The Impact of Anti-Access Area Denial Threats on Future Combat Operations

A Monograph

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Future combat will occur in all domains and at greater ranges and speed than seen in previous conflicts. This is particularly true concerning modern developments in complex Integrated Air Defense Systems and Anti-Access Area Denial strategies. Russia's anti-access strategy in Kaliningrad poses a significant threat to US operations in the Baltics. Additionally, China's power projection throughout the South China Sea presents a challenging hurdle for air operations in the Pacific. This monograph seeks to determine what lessons can be learned from Operation Linebacker II, the 1973 Yom Kippur War, and Operation Allied Force. Most importantly it addresses what information gleaned from these campaigns can imply about future A2AD issues in the next war. Planners and analysts must learn to overcome these operational and strategic challenges presented by complex air defense systems. The paper begins with a vignette detailing the first B-52 loss in Vietnam and the North Vietnamese use of the SA-2 surface-to-air missile in an area denial role. Less than a year later, the 1973 Yom Kippur War provides countless examples of how the robust Egyptian IADS presented a substantial challenge for the Israeli Air Force. Further examination of Yugoslavia's use of mobile surface-to-air missiles in 1999 details the way in which these systems can continue to contest the paradigm air force. Finally, this paper will illustrate the complex nature of a modern IADS and the reasons why it presents substantial issues for the joint force.

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Abstract

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Future combat will occur in all domains and at greater ranges and speed than seen in previous conflicts. This is particularly true concerning modern developments in complex Integrated Air Defense Systems and Anti-Access Area Denial strategies. Russia's anti-access strategy in Kaliningrad poses a significant threat to US operations in the Baltics. Additionally, China's power projection throughout the South China Sea presents a challenging hurdle for air operations in the Pacific. This monograph seeks to determine what lessons can be learned from Operation Linebacker II, the 1973 Yom Kippur War, and Operation Allied Force. Most importantly it addresses what information gleaned from these campaigns can imply about future A2AD issues in the next war. Planners and analysts must learn to overcome these operational and strategic challenges presented by complex air defense systems. The paper begins with a vignette detailing the first B-52 loss in Vietnam and the North Vietnamese use of the SA-2 surface-to-air missile in an area denial role. Less than a year later, the 1973 Yom Kippur War provides countless examples of how the robust Egyptian IADS presented a substantial challenge for the Israeli Air Force. Further examination of Yugoslavia's use of mobile surface-to-air missiles in 1999 details the way in which these systems can continue to contest the paradigm air force. Finally, this paper will illustrate the complex nature of a modern IADS and the reasons why it presents substantial issues for the joint force.

Contents

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Acronyms

A2AD	Anti-Access Area Denial
CAOC	Combined Air Operations Center
CINCPAC	Commander in Chief, Pacific Air Forces
ECCM	Electronic Counter-Countermeasures
ECM	Electronic Countermeasures
EMCON	Emissions Control
FRY	Federal Republic of Yugoslavia
GCI	Ground Control Intercept
HARM	High-Speed Anti-Radiation Missile
IADS	Integrated Air Defense System
IDF	Israel Defense Force
IFF	Identification Friend or Foe
IP	Initial Point
JCS	Joint Chiefs of Staff
JDAM	Joint Direct Attack Munition
KTAS	Knots True Airspeed
NATO	North Atlantic Treaty Organization
NM	Nautical Mile
NVA	North Vietnamese Army
RTAFB	Royal Thai Air Force Base
SAC	Strategic Air Command
SACEUR	Supreme Allied Commander Europe
SAM	Surface-to-Air Missile
SEAD	Suppression of Enemy Air Defenses

Illustrations

Chapter One: Introduction

On November 22, 1972, "Olive 2" was part of a strike package consisting of eighteen B-52s with targets in the heavily defended portion of North Vietnam. Captain Norbert Ostrozny was an experienced aircraft commander with over 2,200 hours and eighty-eight combat missions in the "Stratofortress." His skills led the crew of six to a target complex defended by overlapping surface-to-air (SAM) missile sites.[1] After completing a standard takeoff from U-Tapao, Royal Thai Air Force Base (RTAFB), Thailand, and routine routing to the target area, the crew checked their electronic countermeasure (ECM) systems and leveled off in formation at 35,000 feet and 470 knots true airspeed (KTAS). Regardless of SAM or enemy aircraft activity, Strategic Air Command (SAC) orders were for this to be a "press-on" mission where the aircraft was not to divert or alter the flight path before bomb delivery.[2] Before Olive 2's time on target, a flight of four F-4 fighters laid a chaff corridor across the target area, attempting to hide the radar cross-section of the B-52s. Additionally, three EB-66 electronic attack aircraft provided electronic surveillance and stand-off jamming.[3]

On the final portion of the bomb run, the co-pilot called out a surface-to-air missile (SAM) launch. With instructions not to maneuver the aircraft, Ostrozny remained committed to the attack while Larry Stephens, the electronic warfare officer, attempted to locate the enemy system and use self-protection jamming.[4] Seconds later, there was a blinding flash and loud explosion as one of the two SA-2 "Guideline" missiles exploded near the jet. With substantial damage, Ostrozny turned the aircraft back towards U-Tapao and accelerated. However, the

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[1] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972* (Washington, DC: Government Printing Office, 1978), 31.

[2] James R. McCarthy and George B. Allison, *Linebacker II: A View From the Rock* (Memphis: Tommy Towery, 2011), 46.

[3] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 31.

[4] Ibid.

aircraft was fatally hit and began losing altitude. At 19,000 feet, the aircraft commander turned on the red abandon light triggering the navigator to immediately fire his ejection seat with the remaining crew members following.[5]

Olive 2 was the first combat loss of a B-52 in Vietnam, and the unfortunate manner in which it was shot down became commonplace during the remaining Linebacker missions.[6] Today, the increasing complexity of overlapping Integrated Air Defense Systems (IADS) still poses a substantial problem for modern combat operations. IADS are an effective way for many countries to augment their Anti-Access Area Denial (A2AD) systems. Advances in modern low observable aircraft and cruise missile technology led many nations to focus predominantly on the modernization of their approach to A2AD. The 1973 Yom Kippur War conclusively demonstrated that an advanced surface-to-air missile network consisting of hundreds of radar-guided systems and new mobile SA-6 missiles could neutralize the then-dominant Israeli Air Force. During the 1972 Operation Linebacker II and 1999 Allied Force, political constraints limited aircraft attack options, forcing predictable attack profiles and enabling missile engagements. More specifically, the "Christmas Bombings" of 1972 and Allied Force demonstrate problems with geographically separated planning, inability to disseminate strategic intelligence quickly, and failure to maximize the use of multi-domain warfare to neutralize the enemy's air defense network.

SAMs provide a cheaper alternative to securing air superiority. Increasing aircraft performance and low-observable capabilities are more challenging and time consuming for many nations. However, implementing a substantial SAM defense umbrella provides a more effective way of mitigating an opponent's ability to execute multi-domain operations through the use of A2AD techniques. Anti-access strategies center on prohibiting adversary entry into an area of

[5] McCarthy and Allison, *Linebacker II: A View From the Rock*, 81.

[6] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 31.

operations, using aircraft, naval vessels, and a variety of missile systems.[7] Area denial tactics focus on defensive measures to restrict freedom of action in the area of operations.[8] The combination of these strategies presents a complex, layered system and should be particularly worrisome to the Joint Force, specifically in the South China Sea and Western Europe. The United States military and allies must learn from historical campaigns to adequately prepare for future wars.

In-depth analysis of Linebacker II, the 1973 Yom Kippur War, and the 1999 Operation Allied Force provides insight into future A2AD issues in major combat operations. These conflicts show how a Joint Force may be required to operate with only localized air superiority. Such limited air superiority may delay theater entry and follow-on operations. Current A2AD advancements share many parallels to the conflicts mentioned above. These case studies illustrate how modern systems focus on maneuverability, minimizing emissions, and longer ranges all present operational and strategic challenges for the Joint Force. The South China Sea and Kaliningrad, a small Russian exclave between Poland and Lithuania, are excellent examples of how other nations rely on advanced A2AD strategies to project power throughout the region and defend their borders.

Research for this project uses a case study methodology to analyze the 1972 Christmas Bombings, 1973 Yom Kippur War, and Operation Allied Force in 1999. Chapter two examines the impacts SA-2s had on US losses in Vietnam and American attempts to counter area denial tactics used by the Vietnamese. Chapter three centers on the Egyptian IADS used in the Sinai in 1973. This campaign conclusively demonstrates the impact a dense and mobile surface-to-air network can have on adversary air operations in the form of both anti-access and area denial. This

[7] "China's Anti-Access Area Denial," Missile Defense Advocacy Alliance, accessed November 26, 2019, https://missiledefenseadvocacy.org/missile-threat-and-proliferation/today's-missile-threat/china-anti-access-area-denial-coming-soon.

