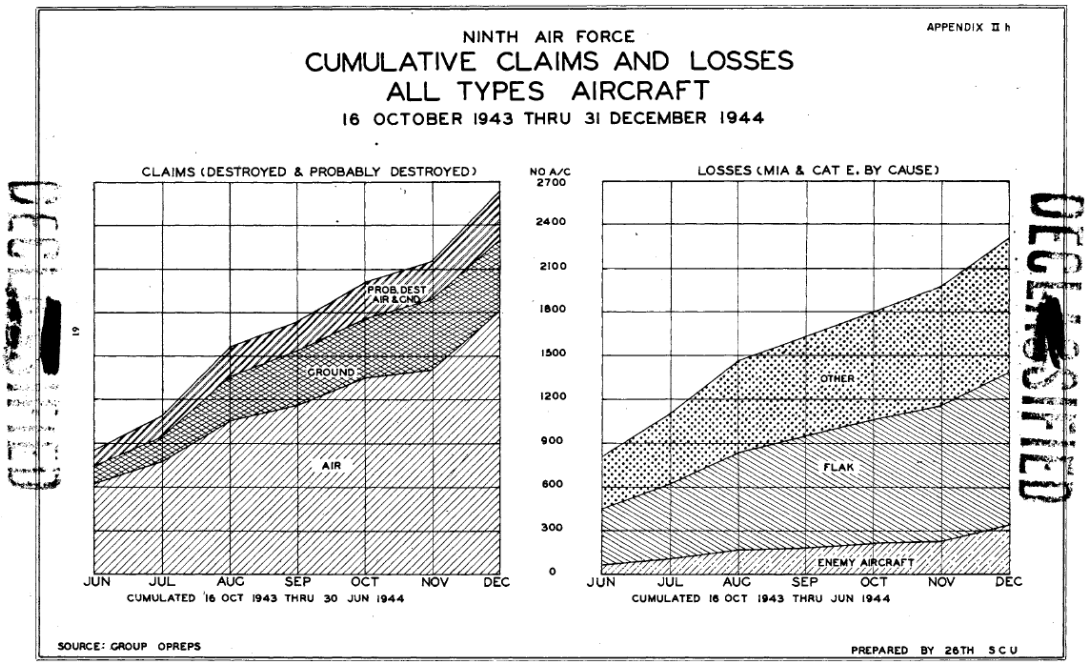

Figure 2. Cumulative Claims and Losses All Types Aircraft. Tactics and Techniques Developed by the United States Tactical Air Commands in the European Theatre of Operations: Appendix II(f) (Washington, DC: Government Publishing Office, 1945), 59, 61.

The Necessity of Cooperation

Competition between air attackers and ground defenders from 1939 to 1945 rendered several lessons for future conflict. A critical deduction was that ground-based air defenses are formidable. As demonstrated in Figure 2 and reiterated by Dr. Werrell, Flak fire downed the preponderance of Allied aircraft in WWII.[35] A weapon that was little more than a nuisance in The Great War had become a disruptive capability. AAA was cheap and could be replaced more readily than a plane and crew. RADAR gave the advantage to defending forces but could be

[35] Werrell, *Archie to SAM*, 57-59.

disrupted with physical and electronic countermeasure. Emerging RADAR countermeasures implied that attacking a weapons sensory system might provide an asymmetric solution. The ability of ground forces to provide sustained pressure on the enemy created a symbiotic advantage for airpower. The allotment of AGCP teams to Corps and Division staffs allowed for what we would term today as cross-domain coordination. Finally, it was essential to account for emerging technology. The V weapons failed to have a major impact on the war. Still, the combination of proven technology, RADAR, and the emerging technology of maneuverable missiles presaged the next major obstacle that attackers would need to overcome.

Chapter 3: Proxy Missiles

By the 1960s, monumental technological developments had changed the tools of war. In less than two decades, air defenses had transitioned from simple RADAR, flak guns, and propeller aircraft to jets, missiles, and guns, all guided by multiple RADAR systems.[36] Jet propulsion, missile guidance, and electronic sensors gave aviators new options, but it was unclear whether the new technologies favored the attacker or the defender. Despite these advances, the principles remained the same. Defending forces needed to identify and predict where and when aircraft would be, and the attacking air force had to evade or neutralize ground to air weapons and sensors before it could strike its targets. The tools had changed, and the question to be answered was, who could adapt them to best advantage first?

The Vietnam war served as a proving ground for both the United States and the Soviet Union to test how to achieve air superiority at the least cost.[37] The Soviet Union equipped the People's Army of Vietnam (PAVN) with advanced ground to air weaponry and modern fighter aircraft. The introduction of the SA-2 Surface to Air Missile (SAM) expanded the risk the PAVN posed to US airpower. The integration of this weapon into the RADAR and anti-aircraft gun

[36] Hewitt, *Planting the Seeds of SEAD*, 19-21.

[37] Wayne Thompson, *To Hanoi and Back* (Washington, DC: Air Force History and Museum Program, 2000), 33.

network around Hanoi changed how the Air Force approached its strategic bombing task in North Vietnam.

In the 1950s and 60s, Air Force bombers and fighters evaded air defenses by approaching their targets at high altitude and out of range of AAA guns.[38] This tactic came into serious doubt in May of 1960 when an SA-2 downed a U-2 on a reconnaissance flight over the Soviet Union, proving that altitude was no longer a sanctuary.[39] Captain Powers' shootdown forced the US Air Force to consider a combination of high-altitude approach with low altitude attack on the final target. The PAVN's multilayered defensive system would resist this tactic in the Hanoi and Red River Delta region.

Early in 1965, missile crew members and technicians from the Union of Soviet Socialist Republics (USSR) began to build launch sites in the Red River Delta. These sites incorporated the Soviet SA-2 into the North Vietnamese IADS that protected Hanoi.[40] The SA-2 missile system was effective up to 28,000 meters against high-altitude bombers and was employed to defend strategically critical fixed sites. In 1967, approximately 150 SA-2s complemented thousands of anti-aircraft guns, 100 MiG fighter jets, and more than 200 RADAR facilities that defended the Hanoi and Haiphong region.[41] This IADS was responsible for downing about 2,400 US fixed-wing aircraft with causes of loss attributed at eighty-nine percent to AAA and guns, eight percent to SAMs, and three percent to enemy fighters.[42] The export of the SA-2 by the USSR succeeded in achieving a cost-effective way of amplifying the toll that the PAVN IADS extracted from the US Air Force and Navy as they attempted to use strategic airpower to subdue the government of North Vietnam. PAVN IADS showed the SEAD mission's importance and how technological

[38] Grant, *Flight*, 288.

[39] Hewitt, *Planting the Seeds of SEAD*, 4.

