THE UTILIZATION OF INERTIALLY GUIDED WEAPONS IN PERFORMING CLOSE AIR SUPPORT

A thesis presented to the Faculty of the U.S. Army Command and General Staff College in partial fulfillment of the requirements for the degree

MASTER OF MILITARY ART AND SCIENCE

by

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This thesis investigates the question: Should inertially guided air-to-ground weapons be used to perform Close Air Support (CAS)? With inertially guided weapons it is possible to strike targets with precision, even when crewmen in attack aircraft cannot see them. Current procedures do not permit CAS when crewmen cannot see their targets. The capability provided by inertially guided weapons would make CAS possible in situations when targets are not visible from the air.

The method for this thesis was to compare field artillery and CAS as fire support systems. Research included documenting the history of fratricide resulting from artillery and CAS, and reviewing the procedures for CAS and artillery. Systems currently used to determine and disseminate target coordinates were also examined, as were systems that will perform these tasks in the future. The impact of situational awareness-building tools on indirect fire support was considered. Finally, the availability of inertially guided weapons for use in CAS was investigated.

The conclusion is that inertially guided weapons should be used to perform CAS in specific situations, as long as accurate coordinates are available.

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ABSTRACT

THE UTILIZATION OF INERTIALLY GUIDED WEAPONS IN PERFORMING CLOSE AIR SUPPORT by Maj Kenneth T. Stefanek, USAF, 83 pages.

This thesis investigates the question: Should inertially guided air-to-ground ordnance be used to perform Close Air Support (CAS)? With inertially guided weapons it is possible to strike targets with precision, even when crewmen in attack aircraft cannot see them. Current procedures do not permit CAS when crewmen cannot see their targets. The capability provided by inertially guided weapons would make CAS possible in situations when targets are not visible from the air.

The method for this thesis was to compare field artillery and CAS as fire support systems. Research included documenting the history of fratricide resulting from artillery and CAS, and reviewing the procedures for CAS and artillery. Systems currently used to determine and disseminate target coordinates were also examined, as were systems that will perform these tasks in the future. The impact of situational awareness-building tools on indirect fire support was considered. Finally, the availability of inertially guided weapons for use in CAS was investigated.

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LIST OF ABBREVIATIONS

ASCIET	All-Service Combat Identification Evaluation Test
BOC	Bomb on Coordinates
CALL	Center for Army Lessons Learned
CAS	Close Air Support
CBU	Cluster Bomb Unit
CEP	Circular Error Probable
DMA	Defense Mapping Agency
EPLRS	Enhanced Position Location Reporting System
FAC	Forward Air Controller
FDC	Fire Direction Center
FLIR	Forward Looking Infrared
FM	Field Manual
GP	General Purpose
GPS	Global Positioning System
IP	Initial Point
IR	Infrared
JDAM	Joint Direct Attack Munition
JFC	Joint Forces Commander
JSOW	Joint Stand-Off Weapon
LGB	Laser Guided Bomb

LR	Laser Rangefinder
MACV	Military Assistance Command--Vietnam
MGRS	Military Grid Reference System
mm	Millimeter
NCS	Network Control Station
NIMA	National Imagery and Mapping Agency
PGM	Precision Guided Munition
PI	Probability of Incapacitation
RS	Radio Set
SA	Situational Awareness
SD	Situation Dependent
SOP	Standard Operating Procedure
TACC	Tactical Air Control Center
USAF	U.S. Air Force
WCMD	Wind Corrected Munition Dispenser
WGS	World Geodetic System

CHAPTER 1

INTRODUCTION

The purpose of this thesis is to investigate the utilization of inertially guided air-to-ground ordnance in performing Close Air Support (CAS). With inertially guided weapons, it is possible to strike targets in all weather conditions, even if crewmen in the attack aircraft cannot see their targets. Current procedures based on joint and service-specific doctrine do not permit CAS when crewmen cannot see the targets they are attacking. The increased capability provided by inertially guided weapons would improve the lethality and responsiveness of CAS platforms in situations when targets are not visible from attacking aircraft, provided the procedures are updated to account for the increased capabilities of these weapons. This thesis will examine applicable doctrine along with improvements in technology to determine if inertially guided weapons should be used to perform CAS.

CAS has been the focus of numerous studies and papers, as well as being the source of debate between ground and air commanders. In spite of the debate, both ground and air commanders agree that CAS gives the ground commander a valuable tool to compliment organic artillery systems. The fluid nature of today's battlefields may in fact lead to situations where CAS is the only indirect fire support option available, as even self-propelled artillery cannot always keep pace with tanks on the move. When properly used, CAS provides flexible fire support that can greatly increase the ground commander's ability in meeting tactical objectives. Both fixed-winged and rotary-winged aircraft combine speed and mobility that are not found in any other battlefield operating system, and as a result offer unique capabilities to the battlefield (Warden 1989). This point is further illustrated by Army Field Manual (FM) 100-5 when it states, "CAS can enhance ground force operations by delivering a wide range of weapons and massed firepower at decisive points. It can surprise the enemy and create opportunities for the maneuver or advance of friendly forces through shock action and concentrated attacks" (U.S. Department of the Army 1993, 2-19).

The Army formalized requirements for CAS in a 1987 document that specifically examined CAS in a mid-intensity to high-intensity conflict. The document stated "CAS delivery systems must be capable of: (1) Providing the required dedicated air-ground interface; (2) Responsive delivery of effective ordnance in close proximity to friendly ground forces during day, night, and under-the-weather conditions; (3) Surviving in the threat environment during mission execution" (Kemp 1989, 10). Obviously, the writers of these requirements document perceived a need for CAS in situations when the weather was not optimum. This requirement is reinforced by Colonel John Warden in *The Air Campaign* when he writes "One very important deficiency is the inability of close air support to operate when the weather is bad. The commander who counts on close air may be badly shocked if it is not available. Conversely, the commander who is trying to operate without significant air support may be able to execute a movement in bad weather that would be impossible in good weather, when enemy air could strike him repeatedly" (Warden 1989, 94). A historical example cited by Warden that illustrates his final point is the Battle of the Bulge, where a German attack initially succeeded because poor weather made it impossible for Allied fighters to detect or attack the German ground forces.

Looking back to the 1987 requirements document, no mention is made of how bad the weather should be before CAS is no longer available. Performing CAS under a weather deck decreases effectiveness and increases the complexity of the mission for several reasons. First, fixed-wing aircraft flying under clouds are more vulnerable to enemy attack, as they are usually highlighted against the cloud background and are easy to see. In addition, flying at lower altitudes puts the aircraft in more threat "envelopes," meaning more threat systems can engage aircraft at low altitudes, increasing the risk for these aircraft of being shot down. Secondly, low line-of-sight angles from the aircraft to the target combine with inability to see through terrain that may surround the target to make it far more difficult for crewmembers to identify specific targets when attacking from low altitudes. To illustrate this point, consider a large parking lot full of cars. It is far easier to identify one specific car in the middle of that lot when perched on a platform overlooking the lot than it is from ground level. Finally, there are more attack restrictions for crewmembers to consider when attacks are flown at low altitude, making the attacks harder to accomplish. These restrictions are required to ensure that fuses on the bomb have time to function properly. Also, if an aircraft is too low or flies an improper escape maneuver when dropping a bomb from low altitude, it is possible that fragments created by the bomb as it explodes will impact the aircraft, causing damage that could bring it down. These three factors combine to define weather minimums below which CAS under the weather is no longer possible. With the technology of the time, dropping ordnance through the weather was not even considered a viable option in a CAS environment.

In spite of the controversy surrounding CAS, the choice of ordnance to use for CAS has not been a point of contention. The reason for this is that any conventional ordnance carried by attack aircraft was assumed to be suitable for CAS. This point is illustrated in Joint Publication 3-09.3.

> To achieve the desired level of destruction, neutralization, or suppression of enemy CAS targets, it is necessary to tailor the weapons load and arming and fuzing settings for the required results. For example, cluster and general purpose munitions would be effective against troops and vehicles in the open, whereas hardened, mobile, or pinpoint targets may require specialized weapons such as laser guided, electro-optical, infrared munitions, or aircraft with special equipment or capabilities. In all cases, the requesting commander needs to know the type of ordnance to be expended (especially cluster munitions). (U.S. Department of Defense 1995, I-6)

The types of ordnance used by the U.S. Air Force (USAF) aircraft for CAS include general purpose (GP) bombs, cluster bomb units (CBU), laser-guided bombs (LGB), infrared (IR) Maverick missiles, and bullets. A complete description of different types of ordnance is provided in chapter 4. The only procedural difference that results from using the various munitions is the required distance between friendly forces and the intended point of weapon impact. The different distances are required to protect friendly troops from the different fragment patterns associated with each weapon. For example, bullets can be used for CAS closer to friendly troops than bombs can since bullets have a smaller fragmentary pattern than bombs. This point was illustrated during the North Vietnamese attack on Plei Mei during the Vietnam War. During an attack, enemy troops closed on and seriously threatened the established defensive perimeter. Friendly troops were down to thirty rounds of ammunition per man when CAS finally drove the enemy troops off. According to an Army officer working with South Vietnamese defenders, "they (the USAF strike aircraft) came right down our perimeter with cannon, antipersonnel mines, and then when the enemy began pulling back, they hit them with high explosive stuff." Of the 326 enemy troops killed in the fighting, 250 perished as a result of air strikes (Cooling 1990, 451).

While these weapons differ widely in how they are dropped and in the weapons effects they create, they all have one important feature in common. Specifically, in order to drop them accurately the pilot has to see the target, either visually with the "mark-one" eyeball or with a sensor that guides or aims the weapon. The requirement to see the target was never considered to be a limitation because in most cases current CAS procedures dictate that the pilot see and positively identify the target before expending any air-to-ground ordnance. The obvious reason for this restriction is to prevent aircraft from bombing the wrong target or bombing their own troops, commonly referred to as fratricide.

The restriction to visually see and identify targets does theoretically decrease the risk of fratricide, but it also leads to a problem with CAS. Battlefield conditions do not always permit visual acquisition of the target by the pilot. Examples of these conditions are when the target is obscured by smoke or clouds (bad weather), when the enemy camouflages or hides his assets, or when the situation on the ground is too chaotic to allow the pilot to determine who is friendly and who is not. Whatever the case, in most situations when the pilot cannot see the target, CAS is not available. This potentially serious shortfall is highlighted by Joint Publication 3-09.3 which states "Before CAS missions are executed, minimum weather conditions will be met" (U.S. Department of Defense 1995, I-6).

The inability to hit targets without seeing them is a problem not only in the CAS arena, but throughout the spectrum of air-to-ground operations. During Operation Desert Storm, many missions were postponed or canceled because clouds that obscured the target area would have prevented pilots from seeing and identifying specific targets. In an effort to overcome this shortfall, the military has focused weapons development efforts on being able to strike targets without the pilots having to see them. This development eventually led to weapons with onboard inertial guidance systems. Inertial guidance systems work by using gyroscopes, accelerometers, and sophisticated electronic units to measure velocity, roll, pitch, and yaw. After the inertial guidance system is aligned and given an initial position in three-dimensional space, it keeps track of where it is by accounting for the effects of velocity, roll, pitch, and yaw over time (Microsoft Encarta, 1996 ed., s.v. "Guided Missiles"). Basic inertial guidance units are completely self-contained, that is, they do not need outside input to function properly.

While usually very accurate, inertial guidance systems do have one problem. Since the gyroscopes and accelerometers that make up inertial guidance systems are subject to external forces like gravity and mechanical friction, the systems can drift. Simply stated, inertial guidance systems drift when there a difference between where the inertial guidance unit "thinks" it is and where it actually is. The amount of drift is unique to each inertial guidance unit and can change over time. There is no way to predict how much drift will occur, and as a result, there is no way for the inertial guidance unit to account for it.

The global positioning system (GPS) can be used to increase the accuracy of inertial guidance systems by providing an external source of three-dimensional position and velocity. GPS is based on a series of twenty-four satellites in low-earth orbit that communicate with compatible GPS receivers on earth. These GPS receivers are able to triangulate a position as long as they can communicate with three or more GPS satellites. The accuracy of the position and velocity update provided to any inertial guidance unit depends on which level of service the receiver is capable of. Commercial receivers use the standard positioning service, which is accurate to about one hundred meters. Most military receivers use the precise positioning service, which is accurate to twenty meters. Enhanced techniques, like differential GPS, improve accuracy of the system to three meters (Microsoft Encarta, 1996 ed., s.v. "Global Positioning System"). Access to the more accurate GPS services is controlled by encoding the GPS signal, which is then decoded by receivers with the required decoding equipment and correct codes. Although weapons with inertial guidance systems and GPS are still in developmental and operational testing, these weapons have demonstrated an accuracy on the order of ten meters (Stefanek 1997).

The limitation with these new weapons is that target coordinates must be known before the weapon is dropped. This is not a problem when bombing strategic or interdiction targets, because they typically do not move. Ideally, their exact position will be determined well before a conflict. CAS targets, on the other hand, are highly mobile.

As a result, their location may not be known until it is time to bomb them. This would seem to indicate that inertially guided weapons are not suitable for use in the CAS scenario.

This assumption may be premature after stopping to consider changes in other battlefield systems being tested and fielded. The proliferation of hand-held GPS systems and laser range-finding equipment, along with the emphasis on situational awareness tools among ground troops is changing the way the battlefield will be managed in the future. In addition, information now literally moves across the battlefield at the speed of light, as man-portable computers are linked to each other via wireless networks. Since battlefield management will change, it may be time to reconsider the basic assumption that pilots must see the CAS target before dropping ordnance on that target. Another reason why the assumption may be premature comes from examining another source of indirect fire support, namely artillery fire.

The basic nature of both artillery and CAS is that they are means of delivering indirect fire support to the ground maneuver commander. Differences between the two arise when looking at the characteristics of the ordnance being delivered and the restrictions placed upon the soldiers or airmen delivering it. There are two specific ordnance characteristics that are of interest. The first is warhead size, or how big is the bomb being used. The second characteristic is area of coverage, which applies to the family of cluster bombs. It tells how big the area is that is covered with submunitions.