[8] Ibid.

prevented Israeli access to strategic Egyptian targets and ensured the freedom of movement for Egyptian ground forces. Chapter four examines the systems and area denial tactics used by Yugoslavia during Allied Force, specifically those which brought down the first, low-observable, F-117 aircraft. Each of these case studies briefly addresses the belligerents' objectives, specifications on IADS of the period, and their impact on the operational strategy and outcome of the conflict. Chapter five will analyze some of the tactical aspects of modern surface-to-air missiles and their ability to have a strategic impact on the tempo, basing, and risk of future combat operations in Western Europe and the South China Sea. The three case studies addressed in detail throughout the remaining chapters will highlight the evolution of IADS and their use in executing an A2AD strategy as well as the importance of thoroughly understanding how these systems operate in order to gain and maintain air dominance in future combat operations.

Chapter Two: Operation Linebacker II

Approaching Christmas Eve in 1972, B-52 mission planners frantically worked with intelligence specialists in the ARC LIGHT Center on Andersen Air Force Base, Guam, preparing mission materials for the next day's bombing sorties to North Vietnam. Fuel calculations were critical due to the round trip distances exceeding 6,000 nautical miles (NM), and sixteen to eighteen hours airborne.[9] The coordination of supporting tanker aircraft for this complex mission was no easy task. The following day, over 100 B-52 Stratofortress heavy bombers made the turn from the initial point (IP) to the target. As another "press-on" SAC directed mission, crews would not abort for a loss of engines, bombing computers, defensive systems, or radars.[10] Between the IP and target, the lead radar navigator counted down the weapon release and directed a post target turn when the crew suddenly felt as if they were in the deafening center of a thunderstorm as the aircraft shook violently. A surface-to-air missile damaged both the number one and two engines

[9] McCarthy and Allison, *Linebacker II: A View From the Rock*, 22.

[10] Ibid., 48.

on the left wing outboard nacelle, with fire and fuel streaming into the night sky.[11] The bomber began a descent with the structural damage and loss of thrust, as the aircraft commander flipped on the red guarded ABANDON switch signaling the crew to bailout.

Fifteen B-52s were shot down due to SAMs during the eleven-day bombing campaign known as Linebacker II.[12] In 1972 President Richard Nixon had two limited objectives for the war in Vietnam. The first objective was to secure an American withdrawal without abandoning South Vietnam and enabling a communist invasion. The second objective was to convince South Vietnamese President Nguyen Van Thieu that US forces would continue to support him if the North Vietnamese resumed fighting.[13] Linebacker I, 9 May – 23 October 1972, was initially intended to meet these objectives, permanently destroying North Vietnam's industrial capacity, but continued hostilities necessitated follow on operations. The political situation deteriorated rapidly after Linebacker I due to the collapsing Paris peace talks and North Vietnamese incursion of the demilitarized zone.[14] In response, the United States initiated a devastating and decisive string of interdiction attacks on the North Vietnamese cities of Hanoi and Haiphong known as Linebacker II or the "Christmas Bombings."[15] Linebacker I's inability to bring the war to an end, drove President Nixon to increase the intensity in the subsequent operation and target the North's will to continue fighting. Nixon wanted the bombings to have a maximum psychological effect on the North Vietnamese, proving the United States would not continue negotiations indefinitely.[16] To meet President Nixon's desired end state, the Joint Chiefs of Staff authorized strikes on a variety of target sets, including transportation resources, petroleum storage areas, North

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[11] McCarthy and Allison, *Linebacker II: A View From the Rock*, 80.

[12] Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam* (Lincoln: University of Nebraska Press, 2006), 193

[13] Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam*, xiii.

[14] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 2

[15] Ibid.

[16] Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam*, 182.

Vietnamese lines of communication, as well as anti-aircraft defense systems, and their supporting command and control centers.[17]

The intensive bombing campaign on Hanoi and Haiphong employed a three-phased approach. Phase one included a three-day maximum effort to target eleven different areas with 314 B-52 bomber sorties at night.[18] The second phase consisted of a reduced level of bombing and a focus primarily on the Haiphong area of North Vietnam, using only 120 B-52 sorties.[19] The final phase, planned for 26-29 December 1972, once again ramped up the bombing intensity with 295 B-52 sorties against thirteen different targets near both Hanoi and Haiphong.[20] On 18 December 1972, the JCS authorized the execution of Operation Linebacker II, leading to the loss of fifteen B-52 bombers due to the effectiveness of North Vietnamese SAM systems.

To understand why the SAMs used by North Vietnam were so effective throughout this American bombing campaign, it is imperative to appreciate the aircraft targeted. The B-52 Stratofortress, an all-weather heavy bomber capable of carrying a massive payload of weapons. This aircraft is powered by eight jet engines, propelling it at speeds higher than 650 miles per hour, with an unrefueled range of 6,000 miles.[21] A "big belly" B-52D's standard loadout was forty 750 pound M-117 general-purpose bombs in the internal bay while still carrying an additional twenty-four 500 pound Mk-82 weapons externally.[22] The large size of this aircraft produced a substantial radar cross-section, making it easily detectable by enemy radar systems. Despite this vulnerability, the amount of ordnance it delivered made it the appropriate choice for

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[17] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 4.

[18] Ibid., 55.

[19] Ibid.

[20] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 4

[21] Lon O. Nordeen Jr., *Air Warfare in the Missile Age* (Washington: Smithsonian Institution Press, 1895), 68-69.

[22] Ibid.

both the operation and intended psychological effect on the North Vietnamese.[23] The Viet Cong Minister of Justice describes his experience on the ground during a Linebacker II raid stating; "The terror was complete. One lost control of bodily functions as the mind screamed incomprehensible orders to get out."[24]

Figure 1. Boeing B-52D "Big Belly."
National Museum of the United States Air Force, "Boeing B-52 D," accessed January 10, 2020, https://www.nationalmuseum.af.mil/Upcoming/Photos/igphoto/2000532452.

The NVA was well prepared to defend against the formidable bomber threat. Many considered North Vietnam's layered air defense system one of the most capable in the world with the Soviet-built SA-2 missile system and the MiG-21 "Fishbed" fighters.[25] In addition, this system was extremely deadly due to the combination of SAMs, Anti-Aircraft Artillery (AAA), the integration of fighters and early warning radars, and visual observers in constant communication.[26] The MiGs were capable of out-maneuvering the large bombers that had little defensive capability against the fast-moving jets other than four .50 caliber machine guns in the tail turret. While the MiG-21 fighter proved challenging for American fighter aircraft, it had little

[23] Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam*, 182.

[24] Ibid., 183.

[25] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER: Overview of the First 120 Days* (Washington, DC: Government Printing Office, 1973), 44.

[26] Nordeen Jr., *Air Warfare in the Missile Age*, 17.

effect on B-52 bombing runs due to the rudimentary Vietnamese means of target identification and the challenges associated with positively identifying friendly and enemy aircraft. To degrade the intense American bombing raids, the North Vietnamese relied more heavily on the radar-guided SA-2 for area denial, rather than the counter-air missions flown by their air force.

A SA-2 battery consists of a "Fan Song" guidance radar, support equipment in seven wheeled vans, and six individual missile launchers.[27] While the SA-2 system consists of wheeled vehicles, it is not considered mobile. Because of the size and time required to set up the radar system, communication equipment, and the launcher, the SA-2 is primarily used in fixed locations to defend specific areas. This system launches a "Guideline" missile the size of a telephone pole, guided by the radar unit from altitudes of 3,000 to 60,000 feet, and detonated by a proximity fuse.[28] B-52 strike sorties were flown between 30,000 and 40,000 feet, putting them in the heart of the SA-2 engagement envelope. The guidance system for the missile and Fan Song acquisition radar was augmented by additional off-board systems, including the "Spoon Rest" early warning radar. Spoon Rest radars were capable of detecting aircraft at over 110 nautical miles and altitudes of over 50,000 feet.[29] The integration of these area denial systems proved challenging for B-52 operations to overcome.

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[27] Center of Military History, *History of Strategic Air and Ballistic Missile Defense Volume II: 1956-1972* (Washington, DC: United States Army, 2009), 266.

[28] Nordeen Jr., *Air Warfare in the Missile Age,* 15.

[29] Center of Military History, *History of Strategic Air and Ballistic Missile Defense Volume II: 1956-1972*, 276.

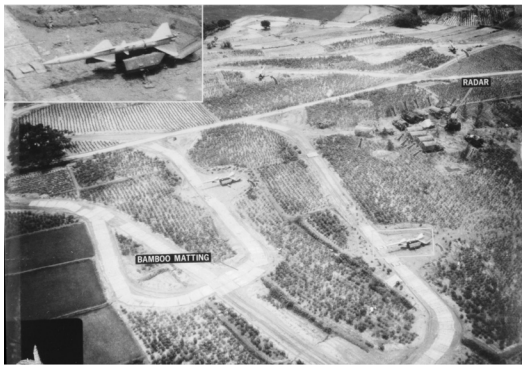

Figure 2. SA-2 SAM Site.
National Museum of the United States Air Force, "First in, Last Out: Wild Weasels vs. SAMs," accessed January 9, 2020, https://www.nationalmuseum.af.mil/Upcoming/Photos/igphoto/2000558803.