[40] Thompson, *To Hanoi and Back*, 33.

[41] Ibid., 40.

[42] Werrell, *Archie to SAM*, 118.

proliferation from near-peer adversaries to proxy forces could threaten US operations. The tax the PAVN defenders imposed on US forces required planners to change how they conducted the air campaign and needed a particular set of tools to enable their bombers to get through.

The US response to the PAVN IADS was technological, tactical, and highly specialized. Termed Wild Weasel, it combined Electronic Counter Measures (ECM) to combat detection, RADAR seeking missiles to destroy SAM guidance systems, and brinksmanship tactics with the F-100 Super Saber, F-105 Thunderchief, or F-4 Phantom airframes. An Air Staff Task Force recommended equipping fighters with electronic systems to locate SAM sites, creating a RADAR seeking missile to find and destroy RADAR emitters, the development of electronic jamming equipment for fighters, and the creation of a RADAR Homing and Warning (RHAW) capability immediately.[43] The Wild Weasel recommendations were first realized on the F-100 and later on the F-104 and F-4 airframes. Wild Weasel aircraft used the brinksmanship tactic of deliberately stimulating SAM sites to entice them to employ their local FAN SONG RADAR systems to engage the attacking fighter bombers. When PAVN missile crews initiated their FAN SONG, the Wild Weasel used its RHAW to locate the SA-2 site and attack it with an Anti-radiation Guided Missile (AGM-45) Shrike.[44] Combined with effective tactics, the technical advancement created a capable tool for the US Air Force to use in its attacks into the Red River Delta. The Wild Weasel program was the first time the US Air Force gave the SEAD mission pride of place in weapons development. It showed that deliberately targeting the critical vulnerabilities of an IADS could be done successfully.

The Wild Weasel program, combined with other aircraft that employed ECMs, chaff, and flares, ensured that Strategic Air Command's attacks on North Vietnam achieved their targets;

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[43] Maj John Deeney, *Finding, Fixing, and Finishing the Guideline: The Development of the United States Air Force Surface-to-Air Missile Suppression Force During Operation Rolling Thunder* (Fort Leavenworth, US Army Command and General Staff College, 2010), 41.

[44] Ibid., 41-60.

however, the cost was high. During Operation Linebacker I, the ratio of support aircraft, including SEAD sorties, to strike aircraft rose to 3.4:1.[45] Commanders had to allocate more than one-third of their sorties to protection efforts, detracting from assets used to strike targets on the ground. Or, to put it another way, the ability to employ airpower is limited by the number and type of support aircraft available. This statistic has held over time. A 2005 report to the US Congress put the percentage of SEAD to strike aircraft as high as thirty percent.[46]

Communist forces in the south responded to the Americans and Army of the Republic of Vietnam (ARVN) with light anti-aircraft guns and, late in the war, the SA-7. In 1972 the SA-7 "Strela" or "Grail" made its appearance in Vietnam. The SA-7 is a man-portable, shoulder-fired, heat-seeking, anti-aircraft missile. It is effective to both a range and altitude of three and a half kilometers.[47] The SA-7 was highly capable against rotary-wing and propeller aircraft. It forced the higher performance airframes to greater altitudes, where they were susceptible to larger SAM systems and faster speeds where they were less effective against ground targets. This example demonstrated that even short-range, man-portable ground to air weaponry could have synergistic effects against US capabilities.[48]

Focused Capability Required

The PAVN IADS changed the way the United States fought its air campaign. The North Vietnamese demonstrated an ostensibly weaker opponent's ability to use less sophisticated technology to force a world superpower to scramble to adopt new technologies and techniques. Though it did not defeat offensive air operations, the IADS around Hanoi forced decision-makers to change their behavior. This example indicated that a wide array of defensive technologies

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[45] Werrell, *Archie to SAM*, 131.

[46] Christopher Bolkom, *Military Suppression of Enemy Air Defense (SEAD): Assessing Future Needs* (Washington, DC: Congressional Research Service, 2005), 5.

[47] US Department of the Army, Field Manual (FM) 100-2-3, *The Soviet Army* (Washington, DC: Government Publishing Office, 1991), 319-320.

[48] Werrell, *Archie to SAM*, 128.

employed by a determined force can force a superior opponent to adapt. More importantly, the support and protection requirements that Hanoi's efforts extorted, upwards of thirty percent of support to attack sorties, significantly increased the operational needs of exerting airpower. The United States took this hard lesson to heart and nearly twenty years later adapted effectively in the Middle East.

Chapter 4: Brittle Spokes

The 1991 air campaign against Iraq proved that independent air operations could achieve significant war aims with minimal ground contribution and hinted at chinks in the AirLand battle armor that future technologies might exploit. The implications of coalition operations against Saddam Hussein were far-reaching and closely analyzed by the world's militaries.

The sixth-largest air force in the world prepared to frustrate the most powerful opponent on the planet by digging in and trusting to its massive array of ground to air weapons.[49] Iraq's IADS reflected a similar structure to what the PAVN had established around Hanoi twenty-three years earlier. It centered around a French-designed system name Kari that orchestrated a highly centralized array of SAMs, AAA, and interceptor aircraft. This centralization was simultaneously its greatest strength as well as its greatest weakness.

Kari was a joint project between the Iraqis and French that focused on defending against Iranian, Syrian, and Israeli incursions. This custom-built IADS linked outlying Intercept Operation Centers (IOC) to regional Sector Operation Centers (SOC) and ultimately to the Defense Operations Center in Baghdad. Kari focused on threats from the north, west, and east, leaving it vulnerable to attack from the south.[50] Kari's strength was its ability to coordinate the sixth-largest air force, employing 500 modern aircraft and 400 older airframes, in conjunction with 707 RADARs, 3,679 SAMs, 972 AAA, and 8,504 gun systems. It was estimated to have

[49] Werrell, *Archie to SAM*, 239.

[50] Davis, *On Target*, 176-177.

twice the density of air defense systems than anywhere in Eastern Europe.[51] This intense centralization had the potential to be a challenging obstacle for the coalition. However, this same high level of integration, inherent in an IADS concept, was to be its greatest weakness.