Moving to restrictions placed on the soldiers or airmen delivering fire support, there are basic differences between artillery and CAS. The first of these is that fire from an artillery tube can easily be "corrected," while fire from an aircraft cannot be. In other words, if a shell fired from an artillery tube misses a target, an observer can use the miss distance and azimuth to determine corrections that will be used to subsequently hit the target. The process is relatively easy because the artillery tube is stationary. Conversely, since aircraft move, it is more difficult for crewmembers to include corrections in subsequent attacks, especially if an entirely different aircraft is executing the attack. The second and possibly most important difference between CAS and artillery, is that artillery units are a part of the ground situation. This probably means that the artillery commander has coordinated with the maneuver commander and has preplanned the fire support. It also hopefully means that the artillery and maneuver units have trained together and know how the other operates. This is not always true for crewmembers in attack aircraft who may be on a strategic attack or interdiction mission before being diverted to provide CAS. Even on preplanned CAS missions, the fluid nature of battle and the separation between air and ground assets may limit prior coordination. Therefore, although crewmembers providing CAS should have some awareness of the ground situation, they may not always be totally familiar with the entire ground situation. As a result of these distinctions, some of the restrictions involving the use of these systems to provide indirect fire support are different. This thesis will examine one of the key differences, namely the requirement for airmen to see the target while the soldier pulling the lanyard on the artillery tube has no such restriction.

Research Question

The primary research question of this thesis is, Should inertially guided air-to-ground ordnance be used to perform CAS? The importance of this question results from the emphasis being placed on these weapons. If they cannot be used for CAS, it would mean that the newest generation of smart bombs is truly limited in where it can be used. Subordinate to this primary question are secondary questions. The first of these is, Do pilots need to see and visually identify CAS target before dropping ordnance on them?

Another secondary question is, What method will be used on the battlefield of the twenty-first century to pass targeting information, not only from ground troops to pilots, but also from one soldier to another? This question will lead to an examination of how the Army intends to operate with the new equipment it will field.

The final secondary question deals with cost and weapon availability. Assuming this thesis determines that inertially guided weapons should be used for CAS, the cost and availability of these weapons is still a factor. In other words, Do inertially guided weapons cost too much to use in a CAS environment?

Definitions

Moving to definitions, Joint Publication 1-02 defines CAS as "air action by fixed- and rotary-wing aircraft against hostile targets which are in close proximity to friendly forces and which requires detailed integration of each air mission with the fire and movement of those forces" (U.S. Department of Defense 1989, 98). The vagueness of the term "in close proximity" is one source of the debate surrounding CAS. According to Joint Publication 3-09.3, "The word close does not imply a specific distance; rather, it is situational" (U.S. Department of Defense 1995, I-2). This vague statement provides flexibility to both pilots and ground troops, but also confuses the issue as to when CAS procedures should be in effect and when they should not be.

Another term that merits notice is "detailed integration." Detailed integration leads to the numerous CAS execution procedures followed both by the ground forces receiving CAS and the aircraft providing CAS. According to these procedures outlined in Joint Publication 3-09.3, "Responsibility for expenditure of ordnance rests with the maneuver force commander. The terminal controller has the authority to clear aircraft to release weapons after specific or general release approval from the maneuver force commander. Battlefield conditions, aircrew training, ordnance capabilities and terminal controller experience are factors in the decision to authorize weapons release" (U.S. Department of Defense 1995, V-9). Of note in this excerpt is that ordnance capabilities do impact the decision to allow pilots to drop ordnance. This implies that one type of ordnance could be dropped in a CAS scenario when another type could not.

Another definition of CAS is offered by Colonel John Warden in his book *The Air Campaign.* Warden writes, "define close air support as any air operation that theoretically could and would be done by ground forces on their own, if sufficient troops or artillery were available" (Warden 1989, 87). The interesting thing about this definition is that it seems to equate CAS and artillery, implying that in one sense, the two perform a similar role.

Two other terms used frequently in CAS discussions are "danger close" and "troops in contact." Starting with troops in contact, the distance between enemy troops who are in contact with each other actually depends on the type of weapon being used. For example, troops with rifles would have to close to within 1,000 meters of each other to actually be in contact. On the other hand, troops facing each other in main battle tanks will be in contact if they are in range of the main guns on either tank, which could be out to 3,500 meters. According to Joint Publication 3-09.3, "troops in contact" is defined as troops within one kilometer of each other (U.S. Department of Defense 1995, V-4).

"Danger close" is defined in Joint Publication 3-09.3 as "ordnance delivery inside the 0.1% probability of incapacitation (PI)" (the distance depends on the kind of ordnance being dropped) (U.S. Department of Defense 1995, V-4). Table 1 shows these distances for different artillery shells at various ranges as shown in FM 6-141-1, while table 2 shows corresponding risk estimate distances for different types of air-to-ground ordnance as shown in Joint Publication 3-09.3.

Table 1. Minimum Safe Distances for Various Artillery Shells

Weapon Projectile	Range to Target (meters)	Minimum Safe Distance (meters)
60-mm mortar	2000	330
4.2-inch mortar	4000	360
105-mm howitzer	10000	360
155-mm howitzer	18000	680
8-inch howitzer	20000	610

Source: Anderson n.d., 2.

Table 2. Risk Estimate Distances for Air-to-Ground Ordnance

Item	Description	Risk Estimate Distance 0.1% PI (meters)
MK 82	500 pound GP bomb	425
MK 84	2000 pound GP bomb	500
CBU-87[a]	Antitank/antipersonnel cluster bomb	275
GBU-12	500 pound LGB	425[b]
GBU-10	2000 pound LGB	500[b]
AGM-65D	Imaging IR Maverick	100
M-61	20-mm Gatling gun	150

Source: U.S. Department of Defense 1995, G-3.
Notes:
a. Not recommended for use near troops in contact.
b. Risk estimate distances are to be determined. For LGBs, the values shown are for weapons that do not guide and that follow a ballistic trajectory similar to GP bombs.

The recent joint doctrinal statement issued by General John Shalikashvili, former Chairman of the Joint Chiefs of Staff, made use of the term "precision engagement." The term connotes the ability to hit targets with a high degree of accuracy. A measure of accuracy for air-to-ground ordnance is circular error probable (CEP), which is usually measured in meters. CEP applies to specific aircraft for a specific type of ordnance. A CEP of X meters means that one-half of the bombs dropped on a given target will fall within X meters of the target. In general, a "precise" type of ordnance has a CEP of less than three meters. LGBs and terminally guided IR weapons like the Maverick missile fall into this category. An "accurate" weapon has a CEP of greater than five meters but less than thirteen meters. The inertially guided weapons that are the subject of this study fall into this category. GP bombs, CBU, and other unguided bombs are neither "precise" nor "accurate," but are generally categorized as "unguided." Current bombing platforms like the F-16 can achieve a CEP of twenty-two meters using GP bombs if the bombs are dropped from a forty-five degree dive at 10,000 ft (Stefanek 1997, 9).

The same definition for CEP is used to define accuracy for field artillery systems. As is the case with ordnance dropped from aircraft, the CEP for a given system is not fixed, but varies with the distance from the artillery tube to the target and with the trajectory the shell travels. Trajectory is a major factor because it determines how long the shell will fly through the air, which in turn determines the length of time external forces like the wind can act on the shell. A representative CEP achievable by an artillery system is twenty two meters in range and nine meters in azimuth (deflection), which is the CEP for a towed 105-millimeter (mm) howitzer when fired at a target 11,000 meters away (U.S. Department of the Army 1971).

Finally, the noun "coordinate" will be used extensively throughout this thesis. Many people, especially those who operate exclusively on the earth's surface, consider only two dimensions when using this term. Typically, coordinates are given in grid numerals or in latitude and longitude. The obvious assumption is that whatever is at the specified coordinates sits on the surface of the earth. Since this thesis deals with weapons delivered from well above the surface of the earth, it is necessary to include the third dimension. Thus, in this thesis the term coordinate will identify a specific point in three-dimensional space which may be on or above the earth's surface.

Assumptions

The primary assumption for this thesis is that a secure means of passing targeting information from ground troops to forward air controllers (airborne) and on to pilots in the CAS aircraft exists now and will continue to exist in the future. This secure means could be in the form of encrypted voice or data transmissions. In the absence of encrypted transmissions, the assumption will be made that unprotected or unencrypted transmissions will not be interrupted or interdicted by enemy forces.

Limitations

To narrow the scope of the large number of possible CAS scenarios, this thesis will be limited to cases where the pilot cannot positively identify the target either visually or with on-board sensors. The specific reason for the pilot's inability to identify the target is not important other than to say that the reason does not also limit the pilot's ability to safely and tactically operate. Examples could include weather below that required to fly low altitude attacks or smoke obscuring the target area. With this limitation, GP bombs, CBU, LGBs, or Mavericks could not be used for CAS.

Delimitations

The first delimitation of this thesis deals with the level of classification. Since many of the weapons and systems that will be discussed in this thesis are under development, much of the information on them is classified. In order to ensure the widest possible dissemination for this thesis, classified information will not be included, and the thesis will be written on an unclassified level.

The second delimitation of this thesis deals with some of the other debates surrounding the CAS topic. This thesis will not discuss whether or not CAS should be a mission on the twenty-first century battlefield, and if so who is best equipped to do it. It will also not discuss controversial issues like the placement of the fire support coordination line, the priority of CAS versus other U.S. Air Force missions, or the various fire support coordination measures that can or should be in place on the battlefield. In addition, this thesis will not attempt to prove that CAS should replace field artillery as the primary source of indirect fire support. Rather, it will compare the use of CAS and field artillery in generic scenarios. Finally, it will not discuss new procedures or control measures that may be required if CAS is performed using inertially guided weapons. In short, this thesis will not consider how to do CAS with inertially guided weapons.

CHAPTER 2

LITERATURE REVIEW

As mentioned in chapter 1, there is a wealth of information on the subject of CAS. The majority of work centers on four themes. First, Is CAS an effective means of providing ground troops with fire support? Second, Which service should provide CAS and what priority should CAS be given versus other missions? Third, What type of aircraft is the ideal CAS platform? Finally, How should control measures and fire coordination lines be set up so both ground and air forces can effectively employ when air forces are providing CAS? The nonlinear battlefield, increased mobility of ground battlefield operating systems, the range and lethality of ground-based artillery, and the emphasis by ground forces on the deep battle have only served to complicate the CAS debate.

CAS is the topic of books, published and unpublished articles, and doctrine. Joint and service specific doctrine (from literally every branch of the armed forces) serves as the baseline for this body of work. Joint Publication 3-09.3, *Joint Tactics, Techniques, and Procedures for Close Air Support,* is a comprehensive document that covers everything from the CAS command and control network to CAS procedures for fixed-winged and rotary-winged aircraft. FM 100-5, *Operations*; FM 6-71, *Tactics, Techniques, and Procedures for Fire Support for the Combined Arms Commander*; FM 100-15, *Corps Operations;* and FM 6-20, *Fire Support in the Airland Battle,* are only four of many U.S. Army manuals that contain information on CAS. Air Force Doctrine Document 1, *Air Force Basic Doctrine,* published in September 1997, is part of a doctrine program instituted by the Air Force Chief of Staff. The new doctrine includes CAS as one of the Air Force's primary missions, but does add that CAS, "by itself, rarely achieves campaign-level objectives" (U.S. Department of the Air Force 1997, 50).

Numerous books on CAS have been published. *Case Studies in the Development of Close Air Support* examines CAS from the earliest days of powered flight to the Arab-Israeli wars of 1967 and 1973. This book, published by the Office of Air Force History, analyzes the use of CAS in actual combat conditions. Of interest is how effective CAS was in different battlefield scenarios. The *Gulf War Air Power Survey Volume II, Operations and Effects and Effectiveness* examines CAS during Operation Desert Storm. This report, submitted to the Department of Defense, contains detailed information on all CAS sorties flown. Another work that merits examination is Lieutenant Colonel Charles R Shrader's *Amicicide: The Problem of Friendly Fire in Modern War.* This work, published by the Combat Studies Institute at the Army Command and General Staff College, examines cases of friendly fire resulting from all battlefield systems, to include artillery, tanks, and aircraft. This study will help when comparing CAS to other indirect fire support platforms. A final historical work that contains pertinent information is Kenneth Werrell's article entitled "Did USAF Technology Fail in Vietnam?" This article, published in the spring 1998 edition of *Airpower Journal*, examines the use of "smart bombs" in the various bombing campaigns of Vietnam. It is of interest because Vietnam marks the first time "smart bombs" were dropped in large numbers. Their impact on the bombing campaigns of that conflict give insight into the possible impact of another revolutionary weapon, namely the inertially guided bomb.

Moving from historical works, Colonel John Warden's book *The Air Campaign* offers an in-depth look at CAS and the author's opinion on how it should be used to assist ground commanders. Since Colonel Warden's book deals with CAS on a theoretical level, it should prove useful in extrapolating CAS procedures into future conflicts with new systems.

The Center for Army Lessons Learned (CALL) maintains newsletters that contain a wide variety of articles that deal with CAS and the larger subject of indirect fire support for ground maneuver units. This second topic is important, as it analyzes the use of an organic battlefield operating systems that are used to provide fire support in much the same way CAS is. The area of interest when comparing ground based fire support to CAS is how these fires are "cleared" or how fires and ground troops are deconflicted to prevent fratricide. Specific articles include "Clearance of Fires" by Captain Samuel R. White, an observer/controller at the National Training Center at Fort Irwin and "Fast and Accurate Fires in the Close Fight" by Lieutenant Colonel David L. Anderson, the senior brigade fire support officer at the Joint Readiness Training Center. CALL also maintains the standard operating procedures (SOP) for operational units, specifically the 4th Infantry Division. These SOPs provide insight into current procedures for clearing fires.

