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GUIDED STANDOFF WEAPONS: A THREAT TO EXPEDITIONARY AIR POWER

by

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13. ABSTRACT The Air Base has long been a potential target of attack for enemy planners. An effective way to attack the United States Air Force (USAF) is to avoid the United State's usual dominance in the air, attacking airbases with ground forces inserted into the Joint Rear Area.

The history of airbase ground attacks from 1942 to 1994, documented in the book *Snakes in the Eagle's Nest*, shows that the dominant strategy employed by air base attackers has been the standoff attack. Roughly, 75 percent of all airbase attacks have been through the use of rockets or mortar fire from outside the airbase's perimeter defenses. In Vietnam, where the defenses against penetrating ground attacks were emphasized, this percentage rose to 96 percent.

Historically robust main operating bases, with passive defensive measures such as hardened facilities and redundant systems, have been able to withstand standoff attacks. The relative inaccuracy of the attacker's standoff systems and their limited ability to sustain fire on the air base minimized damage.

The USAF finds itself operating in an expeditionary mode across the globe. Expeditionary Air Forces cannot depend on the luxury of operating off main operating bases. In addition, the emergence of guided munitions for mortars and anti-tank missiles has increased the accuracy of potential standoff weapons. Finally, the sophistication of Improvised Explosive Devices in Iraq and of modern radio-controlled model aircraft even suggests a potential for attackers to build guided weapons. The potential for a "one shot, one kill" standoff weapon is here, negating the effectiveness of passive hardening measures.

Disrupting these attacks will take new strategies. Understanding current Joint and USAF doctrine is the first step. Areas for further study include disrupting the enemy forces before they launch a standoff attack, intercepting the standoff round in flight and mitigating the damage on impact are discussed.

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GUIDED STANDOFF WEAPONS: A THREAT TO EXPEDITIONARY AIR POWER

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ABSTRACT

The Air Base has long been a potential target of attack for enemy planners. An effective way to attack the United States Air Force (USAF) is to avoid its usual dominance in the air and use an asymmetrical approach, attacking airbases with ground forces inserted into the Joint Rear Area.

The history of airbase ground attacks from 1942 to 1994, documented in the book *Snakes in the Eagle's Nest*, shows that the dominant strategy employed by air base attackers has been the standoff attack. Roughly, 75 percent of all airbase attacks have been through the use of rockets or mortar fire from outside the airbase's perimeter defenses. In Vietnam, where the defenses against penetrating ground attacks were emphasized, this percentage rose to 96 percent.

Historically robust main operating bases, with passive defensive measures such as hardened facilities and redundant systems, have been able to withstand standoff attacks. The relative inaccuracy of the attacker's standoff systems and their limited ability to sustain fire on the air base minimized damage.

Times have changed and the USAF finds itself operating in an expeditionary mode across the globe. Expeditionary Air Forces cannot depend on the luxury of operating off airfields with the robust infrastructure of main operating bases. In addition, the emergence of man portable, guided munitions for mortars and guided anti-tank missiles has increased the accuracy of potential standoff weapons. Finally, the sophistication of Improvised Explosive Devices in Iraq and of modern radio-controlled model aircraft even suggests the potential for attackers to build their own guided standoff weapons. The potential for a "one shot, one kill" standoff weapon is here today, negating the effectiveness of passive hardening measures.

Disrupting these attacks will take new strategies. Understanding current Joint and USAF doctrine is the first step. Areas for further study include disrupting the enemy forces before they launch a standoff attack, intercepting the standoff round in flight and mitigating the damage on impact are discussed.

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I. INTRODUCTION

A. CHANGES AT THE END OF THE COLD WAR

With the emergence of the Expeditionary Air Force (EAF) concept in the mid 1990's, a major change in the structure and mindset of the United States Air Force (USAF) occurred. An Air Force that was structured to reinforce North Atlantic Treaty Organization (NATO) forces in the defense of Western Europe (as well as Japan, South Korea, etc) and to carryout the nuclear Single Integrated Operations Plan (SIOP) was transformed to meet emerging requirements. The need to project combat power to different locations across the globe was the new requirement for the USAF in the post-Cold War environment.

Under this new EAF concept a major change in the basing of expeditionary aircraft occurred. In the Cold War, expeditionary aircraft could count on arriving at massive main operating bases with hardened and redundant support systems. With hardened aircraft shelters, redundant fuel systems, redundant runways and taxiways, and hardened personnel structures, main operating bases contained everything an Air Force needed to generate aircraft while under fire. Today, EAF personnel must set up operations on any available airfield in the region where they deploy. The advantages of hardened and redundant support systems are, for the most part, gone.

The USAF generates all of its air-breathing combat power from air bases. The skilled men and women who perform the tasks that make an air base work have transformed the generation of fixed-wing combat aircraft, specially modified sensor platforms that support air and ground operations, and cargo and tanker aircraft sorties into an art form. The complex interactions of hundreds of personnel are needed to launch each aircraft. Maintenance personnel must ensure the aircraft are ready to launch, fuels personnel must fuel them, ordinance personnel must prepare the munitions and on and on. Any breakdown in this chain of interactions can leave aircraft on the ground and necessary missions unflown. The environment where all of these tasks occur is the air base.

The shift from the main operating bases to airfields that lack hardened and redundant systems have left today's Expeditionary Air Forces more vulnerable to attack on the ground then ever before. "Operations may require the Air Force to deploy on short notice to air bases where combat support functions are not fully in place, to include urban, remote and, in rare cases, bare base environments (AFI 31-101, 2002, pg 4)." Because this vulnerability exists, a future opponent of the USAF would be wise to attempt to exploit it.

The USAF is a dominant force in the skies. The skill level of USAF personnel is extremely high and the amount of money the nation has invested is unmatched. In 2005, the budget of the United States Air Force was $120.5 billion (GlobalSecurity.org, 2006); easily more than the combined *total* defense budgets of China, North Korea and Iran combined (CIA World Fact Book, 2006). Attempting to overcome the USAF in the sky to exploit the vulnerabilities of on the ground is an expensive option for an enemy that does not guarantee success.

Ground attack has been an effective method of attacking airbases when attack from the air is not possible. The attacks launched by British Special Air Services personnel against the Luftwaffe in North Africa during World War II provide an example of ground attacks by special operations forces (Vick, 1995). Viet Cong attacks on U.S. air bases during the Vietnam War show that insurgent forces can also carry out these attacks. Over the years the standoff attack, where attackers fire at the base with long-range weapons from beyond the perimeter defenses of the base, has emerged as the most frequently used method of attack.

B. THE STANDOFF THREAT TO AIRBASES

A Rand Corporation study titled "Check-Six begins on the Ground" (Vick, 1995) found that 75 percent of all ground attacks against air bases from 1940 to 1994 utilized standoff weapons. The types of weapons used to complete these attacks were mainly medium mortars and unguided rockets.

During the Vietnam War, Viet Cong and North Vietnamese Army units executed 493 separate air base attacks with the primary intention of disrupting

operations and raising the cost of the war for the U.S. The result was 375 aircraft destroyed and over 1,200 damaged. Approximately 96 percent of these attacks were made using standoff weapons (Vick, 1995).

During the Vietnam War, the U.S. Air Force created a hardening program that included the use of aircraft revetments that greatly reduced the effectiveness of these unguided attacks in destroying aircraft. While continued attacks slowed sortie production, aircraft losses to these attacks greatly declined (Vick, 1995).

Hardening has limits. Large, easy to recognize transport planes are difficult to protect from the effects of standoff attacks. Areas where personnel gather—dining facilities, tents, and other temporary quarters—are expensive and difficult to protect as well. In addition, hardening is intended to keep the damage from an effective attack from spreading to other resources, as a firewall is meant to protect other parts of a building.

The ability of an enemy to use guided weapons to target individual aircraft or facilities would seriously undermine the effectiveness of hardening. A small, guided weapon provides an effective means to attack aircraft and facilities, even when revetments protect them. An airbase attack that used this type of weapon could directly affect the ability of an airbase to launch and recover its aircraft.

In his book, Snakes in the Eagle's Nest, Vick (1995, p. 110) warns about the introduction of guided standoff weapons tipping the balance of power in the favor of the attacker. The potential for the attacker to use laser-guided mortar rounds, wire or laser-guided anti-tank rounds or Guided Standoff Improvised Explosive Devices (i.e., a small Unmanned Aerial Vehicle with a camera and an explosives charge) adds a degree of effectiveness to an attack that poses a very serious challenge to the defender. The range of these weapons gives the attacker the ability to operate in an area too large for the defender to effectively control using today's base defense concepts and systems.

This paper will explore the possible introduction of guided standoff weapons into the role of attacking air bases. Chapter II will look at U.S. airbase defense doctrine. Chapter III will use mathematical modeling to look at three game scenarios involving air base defense. Chapter IV will survey the availability

and suitability of current weapons systems to perform a guided standoff attack on an airbase. Chapter V will look at the feasibility of building a guided standoff improvised explosives device. Finally, Chapter VI will look at potential strategies to counter the emerging threat of guided standoff weapons to air bases.

II. U.S. AIR BASE DEFENSE DOCTRINE

A. JOINT DOCTRINE

In Joint Pub (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms,* base defense is defined as "local military measures, both normal and emergency, required to nullify or reduce the effectiveness of enemy attacks on, or sabotage of, a base to ensure the maximum capacity of its facilities and resources are available to U.S. forces (AFI 31-101, 2002, pg 4)."

Military organizations run their operations based on established doctrine. The key doctrine document that discusses base defense is JP 3-10, *Joint Doctrine for Rear Area Operations.* U.S. conventional military operations are dependent on the projection of combat power from the rear area to support ongoing military operations. It is hard to imagine the success of Operation Desert Storm without airpower and logistical support from the bases in the rear area.

JP 3-10 is the collected set of lessons learned from past conflicts, military history, combined with expectations on the future form of military conflict. Searching through this document, no discussion of standoff attack, except for preparations for air and large missile attacks can be found. What is discussed is the increasing vulnerability of the rear area to attack.

> Rear areas are increasingly vulnerable to modern enemy forces with sophisticated surveillance devices and systems, accurate, long-range weapon systems, and transport assets, which are capable of inserting forces deep behind friendly lines. Foreign intelligence and security services will continue to pose espionage, disinformation, and psychological operations threats. Threats posed by indigenous elements capable of the full spectrum of unconventional operations ranging from sabotage to large-scale raids and ambushes are also likely. (JP 3-10, 1996, p. I-1)

Enemy threats to the rear area are classified into three categories, Level I, Level II, and Level III. These categories are intended to provide a common magnitude of these threats to military forces. Typical Level I threats include:

enemy-controlled agents, enemy sympathizers, terrorism, and civil disturbances (JP 3-10, 1996, p. I-5). Level II threats are guerrilla forces ("irregular and predominantly indigenous forces conducting guerrilla warfare"), unconventional forces ("special operations forces are highly trained in unconventional warfare techniques") and small tactical units ("specially organized reconnaissance elements with the capability of conducting raids and ambushes") (JP 3-10, 1996, p. I-6).

Level III threats include large numbers of conventional forces, tactical missile and aircraft attacks, and nuclear, chemical, and biological weapons attacks (JP 3-10, 1996, p. I-6).