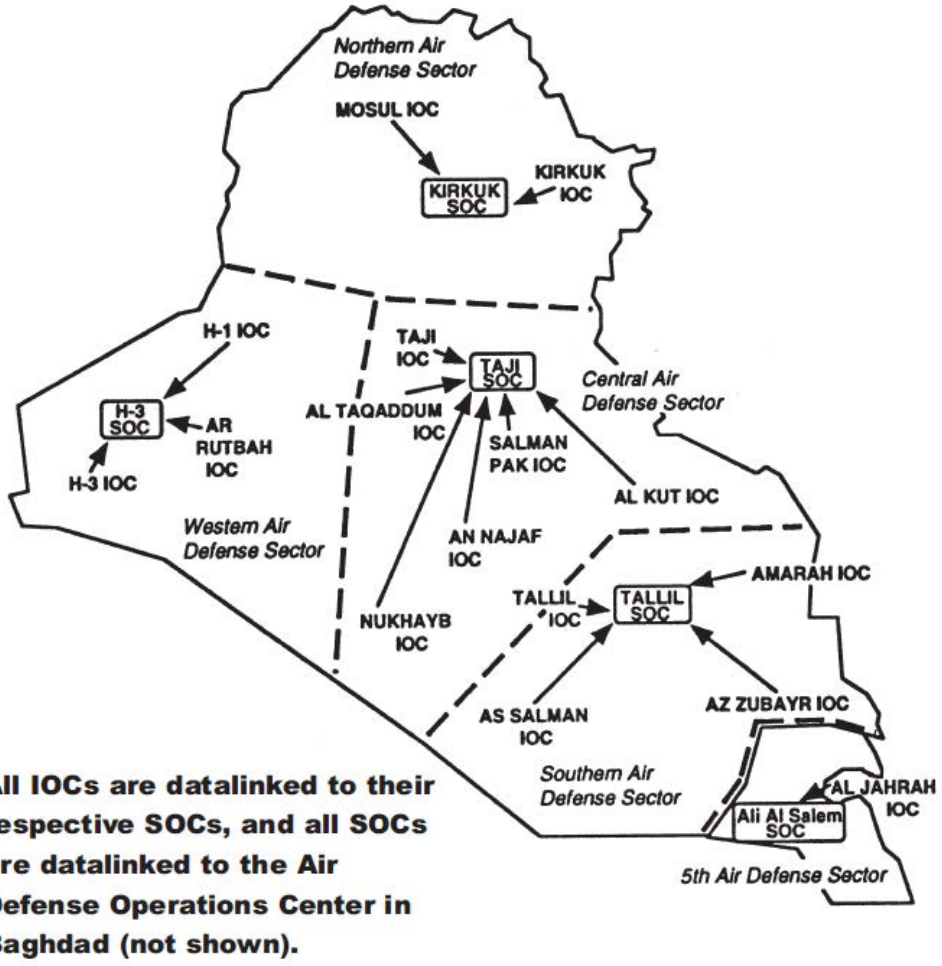

Figure 3. The Kari System. *On Target: Organizing and Executing the Strategic Air Campaign Against Iraq* (Washington, DC: The Air Force History and Museums Program, 2002), 177.

Coalition planners evaluated that the Iraqis could inflict air losses of up to sixty-three aircraft in the first three phases of the operation. The attrition rate fell to approximately two per day, early in Phase III. Planners expected ground losses to approach 10,000.[52] Neither of these

[51] Davis, *On Target*, 152

[52] Ibid., 106-107

estimates implied that the coalition would not achieve victory, but they indicate how seriously planners took Iraqi combat power. Expected loss rates drove the force levels that each service requested and anchored leaders in their decision making. The risks that the coalition faced required a cohesive and tightly coordinated plan. Many leaders and thinkers contributed, but one polarizing theorist provided the framework that became the foundation for campaign development.

Colonel John Warden was one of the most influential Air Force planners to address operational challenges in the Middle East. His theories about the primacy of targeting centers of gravity, enemy leadership, and the value of shock effect, as laid out in his draft plan Instant Thunder, were adopted to devastating effect as part of Operation Desert Storm. Colonel Warden's project stemmed from his theoretical work, *The Air Campaign: Planning for Combat*. Published in 1988 by the National Defense University, his visualization of centers of gravity as concentric rings and his five conceptual "cases" of air war were the air campaign's foundational assumptions. Colonel Warden had an outsized impact on the planning of the Desert Storm air plan. His experience as a pilot in Vietnam and his time as a Pentagon planner fueled his airpower theories. Colonel Warden's ideas set a precedent for war planners in the Middle East and framed how they would target the Iraqi defenses.[53]

Colonel John Warden's experience in Vietnam was instrumental in his understanding of the proper use of airpower. Like other military leaders of the era, he viewed the gradual employment of airstrikes in Operation Rolling Thunder as a misapplication of the immense force available. In contrast to the measured methodology in southeast Asia, Col. Warden advocated for

[53] John Olsen, “Warden Revisited: The Pursuit of Victory Through Air Power,” *Air Power History* 64, no. 4 (Winter 2017): 39-40.

highly targeted operations conducted at a high tempo to incapacitate specific functions of the opponent's nation. He called the campaign Instant Thunder.[54]

Instant Thunder exhibited Warden's theories on modern airpower. Warden sincerely believed that the technological advances in aviation had given air forces the potential to be the decisive arm in conflict that Douhet had imagined.[55] Col. Warden's concepts revolved around a specific set of enemy centers of gravity. He espoused five systems organized in concentric circles, like a bullseye target, prioritized from the center out. These interconnected systems were the enemy's leadership, system essentials, infrastructure, population, and finally, their fielded military forces. Together they form what came to be called the Five Rings. The implicit prioritization of these target sets established the underpinnings of air strategy in Iraq. Their influence can be traced from his development of the Instant Thunder concept to the tactical actions of sorties over the Middle East. Warden's theory on the Five Cases of War can also be seen in Desert Storm planning. Col. Warden defined five basic scenarios that he believed encompassed most air war environments.[56] Case II describes a scenario in which the friendly forces can strike deep into enemy territory while the enemy can only reach local targets.[57] Operation Desert Storm fit these criteria, and Col. Warden analogized it to the Allied air offensive against Germany from 1943 to 1945. He lauded it as the "commander's dream" and as an "opportunity for action so decisive that the war can theoretically be won from the air."[58]

The Instant Thunder concept began as an independent project by Col. Warden and his team at the Deputy Directorate for Warfighting Concepts, also known as Checkmate. Checkmate

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[54] Davis, *On Target*, 75.

[55] Olsen, “Warden Revisited,” 39.

[56] John Warden III, *The Air Campaign: Planning for Combat* (Washington, DC: National Defense University, 1988), 20.

[57] Ibid., 20.

[58] Ibid., 39.

anticipated the need for an offensive air campaign against Iraq. It developed Instant Thunder before GEN Schwarzkopf requested that the Air Force provide a retaliatory option to strike Saddam Hussein if the dictator committed heinous that required a response. The CINCENT adopted Instant Thunder as that retaliatory plan.[59]

Figure 4. Warden System Model. *Battlefield of the Future: 21st Century Warfare Issues* (Maxwell Air Force Base: Air University Press, 1998), 108.

