Defense Suppression

Building Some Operational Concepts

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Contents

Abstract

What operational principles and concepts should be used to defeat a highly capable ground-based, strategic air defense system? This study examines the theories of Carl von Clausewitz, Basil H. Liddell Hart, Giulio Douhet, and Col John A. Warden III, and reviews United States, British, and Israeli Air Force doctrines for concepts and principles to overcome defensive strength. A historical analysis of Linebacker II, the Yom Kippur War, the 1982 Bekaa Valley Operation, and Operation Desert Storm shows the value of maneuver, surprise, and mass in sustaining offensive airpower. Four operational concepts are presented: the indirect approach (maneuver), the stealth approach (surprise), the mass simultaneous attack (mass), and a balanced concept (mass and surprise). A 28-day war game examines their operational effectiveness. The war game demonstrated the high survivability of stealth aircraft at the expense of approximately 50 percent fewer targets destroyed. The mass concept illustrated the significant damage possible when a large-scale simultaneous attack saturates an air defense system. The balanced approach proved most robust, approaching the productivity of the mass concept (number of targets destroyed) and the efficiency of the stealth concept (cost of target destroyed). This study suggests the USAF should pursue stealth, stand-off weapons, real-time intelligence, drones, Wild Weasels, and electronic warfare technologies—while balancing them with a large inventory of relatively "inexpensive" multirole aircraft.

About the Author

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Introduction

Since the beginning of airpower, airmen have grappled with how to avoid, defeat, or destroy ground-based air defenses. During World War II the invention and deployment of radar dramatically increased the difficulty of this task. Essentially, radar provides warning and permits the defense time to react and engage attacking aircraft effectively—making ground-based radar defenses formidable. Without some method of defense suppression, any offensive air campaign will result in limited success and high-aircraft attrition. This conflict between air forces and ground defenses is part of the fundamental struggle in warfare between offensive and defensive strength.

Understanding and properly applying the principles of offense and defense is the basis of operational art.[1] When these principles are applied properly, they enhance the prospect of military victory; when not, defeat is more probable.

This study identifies and assesses operational concepts used to defeat a sophisticated ground-based air defense system. It focuses at the operational level;[2] however, tactical applications are addressed when necessary to provide the reader a more complete analysis. Military planners should find the principles and operational concepts discussed useful in formulating future air campaigns. Although the study specifically addresses air defense suppression, many of the principles discussed apply to land and sea warfare as well.

The search for these operational concepts will survey representative works of military theory, history, and airpower doctrine. The study begins with an examination of the theoretical works of Carl von Clausewitz, Basil H. Liddell Hart, Giulio Douhet, and Col John A. Warden III to provide a broad perspective on the relationship between offensive and defensive power. Next comes a review of United States Air Force (USAF) doctrine, Royal Air Force (RAF) doctrine, and Israeli Air Force (IAF) doctrine for insights into constructing a successful air defense suppression operation. Finally, the work briefly reviews how ground-based air defenses were suppressed in Operation Linebacker II, December 1972; the Yom Kippur War, October 1973; the Bekaa Valley air battle, June 1982; and Operation Desert Storm, January 1991.

Following this review of theory, doctrine, and history, a contemporary analysis of air defense suppression will examine the current ground-based threat, current suppression technology, emerging technology, and identify some likely operational campaign objectives and constraints. With these factors in mind, four operational concepts will be constructed using a modification of Glenn A. Kent's, *Framework for Defense Planning*.[3] The concepts' utility will be judged on their technical feasibility, affordability, and operational effectiveness using the Tactical Air Command (TAC) air war game.[4]

The purpose of the war game is not to prove a particular concept, but rather to determine the strengths and weaknesses of the four concepts. Conclusions drawn from this evaluation will provide insight for future campaign planning, doctrine improvement, and force structure planning.

Theory

Four noteworthy military theoreticians provide particular insight into the concepts of offensive versus defensive strength: Clausewitz, Douhet, Liddell Hart, and Warden. An analysis of their works should yield principles for later synthesis into operational concepts.

Clausewitz was a Prussian military officer who lived in the Napoleonic era and wrote extensively on military theory. His book *On War* is a sparsely edited compilation of writings published by his wife in 1832 after his death. The book is a comprehensive and systematic analysis of the elements of war. Many of his thoughts on war have a timeless characteristic; and even though he wrote in reference to land warfare, many of his ideas may apply to air warfare as well. However, this study is primarily concerned with Clausewitz's comparison and relationship between defense and offense.

Clausewitz believed the defense was the stronger form of war. He wrote, "It is easier to hold ground than take it. It follows that defense is easier than attack, assuming both sides have equal means."[5] The advantage of time normally accrues to the defender because he has the passive purpose of preservation. The attacker in contrast has the positive purpose of conquest. In the absence of attack, the defender wins because he has the negative object, which requires no action. At the tactical level, the defense gains strength from the advantages of surprise, terrain, and concentric attack. In the absence of these advantages, defensive power is equivalent to offensive power.

Surprise is more often advantageous to the defense because the defender can normally observe the attacker's approach while remaining concealed until the decisive moment arrives.[6] Thus the attacker should conceal his approach and deployment of troops. If the defense cannot detect the attacker's approach, warning time is reduced and the defender may not be able to effect a credible defense. The defender is at greatest disadvantage when compelled to protect a wide area against multiple axes of advance. In this instance, the attacker using surprise may throw his full strength at any one point.[7] Terrain confers another advantage to the defender: It provides him concealment and protection. Using terrain features properly creates significant advantages for the defender. For example, a river with one crossing point allows only a portion of the attacking force to cross at once, creating a choke point. The defender can engage this partial force with a temporary numerical advantage. In addition, prepared terrain increases the defender's protection like a fortress. The defender also enjoys the choice of terrain which best suits his troops and tactics in order to repulse an attack. The benefit of terrain belongs exclusively to the defense.[8] According to Clausewitz, the defense will always have "the benefit of terrain, and it will generally ensure [the defense's] natural superiority."[9]

"Concentric attack comprises all tactical envelopment."[10] Though the attacker has the advantage of choosing the place and time of attack, any penetration he makes subjects him to concentric attack—cross fire—and threatens his line of communication and retreat. Hence, the wise attacker tries to overwhelm the defense by conducting simultaneous mass attacks, where the defender cannot engage all the attackers. Mass reduces the defensive advantage of concentric attack.

Clausewitz believed the greatest moment of the defense was the transition from defense to offense. As the attacker's strength diminishes during the attack due to longer lines of supply and the detachment of garrisons, the defense gains relative strength. "It benefits from its fortresses, nothing depletes its strength, and it is closer to its sources of supply."[11] The defender remains on the defense until he achieves an advantage and then counterattacks. If the attacker moves beyond the point at which he can sustain a successful defense (Clausewitz called this the culminating point),[12] a counterattack could result in a decisive victory.

What should the campaign planner attack, and what should he defend? "Clausewitz addressed these issues in reference to the center of gravity, . . . the hub of all power and movement, on which everything depends. This is the point which all energies should be directed."[13] Clausewitz gave three likely strategic centers of gravity: the enemy army, his capital, or a principal ally.

Clausewitz was convinced the defense was the stronger form of war. But even with its preponderance of strength, he insisted victory was not possible without attack. He advised the weaker foe to rely on the defensive only so long as weakness compelled then counterattack "unleashing the flashing sword of vengeance" against the enemy center of gravity.[14] Clausewitz urged his readers not to underestimate the power of the defense. It normally takes less relative force to conduct a successful defense than it takes to conduct a successful attack, but only the offense can achieve a positive object.

World War I's western front demonstrated the superior strength of the defense. In an effort to break the stalemate of warfare and strengthen the offensive, Liddell Hart, a twentieth-century British military theorist, developed his ideas on the indirect approach. His theory advocated attacking the enemy's vulnerable point(s) instead of his strength. "The true aim is not so much to seek battle as to seek a strategic situation so advantageous that if it does not of itself produce the decision, its continuation by a battle is sure to achieve this."[15]

Liddell Hart's indirect approach threatens multiple objectives simultaneously, using maneuver and surprise to distract and dislocate enemy forces, creating an opportunity to strike with effect and exploit the situation. If the enemy commander can determine the attacker's objective, he can deploy his defense accordingly to thwart the attack. Therefore, the enemy commander must be distracted by threats against multiple objectives, creating confusion in his mind, and limiting his freedom of action. Next, a deep penetration that threatens the enemy's lines of communication and retreat should create alarm and heighten confusion. To alleviate his vulnerable situation, the enemy commander will dislocate his deployed forces via retreat or by prematurely committing his reserves. Once off balance, the enemy becomes susceptible to defeat. Exploiting this opportunity can magnify enemy confusion and panic, resulting in further dislocation of defensive forces.

After World War I, Liddell Hart argued that the offense was stronger than the defense because of the mobility of mechanized and armored forces. These forces could make fast, deep penetrations creating great consternation and dislocation of forces. However, as armored warfare technology improved during the 1930s, Liddell Hart changed his point of view. The same mobility which had strengthened the offense, also strengthened the defense. Now a mobile defense using mechanized forces could reinforce quickly, effectively blunting and/or cutting off offensive penetrations.[16]

An advocate of defensive strength like Clausewitz, Liddell Hart saw the transition from defense to offense as the most decisive moment for both. The counterattack is most effective when the enemy has "fully committed his own strength without having gained his objective. At that moment, his troops will be suffering from the natural reaction due to a prolonged effort, while the Command will have relatively few reserves of its own ready to meet a counterstroke—especially if it comes from a different direction."[17] The enemy is most vulnerable at this point and any penetration will result in a great dislocation of forces which can be exploited.

In addition to Clausewitz and Liddell Hart, airpower theorists Douhet and Warden also addressed the relationship between the offense and the defense. Considered by many to be the father of strategic bombing, Douhet based many of his ideas, like Liddell Hart, on his World War I experience. Douhet witnessed the horrific costs of the ground war that was mired in the trenches, and contended that the airplane could strengthen the offense with better mobility. The airplane's mobility unlocked the door for strategic attacks against the enemy's war-making capacity and civilian morale. Douhet envisioned airpower as the decisive tool to shorten and win future wars.

He further believed the airplane was invulnerable to air and ground defenses. It could, he maintained, simply fly over ground defenses with its speed and maneuverability, it would be nearly impossible for air defenses to detect and intercept. To defend against an air attack would require numerous interceptors based throughout the country. Douhet saw this defensive effort as a waste of resources. He proposed instead an offensive air force with aircraft capable of self-defense. His "battle planes" would deliver enough high explosives, incendiaries, and poison gas to create a fire storm in poorly defended cities, destroying both the industrial base and civilian morale. This he felt would cause rapid capitulation and end the war quickly.[18]

Essentially, Douhet's offensive bombing theory was based on three propositions: "The destructive power of the heavy bomber, the impotence of air defense, and the fragility of a modern industrial society in the face of heavy bombing. . . ."[19] Douhet has been widely criticized for exaggerating these propositions. For example, until the advent of nuclear weapons and the subsequent development of conventional precision-guided munitions (PGM), the bomber did not possess the destructive power Douhet claimed. Second, the development of radar tended to invalidate one of Douhet's assumptions (i.e., that strategic bombers could not be detected en route to their targets). Radar permitted early warning of air attacks, giving the defense time to react. Finally, civilian morale and industry proved more resilient than Douhet expected.[20]

Douhet's theory, with some modification, is a framework for a successful offensive air campaign. First, intelligence must identify which enemy centers of gravity are vulnerable to air attack, and if destroyed will result in military victory. Second, the enemy air defenses must be rendered impotent by avoidance, disruption, or destruction. Finally, offensive airpower must be delivered accurately and with sufficient mass at the vulnerable points to destroy the enemy centers of gravity. This is certainly easier said than done, as the World War II air campaign planners found out, but it is a logical framework for campaign planning.

The last theorist for review is Colonel Warden. A fighter pilot and former member of the Pentagon's Air Staff, he also offers insight into the nature of aerial offense and defense. Warden is a contemporary airpower theorist, responsible in part for planning the Desert Storm air campaign. In his 1988 book, *The Air Campaign: Planning for Combat*, he examines the missions of air superiority, interdiction, and close air support, when to use them, why to use them, and how long to use them. Achieving air superiority is the cornerstone of his campaign plan.

Warden believes that the offense is the stronger form of air war. Like Douhet, he bases his assumption on the airplane's speed, range, and maneuverability. Mobility gives air forces the unique capability to concentrate rapidly and strike distant targets, thereby inherently threatening multiple objectives. Airpower's ability to concentrate is further complemented by its ability to disperse rapidly following attack. To defend effectively against air attack, the defender may use a large dispersed force to defend against all avenues of attack or use a smaller force in conjunction with early warning to concentrate mass rapidly once the attack is detected. At the tactical level, airborne defenders do not have the benefit of terrain for protection. In Warden's opinion there is little difference between offensive and defensive strength once aircraft are engaged.

Colonel Warden favors the attack and believes "the operational commander should want to go on the offensive at the earliest opportunity. . . ."[21] He also cautions against underestimating the enemy. Any offensive strategy development should consist of assessing the enemy's capabilities via intelligence, followed by war gaming, and further analysis. This cycle should continue until hostilities breakout. To him, the key principles of war are mass and concentration. In fact, the commander should ensure his forces outnumber the enemy every time they meet.[22] "The larger force almost always inflicts greater absolute and relative casualties on the smaller force."[23]

Warden does not favor the piecemeal application of airpower. Instead, he favors large-scale raids to achieve great shock. Finally, Warden stresses persistence. Most target sets are not easily destroyed, and if destroyed can be easily repaired—requiring persistent attack.

When planning the air campaign, Warden believes the operational commander must assess the enemy's air defense structure. "Suppression of air and ground-based defenses may be necessary before attacking systems supporting offensive air."[24] If ground defenses threaten offensive operations, they must be neutralized by destruction of their key parts, electronic suppression of key parts, disruption of command, control, and communications (C^3), or isolation from its source of supply. Ground-based defenses normally have certain characteristics. First, they are finite and normally have flanks. Second, they have a directional orientation based on the predicted route of attack. Third, they are rarely strong in both depth and width. Fourth, they are not theater mobile—meaning they cannot be relocated within the theater quickly. "These characteristics suggest campaigns against the system based on flank attacks, penetration and exploitation, or systematic reduction from front to rear."[25]

In planning suppression of enemy air defenses (SEAD), like any other offensive operation, Warden recommends using the principles of surprise, mass, and persistence advantageously. Without surprise, the enemy can prepare a satisfactory defense to blunt an offensive blow. Surprise actually ensures the offensive mass employed will be sufficient to overcome the defensive power. Persistence is necessary due to the resilience of ground-based defenses.

After reviewing these four theoreticians, it is clear that the relationship between offensive and defensive strength is situational and relative. Obviously mobility and technology have made a significant impact on the conduct of warfare. Clausewitz argued the defense was stronger even though it was relatively immobile and susceptible to envelopment. Liddell Hart stated that mechanized warfare increased the mobility of both offense and defense, with multiple lines of approach for attack as well as defense, but did not necessarily weaken the defense's inherent strength. Douhet believed the airplane's superior mobility made offense the stronger form of war because air and ground forces were incapable of stopping an aerial offensive, leaving the enemy's center of gravity exposed to direct attack. Warden also recognized airpower's speed, range, and flexibility as decisive for offensive power, but noted that lethal air defenses should be suppressed to sustain offensive strength. In addition, he asserted that aircraft engaged in air-to-air combat were essentially equal in relative strength.

All four theorists saw the value of the following principles in planning offensive campaigns: initiative (offensive), surprise, mass, maneuver, and security. Each theorist noted the defense has a negative object, and only offensive action can achieve positive results. Although Clausewitz was pessimistic about the probability of achieving surprise, all theorists agreed, "surprise lies at the foundation of all undertakings, for without it the preponderance at the decisive point is not properly conceivable."[26] Superior force at the decisive point is necessary to overwhelm the defense; without it, success is doubtful. All noted it was the operational commander's responsibility to ensure that superior force is formed at the point of attack. "In fact, it is the essence of generalship."[27] Maneuver played a major role in all of the theories. Speed of maneuver and penetration threaten the enemy's lines of communication, distracting him, and dislocating his forces. Finally, without security, the commander cannot achieve surprise or mass.

The primary difference between air and land warfare is the effect of terrain. In ground warfare terrain provides protection and restricts mobility. In air warfare the absence of terrain enhances mobility while giving up its protection. This increased mobility reduces warning time and makes achieving surprise more likely. By using this superior mobility the attacker can threaten an entire theater with air attack, spreading out the defense, and then concentrating superior forces at the decisive point to overwhelm the defense. In conventional war, surprise is a powerful force multiplier.[28] First, it takes the initiative away from the enemy by confusing the defense and, distracting the enemy commander. Second, it ensures the defense cannot reinforce the position with superior force prior to attack. Fourth, surprise enhances the ability to maneuver.