The layered effects produced by North Vietnam's integrated air defense system, as well as SAC constraints dictating the approved ingress routes for bombers, significantly hindered the flexibility in their attacks. Small arms fire and AAA forced the bombers to operate at higher altitudes. However, this pushed delivery altitudes to above 30,000 feet and into the prime engagement window of the SA-2 as well as increasing susceptibility to MiG-21s. To mitigate the effects of enemy radar and fighter engagements, the bombers flew in tight, non-maneuvering formations. These adjacent three-ship cells used electronic countermeasure equipment to degrade Fan Song and Spoon Rest radar acquisition.[30] ECM equipment limitations prevented maneuvering bomb runs because the jamming capabilities would be reduced while in a turn. For this reason, SAC determined all B-52 sorties as "press-on" missions meaning they were to continue as a complete cell for mutual support, regardless of the availability of support aircraft.[31] Tight bomber formations provided critical mutual support and maximized the effect of radar

[30] Nordeen, *Air Warfare in the Missile Age*, 70.

[31] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 59.

jamming, which substantially interfered with the enemy signals and confused missile guidance.[32] Bombers participating in the first Linebacker II raids were mandated to remain wings level for four minutes before bomb release to ensure accurate weapon deliveries, creating an extremely predictable target for Viet Cong SAM operators to engage.[33] To further mitigate North Vietnamese radar capabilities, the US relied heavily on chaff and other aircraft to suppress the enemy air defenses.

Linebacker II relied heavily on SAM suppression from F-105G "Wild Weasel" missions and standoff jamming by EB-66 aircraft to support the intensive bombing campaign. A modified variant of the B-66 Destroyer, the EB-66, was outfitted with a multitude of radar jamming equipment to fulfill a support role for the B-52s. These aircraft would fly orbits clear of the North Vietnamese SAM and MiG threat environment to jam Fan Song and Spoon Rest radars.[34] Wild Weasel sorties were effective in targeting SA-2 systems by using hunter and killer teams where one aircraft would detect the system and the other strike it. At times, "Wild Weasel" sorties were capable of denying SAM operators the use of their radar with anti-radiation missiles or jamming. However, if the SAM operators chose to use the system in a degraded passive tracking mode, there was little the F-105s could do to prevent them from firing on B-52s.[35]

US counter-air or MiG Combat Air Patrol (MiGCAP) missions also played a significant role in allowing bomber missions free access to their targets without fear of harassment by MiG-21s. Before the MiGCAP missions, the MiG-21s were effectively relaying targeting information to the SAM operators attempting to engage aircraft with their radars being jammed. The MiGs were flying behind the bomber formations and reporting altitudes and airspeeds to the SA-2

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[32] McCarthy and Allison, *Linebacker II: A View From the Rock*, 65.

[33] Ibid.

[34] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 47.

[35] Ibid., 46-47.

operators and then turning away when a firing solution was achieved, similar to how German aircraft had done with Allied bombers in World War II.[36] Air Force EC-121Ts, "Disco," and Navy ships equipped with surface-to-air-radars, code-named "Red Crown," were extremely effective in locating and vectoring American fighters to shoot down MiGs.[37] Within a matter of days, the North Vietnamese had found a way to counter US airborne warning and control systems. For instance, the MiG-21s came to rely on the extensive ground control intercept (GCI) radar network to vector them to the B-52 formations at low altitude, below US radar coverage, then climb to attempt engagements on the bombers.[38] Not only were the North Vietnamese innovative and capable of adapting operations, but the United States also had substantial problems with coordination and equipment.

The quality of B-52 aircraft varied in each formation, particularly the ECM suite onboard. The fleet of jets consisted of 107 older B-52D models and 99 of the new B-52G models.[39] The G models had a substantially improved ECM system and made a significant difference in SA-2 operators' effectiveness.[40] Coordination issues also plagued the bombing campaign. Operationally, SAC headquarters in Omaha over controlled attacks by building theater battle plans and dictating specific tactics while geographically separated from the actual combat.[41] This continued to challenge the air campaign during inflight coordination as SAC controlled the bombers, and another command was responsible for the support aircraft. This inability to adequately coordinate flight plans and tactics led to US radios being jammed by their

[36] Nordeen, *Air Warfare in the Missile Age*, 71.

[37] Nordeen, *Air Warfare in the Missile Age*, 75.

[38] Ibid., 77.

[39] Kenneth P. Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell Air Force Base: Air University Press, 2005), 132-133.

[40] Ibid.

[41] Ibid.

own EB-66 jets and US radars being significantly degraded by friendly B-52 ECM.[42] American aircraft were forced to use standardized tactics to mitigate the coordination and ECM challenges, with the Vietnamese quickly adapting.

In the first three days of Linebacker II, the Vietnamese shot down twelve aircraft, which on the surface, may not sound like an excessive amount of jets. However, the B-52 losses were worrisome as they serve as America's primary strategic bomber and one-third of the nuclear triad. Three to six losses a night was an unsustainable rate for America's strategic fleet.[43] Specifically, on the third day, missile operators determined that the B-52s used the same flight path every night and knew exactly where they would be vulnerable. They identified that the most effective tactic to counter the aircraft would be to launch a large number of missiles preemptively at the jets projected flight path.[44] To further complicate these missile launches, the North Vietnamese limited their radar emissions, to avoid detection or jamming until the final five to ten seconds of the intercept, making suppression difficult for the Wild Weasels.[45] In addition to delaying radar emissions, the SA-2 system also employed a "track on jam" mode of the radar, which would allow the system to acquire, track, and ultimately engage the aircraft attempting to jam the SAM.[46]

Predictable flight paths, coordination challenges, and delayed illumination tactics by the NVA were concerning to bomber crews, planners, and commanders. The staff made recommendations for SAC to approve maneuvering bomb runs and varied ingress and egress routes until just before weapon release.[47] Approval was quickly gained for modifying tactics, due

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[42] Ibid., 133.

[43] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 132.

[44] Nordeen, *Air Warfare in the Missile Age*, 71.

[45] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense,* 133-134.

[46] McCarthy and Allison, *Linebacker II: A View From the Rock*, 65.

[47] Ibid., 84.

in large part to the detailed debriefing provided by crews shot down in the early days of the operation. Additionally, Commander in Chief, Pacific Air Forces (CINCPACAF), the general commanding all Pacific Air Force assets, sent a detailed message to the 7th Air Force commander stating continued B-52 losses were unacceptable and recommended immediate changes.[48] The intervals between aircraft weapon releases were shortened to create minimal time in the SAM engagement area over the target, with altitudes modified to avoid predictable firing solutions for the SA-2s.[49] Innovative tactics and the speed at which the entire Air Force instituted them, combined with the deteriorating Vietnamese IADS network and resupply challenges, considerably lowered the bomber loss rate for the remainder of the campaign.[50]

During the eleven-day maximum effort bombing campaign, B-52s flew 729 sorties to target thirty-four different complexes in North Vietnam and dropped over 15,000 tons of high explosives.[51] Intelligence assessments determined the bombing campaign impacted 1,600 military structures, 500 rail interdictions, 372 pieces of rolling stock, three million gallons of petroleum products, destroying eighty percent of electrical power production capability, and cratering ten airfields.[52] However, achieving these effects resulted in the loss of a substantial number of aircraft. During the more than 700 Linebacker II B-52 sorties, fifteen bombers were shot down, with another ten damaged.[53] The fifteen bombers destroyed were all lost to the SA-2 Guideline missile, of which 884 were launched.[54]

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[48] Headquarters Pacific Air Force, *Project CHECO Report: LINEBACKER Operations September-December 1972*, 62.

[49] McCarthy and Allison, *Linebacker II: A View From the Rock*, 117.

[50] Ibid.

[51] Ibid., 201.

[52] Ibid.

[53] Nordeen, *Air Warfare in the Missile Age*, 71.

[54] McCarthy and Allison, *Linebacker II: A View From the Rock*, 202.

The peace treaty was signed less than a month after the conclusion of Linebacker II, demonstrating the impact of strategic bombing in a challenging operational environment. This campaign's primary bomber was first designed in 1949 and first flown in 1952, yet was successful against a sophisticated air defense system.[55] The integrated and layered IADS employed by the North Vietnamese in 1972 marked the beginning of the modern IADS and representative of an area denial strategy. This campaign demonstrated the effects these systems have on friendly aircraft and the ease with which adversaries can adapt their tactics. The NVA were able to quickly use multiple modes on their radars to reduce emissions and complicate SEAD missions. Additionally, the detailed coordination required by numerous commands that are geographically separated and operating different equipment challenged American force packaging during Linebacker II.