Its consistent and comprehensive focus on, what Col. Warden assessed to be, Iraq's strategic centers of gravity led GEN Schwarzkopf to direct Lt. Gen. Horner to develop it into an executable plan. Colonel John Warden had synthesized the lessons from earlier airpower theorists and crystalized them into a conceptual structure that other planners would operationalize into real-world effects. His conviction that the systems approach would lead to the disintegration and destruction of a nation-state military was instrumental in Operation Desert Storm's victory. Col. Warden's Case II war and his Five Rings evolved into twelve strategic target sets that focused 11,610 strikes against Iraq's vulnerabilities. SEAD was a major focus of this campaign.

Instant Thunder stood in stark contrast to Rolling Thunder. In Vietnam, the national command authority closely controlled the air campaign to prevent wide-scale destruction that

[59] Diane Putney, *Airpower Advantage: Planning the Gulf War Air Campaign 1989-1991* (Washington, DC: Air Force History and Museums Program, 2004), 348-355.

could have triggered a world war. Instant Thunder, and later Desert Storm, embraced the idea that Iraq was an interdependent system that should be attacked broadly and at intersecting functional points. The twelve strategic target categories that resulted from this idea were: leadership, electric power, naval targets, oil, telecommunications/government command, control, communications, IADS and Kari, military industry, nuclear biological and chemical sites, lines of communication, SAMs, Scud missiles, and airfields. These twelve categories fit the Five Rings model and guided the targeting approach for the duration of the conflict. During the campaign, 2,860 strikes out of a total of 11,610 were executed against IADS related targets.[60] Commanders directed almost one-quarter of the air campaign's total effort toward defeating the Iraqi air defenses. This prioritization was in stark contrast to prior conflicts where strikes against ground to air systems were conducted only out of short-term necessity to enable access to other target sets. The understanding that SEAD operations had become a broad necessity in modern warfare was evident in the planning and execution of Desert Storm.

Kari was incapable of absorbing the high tempo, whole-of-system attack. The shock was too much. Kari was like a spoked wheel that can withstand significant impact and leverage enormous force, but that is vulnerable to disintegration when its major connection points are struck. Its design was efficient but ultimately fragile. The opening salvo of Desert Storm attacked Kari at multiple vital points and rapidly eliminated Saddam Hussein's ability to employ his air force and air to ground weaponry effectively.

The war began at 0238 hours on 17 January 1991 when a flight of attack and special forces helicopters breached Kari's first layer by destroying an early warning RADAR site linked to the Nukhayb IOC. Eliminating the southern early warning RADAR opened the door for stealth aircraft to infiltrate north and strike the Nukhayb IOC itself. The facility survived but was not employed by the Iraqis afterward. Within minutes of these first two attacks, laser-guided bombs

[60] Putney, *Airpower Advantage*, 351-352.

delivered by a sortie of stealth bombers destroyed two telecommunications facilities in downtown Bagdad that were critical to the IADS communications network and civilian broadcasting system.[61] Saddam's forces responded by blindly firing massive barrages of AAA shells and SAMS, which had no effect. The coalition bombed the Taji SOC and Tallil SOC, further crippling the brittle spokes of the IADS. Between 0238 and 0420 hours, coalition air forces severely disrupted command and control, early warning, and SAMs coordination capabilities. The SOC attacks enabled the SEAD effort to begin in earnest with two large strike packages nicknamed Gorilla and Poobah's Party. Using HARMs, decoy drones, EW systems, and a mix of conventional and precision munitions, the US Air Force achieved air superiority over Iraq in less than twenty-four hours.

The Risk of Rigidity

Instant Thunder and Desert Storm stand in stark contrast to the methodical escalations of Rolling Thunder. Coalition forces in the Middle East showed the impact that combat power's high tempo application could have. The United States had proven that a wide-ranging, systematic attack of a nation state's critical requirements could bring an opponent's conventional military capability to its knees in a matter of hours. In particular, the joint employment of stealth, precision weapons, and long-range strike capabilities demonstrated that highly centralized defensive networks were vulnerable to collapse when overwhelmed by precision targeting of their critical nodes. The French designed Kari as a robust system, but it proved rigid and brittle. It was not an adaptive system. Future defenses would need to be more flexible to counter SEAD operations. The increased connectivity and redundant organization made capable by the burgeoning internet and cellular communications networks, combined with the continued proliferation of ever-smaller sensors and processors, would make this possible. The competitors of the United States took note.

[61] Putney, *Airpower Advantage*, 339-346.

Chapter 5: Defense Rising

The tremors from the coalition victory over Saddam Hussein reverberated through the world's militaries, shaking their confidence in their abilities to repulse a similar future attack. Iraq's destruction was so swift and so thorough that it caused military leaders to reevaluate their forces and their approach to operations. The Russian Federation and the Chinese Communist Party (CCP) keenly felt pressured to keep up with the military might of liberal democracies.

In 2008 the Russian Federation embarked on the "New Look" military reform to update its technology, optimize its structure, and professionalize its force. Air defense was a specialty for the Russian military, and this continued in its most recent restructuring. Russian forces reorganized and reequipped in response to their competitors' aeronautical prowess. The Russian Army developed redundant, flexible, and overlapping defensive coverage at every echelon from the battalion to the strategic level. Current assets range from MANPADS to larger missile systems like the S-400 capable of engaging targets from ground level to the stratosphere. Many of these modern weapons can fire on the move supported by specialized electronic warfare systems designed to confuse NATO cruise missiles, attack aircraft, and UAVs. These systems provide a mobile and flexibly networked IADS from the national to the small unit level.[62] The combination of mobile SAMS, AAA, MANPADS and EW make for a formidable and adaptive protection system that is a far cry from the brittle rigidity of traditional IADS like Kari.

To further reinforce this robust, formal defensive system, the Russian Federation under President Putin has shown a penchant to use tactics that skirt the edge of conventional war. The employment of "Little Green Men" in the annexation of Crimea and the use of private military

[62] Lester Grau and Charles Bartles, *The Russian Way of War: Force Structure, Tactics, and Modernization of the Russian Ground Forces* (Fort Leavenworth, Foreign Military Studies Office, 2016), 27, 31, 101, 266-271.

companies like the Wagner Group in eastern Ukraine and across the globe brings with it a profound challenge for any air force seeking air superiority. These irregular and deniable forces have at times been armed with state-of-the-art military equipment to include advanced SAMs. The Dutch Safety Board Joint Investigation Team concluded that a Buk missile shot down Malaysian Airlines Flight 17. This missile system had at one point belonged to the Russian 53rd Anti-Aircraft Missile Brigade.[63] The MH-17 incident raises the specter of future conventional IADS combined with a complimentary informal structure of irregularly employed air defense weapons that possess the same potency as their government sponsors. The density, depth, flexibility, and opacity of this modern hybrid IADS begs the question of whether or not current air forces have the tools to penetrate it.