From this review of theory, the following propositions form the theoretical base for development of key operational concepts for attacking ground-based defenses. First, the planner must accurately assess the situation and locate the defense's strengths and vulnerable points through which the enemy centers of gravity can be successfully attacked.[29] Second, deceptions, feints, or effective maneuvers may distract and dislocate enemy forces. Third, the use of a concealed (stealth) approach and/or speed of action can reduce or prevent defensive reinforcement prior to attack. Fourth, attack simultaneously in mass to achieve a numerical advantage. Fifth, attack persistently until the objective is achieved.

Doctrine

The next step in the search for operational concepts leads us from theory to current airpower doctrine. Doctrine is basically "approved" theory. By definition, "Doctrine refers to a theory based on carefully worked out principles and taught or advocated by its adherents."[30] By comparing the air doctrines of three air forces, some core principles should be identified for defense suppression. This overview examines the doctrines of USAF, RAF, and the IAF, all of which have conducted successful defense suppression operations during the past decade.

USAF doctrine includes SEAD in the offensive aerospace control mission. Air Force Manual (AFM) 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 1, March 1992, defines "Offensive aerospace control [as those] operations [which] seek out and neutralize or destroy enemy aerospace forces and ground-based defenses at a time and place of our choosing."[31] Its purpose is to create a favorable air situation, permitting friendly aircraft freedom of action. "Aerospace control normally should be the first priority of aerospace forces."[32]

Defense suppression constitutes "that activity which neutralizes, destroys, or temporarily degrades enemy air defenses in a specific area by physical attack and/or electronic warfare."[33] It can be either passive or active. Passive SEAD attempts to degrade or disrupt normal C^3 of defensive operations by using radar electronic countermeasures (ECM) and communications jamming. Active, or lethal, SEAD attempts to destroy early warning radars, command, and control nodes, acquisition radars, tracking radars, surface-to-air missile (SAM) batteries, and antiaircraft (AAA) batteries with standoff munitions or bombs.

In a high-threat air environment, defense suppression is an integral part of the air superiority mission ensuring freedom of action and preventing unacceptable attrition.[34] Defense suppression will precede and/or take place in conjunction with the offensive air campaign. The most important SEAD targets include early warning radar and associated C^3 systems. Attacks on these systems are designed to put the enemy in a catatonic state, denying him "access to surveillance, reconnaissance, and intelligence-gathering systems."[35] This is not an Air Force mission only; other forces have sufficient range and firepower to destroy or capture enemy bases, ground-based defenses, warning systems, and C^3 nodes.

The defense suppression mission is enhanced by a combination of factors such as speed, maneuverability, tactics, and deception.[36] All of these factors produce surprise. Surprise helps gain the initiative. The commander with initiative and airpower can attack in a multitude of ways, due to the versatility of airpower. This versatility makes surprise airpower's strongest advantage.[37]

RAF doctrine articulates the advantages of both aerial offense and aerial defense. According to their basic manual, "the inherent strengths of airpower tends to favor offensive rather than defensive action. Offensive action allows the attacker to seize the initiative, exploit to the full the capabilities of airpower and saturate enemy defenses. It carries the war to the enemy and forces him to react."[38]

RAF doctrine defines SEAD as that "activity which neutralizes, destroys or temporarily degrades enemy air defense systems in a specific area by physical attack and/or electronic warfare to enable air operations to be conducted successfully. [SEAD] can greatly reduce loss rates and help to sustain offensive air action."[39] Typical target sets include radars and other sensors, SAM, and AAA batteries.[40] The RAF does not have a dedicated SEAD aircraft. Instead, it relies on ECM for self-protection, and most RAF aircraft can carry the air launched antiradiation missile (ALARM).

RAF doctrine recommends SEAD during offensive counterair operations. When opposed by an enemy with significant airpower, the counterair campaign will normally take priority over other air campaigns.[41] The campaign should exploit the capabilities of speed, reach, and flexibility. These capabilities give airpower flexibility and balance, enabling them "to concentrate force anywhere and to attack any element of the enemy's power."[42] Furthermore, airpower must be applied persistently to sustain its impact.

RAF doctrine identifies three factors which the planner must consider before embarking on an air campaign: the depth, density, and technology of the defense. Depth enhances the defense. Early detection gives the defender additional time to concentrate his forces against incoming raids. A defense in depth presents sequential and layered barriers the attacker must overcome. These multiple threats can engage the attacker simultaneously, thus increasing his vulnerability. "Historically, a layered system capable of inflicting progressive attrition on the attackers has always produced the best results."[43]

Density connotes the concentration of the defense. Normally low density favors the offense. If the defender tries to defend everywhere, he spreads his defense too thin, and the offense can easily saturate it, because of the attacker's ability to concentrate quickly.[44]

Technology also affects the offense/defense balance. For example, electronic countermeasures, improved warning and acquisition sensors, and long-range air defense weapons increase defensive depth and density—strengthening defensive power. In contrast, improved ECM, standoff weapons, and stealth reduce defensive power.[45]

Defense suppression reduces attrition. The British are keenly aware of how sensitive air forces are to attrition from the 1940 Battle of Britain experience. Because air forces may engage the enemy continuously by flying sorties around the clock, even a small attrition rate can have a devastating overall impact. As shown below, for example, a force of three hundred aircraft flying three sorties a day and sustaining a 3 percent per sortie attrition rate for one week would reduce the force to 158 aircraft—almost a 60 percent reduction in airpower. In addition, airpower is expensive and replacement requires long lead times for aircraft production and aircrew training.[46]

Effect of 3 Percent (per sortie) Attrition Rate

		1st Go Sorties	2d Go Sorties	3d Go Sorties	Daily Total
DAY	1	300	291	282	873
DAY	2	274	266	258	798
DAY	3	250	242	235	727
DAY	4	228	221	214	663
DAY	5	208	202	196	606
DAY	6	190	184	178	552
DAY	7	173	168	163	504
DAY	8	158	153	148	459

IAF doctrine is based on supporting fast-moving armored columns by conducting deep attacks into enemy territory. IAF doctrine calls for a SEAD campaign in conjunction with their initial offensive air campaign to gain air superiority. Without air superiority, Israeli armored columns are vulnerable to air attack. Air superiority is accomplished by suppressing enemy air defenses, and offensive counter air operations. Israeli doctrine calls for simultaneous attacks on ground-based air defenses and airfields to win air superiority quickly. The objective of these actions is to gain the initiative, confuse the enemy, and deliver a knock out blow before the enemy can react defensively, thus precluding a coordinated air defense.

Current IAF doctrine concentrates on intelligence, surprise, mass, and persistence to suppress enemy air defenses. The Israelis concentrate on maintaining a qualitative advantage and rely on surprise to compensate for their quantitative disadvantage. Surprise is achieved by good security, lulling their opponent into complacency, and then using speed and special tactics to attack quickly before the defense can respond. First, they use reconnaissance to gain knowledge of their enemy, using remotely piloted vehicles (RPV) to collect enemy order of battle, air defense procedures, communications frequencies, and radar frequencies. When the battle begins, they blind and confuse the air defense system with ECM, drone decoys, antiradiation missiles, ground artillery/missiles, electronic jamming of radio communications, and attacks on command and control nodes. Once the defense is blind, deaf, and dumb, the Israelis use airpower to destroy the isolated SAM and AAA sites with iron bombs or ground artillery. This provides freedom of action for air attacks—maintaining the initiative.

After examining the three doctrines, what common principles or concepts emerge as central to suppression of enemy air defenses? It is clear that all three air forces favor offensive action. In addition gaining and maintaining the initiative in battle is clearly desirable to all military commanders. By doing so military commanders can accomplish their operational objectives. Otherwise their actions are purely in reaction to the enemy.

All three doctrines use a combination of speed, maneuver, specialized techniques, and deception to create surprise, thereby reducing the defense's time to react. Deception creates a defensive vulnerability by dislocating forces. Once the vulnerability is created, maneuver is used to mass superior firepower quickly, creating a quantitative advantage at the point of attack. Special tactics such as low-level flying or stealth qualities conceal the approach and the objective of the attack until it is too late for the enemy to react. Surprise essentially permits the offense to attack a vulnerable point with superior mass, because the defense cannot react quickly enough to repulse the attack.

The principle of surprise can temporarily multiply offensive strength. Without the element of surprise, the enemy can coalesce the necessary defensive strength to repulse the attack. To gain surprise, the commander must know his enemy. Good reconnaissance and intelligence analysis should identify the enemy's order of battle, air defense structure, centers of gravity, and possible vulnerabilities. The commander must assess which, if any, vulnerabilities can be successfully exploited.

The vulnerable points normally associated with a defense suppression campaign consist of the enemy's command, control, and communications functions. Such targets normally include warning radars, command posts, and communication links. Disrupting or destroying these targets will increase the lethargy of the defense and reduce its capability to react effectively to an attack. Another target set includes the air defense sites themselves. Mobile air defenses require real-time target acquisition provided by improved intelligence gathering and electronic sensors which locate radar signals. Once the site is located and frequency identified, the site can be avoided, disrupted (via ECM), or destroyed. Overhead national assets, airborne platforms, and RPVs can collect intelligence and acquire target location. Electronic warfare and command, control, and communications countermeasures (C^3CM) are used to disrupt the effective operation of air defenses. If destruction is necessary, the full range of firepower can be used, depending on what is available. Special operations forces, artillery, standoff munitions, antiradiation missiles, and iron bombs can be used to destroy the site. It is not necessary to destroy the entire defense system at once. Opening a corridor through the defenses may be all that is required. Once air defenses are suppressed, offensive power enjoys a greater freedom of action to conduct aerial attacks, thus increasing mission effectiveness and reducing aircraft attrition.

History

Theory and doctrine have provided several principles which enhance a SEAD campaign. Next, an examination of history should provide tangible evidence to evaluate the validity of the principles already addressed. In this historical review, four air campaigns will be examined—Operation Linebacker II 1972, the 1973 Yom Kippur War, the 1982 Bekaa Valley Operation, and Operation Desert Storm 1991. Heavy ground-based air defenses were present in each case, and defense suppression played a major role in all four air battles. This review will highlight the principles and concepts employed that contributed to the outcome of the campaigns.

United States aircraft conducted Linebacker II against North Vietnam beginning on 18 December 1972, in response to the stalemated Paris peace talks. The US objective of Linebacker I (spring and summer 1972) had been to destroy North Vietnam's war-making capability. President Richard M. Nixon's objectives in Linebacker II were to break North Vietnam's will to resist, demonstrate America's commitment to South Vietnam and achieve an agreement permitting disengagement of US armed forces before Congress reconvened in January 1973.[47] The air campaign targets included industrial centers, transportation nodes, airfields, and SEAD targets in and around Hanoi and Haiphong. Besides the poor December weather conditions which necessitated the B-62s all-weather radar bombing capability, its substantial firepower "was airpower's best tool to disrupt an enemy psychologically."[48] The original campaign was planned to last three days; however, it was extended during the campaign to 11 days (18–28 December 1972) due to continued intransigence by North Vietnam.[49] A substantial SEAD effort was planned to keep B-52 losses at less than 3 percent.[50]

North Vietnam's air defense system was an integrated combination of AAA, SAMs, and MiG aircraft. It was considered at the time to be the world's most formidable air defense environment.[51] During Linebacker II, the United States relied on self-protection ECM, standoff ECM jammers, chaff, Wild Weasels,[52] Iron Hand[53] operations for and air defense suppression. On the first three nights, B-52s flew three waves of 20 to 50 bombers each, with waves spaced four to five hours apart. Each B-52 wave consisted of a stream of three ship cells with two-minute separation over the target. This tactic, known as compression "served to saturate enemy defenses, increase mutual ECM support, and simplify the effort of the supporting tactical and countermeasures aircraft."[54] Twenty to 60 minutes before the first B-52 wave crossed the target, Air Force, Navy, and Marine fighter-bombers attacked airfields and known AAA and SAM sites.[55] About five minutes prior to the raid, F-105 Wild Weasels flew into the target area to suppress the remaining radar-guided ground defenses.[56] F-4 fighter-bombers sowed protective chaff corridors and EB-66s, EA-3s, and EA-6s emitted ECM jamming signals to help hide the penetrating force.[57] Additional F-4s provided escort and combat air patrol (CAP) for the strike package.

At the outset US SEAD operations were not well coordinated, and bomber routes, tactics, and altitudes became *predictable* resulting in heavy B-52 losses (6.8 percent on night three). Mistakes included B-52s firing their tail guns at other US aircraft, EB-66s jamming friendly radios, and B-52s jamming friendly radars. In addition, one-fourth of the B-52s did not have up-to-date ECM modifications. Of the 13 B-52s hit by SAMs in the first three days, five were unmodified models.[58] B-52 protection was degraded by five factors. The sharp 100-degree post-target turn increased the B-52's radar cross section and reduced ECM radar jamming effectiveness. Unforecast winds displaced the chaff corridor.[59] North Vietnamese used a one band radar for SAM guidance, which most American aircraft were unable to jam.[60] The predictable B-52 flight paths in conjunction with SAC's policy of no evasive action on the bomb run (directed to enhance mutual ECM protection), permitted the North Vietnamese to use salvo barrages of SAMs at the post-target turn point where ECM protection was least effective and the B-52s most vulnerable. Finally, Wild Weasel efforts were hampered because SAM operators limited their radar guidance to the last five to 10 seconds of missile flight. Most aircraft losses resulted from SAMs.

Many of the errors made during the first three nights were corrected on the remaining eight nights. However, B-52 losses in the Hanoi and Haiphong areas increased from 3 percent to a campaign average of 4 percent.[61] One reason for this surprising higher attrition rate was reduced offensive mass.

With the exception of 26 December, all nights had a marked decrease in sorties attacking North Vietnam. Had the sortie weight remained high, the overall attrition rate may have been lower-emphasizing the need for mass. Other lessons from the first three nights include improved chaff delivery, use of random penetration routes, simultaneous attacks, and SAM suppression at the source (Hanoi SAM assembly plant).[62]

Narrow chaff corridors provided limited protection during the first three nights. Starting on 22 December the corridors were widened and on 26 December a wide chaff "blanket" was used, which provided greater protection. In addition, during the 18–24 December period, the chaff had only 3.5 to 16 minutes "blossoming" time prior to the first B-52 time over target (TOT). Optimum blossoming time for maximum protection was 20 to 30 minutes. During the remainder of Linebacker II, chaff was dropped between 18 to 30 minutes prior to the first TOT.

After the heavy aircraft losses of the first three days, B-52 routes were changed and varied to reduce their predictability. On the 25th, "The B-52Ds flew around the flanks . . . remaining beyond effective SAM range for as long as possible."[63] This approach to Hanoi from the northwest avoided the Haiphong defenses. Multiple axes of attack also reduced predictability.

A massive simultaneous attack was delivered on 26 December, when 120 B-52s conducted the largest and most concentrated strike of the operation. In a 15-minute span, seven waves of B-52s attacked nine targets simultaneously.[64] Only two B-52s were lost to the extensive SAM barrage, resulting in a reduced attrition rate per sortie of 1.66 percent.[65]

Wild Weasel and Iron Hand operations reduced SAM accuracy, but did not succeed in stopping the barrage firing. Radar bombing of SAM sites was also ineffective. During the operation, 58 sorties bombed 13 SAM sites, achieving only 50 percent damage on two sites, while the other 11 sustained no damage.[66] To limit SAM losses, Strategic Air Command (SAC) planners asked the Joint Chief of Staff (JCS) for permission to attack the main SAM assembly plant in Hanoi with B-52s. The JCS authorized the attack, however, substituted 16 F-4s with long range navigation (LORAN) to conduct the attack on the SAM assembly facility.[67] The success of this mission in conjunction with, subsequent B-52 attacks (26–29 December) on SAM storage facilities, the mining of Haiphong harbor, air interdiction of rail and road transportation nodes, and the high SAM usage rate, resulted in depletion of missile stocks.[68]

"By 29 December the North had exhausted its SAM supply making further defense impossible."[69] Hanoi no longer had the means to resist air attack and agreed to Nixon's ultimatum. The North Vietnamese communiqué arrived in Washington, on 28 December, and President Nixon called a halt to bombing north of the 20th parallel at 1900 hours on 29 December Washington time.[70]

Linebacker II seemingly had achieved its objectives. SEAD played a major role in its successful outcome. Incorporation of the principles of intelligence, maneuver, surprise, and mass contributed greatly to this victory. However, better campaign planning (predictability/mass) and proper orchestration of SEAD operations may have produced lower aircraft attrition.

