

MANNED, FIXED-WING AVIATION: SHOULD IT CONTINUE
TO CONDUCT THE PREPLANNED INTERDICTION MISSION?

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General Studies

by

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The opinions and conclusions expressed herein are those of the student author and do not necessarily represent the views of the U.S. Army Command and General Staff College or any other governmental agency. (References to this study should include the foregoing statement.)

ABSTRACT

MANNED, FIXED-WING AVIATION: SHOULD IT CONTINUE TO CONDUCT THE PREPLANNED INTERDICTION MISSION? by Maj Timothy J. MacKenzie, 82 pages.

Manned flight has been integral to the fight on the battlefield since World War I. World War II was the first large-scale showcase for aviation in the interdiction role while the Vietnam War heralded the advent of precision-guided munitions. During Operation DESERT STORM, the interdiction mission, once almost exclusively conducted by manned aviation, had to share the mission with new weapon systems. This trend in technological evolution brings about the question, As military technological advancements evolve toward *Joint Vision 2020*, should manned, fixed-wing aviation continue to conduct the preplanned interdiction mission? The design for this project revolves around a comparative assessment model of weapon systems that can accomplish the preplanned interdiction mission. The performance results of the selected weapon systems across interdiction relevant categories provide the framework for this analysis. The determination from this study is that manned, fixed-wing aviation should expect to be phased out of the preplanned interdiction mission over the next 20 years. This phase out process began in 1991 during Operation DESERT STORM with the introduction of cruise missiles. The process will begin to reach completion with the maturity of UCAVs in about 2010. UCAVs and missiles will become the principal elements of the U.S. military's preplanned interdiction effort.

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ABBREVIATIONS

AAA	Antiaircraft Artillery
AP	Armor-Piercing
AP-LASM	Armor Piercing LASM
APAM	Anti-Personnel/Anti-Material
ATACMS	Army Tactical Missile System
AVMRL	Armored Vehicle-Multiple Rocket Launcher
BAT	Brilliant Anti-Armor Technology
BDA	Bomb Damage Assessment
CALCM	Conventional Air Launched Cruise Missile
CAS	Close Air Support or Control Actuation System
CEB	Combined Effects Bomblets
CEP	Circular Error Probability
DAMASK	Direct Attack Munition Affordable Seeker
DARPA	Defense Advanced Research Projects Agency
D3A	Decide, Detect, Deliver, and Assess
DSMAC	Digital Scene-Mapping Area Correlator
ER-LASM	Extended Range LASM
ERGM	Extended Range Guided Munitions
FAS	Federation of American Scientists
FLIR	Forward-Looking Infrared
FWS	Fighter Weapons School
GA INS	GPS-aided inertial navigation system

GCU	Guidance Control Unit
GMLS	Guided Missile Launching System
GPS	Global Positioning Satellite
IADS	Integrated Air Defense System
IIR	Imaging Infrared
IMGS	Improved Missile Guidance Set
INS	Inertial Navigation System
IOC	Initial Operational Capability
JDAM	Joint Direct Attack Munition
JMEM	Joint Munitions Effectiveness Manual
JSOW	Joint Stand-Off Weapon
KTAS	Knots True Airspeed
LASM	Land Attack Standard Missile
LGB	Laser-Guided Bomb
LTD	Laser Target Designator
MAWTS-1	Marine Aviation Weapons and Tactics Squadron One
MLRS	Multiple-Launch Rocket System
MOE	Measure of Effectiveness
MSL	Mean Sea Level
NAVAIR	Naval Air Systems Command
NAVSEA	Naval Sea Systems Command
NSAWC	Naval Strike and Air Warfare Center
NSFS	Naval Surface Fire Support

NTACMS	Naval Tactical Missile System
ORD	Operational Requirements Document
Pd	Probability of Destruction
PEO(W)	Program Executive Office for Strike Weapons and Unmanned Aviation
P3I	Pre-Planned Product Improvement
RCS	Radar Cross Section
SAASM	Selective Availability Anti-Spoofing Module
SAIC	Science Applications International Corporation
SAM	Surface-to-Air Missile
SLAM-ER	Standoff Land Attack Missile–Expanded Response
TACTOM	Tactical Tomahawk
TERCOM	Terrain-Contour Matching
TLAM	Tomahawk Land Attack Missile
TLE	Target Location Error
TOC	Tactical Operation Center
TOT	Time On Target
UAV	Unmanned Aerial Vehicle
UCAV	Unmanned Combat Air Vehicle (Uninhabited Combat Aerial Vehicle)
USNI	U.S. Naval Institute
VLS	Vertical Launching System
WLR	Weapons-Locating Radar

CHAPTER 1

INTRODUCTION

Manned flight has been integral to the fight on the battlefield since World War I. The evolution of aviation technology and aviator ingenuity has resulted in monumental changes in comparison to the humble beginnings as battlefield reconnaissance assets. World War II was the first large-scale showcase for aviation in the interdiction role. In both the European and Pacific theaters, aviation was able to strike deep into enemy territory to attack key nodes within their respective infrastructures. The successful Allied bombing efforts on Germany's transport system and industrial centers, artificial rubber and petroleum products, resulted almost immediately in the degradation of their fighting force.¹ The execution of these bombing missions relied upon numerous aircraft delivering large quantities of "general purpose" ordnance. These bombs were ballistically released and relied on the use of basic bombsights, manual environmental corrections, bomb construction consistency, and proper aircraft placement to achieve success. These actions were not without Axis resistance. The German and Japanese counterair capability coupled with antiaircraft artillery (AAA) created an environment of significant risk for bomber aircraft and the crews that manned them.

During the Korean War, aviation operated much the same way as it did during World War II. Aviation functioned as the primary means of interdiction by concentrating predominantly on key nodes and the lines of communication. Aviation attempted to constrict the lifeblood of ground forces by striking the long supply lines on the Korean peninsula.

The Vietnam War heralded the advent of precision-guided munitions. The development of the laser-guided bomb (LGB) aided interdiction success by reducing the number of sorties and amount of ordnance required to destroy targets. From 1965 to 1972, the U.S. dedicated hundreds of sorties and thousands of tons of ballistic ordnance to destroy the Paul Doumer Bridge on the outskirts of Hanoi without success. With the use of the new laser-guided bomb, a single strike resulted in the dropping of this bridge with no loss of aircraft.² Fewer aircraft sorties generally equated to the less likelihood of losing aircraft due to enemy fire. Although AAA continued to be the most significant contributor to downing aircraft during Vietnam, the new surface-to-air missile (SAM) brought additional lethality to aircraft operations. The Soviet built SA-2 Guideline and man portable SA-7 Grail challenged aviation's attempt to strike targets. However, aside from the Iowa class battleships with their 2,700-pound shells and associated 23-nautical-mile range, aviation continued to be the primary means of interdiction in the Vietnam battle space.