Individual bases in the rear area must build their defenses to meet the specific demands of the threats and the terrain in which they are located. Bases and base clusters (closely located bases that integrate their defenses) are expected to detect and defeat Level I and Level II attacks. Bases must have the capability to delay a Level III attack until the arrival of supporting, friendly forces (JP 3-10.1, 1996, p I-5).

In this era of coalition warfare, host-nation and allied forces play a major role in the defense of the rear area. If a base is fortunate to be located in a country with capable police and military forces, these forces add a great deal of depth to the base's defenses. The effective control of the areas between bases in the rear area by host-nation forces helps to deny attackers a safe haven. As the effectiveness of the host nation's control of its territory increases, the probability that an enemy attack on a base will fail also increases.

Allied forces may be collocated on a base with U.S. forces and take some of the responsibility for the defense of the base. Allied forces may also make up the reaction force to counter a Level III threat to the rear area.

Understanding joint doctrine is important to understanding the importance of base defense to the United States military. Understanding the way that the Air Force implements this doctrine is the next step.

B. AIR FORCE DOCTRINE

As stated earlier in this paper, the Air Force generates its air-breathing combat power from the rear area. Ground combat units are dependent on the rear area for logistical support but the actual combat power is generated on the front lines.

Because of the dominance of the US Air Force in the air, future enemies may adopt an asymmetric strategy that attempts to use ground attacks to neutralize the USAF in the skies. It follows that winning the majority of the battles in the base defense struggle is critical to winning the war in the air. The USAF's base defense strategy is critical in this effort.

As stated, the key document to look at to understand the Air Force's implementation of U.S. base defense doctrine in Air Force Instruction 31-101, *Air Base Defense*. AFI 31-101 recognizes the history of attacks on air bases and the potential for future problems.

> Asymmetric threats will increasingly challenge base defense forces. Historically, elements such as special forces, light infantry, airborne, airmobile, terrorist, guerrilla, and irregular units have successfully employed unconventional warfare tactics to harass personnel and equipment (AFI 31-101, 2002, pg 4).

From a review of this document, it is clear that the knowledge of the potential threat to airbases is available in the Air Force. AFI 31-101 uses the information from Vick's *Snakes in the Eagle's Nest* and the Rand Corporation's *Check-Six Begins on the Ground* to understand base attacks of the past.

One of the critical areas discussed in 31-101 is the threat from standoff weapons attacks. It states:

> The standoff attack is more difficult to detect and defeat and can include attacks against resources outside the legal base perimeter (e.g., water lines, fuel lines, power grids). Historically, seventy-five percent of the attacks against air bases have been conducted with standoff weapons making this the most likely threat to Air Force personnel and resources. [T]he range of rockets, mortars, shoulder launched anti-aircraft weapons, and large caliber machine guns offer the potential adversary a large area beyond the perimeter fence from which to attack an air base, to include departing and recovering aircraft. (AFI 31-101, 2002, pg 6)

From this quote, it is clear that the problem of standoff attacks is understood.

Air Force Instruction 31-101 also recognizes the impact of advances in technology on the attacker's ability to affect the operations airbase. "The acquisition of technologically advanced equipment such as portable surface-to-air missiles, guided mortar munitions, and night vision devices make these adversaries even more difficult to detect and neutralize. (AFI 31-101, 2002, pg 5)" Of particular interest to this thesis is the mention of guided mortar munitions. These weapons and others with similar capabilities are the emerging standoff threat that poses a prime challenge to airbases in the future.

It is clear from reading AFI 31-101 that the Air Force recognizes the threat that standoff weapons, and especially guided standoff weapons pose. Recognizing an emerging threat is the first step in dealing with it but recognition does not guarantee that a problem will be dealt with. Unless this threat is mitigated, future Air Force operations might be threatened. A look at how the USAF defends its air bases is required to see if this emerging threat is being properly handled.

C. DEFENDING THE BASE

In looking at a base defense plan, the first step is to understand the threat. As listed above there are three levels of threat that are categorized by Joint and USAF doctrine, Level I, Level II and Level III.

A Level I threat can be "characterized as small-scale operations conducted by agents, saboteurs, sympathizers, partisans, and agent-supervised or independently initiated terrorist activities (AFI 31-101, 2002, pg 5). " Level I threats are small in size, difficult to detect and generally must get close to their target to cause damage. In addition, once they are detected, they are the easiest threat for a base security force to defeat.

Because of the characteristics of a Level I threat, a strong counter intelligence program and basic security measures (controlling access, recognition systems, barriers a co-located response element) are usually enough to defeat or deter an attack. AFI 31-101 recommends that the "way to defeat the Level I threat is to disrupt the planning process through the use of sound

antiterrorism/force protection techniques before an attack occurs (pg 5, 2002). Protection against the Level I threat causes the defense force (either dedicated defense personnel or personnel from the resource to be defended) to distribute defensive forces to many different points across the base. These forces are tied to the resources they are protecting and are difficult to assemble and maneuver to provide effective defense against a Level II or III threat.

The second threat to an air base (Level II) "include(s) long-range reconnaissance, intelligence gathering, and the sabotage of air or ground operations conducted by special-purpose, guerrilla and unconventional warfare forces or small tactical units (AFI 31-101, 2002, pg 5)." Level II threats, which encompass the use of standoff attacks, generally demand higher skills and more capable weaponry they Level I threats. They do not have to get close to a resource to damage or destroy it.

Countering the Level II threat requires a different defensive posture than the Level I threat. A nominal air base defense would consist of observation posts on the base perimeter, defensive strong points (containing crew-served machine guns and grenade launchers), and a vehicle-mounted mobile reserve. Barriers along high-speed avenues of approach, anti-personnel obstacles, sensors, night vision devices, and reinforced base entry control points would add to a base's defenses. When relations with the host nation allow for it, off-base patrols to gather intelligence and deny standoff weapons launch locations add an extra layer to this formidable defense.

The effectiveness of this defensive scheme in deterring and defeating penetrating Level II attacks is impressive. The air base attack data from Vick show that 75 percent of attacks on airbases used stand off weapons. If we focus on just the Vietnam War, this number rises to 96 percent, showing the evolving effectiveness of base defenses against direct attacks and the ineffectiveness of these defenses against standoff attacks (Vick, 1994, p. 106).

Even with the majority of attack on airbases coming from standoff attacks, base defenders cannot simple abandon their defensives against a ground assault and distribute their forces to look for standoff weapons. The results of a

successful Level II ground assault can be disastrous. In 2001, a ground assault by the Tamal Tigers on a combined airbase and airport in Colombo, Sri Lanka destroyed four wide-body commercial aircraft and a large portion of Sri Lanka's "small but effective" Air Force (Brown, 2001). Consequently, defenses against a ground attack must remain the first priority of an air base.

Defending against a Level III threat is the final task for a base defense force. A Level III threat is a "major attacks by large tactical forces that can use airborne, heliborne, amphibious, and infiltration operations. Attacks can also come from aircraft and theater missiles armed with conventional and Nuclear, Biological, or Chemical (NBC) weapons (AFI 31-101, 2002, pg 6)." Individual bases are not expected to defeat a Level III attack; they are supposed to delay the assault until support can arrive. In the case of a ground assault, the defenses that are set up to defend against the Level II assault are the basis for the defense.

A threat-based defense is the standard concept for protecting an airbase from attack. The Level I threat drives the defender to distribute personnel to control access to specific resources. These personnel are difficult to assemble and maneuver against Level II and III threats. The Level II and, because they use the same defenses, Level III threats drive a system of observation posts, strong points and mobile forces controlling the approaches to the perimeter of the base.

The effectiveness of these defenses in defeating penetrating attacks has driven base attackers to use standoff weapons to launch their attacks on airbases. These standoff attacks exploit a hole in the active defenses of an airbase and force the base to rely on hardening and protective measures to mitigate their effects. In the era of unguided standoff attacks, this system proved to be effective enough to keep an airbase operating. However, what happens if a standoff attack can be tailored to defeat these hardening measures? Chapter III will model this possibility using game theory.

III. MODELING

A. MODELING THE PROBLEM

Modeling provides a powerful tool to make complex interactions understandable. This chapter of this thesis will apply modeling to look at the problem of an air base defense force opposing an attacker. The defending force can posture its forces to counterattack a ground attack or a standoff attack. The attacker can choose to launch a ground attack against the base or employ standoff attack weapons from beyond the range of the base's defenses. Three different games will be explored: The attacker using unguided standoff weapons, the attacker using guided standoff weapons, and the defender introducing a methodology to greatly reduce the effectiveness of any type of standoff attack, guided or unguided.

The advantage of a standoff attack for the attacker is the large operating area the attack can come from (and hence the defender has to control with observation and fire) and the ability of the attacker to avoid the majority of the base's defense. The range of his standoff weapon defines the area where an attacker can operate and the distance to the target (a tent city, an aircraft parking area, etc) he wishes to attack. This area can be simply defined by the formula for a circle, Area = $\pi (r)^2$. If the attacker has an 82mm mortar with a range of 8 km, the defender must defend an area of approximately 201 km^2 from each target. For simplicity, we will assume one target for the attacker, an aircraft parking area, located at the center of the airbase. (With the large number of potential targets for standoff attacks on an airbase, many of them located on the edge of the base's perimeter, it is easy to see how this area can increase greatly. The size of a modern airbase, many containing 10 km runways, only increases this problem).

American base defense doctrine says that the defender must be able to keep an attacker from interfering with or destroying the base's critical assets (Joint Publication 3-10.1, 1996, p. IV-8). The foundation of any good base defense plan ensures that these resources are protected. The reason for this is

tied to the vulnerability of aircraft and air-launched weapons on the ground. I offer the following analogy: Hit an aircraft with a sledgehammer, you can do hundreds of thousands of dollars in damage with each blow and, in a short time, make it unflyable and possibly put it beyond repair. Hit an M-1 tank with a sledgehammer and you hurt your hands.

Starting the defense at the resource that is being secured makes the attacker's task more difficult. Increasing the distance between the resource and where the attacker can launch his attack, increases the complexity of the methods that the attacker must use. If the attacker can touch the aircraft, the methods of attack can be very simple (the proverbial sledgehammer, arson, etc). As distance increases, the attacker must use methods that are more complex. For example, hitting a target with a rifle from 300m takes more skill than a point blank attack. A 1200m shot with a sniper rifle takes more skill than the 300m shot. Hitting the target with a mortar round from 7 km is still more complex.

In addition to the factor of complexity of the attack, close in attacks are thought to be more precise then standoff attacks. "Penetrations allow attackers to defeat camouflage, deception and hardened systems designed to protect against air and stand-off attacks. Close-in attacks can generally inflict more precise damage than that caused by stand-off weapons (AFI 31-101, 2002, pg 6)."

Hence, a Level I attacker can be best characterized by a sapper or an attack enemy agent operating on the airbase. If a small number of these individuals can gain unrestricted access to an aircraft or other target, they can do massive damage with relatively simple means. A Level II attacker, which has a force of up to battalion size (600-man), can use sapper attacks, direct ground attacks, or standoff attacks to affect the airbase. A Level III attacker strikes with a force of greater than 600-men. A Soviet-style breakthrough force provides a potential example. As noted earlier, doctrine expects a base to be able to defeat Level I and II attacks and to delay Level III attacks until reinforced.