Ten months after Linebacker II, the Israeli Air Force also experienced first hand the lethality of SAM and AAA in the Yom Kippur War during October 1973. (For brevity, this summary will not address the northern/Syrian front.) The Egyptians built a dense antiaircraft missile defense consisting of 63 Soviet SAM batteries (25 SA-2s, 20 SA-3s, and 17 SA-6s) of 4-6 launchers each.[71] These SAM batteries, in conjunction with the antiaircraft artillery (ZSU 23-4), provided an air defense umbrella, effectively denying, for the first time, IAF air superiority in support of the IDF armored forces.[72]

Israel was aware of these defense buildups, and Gen Moshe Dayan directed his General Staff to "plan for the possibility of an Egyptian initiated war in the autumn of 1973."[73] However, the Egyptian's successfully disguised their mobilization as a military exercise. The Egyptians started the war on Yom Kippur (a Jewish holiday) because Israeli preparedness was assumed to be lowest on this day and the tides in the Suez Canal were favorable.[74] The 6 October attack took Egyptians as well as Israelis by surprise. In fact, "95 percent of the Egyptian officers taken prisoner by Israel knew for the first time that this exercise would turn into a war only on the morning of 6 October."[75]

Israel delayed mobilization of reserves for economic reasons and depended on advanced intelligence warning to provide time for mobilization. The IAF originally planned to conduct an all-out attack against the missile systems to gain air superiority and enhance its ground support effort. However, the massive surprise attack put the Israeli Defense Force (IDF) in a desperate situation along the Suez Canal and prevented the IAF from attacking as planned. Instead, the IAF threw the weight of effort to close air support (CAS) to stop the Egyptian armored columns, while IDF reserves mobilized.[76] Initially IAF losses were heavy; 50 aircraft were lost in the first three days, primarily to SAMs and AAA.[77] More than 20 percent of the IAF's frontline combat aircraft were shot down or put out of action during the first four days.[78]

A shortage of ECM equipment, poor tactics, and a significantly improved jam resistant SAM contributed to the high-attrition rate. The IAF had only 161 ECM pods and 30 radar-homing and warning (RHAW) sets available for 230 A-4 Skyhawks.[79] This vulnerability restricted A-4s from deep penetration missions; however, their limited exposure to SAMs and AAA in the CAS role still resulted in a high-attrition rate. To reduce exposure time to SAM threats, IAF pilots flew as low and as fast as possible. However, this made target acquisition difficult. As a result, many pilots were hit making multiple passes searching for their target. Finally, the new SA-6 significantly enhanced the SAM threat. Besides being a mobile threat, the SA-6 missile used a frequency-hopping ground radar and an infrared missile seeker to home in on its target.[80] Its improved low-altitude capability forced IAF aircraft down to extremely low altitudes where AAA was most effective.[81]

When the Arab advance slowed and recently mobilized IDF reserves arrived, the IAF began to shift its effort to air interdiction (AI), offensive counterair (OCA), and SEAD. AI proved effective in slowing the movement of Egyptian armor coming across the canal. OCA attacks, in contrast, proved relatively ineffective because the Arabs were using hardened aircraft shelters. SEAD played an integral role in both AI and OCA. To improve the probability of penetration, AI and OCA attacks were flown at medium altitude (above most AAA), while Shrike radar-homing missiles and standoff radar jammers suppressed early warning and SAM radars.[82]

To reduce aircraft and pilot losses, the IAF used Firebee I drones for dangerous battlefield reconnaissance and decoy drones to distract and confuse Egyptian defenses.[83] In both roles, the drones were successful gathering valuable intelligence and drawing the fire of Egyptian SAMs. To reduce exposure to SAMs on interdiction missions further, aircraft used indirect flight paths to maneuver around battlefield defenses and achieve surprise. "These new tactics . . . considerably reduced the Israeli loss rate during strike operations."[84]

On 9 October, nearly one hundred IAF sorties attacked four SAM batteries around Port Said.[85] SEAD attacks continued and by 13 October no SAMs existed in Port Said.[86] On 14 October, the Egyptian ground forces attempted a breakout into the Sinai, leaving the protection of their SAMs. Without SAM coverage, the Egyptian armor came under heavy air attack and within two hours began retreating to their SAM umbrella having suffered heavy losses.[87]

The IDF's counterattack began on 16 October when Maj Gen Ariel Sharon's paratroops drove through a gap between two Egyptian armies, crossed the canal on ferries, and established a bridgehead on the western shore. Using captured Egyptian tanks, they fanned out, raiding and destroying Egyptian supply dumps, communications positions, and three SA-2 batteries.[88] "These ground attacks opened a hole in the Egyptian air defense shield and allowed the IAF to operate with greater safety and effectiveness in the area."[89] On 18 October the IAF began a five-day SEAD campaign attacking Egyptian missile sites all along the Suez Canal, from Port Said to the Gulf of Suez. At the same time Israeli army units attrited SAM sites with artillery and tank fire, and captured many intact.[90] By 21 October most of the Second Egyptian Army and all of the Third Army had no SAM defenses.[91] As a result, IAF attrition dropped dramatically. Between the start of the Israeli "cross-canal thrust" and the 24 October cease-fire, the IAF flew some 2,261 strike sorties with the loss of only four aircraft. In contrast, before the western bank thrust destroyed the SAM sites, the IAF lost 38 aircraft for 3,181 sorties flown against the Egyptian defenses.[92]

The war provided a key lesson for the Israelis. "After the conflict, the IAF set its sight on overcoming the challenge of surface-to-air missile and gun systems."[93] Specifically, they needed a means to locate SA-6 mobile missiles and a weapon to destroy them from standoff range (25–40 miles).[94] (The USAF heeded this lesson and developed the F-4G expressly for the mobile SA-6 threat. The F-4G reached initial operational capability in 1978.)

Following the 1973 war, Israel developed a coherent SEAD doctrine.[95] This doctrine provided the foundation for their astounding performance in the 1982 Bekaa Valley Operation. Here, following a crucial SEAD operation, the IAF won air superiority, destroying 80 to 90 Syrian aircraft during two months of fighting with the loss of three to six Israeli aircraft.[96]

Air superiority and this lopsided victory were made possible by a well-coordinated SEAD operation destroying SAM and AAA sites in the Bekaa Valley. Before the actual attacks, Israeli reconnaissance aircraft and unmanned aerial vehicles (UAV) detected and located the Syrian air defense sites. Just prior to the air attack, a commando raid destroyed/neutralized a control 27 center, beginning the paralysis of Syrian C^3.[97] During the attack the Israelis dominated the electronic spectrum. First, they used Samson decoy drones to trick the Syrians into activating their acquisition and tracking radars.[98] Second, reconnaissance drones reported the frequency and location of the radars. Third, Israel used a wide array of intense electronic warfare operations to confuse and deceive Syrian communications, and to blind Syrian SAM radar units. Finally, long-range artillery, surface-to-surface rockets, surface-to-surface antiradiation missiles (ARM), and air-launched ARMs pounded the SAM and AAA radar sites.[99] Once blinded, the surviving missile batteries were vulnerable to and subsequently destroyed by cluster munitions.[100] Ten of the 19 Syrian SAM batteries were knocked out within the first 10 minutes, and the Israelis claim to have destroyed 17 batteries and damaged two others during the attack without losing a single aircraft.[101] "The Syrians pushed more SAM units into the Bekaa Valley (over night), but to no avail. On day two, the IAF destroyed 11 more missile batteries."[102]

The IAF used surprise, real-time reconnaissance, superb coordination, and simultaneous joint attacks[103] delivering the necessary mass to overcome the defense and achieve air superiority quickly. Examples of many of the principles already discussed were evident in this operation. Strategic surprise was achieved by desensitizing Syrian defenses with four threatened attacks and ongoing defense exercises.[104] Syrian defensive reactions to these activities formed the basis for Israeli wartime countermeasures. Unmanned aerial vehicles with a small radar cross section provided real-time intelligence prior to and during the battle. This information was used to plan the systematic destruction of the air defenses. The joint, simultaneous attack concentrated overwhelming offensive force at the decisive time and place. The combination of communication jamming, radar jamming, command post attacks, decoy drones, artillery, surface-to-surface ARMs, and standoff air-to-surface ARMs blinded and incapacitated Syrian air defense units. Israeli fighter-bombers then blasted the surviving Syrian air defense sites with missiles and bombs. Ten sites were destroyed in 10 minutes and 17 by the end of the day—a superb example of successful SEAD operations.

The lessons learned from the three previous cases were driven home by Desert Storm. Iraq, with French and Soviet assistance, constructed a formidable integrated air defense network with over three thousand AAA and 60 SAM batteries.[105] Baghdad was the most heavily defended. Lt Gen Charles

Horner, the joint forces air component commander (JFACC), described its defenses as twice the strength of anything in the Soviet Union.[106]

In designing the Desert Storm air campaign, the Central Command commander, Gen H. Norman Schwarzkopf, and General Horner established the following objectives:

1. Destroy/neutralize air defense command and control.
2. Destroy nuclear, biological, and chemical storage and production.
3. Render ineffective national and military C^3 infrastructure.
4. Destroy key electrical grids and oil storage facilities.
5. Deny military resupply capability.
6. Eliminate long-term offensive capability.
7. Disrupt and weaken Republican Guard forces.[107]

The importance of SEAD and command, control, and communications countermeasures (C^3CM) in the campaign is indicated in its top priority. The early morning offensive on 17 January 1991 began with a helicopter attack on two Iraqi early warning radar sites.[108] Five minutes later, F-117s destroyed an interceptor operations center which linked border radar sites with the Iraqi air defense headquarters in downtown Baghdad.[109] Fifteen minutes after that, the air defense headquarters and the telecommunications center in Baghdad were destroyed by other F-117s.[110] Immediately following, 52 Tomahawk land attack missiles (TLAM) hit their Baghdad targets in a five-minute span.[111] These attacks, in the words of General Schwarzkopf, "plucked out the eyes" of Iraq's air defense system. The command and control targets not destroyed in the initial attack were disrupted with EC-130 Compass Call communications jamming aircraft. This well-executed C^3 attack paralyzed Iraqi air defenses and permitted waves of nonstealthy aircraft to strike with high effectiveness and very low losses.[112]

The size, makeup, and timing of each strike package was based on the expected Iraqi air defense.[113] F-15s flew fighter sweeps or escort, clearing away Iraqi fighters. F-4G Wild Weasels, F-18s, and EA-6Bs fired high-speed antiradiation missiles (HARM) to suppress enemy SAM and AAA radars, while EF-111s jammed early warning radars.[114] In addition, strike packages utilized the principle of mass to reduce friendly losses by saturating enemy defenses. These forces also made battle management easier because once formed, they became integral fighting units, capable of being retasked against a similar target—thus providing needed operational flexibility and precluding numerous mission changes.[115]

With the disruption of Iraqi C^3, the air defense system lost its integration. As General Horner described it, "We took out the command and control nodes in a simplistic way. We made each one of those SAM batteries and AAA units operate autonomously."[116] Once autonomous, SAM radars had to "radiate" for extended periods to acquire aircraft, making them vulnerable to ARMs. Although ARMs were launched from numerous tactical aircraft, only the F-4G Wild Weasel could pinpoint "pop-up" mobile SAM threats. This capability increased the ARM's effective standoff range. According to Maj Gen John

Corder, Horner's deputy for operations, "The demand for Weasels went right through the roof.[117] In the first 36 hours, F-4Gs launched approximately 268 ARMs."[118] In fact, according to General Corder, "The Wild Weasels beat up on the enemy radar so bad that they essentially stopped radiating; and they'd only come up for 4 or 5 seconds at a time, shoot, and go back down again."[119] With limited radar guidance the missile's probability of kill dropped dramatically. The Weasels were so intimidating, that if "they [the Iraqis] knew an F-4G was there, they would not come up on the air."[120] Besides the F-4G, the F-117, and the Army Tactical Missile System (ATACMS) also proved to be superb in the SEAD role. For example, before Taji (a heavily defended expanse of military warehouses and maintenance facilities located just north of Baghdad) could be attacked by B-52s, the SAMs had to be destroyed. Sixteen F-117s struck every SA-2, SA-3, and SA-6 site positioned to defend Taji, opening the way for the highly successful B-52 attacks that followed.[121] ATACMS, in conjunction with joint surveillance target attack radar system (JSTARS), made a dynamite team. Using near-real-time electronic intelligence (ELINT) and radar information, the JSTARS/ATACMS team could locate, target, and destroy SAM sites from a standoff position.[122] In addition to lethal SEAD, disruptive SEAD in the form of ECM proved extraordinary. General Horner noted, "We were able to bring electronic combat (EC) together, and it did a superb job, as our loss rate showed."[123] The operational flexibility of in-theater ECM reprogramming in conjunction with ELINT from RC-135s and other national sources provided the best possible ECM for both self-protection jamming pods and EF-111/EA-6B escort jammers.

The results of C^3CM, lethal SEAD, disruptive SEAD, and air supremacy made flying at medium or high altitudes relatively safe. Without radar and communications, Iraq could only defend with AAA, and coalition aircraft flew above that. Flying at medium altitude enhanced allied capabilities, making target acquisition easier and providing greater range to both aircraft and weapons.[124] Allied use of PGMs made very accurate bombing possible from medium altitude.

The SEAD campaign's effectiveness is measured in part by aircraft attrition. The allies flew 112,756 sorties and lost 44 aircraft in combat (with a further 20 lost due to accidents). This equates to a combat attrition rate of 0.06 percent.[125] The SEAD campaign was so intimidating that Iraq began moving its mobile SAMs into the mountains along the Iranian border for preservation beginning on about day eight.[126] However, this phenomenal success must be weighed against three variables that heavily favored coalition forces: adversary's determination, desert terrain, and technology advantage. First, the Iraqi Air Force virtually refused to fight.[127] Second, desert terrain is the "ideal terrain to fully exploit air superiority and conversely, the worst terrain for ground troops deprived of both air cover and effective AA defenses."[128] Finally, "There was at least a one generation (and probably two generation) gap in the technical level of the opposing armed forces."[129]

Even with these caveats in mind, the coalition SEAD campaign was a resounding success. The following factors made major contributions: C^3 and SEAD were made top priority, stealth technology made surprise possible, electronic combat was integrated into the campaign plan. Standoff weapons like TLAM and ATACMs were responsive and accurate, PGMs reduced sortie requirements, multirole aircraft and munitions provided operational and tactical flexibility, signals intelligence (SIGINT) collection was accurate and near real time, all air forces were unified under the JFACC, and well-trained aircrews executed the plan superbly.

All four air campaigns examined provide excellent examples of the principles previously identified. SEAD played a major role in their successful outcome. In each case the principle of intelligence or "know your enemy" was present. Intelligence identified and located the adversary's tactical and operational vulnerabilities. In the case of defense suppression, intelligence constructed a "3-D map" of the adversary's air defense system.[130] This, in a theoretical sense, mapped out the "aerial terrain"[131] which restricted coalition aircraft maneuverability. Once mapped, this "aerial terrain" could be either evaded or changed and shaped by both lethal and passive SEAD. In the case of Linebacker II and the Yom Kippur War, the "aerial terrain map" was inaccurate, incomplete, and the SEAD capability to change and shape it was limited. In the case of Bekaa Valley and Desert Storm, improvements in ECM, ARMs, stealth, PGMs, cruise missiles, SIGINT collection, UAVs, and aerial reconnaissance increased the aerial terrain map's accuracy along with airpower's ability to change and shape it. The Desert Storm initial C^3 attacks and on-going SEAD campaign eliminated many aerial terrain obstacles ensuring freedom of action for the air war to follow. The principle of knowing one's adversary appears to underlie all others, for without knowledge of the enemy defenses and vulnerabilities, military force cannot be focused in a timely manner at the decisive point.

Attempts to conceal attacking aircraft from ground- and air-based defenses were evident in all four campaigns. Night and/or ECM were used in each case to conceal penetrating aircraft. Although radar jamming announced an attack was under way, it reduced the defender's useful radar tracking range and his available reaction time—helping to achieve the benefit of surprise. In Desert Storm, stealth technology eliminated the ECM warning of imminent attack and reduced the defender's radar tracking range to almost zero-permitting complete surprise. Under the concealment of ECM or stealth, lethal SEAD degraded radar tracking for extended periods. C^3CM or destruction of C^3 nodes "paralyzed" ground-based air defense and prevented any timely response to mount a credible defense. In most cases, the offense exacerbated this vulnerable situation with a simultaneous mass attack, overwhelming the suppressed air defenses.

In the two campaigns where absolute electronic domination of the battlefield did not exist, Linebacker II and the Yom Kippur War, offensive forces attempted to improve the probability of penetration by avoiding the strongest concentrations of ground-based air defenses. In both cases, the only reported detrimental impact of this "indirect" maneuver was extended sortie duration.

These representative examples chosen from theory, doctrine, and history sustain the validity of intelligence, surprise, mass, and maneuver as principles to use in overcoming defensive strength. These principles form the basis of the four operational SEAD concepts.

Contemporary Analysis

This chapter examines current SEAD issues with a forward-looking perspective, beginning with a brief description of the most promising current SEAD systems as well as those in development. This is followed by an examination of the possible military threats and how the US armed forces expect to cope with them. Finally, it presents an outline of probable operational campaign objectives, as well as constraints, for consideration in developing the four operational concepts and the subsequent force structures.