Nineteen years after removing U.S. ground forces from South Vietnam, military aviation found itself over the battlefield of Kuwait and Iraq. The evolution of technology brought new systems to the battle space. The interdiction mission, once almost exclusively conducted by manned aviation, now had to share the battle space with new weapon systems. Weapons, such as the Army Tactical Missile System (ATACMS), the Tomahawk Land Attack Missile (TLAM), and the Conventional Air-Launched Cruise Missile (CALCM), struck interdiction targets at ranges in excess of 100 kilometers (55 nautical miles).

Following Operation DESERT STORM, technology has continued to evolve with aviation and ground-based interdiction systems. New aviation standoff weapons, such as the Joint Stand-Off Weapon (JSOW) and the Standoff Land Attack Missile–Expanded Response (SLAM-ER), have been developed and are currently fielded. Surface Navy interdiction capabilities, having initially diminished with the retiring of the Iowa class battleships, continue to expand with the development of Extended Range Guided Munitions (ERGM) rounds, TLAM improvements and Land Attack Standard Missile (LASM) development. The U.S. Army has continued to improve the Multiple-Launch Rocket System (MLRS), its associated M77 rockets, and the ATACMS. Additionally, the evolution of the unmanned aerial vehicle (UAV) continues with strong multiservice support. The incorporation of forward-looking infrared systems (FLIRs) and laser target designators (LTDs) on these platforms has allowed reconnaissance and offensive operations without putting man “in harms way.” The U.S. Navy and the U.S. Air Force have demonstrated terminal guidance of laser-guided bombs by these remote systems. In addition, the incorporation of ordnance attached to an unmanned combat air vehicle (UCAV) is already in development. Maturing this offensive capability provides additional possibilities for the conduct of the interdiction mission.

The primary research question is, As military technological advancements evolve toward *Joint Vision 2020*, should manned, fixed-wing aviation continue to conduct the preplanned interdiction mission? Several secondary questions need to be answered in order to address the primary research question. The first question that must be undertaken is, What is preplanned interdiction? This is required to clearly define the scope of this research. The second question is, What are the manned, fixed-wing aviation

platforms that can conduct the preplanned interdiction mission? By identifying the specific aircraft that are the focus of this study, the “who” associated with the phrase “manned, fixed-wing aviation” will become evident. The third and fourth questions, respectively, are, What are the alternative interdiction means to manned, fixed-wing aviation? and What are the means of comparing the different interdiction systems? The information acquired to answer these questions will establish the basis for the creation of a comparative assessment model. Finally, the fifth question is, What does *Joint Vision 2020* envision concerning the interdiction mission? Answering this question will show relevance of this study and ensure its focus parallels *Joint Vision 2020*’s transformation of America’s Armed Forces.³

The term “preplanned interdiction” identifies the scope of this study and must be defined from the onset. The purpose is to define the mission and the type of targets associated with the mission. Joint Publication 1-02 defines interdiction as “an action to divert, disrupt, delay, or destroy the enemy’s surface military potential before it can be used effectively against friendly forces” (2001, 212).⁴ The “enemy’s surface military potential” includes those targets that are not functionally military by nature but rather affect the possible performance of the military. This allows the target set to be expanded beyond that of just “fielded forces.”

Tactical, operational, and strategic targets are within the scope of this study. These target categories can be generally correlated with Warden’s Five Strategic Rings (fig. 1). In 1988, John Warden created a model that relates the centers of gravity of a strategic entity. Analyzing the enemy as a system, Warden contends that one can break down all strategic entities into five component parts. The most crucial element of the

system--the inner most ring--is leadership. Extending outward from the center, in descending importance to the overall functioning of the system, are organic essentials, infrastructure, population, and fielded forces.⁵ This strategic ring model implies that the military and its potential are affected when other nonmilitary centers of gravity are struck. Thus, striking at operational and strategic targets affects the military potential of the fielded forces. This thesis will use the term interdiction to include target sets at the tactical, operational, and strategic levels.

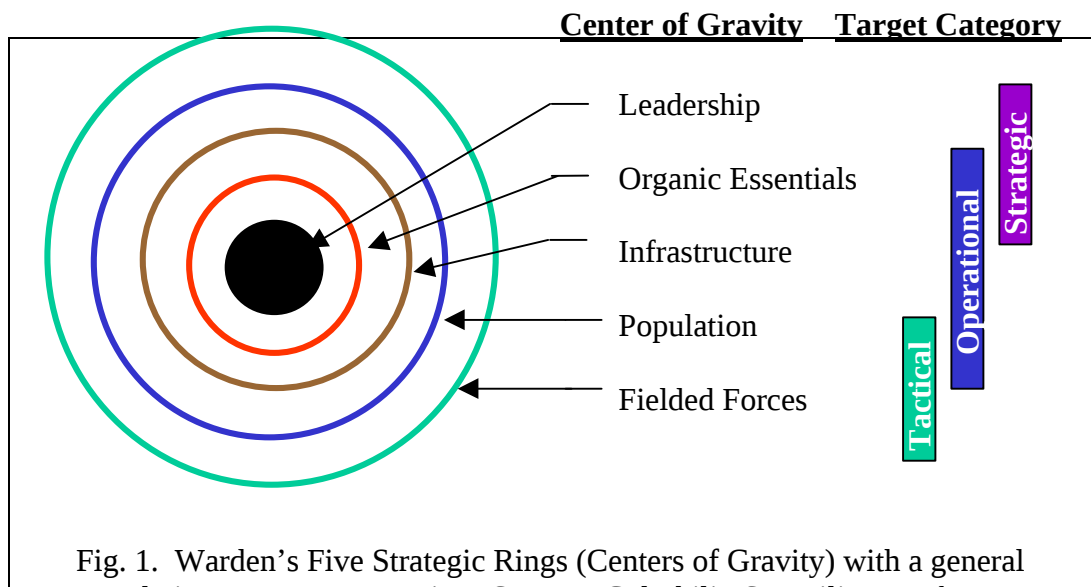


Fig. 1. Warden's Five Strategic Rings (Centers of Gravity) with a general correlation to target categories. Source: Col Philip S. Meilinger, *The Paths of Heaven*, 373.