Chapter Three: 1973 Yom Kippur War

Col Shmuel Hetz, the commander of one of two Israeli Air Force (IAF) F-4 Phantom squadrons, took off in full afterburner, leading a flight of twenty aircraft in tight formation to the Egyptian missile zone along the Suez Canal. The ECM pods his aircraft carried and the tactic of flying in close formation was untested against the new and more modern SA-3 missiles acquired from the Soviets.[56] On this mission, the F-4s were able to penetrate the missile engagement zones, striking four of ten targeted missile batteries. However, egressing from the target, Hetz's aircraft was hit, killing him and forcing his navigator to eject.[57] During this strike, five Phantoms were destroyed, showing the IAF that unlike the 6-Day War in 1967, they no longer controlled the sky over the Suez.[58]

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[55] Ibid.

[56] Abraham Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East* (New York: Schocken Books, 2017), 35.

[57] Ibid.

[58] Ibid., 36.

While the Vietnam conflict demonstrated heavy use of the SA-2 Guideline, the introduction of more modern SAM systems in the Yom Kippur War, consisting of mobile missile launchers, created an A2AD environment, unlike any previous war. The quality, quantity, and sophisticated electronic nature of the weapon systems used in the 1973 Yom Kippur War caught the IAF by surprise. Ron Huldai, another F-4 Phantom squadron commander during the war, after doing battle with the IADS, told his pilots to "take a good look at each other, when this war is over, a lot of us won't be here."[59] The lack of tactics, doctrine, and unknown system capabilities was extremely challenging for the IAF.

In June of 1967, the Israel Defense Force (IDF) launched a military campaign that ultimately captured the Sinai Peninsula from Egypt, the West Bank, and East Jerusalem from Jordan and the Golan Heights from Syria.[60] The Egyptian crossing of the Suez Canal in the fall of 1973 was in direct retaliation to reacquire the territory lost to the Jewish state. Egyptian President, Anwar Sadat, understood that his military did not possess adequate combat power to take on Israel directly, forcing him to fight a limited war with the objective of political negotiation.[61] Before the outset of this campaign, the Arab nations understood that diplomatic and military activities were not mutually exclusive, and their complementary effects were required to meet the strategic goal of once again controlling the land they lost in 1967.[62] Operationally, the Egyptians knew that to be successful, they must neutralize the IDF's superior intelligence, Air Force, and armor forces.[63] Nullifying these Israeli assets would require a massive overhaul of the existing Egyptian forces and doctrine.

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[59] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East*, 243.

[60] David Wallsh, "Lessons From the October 1973 Arab-Israeli War," Modern War Institute at West Point, October 4, 2017, accessed February 25, 2020, https://mwi.usma.edu/timeless-lessons-october-1973-arab-israeli-war.

[61] Wallsh, "Lessons From the October 1973 Arab-Israeli War".

[62] Central Intelligence Agency, *The 1973 Arab Israeli War: Overview and Analysis of the Conflict* (Langley: Government Printing Office, 1975), 11.

[63] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 43.

After the embarrassing defeat in 1967, the Egyptians heavily emphasized the improvement of the air defense force. General Hassan Kamal was relieved of the Air Defense command after two Israeli Air Force Mirages entered Egyptian airspace undetected and flew supersonic over the president's home.[64] In addition to a change in leadership, there was a noticeable increase in the size of the Air Defense Command. Its' size ballooned to over seventy-five thousand men or one-fourth of the entire Egyptian armed forces.[65] Egypt's belief that Israel's proven air superiority in the last war would continue to be a problem and critical in the formulation of strategy. General Saad el-Shazly, the Chief of Staff for Egypt's military, stated that they had no choice but to fight under conditions of enemy air superiority, and the only way they could effectively accomplish this was with better SAM coverage.[66] El-Shazly went on to describe the integrated pillars of this new IADS as having the capability to detect and monitor from a distance while engaging the enemy from superior range, with better maneuverability and speed.[67]

Only three years before the commencement of hostilities, the Egyptian IADS was not mobile with bulky radar and electronic systems easily targeted by enemy aircraft.[68] To solve the problem of ineffective SAM systems, Egypt enlisted the help of the Soviet Union to modernize the air umbrella. Moscow sent not only countless SA-2, SA-3, and new SA-6 missile systems, but also advanced radars, aircraft, and well-trained pilots.[69] These defense systems were the most modern in the world and would pose a significant challenge to the IAF. When the October War

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[64] James Crabtree, *On Air Defense* (Westport: Praeger, 1994), 151.

[65] Crabtree, *On Air Defense*, 152.

[66] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 30.

[67] Saad El Shazly, *The Crossing of the Suez* (San Francisco: American Mideast Research, 2003), 20-21.

[68] Ibid., 21.

[69] Martin van Creveld, Steven Canby, and Kenneth Brower, *Air Power and Maneuver Warfare* (Maxwell AFB: Air University Press, 2004), 171.

began, Egypt possessed over 150 batteries of SA-2, SA-3, and mobile SA-6 missile launchers, creating a deeply layered system capable of mitigating defensive gaps.[70]

The SA-2 Guideline had proven its worth in the skies over North Vietnam by downing fifteen B-52s and many other aircraft. This older missile system with an engagement range of over seventeen nautical miles and an altitude capable of reaching the highest aircraft was now supplemented with a more agile missile the SA-3 "Goa" and its range of fourteen nautical miles.[71] The most revolutionary system introduced during this conflict was the ultra-modern and mobile SA-6 "Gainful" launcher. This SAM has numerous advantages over the legacy SA-2 and only slightly more advanced SA-3. The Gainful's purpose was to provide superb low to medium altitude coverage for ground forces in a mobile platform. The SA-6 integrated the radar and fire-control unit with four transporter/launcher vehicles that carried three missiles each on a modified light tank chassis.[72] The range of seventeen nautical miles against low altitude targets and upwards of thirty-five nautical miles against medium-altitude targets provided a perfect complement to the static, high altitude coverage supplied by the Guideline and Goa.[73] Mobility and low altitude capability aside, the missile itself was significantly more capable than previous systems. Its size, speed of over Mach 2.5, and use of a smokeless sustainer engine made it very challenging for pilots to acquire visually.[74] This missile, unlike the others, uses its radar to guide the flight path initially and rapidly changes frequencies to avoid jamming as it homes in on its target using infrared technology.[75] The combination of sophisticated guidance measures, using

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[70] Nordeen, *Air Warfare in the Missile Age*, 149.

[71] Stanley Ulanoff and David Eshel, *The Fighting Israeli Air Force* (New York: Arco Publishing, 1985), 76.

[72] Nordeen, *Air Warfare in the Missile Age*, 149.

[73] Ibid.

[74] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 150-151.

[75] Ibid.

frequencies outside of the range covered by Israeli ECM, mobility, and high-speed gave the SA-6 a significant advantage against the IAF.[76]

[76] Ibid., 150.

Figure 3. SA-6 SAM.
Kenneth P. Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell Air Force Base: Air University Press, 2005), 150.

The final new addition to the Egyptian IADS was the ZSU-23-4 anti-aircraft artillery (AAA) piece. This system was mounted on a PT-76 tank chassis, making it mobile, and housed four 23mm barrels capable of firing upwards of 4,000 rounds per minute.[77] Additionally, its gun was able to engage aircraft via radar at over twelve nautical miles or closer range with optical sights, up to a sufficient altitude of 4,000 feet.[78] The mobility and low-altitude capability provided by the ZSU-23-4 and to some extent, the SA-6 completed the dense multi-layer air defense network the Egyptians needed to thwart Israeli air attacks.

While the SAM radars were capable of acquiring and tracking adversary aircraft, some were susceptible to deception or jamming by countermeasure tactics. One of the primary jamming tactics used by the IAF was broadcasting a powerful signal on the same frequency as the radar, in effect blinding the radar by overpowering it.[79] However, the more modern SAMs possessed electronic counter-countermeasures (ECCM) of frequency agility, meaning the radar can switch frequencies to avoid matching that which the jammer is operating on and once again creating the

[77] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 151.

[78] Ibid.

[79] Crabtree, *On Air Defense*, 156.

ability to engage aircraft.[80] With the SA-6's ability to operate in so many different frequency bands of the radio spectrum, fighter aircraft could not carry enough ECM equipment to defend themselves, and as a result aircraft mounted ECM proved only moderately useful.[81] To further complicate the IADS issue for the Israelis, Egypt also used additional passive measures. They built fake missiles, launchers, and radars diluting the IAF attacks along the canal.[82]

At the beginning of the 1973 Arab-Israeli War, Maj Gen Hosnay Mubarak's Egyptian Air Force consisted of approximately 620 combat aircraft, mainly Soviet varieties.[83] These jets were not a significant contributor to the Egyptian air defense, but they did play an active role in the destruction of IDF on the east side of the Suez Canal. Due to the poor Soviet Identification Friend or Foe (IFF) technology, Egypt was unable to maximize the deconfliction of the missile engagement zones and fighter engagement zones. They essentially had to turn off the air defense barrier to allow their aircraft to pass through, and transit to the Sinai and turn the system back on once all jets were clear.[84] Had Egyptian aircraft been able to transit their airspace more freely. It could have resulted in a much more deadly situation for the IAF.