A final source of information on both CAS and ground systems is the number of graduate theses available. Initial research has shown three of these to be very useful: Major Edward Francis' thesis entitled "Is Current Fire Support Doctrine for the Deep Battle Effective in the Post Desert Storm Environment," and Major Steven E. Bell's thesis entitled "Close Air Support for the Future." Both of these theses address the future of CAS, presenting several views on how CAS will be conducted in the future. Finally, Major Kenneth R. Rosson's unpublished graduate research project entitled "The Tactical Utility of the Litton Mark VII Handheld Laser Rangefinder in Target Acquisition of the LANTIRN F-16 in the Close Air Support Role" examines the performance of a specific ground system used by soldiers to determine target coordinates.

Information dealing with inertially guided weapons is not as plentiful. Operational test data is available for one of these new munitions, the Joint Direct Attack Munition (JDAM). Testing of this weapon is still on-going, but the unpublished thesis "The Accuracy of JDAM in an Operational Environment" documents the performance of the JDAM in operational tests. John A. Tirpak's article "Brilliant Weapons," published in the February 1998 issue of *Air Force Magazine*, gives valuable information on the Joint Stand-Off Weapon (JSOW). Other information is available in trade journals like *Aviation Week and Space Technology,* contractor journals like *Code One* published by the Lockheed Martin Tactical Air Systems company, or from test reports written by developmental and operational test organizations. A final source of information for these new weapons comes from staff officers responsible for weapon development. A draft of an operational requirements document or a concept for operations for a new weapon can provide insight into how these weapons will perform and how they will be used.

A final source for this thesis is the personal experience of officers that are currently students at the Army Command and General Staff College. Although this source is not in written form, there is no doubt that these students, with an average of twelve to fourteen years of experience in the military, have a wealth of knowledge to offer. Of particular interest will be those students with a background in field artillery, as they will be able to provide an understanding of the procedures used by artillery units.

All of the sources mentioned above are directly related to this thesis. As for the body of work on CAS, it should help define the history of CAS, how the military views CAS now, and what the future holds for CAS. The U.S. Army's "Force 21" reports on how the battlefield of the twenty-first century will operate will also help with predicting the future of CAS. Information on ground equipment that will be part of "Force 21" is available from defense contractors and on the Internet. As for the works on inertially guided munitions, they will provide basic background information for weapon capabilities. This thesis will attempt to merge these to areas in answering the primary research question.

CHAPTER 3

METHODOLOGY

As stated in chapter 1, primary and secondary research questions for this thesis are: Should inertially guided air-to-ground ordnance be used to perform CAS? Do pilots need to see and visually identify CAS targets before dropping ordnance on them? What method will be used on the battlefield of the twenty-first century to pass targeting information? and Do inertially guided weapons cost to much to use in a CAS environment? In order to answer the first two of these research questions, this thesis will compare CAS using inertially guided weapons to field artillery as two distinct sources of indirect fire support. The comparison will focus specifically on how ordnance arrives on target, not on the availability of systems delivering it. The topics of interest include how a forward observer defines the target, how that observer communicates targeting information to the people providing fire support, and how seeing the target adds to or detracts from the process. It is not the intent of this thesis to claim that CAS using inertially guided weapons should replace field artillery in any given situation, only that it could be used if artillery or CAS using other air-to-ground munitions were not available. When analyzing indirect fire support, two distances are of primary concern. The first of these is the distance away from friendly forces a target needs to be before it can be attacked by indirect fire without also hitting the friendly troops. For purpose of illustration, call this distance "A." Units of measurement are not important, but for consistency, the unit will be meters. For example, consider the case where a forward observer without artillery support spots an enemy mortar two hundred meters from his own position. The situation is stabilized, meaning neither side is advancing nor retreating, but the observer would like to destroy the mortar. Since artillery is not available, the observer calls for CAS and is soon talking with an F-16 pilot who is armed with five hundred pound GP bombs. The observer, referring to the risk estimate distances in Joint Publication 3-09.3, discovers that the risk estimate distance for five hundred pound bombs is 425 meters (U.S. Department of Defense 1995). The observer passes targeting information to the F-16, allowing the pilot to see and positively identify the target. In this normal situation, the forward observer would not want the F-16 to attack even though the pilot sees the target because there is the good possibility that the observer would be incapacitated by the attack.

Now consider the same scenario but instead of the situation being stabilized, the forward observer is being overrun by the enemy. This change makes the situation an emergency, meaning the observer will do whatever it takes to kill the enemy. In this emergency case, the observer would instruct the F-16 pilot to attack even though the observer risks incapacitation. The reasoning is that either way, the observer is in serious trouble, and it is better to attack with risk of incapacitation than not to attack and get overrun. This example is illustrated in historical cases documented by Lieutenant Colonel Charles Shrader in his study on fratricide:

> As in earlier conflicts commanders and operations officers were not unprepared to accept some casualties from friendly artillery fire as the price for the close and continuous fire support needed to overcome enemy resistance in the assault or to break up heavy enemy attacks on defensive positions, and fires on own position, not included in this study, were not uncommon. This rather pragmatic approach to the problem was--and is--neither unusual nor unwarranted and was clearly recognized in earlier conflicts. The commander of the 2d Battalion, 9th Infantry, for example, told an Army Ground Forces observer in

> Normandy on 1 July 1944, "We must teach our soldiers to remember that when they follow the artillery barrages and air strikes closely, they eventually suffer fewer casualties even though an occasional short may fall on them." (Shrader 1982, 17)

Now consider the same example, again with the stabilized situation. This time however, the forward observer learns from the F-16 pilot that the F-16 has five hundred pound GP bombs and 20-mm bullets. The observer, referring to Joint Publication 3-09.3, determines that the risk estimate distance for 20-mm bullets is 150 meters (U.S. Department of Defense 1995). Since the target is further away than 150 meters, the observer can direct the F-16 pilot to attack with the 20-mm ammunition, even under normal conditions.

By definition, distance "A" is equal to the danger close distance defined in Joint Publication 3-09.3. Specific distances are unique for each type of ordnance, both for CAS and artillery ordnance. This thesis will consider attacks on targets within the danger close distance (distance from friendly troops to the target is less than "A") to be "emergencies." Attacks on targets further away than the danger close distance will be considered "normal."

The second distance of importance when discussing indirect fire support is the distance away from friendly forces a target must be before detailed integration with those forces is no longer required. For purpose of illustration, call this distance "B," again measured in meters. Consider a forward observer, again without artillery support, positioned on a mountainside overlooking a large valley. The observer spots a column of enemy tanks moving across the valley and determines the tanks are 5,000 meters away. Wanting to destroy the tanks, the observer calls for air strikes. Since the tanks are so far away from the observer and no other friendly troops are in the valley, the observer determines detailed integration with the attack aircraft is not required. Instead, the observer passes the approximate target location and a description saying that the tanks are in a valley moving north and no friendlies are in the valley. The pilots find the valley, see the tanks, and attack. Since there are no friendly troops in the valley, the pilots can attack without fear of fratricide. In this example, since detailed integration between the aircrew and ground troops is not required, the attack by the aircraft is not CAS, but interdiction. As stated in chapter 1, the transition point between CAS and interdiction is unique to each case, with no specific distance is given.

Two other points about the previous scenarios are important. First, the examples do not mention other fire control measures like restricted-fire or free-fire zones, the fire support coordination line, or any of the other control measures. These obviously cannot be ignored, but they are beyond the scope of this thesis. This thesis will assume that everyone is aware of these measures and that they are all complied with. Second, even though CAS was the method of indirect fire support used in the example, the type of fire support does not change the outcome. Although artillery might not be the best battlefield system to attack tanks with, the only things that would change if artillery were used instead of CAS are the coordination and communication required to get artillery instead of CAS, and the actual number of meters for distance "A."

The premise of this thesis is that unless the target is within the danger close criteria (less than distance "A") for the ordnance being used as defined by Joint Publication 3-09.3, both CAS using inertially guided weapons and artillery should be viable fire support options. The decision by the ground commander on which system to use is beyond the scope of this thesis, but should take into account such considerations as the availability of artillery or CAS support, the need to conserve resources, and the specific strengths and weaknesses of each system. The danger close distance is dependent solely on the type of ordnance being used, not on whether the ordnance arrived via aircraft or artillery tube. The example given earlier in this chapter illustrated how a target could be attacked with 20-mm bullets, but not with five hundred pound GP bombs. Under the stated premise, the same thought process can be applied to ordnance dropped from aircraft and fired from artillery tubes. For instance, 20-mm bullets fired from an aircraft can be used against targets closer to friendly troops than a 105-mm howitzer because the risk estimate distance for 20-mm ammunition is 150 meters (U.S. Department of Defense 1995) while the risk estimate distance for the 105-mm howitzer ammunition is over three hundred meters (Anderson n.d.).

To graphically illustrate where indirect fire support is available, consider figure 1 showing a typical battlefield and areas on that battlefield where indirect fire support could be used to engage a target. The area labeled "area A" represents the area where the distance between friendly troops and the target is less than the danger close distance for the particular ordnance being used. Any indirect fire support directed against targets in the area A, like target 1, could result in friendly troops being injured.

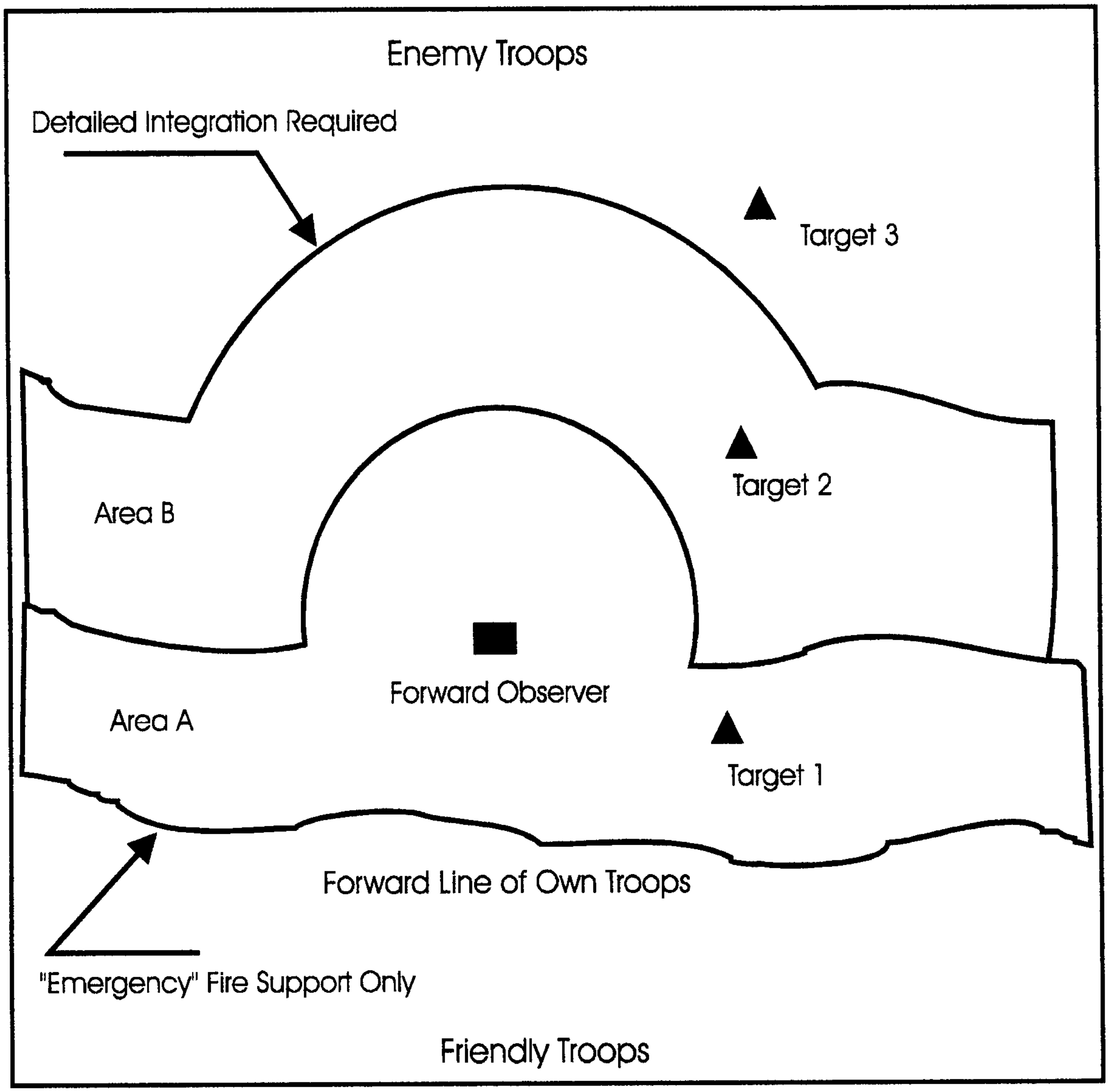

Figure 1. Typical Battlefield with Fire Support Areas

The area labeled "area B" represents the area where indirect fire support using normal procedures is available, but detailed integration with friendly troops is still required before ordnance is expended. Detailed integration is required because of the proximity of targets in this area, like target 2, to friendly troops. If the targets in the area B were attacked by aircraft, normal CAS procedures would be used because the distance from friendly troops to the targets is not within the risk estimate distance for the ordnance being used. Detailed integration with ground troops is not required to attack targets above area B, like target 3, although some level of coordination between the ground maneuver commander and the unit providing indirect fire support may be required, depending on how far from friendly troops the target is. This thesis is primarily concerned with targets inside area B, where normal procedures apply and detailed integration is required.