Preplanned interdiction is the mode of interdiction operations where the specific targets are known well in advance. Detailed intelligence information is normally available to support strike planning. For this study, preplanned interdiction targets will be those at fixed sites with known coordinates. This is not to say that mobile targets

cannot be preplanned interdiction targets. A nonmoving mobile target that remains at a fixed location for a period, the time required to decide, plan, and execute a mission, will fulfill the requirement for the scope of this study. Moving targets will not be used because their location information is normally given as an area as opposed to a fixed set of coordinates. Command, control, and communications issues significantly increase in the effort to find and attack targets that are not at known (fixed) locations. For aviation, this type of mission is generally known as armed reconnaissance or flexible air interdiction. Due to the numerous variables associated with this type of mission and, similarly, those associated with the close air support (CAS) mission, these types of strikes will not be addressed in this research. This will assist in keeping the variables manageable. Figure 2 graphically displays the aviation function comparison across the services and depicts the relative location of the preplanned interdiction mission.

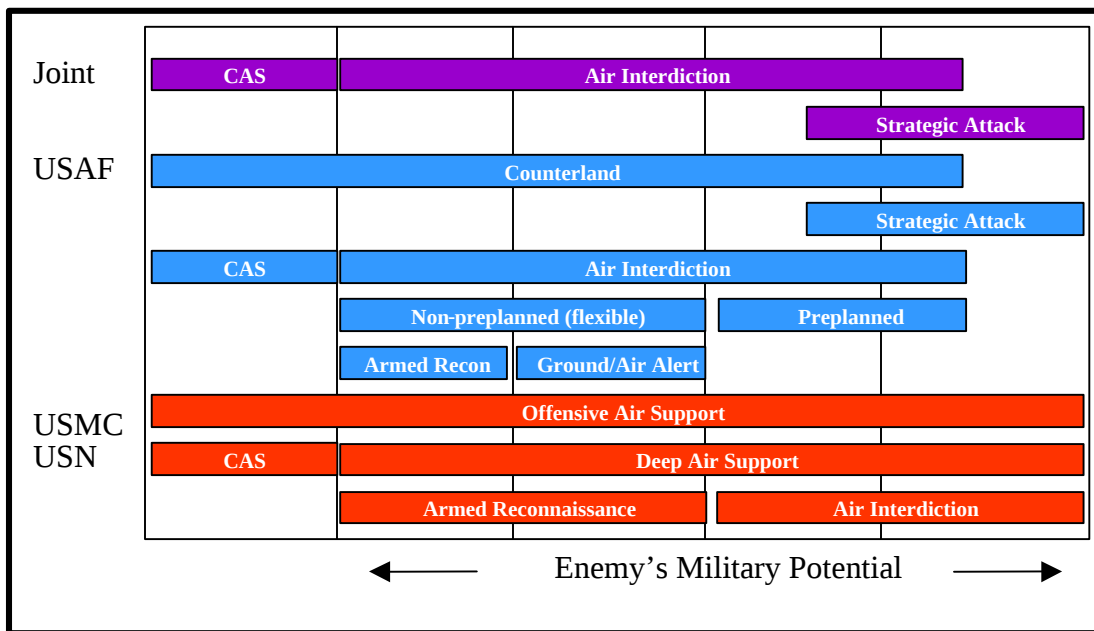


Fig. 2. Doctrinal Aviation Function Comparison

Two assumptions are made for this project. The first is that the weapon systems in development and currently fielded will operate as they are intended to operate. This includes the assumption that upgraded and new equipment will operate to the predicted manufacturer's specifications. These standards are established by the operational requirements documents (ORDs). The second assumption is that the programs and budget for each of the systems will continue as scheduled.

The desire to keep the scope of this research project strictly defined has resulted in several limitations and delimitations. Selection of weapons systems for comparison will involve using only the most capable platform and weapon combination. Uniting a smart platform with a smart munition will be done whenever possible. As an example, the M270 Armored Vehicle-Multiple Rocket Launcher (AVMRL) will be outfitted with the precision-guided ATACMS instead of the ballistic M77 rocket.

The time frame for the research and analysis of this study will be from Operation DESERT STORM in 1991 through the period associated with *Joint Vision 2020*. Preceding this time window, U.S. interdiction actions were almost exclusively executed by aviation. The evolution of technology after 2020 and its associated "what ifs" are beyond the scope of this project. As an aviation example, Will all strike and fighter aircraft no longer be manned but rather coupled by data link to a manned, virtual reality ground station? This forward-looking type of research, although interesting, has little applicability to the improvement of U.S. warfighting capability in the next twenty years. This study's time frame will limit its focus to full spectrum dominance as associated with *Joint Vision 2020*, specifically the operational concept of precision engagement.

Joint Vision 2020 identifies that if the U.S. “Armed Forces are to be faster, more lethal, and more precise in 2020 than they are today, we must continue to invest in and develop new military capabilities.”⁶ The overarching focus of this vision is full spectrum dominance. This is the ability to be persuasive in peace, decisive in war, and preeminent in any form of conflict. The four applications used to achieve full spectrum dominance are dominant maneuver, precision engagement, focused logistics, and full dimensional protection. The relevance of this study is to precision engagement. Precision engagement is defined as “The ability of joint forces to locate, surveil, discern, and track objectives or targets; select, organize, and use the correct systems; generate desired effects; assess results; and reengage with decisive speed and overwhelming operational tempo as required, throughout the full range of military operations.”⁷ This study will focus on the issues associated with selecting and using the correct weapon systems to generate the desired interdiction effect. The emphasis will be on manned, fixed-wing aviation-based systems. Operating in the joint environment of today and that envisioned by *Joint Vision 2020*, the commander will have a very broad range of capabilities to execute the interdiction mission.

The intent of this thesis is to determine if aviation is the best instrument for the preplanned interdiction mission. Narrowing the aviation audience, only fixed-wing aircraft, not rotary-wing, will be considered. This research project will not attempt to identify alternative aviation missions and associated training plans if it is determined that aviation is not best suited for this mission. Additional research and analysis would be required to address those issues.

A portion of the research will include the assessment of conventional munitions effects from the various interdiction systems. The effects will focus on the physical damage only. The second order effects of strikes and demonstrations, such as the psychological effect on the civilian population and enemy forces or the reluctance to move forces during daylight hours, will not be addressed.

The definition of several key terms is required. Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms*, is the reference standard used for this thesis. Service specific definitions will only be used when a joint term does not exist.