In his book, Snakes in the Eagle's Nest, Vick (1994, p. 110) warns about the introduction of guided standoff weapons tipping the balance of power in the

favor of the attacker. The potential for the attacker to use laser-guided mortar rounds, wire or laser-guided anti tank rounds or Guided Standoff Improvised Explosive Devices (i.e., a small Unmanned Aerial Vehicle with a camera and an explosives charge) adds a degree of effectiveness to an attack that cannot be matched by the defender.

B. THE GAMES

In this chapter, we will look at three zero-sum games where the attacker (assuming a Level II force operating in the area around the base) can choose a ground attack or a standoff attack, and the base defenders can choose to defend against a standoff attack or a ground attack. Based on the Vietnam base attack data from Vick's study, the following scale shows the potential values of the game.

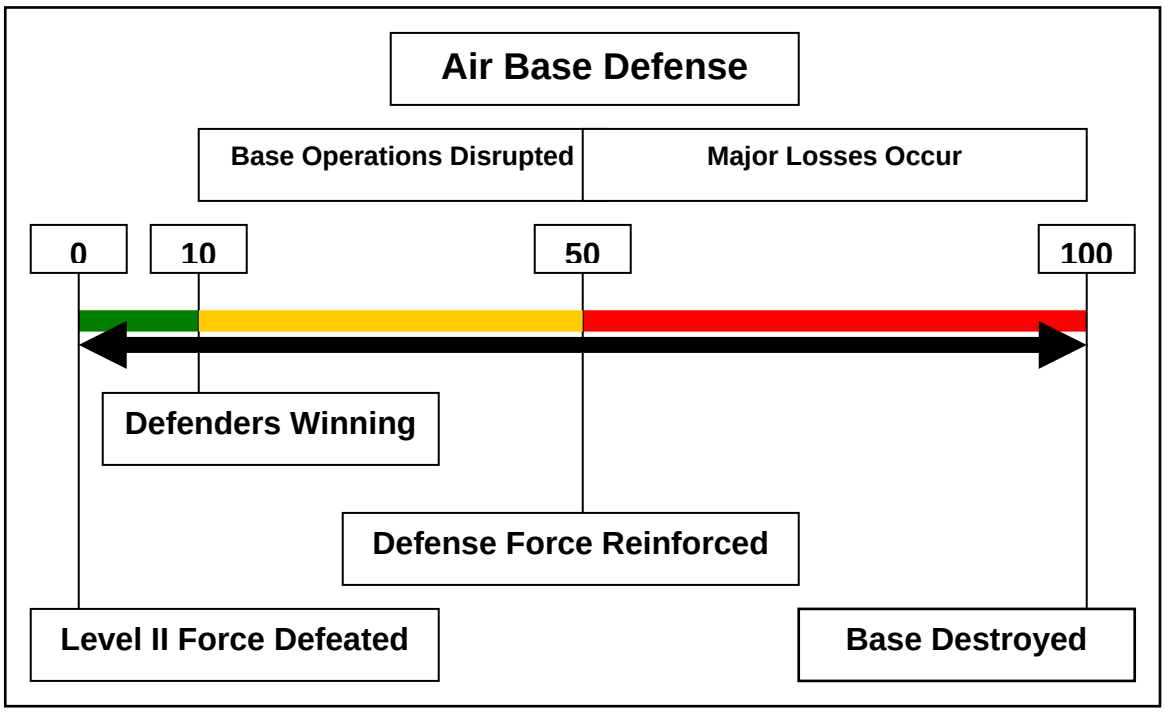

Figure 1. Scoring the Game

Let us breakdown these values and look at their graphical representation in Figure 1:

- At a value of zero the Level II force is destroyed

- At a value of 100 the base is destroyed/held by the Level II force.

- Between 0 and 10, the Level II force is only able to do minimal damage to the airbase and cause limited disruption to operations. The defender wins the game in this range.

- Between 0 and 50, the Level II force is able to cause damage to the base and disrupt operations. As the score gets closer to 50, more pressure is placed on the defense force to stop attacks.

- Once the score reaches 50 and above major damage is inflicted to the base and the defense force is reinforced. The game is lost by the Defense Force/won by the Level II force. This is considered a loss by the defense force because reinforcements must be pulled from other operations, potentially affecting the broader war effort.

1. Game One: Conventional Standoff Weapons

In the first game, we will look at a scenario where the enemy is armed with conventional standoff weapons. These weapons can be mortars, unguided rockets or any other weapon with an effective range of over 1500 meters (the maximum range of the Mk-19 grenade launcher, the most powerful weapon organically available to USAF ground defenders, (AF I 31-301 (2002), p. 30). In this game, the defense force is trying to minimize the value of the game while the attacker is trying to maximize it. The defense force can choose to concentrate their forces to defend against a ground attack (keeping them close to the base) or to defend against a standoff weapons attack by spreading them out on ambush patrols to attempt to stop these attacks. The Level II force can choose to launch a ground attack or a standoff attack against the base.

Neither player has a dominant strategy. Both players will adopt a mixed strategy to attempt to improve their positions (see Figure 2). Let us look at this game.

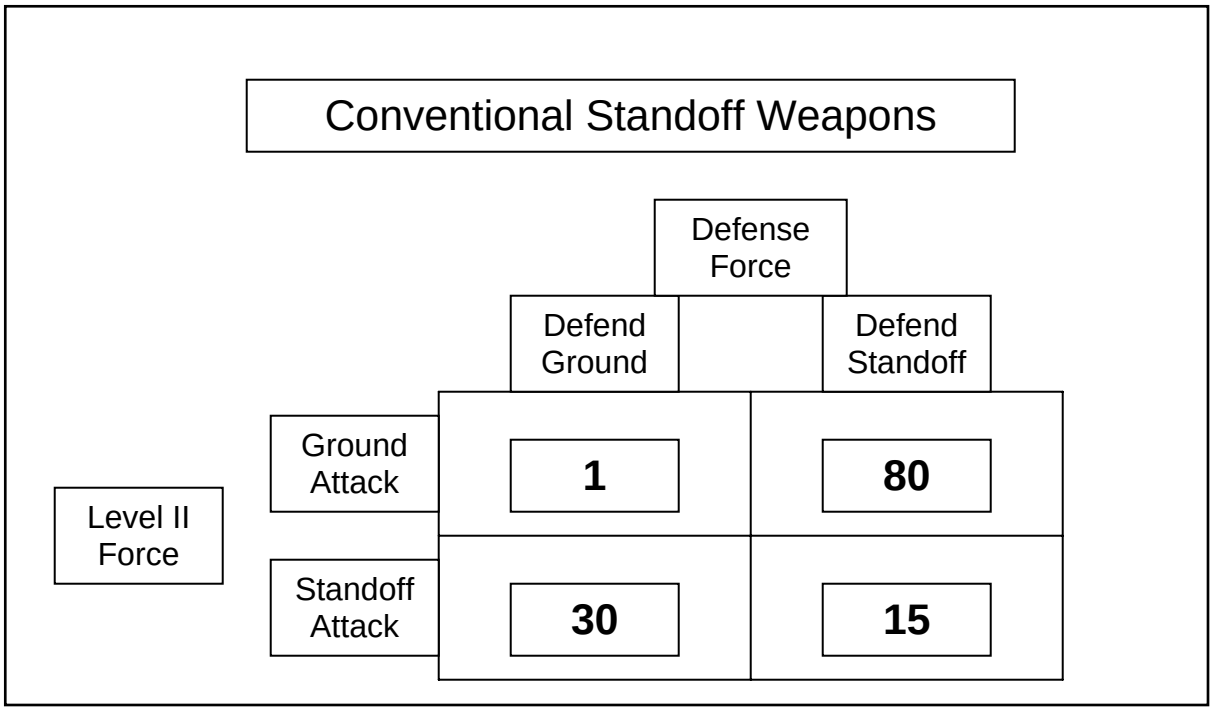

Figure 2. Game One Courses of Action
(See Appendix 1, Game 1 for calculations)

a. Game One Results

In game one, the attacker has the choice of using a ground attack or a conventional standoff attack and the defender has the choice of concentrating his forces to counter the ground attack or spreading them out in the potential launch area in an attempt to stop a standoff attack. Neither player has a dominant strategy and to obtain the optimal score, both players will pursue a mixed strategy. In this mixed strategy, the defender should defend against a ground attack in 69.1 percent of the games and defend against standoff attacks 30.9 percent of the time while the attacker should use 84 percent standoff attacks and 16 percent ground attacks (See Appendix 1, Game 1 for calculations).

The value of this game is 25.372. The attacker is causing damage to the base and disrupting operations but not to the level where he is able to win the game (50 or above). The defender is receiving more damage then he wants and while not losing the game, base operations are disrupted, limiting the effectiveness of the base in supporting the large military effort.

2. Game Two: Guided Standoff Weapons

In the second game, we will look at a situation where the enemy is armed with guided standoff weapons. These weapons offer the attacker a much greater chance of destroying the target because of their guidance systems and improved accuracy and again have an effective range of over 1500 meters. In this game, both players have identical goals and strategies as game one. The defense force is trying to minimize the value of the game while the attacker is trying to maximize it. The defense force can choose to concentrate their forces to defend against a ground attack (keeping them close to the base) or to defend against a standoff weapons attack by spreading them out on ambush patrols to attempt to stop these attacks. The Level II force can choose to launch a ground attack or a standoff attack against the base.

Neither player has a dominant strategy but the value of ground attack vs. standoff defense; standoff attack vs. ground defense and standoff attack vs. standoff defense all greatly increase (See Figure 3). All of these increases can be attributed to the increased effectiveness of the guided standoff weapon. (The increase in standoff attack effectiveness is obvious. The increase in the ground attack vs. a standoff attack is due to the ability to use the guided standoff weapon to eliminate a key component of the base's remaining defenses, supporting the attacker's ground assault.) Both players will adopt a mixed strategy to attempt to improve their positions. Let us look at this game.