Desert Storm was a show-case of high technology weapons. In the words of General Corder, "Desert Storm was a HARM war."[132] About 1,000 HARMs were fired during Desert Storm. HARMs were used by both the USAF and US Navy to pinpoint enemy radar emissions, delivering a proximity-fused warhead containing 2,500 tungsten alloy cubes at Mach 2+ for target penetration.[133] To enhance its ability to counter frequency-agile radars, a more advanced seeker is being developed.[134] The USAF's primary HARM launcher, the F-4G Wild Weasel, could not fire enough HARMs to support all Desert Storm SEAD requests. USAF F-16s and US Navy F-18s and EA-6Bs all fired HARMs; however, they could not use the HARM's full range capability, unless range to the emitter was known. The F-4G, however, using its sophisticated RHAW system, the AN/APR-47, could locate radar emitters to within one degree of azimuth. Multiple bearings determine the target's range and cue the HARM into its range-known mode, which increases the missile's standoff range and accuracy.[135] In addition, the AN/APR-47 correlates the HARM's launch with enemy radar shut-down time, to verify the radar's destruction with a 95 percent accuracy.[136] Two follow-on Wild Weasel concepts are in development. The F-16 variant would use a pod version of the AN/APR-47, and the F-15E version would use an upgraded "ALR-56 radar warning receiver (RWR) and an external pod to house sensors similar to those used in the F-4G's targeting system."[137]

In the realm of passive SEAD, ECM should continue to improve and evolve at an accelerating pace. Higher speed computer processors continue to produce more effective jammers, able to process sensor information quickly and adjust the jamming frequency, power, and direction rapidly. The ALQ-131 Block 11 ECM pod is an example of this capability. None of the aircraft carrying Block 11 pods were lost to enemy fire during Desert Storm.[138] Two follow-on systems are in development and nearing low rate production, the airborne self-protection jammer (ASPJ), and the Navy's AN/ALO-165 self-protection ECM pod. Besides ECM pods, EF-111s and EC-130s both enjoyed resounding success in Desert Storm. The EF-111's tactical jamming system (AN/ALQ-99) is also being upgraded with prototype tests scheduled for 1995.[139] In addition, a high-powered standoff jammer to work in concert with an EF-111 or an EC-130 is also being developed.[140]

Intelligence collection and distribution systems made the coalition victory in Desert Storm appear easy. National intelligence systems collected a vast amount of detailed information, but the information was slow in getting to the soldiers and airmen needing it.[141] One new concept to speed information flow is Project Fastball.[142] Fastball consolidates and passes real-time intelligence data directly to the pilot's heads-up display, which depicts relevant information such as enemy aircraft and/or SAM threats. Fastball, in conjunction with the JSTARS, airborne warning and control system (AWACS), and airborne command, control, and communications (ABCCC) aircraft can direct the pilot to attack a specific target or provide him with a menu of targets. Using this accurate targeting information, SEAD aircraft could launch HARMs from maximum standoff range.

At the operational level, JSTARS provides the theater commander a 24-hour intelligence picture of enemy concentrations and movement, giving him advance warning of enemy intent and denying the enemy a sanctuary at night.[143] However, JSTARS can only "see" about 100 miles past the front. To extend sensor range, two UAV concepts are in development. The medium range concept (BQM-145A) can fly .9 Mach, has a range of seven hundred nautical miles, and an endurance of two hours. The vehicle can be air launched by an F/A-18 or RF-16 and carry a low altitude day/night electro-optic/infrared sensor payload, capable of real-time data link transmission or storage on tape.[144] If funded, the system could be operational by 1995.[145] The endurance UAV concept is a stealthy, long-range, high-altitude UAV capable of remaining on station 24 hours. A wide variety of sensors are being considered for this concept.[146] Additionally, UAVs could be used in both the passive and lethal SEAD roles as either a "penetrating" ECM jammer or a "loitering" antiradiation missile, which remains passive until it locates an enemy radar signal.

As already mentioned, the F-117 stealth fighter was one of the star performers in Desert Storm. This aircraft is capable of Mach 1+, but normally flies at .9 Mach. In Desert Storm it carried two 2,000 lb. laser-guided bombs. It can also carry two HARMs or two mavericks.[147] The maverick is a television, infrared, or laser-guided stand off air-to-surface missile with a shaped or fragmentary warhead. Follow-on stealth concepts are the advanced technology bomber (B-2), now in low rate production, and the advanced technology fighter (F-22), now in prototype testing. The B-2 is a long-range (seven thousand miles without refueling) subsonic multirole bomber capable of delivering virtually any modern weapon.[148] Its weapons bays can hold up to 16 cruise missiles, 16 laser-guided bombs, or 80 Mk-82 (500 lb.) bombs.[149] Like the F-117, it could perform the lethal SEAD role. The F-22 advanced tactical fighter prototype is capable of 1.58 Mach without after burner.[150] Its stealth and speed enable it to penetrate enemy airspace, attacking large aircraft formations or enemy AWACS. This latter role is an essential mission in future C^3/SEAD campaigns.

The final stars of Desert Storm were the standoff weapons. These included the short-range air-to-ground missile, AGM-130, the long-range TLAM, and the ATACMS. The AGM-130 is a rocket propelled, television, or imaging infrared guided Mk-84 bomb with a maximum range of 15 miles.[151] The weapon is currently in low-rate production. The TLAM missile is a long range cruise missile capable of low-level penetration at one hundred to three hundred feet and navigates using terrain contour matching. Two types of TLAM warheads were used in Desert Storm—a single 1,000 lb. warhead (TLAM/C) and a submunitions version containing up to 166 bomblets (TLAM/D). During Desert Storm, 288 TLAMs were fired—85 percent hit their targets.[152] ATACMS, though not as well known as the TLAM, is a deep attack, counterfire,[153] surface-to-surface missile. It uses millimeter wave[154] or infrared image matching for terminal guidance. The warhead is proximity-fused and contains armor-piercing submunitions designed to attack collocated targets within a limited area.[155] Both TLAM and ATACMS were used successfully in the lethal SEAD role during Desert Storm. Both are currently in production.

This brief review of current and planned SEAD systems highlights the technical fragility of the offense/defense balance. Many, if not all, of these systems, require long lead times in research and development. Choosing which technologies to fund and the degree to which to fund them are difficult choices. Making these tough choices requires an analysis of potential military threats, defensive capabilities, and probable military requirements.

Now that the cold war has subsided, what is the US defense threat? This is a puzzling question in an ever-changing world. It would be foolish to ignore completely the Commonwealth of Independent States (CIS) as a threat. It remains, even in this era of nuclear and conventional force reductions, the one nation in the world with the capability to destroy the United States. The United States must maintain its ability to deter or defeat the commonwealth. As for regional contingencies, a disturbing number of Third World countries possess formidable conventional forces that threaten US interests—as demonstrated by the Gulf War. A USAF white paper, produced by Air Force secretary Donald Rice on the eve of the Gulf War, titled "Global Reach—Global Power," addresses this uncertain threat.

> The combination of continued and emerging threats to national security interests, proliferation of sophisticated weapons, and reduced numbers of overseas U.S. forces in an unstable world presents new challenges for U.S. military forces. The likelihood that U.S. military forces will be called upon to defend U.S. interests in a lethal environment is high, but the time and place are difficult to predict.[156]

This uncertain threat poses a wide array of possible threats, requiring a force structure of versatile military forces, possessing rapid mobility for power projection, able to contain conflict and restore peace promptly.

These power projection forces must be prepared to thwart increasingly sophisticated radar-guided air defense systems. Air defenses since the Battle of Britain have used radar as the primary means to warn, locate, and intercept hostile aircraft. Technical advances in radar have steadily increased its detection range and tracking capability. In the past 25 years, the former Soviet Union spent over $235 billion on its integrated air defense system.[157] Recent improvements include deployment of Mainstay AWACS, look-down shoot-down interceptors, passive detection systems, better low-altitude coverage, and new phased-array radars with better detection, tracking, and height-finding capabilities-making penetration of sophisticated air defenses hazardous.[158] They also have a wide variety of SAMs as shown below.[159]

	SA2	SA3	SA4	SA5	SA6	SA8	SA9	SA10	SA11	SA12	SA13
RANGE (KM)	50	20	70	300	30	12	8	100	30	80	8
ALTITUDE	M	L-M	M-H	M-H	L-M	L	L	L-H	L-M	L-H	L

(L=Low, M=Medium, H=High)

The former Soviet Union has exported its air defense systems to many Third World nations. During the past decade, the USSR sold more than 32,000 SAMs (excluding man-portable systems) to Third World nations around the globe.[160] Weapons proliferation is expected to increase as the Russians, Chinese, French, and others expand arms exports to bolster their economies.

High-technology weapons proliferation, combined with the emerging post-cold-war environment of uncertainty, economic problems, and social unrest have produced an explosive world situation. In the event of conflict, probable military operational objectives would be "to neutralize or destroy enemy capability to resist, to limit his freedom of action and to disrupt his scheme of operations while at the same time enhancing our capabilities and shaping the battle to friendly force advantage."[161] To support these objectives, the air component commander would likely assign the following missions to his air forces in accordance with USAF doctrine:[162]

1. Locate enemy forces, assess capabilities, order of battle, and intent
   a. Surveillance and reconnaissance
2. Gain control of the air
   a. Defensive counterair (DCA)
      Combat air patrol
      Escort offensive air raids
   b. Offensive counterair (OCA)
      Attack enemy airfields
      Fighter sweeps
   c. Suppression of enemy air defenses (SEAD)
      Attack enemy command, control, and communications
      Destroy enemy early warning radars
      Destroy enemy communication nodes
      Destroy enemy command centers
   d. Attack surface to air missile sites
      SEAD escort of offensive air raids

3. Delay, disrupt, and destroy enemy combat power
   a. Strategic Attacks
      Destroy strategic weapons of mass destruction
      Destroy enemy's capacity to make war materials
      Destroy enemy's will to fight
   b. Interdict enemy follow-on forces and material
      Destroy transportation choke points
      Harbors
      Railroad switching yards and bridges
      Mine inland waterways
      Destroy road bridges
      Destroy troop concentrations and assembly areas
   c. Close air support of ground forces
4. Deny the enemy use of the electromagnetic spectrum
   a. Electronic counter measures
   b. Command, control, communications counter measures

These missions, though not all inclusive, highlight the pervasive operational requirements for avoiding, disrupting, or destroying enemy air defenses in conventional conflict. The interdependent nature of these missions necessitates incorporation of defense suppression into operational concepts to sustain combat power and achieve the operational objectives.

This concludes the analysis of theory, doctrine, history, technology, and operational military requirements with respect to defense suppression. The next section puts these principles, technologies, and operational requirements together to construct four operational concepts of defense suppression for evaluation.

Constructing Operational Concepts

The framework presented in this paper for constructing operational concepts is a modification of Kent's *Framework for Defense Planning*.[163] It asserts that operational concepts are influenced by three factors: operational requirements, theoretical principles, and technological possibilities. Operational requirements are derived from military objectives with regard to the probable military threat. They are defined in the form of roles and missions. These roles and missions are then matched with theoretical principles that offer the best prospect of accomplishing the requirement. Finally, technology is examined to determine what hardware best supports the theoretical principle in performing the operational requirement and achieving the operational objective.

Once constructed, the operational concept should be tested and evaluated by war gaming and further analysis. When the concept is fully developed and the weapon systems are fielded, it then becomes an operational capability. The military commander formulates his SEAD operation by selecting applicable operational capabilities that best match his situation. The conceptual linchpin of this framework is the operational concept. It brings together operational requirements, theoretical principles, and available technology to best meet the demands of operational objectives.

In constructing four operational concepts for defense suppression, the study will draw from information presented in the previous sections. At the conclusion of the history section, five fundamental principles were identified: offensive, intelligence, maneuver, surprise, and mass. The principles of offense and intelligence appear to underlie the latter three. Because suppression of enemy air defenses is part of the offensive counterair mission, all four concepts are based on taking offensive action. In addition, all four concepts rely on sound intelligence to avoid engagement or ensure a numerical advantage if an engagement should occur. The principles of maneuver, surprise, and mass will form the theoretical building blocks for each operational concept developed.

The first concept, which emulates Liddell Hart's indirect approach, relies on the principle of maneuver. The object of maneuver is to "place the enemy in a position of disadvantage through the flexible application of combat power."[164] The concept uses intelligence information to construct and update a near-real-time, three-dimensional "aerial terrain" map of the enemy's integrated air defense system (IADS), and uses maneuver to traverse this aerial terrain safely, improving the penetrability of nonstealth aircraft for deep attack. Intelligence sensors may include national "overhead" systems in addition to SIGINT collectors and penetrating UAVs. Mission planners use the aerial terrain map to determine the best penetration route (line of least resistance). IADS normally are finite with flanks, have a directional orientation, and are rarely strong in both depth and width—several preferred routes of penetration should be evident.[165] Flying wide-flanking routes around the strongest enemy defenses may require long-range aircraft or significant air refueling. The objective is to minimize or avoid IADS engagement.

Determining the most unobtrusive route is difficult. It requires the analysis of both defensive force deployment and human intelligence (HUMINT); collection. No commander can be certain of the enemy's expectations. He can, however, reinforce the most likely enemy expectations through deception. Decoy UAVs and standoff jammers can threaten attack on multiple objectives, and stimulate the IADS sufficiently to cause the enemy to commit its air-to-air interceptor reserves (distraction). The standoff ECM jammers announce to the defense that an attack is imminent while disrupting the defense and creating confusion. By using the same ECM barrage that normally precedes a large air attack, the defense should anticipate the attack and scramble defensive aircraft to intercept it as soon as the decoys are detected (dislocation of enemy force). This ploy reduces the defense's capability to defend against the actual attack.

The attacking force composition should be based on the enemy's defensive capabilities. A notional force would consist of Wild Weasels to suppress mobile SAMs, penetrating ECM jammers, escort fighters, and attack aircraft with PGMs. The global positioning system (GPS), in conjunction with high-altitude

UAV reconnaissance platforms and Fastball data link, could provide real-time targeting information or laser designation for standoff weapons. The priority SEAD targets would be: Early warning radar, communication nodes, command centers, air defense bases, and strategic (long-range) SAM batteries.

The second concept, called the stealth concept, relies on the principle of surprise. The concept uses stealth aircraft and cruise missiles to reduce the defender's warning time. Since virtually all air defense systems rely on radar as the primary sensor, the key to penetrating and defeating a sophisticated air defense network is whether radar can "detect aircraft and cruise missiles and direct forces against them."[166] This depends on the attacker's radar cross section (RCS) and speed. Lowering the RCS shortens the effective radar range, compounds the detection and tracking problem, and makes ECM more effective. A small RCS combined with speed reduces the effective range of an adversary's defenses to the point where they are essentially nullified. Stealth aircraft such as the F-117 and the B-2 are designed specifically to reduce their RCS as well as their infrared emissions. They are black and flown at night to take advantage of darkness for concealment. This night only characteristic is complemented with standoff missiles such as TLAM or air launched cruise missile (ALCM) which have a day or night capability. Their small RCS, accuracy, payload, and relative cost make them attractive weapons for defense suppression against fixed targets. Standoff missiles depend on a known target location, while stealth aircraft have greater endurance and range (with air refueling) for hunting and killing ground-based air defenses and C^3 nodes. Real-time intelligence using overhead sensors or UAVs can transmit targeting information via Fastball data link to target mobile air defense threats without revealing the stealth aircraft's location.

Contrary to popular belief, stealth aircraft are not invisible to radar. Flying in close proximity to a SAM or AAA site would unnecessarily risk this expensive asset. Therefore, a short-range, standoff weapon, using GPS internal guidance with a radiation, millimeter wave, or infrared imaging seeker would not reveal the launching platform. Stealth aircraft and long-range standoff missiles are expensive. In a limited operation, standoff missiles could provide more mass, at considerably less cost than stealth aircraft. In a lengthy campaign, however, the reusable nature of the stealth aircraft would prove less expensive. A balance of stealth aircraft and standoff missiles would provide a more robust force mix.

The third concept is based on the principle of mass and calls for simultaneous large-scale attacks. It relies on a large number of aircraft to saturate and overwhelm an air defense system at a given point. The defender is thus faced with a dilemma. Should he concentrate his SAM forces around key point targets, or spread his defenses out to form a series of defensive barriers? He can ill afford to grant the attacker air superiority over 80 percent of his territory or ignore the benefits of concentration in defending key facilities. He will likely compromise by spreading out long-range systems for maximum coverage and use short to medium range missiles for point defense. By spreading his defense assets, he can improve his chances of engaging attacking aircraft, but he cannot mass his dispersed defensive power to overcome it. Such a "thin" defense is susceptible to a mass simultaneous attack because airpower can concentrate in time and space to overwhelm it. The mass attack concept will not eliminate attrition to attacking aircraft, but it should lower the percentage of aircraft lost, since the defender cannot engage all of the attackers.

To enhance the inherent value of mass, the attacking force should be as large as possible, augmented with decoy UAVs or UAVs equipped with ECM payloads. Attacking aircraft require accurate weapons delivery capabilities, such as GPS updated inertial navigation system (INS) or laser designation. In addition, the use of multirole aircraft can act as a force multiplier, since multirole aircraft can switch between the escort, attack, and SEAD roles. In the SEAD role, all aircraft should be able to carry the HARM missile. Dedicated ECM escort jammers may be necessary to degrade air defenses sufficiently to achieve saturation. Additionally, air, land, and naval power should be combined to multiply the attacking mass. This offensive effort should put extreme pressure on a narrow front, creating confusion and panic, thus limiting the defense's ability to respond in a coordinated manner.