Air Interdiction. Air operations conducted to destroy, neutralize or delay the enemy's military potential before it can be brought to bear effectively against friendly forces at such distance from friendly forces that detailed integration of each air mission with the fire and movement of friendly forces is not required.

Battle Damage Assessment. The timely and accurate estimate of damage resulting from the application of military force, either lethal or nonlethal, against a predetermined objective. Battle damage assessment can be applied to the employment of all types of weapon systems (air, ground, naval, and special forces weapons systems) throughout the range of military operations. Battle damage assessment is primarily an intelligence responsibility with required inputs and coordination from the operators. Battle damage assessment is composed of physical damage assessment, functional damage assessment, and target system assessment. Also called BDA.

Centers of Gravity. Those characteristics, capabilities, or localities from which a military force derives its freedom of action, physical strength, or will to fight.

Command. The authority that a commander in the Military Service lawfully exercises over subordinates by virtue of rank or assignment. Command includes the authority and responsibility for effectively using available resources and for planning the employment of, organizing, directing, coordinating, and controlling military forces for the accomplishment of assigned missions. It also includes responsibility for health welfare, morale, and discipline of assigned personnel.

Fires. The effects of lethal or nonlethal weapons.

Host Platform. The vehicle that provides a weapon's means of delivery to its launch point. Host platform is a subset of the weapon system.

Interdiction. An action to divert, disrupt, delay, or destroy the enemy's surface military potential before it can be used effectively against friendly forces.

Joint Target List. A consolidated list of selected targets considered to have military significance in the joint operations area.

Strike. An attack which is intended to inflict damage on, seize, or destroy an objective.

Targeting. (1) The process of selecting targets and matching the appropriate response to them, taking account of operational requirements and capabilities; and (2) the analysis of enemy situations relative to the commander's mission, objectives, and capabilities at the commander's disposal, to identify and nominate specific vulnerabilities that, if exploited, will accomplish the commander's purpose through delaying, disrupting, disabling, or destroying enemy forces or resources critical to the enemy.

Weapon. The individual device used to directly strike an opponent. Weapon is a subset of the weapon system.

Weapon System. A combination of one or more weapons with all related equipment, materials, services, personnel, and means of delivery and deployment (if applicable) required for self-sufficiency. Authors use: The term “weapon system” includes both the host platform and the weapon.

The commander determines which enemy targets must be attacked to accomplish the mission. His decision-making process is framed by using the decide, detect, deliver, and assess (D3A) targeting methodology. This facilitates attacking the right target with the right asset at the right time. As part of this methodology, the targeting process provides an effective method for commanders to match friendly force capabilities against enemy targets.⁸

The commander’s execution of the decide and deliver functions are applicable to this study. The decide function provides the overall focus and sets priorities for attack planning while the deliver function executes the target attack guidance. The attack guidance matrix (AGM) is a product of the planning process. It is through this tool that the commander addresses which targets will be attacked, which weapon systems may be employed, the execution time line, and the desired effects. Additionally, the commander considers such items as weapon accuracy, weapon system availability, time constraints, and limitations on the amount or type of weapons.⁹

Once targets have been located and identified, the deliver function begins with the attack of targets. Tactical and technical decisions are required of the commander. The tactical decisions include the time of the attack, the desired effect, the specific weapon system to be used, and the degree of acceptable risk associated with the use of the weapon system. Based on the tactical decisions, the technical decisions concerning the

response time of the weapon system and the number and type of weapons must be determined. Various reasons may cause a weapon system not to be able to meet the commander's requirements, including weapon system nonavailability, weapon nonavailability, and a target located beyond the weapon system's range capability.¹⁰

The significance of this study is to allow the commander to gain insight concerning the application of airpower in the preplanned interdiction role. The commander's responsibility is to allocate and employ the most feasible, acceptable, and suitable asset to accomplish the mission. The military interdiction assets available today are of limited supply, have varying levels of risk associated with mission execution, and have a variety of resultant effects. The question posed to the commander is whether manned, fixed-wing aviation is the weapon of choice for the preplanned interdiction mission. The result of this thesis will assist the commander in making that decision.

¹Lieutenant Colonel Eddy Bauer, *Illustrated World War II Encyclopedia*, vol. 21, ed. Brigadier Peter Young (New York: H. S. Stuttman, Inc., 1978), 2873.

²U.S. Joint Chiefs of Staff, Joint Publication 3-03, *Doctrine for Joint Interdiction Operations* (Washington, DC: Joint Chiefs of Staff, 1997), IV-4. During World War II, nine thousand bombs were necessary to hit a given point; during Vietnam, prior to LGBs, three hundred bombs were necessary. During Desert Storm, one or two bombs were sufficient (Friedman 1996, 269).

³U.S. Joint Chiefs of Staff, *Joint Vision 2020* (Washington, DC: U.S. Government Printing Office, 2000), 1. The office of primary responsibility is the Director for Strategic Plans and Policy, J5; Strategy Division.

⁴U.S. Joint Chiefs of Staff, Joint Publication 1-02, *Department of Defense Dictionary of Military and Associated Terms* (Washington, DC: Joint Chiefs of Staff, 2001), 212.

⁵The School of Advanced Airpower Studies, *The Paths of Heaven, The Evolution of Airpower Theory*, ed. Colonel Philip S. Meilinger (Maxwell AFB, AL: Air University Press, 1997), 372.

⁶U.S. Joint Chiefs of Staff, *Joint Vision 2020*, 1.

⁷*Ibid.*, 22. OPERATION Desert Storm quantitatively demonstrated the value in using precision engagement to achieve the desired effects. Of the 88,500 tons of bombs dropped in the Gulf War, only some 6,250 were precision guided – around 7 percent – yet it was those ‘smart’ weapons that accounted for about half the Iraqi targets destroyed (Shukman 1996, 148).

⁸Headquarters Department of the Army, United States Marine Corps, FM 6-20-10/MCRP 3-1.6.14, *Tactics, Techniques, and Procedures for the Targeting Process*, (Washington, DC: HQ TRADOC, 1996), 2-1.

⁹*Ibid.*, 2-8.

¹⁰*Ibid.*, 2-12.

CHAPTER 2

LITERATURE REVIEW

Reference material for this project can be generally divided into two categories. The first group provides the knowledge base to understand the scope of the interdiction mission. These resources assist in the establishment of a solid foundation for this study. The second group is composed of those materials that identify the capabilities of various current and near future interdiction systems. This information will serve as the backbone for the comparative assessment. Across these two groups, sufficient literature is available to investigate and answer the research question.