An attacking force entering a Russian Federation A2/AD network would encounter hostile partisan forces backed by well-trained private military contractors capable of coordinating with the conventional Russian IADS. These low-visibility forces would remain out of sight, keeping their SAMS and AAA concealed inside buildings and hide-sites until the conventional IADS required reinforcement. When the attacking force maneuvers towards the conventional IADS, partisans and PMCs would intermingle with its formations, particularly in urban areas, and activate independent anti-aircraft systems in proximity to the aggressor's formations. This hybrid approach would disrupt the SEAD effort, expose maneuver forces, drain the attacker's resources, and threaten their basing. Ground forces would be required to hunt SAMS, AAA, and MANPADS in parallel with the broader SEAD effort against the national IADS.

While Russia adapted to the overt and physical implications of US AirLand Battle, the Chinese People's Liberation Army (PLA) sought to understand and counter the connective tissue that supported the global reach and synchronized impact of US technologies. In an extensive

[63] "MH17: Four charged with shooting down plane over Ukraine," British Broadcasting Corporation, 19 June 2019, accessed 24 November 2020, https://www.bbc.com/news/world-europe-48691488.

study of Western military thought titled *Unrestricted Warfare*, two PLA officers detailed the Western way of war's strengths and weaknesses. They proposed a new conceptual approach for the PLA to employ.

Colonels Qiao Liang and Wang Xiangsui proposed that Desert Storm had not only changed the way militaries employed technology but that the nature of coalition actions outside of the military sphere had changed the very heart of warfare. They defined the new way of war as "unrestricted warfare" and framed it as actions in all domains, both military and non-military, that a nation uses to exert its will on others. It is warfare that "transcends all boundaries and limits."[64] Unrestricted warfare's influence can be seen in the Chinese Communist Party's cyberspace actions, the economy, and the South China Sea. The connective tissue that transcends all boundaries and limits is "informatized" and "integrated joint operations." Informatization recognizes that modern militaries must synchronize through near real-time transmission of data between elements in contact with the enemy and decision-makers at the supporting headquarters. Integrated joint operations indicate that the PLA has adopted the perspective that forces in all domains need to cooperate to achieve the maximum effect possible against an enemy.[65]

Applying the strategic concepts of unrestricted warfare, joint operations, and informatization to an IADS manifests various PLA options. The Chinese military approached the challenge of potential technological overmatch by Western armies from a broad view and a high angle. Instead of seeking to counter US capabilities directly, their analysis of Desert Storm led them to seek the linkages that made that technology successful, namely the shared information that enabled such successful targeting. As early as 1999, PLA strategists viewed space and cyberspace as the new "high-ground" and sought to achieve a position of advantage in these

[64] Qiao Liang and Wang Xiangsui, *Unrestricted Warfare* (Beijing: PLA Literature and Arts Publishing House, 1999), 12.

[65] M. Taylor Fravel, *Active Defense: China's Military Strategy Since 1949* (Princeton: Princeton University Press, 2019), 230-235.

domains.[66] The PLA's approach prevents an opponent from ever reaching air-superiority by preempting their space and cyberspace efforts. By degrading an attacker's ability to employ precision, navigation, timing, and data networks, they intend to nullify the advantage of the types of high technology used in the Gulf War. Advanced weaponry like the HQ-9 SAM supports this prepositioned advantage.[67] The HQ-9 is deployed on land and aboard ships to push China's defensive perimeter onto coastal islands and the South China Sea. China has been investing heavily in the Peoples Liberation Army-Navy (PLAN) to create as much time and space between themselves and any potential attacker from the east.

On the mainland President Xi Jinping designated the People's Liberation Army Rocket Force (PLARF) as an independent service branch in 2015 and charged it with the employment of both nuclear and conventional missile systems in defense of the homeland.[68] The PLARF possesses precision missile systems that include short, medium, intermediate, and intercontinental missile systems. The PLARF is organized and equipped to strike targets regionally and globally with either conventional or nuclear weapons. Modernization efforts focused on mobility, range, speed, and penetrability.[69] State-owned enterprises support rapid capability development that allows for highly focused force development and acquisition. The PLARF and PLAN are representative of China's response to Operation Desert Storm. The lesson they embraced is that the United States is over-reliant on its satellite-based sensor and communications assets. Holding coalition forces at risk at extreme ranges is likely to preempt any aggression towards mainland China. Their view is that terrestrial weaponry, combined with space and cyberwarfare

[66] Michael Chase, Jeffrey Engstrom, Tai Ming Cheung, Kristen Gunness, Scott Warren Harold, Susan Puska, Samuel Berkowitz, *China's Incomplete Military Transformation: Assessing the Weaknesses of the People's Liberation Army (PLA)* (Santa Monica: RAND, 2015), 17.

[67] Ibid., 88-91.

[68] Brendan Mulvaney, *PLA Aerospace Power: A Primer on Trends in China's Military Air, Space, and Missile Forces* (Montgomery: China Aerospace Studies Institute, Air University, 2019), 45.

[69] Ibid., 51-53.

capabilities, will make the cost of entry for any conflict with the PLA so high as to be politically untenable.

PLA forces would counter a penetration operation with long-range strikes against the enemy's airbases and logistics facilities. As the conflict escalated, the PLA would transition from spoofing their opponent's satellites and communications networks to the physical destruction of space systems. CCP cyber forces would weaponize "smart city" technologies to track and target maneuvering forces.[70] Attacking formations would suffer losses to their intermediate staging bases, constant surveillance from military and civilian sensors, corrupted and degraded navigation and communications, as well as counterstrikes from an IADS, intermingled with both conventional and nuclear long-range missiles.

Competitive Responses

The Chinese and Russian militaries embraced Desert Storm's implications and restructured themselves to contest the advantages that airpower provided in that conflict. Irregular forces with advanced anti-aircraft weapons support mobile, layered, and redundantly networked IADS. "Informatized" warfare hinders US command, control, and targeting. Competitors of the United States studied and leveraged the chinks in the AirLand battle armor to question the efficacy of the SEAD paradigm employed in 1991. The US reliance on space-based networks and stealth has ceased to be the advantage it once was. Competing militaries are deliberately countering these options. The edge has tipped toward the defender. The shootdown of Vega 31, the damaging of a second F-117 over Serbia in 1999, and the 2007 Chinese anti-satellite weapon test show that stealth is vulnerable and US command and control is fragile. Distance from the

[70] BBC Future, "Safe cities: Using smart tech for public security: A Better Connected World," BBC Worldwide, accessed 03 March 2021, https://www.bbc.com/future/bespoke/specials/connected-world/government.html#:~:text=Smart%20cities%20are%2C%20as%20a%20concept%2C%20safer%20cities.&text=Its%20safe%20city%20solution%20uses,line%2C%20fibre%20and%20microwave%20technologies.

conflict zone is no longer a shelter.[71] The US Joint Force must address these shortcomings if it is to remain competitive.