The fourth concept relies on a balanced combination of surprise and mass. It emulates the two previous concepts to a degree, and strives to achieve a synergistic effect. Stealth attacks on early warning radar and air defense C^3 nodes "paralyzes" the enemy's ground-based air defenses and prevents a timely defensive response. This blinding of the enemy air defense allows nonstealth aircraft to attack with enhanced survivability. To exacerbate this vulnerable situation, nonstealth aircraft should attack in mass to saturate and overwhelm the degraded air defense system. Use of decoy UAVs should draw fire away from the aircraft penetrating the defensive network, while compounding the attacking mass and the effects of air defense saturation.

As in the mass concept, the balanced concept should include multirole aircraft capable of changing roles or performing two simultaneously, such as attack aircraft providing their own air-to-air or SEAD escort. When the SAM or air-to-air threats are reduced the multirole aircraft can gradually be switched to attack. Dedicated penetrating and standoff jammers (ECM and C^3CM) may be necessary for nonstealth penetration, until stealth attacks achieve defense paralysis.

Michael Howard's criteria of operational requirement, technological feasibility, and financial capability will serve to evaluate the validity and usefulness of these concepts.[167] Financial capability is fixed, using identical budget allocations for purchasing hardware. To ensure the technical feasibility of each concept, only current weapon systems or systems in development with the capability of reaching an initial operational capability (IOC) by 1997 (regardless of their congressional funding situation) will be considered. The variable measurement of effectiveness will be based on the operational requirement of preserving one's own force, while neutralizing or destroying the enemy's.

Concept Force Procurement

This chapter completes the concept formulation by designing a force structure. The weapon systems that best match the operational concept's principle and objective will be procured under the constraints of a 3 billion-dollar budget. This budget fixes the cost variable for each concept force, demonstrating affordability. The procurement costs are included in the aircraft unit flyaway cost.[168] Most of the costs are in FY89 dollars and extracted from Air Force Regulation (AFR) 173-13, *USAF Cost and Planning Factors*. Weapon systems cost figures not included in AFR 173-13 were extracted from congressional testimony.[169]

Overhead national reconnaissance assets are assumed to be available for all four-concept forces. To speed near-real-time intelligence to aircrews, all aircraft are assumed to have the Fastball data link. Additionally, a supplementary intelligence force consisting of RC-135 SIGINT aircraft, endurance concept reconnaissance UAVs, AWACS, JSTARS, and ABCCC will collect and distribute intelligence and control forces via Fastball data link.

Aircraft bases are assumed to be secure to limit the scope and purpose of the four concept forces. Air-to-air capability in each concept is strictly for self-defense and escort purposes.

Indirect Approach Force Structure

This concept (shown in list below) contains F-4G Wild Weasels for SAM suppression, F-15C escort fighters, F-15E fighter bombers, RF-16 reconnaissance fighters for UAV launching, EF-111A penetrating ECM jammers, EC-130E standoff communications jammers, KC-135E air refueling tankers, and medium range concept decoy UAVs. The F-4G was included primarily because of its economical price, when compared to a comparably equipped F-15E Wild Weasel. The F-15E was chosen as the primary fighter bomber because of its longer range, multirole flexibility, and precision-guided ordnance delivery capabilities.

Type Aircraft	Cost in Millions	Quantity Purchased	Total Cost
F-4G	$15.7	12	$188.4
F-15C	$32.2	12	$386.4
F-15E	$30.7	42	$1,289.4
F-16D	$13.7	6	$82.2
EF-111A	$73.9	6	$443.4
EC-130E	$21.8	6	$130.8
KC-135E	$26.1	16	$417.6
Decoy UAV	$1.0	62	$62.0
			$3,000.2

Stealth Concept Force Structure

The stealth concept (listed below) contains a mixture of P-117A, B-2, and TLAM. A mix of F-117A and B-2 aircraft provides greater targeting flexibility. The B-2 has much longer range, can carry four times the precision ordnance, and if necessary can deliver a heavy load of unguided bombs or mines. TLAMs provide a 24-hour strike capability. A small contingent of refueling assets can extend the F-117's range if required.

Type Aircraft	Cost in Millions	Quantity Purchased	Total Cost
B-2	$476.7	4	$1,906.8
F-117B	$64.0	12	$768.0
KC-135E	$26.1	3	$78.3
TLAM	$1.0	247	$247.0
			$3,000.1

Mass Concept Force Structure

This below-listed concept relies on a large number of multirole aircraft capable of accurate weapons delivery. The shorter range F-16D was chosen over the F-15E primarily because it was half the cost of an F-15E, while still delivering a diverse list of capabilities. ECM protection is provided by three sources, ASPJ, EF-111s with an upgraded AN/ALQ-99, and the medium range concept UAV with an ECM payload. Standoff communications jamming is provided by EC-13OEs. For lethal SEAD, the F-16 can carry two HARM missiles. Compared to the F-4G Wild Weasel, the F-16 has about one-half the effectiveness because its RHAW system cannot determine range to the emitter. To compensate for this reduced capability larger numbers of SEAD aircraft and decoys will be used. KC-135E air refueling tankers are necessary to extend the range of the F-16s for deeper penetration. To magnify the size of this force, 107 reusable medium range concept UAVs were purchased for decoys. One F-16 can carry and launch five UAVS.

Type Aircraft	Cost in Millions	Quantity Purchased	Total Cost
F-16D	$13.7	124	$698.8
EF-111A	$73.9	6	$443.4
EC-130E	$21.8	6	$130.8
KC-135E	$26.1	21	$548.1
ECM UAV	$3.0	24	$ 72.0
Decoy UAV	$1.0	107	$107.0
			$2,000.1

Balanced Concept

This concept (listed below), like the mass concept, relies on a large number of multirole aircraft. In addition F-117 stealth fighters are included for attacks against heavily defended C3 and strategic defense systems. Ten F-117s were procured instead of one B-2 to cover several targets simultaneously and avoid the risk of losing all stealth capability if one B-2 was lost for any reason. The F-16 and reusable decoy UAVs were selected to emphasize mass. A tradeoff in range was consciously made to achieve sufficient mass. KC-135E air refueling tankers are included to maximize the F-16's and F-117's range. As in the mass concept, ECM protection is provided by ASPJ pods, EF-llls, and UAVs with an ECM payload. EC-13OEs will be used for communications jamming.

Type Aircraft	Cost in Millions	Quantity Purchased	Total Cost
F-16D	$13.79	8	$1,342.6
F-117	$64.0	10	$640.0
EF-111A	$73.9	5	$369.5
EC-130E	$21.8	3	$65.4
KC-135E	$26.1	18	$469.8
ECM UAV	$3.0	16	$48.0
Decoy UAV	$1.0	65	$65.0
			$3,000.3

The concept forces have some similarities, but they appear sufficiently diverse to permit some conclusions on their performance in the war game to follow. The next section tests the operational effectiveness of each concept force in a simulated 28-day air campaign using the TAC air war game.

Testing Operational Effectiveness

The discussion to this point has been a framework for developing operational concepts to satisfy the operational requirement of air defense suppression, a subset of the counterair role. The objective of defense suppression is to enhance and sustain offensive combat capability. The following five criteria will be used to measure sustained combat capability:

1. Total number of enemy targets destroyed.
2. Offensive combat power remaining.
3. Percentage of "offensive" aircraft remaining.
4. Dollar value of hardware remaining.
5. Average cost per target destroyed.[170]

Red Force Description

The Red air defense forces for this simulation consist of 70 SA-6 missile launchers, 30 SA-12 missile launchers, 24 MiG-31s, 12 MiG-29s, and 24 MiG-23s. Red territory (shown below) has been divided into nine sections

Northwest	North	Northeast
5 SA-6	5 SA-6	5 SA-6
West	**Central**	**East**
12 MiG-31	12 MiG 29	12 MiG 31
12 MiG-23	12 MiG-23	12 MiG 31
5 SA-6	15 SA-6	5 SA-6
	15 SA-12	
Southwest	**South**	**Southeast**
5 SA-6	5 SA-6	5 SA-6
15 SA-12	15 SA-12	15 SA-12

(NW, N, NE, W, C, E, SW, S, and SE). Red interceptor forces were divided into three zones (West, Central, and East).

This force deployment conforms to the characteristics described by Warden. They are directional in nature (oriented southward), layered in depth, with reduced strength on flanks and rear.

Summary of TAC Air Game Rules

The actual game rules are extensive and detailed. This summary will highlight the rules used in this simulation and factors not covered in the game rules.[171] All Blue aircraft have a constant 90 percent mission capable rate. At any time only 90 percent of the available aircraft can fly. All tactical fighters fly in two-ship flights except stealth aircraft. The combat power of each weapon system used is listed below.

	Blue							**Red**	
	Offense				Defense			Offense	
A/A	*A/G*		*HARM*		*A/A*	*SAM*		*A/A*	*SAM*
1 F-4G	1		3.5		1.5	1.5	1 MiG-31	2	
1 F-15C	2.5				2.5	0.5	1 MiG-29	2	
1 F-15E	2.5	2.5			2.5	2.5	1 MiG-23	1.5	
1 F-16D	2	2/1	2		2	2	1 S/A-6		3
1 EF-117B		5			10	10	S/A-12		4
1-111				2	2				
1 B-2	20			10	10				
1 TLAM		1			2	2			
1 ECM UAV					2	2			
1 Decoy UAV				1	1				

Any time an EF-111 is escorting a strike force, Red offensive factors are reduced by two and radar range is reduced to one-third of normal. Standoff C^3CM jamming by EC-130s in concepts one, three, and four reduce Red air defense command and control by 50 percent. Ongoing SEAD efforts in all concepts degrade Red SAM batteries at the constant rate of 3 percent. SAM engagements are computed using these degradations, aircraft routing, ECM, C^3CM, and stealth qualities. For example, on Day 1, Concept One flew through two air defense zones containing a total of 35 SAMs (35 SAMs x .3 ECM degrade x .5 C^3CM degrade x 1.0 stealth degrade) = 6 SAM engagements. Five pairs of F-4Gs successfully suppress five of the six SAM engagements. The remaining SAM destroys one aircraft. The type aircraft lost was selected randomly. Interceptor engagements were computed similarly with the addition of a random night degrade. One-third of interceptor engagements resulted in a Blue aircraft lost.

The number of targets destroyed was computed according to the TAC Air combat results, which indicates a combat power of eight is sufficient to destroy one target. To calculate the total amount of damage each force package could deliver, a simple formula was used: number of targets destroyed equals the number of successfully penetrating aircraft times their air to ground (A/G) combat power divided by eight. The F-16's degraded night capability was factored in using a 50 percent reduction in night air to ground combat power (1 versus 2). For example, to destroy one target during daylight, four F-16s must penetrate successfully, 1-(4x2)/8. EC-130s and KC-135s do not penetrate enemy airspace and are not attrited.

These equations were placed into a spreadsheet computer program to determine sorties generated, SAM degradation due to SEAD, SAM engagements, air-to-air engagements, aircraft losses, and enemy targets destroyed. A random number generator was used to factor chance into engagements and aircraft losses. A duration of 28 days was used to assess the effects of attrition on operational effectiveness and combat force preservation in an air only phase similar to Operation Desert Storm. All concepts were tasked to penetrate and attack targets in the central air defense zone (see Red Force Description).

The concept of employment for the indirect approach was to penetrate either the west or east zones for attacks against targets located in the central air defense zone. F-15E range limitations prevented penetration via the northern sectors. Deception jamming and decoys were used along the southern front to draw interceptors away from the strike package. The B-2s in the stealth concept had sufficient range to penetrate via any air defense zone. The F-117s, even with air refueling, could only penetrate through the south zone due to their limited range. The mass attack concept lacked the range to fly around the flanks and was limited to penetrating the southern sectors to reach targets in the central zone. The balanced concept mirrors the mass attack, but it also includes F-117s which penetrate independently from the F-16s. The detailed war game results are located in the appendix.

Simulation Results Summary

	Targets Destroyed	Power Remaining	Aircraft Remaining	Dollar Value	Cost Per[172] Target
Indirect	481	150	62.5%	$2,050.2	$1.975
Stealth	378	135	93.8%	$2,689.1	$0.823
Mass	690	252	67.7%	$2,253.3	$1.082
Balanced	647	242	69.0%	$2,423.6	$0.891

Ranking by Category

	Targets Destroyed	Power Remaining	Aircraft Remaining	Dollar Value	Cost Per Target
Indirect	3	3	4	4	4
Stealth	4	4	1	1	1
Mass	1	1	3	3	3
Balanced	2	2	2	2	2

These criteria should be weighted to determine the best concept. By weighting each criteria equally you gain no real insight, other than possibly discovering the most robust concept that performs reasonably well under all criteria. The commander's guidance and/or the campaign objectives are a good source for determining how these criteria should be weighted. improper weighting can skew the results away from the optimum solution.

Just by looking at rank by category, the balanced concept appears the most robust (ranking number two in all criteria). On the other hand, if only one criterion mattered, say "Targets Destroyed," then the mass concept would be the best choice, since it dominates all other concepts in that criterion. The following chart assigns a percentile score for each criterion: Top rank receives 1.00, bottom rank receives 0.0, and the two in between are assigned a percentile score depicting their proximity to the top and bottom rankings. The underlined values indicate the top percentile score for each weight.

Percentile Score by Category

	Targets Destroyed	Power Remaining	Aircraft Remaining	Dollar Value	Cost Per Target	Average Score	Rank
Indirect	.33	.13	.00	.00	.00	.09	4
Stealth	.00	.00	1.00	1.00	1.00	.60	3
Mass	1.00	1.00	.17	.32	.77	.65	2
Balanced	.86	.91	.21	.58	.94	.70	1

The balanced concept had the best average percentile score (.70) and appears to be the most robust concept when all criteria are weighted evenly. Next (the following listings), a parametric sensitivity analysis illustrates the change in percentile scores when one criterion is weighted more heavily in relation to the others.

Overall Percentile Score
If Targets Destroyed Were Weighted

	20%	30%	40%	50%	60%	70%
Indirect	.09	.12	.15	.18	.21	.24
Stealth	.60	.52	.45	.37	.30	.22
Mass	.65	.70	.74	.78	.83	.87
Balanced	.70	.72	.74	.76	.78	.80

Overall Percentile Score
If Power Remaining Were Weighted

	20%	30%	40%	50%	60%	70%
Indirect	.09	.10	.10	.11	.11	.11
Stealth	.60	.52	.45	.37	.30	.22
Mass	5	.70	.74	.78	.83	.87
Balanced	.70	.73	.75	.78	.81	.83

Overall Percentile Score
If Aircraft Remaining Were Weighted

	20%	30%	40%	50%	60%	70%
Indirect	.09	.08	.07	.06	.05	.03
Stealth	.60	.65	.70	.75	.80	.85
Mass	.65	.59	.53	.47	.41	.35
Balanced	.70	.64	.58	.52	.45	.39

Overall Percentile Score
If Dollar Value Remaining Were Weighted

	20%	30%	40%	50%	60%	70%
Indirect	.09	.08	.07	.06	.05	.03
Stealth	.60	.65	.70	.75	.80	.85
Mass	.65	.61	.57	.53	.48	.44
Balanced	.70	.69	.67	.66	.64	.63

Overall Percentile Score
If the Cost Per Target Was Weighted

	20%	30%	40%	50%	60%	70%
Indirect	.09	.08	.07	.06	.05	.03
Stealth	.60	.65	.70	.75	.80	.85
Mass	.65	.67	.68	.70	.71	.73
Balanced	.70	.73	.76	.79	.82	.85

War Game Results Analysis

The balanced concept appears to be the most robust alternative in this simulation. The stealth performed best in three categories, however, it finished last in targets destroyed and combat power remaining. The low starting combat power and the night-only sortie restriction dramatically reduced this concept's overall value. The Tomahawk cruise missiles used in the stealth concept to compensate for the daytime restriction contained insignificant combat power, when compared to either the F-117 or the B-2. In fact, had three F-117s been procured instead of Tomahawks, approximately 21 more targets could have been destroyed during the 28-day period and the cost per target reduced to $160,000. The most desirable characteristic of this stealth force is its survivability. The stealth concept had a dramatically low attrition rate, flawed by the loss of one aircraft. Yet the loss of a B-2 instead of an F-117 would have reduced the number of targets destroyed by approximately 20 percent, and the dollar value remaining to within 23 million of concept three.

Stealth's survivability characteristic could prove extremely valuable in some contingencies, where low or no attrition is the overriding constraint. However, stealth's night-only restriction permits the enemy to operate undisturbed during the day. Permitting enemy freedom of action during daylight would likely be unacceptable in a sustained 28-day air campaign.

The value of mass was evident in the large number of targets destroyed by the third concept force (top ranked in targets destroyed and power remaining). Even on the 28th day, the mass concept destroyed more targets than the other three. If the simulation had continued, it seems reasonable that the mass and balanced concepts would have continued to perform well, given the incapacitated state of Red air defenses. The mass and balanced options are best applied in large-scale raids which maximize the amount of damage inflicted on saturated defenses. Smaller raids would be expected to destroy fewer targets, at a similar or greater cost in aircraft lost. The decoys worked well in the simulation. Had decoys not drawn fire from the attacking force, all five measures of effectiveness would have scored lower.