Doctrinal publications serve as the groundwork for this study. Issues, such as thoroughly defining the interdiction mission, are key to clearly analyzing this subject. Individual services define some terms with parochial influences in their service doctrinal manuals. Joint doctrine is used whenever possible in this thesis to ensure multiservice applicability. Joint Publication 3-03, *Doctrine for Joint Interdiction Operations*, serves as a basis for this work. Additional sources include Joint Publication 3-0, *Doctrine for Joint Operations*, and Joint Publication 3-09, *Doctrine for Joint Fire Support*. Joint Publication 3-54, *Doctrine for Strategic Attack*, is being drafted and is not available. Its content is relevant due to the complementary relationship between strategic attack and interdiction operations. Air Force Doctrine Document 2-1.2, *Strategic Attack*, is used to fill the current void.

Information concerning the evolution of technology, including applications to the interdiction mission, is available in several publications. David Shukman's *Tomorrow's War: The Threat of High-Technology Weapons* provides valuable insight into how a

revolution in hardware will affect the U.S. military's future. George and Meredith Friedman's *The Future of War* focuses on the innovations in weapons technology and how they will create new challenges, force the reorganization of forces, and affect America's defense strategy. Both of these publications, along with *Joint Vision 2020*, aid in understanding the interdiction mission through 2020.

Extensive material exists that identifies the U.S. manned, fixed-wing aviation systems and comparable interdiction systems. Publications, such as *Janes, All the World's Aircraft*, the Naval Air Warfare Center Weapons Division's *Naval Weapons Handbook*, and Air Armament Center's *2000 Weapons File*, provide sufficient baseline information. Numerous articles have been written accounting the performance of interdiction systems on the battlefield. Articles from Operation DESERT STORM (Iraq, Kuwait), Operations DENY FLIGHT and DELIBERATE FORCE (Bosnia Herzegovina), Operation DESERT FOX (Iraq) and Operation ALLIED FORCE (Kosovo, Serbia) provide the historical material. The periodicals *Aviation Week and Space Technology*, *Field Artillery*, and *Surface Warfare* expound upon the capabilities of current and future interdiction systems.

Military sources provide an additional avenue for attaining capabilities and performance information. The military services maintain several Internet websites that have relevance to this topic. The U.S. Navy's Program Executive Office for Strike Weapons (PEO(W)) maintains the U.S. Navy Fact File database that identifies performance capabilities of naval surface and air-delivered weapons. Periscope, a U.S. Naval Institute military database, provides similar information. The U.S. Air Force maintains USAF Fact Sheet, a comparable database of air-delivered weapon's

performance. Additionally, and although not directly associated with the military, the Federation of American Scientists provides an in-depth on-line database that covers a large majority of U.S. military systems.

The tactical schoolhouses of the services are on the leading edge of weapon systems tactical employment. The Naval Strike and Air Warfare Center (NSAWC), Marine Aviation Weapons and Tactics Squadron One (MAWTS-1) and the U.S. Air Force's Fighter Weapons School provide additional insight into system employment issues and function to validate information provided by periodicals and Internet sources. The U.S. Air Force Battlelabs, U.S. Marine Corps Warfighting Lab, and U.S. Navy Fleet Experiments coupled with the program offices of the various interdiction systems provide the near future performance requirements.

Generally, the articles available provide information on individual systems and their performance capabilities. Far fewer articles have done any comparable assessment between the different systems. *Cruise Missiles Technology, Strategy, Politics* (1981) by The Brookings Institute was one of the first published documents to compare the ratio of tactical aircraft costs to nonnuclear cruise missile costs at various attrition rates. The U.S. Government Accounting Office created a document entitled *Cruise Missiles: Proven Capability Should Affect Aircraft and Force Structure Requirements* (1995) that compares manned, fixed-wing aviation and the Tomahawk cruise missile. These documents, although somewhat dated, provide assistance in the construction of a comparative model for this study.

Literature research has resulted in not finding a comparative study that focuses on more than two interdiction weapon systems. The value of this thesis will be based in its

ability to quantitatively compare several systems. This project is principally focused on the outcome of the manned, fixed-wing aviation-based weapon systems; however, the resultant database will be beneficial towards additional studies on the other weapon systems.

CHAPTER 3

RESEARCH DESIGN

The goal of this thesis is to answer the question, As military technological advancements evolve toward *Joint Vision 2020*, should manned, fixed-wing aviation continue to conduct the preplanned interdiction mission? The design for this project revolves around a comparative assessment model of systems that can accomplish the preplanned interdiction mission. The course to answering the research question is a five-phased process.

1. Establish the foundation of knowledge and terms.
2. Develop a comparative assessment model.
3. Attain test and operational data of interdiction systems.
4. Analyze and compare the data.
5. Assess the feasibility, acceptability, and suitability of manned, fixed-wing aviation in the preplanned interdiction mission.

Phase 1 concentrates on the first and last of the five secondary questions, What is the preplanned interdiction mission? and What does *Joint Vision 2020* envision concerning the interdiction mission? Chapter one answers these questions and lays the groundwork for transition to Phase 2, the development of the comparative model. During this phase, the subsequent secondary questions, What are the manned, fixed-wing aviation weapons systems that conduct the preplanned interdiction mission? What are the alternative interdiction systems to manned, fixed-wing aviation? and What are the means of comparing the different interdiction systems? are answered. The answers to the first two questions result in the “weapon systems” portion of the model design. The answer to

the third question results in “categories” which provides the means for comparison between the different interdiction systems. The data acquisition of Phase 3 focuses on actual weapons employment from Operation DESERT STORM to the present, manufacturer’s data, and military specifications for future systems and upgrades. Again, the horizon is limited to *Joint Vision 2020*. Phase 4 is the analysis of the collected data. Each system will be evaluated by category in response to its performance and ranked accordingly. The final phase determines the answer to the primary research question. Both quantitative and qualitative reasoning is exercised for Phases 4 and 5.

Phase 2 requires the identification of manned, fixed-wing assets that conduct the preplanned interdiction mission. The versatility of aircraft provides the commander an asset that can be employed in diverse environments and can conduct multiple combat tasks throughout a theater of operations. The manned, fixed-wing aircraft contributes significantly to the overall joint interdiction effort by its flexibility, range, speed, lethality, precision, and ability to mass at a desired time and place.¹ In the United States inventory, the U.S. Navy, U.S. Marine Corps, and the U.S. Air Force have manned, fixed-wing aviation platforms that are capable of inflicting physical damage to surface targets. Table 1 identifies by service the aviation platforms addressed by this study. Aviation platforms that attack interdiction targets by electromagnetic means only will not be included.