More important than any other component of the redesigned Egyptian air defense was the integration of the system. The ability for all elements to communicate created a mutually protective defense that had a well-planned surveillance network that covered the entire Suez Canal.[85] This system was nearly impenetrable due to the overlapping coverage of the IADS. SA-2 missiles were responsible for the high-altitude aircraft, SA-3s would cover the medium-altitude

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[80] Crabtree, *On Air Defense*, 156.

[81] Central Intelligence Agency, *The 1973 Arab Israeli War: Overview and Analysis of the Conflict*, 32.

[82] Crabtree, *On Air Defense*, 152.

[83] Nordeen, *Air Warfare in the Missile Age*, 148.

[84] Crabtree, *On Air Defense*, 153.

[85] Ulanoff and Eshel, *The Fighting Israeli Air Force*, 75.

attacks in coordination with the new SA-6.[86] All of these systems received protection from significant numbers of radar and optically guided AAA in the low-altitude environment.[87]

To fully appreciate the actual density of missile systems the Egyptians placed along the canal, it is necessary to describe a typical SAM layout. The launchers are situated in a circular pattern with the missiles deployed in pairs and protected by concrete or earthwork walls.[88] For the SA-2, this structure housed the "Fan Song" radar or the "Flat Face" for the SA-3 Goa in radar trailers as well as the control caravan forming the center of the circle.[89] Scattered around the site were well-crafted decoy missile and radar systems, making it extremely challenging for enemy aircraft to target them with solely visual means. Most importantly, the entire site was interconnected with a complex communication network that used underground telephone cable and radio lines.[90] Each of these sites is further protected with a multitude of AAA pieces, such as the ZSU-23-4. Several SAM sites were then combined into an integrated sector system controlled by a single coordination site which, in turn, supervises the entire area with the assistance of additional radars.[91] The IAF was unprepared for the massive number of SAMs, their density along the canal, and the effective control by a coordinated network.

Even before the war broke out, General David Elazar, IDF Chief of Staff, felt the missile systems would be of little trouble to the IAF. Based on precious experience he expected that they would be neutralized in less than twelve hours.[92] Commander Benny Peled, Israeli Air Force, was clear that the operation would require at least two days, but Elazar's overconfidence led to the

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[86] Nordeen, *Air Warfare in the Missile Age*, 148.

[87] Ibid.

[88] Ulanoff and Eshel, *The Fighting Israeli Air Force*, 76.

[89] Ibid.

[90] Ibid.

[91] Ibid.

[92] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 54.

loss of numerous aircraft during the first few days of the war.[93] The IAF lost nearly ninety aircraft in the first week of the war, almost twice the rate of the 1967 War, shocking the Israelis and forcing them to pause air operations within fifteen miles of the Suez Canal.[94] This operational pause achieved the anti-access and area denial effect the Egyptians desired.

To counter the Egyptian IADS, Peled planned Operation Tagar on 7 October. This four-stage attack targeted sixty-two SAMs along the canal with the first wave striking the guns defending the missiles to try and peel back the self-protective layers.[95] Seven different Egyptian airbases were struck on the first wave to remove them from the fight, with missiles and radar systems hit on subsequent attacks.[96] There were multiple problems with this strategy. The first issue was the mobility of the SA-6s, and the lack of adequate and timely reconnaissance capability to identify new systems locations. The SA-2s and SA-3s would likely be at the expected coordinates, but the SA-6s mounted on vehicles moved with little effort.[97]

Even with proper coordinates for the targets, IAF jets initially flew level attacks, making them susceptible to a barrage of missiles and anti-aircraft fire. The SA-6 specifically, created additional challenges through the use of its undetectable continuous-wave radar.[98] The SAMs effectively negated the IAFs ability to control the skies over the battlefield, and in turn, made them resort to toss bombing. This method of employing weapons was inherently inaccurate. Aircraft would ingress fast at low-altitude and then pull up aggressively approaching the SAM engagement zone to throw the weapon toward the target while performing an escape maneuver to avoid being hit by the surface fires. With no artillery support and the IAF unable to provide any

[93] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East*, 140.

[94] Werrell, *Archie to SAM: A Short Operational History of Ground-Based Air Defense*, 152.

[95] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 195.

[96] Ibid.

[97] Ibid. 196.

[98] Nordeen, *Air Warfare in the Missile Age*, 152.

effective close air support, Israeli General Avraham Adan was frustrated by the success of the Egyptian A2AD.[99]

The Israeli Air Force attempted a series of suppression attacks with Shrike anti-radiation missiles designed to home in on enemy radar systems, but with little effect.[100] With no real progress on the SAM mitigation, night air attacks were canceled by the IAF because the pilots were unable to accurately judge how close they flew to the SAMs and inevitably flew into the threat rings.[101] At this point in the war, one of the premier air forces in the world was effectively rendered ineffective. Joel Arnoff, an American born United States Air Force Academy graduate, Joel Arnoff, had flown over 200 missions in Vietnam and felt that during his missions with the IAF that the ground fire over the canal was unlike anything he had ever seen.[102] Neutralizing the SA-2 threat was relatively uneventful in itself for the Israelis due to their experience engaging it during the 1967 War. However in 1973, the variety and pure density of systems now employed by the Egyptians was more challenging than targeting single SA-2s, and the Israeli's struggled to find an acceptable solution.[103]

The Israeli military possessed many electronic countermeasures, most of which were supplied by its ally the United States. These countermeasures included the ALT-27 standoff jammer, the Hughes Aircraft ALQ-71, and the Westinghouse ALQ-87 noise jamming pods.[104] Integrating new ECM with threat warning sensors and expendables such as flares and chaff was now commonplace but still failed to produce the decisive effect the IAF needed. The SA-6 was still challenging even the most skilled pilots attempting to counter it. Aircraft began carrying

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[99] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 274.

[100] Nordeen, *Air Warfare in the Missile Age*, 152.

[101] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 136.

[102] Ibid., 372.

[103] Crabtree, *On Air Defense*, 156.

[104] Nordeen, *Air Warfare in the Missile Age*, 147.

chaff in a variety of different dispensers and even resorted to filling airbrake cavities with the foil packets to maximize the chance of fooling Egyptian radars.[105] The pilots attempted to take advantage of the relatively low angle that SA-6 missiles left the rail by attacking the launchers via a steep, high-speed dive, but even this technique was minimally effective.[106] While innovative tactics can help find a solution to problems on the battlefield, the IAF was poorly organized, and squadrons began trying random attacks on every sortie. The IAF lacked any standardized doctrine forcing units to develop their attack options instead of relying on unified tactics and techniques from the headquarters.[107]

With the IAF effectively removed from the fight, the IDF ground forces were forced to take on the SAM suppression mission. Israeli armor units crossed the canal where they could punch a hole in the SAM batteries by taking advantage of the tank's maneuverability. The cross canal thrust was shockingly effective, and in a surprising turn of events, the ground forces were executing close support missions for the Air Force by destroying SAMs.[108] At this time, the IAF also discovered that suppression missions were most effective if they targeted only small clusters of missile systems to methodically open up slight holes in the IADS, allowing further penetration by follow on strike sorties.[109] Seizing the initiative, the IDF continued to send forces across the canal with the support of air attacks now operating with little resistance.

The 1973 Yom Kippur War introduced the first formidable integrated SAM system ever seen in combat. The dense placement of the systems and the introduction of countless new varieties of technology challenged what was perhaps touted as one of the greatest air forces in the world. The SA-2 and SA-3 batteries supported by mobile systems, specifically the SA-6 and

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[105] Nordeen, *Air Warfare in the Missile Age*, 156.

[106] Ibid.

[107] Rabinovich, *The Yom Kippur War: The Epic Encounter that Transformed the Middle East,* 372.

[108] Ibid., 470.

[109] Ibid.

ZSU-23-4, created a web of integrated systems capable of engaging aircraft from the surface to over 60,000 feet. In only eighteen days, there were over 500 aircraft shot down, 1,500 tanks destroyed, and more than 10,000 men killed.[110] It is essential to recognize that aircraft shot down may not be the most accurate way to measure the performance of the Egyptian Air Defense because their ability to prevent the enemy from inflicting damage on their forces must be considered.[111] While there is no detailed information available on how much damage was prevented, it appears that in this war, the Egyptian IADS was quite successful.[112] However, the Israeli ability to use joint operations, specifically the ground forces, to target Egyptian missile systems ultimately led to its loss and an Israeli victory.