Methodology will focus on research of the CAS and field artillery, starting with their historical use and the results of this use. Of specific interest in historical cases is occurrence of fratricide for each system. Cases of fratricide are important because they highlight limitations of CAS and artillery, while providing a clue as to the origin of current procedures and restrictions regarding their use. In addition, current doctrine and procedures for using both CAS and artillery on the battlefield will be examined. Again, the focus of this examination is the reason for existing restrictions and to identify commonality or discrepancies between how the two systems are used. Finally, the systems used by ground troops who require fire support will be examined, as will systems used by pilots or soldiers who provide fire support through CAS or artillery. Of special interest here are systems used to identify current positions, systems used to determine target location, and systems or methods used to pass this location to the "shooters" providing the fire support.

The third research question deals with how soldiers will pass targeting information on battlefields of the twenty-first century. Equipment recently developed by the Army and the Air Force, some of which is already under test, will be used as the baseline for answering this question. In addition, information will be gathered from defense contractors, many of whom have insights into ambitious programs that will impact how the military will fight in the future.

The final research question deals with the cost effectiveness of using inertially guided weapons to perform CAS. This issue is a delicate one because it attempts to place a dollar value on the lives of soldiers in the field, which is obviously impossible. While it is impossible to quantify how much money the military should spend to save the lives of soldiers on the battlefield, fiscal realities do determine how many inertially guided weapons will be bought and will be available in any future conflict. For example, if inertially guided weapons cost so much that the military could only afford ten of them, it is unrealistic to expect that they would be used to perform CAS. Rather, they would probably be used to destroy the enemy's high value targets. On the other hand, if inertially guided weapons were cheap, the military could buy thousands of them. This would mean that these inertially guided weapons could be used against high value targets and enough of them would still exist to make them available for use in CAS missions.

An examination of the use of all "smart bombs" in recent air campaigns like Desert Storm and Deliberate Force may provide a clue as to how often smart bombs will be needed in future campaigns. Of course, projecting future needs based on past conflicts is accurate only if conditions for the future campaign are similar to the conditions of the past campaigns (same target array, same length of conflict, etc.). Once projected requirements or future needs are determined, this projection can be compared to the number of inertially guided weapons the military plans on purchasing to see which number is greater. From this comparison, the conclusion could be made that performing CAS with inertially guided weapons would not be cost effective if the number of these weapons is less than the existing need. If, on the other hand, there will be enough inertially guided weapons to cover the existing need, any extra ones would be available for use while performing CAS.

CHAPTER 4

RESULTS AND ANALYSIS

Historical Prospective

In order to more fully understand the history of CAS as an indirect fire support tool, a brief history covering CAS developments and incidents of fratricide resulting from CAS is provided. In addition, since this thesis will compare CAS to field artillery as a source of indirect fire support, the same historical analysis will be done for artillery.

Close Air Support

In the eleven years between the Wright brothers' first flight at Kitty Hawk and the start of World War I, developments in aircraft design and technology were relatively small and insignificant. Although both sides used the new contraptions, the slow speed, light armament, inability to carry a significant amount of ordnance, and fragile nature of World War I aircraft limited their impact on the war, as they were relegated to acting as forward observation platforms for field artillery. In spite of a ground war characterized by static and easily identifiable trench lines which would seem ideal for pilots in attack aircraft, there were cases on both sides where ground troops were bombed and strafed by their own aircraft. In comparison with the carnage of the ground war however, these incidents were insignificant and did not impact the war one way or another (Shrader 1982).

By the 1930s, aircraft development had progressed to the point where bombers could fly with large bomb loads and drop them with relative accuracy. Research and development efforts were focused on aircraft that could carry large bomb loads because airpower advocates were eager to develop machines that could perform the strategic bombing missions envisioned by theorists, such as Guilio Douhet, Hugh Trenchard, and Billy Mitchell. With the revolutionary Norden bombsight, these bombers were able to achieve a CEP on the order of a thousand feet when dropping from a level attitude at 20,000 feet (Stefanek 1997). Although accurate when properly used, limitations and assumptions made by the Norden bombsight in deriving bombing solutions limited the potential of these bombsights. Chief among these limitations was the need for the bomber to maintain level, unaccelerated flight for a few minutes before dropping its bombs. The inability to maneuver rendered the heavy bomber vulnerable to enemy attack from both air defense fighters and antiaircraft artillery. As a result of the large CEPs heavy bombers equipped with the Norden bombsight achieved as well as their vulnerability to threats near the front lines, these aircraft were viewed as not being suitable for CAS missions. Instead, CAS missions were primarily flown by smaller fighter/bombers. These fighter/bombers could achieve CEPs on the order of a hundred feet using more accurate dive-bombing techniques. In addition, the fighter/bombers were much more maneuverable than heavy bombers, and thus were less vulnerable to threats typically found near the front lines. As a result, fighter/bombers were considered more suited for the CAS mission. The restriction on not using heavy bombers to perform CAS disappeared after the invasion of Normandy, as the intensity of the Allied ground campaign resulted in heavy bombers being used in conjunction with fighter/bombers to perform CAS.

The fluid nature of the ground war in Europe presented both heavy bombers and fighter/bombers performing CAS with difficult coordination and control problems. Coordination between aircraft and ground troops was initially accomplished through colored smoke or cloth panels, which were used to identify friendly and sometimes enemy positions to the pilots overhead. Additionally, geographic, or lateral, deconfliction was also practiced. With geographic deconfliction, significant landmarks like highways or rivers were used to mark the areas bombers could drop bombs without fear of dropping on friendly troops. The idea was that bombadiers would see these smoke signals, colored panels, or geographic features and use them to identify the correct target. Inexplicably, troops on the ground were not always in radio communication with attack fighters or bombers providing CAS. This oversight limited flexibility and would lead to disastrous results on at least one occasion, as bombers already airborne could not be recalled after a planned ground offensive was postponed.

Aside from the limitation that both heavy bombers and fighter/bombers had to see and track (keep the target steady in the bombsight) the target for a period of time prior to bomb release (which was not possible with clouds or smoke obscuring the target), other problems surfaced as well. While it would seem obvious not to use the same color smoke to mark friendly and enemy positions, this was not always done. On one occasion during the breakout from the Normandy beachhead, the same color smoke was used for both, and in the resulting confusion, the Allied bombers bombed friendly troops. In another unfortunate case, proper procedures were followed, but a mechanical failure resulted in tragedy. In this instance, a formation's lead bomber experienced the mechanical failure which resulted in the bomber dropping its bombs early. The remaining bombers in the formation, taking their cue of the lead bomber, released their bombs as well. The bombs fell on friendly ground troops, causing over 400 casualties (Cooling 1990).

These and other catastrophes reinforced the previously held view that heavy bombers should not participate in CAS missions. This view was challenged by the introduction of guided bombs by the end of World War II. These guided bombs were controlled through radio signals sent by bombadiers in the bombing aircraft to the bombs as they fell. Although more accurate than unguided bombs, the new radio-controlled bombs still required input from a bombadier who could correctly identify the target to guide the bomb to it.

Airpower advocates recognized the need to develop a bombing system that could be used at night or under adverse weather conditions, when pilots and bombadiers could not see their targets. In fact, both the German and Allied air forces developed blind bombing navigation systems based on radio waves. The German Knickebein system was one that consisted of two radio stations separated by some distance. These stations both transmitted radio beams toward the intended target. Bombers flew down one of the radio beams until they intersected the other, dropping their bombs at the point of intersection. Accuracy of this system depended on the distance of the target from the radio transmitters. For transmitting stations in France and targets near London, German bombers were able to use the Knickebein system to navigate to within one nautical mile of intended targets. The Allied Oboe system also made use of signals generated by two distinct ground stations. The Oboe system was accurate to within three hundred yards, but was limited in that it could only be used by one aircraft at a time. Although accurate enough for use in the strategic bombing of Germany, neither system was considered accurate enough when bombs were dropped near friendly troops (Knight 1989).

By the Vietnam War, the need to develop a blind bombing system that could be used at night or in bad weather still existed. In fact, according to the Office of Air Force History, "One of the greatest challenges for the close air-support mission in South Vietnam centered on the need for night and all-weather strike capabilities" (Cooling 1990, 447). Three methods were developed to solve this challenge. The first involved special aircraft who dropped illumination flares for the forward air controllers (FAC) and the strike fighters. These flares hung under a parachute and illuminated the target with up to two-million candlepower, lighting target areas so crewmembers could see their targets. This method was used on sixty percent of the night CAS sorties flown in Vietnam. The second method involved the use of large gunships who were able to drop their own flares. While these methods solved the night CAS challenge by temporarily lighting the target area, neither worked when clouds obscured targets.

The third method, developed in 1966, was named Sky Spot. A radar beacon installed on the strike aircraft was the main piece of equipment for Sky Spot. Ground stations monitored these beacons, and vectored the strike aircraft to precomputed release points. The strike aircraft dropped their bombs when commanded by the ground radar stations. There were five Sky Spot stations in Vietnam, and each of these stations gathered precise bearing and distance data to prominent landmarks used by crewmembers to orient themselves. Even with these five stations, there were areas in Vietnam not covered by the system. A second limitation of the system was that each ground station could only handle one flight of strike aircraft at a time.

Tests conducted on the Sky Spot system demonstrated a CEP of seventy-two meters when eight digit map coordinates were used to derive target coordinates. In spite of this demonstrated accuracy, a Military Assistance Command--Vietnam (MACV) directive forbade Sky Spot missions from dropping ordnance within 1,000 meters of friendly troops without specific approval of the ground commander. This restriction did not dampen support for the Sky Spot system, as one ground commander who benefited from the system stated that he would not hesitate to use Sky Spot within five hundred meters of his troops if the targets were valid and lucrative (Cooling 1990).

Operation Desert Storm was a showcase for the new weapons and technology developed during the military buildup of the Reagan years. Stealth aircraft, an abundance of smart bombs, and military leaders determined not to repeat the mistakes made in Vietnam all had a part in the overwhelming military success in southwest Asia. While it is true that the Air Force progressed significantly in the years between Vietnam and Desert Storm, this progress did not apply to every mission flown. In fact, pilots flying CAS missions over the deserts of Kuwait and Iraq faced many of the same problems that pilots flying CAS missions over the jungles of Vietnam faced over twenty years earlier, despite the fact that the terrain in Iraq and Kuwait was much more suitable to CAS than it was in Vietnam. Specifically, pilots in both wars had trouble finding and hitting targets during periods of bad weather.

Poor weather during the short coalition ground offensive of Operation Desert Storm severely limited CAS effectiveness. Lieutenant General Charles Horner, the Joint Force Air Component Commander, even relaxed minimum altitude restrictions so pilots had a better chance of hitting their targets. He also encouraged his crews to feel a compulsion to hit targets when supporting ground troops since coalition soldiers' lives may have depended on it. In spite of the emphasis on supporting ground troops during the ground offensive, visual bomb releases on CAS targets were rarely possible due to the poor weather over the entire theater of operations (Watts and Keaney 1993).

There was good weather during the earlier Iraqi attack towards Al Khafji. The attack, designed in part to induce coalition forces into a ground war before they were prepared, generated the first true CAS sorties of the war. The Iraqi plan called for a three-pronged push into Saudi Arabia. Two of the prongs were stopped by air interdiction before they could cross the border, while the third advanced to the town of Al Khafji. The battle lasted only a few days, as fixed-winged and rotary-winged aircraft assisted ground forces in repulsing the attack. Two specific topics make the battle of Al Khafji significant with regards to CAS. First, there were two separate instances of fratricide during the battle. In one of these, an A-10 attack aircraft fired a Maverick missile that hit a Marine armored personnel carrier, killing seven and wounding two. According to the official news release on the incident, a missile malfunction was the cause of the accident. Regardless of the cause, the incident showed that despite advances in technology, fratricide was still a very real concern (Watts and Keaney 1993).

The second topic involved the types of aircraft that were tasked to participate in CAS sorties during the battle. As the Al Khafji situation developed, A-10s, AC-130 gunships, F/A-18s, AV-8B Harriers, and AH-1W Super Cobras were tasked with providing CAS for coalition ground forces. These aircraft routinely fly CAS missions, so their participation was to be expected. What was unexpected was a Marine request to divert B-52 bombers from their scheduled sorties to attack Iraqi armored formations along the Kuwait border. B-52s had been used exclusively to attack either strategic targets or the heavy divisions of the Republican Guard, neither of which were close to coalition ground forces. The Tactical Air Control Center (TACC) decided not to permit the B-52s to participate for two reasons. First, the TACC was not convinced that the B-52s would be effective against the armored formations. Second, since the Iraqi armored formations were in close proximity to coalition ground forces, the TACC feared the use of B-52s in this mission could lead to an incident of fratricide.

Data on fratricide events caused by CAS for World War II and Vietnam show ninety-nine instances of fratricide, with fifty-seven caused by some sort of human error (misidentification of the target, coordination errors, pilot-FAC problems). Additionally, cases of fratricide due to CAS typically result in larger numbers of casualties than fratricide resulting from other sources. The probable explanation for this is that the amount and concentration of ordnance dropped by attack aircraft on CAS bombing runs tended to be higher and more concentrated than ordnance delivered by other methods. This point is illustrated by the case cited previously, where large numbers of bombers dropped their bombs on friendly troops during the breakout from the Normandy beachhead. Table 3 summarizes CAS fratricide data for World War II and Vietnam (Shrader 1982).

Artillery

During the late 1800s, artillery systems capable of firing a high volume of lethal explosives on targets well beyond visual range were developed. Army planners and doctrine authors, seeking ways to exploit this increase in combat capability, developed new tactics that emphasized the shock value and firepower these artillery systems delivered. Unfortunately, the battlefield communication systems and other coordinating means required to clear artillery fire from other ground troops, particularly infantry, were in their infancy. As a result, ground troops were placed in a hazardous position by their own artillery. In spite of improvements in the accuracy and reliability of artillery systems along with improvements in communication systems and position determining devices, fratricide caused by artillery continued to be a problem.