Table 1. Preplanned Interdiction Capable Aircraft	
Service	Manned, Fixed-Wing Aircraft
USN	F-14, F/A-18, JSF, EA-6B, P-3, S-3
USMC	AV-8B, F/A-18, JSF, EA-6B
USAF	A-10, F-16, F-15E, JSF, F-117, F-22, B-1, B-2, B-52, EA-6B

Military assets capable of interdiction operations include land- and sea-based air, naval, land, and special operations forces (table 2). In the effort to be as objective as possible and compare systems to systems, only the “systems” within these forces are used. Those operational forces that interdict by way of manpower (air assault, amphibious operations, conventional airborne, etc.) will not be included for comparison. In addition, as identified in chapter one, only the most capable platform and weapon combination of an interdiction force is used. The interdiction forces for this study include land- and sea-based air forces employing precision-guided munitions, naval forces employing missiles, and land forces employing missiles.² The specific preplanned interdiction systems for this study are:

1. Manned, fixed-wing aircraft with Joint Direct Attack Munition (JDAM)
2. Manned, fixed-wing aircraft with Joint Standoff Weapon (JSOW)
3. Rocket launcher with Army Tactical Missile System (ATACMS)
4. Ship with Land Attack Standard Missile (LASM)
5. Ship with Tomahawk Land Attack Missile (TLAM)

6. Unmanned Combat Air Vehicle (UCAV) with JDAM

Table 2. Interdiction-Capable Forces
Land- and sea-based air forces employ such weapons as missiles, bombs, precision-guided munitions, cluster munitions, land and/or sea mines, electronic warfare systems, and sensors from airborne platforms
Naval forces employ missiles, munitions, torpedoes, and mines
Land forces employ such assets as attack helicopters, missiles, artillery, and those forces capable of conducting conventional airborne, air assault, and amphibious operations
Special operations forces may support conventional interdiction operations by providing terminal guidance for precision-guided munitions, or may act independently when the use of conventional forces is inappropriate or unfeasible

Source: U.S. Joint Chiefs of Staff. *Doctrine for Joint Interdiction Operations*, V1.

The selection of common categories provides standards to compare each of the weapon systems. These categories are related to the interdiction mission in that they are employment considerations. The commander must evaluate these different factors when pairing the appropriate weapon system with a specific target.

1. Destructive capability of the weapon (Pd)
2. Weapon accuracy (CEP)
3. Responsiveness of weapon system
4. Weapon system effective reach
5. Survivability of weapon system
6. Cost of weapon
7. Ability to redirect or self-detonate the weapon
8. Risk to man

The performance results of the selected weapon systems across interdiction relevant categories provide the framework for this analysis. Each of the categories will include a measure of effectiveness (MOE). The MOE will allow each weapon system to be compared to a desired end state.³ Subsequently, the weapon systems will be relatively ranked in each category. This analysis process will be conducted in chapter 4. Table 3 is the comparative assessment model. The following paragraphs provide background information on each of the weapon systems and categories.

Table 3. Comparative Assessment Model									
Weapon Systems	Comparative Categories								
		Pd	CEP	Response Time	Reach	Survival	Cost	Redirect Destruct	Risk to Man
	Aircraft w/JDAM								
	Aircraft w/JSOW								
	AVMRL w/ATACMS								
	Ship w/LASM								
	Ship w/TLAM								
	UCAV w/JDAM								

Manned, Fixed-Wing Aircraft with Joint Direct Attack Munition

The GBU-31/32 Joint Direct Attack Munition (JDAM) is selected for this study because: (1) it is planned to be a mainstay of the U.S. arsenal through at least 2010, (2) its performance is near the top end of U.S. munitions, (3) its employment requires aircraft to get relatively close to the intended target (generally less than 10 nautical miles), and (4)

the majority of attack aircraft in the U.S. inventory are capable of its employment. Those aircraft that are capable, or are planned to become capable, include the AV-8B, F-15E, F/A-18C/D/E/F, F-14A/B/D, F-16C/D, F-22, F-117, B-1B, B-2, B-52H, JSF, P-3, and S-3.⁴ The JDAM is the result of attaching an inertial navigation system (INS), with Global Positioning Satellite (GPS) assistance, to an existing freefall bomb. Each tailcone kit has this Guidance Control Unit (GCU) and a Control Actuation System (CAS) with maneuvering tailfins for inflight corrections. The integration of the kit with a Mk-84 (2,000-pound) general-purpose bomb or BLU-109 (2,000-pound) penetrator is known as a GBU-31 (fig. 3). The GBU-32 version results from attaching a kit to a Mk-83 (1,000-pound) general-purpose bomb. Production line deliveries of the kits to the active duty forces began June 1998 with a total acquisition estimate of 87,500 by the year 2008.⁵



Fig. 3. GBU-31 on a F/A-18.
Photograph courtesy of FAS.

Manned, Fixed-Wing Aircraft with Joint Standoff Weapon

The AGM-154 Joint Standoff Weapon (JSOW) was selected for this study based on the same reasons as those given for the JDAM, except for the employment range. The JSOW allows for weapon's employment at significant standoff ranges (greater than 40 nautical miles). This standoff capability allows aircraft to employ the weapon from low threat (relatively) sanctuaries. Many of the same aircraft that employ JDAM can also employ JSOW. The aircraft capable, or expected to become capable, of employing JSOW are the AV-8B, F-15E, F/A-8C/D/E/F, F-16C/D, B-1B, B-2, B-52H, P-3, and S-3.⁶ The weapon has three variants, all which weigh approximately 1,000 pounds and navigate by way of a tightly coupled INS and GPS. The AGM-154A or JSOW baseline carries 145 BLU-97B/B Combined Effects Bomblets (CEB) and is depicted in figure 4.⁷ The AGM-154B variant dispenses 24 infrared-seeking antitank warheads. The third variant, the AGM-154C, is fitted with a BLU-111 unitary warhead that uses an Imaging Infrared (IIR) seeker. Along with the AGM-154C's INS and GPS, it plans to have an AN/AWW-13 Weapon Data Terminal man-in-the-loop data link.⁸ Initial operational capability (IOC) for JSOW baseline was 1999. The submunition and unitary variants of JSOW expect an IOC of 2002. Total combined acquisition estimate is 22,800 weapons.