Chapter Four: 1999 Operation Allied Force

On March 27th 1999, stealth F-117A Nighthawk bombers flew missions into Serbia without Suppression of Enemy Air Defenses (SEAD) support, specifically EA-6B Prowlers, which are capable of jamming enemy radars as well as collecting critical information about SAM locations.[113] The lead stealth bomber, call sign "Vega 31," piloted by Lieutenant Colonel Dale Zelko had just dropped his precision munitions on critical Serbian IADS components near Belgrade when his radar warning receiver indicated the aircraft was likely being tracked by a Soviet SA-3.[114] Only seconds later, one of America's technologically advanced stealth bombers was falling from the sky with Lt Col Zelko riding down in a parachute into hostile territory. As rescue helicopter forces flew into the Belgrade area and one of the deadliest SAM environments in the world, more unlocated Serbian SAMs attempted to engage the rotary-wing aircraft. Over the rescue frequency, crews reported "SAM active BAT 320/32, SAM BAT 195/25 now reported

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[110] Nordeen, *Air Warfare in the Missile Age*, 143.

[111] Central Intelligence Agency, *The 1973 Arab Israeli War: Overview and Analysis of the Conflict*, 35-36.

[112] Ibid.

[113] Ross Simpson, *Stealth Down* (Charleston: Narwhal Press, 2002), 24.

[114] Ibid., 103.

active, SANDY Five-One is magnum SAM north."[115] SAM sites were now tracking multiple rescue aircraft, and the F-16CJs were launching HARM, indicated by "magnum" calls, to suppress the enemy radars. The combat search and rescue crews were able to quickly ingress and egress this dense IADS, rescuing Lt Col Zelko. While the rescue package executed its mission flawlessly, a SAM system designed with 1970s technology was able to destroy one of America's most complex and advanced aircraft, and ultimately, the confidence in the effectiveness of stealth bombers.[116]

The killing of countless Albanians by Slobodan Milosevic, President of the Federal Republic of Yugoslavia (FRY), drove the United States and NATO to take action. President Bill Clinton had three objectives for the campaign: "demonstrate the seriousness of NATO's purpose, deter an even bloodier offensive against innocent civilians, and if necessary, seriously damage the Serbian military's capacity to harm the people of Kosovo."[117] The goal was to avert increasing atrocities and widespread violence against the local populace while also preventing regional instability.[118] Before the outset of this campaign, policymakers were clear that ground forces would not be used in this war. The belief that airpower alone could be successful stemmed from the overwhelming success during the Gulf War in 1991, and the desire to avoid a ground quagmire.

The air campaigns initial objectives were to force the Serbs to peace negotiations at Rambouillet, stop ethnic cleansing, and ultimately establish a cease-fire.[119] This campaign was

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[115] Christopher Haave and Phil Haun, *A-10s Over Kosovo: The Victory of Airpower Over a Fielded Army as Told by the American Airmen Who Fought in Operation Allied Force* (Maxwell AFB: Air University Press, 2003), 227. BAT refers to a BULLSEYE or location only known by friendly forces and the subsequent numbers are a bearing and range from that location.

[116] Simpson, *Stealth Down*, 23.

[117] Robert Gregory Jr, *Clean Bombs and Dirty Wars: Air Power in Kosovo and Libya* (Lincoln, NE: Potomac Books, 2015), 49.

[118] Dag Henriksen, *NATO's Gamble: Combining Diplomacy and Airpower in the Kosovo Crisis 1998-1999* (Annapolis, MD: Naval Institute Press, 2007), 7.

[119] Henriksen, NATO's Gamble, 8.

built around three phases of increasing escalation; phase one would establish air superiority by creating no-fly zones and destroying the IADS of the FRY, phases two and three would expand operations to a wide variety of targets throughout the region.[120] This seventy-eight-day air campaign ultimately forced the Serbs to agree with NATO terms and withdraw their military forces from Serbia.[121] However, the substantial IADS over Kosovo created significant challenges for Allied airpower.

Yugoslavia's defensive network was built around thousands of Soviet SAMs. Their batteries consisted of three SA-2 battalions, sixteen SA-3 battalions with each one having multiple launchers receiving direction from LOW BLOW fire-control radars, and 25 mobile SA-6 batteries complemented by "Straight Flush" radars.[122] Augmenting these highly capable SAMS were over one hundred vehicle-mounted SA-9 and multiple SA-13 infrared missiles, as well as nearly two-thousand AAA pieces.[123] Rounding out the layered protection was over two-hundred aircraft, including new MiG-29 and MiG-21 fighters.[124] Though much of this equipment was antiquated and used extensively in Vietnam and Yom Kippur, the Serbian operators understood American tactics and routinely exercised their defense techniques for over forty years.[125]

Before the conflict, there were initial unsubstantiated reports that Russia had given Yugoslavia up to ten modern, long-range, SA-10s which would have substantially boosted the Serbian IADS capability. However, these systems were never discovered in the country.[126] Without the most modern systems, the IADS primarily relied on the mobile SA-6s and the SA-3.

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[120] Henriksen, *NATO's Gamble*, 13.

[121] Simpson, *Stealth Down*, 229.

[122] Benjamin S. Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment* (Santa Monica: RAND, 2001), 17-18.

[123] Ibid.

[124] Ibid.

[125] Ibid.

[126] Lambeth, *NATO's Air War for Kosovo*, 113.

The SA-6s remained mostly unchanged from their use in the 1970s. However, Serbian forces were very capable of quickly moving these systems throughout the region. The SA-3 GOA is a short-range theater defense missile with a maximum range of seven miles and relies on the fire control radar to continually provide commands for missile guidance via the ultra-high frequency (UHF) radio link.[127] Each SA-3 battery includes four launch positions, a "Low Blow" fire control radar, a command van, three support vans, and eight missile transporters to provide a rapid reload capability.[128] Most importantly, the SA-3 was capable of operating in degraded environments, particularly those consisting of substantial ECM. The updated "Low Blow" radars were equipped with TV cameras, which provided the same data the radar would produce out to 25 km while allowing an intercept to be carried out without the aircraft detecting radar emissions.[129] Additionally, a few GOA battalions were operating the upgraded P-15M "Squat Eye" radar, which gave the system increased capabilities in the low altitude environment.[130]

The US was able to demonstrate the effectiveness of their ability to quickly strike and destroy an adversary IADS during the 1991 Gulf War. However in 1999, Serbian forces were significantly better trained and well prepared to move their SAM systems than the Iraqi's.[131] Not only could the Serbs take advantage of the mobility, but they were able to use camouflage and concealment to make them more difficult to detect while deploying a complex communication network consisting of fiber optic cables, visual observers, and cell phones to integrate their defense network.[132] The redundant communication networks allowed Serbian troops to track

[127] Simpson, *Stealth Down*, 68-69.

[128] Center of Military History, *History of Strategic Air and Ballistic Missile Defense Volume II: 1956-1972* (Washington, DC: United States Army, 2009), 266.

[129] Simpson, *Stealth Down*, 319.

[130] Ibid.

[131] Ibid., 229.

[132] Simpson, *Stealth Down*, 229.

NATO aircraft routing while providing targeting information to the SAMS via a multitude of communication systems that were difficult for allied forces to attack.

During the early stages of the campaign, it became apparent that the Iraqi's had shared US SEAD tactics and techniques with Belgrade.[133] This knowledge tipped the Serbs off to the most effective means of managing radar emissions to avoid being struck by HARMs. By dispersing their systems, moving them often, and using emission control (EMCON), Serbian SAM systems became increasingly difficult to target and maximized the layered capabilities of the IADS by tempting aircraft to fly lower.[134] SAM operators routinely turned on the acquisition and targeting radars for twenty seconds or less to avoid detection. These techniques were enough to allow numerous SAM systems to survive the duration of the conflict, forcing NATO aircraft to operate above 15,000 feet for most of the campaign, despite launching over 740 HARMs.[135]

Even after repeated HARM shots and airstrikes, Serbian forces were extremely capable of developing innovative ways of rebuilding their communications equipment and radars in as little as twenty-four hours after being attacked.[136] Ultimately this innovation was the enabling factor contributing to their ability to shoot down the state of the art F-117 on the fourth night of the war. On that night, the kill chain was initiated in Italy when visual observers notified the air defense command of Vega 31's takeoff.[137] Upon receiving notification of aircraft en-route to Kosovo, soldiers would continue to track and handoff control of the aircraft through a series of locations by using both radar and optical tracking methods and communicating by landline.[138] Finally, the engagement of the aircraft was completed by a modified SAM capable of detecting

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[133] Lambeth, *NATO's Air War for Kosovo: A Strategic and Operational Assessment*, 18.

[134] Ibid., 102.

[135] Ibid., 109.

[136] Ibid., 37.

[137] Gregory, *Clean Bombs and Dirty Wars: Air Power in Kosovo and Libya*, 66.