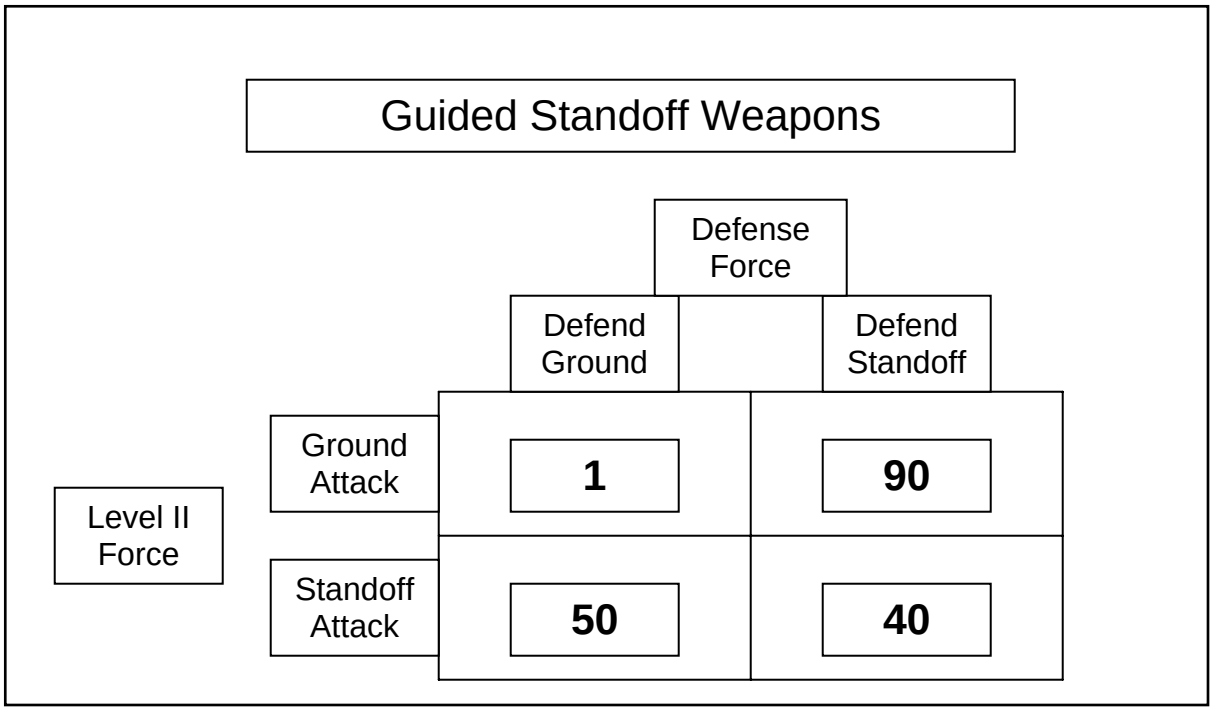

Figure 3. Game Two Courses of Action
(See Appendix 1, Game 2 for calculations)

a. Game Two Results

In game two, the attacker has the choice of using a ground attack or a guided standoff attack and the defender has the choice of concentrating his forces to counter the ground attack or spreading them out in the potential launch area in an attempt to stop a standoff attack. Neither player has a dominant strategy and to obtain the optimal score, both players will pursue a mixed strategy. In this mixed strategy, the defense force should defend against a ground attack in 49.5 percent of the games and defend against standoff attacks 50.5 percent of the time while the attacker should use 89.9 percent standoff attacks and 10.1 percent ground attacks (calculations in appendix one).

The value of this game is 45.051. The attacker is causing almost twice as much relative damage to the airbase and is much closer to the level where he is able to win the game (50 or above). The defender is much closer to losing this game and the ability of the base to support the larger military effort is greatly reduced when compared to game one. The introduction of a more effective standoff weapon has greatly improved the situation of the attacker.

3. Game Three: Counter Standoff System

In the final game, we will look at a scenario where the defender has introduced an improved capability of disrupting standoff attacks. The method(s) used to disrupt standoff attacks is not important to this game. This system can interrupt standoff attacks before they are launched, intercept the rounds in flight, or prevent their detonation when they reach the target (or it can use a combination of these methods to obtain the reduction in the total score seen on the game matrix). The Level II force is armed with the same guided standoff weapons from game two.

Again, in this game, the defense force is trying to minimize the value of the game while the attacker is trying to maximize it. The defense force can choose to concentrate their forces to defend against a ground attack (keeping them close to the base) or to defend against a standoff weapons attack by spreading them out on ambush patrols to attempt to stop these attacks. The Level II force can choose to launch a ground attack or a standoff attack against the base.

Neither player has a dominant strategy but the value of standoff attack vs. ground defense and standoff attack vs. standoff defense both decrease (see Figure 4). All of this decrease can be attributed to the counter standoff system. Both players will adopt a mixed strategy to attempt to improve their positions. Let us look at this final game.

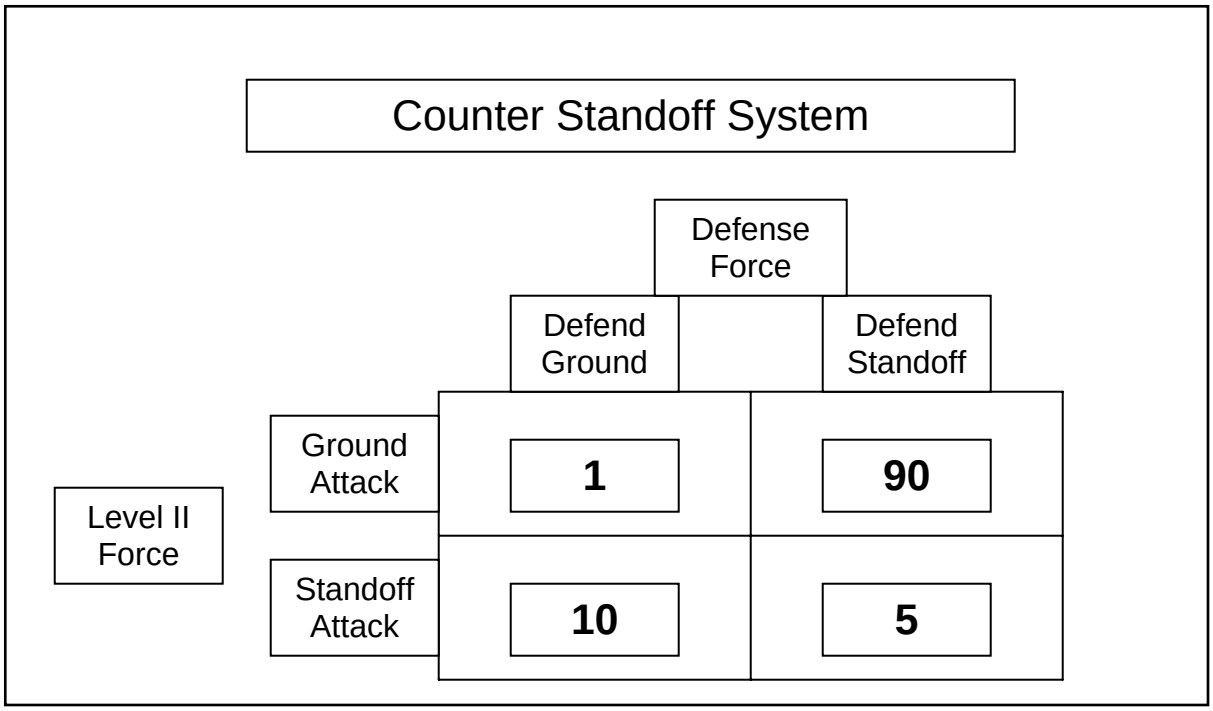

Figure 4. Game Three Courses of Action
(See Appendix 1, Game 3 for calculations)

a. Game Three Results

In game three, the attacker has the choice of using a ground attack or a guided standoff attack and the defender has the choice of concentrating his forces to counter the ground attack or spreading them out in the potential launch area in an attempt to stop a standoff attack. The difference in this game from game two was the introduction of a highly effective method of disrupting standoff attacks against the base. Neither player had a dominant strategy and to obtain the optimal score, both players pursued a mixed strategy. In this mixed strategy, the defense force should defend against a ground attack in 90 percent of the games and defend against standoff attacks 10 percent of the time while the attacker should use 94.7 percent standoff attacks and .053 percent ground attacks (calculations in appendix one, game three).

The value of this game is 9.52. The Level II force is not destroyed but the defender wins the game in this range. Attacks of the airbase will continue but the damage and disruption to operations will be minimal, allowing the base to

freely support the larger military effort. The introduction of a more effective standoff weapon has been trumped by the defender's newly found ability to disrupt standoff attacks.

4. Conclusion

These three games attempted to show different scenarios in the continuing struggle between the attacker and the base defender. The chance for the attacker to improve their results by introducing guided weapons technology to their attacks should cause worry to airpower advocates. This modeling shows that counter standoff systems can be highly effective but unlike the guided standoff weapons available to potential attackers today, these systems do not yet exist.

IV. ADAPTING EXISTING WEAPONS SYSTEMS

A. EXISTING WEAPONS ADAPTABLE FOR GUIDED, STANDOFF ATTACKS

The costs of directly attacking the resources on an air base can be made quite high by the defender. As we have seen by the historical data laid out by Vick (2005) and the modeling of the problem in Chapter II, the attackers of a base have and will increasingly turn to standoff methods to attack air bases.

This chapter will look at the weapons systems, which are readily adaptable for use by countries, or non-state actors who want to attack air bases. The desired characteristics of these weapons systems will be examined and the types of weapons systems that are available will be discussed.

1. Desired Characteristics of Available Weapons Systems

To perform future standoff attacks with existing weapons systems, attackers are looking for a system that is long-range, accurate, simple to use, light and compact, and that allows the attacker to avoid counterattacks and allow them to escape (which will be call survivability). The first factor we will look at is range.

a. Long-Range

In developing standoff methods to attack air bases, an attacker needs a weapons system that outranges the longest range weapon that the defender has while also allowing him to hit the target. The most effective weapon, organic to the United States Air Force, available to engage a standoff attack is the Mark-19 grenade launcher. This weapons system has the ability to fire 40 mm grenades at any attacker without any complex interactions with a fire direction center.

If the defenders have a Mark-19 grenade launcher with a maximum range of 1500 meters on the perimeter of the base and the target is an additional 1000 meters from the perimeter, any weapon with a range of over 3000 meters

would allow the attacker to fire with impunity (with a 500 meter safety zone). Using this as a baseline, an attacker should look at weapons systems that have a range of 3000 meters or greater.

If the attack is overt and the launch location is easily detectable by the defenders, it is easy to imagine the defender maneuvering to close the distance to engage the attackers. However, it takes time to mount a reaction force and the launch location of standoff weapons systems is not always clear.

b. Accuracy

Standoff weapons have always used their long-range to attack targets on airbases. The missing link, from the point of view of the attacker has always been accuracy. The ability of the attacker to hit the target they are aiming at has always been this method's Achilles heel. To overcome this problem, an attacker needs to find existing weapons systems that have guidance systems already installed. The method of guidance can be by global positioning satellite, wire, laser, or gyroscope. Each of these methods of guidance has their own advantages and disadvantages, but from the point of view of the attacker, any reliable guidance package on their standoff ordnance greatly increases their probability of a successful attack. Using this thought process, any weapons system that has a guided capability can meet this criteria.

c. Simple to Use

The attacker is operating in potentially hostile terrain. Therefore, any weapons system that is too complex to rapidly and effectively employ is a liability. However, most of the military systems that are available off-the-shelf can be quickly learned and mastered. As the user interfaces for these systems become more advanced, the complexity of operating these systems should come down.

d. Light and Compact

From the attacker's point of view, it would be advantageous to use large artillery pieces to obliterate the targets on an airbase but the scope of this study does not permit this. This study assumes that the attacker is operating in an area where they must remain relatively covert, similar to the posture of the

Viet Cong forces attacking U.S. bases in South Vietnam. Because of these restrictions, the attacker is looking for a weapons system that is light and compact.

Using the criteria of the Russian Army a system is manportable if it (or the components that make it up) weighs from 11 to 44 pounds (five to 20 kilograms), portable if it weighs from 46.2 to 88 pounds (21 to 40 kilograms) and should be vehicle mounted if it weighs over 88 pounds (40 kilograms) (http://www.globalsecurity.org/military/world/russia/at-4.htm, 2006). Using these criteria and assuming a six-person attack group, a maximum weight of 264 pounds (120 kilograms) is set for man portable systems that will use no vehicle support.

An attacker that can use vehicles to support their attacks has a great advantage in payload and maneuverability. Small trucks have been used very effectively to launch asymmetric attacks on US forces.