Fig. 4. AGM-154A on a F/A-18.
Photograph courtesy of FAS.

Rocket Launcher with Army Tactical Missile System

The Army Tactical Missile System (ATACMS) is the primary long-range, land-based missile system that conducts the interdiction mission (fig. 5). Its host platform is the modified M270 Armored Vehicle-Multiple Rocket System Launcher (AVMRL). Block IA, II, IIA, and Unitary ATACMS are semiballistic missiles that incorporate a ring-laser gyro for inertial guidance and a GPS receiver for inflight updates. The missile can carry three different types of warheads. The Block IA missile dispenses 275 M42

anti-personnel/anti-material (APAM) submunitions. The Block II can deliver thirteen Brilliant Antiarmor Technology (BAT) submunitions while its longer-range relative, the Block IIA, can deliver six.⁹ The BAT submunitions employ a combination of millimeter wave, imaging infrared (IIR) seeker, and acoustic technologies to detect and terminally guide to vehicles on the battlefield. Finally, the Unitary variant provides a 2,000-pound (approximate) blast fragmentary warhead.

The Block IA ATACMS began fielding in 1998 and Block II began full-rate production and deployment in 2000. The Unitary variant is currently in test, 18 April 2001 was the first flight, while the Block IIA has recently become unfunded due to U.S. Army restructuring. The U.S. Army plans to purchase a total of 800 Block 1A missiles and 1,528 Block II missiles.¹⁰ Although the Block IIA program is unfunded, it is still a requirement and future funding is anticipated. In February 2001, as part of the preliminary report for America's Armed Forces Review, it was recommended to Secretary of Defense Rumsfeld that the ATACMS Block IIA program should be restarted.¹¹



Fig. 5. ATACMS Launch from an AVMRL.
Photograph courtesy of FAS.

Ship with Land Attack Standard Missile

The Land Attack Standard Missile (LASM) is a naval surface fire support (NSFS) version of the U.S. Navy's SM-2 Standard surface-to-air missile system (fig 6). It builds on the successful thirty-year evolution of the Standard missile, the U.S. Navy's premier antiair warfare weapon currently deployed on 50 cruisers and destroyers as well as with 13 Navies around the world.¹² The LASM is to be employed from United States destroyers and cruisers with the Mk 41 Vertical Launching System (VLS) and the Mk 26 Guided Missile Launching System (GMLS).¹³ The missile relies on a GPS-aided inertial navigation system (GA INS) to deliver a unitary 76-pound high-explosive fragmentation warhead. Height-of-burst sensor fuzing enables the MK-125 warhead to detonate at the proper height to ensure maximum lethality. The development of an armor-piercing (AP)

warhead is also planned. The weapon's IOC is expected in 2004 with approximately 2,000 SM-2 Standard surface-to-air variants being converted to LASMs by 2010.¹⁴



Fig. 6. SM-2 Standard on a Mk 26 GMLS.
Photograph courtesy of FAS.

Ship with Tomahawk Land Attack Missile

The BGM-109 Tomahawk Land Attack Missile (TLAM) is launched from surface ships and submarines to interdict surface targets throughout the battle space (fig. 7). The conventional variants of the TLAM are the BGM-109C with a 1,000-pound unitary warhead and the BGM-109D with 166 BLU-97/B bomblets. Following the Gulf War, the U.S. Navy improved the Tomahawk missile's operational responsiveness, target penetration, range, and accuracy. It accomplished this by adding GPS guidance and redesigning the warhead and engine. This improved version, TLAM Block III, entered the active duty force in 1993.¹⁵

The Tactical Tomahawk, TLAM Block IV, is due to reach the fleet by 2002 in the form of a unitary warhead (BGM-109E). Expected follow-on Block IV warheads include a hard target penetrator, cluster submunitions, and BAT-type submunitions.¹⁶ Tactical Tomahawk will also provide on-station loiter and in-flight retargeting capabilities. Additional changes from the Block III include the use of a ring-laser gyroscope instead of a mechanical gyroscope, the replacement of the turbofan engine with a turbojet, and the incorporation of a video camera and data link to assist with reconnaissance and retargeting. The TLAM Block III and IV navigation systems include inertial guidance and GPS. Terrain-Contour Matching (TERCOM) and Digital Scene-Mapping Area Correlator (DSMAC) augment the weapon's navigation system to improve accuracy in the mid and terminal phases of flight.¹⁷ The U.S. Navy has established a requirement for 3,440 conventional missiles by fiscal year 2006. Through the year 2020, the TLAM conventional inventory is to be composed entirely of Block III and IV missiles, two-thirds will be Block III TLAM C/D and one-third will be Tactical Tomahawk.¹⁸



Fig 7. TLAM Launch from a U.S. Navy Cruiser.
Photograph courtesy of FAS.

Unmanned Combat Air Vehicle with JDAM

The realization of unmanned aerial vehicle (UAV) military potential during the 1990s has resulted in aggressive efforts to develop new systems. Unmanned Combat Air Vehicles (UCAVs), such as the U.S. Air Force's X-45, are exploring the feasibility of stealthy unmanned vehicles carrying and employing multiple advanced, precision-guided munitions (fig. 8).¹⁹ The Defense Advanced Research Projects Agency (DARPA) and the U.S. Air Force have joined efforts to “demonstrate the technical feasibility for a UCAV system to effectively and affordably prosecute 21st century SEAD/strike missions within the emerging command and control architecture.”²⁰ The Department of the Navy and DARPA are conducting a similar advanced technology program for naval applications. The U.S. Navy and U.S. Air Force have numerous commonalities between their UCAV visions. A general performance theme is that UCAV technology promises to be as effective as manned aircraft. Due to the elimination of the cockpit, the UCAV

airframe is expected to be approximately 40 percent smaller than manned aircraft and weigh only one-third to one-fourth the amount. The weapon's payload associated with these platforms is expected to be from 1,000 to 3,000 pounds. With future weapon's miniaturization, an anticipated standard load may be four 250-pound weapons.²¹ The Program Executive Office for Strike Weapons and Unmanned Aviation (PEO(W)) expects that the GBU-32 JDAM will be fully compatible with the operational UCAV of 2008 to 2010.²² This is the IOC period associated with both the U.S. Air Force and the Naval Service UCAV initiatives.



Fig. 8. X-45 UCAV.
Photograph courtesy of FAS.