Chapter 6: Conclusions and Options

One hundred years of competition between air and ground forces have provided crucial lessons that inform how the US Army could move forward in future conflicts. Each period of air attack and ground defense holds vital experiences. Notable are prediction, cooperation, support to attack ratios, interconnectedness, federation, and long-range strike.

The Great War showed that detection is key to any offensive or defensive capability, but it is only the first step. Applying analysis to a detected target's motion to predict where it will be, enables accurate targeting. RADAR proved to be that prediction tool. Today RADAR technologies are still the foundation of prediction for most defensive and some offensive weapons; however, a military's ability to observe and orient has expanded far beyond the early twentieth century's simple RADAR systems. Russia claims the S-400 can detect fifth-generation stealth aircraft such as the F-35.[72] It is currently unclear with what resolution advanced SAM systems can track stealth aircraft. Even if the system can only provide a general location for an incoming stealth bomber, integrating various systems with data analysis tools could give a refined targeting solution. Identifying a target and predicting where it will be in the near-term is the crux of the defense's problem.

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[71] Thomas Newdick, "Yes, Serbian Air Defenses Did Hit Another F-117 During Operation Allied Force In 1999," *The Warzone*, 01 December 2020, accessed 03 February 2021, https://www.thedrive.com/the-war-zone/37894/yes-serbian-air-defenses-did-hit-another-f-117-during-operation-allied-force-in-1999; William J. Broad, David E. Sanger, "China Tests Anti-Satellite Weapon, Unnerving U.S.," New York Times, 18 January 2007, accessed 03 February 2021, https://www.nytimes.com/2007/01/18/world/asia/18cnd-china.html.

[72] Dave Majumdar, "Could Russia's S-400 Do the Unkthinkable: Kill a F-22, F-35 or B-2 Bomber?" *The National Interest*, 18 January 2018, accessed 03 February 2021, https://nationalinterest.org/blog/the-buzz/could-russias-s-400-do-the-unkthinkable-kill-f-22-f-35-or-b-24114.

The second World War provides the example that combinations of existing technologies and cooperation between adjacent warfare domains can create a decisive advantage. The heavy attrition Flak inflicted on Allied airpower and the associated disadvantage that resulted from reduced air support indicates that cooperation between air and surface forces is critical. Combining technologies and increasing the support between domains was a key lesson of Army Air Forces in the European Theatre of Operations.[73] In future conflicts, this will mean enabling the free flow of targeting information between all domains. In WWII, the Air-Ground Coordination Party exemplified target information sharing between attack aircraft, artillery batteries, and maneuver forces to suppress German Flak positions. Today it means automating data distribution on secure tactical networks that all branches of service can access. The Joint Force effort to field the Joint All Domain Command and Control (JADC2) system intends to make holistic situational awareness a reality.[74]

The jungles of Southeast Asia tipped the advantaged to the defender. They taught US forces that a few advanced systems, when integrated with a broader and robust network of basic weaponry, can significantly increase the attacker's cost. The Hanoi IADS required successful strike packages to employ three SEAD aircraft to every one strike aircraft. Today's A2/AD networks would likely require similar or greater ratios of support to strike, and this would detract from the offensive capacities of both the ground and the air. Increasing requirements on airpower are an argument for an asymmetric approach that employs tools from the other domains. A land-based offensive SEAD option would create multiple dilemmas for an opponent and reduce the Air Forces' requirements.

Desert Storm was an example of offensive dominance. The coalition's thoroughly planned and deeply integrated efforts against Saddam's Iraq rapidly and decisively eliminated the

[73] Army Air Forces (AAF) Evaluation Board, *Tactics and Techniques*, 18-20.

[74] John R. Hoehn, *Joint All-Domain Command and Control (JADC2)* (Washington, DC: Congressional Research Service, 23 October 2020), 1-3.

Kari IADS. Kari's highly interconnected nature provided it great power, but it lacked resiliency. The internet has solved this brittleness problem. Modern militaries can adapt to disintegration attempts by using radio, hardline, line-of-sight, cell towers, and satellite communication systems to stabilize their networks. This increased interconnectedness makes future IADS far more resilient than Kari. Additionally, the ubiquitous coverage of cellular technology enables irregular forces to coordinate an informal air-defense web.

Technology has become orders of magnitude more potent in the past two decades while simultaneously becoming more accessible. Dispersible, intuitive, interconnected technologies will enable future defensive systems to move from being highly integrated to becoming federated. Future IADS might look more like a federated air defense system that can behave in a fully integrated manner when its network fully functions and transitions to localized cellular cooperation when an attack begins to degrade its command-and-control nodes. In essence, the command-and-control function could float from one node to the next when the central node is destroyed. This federated method would make an IADS a complex adaptive system.

The ever-increasing range of missiles indicates the value that competitors place on disrupting their opponents long before an attacker breaches their territory. China claims its DF-26 intermediate-range ballistic missile can strike moving targets on sea or land at ranges up to 4,000 kilometers. [75] If accurate, the DF-26 places Andersen Air Force Base on Guam within range of mainland China. Increasing numbers of long-range weapons should be a driving factor of modernization for the US Army.

The future US Army should take advantage of the six lessons of prediction, cooperation, attack ratios, interconnectedness, federation, and long-range strike by employing offensively mobile air and missile defense assets capable of disrupting modern aircraft attacks and ballistic

[75] Mulvaney, *PLA Aerospace Power*, 50-51.

missile threats. Providing the Army with increased air and missile protection capability is not a new idea. However, this idea should shift from a defensive footing to an offensive posture.

In prior conflicts, the US Army had the luxury of waiting for the US Air Force to establish air superiority before ground forces began their maneuver. In an operating environment where an opponent has a conventional global strike capacity, waiting might not be an option. A future war could see the US Army forced to maneuver out of its intermediate staging bases because remaining in place would subject it to a persistent ballistic missile threat. The Air Force is once again subject to managing the 3:1 attack ratio that the Vietnam conflict exhibited and will not have the spare capacity to simultaneously fight for air superiority, strike strategic targets, conduct SEAD, and provide close air support. Developing an offensive, ground-based anti-air and missile capability will reduce the Air Force's workload. Creating a maneuver-based SEAD option will enable the US Army to maneuver under fire and create diverse challenges for an opponent, contrary to the single-domain solution today. This concept is analogous to the Roman *testudo* formation.