> During the 2003 Operation Iraqi Freedom, US troops encountered an unanticipated, and formidable, weapon in the Iraqi arsenal — Russian-built Kornet antitank missiles. Iraqi commandos traveling in three-man teams dressed in black civilian robes and riding in Nissan pickup trucks moved against the flanks of columns of armor from the US Army's 3rd Infantry Division and launched broadside attacks from several kilometers away using the system (http://www.globalsecurity.org/military/world/russia/at-14.htm, 2006).

The real key for the attacker is the ability to hide the weapons system before and possibly after an attack. A Nissan Titan pickup truck has a payload of 1378 lbs and a bed size of approximately 70 cubic feet (assuming a 24 inch height for ease of hiding) (Nissan USA, 2006) Subtracting weight for other gear and the three personnel, This leaves a payload of 500 pounds and room for a hidden 50 cubic foot system.

e. Survivability

The final criterion that an attacker is looking for in a future standoff attack system is the ability of the system to enable the attacker to avoid counterattacks and escape. Several different system characteristics can aid the attacker.

A small launch signature can be very helpful to the attacker. A weapon that has a low noise and visual signature would be extremely helpful. A defender who does not know where an attack came from does not know where to send the counterforce.

A version of a fire and forget system would also assist the attacker in their attempt to escape the scene. A very simple version of a fire and forget system can be a timer that allows the attacker to set up the system and leave the scene minutes or even hours before the system fires. A remote activation of a weapons system would have the same effect as the timer. A more complex weapons system might have the ability to lock on to a target without any further guidance from the operator, allowing the attacker to concentrate all of his efforts on leaving the scene.

Finally, a system with a rapid launch sequence or a fast flight time can help the attacker to escape. The shorter the flight time of a weapon that required terminal guidance, the sooner the operator can make their escape.

2. Existing Weapons Systems

There are five desired characteristics for existing weapons systems (long-range, accurate, simple to use, light and compact, and survivability) have been identified and discussed. The next step in this process is to look at available weapons systems that meet these specific criteria.

Using the weapons data found in *Jane's Infantry Weapons* (Jane's, 2006); two promising weapons systems for air base attack emerge. These weapons systems are guided mortar rounds and anti tank guided missiles.

a. Guided Mortar Rounds

The first type of weapons system that meets the requirements of a potential airbase attacker is a guided mortar round. Usually using a laser designator to home in on a target, these rounds can deliver their explosive payload to within a few meters of a selected target.

Currently, guided rounds are only available for mortars of 120 millimeters, making it the only available choice. The Russian military currently fields (and has available for export) the laser-guided "Gran" 120-millimeter mortar projectile with a weight of 25 kilograms and a range of 7,500 meters (Jane's, 2006). The U.S. Army's Precision Guided Mortar Munition, offers a range of up to 15 kilometers, accuracy to within a meter of a target and a projectile weight of 17.2 kilograms (Jane's, 2006). This round will enter service in 2008.

Laser designators and guidance packages in guided mortar rounds work in tandem to increase the accuracy these rounds over conventional rounds. The laser designator reflects a beam off the selected target and the sensor in the nose of the round controls impulse thrusters that steer it towards the target. The high trajectory of mortar rounds give the guidance controls more time to function, giving these rounds more accuracy than flat trajectory munitions.

Using a mortar in conjunction with a laser designator is not the simple task that an attacker would like it to be. Coordination between the designator and the mortar crews takes practice. Additionally, it takes basic knowledge of the mortar system and ballistics to get the mortar round close enough to the designated target for the guidance package to function.

The 120-millimeter mortar is not a light weapon. The U.S. Army's M120, 120-millimeter mortar weighs in at 145 kilograms with the tube weight of 50 kilograms, a base plate weight of 62 kilograms and a tripod and sight total weight of 33 kilograms (Jane's, 2006). Added to that weight is the 17.2 to 25 kilogram weight of the U.S. or Russian projectiles respectively.

The 120-millimeter mortar system does not exceed the 50 cubic foot (cubic meter) space limitations. Using the attacker's established

requirements above, the 120-millimeter mortar would be limited to use where vehicle support was available. The use of a simple handcart could greatly improve the mobility of these systems and aide in their resupply.

The ability of the mortar crew to operate in one location and the laser designation team to operate in another area gives the mortar an advantage in the category of survivability. The mortar crew can fire their rounds and be in the process of leaving the area while the laser designator team, potentially operating several kilometers away, guides the rounds on to the target. Additionally, the high trajectory of a mortar round gives it the ability to fire from behind a hill or building, avoiding detection and direct fire from the airbase, further enhancing survivability.

(1) Assessment of the Guided Mortar Round. The high trajectory of the mortar helps make it an ideal weapon for attacking an airbase. The ability to fire the weapon indirectly (although the laser designator must have line of sight to the target), from behind the cover of a building or a hill, is a great advantage. The high trajectory also allows the round to avoid hitting obstacles (buildings, terrain, etc) on its flight path to the target.

The improved accuracy of a guided mortar round also improves on the mortar's strengths. Vick (1995, p. 107) showed that the majority of standoff attacks on airbases used under ten rounds. These rounds usually fell in a circular pattern around the aim point, occasionally hitting the target, but most of the time exploding harmlessly. A guided mortar round can put a single round within one meter of the target, destroying it the first time.

The weight and complexity of the entire mortar system do not make it an ideal system for all airbase attackers. Because of the training and skill required to operate the mortar and the separate laser designator system, only Level II attackers who have the necessary training could benefit from this system. Special Operations teams or insurgents with their support would be the most likely attacker to acquire and effectively use this type of system.

The high weight of this system also cuts down on its effectiveness. Even with the advantage of indirect fire, the threat of attack aircraft from the base requires mobility. The attacker must keep possession of the 145-kilogram mortar if they wish to launch further attacks with it. The use of the mortar in urban areas (where vehicles blend in) or in heavy vegetation (where weapons and people can hide) can mitigate these problems for the attacker.

Moving a 120-millimeter mortar is going to take the support of a motor vehicle or a cadre of dedicated people using wheeled carts and muscle power. In an urban area, motor vehicle support might blend into the background but the use of checkpoints and roadblocks might expose a Special Operations team. Any special operations team operating a 120-millimeter mortar is going to want the support of a large number of local people, increasing their detectable signature, and opening an avenue for counterintelligence efforts to exploit.

Overall, the guided mortar munition could be a very effect system for standoff attacks on an airbase. In terms of cost benefit ratio, this weapons system could have a very high payoff, trading $30,000 dollar munitions for $180 million dollar aircraft.

(2) Available Guided Mortar Rounds. The weapons of ten leading arms manufacturing nations (Belgium, Canada, China, France, Germany, Israel, Russia, Serbia, United Kingdom, and United States) were reviewed in *Jane's Infantry Weapons.* Of these ten nations, only Russia has a guided mortar round currently available, the Gran. This 25-kilogram projectile round has a range of 7,500 meters (Jane's, 2006).

The United States and Israel both have guided 120-millimeter mortar rounds nearing production. The 17.2 kilogram Precision Guided Mortar Munition, expected to begin fielding in 2008, offers a range of up to 15 kilometers and accuracy to within a meter of a target (Jane's, 2006). The Israeli Fireball system offers the same range and one-meter accuracy (Defense-Update, 2004) and is also expected to be fielded in an 81-mm mortar. (The

availability of a guided 81-millimeter mortar to an attacker takes away many of the weight and logistical disadvantages of the 120-millimeter system and makes this mortar more versatile.) Both the U.S. and Israeli systems use the Global Positioning System to guide the mortar round into a positional "basket" where the laser guidance can take over (Defense-Update, 2004).

The limited number of guided mortar systems currently available helps to limit the choice of different threat systems. However, another type of weapons system, using multiple guidance strategies, is widely available…the anti-tank missile.

b. Anti-Tank Missiles

The anti-tank missile was originally designed to give the infantryman a portable, standoff system to destroy armor. Because of its heritage, this system offers many of the features needed for a Level II force to conduct a guided, standoff air base attack.

The requirement for 3000 meters in range limits this search to the medium anti-tank missiles, characterized by the U.S. TOW (Tube-launched Optically tracked Wire-guided) missile or the Russian AT-3 Sagger missiles. Both of these missiles in their original configurations have the required 3000-meter range (Jane's, 2006). Many newer, lighter systems have ranges that exceed 3000 meters.

Anti-tank missiles use a wire guidance system, a laser guidance system, or a fire and forget system. An operator using a control wire that streams from the back of the missile to the operator control station directs wire-guided rounds to a target. For laser-guided rounds, the operator projects a beam of light on the intended target and the laser guided round homes in on the reflected light. A fire and forget system uses a round that locks on to a selected target (using a laser or an imaging system), holds that target, and guides itself to it without any further input from the operator. All of these systems possess the accuracy required.

Because these systems are direct fire by nature, they are less complex to use then indirect fire systems. The process of seeing the target, aiming at the target and firing is an extension of basic marksmanship and inherently easier to teach. Because of their original intended purpose, these systems are designed to be simple to operate and use.

The medium anti-tank missile is designed to be man portable. The TOW missile itself weighs 20 kilograms while the launcher and tripod weigh less than 100 kilograms and are designed to be broken down for carry (Jane's, 2006). This meets the requirement for a man portable system. Adding vehicle support to this type of system would give the attacker more mobility and the ability to carry more ammunition.

Because of the range of these systems is greater than the range of the defender's organic weapons, they are survivable. However, the need for the operator to guide the missile on to the target and to stay on the target until impact lowers the survivability of the operators of some of these systems when compared to fire and forget models. The need for an AT-3 Sagger operator to keep a target locked for the full 25-second flight time of the missile (Global Security.org, 2006) might be a disadvantage if the base defenders have a patrol nearby.

(1) Assessment of Anti-Tank Missiles**.** Anti-tank missiles may present the best, currently available option, for performing guided standoff attacks against air bases. Their original design, to support infantry with an anti-armor standoff capability, has led to a system that is light enough to move, simple to operate and effective out to long ranges.

The anti-tank guided missile gives an attacker the ability to reach out and strike individual targets on an air base at long range.

Even with all of its advantages, the anti-tank missile does have some design drawbacks as a standoff weapon for air base attack. The first of these is its flat-trajectory, which is especially a drawback for wide-guided systems. Such systems require a debris-free flight path to avoid disconnecting

their wires. Obstacles such as building, fences, and hills can break this wire causing the missile to fly off out of control. This flat trajectory also limits the missile to firing positions where the target is in direct view. This can aid the defender by limiting the ground he has to control, allowing him to set up counter measures.

Another drawback of the anti-tank missile is the design of its warhead. Many of these missiles have a shape-charged warhead, designed to puncture a small-diameter hole in the side of a main battle tank. These specialized warheads are far less effective against softer targets than conventional high explosive rounds. Such warheads, however, can be replaced or modified and many systems with dual-purpose warheads have become available.

A final drawback of more sophisticated anti-tank missiles is the lack of a dedicated, man portable, launch platform and control station. As many of these systems became more complex, these missiles were designed to be launched from either aircraft or dedicated vehicle mounts. This does not mean that these missiles and their control stations cannot be modified; it simplify makes their use against an airbase more difficult.