Artillery was the major source of indirect fire support during World War I. With the large amount of artillery fire that occurred, it was reasonable to expect instances of fratricide, especially when considering the prevalent tactic of intense preparatory artillery barrages before infantry advances. In fact, General Alexandre Percin of the French Army calculated that as many as 75,000, or 1.5 percent of France's casualties, resulted from artillery fratricide. In fact, staff planners often included an allowance for casualties resulting from artillery fratricide when planning operations. This problem was not peculiar to the French Army, as German infantry troops jokingly referred to the 49th German Field Artillery Regiment as the "48½th" due to their penchant for firing artillery rounds short of the intended target. Generally speaking, these incidents of artillery fratricide resulted from poor survey and fire control procedures, poor communication systems, and inadequate and coordination measures (Shrader 1982, 2).

Although artillery systems, ammunition, and communications equipment improved by the start of World War II, as did doctrine for integrating artillery with other ground troops, artillery fratricide continued to be a problem. The reason for this was that the improvements achieved were offset by a more fluid battlefield and by continued lack of any system to correctly and accurately determine the position of friendly troops. Difficult terrain ranging from the rugged mountains of the Italian peninsula to the heavy jungles on the Pacific islands made it difficult for troops to pinpoint their own position, making it difficult to determine where exactly they wanted artillery shells to hit. As opposed to artillery fratricide incidents during World War I which resulted as much from insufficient equipment and new tactics as from human error, artillery fratricide during World War II seemed to result primarily from human error on the fluid battlefield.

Artillery and ammunition technology, communication systems, and troop locating procedures and aids all significantly improved by the 1960s and the Vietnam War. In addition to these improvements, commanders at every level were determined to minimize, if not eliminate, cases of artillery fratricide. In fact, MACV instituted several rules of engagement designed expressly to accomplish this goal. These rules included the following safety measures:

1. Firing a smoke shell set for a 200-meter height of burst as the first round for most observed missions.
2. Double- or even triple-checking all firing data at each echelon from the forward observer to the gun.

3. Conducting periodic gunner (firing) inspections and drills.
4. Separating and segregating, by lot, projectiles and powder for separate-loading ammunition.
5. Boresighting guns at least twice daily.
6. Registering guns at least twice weekly.
7. Conducting frequent staff inspections to insure compliance with safety policies (Shrader 1982, 16).

In spite of these precautions, artillery fratricide was still a problem, as forty-seven cases occurred during the war. Like in the Pacific theater of World War II, soldiers had to deal with jungle covered terrain that made it difficult to determine the exact position of friendly troops. Errors by forward observers in either determining their own location or the target location was the proximate cause of several artillery fratricide incidents. In addition, Vietnam saw the emergence of small, almost independent, combat teams who frequently operated apart from their parent organization during both day and night. As a result of the increased number of moving parts on the battlefield a small amount of artillery fratricide seemed inevitable. In one of the most serious of these incidents, a U.S. artillery unit firing a harassment and interdiction mission used the wrong charge (the amount of propellant used to fire the artillery shell) and fired shells into another unit's base camp. The victim unit immediately initiated counterbattery fire toward the firing unit which proved to be very accurate, killing twelve and wounding forty. The entire incident lasted twenty-three minutes and resulted in ninety casualties (Shrader 1982).

Analysis of the cause of artillery fratricide incidents during the Vietnam War leads to two conclusions. First, complex equipment like that used in directing artillery fire is not perfect and will sometimes fail. The result of these failures, though uncommon, can obviously be disastrous. The second, and perhaps more important, conclusion is that even though equipment and procedures improve, human error, the so-called fog of war, will always be present. This is illustrated by the observation that "errors attributable to forward observer mistakes, FDC (fire direction center) miscalculations and failures to follow established procedures, and gun crew errors account for the great majority of all artillery (fratricide) incidents in Vietnam" (Shrader 1982, 17).

Table 3 summarizes the data in Lieutenant Colonel Charles Shrader's study on fratricide with respect to CAS and artillery. This data is incomplete, as more detailed information is available for World War II and Vietnam than for the Korean war; however, it does provide an interesting comparison between artillery and aircraft incidents.

Table 3. Fratricide Data for Artillery and Close Air Support

Conflict	Human Error[a]	Mechanical Error	Unknown	Totals
WWII (Europe)	11 / 31	0 / 4	9 / 18	20 / 53
WWII (Pacific)	15 / 7	1 / 0	12 / 17	28 / 24
Korean War[b]	2 /	0 /	1 /	3 /
Vietnam War	30 / 19	4 / 2	13 / 1	47 / 22
Totals	58 / 57	5 / 6	35 / 36	98 / 99

Source: Schrader 1982, 27, 63.
Notes: Numbers represent fratricide incidents by artillery/aircraft for the selected wars.
a. Human error includes target misidentification, firing errors, or coordination errors.
b. No data was available for aircraft fratricide incidents during the Korean War.

CAS Procedures and Restrictions

There are numerous procedures governing the application of CAS. Basic procedures are outlined in Joint Publication 3-09.3, while tactics and techniques for aircrews are spelled out in aircraft-specific multicommand manuals. A brief explanation of some of these procedures is required to understand where and how an inertially guided weapon would fit in.

As previously stated, the responsibility for ordnance expenditure rests with the maneuver force commander. Responsibility is typically delegated through the FAC, who actually controls attack aircraft during CAS missions. Forward air controllers can be ground based or airborne. There are two specific levels of control used by FACs when dealing with CAS aircraft: positive control and reasonable assurance. Under positive control, "the terminal controller or an observer in contact with the terminal controller must be in a position to see the attacking aircraft and target, and receive verbal confirmation that the objective/mark is in sight from the attacking pilot/aircrew prior to commanding 'cleared hot'" (U.S. Department of Defense 1995, V-9). There are two subsets of positive control: direct and indirect control. Direct positive control, the preferred control level, occurs when "the terminal controller is able to observe and control the attack." Indirect positive control occurs when "the terminal controller cannot observe the attack, but is in contact with someone who can" (U.S. Department of Defense 1995, V-9).

The restrictions ordered by positive control procedures were obviously put in place to reduce or eliminate fratricide. As with most things, however, there is a price to pay for the benefits of positive control. First, compliance with positive control procedures takes time, which in turn means it takes attack aircraft longer to put bombs on target. Taking this one step further while considering how many aircraft can attack a target in a fixed amount of time, it is clear that fewer attack aircraft will be able to go across a target in that time period. The bottom line is that with positive control, targets will be hit with less ordnance than they would if positive control were not required.

The second disadvantage is that aircraft complying with positive control procedures, especially direct positive control procedures, are more vulnerable to enemy attack. This results from the requirement for the terminal controller to observe the attack. If the terminal controller can observe the attack, it seems obvious that anyone near the terminal controller, like the enemy, would also be in a position to observe the attack. If an enemy can observe the attack, he may also be able to target the attacking aircraft with surface-to-air threat systems.

The second level of procedural control, reasonable assurance, allows pilots to drop ordnance without specific positive clearance from the terminal controller. While reasonable assurance is not clearly defined, Joint Publication 3-09.3 says, "The joint force commander established conditions for reasonable assurance and when they will be in effect. When reasonable assurance is in effect, attacks can continue if the maneuver force commander, terminal controller, and aircrew are confident the attack will achieve objectives without harming friendly forces. This only applies if the CAS aircrew has already received initial targeting information. Careful consideration must be given to using reasonable assurance because of the increased possibility of fratricide" (U.S. Department of Defense 1995, V-10).

The joint publication goes on to give two examples of when reasonable assurance procedures would be appropriate. The first is an A-6E aircraft dropping radar beacon bombs under night or limited visibility conditions. Beacon bombing is a technique where systems on the A-6E identify a coded, electronic beacon positioned on the ground by the person requesting indirect fire support. In addition to positioning the beacon on the ground, the person on the ground tells the crew in the attack aircraft where the target is in reference to the beacon, usually given in true bearing and distance. For example, the target may bear 245 degrees for 10,500 feet from the beacon. The crew inputs this information into the aircraft's fire control computer and uses it in conjunction with the location of the beacon to find the actual target. The second example given in the joint publication is a day, visual attack where the pilot in the attack aircraft verbally acknowledges to target brief or sees the target or a mark near the target. In both of these cases, the crew of the attacking aircraft bears the sole responsibility of correctly identifying the target before dropping ordnance. The reason for this is that the attack is unobserved, thus making it impossible for anyone but the crew to determine if the attack is on the correct target until ordnance impacts.

Also of special interest in the examples of where reasonable assurance applies is that writers of the joint publication already seem to imply that the radar beacon used in target identification is equivalent to other sensors used to find targets, like infrared or laser sensors, or the human eyeball. This is illustrated by Joint Publication 3-09.3 when it states, "Aircraft systems (radar, radar beacon, laser, Forward Looking Infrared (FLIR), and television) are relied upon more at night and in adverse weather because of degraded visual target acquisition range and recognition cues" (U.S. Department of Defense 1995, V-13). Of further interest is that in the case of the A-6E, the crew may never see the target before dropping ordnance, relying primarily on the position of the beacon to find the target. Although the joint publication does warn against using only one sensor to find targets, it does not state a requirement to use multiple sensors. This point is illustrated by the joint publication when it states, "while these system-aided employment options can be used independently, combining the systems increases the probability of mission success" (U.S. Department of Defense 1995, IV-17). The publication goes on to state, "Aircrews and terminal controllers should incorporate redundant methods (e.g., radar, laser, and FLIR) into an attack, along with target mark to find and attack a target. Avoid the temptation to rely solely on one information source" (U.S. Department of Defense 1995, V-13).

When performing CAS, attack aircraft generally pass through several command and control networks before contacting the FAC. After the attack aircraft check-in with the FAC and pass information on their number and type of aircraft, position and altitude, ordnance, playtime (time the attack aircraft will be on station), and abort codes, the FAC will pass mission information to the aircraft. Mission information is in the form of a nine-line brief, and contains the following information designed to give aircrews everything they need to successfully complete an attack:

1. Initial Point (IP).
2. Heading from the IP to the target.

3. Distance from the IP to the target.
4. Target elevation.
5. Target Description.
6. Target location (coordinates in either latitude/longitude or grid).
7. Type of mark to be used.
8. Location of friendly troops.
9. Egress direction (U.S. Department of Defense 1995, V-3).

Ideally, the aircrew in the attack aircraft has maps of the target area and intelligence information concerning threats in the area, but this is not always the case. If maps are available, aircrews study the target area, input targeting data to aircraft computers, coordinate attack timing, and accomplish other required tasks after receiving the nine-line brief. If weather and threat conditions permit, the terminal controller may talk the aircrew onto the target by using visual features to describe the location of the target. The terminal controller may also use marks to point out the target. Marks can include smoke from rockets or artillery, a laser spot, an IR pointer, an artillery shell, or bullets fired by the airborne FAC. If target marks are unavailable, friendly positions can be marked. It is critical that the aircrew in the attack aircraft understand if friendly forces or the target is being marked. The ultimate goal of marks and verbal descriptions is to help crewmen gain situational awareness on the battlefield environment, increasing the chances that the correct target will be attacked and lowering the chances for an incident of fratricide.

Even though a visual description of the target area combined with target marks should be sufficient to point out the correct target, the incidents of fratricide documented earlier in this chapter indicate it is not. There are several reasons for this, with the reasons depending on the type of mark being used. For visual descriptions, there is the problem of perception. Stated simply, the visual picture seen by the aircrew in the attack aircraft may be totally different than the visual picture seen by the terminal controller. This is especially true if the terminal controller is on the ground. With the two referencing different visual pictures, visual descriptions are not worth much. An IR pointer is basically a high-powered flashlight that uses light in the IR spectrum. The IR beam is visible when viewed with night vision goggles. The effectiveness of these devices, used for night CAS, varies with the amount of ambient light present. An IR pointer that is easily-seen on a night with no moon or with heavy cloud cover may be invisible on a night with a full moon. Pointers that are invisible are not effective marking devices. Moving to laser marks, when lasers are used as pointing devices, special aircraft equipment is required to see the laser spot. Unfortunately, this special equipment is not installed on most attack aircraft. As a result, these marks are not always useful. Finally, visible smoke can dissipate quickly or be totally invisible, depending on what else is happening on the battlefield.

Once the aircrew identifies the target, standard attack procedures are used to deliver ordnance. The only difference between CAS attacks and interdiction or strategic attacks is the need to get clearance to drop, which comes from the terminal controller. Clearance to drop can be given as soon as the aircrew acknowledges that the target is in sight, or can be delayed until the terminal controller observes that the attack aircraft is in the final stages of weapon delivery, depending on the situation. In either case, clearance to drop is not given until the terminal controller is sure that the aircrew sees the target.

Munition Descriptions

Since different types of ordnance will be discussed, a brief description and explanation of how they work will be useful. The most basic types of air-to-ground ordnance are GP bombs and CBU, which are two types of gravity bombs. Simply stated, after these bombs leave the aircraft that drop them, they fall under the force of gravity until they hit the ground. They are aimed by the pilot before they are dropped, but are unguided during flight. The accuracy of these types of bombs depends not only on the avionics of the dropping aircraft and the ability of the pilot to aim correctly, but also on how close the aircraft is to the target at bomb release and on how unanticipated winds change the bomb's flight path. A GP bomb is a single bomb body that stays intact until it explodes, either just before or after hitting the ground. CBU is a cluster of smaller bomblets carried in one container that opens before hitting the ground, letting the smaller bomblets spread over an area before they each hit the ground and explode. The bomblets, or submunitions, can be optimized for use against either armored vehicles or personnel.

Guided bombs differ from gravity bombs in that they either have small wings or fins that actually change the path of the bombs in flight. The first guided bomb is the LGB, which contains a laser seeker in the nose of the bomb. This seeker can see reflected laser energy as long as the reflected energy is strong enough to be detected and is in the seeker's field of view. As long as there is reflected laser energy emanating from the target, the bomb will literally guide itself to the target. The assumption is that either a pilot or soldier on the ground illuminates the target with laser energy, and keeps the laser energy there until the bomb impacts.