In this simulation, the indirect approach was unable to circumvent the air defenses sufficiently to reduce its losses. The point defenses in the central zone could not be avoided. The benefit of flying around the flanks subjected the attackers to the eastern or western interceptors as well as the central interceptors. The ECM and decoy diversion helped to reduce the number of intercepts, but not enough to gain a significant advantage over the mass concept. If the Red air defense relied on a linear deployment of ground based air defenses, the indirect approach would probably have suffered less attrition and destroyed a greater number of targets. The mobile nature of an interceptor force and point defenses reduces the probability of avoiding air defense engagement when using the indirect approach. A static defense without depth is the ideal defense to attack using the indirect approach.

This simulation defines some clear distinctions between the four concepts. The dichotomy between productivity (targets destroyed) and cost ("dollar value") is clearly evident. The "cost per target destroyed," uses both productivity and cost measures of effectiveness: ("cost per target" [3 billion—"dollar value"] divided by "targets destroyed"). It illustrates the efficiency of target destruction. However, efficiency may likely be a subordinate concern in combat when vital national interests are at stake.

Warfare demands flexibility. The uncertain threat facing the United States demands a balanced flexible force structure. Each concept has inherent advantages and disadvantages. The combination of surprise and mass in the balanced concept illustrated the synergistic effect demonstrated during Operation Desert Storm. A small contingent of stealth aircraft can destroy key military targets quickly, accurately, and with high survivability. This blinding of the enemy air defense creates its own indirect approach and opens an opportunity for nonstealth aircraft to penetrate and attack in mass against a reduced threat enhancing their survivability.

This analysis emphasizes the need for a balanced force structure with emphasis on intelligence, stealth, standoff weapons, UAVs, and an inexpensive fighter to reap the rewards of simultaneous mass attacks. Accurate intelligence was fundamental to all of the concepts. Each concept depended on accurate knowledge of enemy air defenses and targets. The Fastball capability, in conjunction with UAVs and national overhead reconnaissance collectors, offers near-real-time intelligence dissemination of threat advisories, accurate threat locations for targeting standoff weapons, and command and control of the attacking force. The value of standoff cruise missiles was not illustrated in the simulation. They offer enhanced accuracy and responsiveness to defense suppression. However, their limited payload and high cost restrict their usage to high value, soft targets, located in a high-threat area, such as C^3 nodes. All of these high technology systems are limited in quantity. They should be balanced with some measure of quantity to exploit the advantages created by the high-technology systems. A number of relatively inexpensive fighter aircraft with multirole capability can add flexibility and mass to the commander's capabilities. Together, these systems can provide a synergistic effect on defense suppression operations and the overall air campaign.

Future Implications . . . So What?

Technological change creates a constant shift in the offense-defense dialectic. Military leaders must be aware of this relationship to prevent doctrine from becoming dogma. Using an operational framework that systematically joins operational requirements, theoretical principles, and available technology, campaign planners can conceive operational concepts that are responsive to this dialectic. These concepts should then be evaluated and refined by further war gaming, intelligence collection, and technology development. Once a concept is validated and hardware acquired it is transformed into an operational capability. Threat changes and technological developments will continue to test the operational capability and it should be expected to undergo ongoing improvements.

Suppression of enemy air defenses must be an integral part of an offensive air campaign to reduce combat attrition and gain control of the air over the battlefield. The campaign planner has many options available to overcome air defenses. An understanding of theory, doctrine, history, and available technology will assist him in defining the best concepts to suppress enemy air defenses. It is unlikely the enduring principles discussed in this study will change significantly.

Though the principles are unlikely to change, air force doctrine will continue to evolve. Technology will change the way we employ airpower. The development of stealth aircraft illustrates this point. Stealth obviates the need for air defense suppression for itself. However, it offers an excellent tool to suppress the most difficult air defenses, so nonstealthy aircraft can operate with greater freedom of action. USAF operational doctrine should address how stealth aircraft can be incorporated into roles and missions and provide some guidance on which are most appropriate.

USAF basic doctrine should consider adding intelligence as a principle of war. The principle of intelligence appears to underlie all others, for without knowledge of the enemy's defenses and vulnerabilities, military force cannot be focused in a timely manner at the decisive point. Additionally, USAF basic doctrine should emphasize the value of defense suppression in sustaining combat power. The projected retirement of the F-4G Wild Weasel without a replacement aircraft in production illustrates a perceived low priority of the defense suppression mission in relation to the other air control missions.

This study suggests future USAF force structure should emphasize stealth technologies, standoff weapons, real-time reconnaissance, inexpensive UAVs, deception forces, lethal SEAD, electronic warfare, and C^3CM. These quality improvements should be balanced by a large inventory of relatively "inexpensive" multirole aircraft. The stealth concept illustrated the cost effectiveness of stealth at the expense of reduced productivity. The overwhelming damage achieved by the simultaneous mass attack concept demonstrates the value of decoy UAVs, HARMs, ECM, and C^3CM in degrading and saturating an air defense with a large number of aircraft. Procurement of Fastball or a similar real-time intelligence dissemination system is necessary to pass information down for mission planning and improve airborne situational awareness.

Conclusion

Our Desert Storm Forces drew upon twenty plus years of investment. Future capabilities will depend on decisions made today.

—Secretary Donald Rice, USAF
26 February 1991

The effectiveness of any air campaign in today's modern air defense environment depends on the selection of the appropriate operational concept for defense suppression—without it, offensive strength will diminish rapidly.[173] A balanced force structure of high-technology weapon systems, mixed with a large number of reasonably capable multirole aircraft, provides a high/low synergistic mix.

Future analytical studies may be necessary to explore these four concept forces more fully, using actual aircraft capabilities with a more sophisticated defense model to refine the results of this simulation. There is a need for an unclassified computer war game model flexible enough to accept a variety of force structures, but still able to adjudicate accurately engagement outcomes. A war game of this nature would be an excellent learning tool and sounding board for strategic and operational thought.

Notes

1. William S. Lind, "The Operational Art," *Marine Corps Gazette*, April 1988, 45. "The operational art is the art of using tactical events—battles and refusals to give battle—to strike directly at an enemy's strategic center of gravity. In other words, it is the art of deciding when and where to fight battles, and when and where not to, on a strategic basis. It includes the idea that a goal is to win strategically with the fewest possible battles."

2. Air Force Manual (AFM) 1-1, *Basic Aerospace Doctrine of the United States Air Force*, vol. 2, March 1992, 46. "The operational level is concerned with employing military forces in a theater of war or theater of operations to obtain an advantage over the enemy and thereby attain strategic military goals through the design, organization, and conduct of campaigns and major operations."

3. Glenn A. Kent, *A Framework for Defense Planning* (Santa Monica, Calif.,: RAND, August 1989), 16–24.

4. Tactical Air Command *Air: The Game of Modern Air-Land Battles in Germany* (Baltimore, Md.: Avalon Hill Game Co., 1987). The actual war game scenario is considerably larger and longer than TAC Air was designed. In addition, the game emphasizes the defense suppression and interdiction aspects of the game and ignores the close air support aspect of the game. Actual game combat factors are used, except for those systems not included in the game which had to be created. Combat resolution and results are determined in accordance with actual game rules.

5. Carl von Clausewitz, *On War*, ed. and trans. Michael Howard and Peter Paret (Princeton, N.J.: Princeton University Press, 1976), 357.

6. Ibid., 361.

7. Ibid., 364.

8. Ibid., 360.

9. Ibid., 362.
10. Ibid., 360.
11. Ibid., 365.
12. Ibid., 528.
13. Ibid., 595–96.
14. Ibid., 679.
15. Basil Henry Liddell Hart, *Strategy* (New York: Praeger, 1967), 325.
16. Ibid., 279.
17. Ibid., 309.
18. Giulio Douhet, *The Command of the Air* (New York: Coward-McCann, 1942). The last chapter, "The War of 19_, " is Douhet's hypothetical conflict between Germany and the coalition of Belgium and France. France and Belgium procured a diverse and balanced air force of 14 different types totaling 5,976 aircraft. Germany on the other hand, procured only one type of plane, the battleplane, capable of self defense and aerial bombing. The German Air Force consisted of 1,500 battle planes. During the two-day war both sides received heavy losses of aircraft. By the end of the second day 250 battle planes remained and the French and Belgians were incapable of mounting any substantial aerial defense to protect their cities from destruction.
19. Alfred F. Hurley and Robert C. Ehrhart, ed., *Airpower and Warfare* (Washington, D.C.: Government Printing Office [GPO], 1978), 42.
20. *The United States Strategic Bombing Surveys, Summary* Report (Maxwell Air Force Base [AFB], Ala.: Air University Press, October 1987), 39.
21. John A. Warden III, *The Air Campaign: Planning for Combat* (Washington, D.C.: National Defense University Press, 1988), 29.
22. Ibid., 178.
23. Ibid., 170.
24. Ibid., 26.
25. Ibid., 36.
26. Liddell Hart, 343. Clausewitz was pessimistic on whether surprise could be achieved and cautioned not to depend on surprise; however, he stated, "We suggest that surprise lies at the root of all operations without exception, though in widely varying degrees depending on the nature and circumstances of the operation." (*On War*, 198)
27. Warden, 178.
28. Michael Handel, ed., "Clausewitz in the Age of Technology," *Clausewitz and Modern Strategy* (London: Frank Cass, 1986), 65.
29. There is a major difference between a vulnerable point and a center of gravity. A center of gravity is ". . . the hub of all power and movement, on which everything depends." (*On War*, 595). A vulnerable point or vulnerability is a weakness through which the center of gravity can be reached and attacked. If no vulnerable point can be found, the attacker must create a vulnerability, by use of deception or diversion to dislocate enemy forces or by reinforcement of sufficient mass to create a vulnerable point.
30. *Webster's New World Dictionary,* 1985 ed., s.v. "doctrine."
31. AFM 1-1, vol. 1, March 1992, 6.
32. Ibid., 10.
33. AFM 1-1, vol. 2, March 1992, 304.
34. AFM 1-1, vol. 1, March 1984, 2–13.
35. Ibid., 11.
36. Ibid., 2–13.
37. Ibid., 16.
38. Great Britain Royal Air Force, *Royal Air Force Airpower Doctrine: United Kingdom (Wakingham, Bershire: Twin-Tone, 1991),* 90.
39. Ibid., 40.
40. Ibid.
41. Ibid., 33.
42. Ibid., 95.
43. Ibid., 36.

44. Ibid., 36.

45. Ibid., 36.

46. Ibid., 94.

47. Gen John W. Vogt, commander in chief, Pacific Air Forces, address to the Air Force Association, Honolulu, Hawaii, 15 November 1973, 15 [AFRHC K168.06-234]; James R. McCarthy and George B. Allison, *Linebacker II: A View from the Rock,* Robert E. Rayfiels, ed., USAF SEA Monograph Series (Washington, D.C., 1976), 40; and Mark Clodfelter, *The Limits of Airpower: The American Bombing of North Vietnam* (New York: Free Press, 1989), 177–78.

48. William W. Momyer, *Airpower in Three Wars* (Washington, D.C.: GPO, 1978), 240; and Clodfelter, 182.

49. Clodfelter, 187.

50. Kenneth P. Werrell, *Archie, Flak, AAA, and SAM: A Short Operational History of Ground-Based Air Defense* (Maxwell AFB, Ala.: Air University Press, 1988), 125.

51. McCarthy, 40.

52. Werrell, 109 and 118. The Air Force modified two seat F-105s by installing radar homing and warning (RHAW), electronics equipment that could detect SAM radar and indicate its location. The aircraft were redesignated F-105G. Armed with antiradiation missiles (ARM) it was code-named Wild Weasel.

53. Lon O. Nordeen Jr., *Air Warfare in the Missile Age* (Washington, D.C.: Smithsonian Institution Press, 1985), 18. An Iron Hand flight consisted of one F-105 Wild Weasel to seek out SAM radar emissions and three other F-105s carrying bombs or rockets to destroy the SAM site.

54. McCarthy, 31.

55. Ibid., 8–9; and Werrell, 121.

56. Momyer, 131.

57. McCarthy, 9.

58. Lloyd Houchin, ed., *The Battle for the Skies over North Vietnam 1964–72*, 93.

59. Werrell, 122. On the third night, ". . . all of the B-52s downed were five to ten miles from chaff cover." Strategic Air Command briefing, subject: "Chaff effectiveness in Support of Linebacker II Operations, March 1973, Air Force Historical Research Center (AFHRC)-Kl68.06-223, slide 31.

60. Ibid., 122. The North Vietnamese used a radar designed and deployed for gun control to guide the SA-2s. The radar operated in the 1-band frequency range, which Americans were incapable of jamming at the time.

61. McCarthy and Allison, 172. "Of the total sortie count of 729 B-52s, 498 penetrated the especially high threat zones immediately surrounding Hanoi and Haiphong. These aircraft experienced a 4 percent loss rate." See Werrell, 121. ". . . overall B-52 loss rate of 3 percent. . . ."

62. John F. Kreis, *Air Warfare and Air Base Air Defense* (Washington, D.C.: Office of Air Force History, 1988), 295.

63. Nordeen, 72.

64. Ibid., 72.

65. Clodfelter, 188.

66. Headquarters Pacific Air Forces, "Linebacker II USAF Bombing Survey," April 1973, 42. Information extracted is unclassified. AFHRC file number: K717.64-8.

67. Nordeen, 72.

68. Kreis, 295.

69. Clodfelter, 198.

70. Ibid., 189.

71. US Military Equipment Validation Team, Israel (USMEVTI), "Trip Report to Israeli Defense Forces, 28 October – 8 November 1973," 1-2. Information extracted is unclassified. AFHRC file number: K178.203-20.

72. Ibid., 2.

73. Chaim Herzog, *The Arab-Israeli Wars: War and Peace in the Middle East* (New York: Random House, 1982), 228.

74. Ibid., 229.

75. Ibid.

76. Ibid., 309–10.

77. Ibid., 311.

78. Lon O. Nordeen, *Fighters over Israel: The Story of the Israeli Air Force from the War of Independence to the Bekaa Valley* (New York: Orion Books, 1990), 128.

79. USMEVTI, Addendum c.

80. Werrell, 141.

81. Ibid.

82. Nordeen, *Fighters over Israel,* 130.

83. Mike Gaines, "Pilotless over the Battlefield," *Flight International,* December 1979, 1837.

84. Nordeen, *Fighters over Israel,* 130.

85. Ibid., 127.

86. Herzog, 310.

87. Ibid., 260.

88. Nordeen, *Airpower in the Missile Age,* 158.

89. Nordeen, *Fighters over Israel,* 38.

90. Ibid., 141.

91. Herzog, 310.

92. USMEVTI, 5.

93. Nordeen, *Fighters over Israel,* 148.

94. USMEVTI, 9.

95. Matthew M. Hurley, "The Bekaa Valley Air Battle, June 1982: Lessons learned?" *Airpower Journal,* Winter 1989, 61.

96. Werrell, 146.

97. Ibid., 147.

98. Hurley, 64.

99. Nordeen, *Air Warfare in the Missile Age,* 182.

100. Mark G. Ewig, "Surprise from Zion," *Air University Review,* September–October 1984, 55.

101. Nordeen, *Air Warfare in the Missile Age,* 182.

102. Werrell, 147.

103. AFM 1-1, vol. 2, 288. "Joint. Connotes activities, operations, organizations, etc., in which elements of more than one Service of the same nation participate."

104. Ewig, 53.

105. House of Representatives, *Department of Defense Appropriations for 1992: Hearings before the Subcommittee of the Committee on Appropriations,* 102d Cong., lst sess., 1991, 460 and 520.

106. House, 476.

107. Lt Gen Charles A. Horner, "The Air Campaign," *Military Review,* September 1991, 21–22.

108. James P. Coyne, "A Strike by Stealth," *Air Force Magazine,* March 1992, 40.

109. Ibid., 40.

110. Ibid., 40 and 44.

111. Ibid., 40.

112. House, 468.

113. Horner, 23.

114. Group Capt Andrew Vallance, "Royal Air Force Operations in the Gulf War," *Airpower History,* Fall 1991, 36.

115. Maj Gen John Corder, Air Warfare Center, Eglin AFB, Fla., interviewed by author, 10 February 1992.

116. House, 482.

117. Corder.

118. "Wild Weasels: Electronic Wizards of Desert Storm," *Popular Science,* May 1991, 73.

119. Hal Gershanoff, "EC in the Gulf War," interviewed by Maj John Corder, *Journal of Electronic Defense,* May 1991, 46.

120. Ibid., 46.

121. House, 489; and James W. Canan, "Washington Watch: No More SAC, TAC, and MAC," *Air Force Magazine*, October 1991, 15.

122. House, 137.

123. James W. Canan, "Lesson Number One," *Air Force Magazine*, October 1991, 31.

124. Group Capt Andrew Vallance, "The Gulf War: First Thought on the Use of Airpower in Crisis Management and Conflict," *Hawk*, 1991, 31.