(2) Availability of Anti-Tank Missiles. Again, the weapons of ten leading arms manufacturing nations (Belgium, Canada, China, France, Germany, Israel, Russia, Serbia, United Kingdom, and United States) were reviewed in *Jane's Infantry Weapons.* The purpose of this search was to look for Anti-tank Guided weapons that fit the needs of an air base attacker. The results are displayed by country or combined when the countries use the same systems. Belgium, Canada, France, Germany, Serbia, and the United Kingdom produced no unique systems that fit the range and weight requirements discussed in this chapter.

China

System:	Red Arrow
Guidance:	optical wire-guided, microwave-guided or laser beam riding (Depending on variant)
Range:	3000 - 5500 Meters depending on type
System Weight:	89.2 Kilograms with launcher (Variant 8E)
Speed:	200 meters/second
Warhead:	High-explosive Anti-Tank (HEAT) or dual HEAT/High-explosive

Israel

System:	Spike Long-Range (LR) and Extended Range (ER)
Guidance:	Dual mode: fire-and-forget or fire-observe-and-update (using a fiber-optic two-way link)
Range:	4000 (LR) to 8000 (ER) Meters
System Weight:	26 Kilograms
Speed:	Not given
Warhead:	High-explosive Anti-Tank (HEAT)

System:	MAPATS
Guidance:	optical laser beam riding
Range:	5000 Meters
System Weight:	89 Kilograms
Speed:	19.5 seconds to 4000 meters
Warhead:	3.6-kilogram shape charge

Russia

System:	AT-2 Swatter (NATO designation)
Guidance:	optical radio-guided
Range:	4000 Meters
System Weight:	26.5 Kilograms (missile only)
Speed:	150 meters/second
Warhead:	5.4-kilogram HEAT

System:	9P163-1 Kornet
Guidance:	Laser beam-riding missile with Semi-Automatic Command to Line Of Sight
Range:	5000 Meters
System Weight:	55 Kilograms
Speed:	240 meters/second (estimated)
Warhead:	HEAT or Thermobaric Explosive

System:	AT-5 Spandrel

Guidance: optical wire-guided
Range: 4000 Meters
System Weight: 48.5 Kilograms
Speed: 206 meters/second (estimated)
Warhead: 2.7 kilogram HEAT

United Kingdom

System: Swingfire
Guidance: optical wire-guided
Range: 4000 Meters
System Weight: not given
Speed: not given
Warhead: shape charge

United States

System: Javelin Extended Range
Guidance: Infrared homing, fire and forget
Range: 4000 Meters
System Weight: 22.3 kilograms
Speed: not given
Warhead: tandem shape charge

System: TOW
Guidance: optical wire-guided
Range: 3750 Meters
System Weight: 120 Kilograms
Speed: 200 meters/second
Warhead: HEAT

It is clear that there are a number of anti-tank missiles available from weapons manufacturers across the globe. The newer, lighter-weight systems should be of particular interest to any potential airbase attackers, the use of which could give an attacker much greater mobility and survivability then older, heavier systems while delivering warheads through a more reliable means.

c. Final Thoughts on Existing Weapons Systems

It is clear that the anti-tank missile is today's most capable system with the guided mortar round playing a complimentary role by bringing greater range to the fight. Nations who produce and export these highly accurate weapons should carefully consider where and whom they export them to.

Serious consideration should also be given introducing controls that render these systems inoperable if they fall into the wrong hands (for example, components that must receive updated codes when scheduled depot level maintenance is performed). The power of these small, accurate weapons in the wrong hands could cause serious, unforeseen consequences.

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V. AN UNMANNED AERIAL VEHICLE AS A GUIDED, AERIAL IMPROVISED EXPLOSIVE DEVICE

A. INTRODUCTION

The increasing sophistication of Improvised Explosive Devices (IED) attacks in Iraq has shown that insurgent groups have the ability to build complex and lethal standoff weapons. The open source data available demonstrates the ability of these groups to adapt their IEDs when faced with countermeasures. This technical sophistication opens the doors to an even more complex mode of attack.

Instead of waiting for a target vehicle to enter the limited "kill" radius of a roadside IED, future enemies could develop a system to deliver an explosives payload to a target. A small Unmanned Aerial Vehicle (UAV) with a video camera to guide the attack can provide such a capability, and it is not outside the ability of insurgent groups to build such a device. This chapter will explore a possible design for a UAV that could be used to attack aircraft on an airbase.

B. A THEORETICAL GUIDED AERIAL IED DESIGN

A guided aerial IED will have four main components: an explosive payload, a guidance system, an airframe/power combination, and a control station. Let us look at each of these in turn.

1. Payload

The first design factor we will look at is the weight of the explosive payload that the UAV must carry. This weight will affect the size of the airframe, the power requirements for the motor(s) and the effective range of the UAV. The weight of the payload is a function of the accuracy of the delivery vehicle (how close can the UAV get the explosives to the target) and the nature of the expected target.

The data from the Vietnam War shows us that a high explosives 82-millimeter mortar shell would be an effective basic payload. Weighing only 4.2 kilograms (9.24 pounds), it has a kill radius (50% of unprotected personnel within this radius will die from shrapnel or blast effects) of 17 meters (Sinodefense.com,

2006). This shell has demonstrated the ability to destroy parked aircraft in the past (Vick, 1995 and 1996). With its roots in the former Warsaw Pact, the 81-mm projectile is also widely available on world arms markets. Assuming that there might be some additional weight added to ensure the proper detonation of the shell, the required weight for the explosives payload will be raised to 5-kilogram (11 pounds). If we keep the 5-kilogram weight limit, it is easy to imagine different payloads for different purposes.

For a wide-area attack, hand grenades might be used. Imagine fragmentation grenades, with their pins pulled, placed in a thin glass tube (designed to hold their spoons in place and scored to help it shatter on impact). A one-kilogram tube could hold up to eight, half-kilogram grenades with a five meter kill radius and spread them in an arc from the point of impact of the UAV.

A similar payload could be used to start fires. A mixture of fragmentation grenades (to blast holes in fuel tanks) and incendiary grenades to ignite any combustible materials could be devastating. A one-kilogram glass sleeve could theoretically hold two, one-kilogram incendiary grenades and four, half-kilogram fragmentation grenades.

A final payload design that could maximize the destructive effects of the explosives payload is an improvised explosives payload. The 82-millimeter mortar shell contains a large amount of metal that is needed to protect the projectile from the explosive force and rapid launch acceleration from a mortar tube. This durability is not needed if the explosives are delivered by the relatively gentile flight of a small UAV. Designing a custom explosives device for these UAVs would allow for more explosives resulting in a larger kill radius. Metal pieces would still be needed to provide fragmentation but at a much lower weight than the original shell. This route would require more sophistication then simply using existing munitions but an enemy that could build a guided UAV should be able to accomplish such a task.

2. Guidance System

The simplest guidance system for a guided Aerial IED would be a small video camera. This camera could allow the operator to fly the IED into a target. There are several camera systems available to model airplane hobbyists that would provide this capability. Many of these systems are limited to a broadcast range of around 300 meters (www.rc-cam.com) by Federal Communications Commission regulations but there are systems available to HAM radio operators that advertise a range of up to 8 miles (12.8 kilometers) (www.transmitvideo.com/don_article.html, 2006). A group could easily modify one of the short-range camera systems by increasing the power of the transmitter or simply acquire one of the longer-range systems.

A far more sophisticated system would involve the use of gyroscopes and Global Positioning System information. With such a system, an insurgent group could develop an autonomous UAV feasibly capable of flying to within a meter of a point. With a little advanced reconnaissance, a group could have a “fire and forget” IED that flies itself to a target without the need for additional human input. This type of system would be limited to only the most sophisticated of insurgent groups but it would not be beyond the capability of a nation-state to provide it to a group that it is supporting.

3. Airframe and Power

The world of radio-controlled model airplanes offers everything an insurgent group would need to build the airframe of an effective guided aerial IED. From balsa wood to polystyrene, the materials to build an airframe are available. Control surfaces (ailerons, rudders, etc) and the systems to operate them are also available. With an effective design, a practiced hobbyist with a limited workshop and access to parts could easily build a working airframe.

The question of how to power a small UAV comes down to a choice between a gas engine and electric motors. Gas offers more power per weight but requires a generator to power electrical systems. Gas engines also make much more noise than electric motors. Both the Air Force’s Desert Hawk and the Marine Corp’s Dragon Eye small UAVs use electric motors (Dragon Eye, 2003

and Desert Hawk, 2003). Because these systems are very similar in size to the guided aerial IEDs we are discussing and a low noise signature is important to limit early warning for the defender, an electric motor is preferable.

The Desert Hawk uses a very simple system of laptop computer batteries to power it. These batteries give it an operating endurance of 60 to 90 minutes (Perrien, 2003). An insurgent group might not need this much operating endurance and could lower the weight by reducing the number of batteries.

4. Control Station

Controlling the guided aerial IED is the final step to delivering it to a target. The world of radio controlled model airplanes offers a basic control device capable of flying such an airframe. The standard transmitter for radio-controlled airplanes allows the operator to fly it in exactly the same manner. Again, FCC regulations limit the range of these devices to roughly 800 meters (www.novagate.com/~jmartin/hobbie.htm, 2006) but they can be easily modified by increasing the power output of the transmitter and improving the antennas.

One problem with using these control stations is the amount of training and concentration they require. An experienced hobbyist can easily operate one of these platforms if they can see the aircraft but to effectively use a guided aerial IED, it must be used at a distance where observing a small UAV would be difficult. Learning to fly one of these systems through a camera would also be difficult and take a good deal of practice.

The answer that both the Marine Corp and the Air Force turned to was a software-powered autopilot. Operated from a laptop computer, the system uses downloaded maps and waypoint guidance to take the UAV where the operator wants it to go. Using this type of system, an insurgent could program the software to fly the guided aerial IED to within close range of a target and then manually guide the UAV into the target aircraft using the camera. This software-based autopilot is not a requirement for an effective weapons system, but it does reduce the training time and concentration needed to launch an effective attack. Now that we have looked at the elements of a theoretical design, we shall examine an actual prototype.

C. BUILDING AN AERIAL IED

A theoretical design for putting an explosive payload into a small, guided UAV is one thing actually doing it is another. From 2004 through today, the Defense Intelligence Agency (DIA) has sponsored a "Red Cell" program to test possible uses of small UAVs by terrorist groups. As a part of this program, DIA worked with a group of Midshipmen at the United States Naval Academy to come up with a workable Guided Aerial IED prototype (Burns, 2006).

Using parts from radio-controlled model shops, aluminum, carbon fiber and a 31cc Craftsman weed-eater motor (louder than the electric motor recommended earlier in this chapter but has the advantage of not needing heavy batteries and is widely available), these midshipmen built a working UAV that could easily pose a standoff threat to airbases. Their design has an 8-foot wingspan, has an empty weight of 18 pounds, and an estimated payload of 12 pounds. By mounting a video system to RC aircraft using simple zip ties, these Midshipmen have consistently achieved "5-10 foot targeting accuracy from a standoff range" (Burns, 2006).

Although these midshipmen are extremely bright, the ability to build this aircraft did not require any great level of skill. A basic knowledge of radio controlled aircraft, electronics, small engines, and explosives along with access to a very basic shop space would allow a terrorist group to duplicate this feat. The growing sophistication of IEDs in Iraq indicates that terrorist groups possess or have the ability to acquire this knowledge.