[138] Ibid.

the low observable aircraft. Serbian troops discovered that by modifying the Russian SNR-125 Neva/Pechora "Low Blow" I/D-band, "Straight Flush" G/H band, and P-18 "Spoon Rest" to function on longer wavelengths they were able to maintain a track on the stealth jet.[139]

The United States attempted to destroy most of the IADS on the first night of the war, just like they had done near Baghdad at the start of Operation Desert Storm. In that instance, cruise missiles were launched from aircraft and ships targeting command and control nodes, radar, and electrical systems.[140] Even after over 120 strike missions were flown against forty different targets, including airfields, communication centers, and IADS facilities, the Serbian defense network remained a challenge throughout the war.[141] The entire air campaign assumed air superiority would be easily achieved, allowing NATO airpower to bomb at will and ultimately force Milosevic to capitulate. This assumption was founded on the idea that US jamming and other SEAD assets could degrade enemy radars. However, the advanced survival techniques employed by Serbian SAM operators created two tactical problems, with one being how to locate and identify targets, as well as how to strike them while minimizing collateral damage.[142]

The lack of detectable radar emissions made if difficult to locate the SAMs and created the potential for aircrew to routinely fly into areas with unlocated threats. Stealth aircraft were one of the solutions to flying over areas with unknown threats even after learning they were susceptible to innovative tracking methods after the Vega 31 shoot down. B-2s would fly nonstop from Whiteman AFB to deliver guided GBU-31 JDAM from high altitude and through the weather.[143] Stealth aircraft sorties became predictable events for the adversary air defense network. Bombers were routinely forced to take the same routes into Kosovo due to airspace

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[139] Gregory, *Clean Bombs and Dirty Wars: Air Power in Kosovo and Libya*, 66.

[140] Simpson, *Stealth Down*, 65.

[141] Lambeth, *NATO's Air War for Kosovo*, 22.

[142] Haave and Haun, *A-10s Over Kosovo: The Victory of Airpower Over a Fielded Army as Told by the American Airmen Who Fought in Operation Allied Force*, 310.

[143] Lambeth, *NATO's Air War for Kosovo*, 90.

availability limitations and the consideration of minimizing collateral damage.[144] Specifically, the F-117s departing out of Aviano Air Base, Italy, mostly flew the same route every day due to General Wesley Clark's ban on overflying Bosnia in an attempt not to jeopardize the Dayton accords.[145]

As NATO began to attrite Serbia's air defense network, B-52s and B-1 bombers started employing unguided weapons to augment the B-2 and F-117s. Operation Allied Force was the first time that all three Air Force heavy bombers flew in combat together, delivering over 11,000 of the 23,000 munitions dropped during the campaign.[146] While the bombers employed a substantial amount of air-to-ground munitions, the air component struggled to pass updated target information to them once airborne. With the heavy bombers flying upwards of thirty-hour missions, the targeting information was often outdated when they arrived to the target area as the radars they were scheduled to hit had often moved. In an attempt to effectively target the continually evolving threat picture, the Air Force developed flexible targeting options, or "Flex Targeting."[147] Aircraft would takeoff without any specific target information and either be directed to search for targets either by an airborne forward air controller or the Combined Air Operations Center (CAOC).[148] Alternatively, the CAOC could send target changes to the aircrew up to an hour and forty-five minutes before the scheduled time on target, providing the capability to destroy some enemy SAM systems shortly after they were located.[149] Although flex targeting did have some success stories throughout the campaign, overall NATO lacked the capability to find, fix, and target the mobile Serbian systems in a timely manner.

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[144] Lambeth, *NATO's Air War for Kosovo*, 102.

[145] Ibid., 118-119.

[146] Ibid., 87.

[147] Lambeth, *NATO's Air War for Kosovo*, 91.

[148] Ibid., 101.

[149] Ibid., 92.

Operation Allied Force was the first time a war was fought almost exclusively with airpower.[150] Throughout the seventy-eight-day conflict, Serbian forces launched over 800 SAMs at NATO aircraft, including over 450 SA-6s and 124 confirmed man-portable air-defense systems (MANPADS).[151] Serbian air defense forces were able to remain a formidable threat to coalition airpower throughout the duration of the war due to their mobility, selective activation of their radars, and ability to remain dispersed and difficult to find because of camouflage and concealment.[152]

Until the war in Kosovo, no country was able to demonstrate the effective use of mobile SAM systems. The Serbian Army's ability to continually move the SA-6s significantly challenged NATO efforts to target them. Flying over unlocated SAMs was not only nerve-racking for the pilots, but it hindered their tactics by forcing them to fly higher and ultimately lose fidelity on the targets they were striking. As they moved SAMs around the battlefield, the Serb's were also mindful of maintaining a dispersed order of battle to prohibit coalition efforts to target them efficiently. Not only were the IADS components difficult to locate, but the operators were also well trained in the control of emissions. Using techniques from the Iraqi operators, Serbian SAM operators were able to limit the amount of time radars remained on, making it difficult for US SEAD assets to employ anti-radiation missiles.

Operationally, the IADS were well constructed with multiple layers and redundant communication channels. Like the Vietnam and Yom Kippur conflicts, the larger SAMs served to protect against high flying aircraft while AAA and short-range infrared missiles threatened aircraft at lower altitudes. The variety of systems in effect created a three-dimensional umbrella capable of engaging aircraft at all altitudes and speeds with the modified SA-3 and enhanced mobility of the SA-6 posing the most significant threat. Lastly, the precise command and control

[150] Henriksen, *NATO's Gamble*, ix.

[151] Lambeth, *NATO's Air War for Kosovo*, 111.

[152] Ibid.

throughout the kill chain gave Serbian forces the edge required to down one of America's most advanced aircraft. Visual observers relaying takeoff times or aircraft routes via a multitude of communication networks, modified acquisition radars operating in longer wavelengths, and missile systems optically tracking the aircraft to avoid emissions created a deadly system that prevented NATO from achieving air supremacy.

Chapter Five: Future Combat Operations

> By 2030, the threats facing the US around the world will be formidable. They will have twice, if not three times, the lethality and range of today's threats. . . . Potential adversaries could enhance traditional ground-based radar detection methods with advanced passive detection systems and possibly further augment them by acoustic detection means and advanced cyber abilities. These advances would contribute to an adversary's primary goal of attacking and disabling our capabilities before we employ them.
>
> —Then Maj Gen Veralinn "Dash" Jamieson, Air Combat Command Director of Intelligence, October 2015

Modern combat will be contested in every domain, creating a more lethal battlefield that forces combat to occur at increasing speed and range.[153] To effectively counter adversary ambitions, it is imperative that the DoD focus on maintaining a lethal joint force, capable of penetrating enemy A2AD capabilities to enable close combat. These capabilities include forces which are able to penetrate enemy air and missile defense networks, as well as mobile power-projection systems.[154] China and Russia have become peer adversaries and significantly challenge the United States' ability to operate with impunity in Asia and Europe. In the 2017 National Security Strategy, President Donald Trump outlined China's desire to deter United States influence in the Indo-Pacific region by fielding capabilities designed to deny the United States access, thereby creating challenges for America to operate freely in the region.[155]

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[153] James Mattis, *Summary of the National Defense Strategy of The United States of America* (Washington, DC: Department of Defense, 2018), 3.

[154] Ibid., 6.

[155] Donald Trump, *National Security Strategy of The United States of America* (Washington, DC: The White House, 2017), 27.

Additionally, in Europe, Russia employs new A2AD systems that generate an increasing risk to America's combat capability. To ensure America's military primacy in these two regions, it is critical for the US to retain overmatch and the ability to defeat enemy A2AD with impunity.[156]

A modern IADS is far more advanced than those described in the preceding chapters. No longer is a simplistic and linear approach capable of destroying a complex A2AD structure as it will require the detailed integration of multi-domain capabilities.[157] An IADS is a combination of elements that have inherent capabilities integrated throughout all components to shorten the kill chain and enable target engagement at a speed yet to be seen on the battlefield.[158] Attacks on A2AD systems will no longer be successful by targeting single nodes within the system due to heavy reliance on automation and networking. In addition to the speed at which these systems operate, the range at which these modern systems can engage targets is particularly troubling.

Modern Russian systems are currently employed by a variety of nations throughout the world and the S-300, 400, and 500 SAMs are able to range aircraft at upwards of over 500 miles.[159] These SAMs will operate as a first line defense in a multi-layer system of other surface-to-air missiles and fifth generation aircraft. The long-range engagement ability of these systems, combined with the evolution of communication systems is troubling for the United States. New avenues of communication are redundant and much more expedient than those of previous generations and consist of satellite communications, 4G cellular networks, data links, Wi-Fi networks, cloud computing systems, and public switch telephone networks (PSTNs).[160] These A2AD networks are distributed throughout Europe, specifically Kaliningrad, and in the South China Sea, challenging American access in both regions.