125. Ibid., 29.

126. Dan Hampton, "Combat Defense Suppression," *Journal of Electronic Defense*, May 1991, 89.

127. Andrea Nativi, "Any Early Lesson?" *Military Technology*, April 1991, 57.

128. Ibid., 57.

129. Ibid.

130. R. A. Mason, "The Air War in the Gulf," *Survival*, May–June 1991, 216. "Digital maps of the area from the US Defense Mapping Agency were overlaid with US signals intelligence data which showed the locations and effective radius of Iraqi air defence radar. This allowed allied planners to devise effective counter-tactics, through careful positioning of defence suppression aircraft and accurate preprogramming of allied aircraft radar warning receivers." (Mason also cites *Aviation Week & Space Technology*, 12 November 1990).

131. Lt Col Ernest G. Howard, coined the phrase "aerial terrain" when describing flying through the obstacles of an integrated defense system during a seminar while providing comments on this paper, 19 December 1991.

132. Corder.

133. James W. Rawles, "Air Force Plans a Wilder Weasel," *Defense Electronics*, September 1990, 41–46.

134. Duncan Lennox and Arthur Rees, eds., *Jane's Air-Launched Weapons* (Alexandria, Va.: Jane's Information Group, 1990).

135. "On the Trail of a Weasel Successor," *Jane's Defence Weekly*, 9 February 1991, 185.

136. Corder.

137. "On the Trail of a Weasel Successor," 185.

138. Gershanoff, 46.

139. Darryl T. Gehly, "Business as Usual, Wright-Patterson EW Houses Again Face Change, But Continue to Produce," *Journal of Electronic Defense*, September 1991, 61.

140. Ibid., 66.

141. White Paper, "Air Force Performance in Desert Storm," Department of the Air Force, April 1991, 14.

142. Stephen M. Hardy, "Air Force Hits the Intelligence Fastball," *Journal of Electronic Defense*, January 1992, 29.

143. White Paper, 12.

144. "Unmanned Aerial Vehicle Master Plan," Department of Defense, 1 March 1991, 9, 16, 17, and 32.

145. Col Manuel W. Garrido, Project Manager Unmanned Aerial Vehicles, Tactical Warfare Plans Section, Office of Secretary of Defense, Washington, D.C., telephone interview with author, 26 March 1992.

146. "Unmanned Aerial Vehicle Master Plan," 9, 17, and 32.

147. Mark Lambert, ed., *Jane's All the World's Aircraft* (Alexandria, Va.: Jane's Information Group, 1991), 422.

148. House, 1991, 447–48; and Lambert, 459.

149. Lambert, 459.

150. Ibid., 423.

151. Lennox and Rees.

152. "The United States Navy in Desert Shield and Desert Storm," Department of the Navy, 15 May 1991, 47–48.

153. Field Manual (FM) 6-20, *Fire Support in Combined Arms Operations*, 28 January 1983, 1-3. "Counterfires attack enemy indirect fire systems, to include mortar, artillery, air defense, missile, and rocket systems."

154. Col R. G. Lee, *Guided Weapons* (London: Brassey's Defence Publishers, 1988), 114. "The development of mature IR sensors has greatly improved the capability of small homing weapons. However IR sensors cannot easily detect targets through cloud, fog, or dust. For this reason, much effort and research funds are being expended on the development of millimeter radar and passive radiometers. The resolution ability of sensors working at these wavelengths, while not as good as that of IR systems, is better by far than that which could be provided by centrimetric radar. The propagation of millimeter waves through adverse battlefield conditions is considerably better than that of IR. The main interest at the present time is in equipment operating at 94 GHz."

155. Lt Col Rulatz, ATACMS Program Manager, Fort Sill, Okla., telephone interview with author, 25 March 1983.

156. White Paper, "The Air Force and U.S. National Security: Global Reach—Global Power," Department of the Air Force, June 1990, 1-2.

157. House, 507.

158. *Soviet Military Power 1990,* 58; and M. B. Elsam, *Air Defence* (London: Brassey's Defence Publishers, 1989), 54.

159. *Soviet Military Power* 1990, 58 and 76.

160. Tom Singleton and Ray Johnson, "The B-2—Another Perspective," *Combat Crew,* September 1990, 58–59.

161. White Paper, 7.

162. AFM 1-1, vol. 1, November 1991, 9–14.

163. Kent, 16–24.

164. AFM 1-1, vol. 1, November 1991, 1.

165. Warden, 36.

166. Don Bryant, "B-2 or Cruise Missiles: The United States Needs Both," *Air Force Times,* 4 September 1989, 84.

167. Michael Howard, "Military Science in an Age of Peace," *Journal of the Royal United Services Institute For Defence Services,* 1 March 1974, 5.

168. Air Force Regulation (AFR) 173-13, *USAF Cost and Planning Factors,* 31 October 1989, 11. Flyaway cost ". . . represents the approximate original cost of out-of-production and in-production aircraft [adjusted for inflation] in terms of the constant dollars of a specific fiscal year."

169. House, 1991, F-117B: 410; B-2: 377; TLAM: 478; ATACMS: 153, Conventional ALCM: 524; AFR 173-13, 31 October 1989, 66–67; and Col Manuel W. Garrido, Office of Secretary of Defense/Tactical Warfare Programs, Washington, D.C., during telephone interview with author, stated the endurance and medium range concept UAVs could be operational by 1995 given congressional funding. The flyaway cost for the medium concept UAV without payload including support infrastructure is approximately one million. A reconnaissance payload would add an additional million and an ECM payload an additional two million.

170. The "cost per target" – (3 billion - "dollar value remaining") divided by "targets destroyed." It illustrates the efficiency of target destruction.

171. *Air: The Game of Modern Air-Land Battles in Germany.* The actual war game scenario is considerably larger and longer than TAC Air was designed. In addition, the game emphasizes the defense suppression and interdiction aspects of the game and ignores the close air support aspect of the game. Actual game combat factors are used, except for those systems not included in the game which had to be created. Combat resolution and results are determined in accordance with actual game rules.

172. The "cost per target" – (3 billion - "dollar value remaining") divided by "targets destroyed." It illustrates the efficiency of target destruction.

173. House, 363.

APPENDIX

APPENDIX

Indirect Approach Concept One/Week One

		Aircraft Remaining F-15E	F-15C	F-4G	EF-111	UAVs	Mission Capable Flights Total F-15E	F-15C	F-4G	EF-111	Sorties	SAMs Remain	SAM Engs	SEAD	SAM Loss	A/A Engs	A/A Engs	Aircraft Destroyed F-15E	F-15C	F-4G	EF-111	Tgts Dest
Day	1	42	12	12	6	62	18	5	5	2	60	100	6	5	1	4	1	2				10
Night	1	40	12	12	6	61	18	5	5	2	60	97	6	5	1	2	0	1				10
Day	2	39	12	12	6	60	17	5	5	2	58	94	5	5	0	4	1			1		10
Night	2	39	12	11	6	59	17	5	4	2	56	91	5	4	1	2	0	1	1			10
Day	3	38	11	11	6	58	17	4	4	2	54	88	5	4	1	4	1		1		1	10
Night	3	38	10	11	5	57	17	4	4	2	54	85	5	4	1	2	0	1				10
Day	4	37	10	11	5	56	16	4	4	2	52	82	5	4	1	4	1		1		1	10
Night	4	37	9	11	4	55	16	4	4	1	50	79	4	4	0	2	0			1		10
Day	5	37	9	10	4	54	16	4	4	1	50	76	4	4	0	4	1	1				9
Night	5	36	9	10	4	53	16	4	4	1	50	73	4	4	0	2	0					10
Day	6	36	9	10	4	52	16	4	4	1	50	70	4	4	0	4	1					10
Night	6	36	9	9	4	51	16	4	4	1	50	67	4	4	0	2	0					10
Day	7	36	9	9	4	50	16	4	4	1	50	64	3	4	0	4	1		1	1		10
Night	7	36	8	9	4	49	16	3	4	1	48	62	3	4	0	2	0					10
Day	8	36	8	9	4	48					742	60										139

Indirect Approach Concept One/Week Two

		Aircraft Remaining					Mission Capable Flights Total					SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed				Tgts
		F-15E	F-15C	F-4G	EF-111	UAVs	F-15E	F-15C	F-4G	EF-111	Sorties	Remain	Engs	SEAD	Loss	Engs	Engs	F-15E	F-15C	F-4G	EF-111	Dest
Day	8	36	8	9	4	48	16	3	4	1	48	60	3	4	0	3	1	1				9
Night	8	35	8	9	4	47	15	3	4	1	46	58	3	4	0	1	0					9
Day	9	35	8	9	4	46	15	3	4	1	46	56	3	4	0	3	1			1		9
Night	9	35	8	8	4	45	15	3	3	1	44	54	3	3	0	1	0					9
Day	10	35	8	8	4	44	15	3	3	1	44	52	3	3	0	3	1	1				9
Night	10	34	8	8	4	43	15	3	3	1	44	50	3	3	0	1	0					9
Day	11	34	8	8	4	42	15	3	3	1	44	48	2	3	0	3	1	1				9
Night	11	33	8	8	4	41	14	3	3	1	42	46	2	3	0	1	0					8
Day	12	33	8	8	4	40	14	3	3	1	42	44	2	3	0	3	1	1				8
Night	12	32	8	8	4	39	14	3	3	1	42	42	2	3	0	1	0					8
Day	13	32	8	8	4	38	14	3	3	1	42	40	2	3	0	3	1		1			8
Night	13	32	7	8	4	37	14	3	3	1	42	38	2	3	0	1	0					8
Day	14	32	7	8	4	36	14	3	3	1	42	36	2	3	0	3	1	1				8
Night	14	31	7	8	4	35	13	3	3	1	40	34	2	3	0	1	0					8
Day	15	31	7	8	4	34					608	32										119

Indirect Approach Concept One/Week Three

		Aircraft Remaining					Mission Capable Flights Total					SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed				Tgts
		F-15E	F-15C	F-4G	EF-111	UAVs	F-15E	F-15C	F-4G	EF-111	Sorties	Remain	Engs	SEAD	Loss	Engs	Engs	F-15E	F-15C	F-4G	EF-111	Dest
Day	15	31	7	8	4	34	13	3	3	1	40	32	1	2	0	3	1		1			8
Night	15	31	6	8	4	33	13	2	3	1	38	31	1	2	0	0	0					8
Day	16	31	6	8	4	32	13	2	3	1	38	30	1	3	0	2	0					8
Night	16	31	6	8	4	31	13	2	3	1	38	29	1	3	0	1	0					8
Day	17	31	6	8	4	30	13	2	3	1	38	28	1	3	0	3	1				1	8
Night	17	31	6	8	3	29	13	2	3	1	38	27	1	3	0	1	0					8
Day	18	31	6	8	3	28	13	2	3	1	38	26	1	3	0	2	0					8
Night	18	31	6	8	3	27	13	2	3	1	38	25	1	3	0	0	0					8
Day	19	31	6	8	3	26	13	2	3	1	38	24	1	3	0	3	1	1				7
Night	19	30	6	8	3	25	13	2	3	1	38	23	1	3	0	1	0					8
Day	20	30	6	8	3	24	13	2	3	1	38	22	1	3	0	2	0					8
Night	20	30	6	8	3	23	13	2	3	1	38	21	1	3	0	0	0					8
Day	21	30	6	8	3	22	13	2	3	1	38	20	1	3	0	2	0					8
Night	21	30	6	8	3	21	13	2	3	1	38	19	1	3	0	1	0					8
Day	22	30	6	8	3	20					534	18										111

Indirect Approach Concept One/Week Four

		Aircraft Remaining					Mission Capable Flights Total					SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed				Tgts
		F-15E	F-15C	F-4G	EF-111	UAVs	F-15E	F-15C	F-4G	EF-111	Sorties	Remain	Engs	SEAD	Loss	Engs	Engs	F-15E	F-15C	F-4G	EF-111	Dest
Day	22	30	6	8	3	20	13	2	3	1	38	18	1	3	0	2	0					8
Night	22	30	6	8	3	19	13	2	3	1	38	17	1	3	0	1	0					8
Day	23	30	6	8	3	18	13	2	3	1	38	16	0	3	0	3	1			1		8
Night	23	30	6	7	3	17	13	2	3	1	38	15	0	3	0	0	0					8
Day	24	30	6	7	3	16	13	2	3	1	38	14	0	3	0	2	0					8
Night	24	30	6	7	3	15	13	2	3	1	38	13	0	3	0	1	0					8
Day	25	30	6	7	3	14	13	2	3	1	38	12	0	3	0	3	1		1			8
Night	25	30	5	7	3	13	13	2	3	1	38	11	0	3	0	0	0					8
Day	26	30	5	7	3	12	13	2	3	1	38	10	0	3	0	2	0					8
Night	26	30	5	7	3	11	13	2	3	1	38	9	0	3	0	1	0					8
Day	27	30	5	7	3	10	13	2	3	1	38	8	0	3	0	2	0					8
Night	27	30	5	7	3	9	13	2	3	1	38	7	0	3	0	0	0					8
Day	28	30	5	7	3	8	13	2	3	1	38	6	0	3	0	2	0					8
Night	28	30	5	7	3	7	13	2	3	1	38	5	0	3	0	1	0					8
Day	29	30	5	7	3	6					532	4										112

Concealed Approach Concept Two/Week One

		Aircraft Remaining			MC Sorties		Total	SAMs	SAM	SAM	A/A	A/A	A/C Destroy		Tgts
		F-117	B-2	TLAM	F-117	B-2	Sorties	Remain	Engs	Loss	Engs	Loss	F-117	B-2	Dest
Night	1	12	4	247	10	3	13	100	1	0	0				14
Night	2	12	4	237	10	3	13	97	1	0	0		1		14
Night	3	11	4	227	9	3	12	94	1	0	0				14
Night	4	11	4	217	9	3	12	91	1	0	0				14
Night	5	11	4	207	9	3	12	88	1	0	0				14
Night	6	11	4	197	9	3	12	85	1	0	0				14
Night	7	11	4	187	9	3	12	82	1	0	0				14
Night	8	11	4	177			86	79							98

Concealed Approach Concept Two/Week Two

		Aircraft Remaining			Mission Capa		Total	SAMs	SAM	SAM	A/A	A/A	A/C Destroy		Tgts
		F-117	B-2	TLAM	F-117	B-2	Sorties	Remain	Engs	Loss	Engs	Loss	F-117	B-2	Dest
Night	8	11	4	177	9	3	12	79	0	0	0				14
Night	9	11	4	169	9	3	12	76	0	0	0				14
Night	10	11	4	161	9	3	12	73	0	0	0				14
Night	11	11	4	153	9	3	12	70	0	0	0				14
Night	12	11	4	145	9	3	12	67	0	0	0				14
Night	13	11	4	137	9	3	12	64	0	0	0				14
Night	14	11	4	129	9	3	12	62	0	0	0				14
Night	15	11	4	121			84	60							98

Concealed Approach Concept Two/Week Three

		Aircraft Remaining			Mission Capa		Total	SAMs	SAM	SAM	A/A	A/A	A/C Destroy		Tgts
		F-117	B-2	TLAM	F-117	B-2	Sorties	Remain	Engs	Loss	Engs	Loss	F-117	B-2	Dest
Night	15	11	4	84	9	3	12	60	0	0	0				13
Night	16	11	4	78	9	3	12	58	0	0	0				13
Night	17	11	4	72	9	3	12	56	0	0	0				13
Night	18	11	4	66	9	3	12	54	0	0	0				13
Night	19	11	4	60	9	3	12	52	0	0	0				13
Night	20	11	4	54	9	3	12	50	0	0	0				13
Night	21	11	4	48	9	3	12	48	0	0	0				13
Night	22	11	4	42			84	46							91

Concealed Approach Concept Two/Week Four

		Aircraft Remaining			Mission Capa		Total	SAMs	SAM	SAM	A/A	A/A	A/C Destroy		Tgts
		F-117	B-2	TLAM	F-117	B-2	Sorties	Remain	Engs	Loss	Engs	Loss	F-117	B-2	Dest
Night	22	11	4	42	9	3	12	46	0	0	0				13
Night	23	11	4	36	9	3	12	44	0	0	0				13
Night	24	11	4	30	9	3	12	42	0	0	0				13
Night	25	11	4	24	9	3	12	40	0	0	0				13
Night	26	11	4	18	9	3	12	38	0	0	0				13
Night	27	11	4	12	9	3	12	36	0	0	0				13
Night	28	11	4	6	9	3	12	34	0	0	0				13
Night	29	11	4	0			84	32							91