The cost of this guided aerial IED is frighteningly low. Not including the cost of an explosive payload, the midshipmen were able to build this aircraft for a little under $300. Imagine a terrorist or insurgent group trading a $300 guided aerial IED for a $200 million C-17.

D. CONCLUSION

A guided aerial IED is within the capabilities of a sophisticated insurgent group. Using off-the-shelf technology largely aimed at hobbyists and some knowledge of electronics and explosives, an engineer could easily construct a highly effective device. With the power of the internet, successful designs can be

shared on the internet, making their proliferation and improvement easier. The threat of the guided aerial IED is coming, how military and security forces prepare for it will tell us how effective it will be.

VI. COUNTERING THE THREAT

A. THE THREAT IS HERE

The emerging threat of guided standoff weapons attacks against airbases is here. Weapons are available off the shelf and can be constructed that exploit a known weakness in active base defense measures. It is not beyond possibility that a small group of individuals could completely disrupt the operations of an air base during a conventional conflict. It is also possible that such a small group could deny the use of a base to the United States Air Force by making the cost in material and personnel losses too high.

This, the final chapter, will provide some potential areas for countering the guided standoff threat. The effort required to fully develop these ideas is beyond the scope of this thesis. I hope, however, that this chapter will provide some areas for future study and development.

B. THE KILL CHAIN

Looking at the problem of launching a guided standoff attack from the enemies' point of view may provide some insight. The success of improvised explosive device attacks in Iraq offers a tangible model to build on. Colonel William Hix (2006), a National Security Affairs Fellow from the Hoover Institute at Stanford University, offers the following chain of events (Figure 5) for an attacker launching an Improvised Explosive device attack in Iraq.

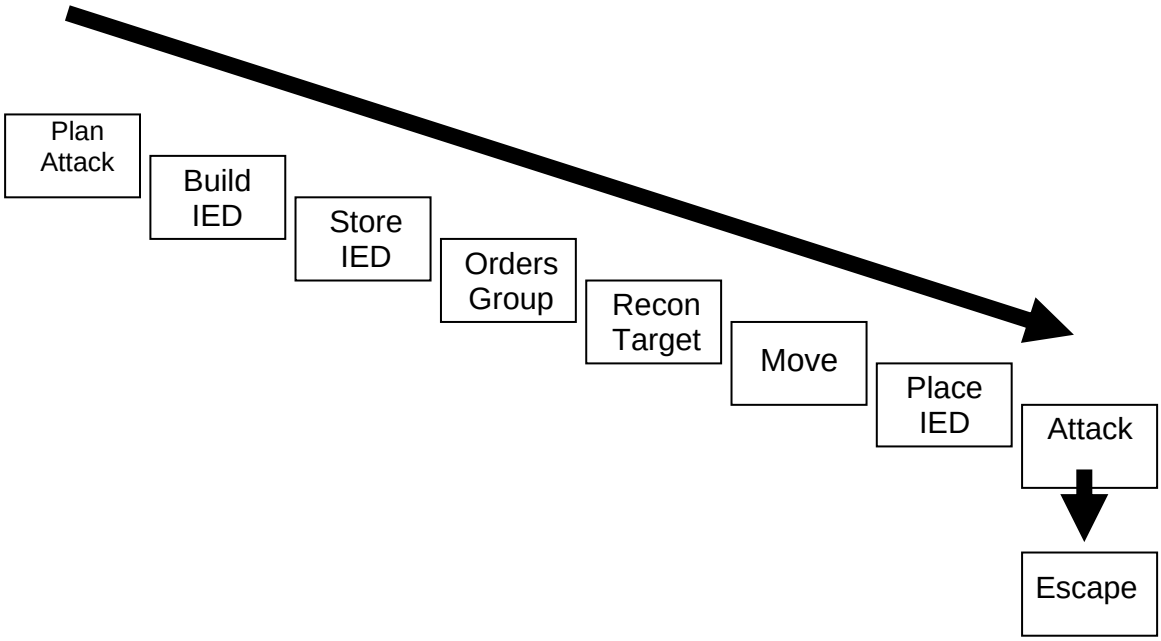

Figure 5. Improvised Explosives Device Kill Chain

From planning to the launch of the attack, the enemy must complete all of the steps in this chain to initiate an attack. If the defender can interrupt the enemy in any of the steps prior to the attack the attack will not occur. If the defender can capture or kill the attackers and prevent their escape, future attacks might be prevented. In attempting to disrupt this process, the defender must find the weakest and most vulnerable links in this chain of events and exploit them.

It is easy to apply this same kill chain process to the problem of guided standoff attacks. A nominal kill chain for a Level II air base attacker is shown in Figure 6. Unlike the established insurgent group in Figure 5, this group of attackers has the additional task of infiltrating the Joint Rear Area and establishing an operating infrastructure before they can deploy their guided standoff kill chain.

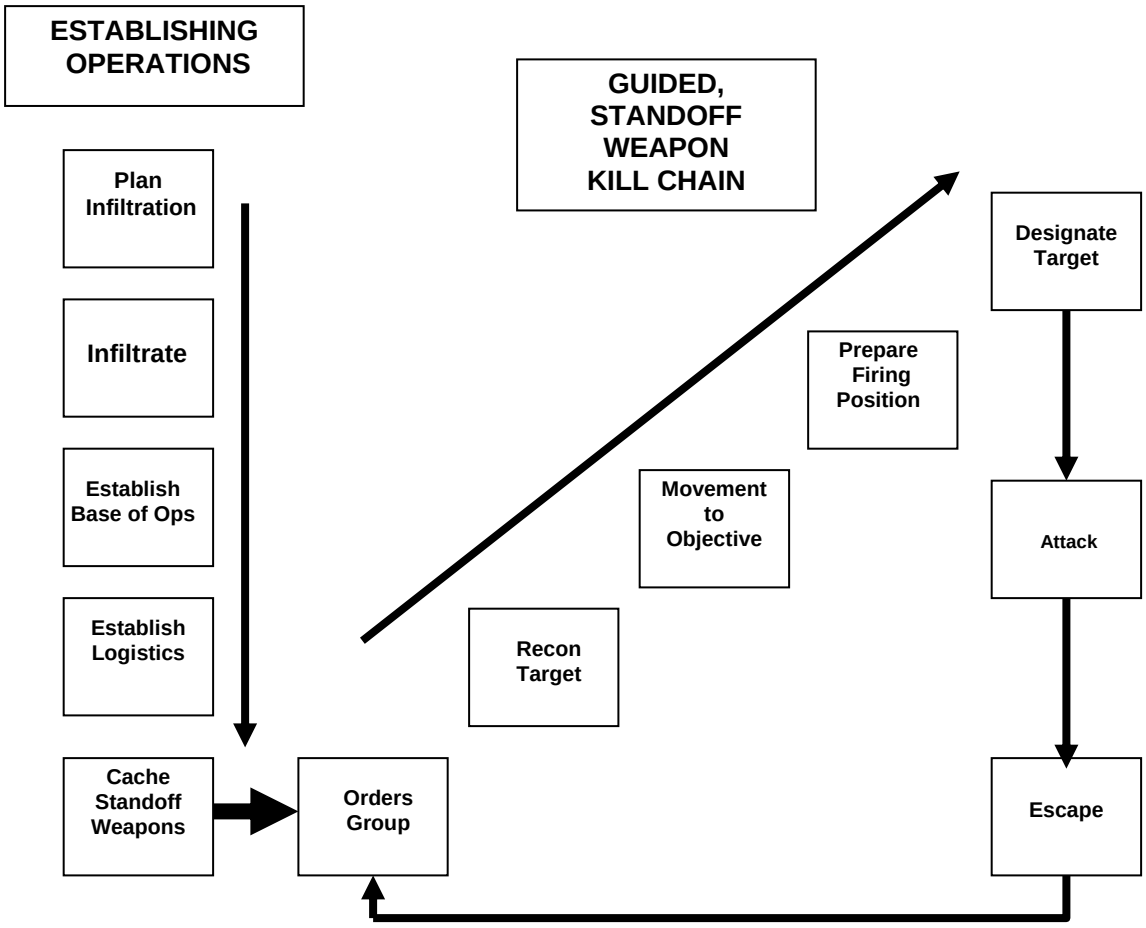

Figure 6. Nominal Air Base Guided, Standoff Weapon Kill Chain

The added complexity here offers additional possibilities in preventing guided standoff attacks. The USAF strikes at the airpower infrastructure (airfields, surface-to-air missile batteries, radars, etc) of an enemy in the process of attempting to achieve air superiority. If it is suspected that an enemy will attempt to use specific ground units to attack friendly airbases, these enemy ground units should be targeted in their garrisons. Attacking these units, prior to their attempts to infiltrate into the Joint Rear Area, becomes an extension of the struggle for air superiority. Targeting suspected infiltration vectors (submarines, boats, planes) may provide another method to prevent these attacks.

C. A DEFENSE OF MANY LAYERS

With the enemies large launch footprint, the task for the base defender becomes very difficult. A defense consisting of multiple layers is needed to

prevent a successful attack. This paper proposes a four-layer defensive concept to protect the resources of an airbase and to preserve the base's ability to generate combat power.

The four-layered approach (Figure 7) proposes to deal with the threat of guided standoff weapons in separate phases. Those phases are pre-launch, post-launch, point defense and attack mitigation.