There are three weakness associated with LGBs aside from the need for someone to see the target. First, in the case where an aircraft illuminates the target, the lasing aircraft must fly a stable flight path in order to keep the laser spot stable on the target. If the laser spot moves excessively as the bomb falls, the bomb may chase the spot, causing it to expend energy as it maneuvers. When the bomb expends too much energy, it does not have enough energy left to make last minute flight path corrections, which will increase the eventual miss distance. In addition, when the lasing aircraft flies a stable flight path, it becomes predictable, making it more vulnerable to enemy attack. Secondly, the seeker in the nose of the LGB is susceptible to damage when flown through rainstorms or severe weather. Damage to the seeker can happen anytime during flight (Werrell 1998). Finally, laser energy is dissipated by moisture. This means that even if a soldier on the ground is lasing the target, the LGB cannot see the reflected laser energy if there are clouds between the target and the bomb. In other words, LGBs cannot be guided through the weather.

Guided missiles like the IR Maverick missile also guide themselves to the target, but in a slightly different manner. The nose of these types of weapons contains a camera that sees whatever the weapon is pointed at. This picture is displayed in the cockpit as long as the missile is attached to the aircraft. The pilot looks at the image the missile sees, finds the target in the image, and locks the missile on the target. The pilot then launches the missile, and the missile flies itself to the target. The pilot does not need to do anything after the missile is launched, as the missile guides itself based on the image it sees as it flies to the target. Like laser energy, IR energy is dissipated by moisture, so missiles that see IR energy are blinded by clouds and cannot be used in the weather.

Another type of guided bomb has a camera in the bomb's nose that sees in either the IR spectrum like the Maverick missile or in the visual spectrum. The difference with this type of bomb is that it transmits the picture the camera sees back to the aircraft after it is dropped. The pilot or weapons system operator look at this picture as the bomb falls and send signals back to the bomb that control the bomb's flight path. Through the signals sent back to the bomb, the pilot or weapons system operator guides the bomb to its target. Again, anything like clouds that blinds the camera in the bomb's nose renders it useless.

Inertially guided bombs are also guided like LGBs and Maverick missiles, but guidance commands are based on a coordinate system rather than on reflected laser energy or an image seen by the bomb. Inertially guided bombs consist of a kit that can be mounted on general purpose or cluster bomb bodies, turning these basic gravity bombs into guided munitions. The kit consists of a GPS receiver, an electronic guidance unit, moveable tail fins, and in some cases, wings. Before the weapon is dropped, the aircraft tells the bomb its current latitude, longitude, and elevation. In addition, the aircraft passes the desired target coordinates to the bomb. More advanced inertially guided bombs also receive the desired impact angle and azimuth, desired impact velocity, GPS almanac data, and GPS crypto key data from the aircraft. GPS almanac data tells the bomb where the GPS satellites are in space, helping the bomb find and track them as it falls. Crypto keys are the codes required to access the more accurate GPS service levels. These codes also prevent an enemy from sending false position data to the GPS receiver.

After the bomb is released, it falls ballistically in an unguided mode until it begins communicating with the GPS satellites. The bomb then uses GPS information to update its position as it falls. Corrections to the bomb's flight path are determined by the guidance unit and are passed to the fins. The fins move as required to correct the bomb's flight path until impact. Simply stated, the bomb knows where it is, knows where it wants to go, and guides itself there. If the bomb's GPS fails, the bomb enters a backup mode, relying solely on its on-board inertial guidance system to guide itself to the target. Although still more accurate than unguided bombs, inertially guided bombs operating in this backup mode do suffer a degradation in accuracy.

There are three different subsets of inertially guided bombs. The first of these is the JDAM. The JDAM is a modified 1,000-pound or 2,000-pound GP bomb that can be fused to detonate at or immediately before bomb impact just like other GP bombs. The 2000 pound version is generally considered inappropriate for CAS because of the warhead size, but the Navy and Marine Corps both are exploring the use of the 1,000-pound version in the CAS role (King 1998). The JSOW, the second subset of inertially guided bombs, is a modified CBU canister that opens before impact, releasing submunitions over a small area. JSOW can be fitted with sub-munitions that are specifically designed to destroy or disable armored vehicles. This obviously makes them well suited for the battlefield. In addition to the difference in the bomb type, the JSOW also has larger wings than the JDAM, allowing it to fly further after bomb release (Tirpak

1998). This means an attacking aircraft using JSOW can drop the bomb further from the target than if dropping JDAM. Another advantage of the JSOW is that it can be programmed to approach the target from any desired direction. An example of when this feature would be desirable is against targets near friendly troops. In this situation, the JSOW could be programmed to approach the target on a course parallel to the line of friendly troops so it would not overfly the friendly troops on its way to the target. Although JSOW has many features that would seem perfectly suited to CAS, the current concept of operations call for JSOW to be used in the interdiction role against heavily defended targets instead of for CAS (Rozelsky 1998).

The final type of inertially guided bomb is the Wind Corrected Munition Dispenser (WCMD). WCMD is similar to the JDAM except that the bomb body is the CBU type rather than the GP type. The submunitions in the WCMD are designed for both antitank and antipersonnel uses, making them ideal for use on the battlefield just like the JSOW. Unlike the JSOW, the WCMD does not have wings, so the WCMD will not fly as far after release as the JSOW will (Rozelsky 1998).

An additional improvement made to the WCMD is the ability to correct for winds in the target area. The submunitions of older CBU weapons were very susceptible to winds after the canister carrying them opened. This occurred because the submunitions had different ballistic properties than the canister that carried them. With these older weapons, it was possible for the canister to open at the correct point in space, but for the submunitions to miss the target because of the wind. WCMD takes these winds into account when calculating where the canister should open. The accuracy requirement for the WCMD is a CEP of one hundred feet, with an objective CEP of eighty-five feet. These numbers are based on a target location error of 7.2 meters, which is currently possible with national-level assets. This target location error is the difference between where a target actually is and where coordinates predict it is (Rozelsky 1998).

As previously stated, all inertially guided weapons fly to a point in three-dimensional space defined by coordinates. The source of these coordinates leads to the two methods of weapon employment. The first, bomb on coordinates (BOC), is the preferred method, as it is the most accurate and takes full advantage of the capabilities of the weapon. BOC is available whenever exact target coordinates are known prior to bomb release. Exact coordinates for high-priority, stationary targets are typically obtained from national assets (satellites, high altitude reconnaissance). BOC could be used for mobile targets if real time intelligence were available. An example of this would be when a FAC who observes a target on the battlefield is able to coordinate fire support before the target moves. While systems currently in use on the battlefield are capable of passing near real time intelligence, efforts continue to speed up this process.

The second method, relative targeting, is used when exact target coordinates are not known, but are calculated by the computers on the aircraft using onboard sensors prior to bomb release. Relative targeting is not as accurate as BOC because relative targeting is based solely on the positional information of the aircraft. To illustrate this principle, consider an F-16 pilot dropping the WCMD on a target the pilot sees but does not have coordinates for. To drop the weapon, the pilot aims it, using the same techniques used to drop an unguided bomb. However, just before bomb release, computers on the F-16 complete several tasks. First, the computers determine the three-dimensional position of the aircraft. Next, onboard sensors like the air-to-ground radar measure the distance from the aircraft to the target on the ground. These two pieces of information, along with angular information obtained from the aircraft's inertial guidance system, are used to determine target coordinates. Three possible sources of error exist when the aircraft determines target coordinates in this manner. First, there may be drift in the aircraft's inertial guidance system, meaning the aircraft is not exactly where it thinks it is. Although the F-16 has GPS to minimize this problem, the accuracy of GPS is still only twenty meters in the precise positioning service mode. Next, on-board sensors used to measure the distance from the aircraft to the target are relatively accurate, but are not exact. An error in this measurement would propagate through the computation. Finally, the computing power on the aircraft is a limiting factor. The computer on the F-16 receives inputs from aircraft sensors and the inertial guidance system at a rate of fifty times per second. While this may seem sufficient, it is easy to see how the conditions used in the computations would have changed when the aircraft is traveling at five hundred miles per hour. Slowing down to reduce this potential error is not practical and would expose the aircraft to more threats.

A final problem with relative targeting that is not related to aircraft limitations is the need for the pilot to see the target. As previously stated, the benefit of using inertially guided weapons is that the pilot is not required to see the target. Using inertially guided munitions in a CAS environment when the pilot can see the target seems to be an inappropriate use of these new munitions, as more conventional gravity bombs or other guided munitions would be available for use.

Battlefield Systems

Since the dawn of land warfare, soldiers have used maps to orient forces, plan campaigns and help provide a clearer picture of the battlefield environment. The accuracy of these maps has obviously improved through the ages, as innovations ranging from orbiting satellites to improved optic and distance measuring devices used for surveying have enabled cartographers to be more precise in their trade. By using these improved maps, today's soldiers are better able to determine their own position on the battlefield, as well as the position of targets they want to attack.

As accurate as maps are, they are by no means perfect. A fundamental problem with maps is that they are a flat, while the globe they represent is not. To solve this basic problem, cartographers mathematically model the globe with a number of spheroids. These models are referenced when overlaying map coordinates onto the map. The models, and subsequently the map coordinates, are most accurate near the reference point for each model (commonly referred to as the datum), and less accurate as the distance from the datum increased. Since more than one datum exists, map coordinates for any given point depend on which datum was used in making the map. Ideally, people use a datum close to the point of interest when deriving coordinates since this would increase the accuracy of the coordinates. Problems arise, however, when moving between maps which are based on different datums. It is possible to have two different sets of coordinates for the same point on the ground. This obviously is the source of confusion, as coordinates alone are not sufficient when defining a point; the datum used is also required.

The following example illustrates the potential for error that results from inadvertently switching datums. A building with the Military Grid Reference System (MGRS) coordinates 51SXE28181402 also has the MSGR coordinates 51SXQ28341331. The "XE" in the first set of coordinates identifies the datum for the first coordinates as World Geodetic System-84, while the "XQ" in the second set of coordinates identifies the datum for these coordinates as the Tokyo Datum. If the second set of coordinate numbers were used with the first datum, the resultant positional error would be 729 meters, which is obviously significant (National Imagery and Mapping Agency 1995).

In fact, there are thirty-two separate datums used in map production in the world today, and eleven different spheroids used on maps produced in the United States alone (U.S. Department of Defense 1995). Some maps may even contain two different sets of coordinates, each with its own datum. This basic problem with maps is highlighted in Joint Publication 3-09.3 when it states, "Several coordinate systems are in use around the world and even within U.S. forces. The use of multiple datums has led to various kinds of inaccuracies during combat operations. Everyone in the joint CAS process must use a common datum as established by the Joint Force Commander (JFC). Should the JFC not designate a standardized datum, or if there is any doubt as to which datum is being used, requesters of CAS should specify the datum in the JTAR" (U.S. Department of Defense 1995, IV-6).

The problem with maps was highlighted during the invasion of Grenada during Operation Urgent Fury. In this operation, the Joint Task Force Commander's map of Grenada was dated 1895, while the Marines and Army had two different maps. As a result of this situation, the commander had no means of developing the situation on the island, and troops had no effective way of calling in targets. The problem was solved by distributing a common chart, one printed by the Office of Tourism in London, that all forces could reference (March and Weissinger-Baylon 1986).

It is possible to switch from coordinates based on one datum to coordinates based on another datum, but the process requires a mathematical conversion. These conversions are quite complex and are generally accomplished by a computer program, like MADTRAN, that is available from the National Imagery and Mapping Agency (NIMA), which recently assumed the mission of the Defense Mapping Agency (DMA).

The effort to reduce confusion created by different datums led to the World Geodetic System (WGS), which was a unified system of coordinates for the entire globe. The WGS was developed during the late 1950s, and was not based on a single datum, but was based instead on high altitude reconnaissance and a worldwide distribution of surface gravity measurements. WGS coordinates were updated periodically as more accurate laser measurements and advanced satellite imagery became available (Rosson 1996). Four updates have been made since the initial system was published in 1960, with the latest update occurring in 1984 (the last two digits of the year are added to the WGS title to clarify which coordinate system is in use, hence the title WGS-84 for the latest version). Most inertial guidance systems used by the military are based on the WGS-84 system of coordinates, as is GPS. Unfortunately, not all maps are based on WGS-84 coordinates. This is obviously true for older maps produced before 1984. The long-term plan for the U.S. is to switch entirely to the WGS, or some compatible system.

In addition to problems resulting from different datums, there is a problem with the accuracy of the map itself. The agency responsible for making most of the maps used by the military is now the NIMA. Before the NIMA assumed the responsibility of providing maps to the military from the DMA, the DMA standard for 1:50,000 and 1:250,000 scale maps stated that ninety percent of all well-defined points printed on any map be accurate to within one millimeter (Rosson 1996). On a 1:50,000 scale map, an error of one millimeter translates to an error of fifty meters. Thus, whenever coordinates for a point are pulled from a map, even if done perfectly, there is a possibility that the coordinates for that point are up to fifty meters off.

There are limitations when using maps on the battlefield to determine coordinates in addition to the limits in precision of the maps themselves. First, many of the precise tools used by surveyors, like theodolites or electronic measuring devices, are not universally available, or practical, in a combat environment. This is especially true for forward observers, who tend to operate from concealed positions with only essential equipment. Instead of precise instruments, forward observers are more likely to use relatively basic tools, like a handheld compass. Next, rather than measuring a distance and bearing from one prominent landmark, soldiers without precise surveying tools are forced to triangulate between numerous landmarks to determine their location. The required number of prominent landmarks are not always available. This was a problem during Operation Desert Storm, as the sand dunes and barren terrain of Saudi Arabia, Kuwait, and southern Iraq made land navigation with maps difficult. Another issue that arises when using maps is the scale of maps. The scale of most maps used by ground troops is 1:50,000. To illustrate the problem caused by map scale, consider a line drawn by a .7 millimeter pencil lead (a medium width pencil lead) on a 1:50,000 scale map. Simple mathematics shows that the line covers thirty-five meters on the ground. This may seem insignificant at first, but when adding a possible fifty meter error that results from DMA limitations and remembering that the risk estimate distance for the 20-mm Gatling gun is 150 meters, it becomes apparent that an error of a few pencil widths could prove catastrophic (U.S. Department of Defense 1995). The common thread to these problems is that when soldiers are placed in stressful situations, like combat, and are required to perform complex tasks such as determining accurate map coordinates, errors will inevitably result. This is especially true when the soldier is forced to use rudimentary tools to accomplish the complex task.