Simultaneous Mass Attack Concept Three/Week One

		Aircraft Remaining					MC Flights			Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed					Tgts
		F-16D	EF-111	SEAD	ECM	UAVs	F-16D	EF-111	SEAD	Sorties	Remain	Engs	SEAD	Loss	Engs	Loss	F-16	EF-111	SEAD	ECM	UAV	Dest
Day	1	76	6	48	24	107	34	2	21	114	100	11	10	1	6	3	1		1		2	16
Night	1	75	6	47	24	105	33	2	21	112	97	10	10	0	4	2	1				1	8
Day	2	74	6	47	24	104	33	2	21	112	94	10	10	0	6	3	1			2		16
Night	2	73	6	47	22	104	32	2	21	110	91	10	10	0	4	2	1				1	7
Day	3	72	6	47	22	103	32	2	21	110	88	9	10	0	6	3	1	1			1	15
Night	3	71	5	47	22	102	31	2	21	108	85	9	10	0	4	2	1		1			7
Day	4	70	5	46	22	102	31	2	20	106	82	9	10	0	5	2	1				1	15
Night	4	69	5	46	22	101	31	2	20	106	79	8	10	0	3	1	1					7
Day	5	68	5	46	22	101	30	2	20	104	76	8	10	0	5	2					2	15
Night	5	68	5	46	22	99	30	2	20	104	73	8	10	0	3	1			1			7
Day	6	68	5	45	22	99	30	2	20	104	70	7	10	0	5	2			1		1	15
Night	6	68	5	44	22	98	30	2	19	102	67	7	9	0	3	1			1			7
Day	7	68	5	43	22	98	30	2	19	102	64	7	9	0	5	2	1				1	14
Night	7	67	5	43	22	97	30	2	19	102	62	6	9	0	3	1					1	7
Day	8	67	5	43	22	96				1,496	60											156

Simultaneous Mass Attack Concept Three/Week Two

		Aircraft Remaining					MC Flights			Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed					Tgts
		F-16D	EF-111	SEAD	ECM	UAVs	F-16D	EF-111	SEAD	Sorties	Remain	Engs	SEAD	Loss	Engs	Loss	F-16	EF-111	SEAD	ECM	UAV	Dest
Day	8	80	5	30	22	96	36	2	13	102	60	6	6	0	5	2					2	18
Night	8	80	5	30	22	94	36	2	13	102	58	6	6	0	3	1	1					8
Day	9	79	5	30	22	94	35	2	13	100	56	6	6	0	5	2	1				1	17
Night	9	78	5	30	22	93	35	2	13	100	54	6	6	0	3	1	1					8
Day	10	77	5	30	22	93	34	2	13	98	52	5	6	0	5	2	2					16
Night	10	75	5	30	22	93	33	2	13	96	50	5	6	0	2	1					1	8
Day	11	75	5	30	22	92	33	2	13	96	48	5	6	0	4	2				2		16
Night	11	75	5	30	20	92	33	2	13	96	46	5	6	0	2	1	1					8
Day	12	74	5	30	20	92	33	2	13	96	44	4	6	0	4	2					2	16
Night	12	74	5	30	20	90	33	2	13	96	42	4	6	0	2	1	1					8
Day	13	73	5	30	20	90	32	2	13	94	40	4	6	0	4	2		1		1		16
Night	13	73	4	30	19	90	32	1	13	92	38	4	6	0	2	1	1					7
Day	14	72	4	30	19	90	32	1	13	92	36	4	6	0	4	2			2			16
Night	14	72	4	28	19	90	32	1	12	90	34	3	6	0	2	1	1					7
Day	15	71	4	28	19	90				1,350	32											169

Simultaneous Mass Attack Concept Three/Week Three

		Aircraft Remaining					MC Flights			Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed					Tgts
		F-16D	EF-111	SEAD	ECM	UAVs	F-16D	EF-111	SEAD	Sorties	Remain	Engs	SEAD	Loss	Engs	Loss	F-16	EF-111	SEAD	ECM	UAV	Dest
Day	15	82	4	17	19	90	36	1	7	88	32	3	3	0	4	2			1		1	18
Night	15	82	4	16	19	89	36	1	7	88	31	3	3	0	2	1					1	9
Day	16	82	4	16	19	88	36	1	7	88	30	3	3	0	4	2	1				1	17
Night	16	81	4	16	19	87	36	1	7	88	29	3	3	0	2	1			1			9
Day	17	81	4	15	19	87	36	1	6	86	28	3	3	0	4	2				1	1	18
Night	17	81	4	15	18	86	36	1	6	86	27	3	3	0	2	1			1			9
Day	18	81	4	14	18	86	36	1	6	86	26	2	3	0	3	1					1	18
Night	18	81	4	14	18	85	36	1	6	86	25	2	3	0	2	1					1	9
Day	19	81	4	14	18	84	36	1	6	86	24	2	3	0	3	1	1					17
Night	19	80	4	14	18	84	36	1	6	86	23	2	3	0	2	1	1					8
Day	20	79	4	14	18	84	35	1	6	84	22	2	3	0	3	1					1	17
Night	20	79	4	14	18	83	35	1	6	84	21	2	3	0	2	1					1	8
Day	21	79	4	14	18	82	35	1	6	84	20	2	3	0	3	1	1					17
Night	21	78	4	14	18	82	35	1	6	84	19	2	3	0	2	1					1	8
Day	22	78	4	14	18	81				1,204	18											182

Simultaneous Mass Attack Concept Three/Week Four

		Aircraft Remaining					MC Flights			Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed					Tgts
		F-16D	EF-111	SEAD	ECM	UAVs	F-16D	EF-111	SEAD	Sorties	Remain	Engs	SEAD	Loss	Engs	Loss	F-16	EF-111	SEAD	ECM	UAV	Dest
Day	22	82	4	10	18	81	36	1	4	82	18	2	2	0	4	2			1		1	18
Night	22	82	4	9	18	80	36	1	4	82	17	1	2	0	2	1	1					8
Day	23	81	4	9	18	80	36	1	4	82	16	1	2	0	4	2	1				1	17
Night	23	80	4	9	18	79	36	1	4	82	15	1	2	0	2	1			1			9
Day	24	80	4	8	18	79	36	1	3	80	14	1	1	0	3	1				1		18
Night	24	80	4	8	17	79	36	1	3	80	13	1	1	0	2	1					1	9
Day	25	80	4	8	17	78	36	1	3	80	12	1	1	0	3	1			1			18
Night	25	80	4	7	17	78	36	1	3	80	11	1	1	0	1	0						9
Day	26	80	4	7	17	78	36	1	3	80	10	1	1	0	3	1			1			18
Night	26	80	4	6	17	78	36	1	2	78	9	1	1	0	1	0						9
Day	27	80	4	6	17	78	36	1	2	78	8	0	1	0	4	2	1		1			17
Night	27	79	4	5	17	78	35	1	2	76	7	0	1	0	1	0						8
Day	28	79	4	5	17	78	35	1	2	76	6	0	1	0	3	1					1	17
Night	28	79	4	5	17	77	35	1	2	76	5	0	1	0	1	0						8
Day	29	79	4	5	17	77				1,112	4											183

Balanced Concept Four/Week One

		Aircraft Remaining				ECM Decoy		MC Flights				Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed						Tgts
		F-16	F-117	EF-111	SEAD	UAVs	UAVs	F-16	F-117	EF-111	SEAD	Sortie	Remain	Eng	SEAD	Loss	Eng	Loss	F-16	F-117	EF-111	SEAD	ECM	UAV	Dest
Day	1	53	10	5	45	16	65	23	0	2	20	90	100	11	10	1	5	2						3	11
Night	1	53	10	5	45	16	62	23	9	2	20	99	97	10	10	0	3	1						1	11
Day	2	53	10	5	45	16	61	23	0	2	20	90	94	10	10	0	5	2				1		1	11
Night	2	53	10	5	44	16	60	23	9	2	19	97	91	10	9	1	3	1	2						11
Day	3	51	10	5	44	16	60	22	0	2	19	86	88	9	9	0	5	2				1		1	11
Night	3	51	10	5	43	16	59	22	9	2	19	86	85	9	9	0	3	1						1	11
Day	4	51	10	5	43	16	58	22	0	2	19	86	82	9	9	0	4	2	2						10
Night	4	49	10	5	43	16	58	22	9	2	19	95	79	8	9	0	2	1						1	11
Day	5	49	10	5	43	16	57	22	0	2	19	86	76	8	9	0	4	2	1					1	10
Night	5	48	10	5	43	16	56	21	9	2	19	93	73	8	9	0	2	1				1			10
Day	6	48	10	5	42	16	56	21	0	2	18	82	70	7	9	0	4	2	2						10
Night	6	46	10	4	42	16	56	20	9	2	18	89	67	7	9	0	2	1			1				10
Day	7	46	10	4	42	16	56	20	0	1	18	78	64	7	9	0	4	2	1			1			9
Night	7	45	10	4	41	16	56	20	9	1	18	87	62	6	9	0	2	1					1		10
Day	8	45	10	4	41	15	56					1,244	60												146

Balanced Concept Four/Week Two

		Aircraft Remaining				ECM Decoy		MC Flights				Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed						Tgts
		F-16	F-117	EF-111	SEAD	UAVs	UAVs	F-16	F-117	EF-111	SEAD	Sortie	Remain	Eng	SEAD	Loss	Eng	Loss	F-16	F-117	EF-111	SEAD	ECM	UAV	Dest
Day	8	59	10	4	27	15	56	26	0	1	12	78	60	6	6	0	4	2						2	13
Night	8	59	10	4	17	15	54	16	9	1	12	87	58	6	6	0	2	1						1	12
Day	9	59	10	4	27	15	53	26	0	1	12	78	56	6	6	0	4	2	1					1	12
Night	9	58	10	4	27	15	52	26	9	1	12	87	54	6	6	0	2	1				1			12
Day	10	58	10	4	26	15	52	26	0	1	11	76	52	5	5	0	4	2						2	13
Night	10	58	10	4	26	15	50	26	9	1	11	76	50	5	5	0	2	1						1	12
Day	11	58	10	4	26	15	49	26	0	1	11	76	48	5	5	0	4	2	1					1	12
Night	11	57	10	4	26	15	48	25	9	1	11	83	46	5	5	0	2	1	1						11
Day	12	56	10	4	26	15	48	25	0	1	11	74	44	4	5	0	4	2	1			1			12
Night	12	55	10	4	25	15	48	24	9	1	11	81	42	4	5	0	2	1	1						11
Day	13	54	10	4	25	15	48	24	0	1	11	72	40	4	5	0	4	2	1			1			11
Night	13	53	10	4	24	15	48	23	9	1	10	77	38	4	5	0	2	1						1	11
Day	14	53	10	4	24	15	47	23	0	1	10	68	36	4	5	0	4	2						2	11
Night	14	53	10	4	24	15	45	23	9	1	10	77	34	3	5	0	2	1	1						11
Day	15	52	10	4	24	15	45					1,090	32												164

Balanced Concept Four/Week Three

		Aircraft Remaining				ECM	Decoy	MC Flights				Total	SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed						Tgts
		F-16	F-117	EF-111	SEAD	UAVs	UAVs	F-16	F-117	EF-111	SEAD	Sortie	Remain	Eng	SEAD	Loss	Eng	Loss	F-16	F-117	EF-111	SEAD	ECM	UAV	Dest
Day	15	60	10	4	16	15	45	27	0	1	7	70	32	3	3	0	3	1	1						13
Night	15	59	10	4	16	15	45	26	9	1	7	77	31	3	3	0	2	1				1			12
Day	16	59	10	4	15	15	45	26	0	1	6	66	30	3	3	0	3	1						1	13
Night	16	59	10	4	15	15	44	26	9	1	6	75	29	3	3	0	2	1					1		12
Day	17	59	10	4	15	14	44	26	0	1	6	66	28	3	3	0	3	1						1	13
Night	17	59	10	4	15	14	43	26	9	1	6	66	27	3	3	0	2	1						1	12
Day	18	59	10	4	15	14	42	26	0	1	6	66	26	2	3	0	3	1						1	13
Night	18	59	10	4	15	14	41	26	9	1	6	75	25	2	3	0	2	1	1						12
Day	19	58	10	4	15	14	41	26	0	1	6	66	24	2	3	0	3	1				1			13
Night	19	58	10	4	14	14	41	26	9	1	6	75	23	2	3	0	2	1	1						12
Day	20	57	10	4	14	14	41	25	0	1	6	64	22	2	3	0	3	1						1	12
Night	20	57	10	4	14	14	40	25	9	1	6	73	21	2	3	0	2	1	1						11
Day	21	56	10	4	14	14	40	25	0	1	6	64	20	2	3	0	3	1						1	12
Night	21	56	10	4	14	14	39	25	9	1	6	73	19	2	3	0	2	1	1						11
Day	22	55	10	4	14	14	39					976	18												171

Balanced Concept Four/Week Four

		Aircraft Remaining				ECM	Decoy	MC Flights		Total			SAMs	SAM		SAM	A/A	A/A	Aircraft Destroyed						Tgts
		F-16	F-117	EF-111	SEAD	UAVs	UAVs	F-16	F-117	EF-111	SEAD	Sortie	Remain	Eng	SEAD	Loss	Eng	Loss	F-16	F-117	EF-111	SEAD	ECM	UAV	Dest
Day	22	60	10	4	9	14	39	27	0	1	4	64	18	2	2	0	3	1						1	13
Night	22	60	10	4	9	14	38	27	9	1	4	73	17	1	2	0	2	1				1			12
Day	23	60	10	4	8	14	38	27	0	1	3	62	16	1	1	0	3	1						1	13
Night	23	60	10	4	8	14	37	27	9	1	3	71	15	1	1	0	2	1	1						12
Day	24	59	10	4	8	14	37	26	0	1	3	60	14	1	1	0	3	1	1						12
Night	24	58	10	4	8	14	37	26	9	1	3	60	13	1	1	0	2	1	1						12
Day	25	57	10	4	8	14	37	25	0	1	3	58	12	1	1	0	3	1	1						12
Night	25	56	10	4	8	14	37	25	9	1	3	67	11	1	1	0	1	0							11
Day	26	56	10	4	8	14	37	25	0	1	3	58	10	1	1	0	3	1						1	12
Night	26	56	10	4	8	14	36	25	9	1	3	67	9	1	1	0	1	0							11
Day	27	56	10	4	8	14	36	25	0	1	3	58	8	0	1	0	3	1						1	12
Night	27	56	10	4	8	14	35	25	9	1	3	67	7	0	1	0	1	0							11
Day	28	56	10	4	8	14	35	25	0	1	3	58	6	0	1	0	3	1						1	12
Night	28	56	10	4	8	14	34	25	9	1	3	67	5	0	1	0	1	0							11
Day	29	56	10	4	8	14	34					890	4												166

Indirect Approach
Starting Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F-4G	$15.7	12	$188.4		
F-15C	$32.2	12	$386.4		
F-15E	$30.7	42	$1,289.4	5	210
RF-16	$13.7	6	$82.2		
EF-111A	$73.9	6	$443.4		
EC-130E	$21.8	6	$130.8		
KC-135E	$26.1	16	$417.6		
Decoy UAV	$1.0	62	$62.0		
		Total:	$3,000.2		210

Indirect Approach
Remaining Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F-4G	$15.7	7	$109.9		
F-15C	$32.2	5	$161.0		
F-15E	$30.7	30	$921.0	5	150
RF-16	$13.7	6	$82.2		
EF-111A	$73.9	3	$221.7		
EC-130E	$21.8	6	$130.8		
KC-135E	$26.1	16	$417.6		
Decoy UAV	$1.0	6	$6.0		
		Total:	$2,050.2		150

Concealed Approach
Starting Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F-117B	$64.0	12	$768.0	5	60
B-2	$476.7	4	$1,906.8	20	80
KC-135E	$26.1	3	$78.3		
TLAM	$1.0	247	$247.0		
		Total:	$3,000.1		140

Concealed Approach
Remaining Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F-117B	$64.0	11	$704.0	5	55
B-2	$476.7	4	$1,906.8	20	80
KC-135E	$26.1	3	$78.3		
TLAM	$1.0	0	$0.0		
		Total:	$2,689.1		135

Mass Simultaneous Attack
Starting Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F-16D	$13.7	124	$1,698.8	3	372
EF-111A	$73.9	6	$443.4		
EC-130E	$21.8	6	$130.8		
C-135E	$26.1	21	$548.1		
Decoy UAV	$1.0	107	$107.0		
ECM UAV	$3.0	24	$72.0		
		Total:	$3,000.1		372

Mass Simultaneous Attack
Remaining Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F16-D	$13.7	84	$1,150.8	3	252
EF-111A	$73.9	4	$295.6		
EC-130E	$21.8	6	$130.8		
KC-135E	$21.1	21	$548.1		
Decoy UAV	$1.0	77	$77.0		
ECM UAV	$3.0	17	$51.0		
		Total:	$2,253.3		252

Balanced Concept
Starting Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F-16C/D	$13.7	98	$1,342.6	3	294
EF-111A	$73.9	5	$369.5		
EC-130E	$21.8	3	$65.4		
KC-135E	$26.1	18	$469.8		
Decoy UAV	$1.0	65	$65.0		
ECM UAV	$3.0	16	$48.0		
F-177B	$64.0	10	$640.0	5	50
		Total:	$3,000.3		344

Balance Concept
Remaining Force Structure

Type Acft	Cost	#Acft	Total Cost	A/G Power	Daily Power
F16-C/D	$13.7	64	$876.8	3	192
EF-111A	$73.9	4	$295.6		
EC-130E	$21.8	3	$130.8		
KC-135E	$26.1	18	$469.8		
Decoy UAV	$1.0	34	$34.0		
ECM UAV	$3.0	14	$42.0		
F-117B	$64.0	10	$640.0	5	50
		Total:	$2,423.6		242

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