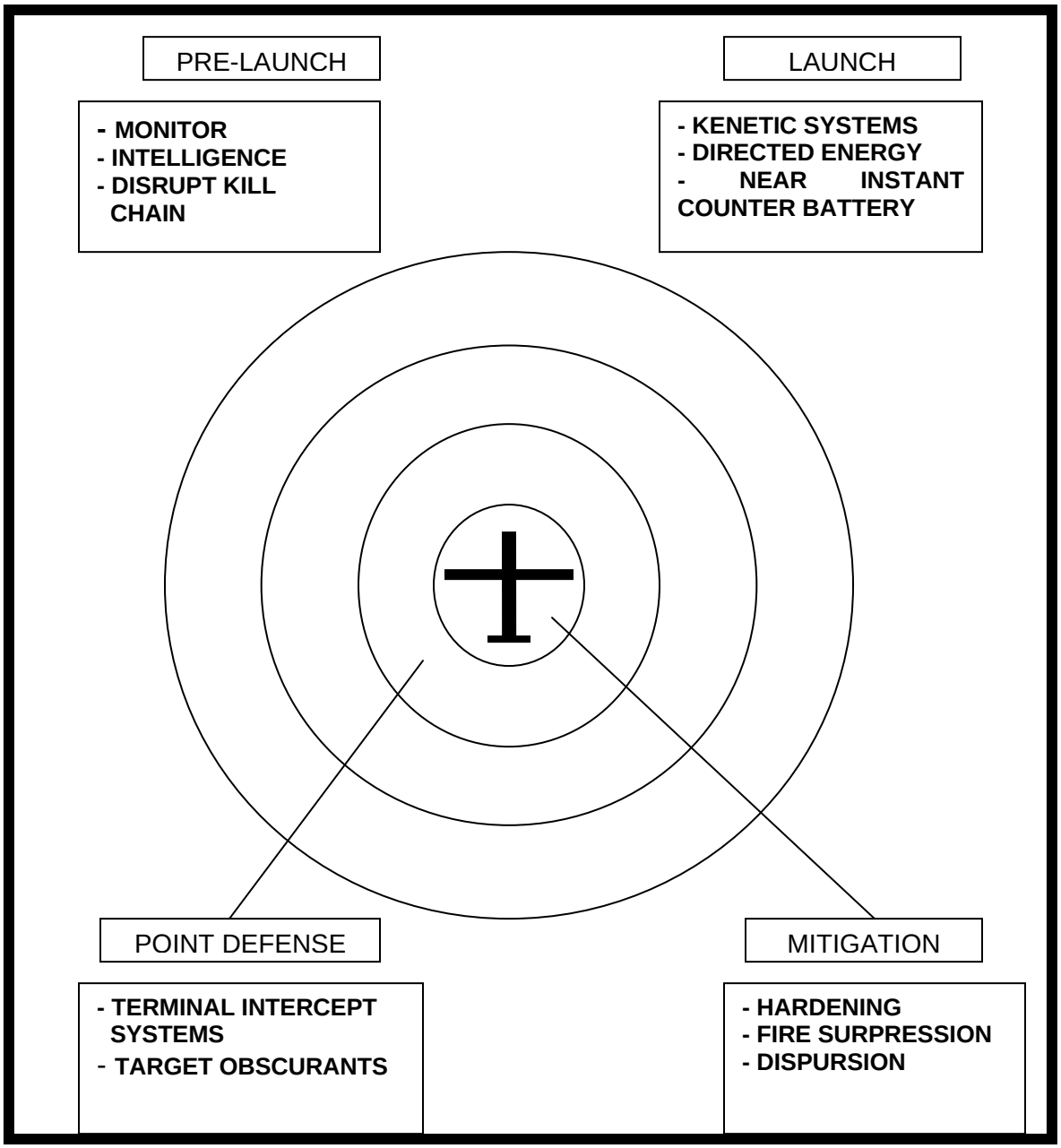

Figure 7. Four-layered Protection

1. Pre-Launch

The outer layer of an airbase's defensives against a guided standoff attack deals with preventing the launch of guided, standoff weapons. The base must be able to find a way to break the attacker's kill chain before a launch is made.

With such a large footprint to control, the need for human intelligence is critical. Gaining the support of the people living in the standoff weapons footprint and gathering information from them will provide the defender with critical information to disrupt standoff attacks and target the forces that are launching them. Major D. T. Young (2005) provides recommendations for a counterinsurgency strategy for airbase defense that may provide some of the building blocks for this effort. By establishing control of the population around the base, this strategy severely limits their usefulness to an attacker and turns that population into sensors that support the base defense. It is difficult to conceive of a technology that could replace the information gained through interaction with the local population while patrolling.

A complimentary effort to gathering human intelligence is the ability to gather information on what is happening in the standoff weapons footprint. The ability to monitor, assess, and target activities in these areas is vital. The development of sensor-based systems that can help the base defense force do this is critical.

Once the intelligence information is gathered, the need to project force outside the perimeter of the base to stop the attack comes next. This force can be from the base, part of a host-nation security force or from a friendly unit operating nearby.

2. Post-Launch Counter Standoff Systems

The defensive measures in the post-launch layer cover the period from the launch of a weapon to the coverage by any point defense systems. The development and fielding of counter standoff systems that attempt to destroy the incoming projectile with a kinetic or directed energy is a major step in this

direction. Systems like Skyguard, under development to guard airports against man portable surface to air missile threats, (Northrop-Grumman, 2006) might be adapted to this purpose.

A second methodology for a counter standoff system could provide rapid counter-battery fire to the standoff weapons launch location or to the location of a target designation or control system. This type of system could interfere with the attacker's ability to terminally guide the weapon or escape by launching rapid counter-battery fire on to the attacker's position.

A final methodology for counter standoff systems might work on the principle of spoofing the guidance system of the standoff round. The ability to send a round to a safe area on the base would negate the effect of an attack. The use of chemical obscurants may interfere with laser or visual guidance systems, decreasing the accuracy of a guided round. Any method of reducing the accuracy of the round to that of a conventional round might give the passive hardening measures a chance to work.

3. Point Defense Counter Standoff Systems

A point defense layer of defense could provide a final line of protection for critical resources against an incoming guided round. The U.S. Navy's Phalanx system, designed to protect ships against incoming anti-ship missiles provides an example. The Phalanx, pair a radar-guided fire control system to a 20-millimeter Gatling gun to provide point defense. The U.S. Army, in an attempt to keep the weight of armor down, is exploring an active protection system for its new self-propelled artillery piece and next generation of fighting vehicles (GlobalSecurity.org, 2006b). This system uses sensors to fire a small projectile at incoming missiles, mitigating their effectiveness. However, the use of these or any similar systems around an active airfield would have to be carefully studied in order to avoid fratricide.

4. Mitigation

The final layer of defense should consist of systems or procedures that mitigate the effects of guided standoff weapons. Any system or effort that can improve the hardening of resources against attack or those that immediately

respond to the effects of a weapon can improve the survivability of resources. The development and deployment of automated fire suppression systems might spearhead this effort.

5. Conclusion

The standoff attack has proven itself as an effective method of harassing air bases and causing damage for at least 60 years. Nonetheless, passive and active defensive measures have limited the amount of damage that these attacks have caused to airbases. Air base operations were, on occasion, temporarily halted by these attacks, but the ability to launch and recover aircraft was quickly restored.

Advancements in weapons technology and a shift in mission of the USAF towards expeditionary operations across the globe have changed the status quo. The wide availability of guided anti-tank missiles and guided mortar projectiles coupled with a shift away from operations from airfields with hardened, redundant systems have created an opportunity for a small number of attackers to cripple an airbase and keep it from operating.

New tactics techniques and procedures for air base defense must be developed. New systems that can prevent standoff attacks from affecting base operations must be studied, resourced, developed, and deployed. Finally, a new level of understanding of the threat posed by ground forces to air bases must be reached by our own and allied forces.

In the past, the functional nature of the air base defense mission has limited the scope of the problem to the areas directly involved. Support personnel, largely working in the Security Forces, Office of Special Investigations, and Civil Engineering career fields (to include Fire, Disaster Preparedness, and Explosive Ordinance Disposal) have been the advocates for base defense issues. The emergence of the threat of guided, standoff weapons attacks has shifted the urgency of this problem. This is no longer a base defense issue; this is an *airpower issue*. It will take the dedication and effort of all Airmen to ensure the ability of future expeditionary bases to operate.

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APPENDIX

A. GAME 1 CALCULATIONS

Base Defense Force

Goal: Minimize Score

No Dominant Strategy

Mixed Strategy

p = percentage of iterations of the game to defend against standoff attacks

1-p = percentage of iterations of the game to defend against ground attacks

$$Ev(A) = Ev(B)$$

$$1(1-p) + 80p = 30(1-p) + 15p$$

$$p = 29/94 = .309 \text{ (Defend against standoff attacks)}$$

$$1-p = 65/94 = .691 \text{ (Defend against Ground attacks)}$$

In this game, the defense force should defend against a ground attack in 69.1 percent of the games and defend against standoff attacks 30.9 percent of the time.

1. Value Game 1 for the Defender

We can get the expected value of the game by substituting the value of p into either expected value formula. As we can see below, the value of this game is 25.372. The attacker is causing damage to the base and disrupting operations but not to the level where he is able to win the game (50 or above).

$$30(1-p) + 15p = \text{value of the game}$$

$$30(1-(29/94))) + 15(29/94)) = \text{value of the game}$$

$$\text{Value of Game} = 25\ 35/94 = 25.372$$

Level II Force

Goal: Maximize Score

No Dominant Strategy

Mixed Strategy

q= percentage of iterations of the game to use a standoff attack

1-q = percentage of iterations of the game to use a ground attack

$$Ev(C) = Ev(D)$$

$$1(1-q) + 30q = 80(1-q) + 15q$$

$$q = 79/94 = .840 \text{ (Use a standoff attack)}$$

$$1-q = 15/94 = .160 \text{ (Use a ground attack)}$$

The attacker should use 84 percent standoff attacks and 16 percent ground attacks.

2. Value of Game 1 for the Attacker

Same as above

B. GAME 2 CALCULATIONS

Base Defense Force

Goal: Minimize Score

No Dominant Strategy

Mixed Strategy

p = percentage of iterations of the game to defend against standoff attacks

1-p = percentage of iterations of the game to defend against ground attacks

$$Ev(A) = Ev(B)$$

$$1(1-p) + 90p = 50(1-p) + 40p$$

$$p = 49/99 = .495 \text{ (Defend against standoff attacks)}$$

1-p = 50/99 = .505 (Defend against Ground attacks)

In this game, the defense force should defend against a ground attack in 49.5 percent of the games and defend against standoff attacks 50.5 percent of the time.

1. Value of Game 2 for the Defender

50(1-p) + 40 p = value of the game
50(1-(49/99))) + 40 (49/99)) = value of the game
Value of Game = 45 5/99 = 45.051

We can get the expected value of the game by substituting the value of p into either expected value formula. As we can see below, the value of this game is 45.051. The attacker is causing almost twice as much relative damage to the airbase and is much closer to the level where he is able to win the game (50 or above).

Level II Force

Goal: Maximize Score
No Dominant Strategy
Mixed Strategy

q = percentage of iterations of the game to use a standoff attack
1-q = percentage of iterations of the game to use a ground attack

Ev (C) = Ev (D)
1(1-q) + 50q = 90 (1-q) + 40q
q = 89/99 = .899 (Use a standoff attack)
1-q = 10/99 = .101 (Use a ground attack)

The attacker should use 89.9 percent standoff attacks and 10.1 percent ground attacks.

2. Value of Game 2 for the Attacker

Same as above

C. GAME 3 CALCULATIONS

Base Defense Force

Goal: Minimize Score

No Dominant Strategy

Mixed Strategy

p = percentage of iterations of the game to defend against standoff attacks
1-p = percentage of iterations of the game to defend against ground attacks

$$Ev(A) = Ev(B)$$
$$1(1-p) + 90p = 10(1-p) + 5p$$
$$p = 9/94 = .10 \text{ (Defend against standoff attacks)}$$
$$1-p = 85/94 = .90 \text{ (Defend against Ground attacks)}$$

In this game, the defense force should defend against a ground attack in 90 percent of the games and defend against standoff attacks 10 percent of the time.

1. Value of Game 3 for the Defender

$$10(1-p) + 5p = \text{value of the game}$$
$$10(1-(9/94)) + 5(9/94) = \text{value of the game}$$
$$\text{Value of Game} = 9\ 49/94 = 9.52$$

We can get the expected value of the game by substituting the value of p into either expected value formula. As we can see below, the value of this game is 9.52. The Level II force is not destroyed but the defender wins the game in

this range. Attacks of the airbase will continue but the damage and disruption to operations will be minimal.

Level II Force

Goal: Maximize Score

No Dominant Strategy

Mixed Strategy

q= percentage of iterations of the game to use a standoff attack

1-q = percentage of iterations of the game to use a ground attack

$$Ev(C) = Ev(D)$$

$$1(1-q) + 10q = 90(1-q) + 5q$$

$$q = 89/94 = .947 \text{ (Use a standoff attack)}$$

$$1-q = 5/94 = .053 \text{ (Use a ground attack)}$$

The attacker should use 94.7 percent standoff attacks and .053 percent ground attacks.

2. Value of Game 3 for the Attacker

Same as above

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