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[156] Ibid.

[157] Peter Mattes, "Systems of Systems: What, Exactly, is an Integrated Air Defense System?," *The Mitchell Forum*, no. 26 (June 2019): 1.

[158] Ibid., 3.

[159] Ibid., 5.

[160] Mattes, "Systems of Systems: What, Exactly, is an Integrated Air Defense System?," 8.

Russia is distributing offensive A2AD systems throughout the world but most notably in the Baltic region. This region is particularly vulnerable to short-notice Russian aggression due to the forward deployment of military systems in the Kaliningrad enclave.[161] S-400 SAMs allow Russia to deny access to NATO forces throughout the Baltics and allow their military to operate freely, specifically creating opportunities to attack Latvia, Estonia, and the Swedish island of Gotland.[162] NATO militaries attempting to defend these areas from Russian aggression will be forced to penetrate complex A2AD systems in Kaliningrad, similar to the actions which would be required to defend against Chinese aggression in the South China Sea.

Figure 4. Kaliningrad A2AD Example.
Bret Perry, "Entering the Bear's Lair: Russia's A2/AD Bubble in the Baltic Sea," The National Interest, September 20, 2016, https://nationalinterest.org/blog/the-buz/entering-the-bears-lair-russias-a2-ad-bubble-the-baltic-sea-17766.

China's A2AD modernization and rapid deployment throughout the South China Sea is designed to limit US access to the region and allows continuous power projection in Asia.[163]

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[161] Timothy M. Bonds et al., *What Role Can Land-Based, Multi-Domain Anti-Access / Area Denial Forces Play in Deterring or Defeating Aggression?* (Santa Monica, CA: RAND Corporation, 2017), 92.

[162] Ibid.

[163] Trump, *National Security Strategy of The United States of America,* 46.

They are placing an increasing amount of effort on countering America's ability to aid western-Pacific allies by fielding anti-access systems that limit US ability to enter the area and area denial capabilities that will challenge the use of air and naval systems.[164] China currently possesses one of the largest stockpiles of modern SAMs, with an abundance of S-300s and their indigenous HQ-9, which can target cruise missiles and aircraft in excess of 200 kilometers.[165] Modern anti-ship and land attack cruise missiles seek to deny naval vessels the ability to position a carrier strike group in the region while simultaneously threatening forward operating bases in Okinawa and Guam.[166] Similar to the way in which Russia employs a complex layer of A2AD in Kaliningrad, China relies on an intricate network of fighter aircraft and air defense systems to deny America the ability to operate while furthering their ambitions in the region.[167]

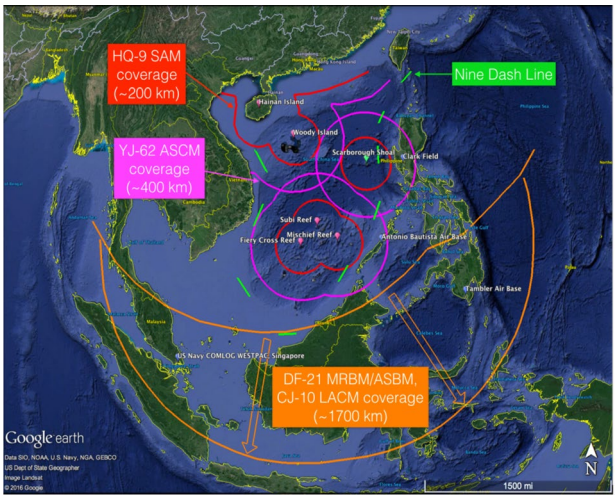

Figure 5. South China Sea A2AD Example.
Thomas Shugart, "China's Artificial Islands Are Bigger (And a Bigger Deal) Than You Think," War on the Rocks, September 21, 2016, https://warontherocks/2016/09/chinas-artificial-islands-are-bigger-and-a-bigger-deal-than-you-think.

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[164] Bonds et al., *What Role Can Land-Based, Multi-Domain Anti-Access / Area Denial Forces Play in Deterring or Defeating Aggression?*, ix.

[165] Ibid., 75.

[166] "China's Anti-Access Area Denial," Missile Defense Advocacy Alliance, accessed November 26, 2019, https://missiledefenseadvocacy.org/missle-threat-and-proliferation/todays-missile-threat/china-anti-access-area-denial-coming-soon., 3.

[167] Ibid.

The design of modern, complex IADS allows Russia and China to challenge the United States in an environment where they are free to project power and degrade the Joint Force advantage.[168] Military planners and systems analysts must understand the implications and lessons learned from previous combat operations to modify their operational approach so the US military can seize the initiative and dominate in any future hostilities throughout Europe and Asia.[169] The responsibility to solve the A2AD problem cannot rest solely with the air component. While it is nearly impossible to provide a single solution for gaining access in these complex regions, it is imperative the Joint Force understand the intricacies associated with these systems and the delays they may force on the remainder of a campaign plan. The classified nature of these systems prohibits detailed explanation of capabilities within this paper, but planners must seek out these details in the appropriate venue. A deeper understanding of these systems will demonstrate the importance of executing simultaneous attack options rather than sequentially targeting A2AD components. The case studies of Operation Linebacker II, the 1973 Yom Kippur War, and Operation Allied Force, provide the foundation for a detailed understanding of the evolution of modern A2AD systems and form a baseline upon which planners can formulate questions about how to best mitigate these challenging threats.

Chapter Six: Conclusion

Captain Ostrozny, aircraft commander of "Olive 2" and his crew were the first B-52 loss of the Vietnam conflict and the beginning of an era where SAMS play a deadly role in modern combat operations. The eleven-day Linebacker II bombing campaign concluded in fifteen Stratofortress's being shot down. The NVA layered air defense system centered on the highly capable radar-guided SA-2. This system's lack of mobility forced it to be used in an area denial

[168] Bonds et al., *What Role Can Land-Based, Multi-Domain Anti-Access / Area Denial Forces Play in Deterring or Defeating Aggression?*, 7.

[169] Mattes, "Systems of Systems: What, Exactly, is an Integrated Air Defense System?," 9.

role, defending specific locations. At the same time, AAA forced aircraft to operate at higher altitudes, which were in the heart of the SA-2 engagement envelope. During this campaign, ECM was introduced to counter North Vietnamese radar capabilities with limited success as the NVA was able to adapt, learning to use MiGs to relay B-52 altitudes and locations. Additionally, the NVA learned to minimize radar emissions to avoid detection, jamming, and HARM targeting by US SEAD assets. While strategic bombing ultimately proved successful in this campaign, the effective Vietnamese use of SAMS marked the beginning of a modern IADS and the employment of an area denial strategy.

Less than a year later, the 1973 Yom Kippur War illustrated a rapid advancement in IADS employment and a more effective A2AD strategy. Heavy reliance on fixed SA-2 systems was a key component, but the introduction of SA-6s was pivotal as it provided low to medium coverage for Egyptian ground forces in a mobile platform. This new air defense strategy proved challenging for the IAF due to Egypt's ability to detect aircraft from a distance while engaging them at greater range with improved speed and maneuverability. Israeli allies aided in the development of jamming capabilities that continually improved throughout the campaign, but the introduction of ECCM and frequency agility was a deadly combination for IAF pilots. This conflict demonstrated the importance of the complete integration of air defense equipment. Systems capable of communicating effectively and integrating their abilities into a system operating as a whole is a trend that continues to be seen in modern combat.

In 1999, the United States thought stealth technology was the key to defeating a complex IADS network. Early in the Allied Force campaign, the downing of Vega 31 proved this theory to be inaccurate. Similar to the Egyptian IADS, Yugoslavia's defense network consisted of a massive number of SAMS, including SA-2s, SA-3s, SA-6s, infrared MANPADS, as well as AAA. The difference being the Serbian operators' understanding of American tactics. Yugoslavia learned to capitalize on the mobility of their SAMS as well as the ability to operate radars in multiple modes while effectively using camouflage, concealment, and deception to hide them.

Future combat will occur at greater speed and range than previously seen in war. China and Russia have developed effective A2AD systems that create a significant risk to America's combat capability. These modern networks use advanced integration throughout all air defense components to shorten the kill chain and defeat American air power at significant distances. Targeting single nodes will no longer be an adequate strategy for US air assets to gain access to a region. The Baltics should be particularly troubling for US forces due to the advanced air defense systems located in Kaliningrad. A lack of forethought on gaining access to this region will significantly delay US aid to coalition partners. Similarly, China's power projection throughout the South China Sea degrades the United States ability to enter much of the Pacific. Military analysts and planners must understand the evolution of a modern IADS through previous conflicts to develop new operational approaches and enable US dominance in the increasingly complex multi-domain A2AD structure. Successfully countering a peer adversary's IADS will require the joint force to gain a detailed understanding of how these systems operate and how to best leverage simultaneous attacks in all domains.

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