The word *testudo* is Latin for tortoise and was used to describe a formation employed by Roman infantry in which the soldiers held their shields to create frontal and overhead protection against enemy projectiles on the battlefield.[76] It was an offensive formation used to maneuver under protection to within close combat range. A modern adaptation of the *testudo* concept is necessary for the US Army to maintain its ability to close with and destroy the enemy. Resourcing the US Army with offensively mobile anti-air and anti-missile systems capable of defeating modern attack aircraft and ballistic missiles will provide a "testudo" like effect and enable ground forces to penetrate modern A2/AD networks.[77]

[76] Philip Rance, "The Fulcum, the Late Roman and Byzantine Testudo: The Germanization of Roman Infantry Tactics?" *Greek, Roman, and Byzantine Studies*, no. 44 (2004): 300-302.

[77] Jeremiah Rozman, "Integrated Air and Missile Defense in Multi-Domain Operations," *Spotlight*, no. 20-02 (May 2020): 3-10.

The Army's Multi-Domain Operations concept proposes that a future force must stimulate, see, and strike enemy formations to win in a near-peer conflict. A *testudo* organization structured with *stimulate*, *see*, and *strike* echelons would disrupt the enemy's prediction, enhance Joint cooperation, reduce Air Force SEAD to strike ratios, overwhelm the enemy's interconnectedness, isolate a defender's federated IADS, and mitigate the enemies long-range strike capability. This penetration force should be equivalent to a division or larger and maneuver subordinate brigades that specialize in the *stimulate*, *see*, and *strike* functions.

A *stimulate* brigade should field many expendable autonomous and semi-autonomous systems capable of replicating the visual, thermal, and EMS signatures of air and ground combat systems, as well as command posts. The purpose of this formation would be to deliberately trigger the sensory apparatus of the opponents A2/AD while employing sufficient deception and mobility to minimize attrition from the enemy's counterstrike. Stimulating the defender's networks with deceptive signatures would enable the following echelons to map, track, and predict enemy maneuver and long-range strike positioning.

The second echelon of a penetration division would fulfill the *see* function. This organization of two or more brigade-sized elements would employ air and ground manned-unmanned teaming (MUMT) formations to exploit the targeting data relayed from the expendable unmanned systems of the *see* echelon. The *see* brigades would strike at high-value targets and shape the battlefield for the subsequent *strike* formations.[78] *See* formations provide the ability to autonomously destroy clearly identifiable combat systems such as SAMS, tanks, and artillery while employing human discrimination to target formations and locations that pose a collateral damage risk. Autonomous anti-radiation loiter munitions and ground-launched anti-radiation missiles, operated in concert with attack helicopters, would be critical capabilities of a *see*

[78] Lt. Col. Steven G. Van Riper, "Apache Manned-Unmanned Teaming Capability," *ARMY Magazine*, September 2014, accessed 03 February 2021, https://lscpagepro.mydigitalpublication.com/publication/?m=22217&i=221334&p=1&article_id=1785129.

organization. The successful armed reconnaissance and shaping of the *see* brigades provide the commander decision space to determine where the *strike* echelon should be employed to best advantage.

Strike echelons would employ mobile infantry and armor formations to exploit the weak points in the A2/AD network. *Strike* brigades use mostly manned ground systems with some autonomous and MUMT capability to maneuver into an A2/AD bubble to disrupt its ability to strike long-range targets and prevent the enemy from massing anti-air weaponry. This echelon would require a high density of air defense artillery systems to prevent its attrition before maneuvering into range with its ground combat systems. This future ADA capability should employ weapons capable of defeating incoming intermediate and short-range ballistic missiles and disrupting attacks by modern aircraft. It must be mobile enough to maneuver alongside major ground combat systems such as the M2/A3 Bradley Fighting Vehicle or M1/A3 Abrams tank. The *strike* formations require close cooperation with Air Force assets to provide windows of opportunity for fifth-generation fighters to exploit further and then jointly disintegrate the opponent's A2/AD capability.

The multi-domain combination of a protected land force, in the form of a Penetration Division, with the SEAD expertise of the US Air Force, will reduce the number of support aircraft the Air Force requires, provide for more rapid maneuver, reduce the ability of an opponent to destroy US forces at staging bases, and speed the disintegration of future IADS.[79] Victory in modern conflict requires close combat, and we must still, as T.R. Fehrenbach phrased it, put young men in the mud. Before we ask our young women and men to step into that mud, we must equip them to do the job.

[79] US Department of the Army, Training and Doctrine Command (TRADOC) Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations 2028* (Washington, DC: Government Printing Office, 2018), 32-42.

Bibliography

Army Air Forces (AAF) Evaluation Board in the European Theatre of Operations. *Tactics and Techniques Developed by the United States Tactical Air Commands in the European Theatre of Operations*. Washington, DC: Government Publishing Office, 1945.

Axthelm, Walter von. "General of the Flak Artillery Walter von Axthelm describes Flak development." interview by Combined Services Detailed Interrogation Centre (CSDIC). *German Flak: Report 321/1945*. London: CSDIC, 1945.

Bolkom, Christopher. *Military Suppression of Enemy Air Defense (SEAD): Assessing Future Needs*. Washington, DC: Congressional Research Service, 2005.

British Broadcasting Corporation. "MH17: Four charged with shooting down plane over Ukraine." *British Broadcasting Corporation*, 19 June 2019. Accessed 24 November 2020. https://www.bbc.com/news/world-europe-48691488.

Broad, William, and David E. Sanger. "China Tests Anti-Satellite Weapon, Unnerving US." *New York Times*, 18 January 2007. Accessed 03 February 2021. https://www.nytimes.com/2007/01/18/world/asia/18cnd-china.html.

Chase, Michael, Jeffrey Engstrom, Tai Ming Cheung, Kristen Gunness, Scott Warren Harold, Susan Puska, and Samuel Berkowitz. *China's Incomplete Military Transformation: Assessing the Weaknesses of the People's Liberation Army (PLA).* Santa Monica: RAND, 2015.

Clausewitz, Carl von. *On War*. Edited and translated by Michael Howard and Peter Paret. Princeton: Princeton University Press, 1976.

Corey, Col Craig. "The Air Force's Misconception of Integrated Air and Missile Defense." *Air and Space Power Journal* 31, issue 4 (2017): 1-10. Accessed 06 July 2020. https://www.airuniversity.af.eduPortals10ASPJjournalsVolume-31_Issue-4V-Corey.pdf

Creveld, Martin van, Steven Canby, and Kenneth Brower. *Air Power and Maneuver Warfare*. Maxwell Air Force Base, AL: Air University Press, 1994.

Davis, Richard. *On Target: Organizing and Executing the Strategic Air Campaign Against Iraq.* Washington, DC: Air Force History and Museums Program, 2002.