In order to compensate for the inability to determine accurate target coordinates from maps, armies of the world wanting to consistently destroy targets with artillery adopted the common practices of registering target areas and correcting fires. The concept behind registering target areas is relatively simple. First, a forward observer selects a target and determines coordinates for it. These coordinates are passed to an artillery battery that is in a fixed position. Next, artillery shells are fired on the target. The forward observer compares where the artillery shell actually impacts to the predicted impact point. From this comparison, the observer and artillery battery are able to derive correction factors that account for the many variables involved in the firing solution. These correction factors may account for weather conditions, actual performance of powder charges being used, actual performance of the artillery tube, and the ability of the person firing the weapon to accurately aim it. In subsequent engagements against targets in the area where the registration occurred, these corrections are applied in an effort to improve artillery accuracy (Sims 1998).

The principle of adjusting fires is also relatively simple. First, the forward observer passes target coordinates to the artillery battery. The target is the precise point where the artillery shell should impact. Next, the weapon is fired with the correction factors derived when registering the artillery tube applied to the firing solution. Finally, the forward observer sees where the shell impacts in reference to the target. If the shell misses the target, the forward observer tells the artillery battery to shift the aiming point in either azimuth or range. The process is repeated until the target is hit. If target area registration is done properly, the number of artillery adjustments required before a target is hit should be small. While not particularly efficient, registering target areas and correcting fires has been proven to be very effective in destroying targets (Sims 1998).

To further improve the ability of all soldiers to determine their precise position on the battlefield, the Army has fielded handheld GPS locators in large numbers. One of these devices is the AN-PSN-11 built by the Collins Avionics and Communication Division of Rockwell International. The accuracy of the AN-PSN-11 and similar systems depends on the number of satellites the device is tracking and where the satellites are relative to the horizon. Highest accuracy is achieved if the device is tracking at least four satellites that are positioned near the horizon. These GPS locators need to maintain a direct line of sight from the satellites to the receiver. This can be a limitation when operating in rugged terrain, as mountains can cut this line of sight. A useful feature of the AN-PSN-11 that is the ability to determine figure of merit, or system accuracy. Basically, the system figures out how many satellites it is communicating with and where they are relative to the horizon, and uses this information to tell the user system accuracy. Accuracy is reported as a plus or minus distance in either feet or meters. This feature is not unique to the AN-PSN-11, but is common to most new GPS locators. Tests conducted by 422d Test and Evaluation Squadron personnel on the Nellis Air Force Base Range Complex showed the AN-PSN-11 typically achieved an accuracy of ten meters in either the horizontal or vertical direction (Beekman 1998).

There are five advantages of these locators. First, they are easy to operate. Secondly, since these systems are digital in nature, it is very difficult for a soldier to induce errors in the system. Stated simply, they either work correctly or don't work at all. Next, they are small, about the same size as a two-way radio. This feature makes them ideal for use in a battlefield environment. Fourth, the locators report current accuracy to the user, helping establish some level of confidence in the coordinates provided by the device. Finally, while they are based on the WGS-84 coordinate system, which is the same coordinate system used by most military inertial guidance systems, they are also compatible with other datums such as those used on older maps. The newest GPS locators are compatible with forty-nine of the most commonly used datums and two user defined datums. User-defined datums allow the user to manually enter datum information, which could be useful in areas not recently mapped. This compatibility feature means no coordinate conversion factor is required when using the GPS locator with non-WGS-84 systems or maps (Beekman 1998).

Once soldiers know coordinates for their own position on the battlefield, the next step is to determine coordinates of objects not collocated with the GPS locator, specifically targets. The Army has fielded a number of handheld laser devices that, together with the GPS locators, can accomplish this task. One of these devices is the Litton Mark VII Handheld Laser Rangefinder (LR). This device was designed for use by long range reconnaissance patrols, artillery, and aircraft fire support personnel, as it weighs just over four pounds with the battery installed. It can be mounted on a tripod for increased stability and has an image intensifier in the unit that provides a night vision capability. Magnification in the day mode is 7.3X, while magnification in the night mode is 4X. The LR must be aligned so it knows which way is up and down and which direction it is pointed. There are two levels of alignment, or digital magnetic compass calibration. With a hard calibration, the unit measures azimuth in one degree increments, while azimuth is measured in one tenth of a degree increments after a soft calibration (Rosson 1996). When the laser beam is pointed at a target, the LR measures vertical elevation and azimuth as well as range to the target. This information, when combined with coordinates from the GPS locator, are mathematically combined to determine coordinates for the target.

While these GPS locators and laser systems are much more accurate in determining coordinates of an object than maps are, they are by no means perfect. One problem with the Litton Mark VII Rangefinder is the ability of the operator to accurately aim the laser beam and obtain consistent distance measurements. This became apparent in testing of the LR, as personnel who tested the device reported problems obtaining uniform distance measurements when aiming at objects over 1,000 meters away unless there was significant vertical development between the LR operator and the target, or unless the target itself was vertically developed. Stated another way, it was difficult for the test personnel to use the LR on small, distant targets unless they were looking down on them. This result is not unexpected. To understand why, consider a flashlight that is placed near the ground and pointed at a distant object. The light from the flashlight will form a large ellipse on the ground. In the analogy, any part of the ground that reflects light would also reflect laser energy. Since the area that is lit is so large, there is no precise point to use when determining distance. Conversely, when the flashlight is held high and pointed straight at the ground, the area lit is a small, tight circle. In this case, any point in the area lit would be useful when determining distance.

Twenty-First Century Battlefield Systems

There are several systems that will impact the way wars are fought in the future, many of which are already being tested or are in use. The systems that are of concern are those used to improve the situational awareness (SA) of battlefield personnel. SA is a term that describes the amount of knowledge concerning the battlefield environment any person has, to include things like where friendly and enemy forces physically are and what state the forces are in. These systems will literally be deployed on every conceivable combat platform, from tanks and armored personnel carriers to attack aircraft performing CAS. Some may eventually be part of the personal gear carried by individual soldiers.

One of these new systems is the Enhanced Position Location Reporting System (EPLRS), which is capable of being the backbone for the digitized battlefield of the future. The design of EPLRS makes it compatible with everything on the battlefield from the Air Defense Antitank Systems and the Advanced Field Artillery System to UH-60 helicopters and the Future Infantry Fighting Vehicle. EPLRS provides users with data communication, the ability to identify other users, and the ability to navigate in reference to these users. The system is composed of a base network control station (NCS) and remote radio sets (RS), with the NCS being the central computer that controls the network used by all of the RS units. Simply stated, each RS can be viewed as a spoke on a wheel with the NCS as the hub. The RS units are assigned communication time slots by the NCS, and the RS units take turns sending and receiving information over encrypted radio frequencies. The NCS collects all of this information and sends it to other users on the network. For long data transmissions, the NCS simply sets parameters for direct communication between two RS units and is not itself in the loop. Information sent of received can include test messages, positional information, and identification information. The obvious limit with EPLRS is that soldiers must be near an RS unit to have access to the benefits provided by the system. EPLRS was used in the first All-Service Combat Identification Evaluation Test (ASCIET) in 1995. ASCIET is the military's major annual exercise that evaluates combat identification equipment and techniques with the goal of identifying the causes and cures for fratricide (U.S. Department of the Army 1996).

To illustrate how the system works for positional information, consider two vehicles on a battlefield, both equipped with RS units that are communicating with a NCS. The RS in the first vehicle sends a message to the NCS, reporting the position of the vehicle. The NCS then sends this information to the RS in the second vehicle. The RS in the second vehicle receives this information and displays the position of the first vehicle on a tactical situation display. Thus, the crew in the second vehicle knows where the first vehicle is without necessarily seeing it. Aside from positional information, EPLRS will be capable of transmitting the speed and direction of movement for the host vehicle (U.S. Department of the Army 1996).

EPLRS radios have already been tested on Air National Guard F-16s and will be installed on over four hundred aircraft starting in August of 1998, providing F-16 pilots with a valuable SA tool (Binger 1998). The system works in the F-16 in the same way it works on ground vehicles, making the F-16 part of the information network. With EPLRS, the F-16 pilot can determine where friendly forces on the ground are and receive targeting information like the nine-line brief in text format. The display used to present this information is a horizontal situation display, which also can be programmed to display things like existing free-fire or restricted-fire zones, the forward line of own troops, or known threat locations. In addition, friendly force positions can be displayed in the aircraft's head-up display, which is used by the pilot during weapons delivery to aim with. With this feature, the pilot can determine if any friendly troops are in the vicinity of where bombs will impact, which is obviously useful in preventing fratricide. The basic assumption here is that all friendly troops will be in the vicinity of an EPLRS RS unit. If a group of soldiers without an RS unit wanders off or gets lost, their position will not be reported over the EPLRS network.

Weapon Availability

According to the project officers working in the Directorate of Requirements for Air Combat Command, the Air Force plans to buy 40,000 of the WCMD kits for installation on existing munitions. Of these, 30,000 will be for the CBU-87 munition. CBU-87, already a preferred CAS munition in its unguided form, is the cluster munition designed for use against both personnel and armor. Acquisition of these WCMD kits should be complete by fiscal year 2006 (Rozelsky 1998). In order to provide insight into how quickly bombs are used during combat operations, information regarding usage rates is required.

Precision guided munitions (PGM) were used extensively during Operations Desert Storm and Deliberate Force. The air campaign of Desert Storm, which lasted forty-three days, targeted both military forces and infrastructure in Iraq as well as Iraqi military forces in and around Kuwait. During this campaign, coalition air forces delivered 227,340 weapons. Of these, 14,400, or just over 6 percent, were PGMs. Deliberate Force, the air campaign waged to protect safe areas in the war-torn former Yugoslavia, lasted just twenty-two days. Of these twenty-two days, air attacks were conducted on only twelve. During Deliberate Force, air forces delivered 1,026 weapons. Of these, 708, or approximately 69 percent, were PGMs. The heavy reliance on PGMs during Deliberate Force resulted from the strategic necessity to limit damage to nonmilitary facilities located near the actual targets as much as possible (Owen 1997).

Analysis

The first of the secondary research questions deals with the pilots' need to see and visually identify CAS targets before dropping ordnance on them. Beyond the goal to hit the correct target, the reason for this restriction ultimately comes down to protection from fratricide. Given this and referring back to the historical use of CAS, it is readily apparent that this restriction does not eliminate fratricide. In spite of this, the restriction made sense because in order to achieve any level of accuracy while delivering ordnance, the aircrew was required to see the target, regardless of the type of weapon being dropped. While it has been possible to drop bombs without seeing the target since World War II, results with regard to accuracy have generally been poor. In all but emergency battlefield scenarios, the accuracy of these blind bombing methods was and still is not sufficient for use in normal CAS situations.

The development of inertially guided weapons has changed this, as it is now possible to hit a point on the ground with precision without having to see it. The challenge with these new weapons is not for the aircrew dropping them to see the target, but for someone to provide accurate target coordinates. In fact, inertially guided bombs are more accurate when dropped in the BOC mode than in the relative targeting mode, where aircraft computers can induce positional errors that degrade the bomb's performance. Thus, when dropping inertially guided weapons, it is not important for the aircrew to see the target, instead, it is critical that the target coordinates passed to the aircrew be accurate. The same is true for artillery systems, as it is obvious that the soldier who pulls the lanyard firing the artillery shell does not see the target, instead relying the accuracy of the coordinates passed by the forward observer.

This leads to the next secondary research question: How will target position be determined on the battlefield of the twenty-first century? and How will this information be passed to appropriate units? The method traditionally used is for forward observers to visually spot targets, plot their coordinates from a 1:50,000 map, and pass these coordinates to artillery batteries or to crewmen in attack aircraft. The problems with this method are well documented, and the coordinates derived using this method were typically a starting point that was referenced to refine targeting. To overcome shortfalls with this method, artillery batteries corrected fires, while crewmen in attack aircraft referenced marks or used visual descriptions to find targets. The development and deployment of handheld GPS locators and LRs changed targeting methodology, allowing observers to determine accurate coordinates. With this new equipment, correcting fires became less popular, as more focus was placed on hitting the target with the first artillery volley. No parallel change in CAS procedures occurred, probably because crewmen still needed to see targets to employ their weapons. With inertially guided weapons, seeing the target is not required; the bombs will hit the target on the first attempt if target coordinates are accurate, just like artillery fire.

Joint Publication 3-09.3 raises the valid concern of depending totally on one sensor when targeting weapons. The concern applies to inertially guided bombs because in theory, the crewmen could drop these bombs on target coordinates alone with no other SA on the battlefield situation. If the coordinates were incorrect, the bombs would miss the targets, and potentially result in fratricide. In the case of CAS, the requirement to see and identify the position of friendly troops as well as the position of the target answered this concern. In the case of artillery, the multiple checks of a firing solution at various echelons was the answer. The question for CAS then becomes if obtaining visual confirmation is not possible, how do crewmen verify targeting information before they drop bombs. The answer to this question lies in the other equipment being fielded as part of the digitized battlefield. With systems like EPLRS, it is possible for crewmen to get a visual depiction of the battlefield in their cockpits, complete with friendly troop locations. Assuming this information is accurate, the crewmen could verify target coordinates against the positions of friendly troops before dropping their bombs. All of this could be done without the crewmen visually seeing the battlefield.