Deeney, John. *Finding, Fixing, and Finishing the Guideline: The Development of the United States Air Force Surface-to-Air Missile Suppression Force During Operation Rolling Thunder*. Fort Leavenworth, US Army Command and General Staff College, 2010.

Douhet, Giulio. *The Command of the Air*, 2nd ed. New York: Coward-McCann, 1942.

Duncan, Austin. "Innovation Determinants of the World's First Integrated Air Defense System." *Real Clear Defense*, May 03, 2018. Accessed 16 September 2020. https://www.realcleardefense.com/articles/2018/05/03/innovation_determinants_of_the_worlds_first_integrated_air_defense_system_113402.html.

Fravel, Taylor. *Active Defense: China's Military Strategy Since 1949.* Princeton: Princeton

University Press, 2019.

Fredette, Raymond. *The Sky on Fire: The First Battle of Britain 1917-1918.* Tuscaloosa: The University of Alabama Press, 1991.

Grant, Reg. *Flight: 100 Years of Aviation.* New York: Dorling Kindersley, 2002.

Grau, Lester and Charles Bartles. *The Russian Way of War: Force Structure, Tactics, and Modernization of the Russian Ground Forces.* Fort Leavenworth, Foreign Military Studies Office, 2016.

Grigorenko, Petro. *FM 100-5: A Soviet Assessment*. Falls Church: Delphic Associates Incorporated, 1983.

Helfers, M.C. *The Employment of V-Weapons by the Germans During World War II.* Washington, DC: Office of the Chief of Military History, 1954.

Hewitt, William. *Planting the Seeds of SEAD: The Wild Weasel in Vietnam.* Maxwell Air Force Base: US Air Force School of Advanced Airpower Studies, 1992.

Historical Association. "The Battle of Britain." *Royal Air Force 100,* 2018. London: Historical Association. Accessed 17 September 2020. https://www.raf100schools.org.uk/resource/40/the-battle-of-britain-and-radar.

Hoehn, John. *Joint All-Domain Command and Control (JADC2).* Washington, DC: Congressional Research Service, 23 October 2020.

Liang, Qiao and Wang Xiangsui. *Unrestricted Warfare.* Beijing: PLA Literature and Arts Publishing House, 1999.

Majumdar, Dave. "Could Russia's S-400 Do the Unkthinkable: Kill a F-22, F-35 or B-2 Bomber?" *The National Interest,* 18 January 2018. Accessed 03 February 2021. https://nationalinterest.org/blog/the-buzz/could-russias-s-400-do-the-unkthinkable-kill-f-22-f-35-or-b-24114.

Mattes, Peter. "Systems of Systems: What, Exactly, is an Integrated Air Defense System?" *The Mitchell Forum*, no. 26 (2019): 1-11. Accessed 29 July 2020. http://docs.wixstatic.com/ugd/a2dd91_2f17e209f90f4aaab80b116e4d139eb4.pdf.

McCanne, Randy, Greg Olson, and Dario Teicher. *Operation Sea Lion: A Joint Critical Analysis.* Norfolk: Joint Forces Staff College, 2002.

Miller, Roger. "Billy Mitchell: Stormy Petrel of the Air," *1903-2003 FLIGHT: The 100th Anniversary*. Washington, DC: Office of Air Force History, 2004.

Mulvaney, Brendan. *PLA Aerospace Power: A Primer on Trends in China's Military Air, Space, and Missile Forces.* Montgomery: China Aerospace Studies Institute, Air University, 2019.

Newdick, Thomas. "Yes, Serbian Air Defenses Did Hit Another F-117 During Operation Allied Force In 1999." *The Warzone*, 01 December 2020. Accessed 03 February 2021. https://www.thedrive.com/the-war-zone/37894/yes-serbian-air-defenses-did-hit-another-f-117-during-operation-allied-force-in-1999.

Olsen, John. "Warden Revisited: The Pursuit of Victory Through Air Power." *Air Power History* 64, no. 4 (Winter 2017): 39-53.

Putney, Diane. *Airpower Advantage: Planning the Gulf War Air Campaign 1989-1991.* Washington, DC: Air Force History and Museums Program, 2004.

Rance, Philip. "The Fulcum, the Late Roman and Byzantine Testudo: The Germanization of Roman Infantry Tactics?" *Greek, Roman, and Byzantine Studies*, no. 44 (2004): 300-302.

Riper, Lt. Col. Steven G. "Apache Manned-Unmanned Teaming Capability." *ARMY Magazine*, September 2014. https://lscpagepro.mydigitalpublication.com/publication/?m=22217&i=221334&p=1&article_id=1785129.

Rozman, Jeremiah. "Integrated Air and Missile Defense in Multi-Domain Operations." *Spotlight*, no. 20-02 (May 2020): 3-10.

Speed, Col Joseph, and Stathopoulos, Lt Col Panagiotis. "Challenges of Future SEAD Operations." *The Journal of the Joint Air Power Competence Centre*, edition 27 (2018): 35-40. Accessed 15 August 2020. https://www.japcc.org/portfolio/journal-27/

———. "SEAD Operations of the Future." *The Journal of the Joint Air Power Competence Centre*, edition 26 (2018): 38-43. Accessed 29 July 2020. https://www.japcc.org/portfolio/journal-26/

Strange, Joe. *Centers of Gravity and Critical Vulnerabilities.* Quantico: Marine Corps University, 1996.

Thompson, Wayne. *To Hanoi and Back.* Washington, DC: Air Force History and Museum Program, 2000.

Trevithick, Joseph, and Tyler Rogoway. "Air Force to Turn Navy Air Defense Busting Missile Into High-Speed Critical Strike Weapon." *The Drive*. 18 March 2019. Accessed September 14, 2020. https://www.thedrive.com/the-war-zone/27022/air-force-to-turn-navy-air-defense-busting-missile-into-high-speed-critical-strike-weapon.

US Department of the Army. Field Manual 100-2-3, *The Soviet Army.* Washington, DC: Government Publishing Office, 1991.

———. Training and Doctrine Command Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations 2028.* Washington, DC: Government Printing Office, 2018.

US Department of Defense. Joint Staff. Joint Publication 3-01.4, *Joint Tactics, Techniques, and Procedures (JTTP) for Join Suppression of Enemy Air Defense (J-SEAD).* Washington, DC: Government Publishing Office, 1995.

———. Joint Staff. Joint Publication 3-01, *Countering Air and Missile Threats*. Washington, DC: Government Publishing Office, 2018.

Warden, John. *The Air Campaign: Planning for Combat.* Washington, DC: National Defense University, 1988.

Werrell, Kenneth. *Archie to SAM: A Short Operational History of Ground-Based Air Defense*. Maxwell Air Force Base: Air University Press, 2005.