The final secondary question deals with cost, or more precisely, with the potential availability of inertially guided weapons for use on CAS missions. During the intense air campaign of Desert Storm, air forces delivered almost 335 PGMs per day. During the more limited air campaign of Deliberate Force, air forces delivered fifty-nine PGMs per day. While the amount of PGMs required for any future conflict will depend on a number of variables, conflict duration being an important one, this historical information does provide a reference.

Two other points are important to remember when comparing past to projected usage rates. First, and most importantly, inertially guided weapons are not being acquired to replace other types of PGMs. Rather, they are being acquired to complement existing PGMs by converting unguided munitions into guided ones. This means more PGMs will be available, with some being laser guided and some being inertially guided. Secondly, for the foreseeable future, the size of the country's military air fleet will continue to decrease. Although a higher percentage of today's aircraft are capable of dropping PGMs, fewer total aircraft exist than did during Desert Storm. The result of all these factors is that PGM usage rates should not increase appreciably, if at all, from those of Operation Desert Storm.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

In order to answer the primary research question, it is necessary to answer the secondary research questions. To simplify the discussion, first consider the final secondary research question regarding the availability or cost of inertially guided weapons to perform CAS. Three facts lead to the conclusion. The first is the PGM usage rate of 335 per day from Operation Desert Storm. The second is that the USAF plans to acquire 30,000 WCMD kits for installation on CBU-87 munitions, thus increasing the number of PGMs in the inventory. Finally, fewer aircraft are available today than there were during Desert Storm, meaning realistic PGM usage rates will not increase in future conflicts. From these three facts, it seems reasonable to conclude that there will be inertially guided weapons available to use while performing CAS. The only caveat to this conclusion is that conflict duration has not been considered. Thus, if the country got into a drawn-out conflict, the number of inertially guided weapons could decrease to the point where they would be used exclusively on high priority strategic or interdiction targets.

The next secondary research question deals with the need for crewmen to see and visually identify CAS targets before dropping ordnance on them. The final one concerns how targeting information will be determined and passed on battlefields of the twenty-first century. There are no simple answers to these questions, as the number of variables present when performing CAS preclude simple answers. Again, in order to limit the possible number of variables, this thesis is focusing on the performance of CAS with inertially guided weapons when the target is obscured from the air (visual targeting is not possible). Also, emergency situations where friendly troops are in dire need of CAS (i.e., being overrun) are not being considered. The variables that are still of concern for CAS in normal situations are: Are target coordinates available? Are friendly troops in contact? What is the confidence level in the accuracy of the target coordinates? and Do crewmen in the attack aircraft have any way to gain SA on the battlefield environment that can be used to confirm targeting?

Starting with the availability of target coordinates, the nature of inertially guided weapons makes having coordinates a requirement. Remember that coordinates can come from an outside source as is the case for BOC, or from the attacking aircraft as is the case during relative targeting. Since this thesis is examining only those CAS situations where the target is not visible to the crewmen in the attack aircraft, relative targeting is not possible. This means target coordinates from an outside source like a forward observer must be available in order to perform CAS with inertially guided weapons.

Moving to the variable regarding troops in contact, recall the definition from joint publications stating that the delineation between troops in contact and not in contact is troops within 1,000 meters. This assumes that it is the CAS target that is within 1,000 meters of friendly troops, not just the enemy troops. This distinction is important, as the CAS target will not always be the enemy troops that are closest to friendly troops. Assuming the CAS target is within 1,000 meters of friendly troops, it seems obvious that more restrictions are required because of the higher threat of fratricide. Conversely, when the CAS target is beyond 1,000 meters from friendly troops, the number of restrictions should decrease because of the reduced risk of fratricide. Exactly how far the number of restrictions can be reduced depends on the specific situation and how far from friendly troops the CAS target actually is. The lack of a definitive definition for the farthest distance from friendly troops a target can be and still be considered a CAS target (as opposed to an interdiction target) confuses the matter. Suffice to say that the number of CAS restrictions should decrease when troops are not in contact.

The next variable is to define the accuracy level of the target coordinates. Two things contribute to this. The first is if a person sees the target or if the target was detected using battlefield equipment, the second is how the coordinates were determined. In reality, there could be a continuum that describes coordinate accuracy, ranging from extremely precise to inaccurate. In order to simplify this discussion on the level of accuracy, consider just two levels of accuracy: high and low. In spite of the advances with battlefield equipment like counterbattery radars and moving target indicators, people feel most comfortable if a forward observer or some other soldier can visually identify targets. The reason is that when equipment is used for targeting, no friendly or enemy identification is actually performed. In other words, moving target indicators see any moving vehicle, not just enemy vehicles. Counterbattery radars see incoming shells, not just incoming enemy shells. Although SA should help with determining identification, the examples of fratricide documented in chapter 4 show this is not always the case. As a result, targets that are detected using battlefield equipment will be assigned a low accuracy value.

The accuracy value for targets detected visually by a soldier will depend on how target coordinates were determined. Recall that there are basically two ways to determine coordinates, with a map or with a GPS locator and LR. The problems outlined in chapter 4 regarding the inaccuracy of coordinates obtained using maps dictate that these coordinates should be assigned a low accuracy level. For coordinates obtained using a GPS locator and LR, recall that the GPS locator tells the user how accurate the system is based on the number of satellites it is tracking. A high accuracy level will be assigned if the GPS locator reports an accuracy of thirty meters or less, a low level of accuracy will be assigned if the GPS locator reports an accuracy of greater than thirty meters. Thirty meters was selected as the boundary between high and low accuracy for GPS locators for two reasons. First, the CEP for the new WCMD is one hundred feet, which is very close to thirty meters. Thus, even if the coordinates derived by the GPS locator are thirty meters off, some WCMD submunitions could still hit the target. Secondly, WCMD is an area munition, meaning the WCMD canister opens before it hits the ground, spreading submunitions out over a small area. The size of the area covered by submunitions varies with fuse settings on the canister, but the area is almost always larger than thirty meters. Again this means that a target coordinate error of thirty meters will result in some of the submunitions hitting the target.

The final variable is the presence of other equipment like EPLRS and a horizontal situation display in the attack aircraft that can be used to build SA on the battlefield. While not necessary for the targeting of inertially guided weapons, requiring this tool fulfills the need stated in Joint Publication 3-09.3 to confirm targeting with more than one sensor. The value of the equipment increases with troops in contact situations, as these are most susceptible to fratricide. While still valuable, the equipment is not as critical if troops are not in contact.

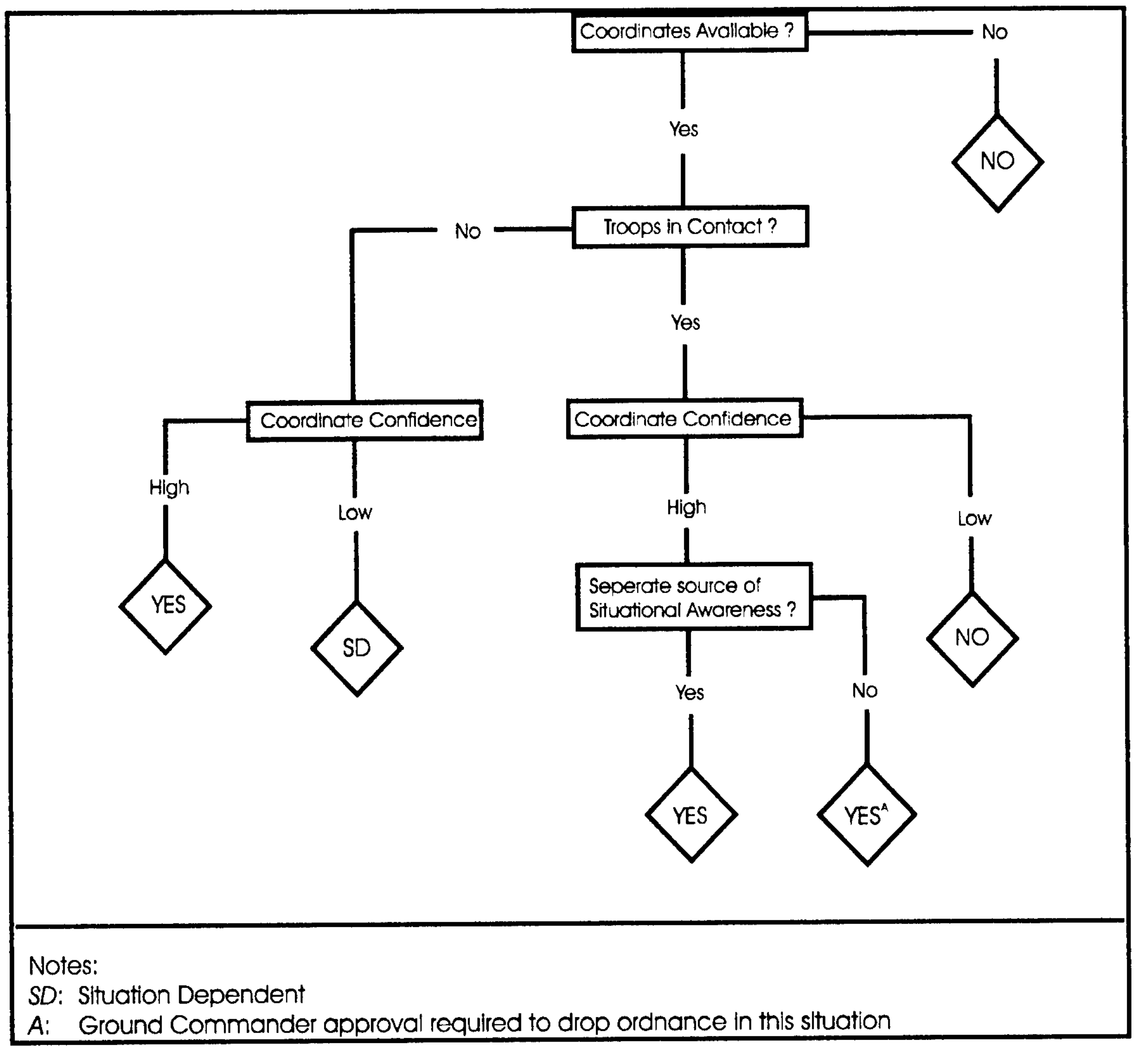

Figure 2. Using Inertially Guided Weapons for CAS Decision Matrix

Figure 2 outlines how these variables can be combined into a decision matrix that answers the primary research question. The diamonds in the matrix are the specific answers for each scenario and tell if inertially guided weapons should be used to perform CAS.

There are two things to point out on this matrix. The first is the term situation dependent. Examining this case, the situation is one where troops are not in contact, coordinate confidence is low, and there is no additional source of situational awareness available to the aircrew. Since troops are not in contact, risk of fratricide is not high, however, since coordinate confidence is low, the bombs could realistically miss the target. Recall from earlier in this chapter that the value for coordinate confidence could be low in several situations. Among these were if a soldier who visually observed the target pulled target coordinates from a map, or if target coordinates were determined by some battlefield system like a counterbattery radar. Looking at the first case, there may be situations where map coordinates are very accurate. For example, consider a soldier overlooking a valley with enemy vehicles moving down a major road. The soldier sees the targets on the road, and identifies the road on a map. Target coordinates in this case could be accurate enough to drop bombs on, especially since the troops are not in contact and the risk of fratricide is not high. Looking at the second case, battlefield systems like counterbattery radars can be very accurate. The reason they were assigned a low accuracy value was primarily one of identification. There may be cases where soldiers on the ground have access to SA building tools that can confirm target identification. Thus, with coordinates provided by the counterbattery that could be accurate along with confirmation of identification by ground troops, it would be reasonable to drop bombs in this case. The bottom line is that the probability of achieving a hit needs to be evaluated based on the specifics of the situation. Other considerations in the situation dependent scenario are the availability of inertially guided weapons (are stocks of these munitions running short, or are stocks high) and the value of the target (is the target a high payoff target). The decision to use inertially guided munitions in a situation dependent scenario needs to be evaluated on a case-by-case basis.

The second thing to point out from figure three is the note stating ground commander approval is required to drop inertially guided munitions. In this instance, troops are in contact and coordinate confidence is high, but the aircrew has no situational awareness on the battlefield other than target coordinates. While target coordinates are all that is required to drop inertially guided weapons, approval is required because the risk of fratricide is high with troops in contact. The decision to drop or not should consider the value of the target, the ability of ground troops to reconfirm target coordinates and identification, and the general situation on the battlefield. Since the ground commander should have the best knowledge of these factors, it should be the ground commander's decision to drop or not drop inertially guided ordnance in these situations.

Recommendations

The first and most important recommendation resulting from this thesis is to modify Joint Publication 3-09.3 which outlines tactics, techniques, and procedures for CAS. The first change should be to allow crewmen who are performing CAS with inertially guided weapons to drop them in accordance with the matrix in figure 2 of this thesis, even if the crewmen do not see the target visually or with other sensors. The second change should be to the nine-line briefing format which is used to pass targeting information to the crew in the attack aircraft. The nine-line brief should not only give target coordinates, but should also give value for the confidence in these coordinates. The coordinate confidence value could be either high or low as was used in this thesis, or some number that more accurately defines the plus/minus value for coordinate accuracy.

The second recommendation is to continue the development and acquisition of SA building tools like EPLRS for attack aircraft. These tools increase aircrew SA in the aircraft that have them, giving these crewmen more confidence that they are hitting the correct targets when employing inertially guided weapons.

The potential to perform CAS when crewmen in attack aircraft cannot see targets on the ground is a reality, but requires a significant paradigm shift. Based on the developments in battlefield technology, this paradigm shift is justified, especially when considering the similarities between CAS with inertially guided weapons and field artillery. Implementation of the recommendations outlined in this thesis will ensure the military maximizes the effectiveness of inertially guided weapons by permitting their use in CAS missions. With these weapons, our enemies can no longer take comfort in knowing that US airpower is limited when the battlefield is obscured by bad weather or anything else.

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