Weapon Destructive Capability

Five interdiction targets have been selected for this category of analysis. Keeping with the scope of this study, these targets can have tactical, operational, or strategic implications. The target arrays have been selected based upon actual aviation interdiction

training scenarios. The Naval Strike and Air Warfare Center (NSAWC), Marine Aviation Weapons and Tactics Squadron One (MAWTS-1), and the U.S. Air Force Fighter Weapons School (FWS) use these types of targets to prepare units to execute real-world contingencies (table 4.).²³ For the study's comparison model, each of these targets is struck with a single weapon from each of the weapon systems. By using the *Joint Munitions Effectiveness Manuals (JMEMs)*, a probability of destruction is determined for each of the systems. These values are expressed as a percentage, the probability of destroying the target with a single weapon. A MOE is established to create a standard by which progress toward the destruction of the target can be measured. The MOE for this category is: A single weapon achieves no less than a probability of destruction (Pd) of .7 (70 percent). NSAWC and MAWTS-1 use 70 percent as the general task standard for probability of destruction. This is the tasking level associated with severely damaging or destroying a target so that it is no longer operable.²⁴

Table 4. Target Sets		
	Target	Characteristics
1	Bunker	80'x60'x10', 6' hard earth overburden, 2 ½' 5000 psi reinforced concrete roof and floor
2	Railroad Bridge	200'x20', steel truss, Pratt curved chord
3	SA-2 Fan Song Radar	18'x8'x20'
4	T-80 Main Battle Tank	28'x12'x8', no reactive armor
5	Building	80'x40'x12', single story reinforced concrete

Source: Naval Strike and Air Warfare Center, Carrier Air Wing Training Department, (December, 2000).

Weapon Accuracy

Weapon accuracy is actually a component of the JMEM's probability of destruction calculation. It is broken out as a separate category because a weapon's accuracy is related to the issue of collateral damage. A commander normally must consider the potential for collateral damage when employing weapons. Accuracy, simply stated, is the ability of the weapon to hit the desired aim point. It is measured by circular error probability (CEP), which is the circle about the target in which 50 percent of the weapons will fall. The result is expressed as the radius distance from the target to the 50 percent line. Accuracy is obviously important to achieve mission success. The destructiveness of a given weapon varies directly with the weight of the explosive filler, but it varies inversely with the cube of the miss distance. Thus, increasing accuracy is a more effective and efficient means of achieving success than simply increasing the size of the warhead. Reviewing the general dimensions of the given targets, the MOE for this category is: A weapon's CEP is no greater than 15 meters (50 feet).

Responsiveness

On the dynamic battlefield, the ability to quickly react to target opportunities is imperative to success. The time required to detect, decide, and act upon a situation must be faster than the opponent's realization of the situation and subsequent action to thwart your plan. Weapon systems, likewise, must be responsive to changes on the battlefield. During Operation ALLIED FORCE in Kosovo, the coalition air force used four hours as the cutoff time. If weapons could not be placed on a target within four hours of its detection, then assets would not be tasked to strike later without reverification of target location. The Serbian forces, leery of airpower, realized that the survival of their assets

relied upon not staying in the same location for greater than four to five hours. The MOE for this category is: Weapon's effect in response to tasking requires no more than four hours. To ensure comparable weapon's employment times, all systems will travel 100 nautical miles (183 kilometers) from launch to weapon's impact.

Effective Reach

The effective reach associated with each weapon system is important because it gives the commander the ability to shape the battlefield before the close fight. The effective reach of a weapon system is the sum of the maximum range associated with the weapon and the range of movement associated with its host platform. The real-world limitations imposed by sovereign territorial rights, including launch site locations and over-flight permission, will not be addressed in this discussion. Only geographical issues, as they relate to weapon system's effective reach, will be considered. The MOE is: A weapon system's effective reach provides worldwide coverage.

Survivability

Survivability is the ability of a weapon system to accomplish its task regardless of the environment. Natural conditions associated with weather, such as cloud cover or rain, may obscure target detection in the visible spectrum. Man-made obstacles may also attempt to negate the attempt at success by weapon systems. In the case of standoff weapons, a survivable one-way trip is all that is required. For systems with an airborne host platform, success is also dependent upon the return trip of that asset. Operation DESERT STORM provides examples of each where man-made obstacles denied mission success. Due to flying numerous TLAMs along the same route, the U.S. has suggested that two were shot down by Iraqi gunfire.²⁵ Likewise, several aircraft were destroyed by

Iraqi antiaircraft artillery (AAA) or surface-to-air missiles while conducting the interdiction mission. The loss of the host platform before weapon's release obviously affects mission success. For the purpose of this category, the operating environment is to include an integrated air defense system (IADS) and a counter battery system centered at the target. The meteorological conditions are set with the weapons unable to acquire the target in the visible spectrum during employment. An enemy air threat will not be included. The MOE for this study is that: A weapon system is not denied successful mission execution because of hostile actions or adverse weather.

Cost of Weapon

Although cost is not directly attributable to weapon's success on the battlefield, it does relate to weapon's availability due to procurement and command decisions associated with target value versus weapon's value. Cost, in this study, will just apply to the weapon being employed. The associated costs with getting the weapon to its release or launch point will not be included. As an example, the cost associated with the manned, fixed-wing aviation and JDAM system will be the same as that of the UCAV and JDAM system. The associated MOE for this category is that: Individual weapon's cost is no more than 1 million dollars.

Ability to Redirect or Self-Detonate the Weapon

The ability to modify a weapon's course of action near its terminal phase of operation is important in this age of collateral damage concern and real time information updates. This poses two questions for this category. The first is, Can the weapon be directed to self-detonate or be steered off course to detonate elsewhere? The second is, What is the closest time to impact that a commander can direct the weapon not to strike

the desired aim point? To establish a standard for this category, the MOE is that: The commander can direct a mission abort within five minutes of weapon's time on target. All weapon systems will have a one-way employment range of 100 nautical miles (183 kilometers).

Risk to Man

In the U.S. military, it is generally accepted that the most precious resource is its Soldier, Sailor, Marine, and Airman. Equipment and tactics are developed that attempt to minimize the risk to man while accomplishing a mission. The interdiction mission is no different. This category will look at the man component of the host platforms and assess their relative survivability in relation to the threat. Similar to the survivability category, the threat will be composed of an integrated air defense system and a counter battery system centered at the target. The MOE for this category is that: Man will not be lost because of the enemy's immediate reaction to the interdiction strike.

The research data for each of the categories will be inserted into the comparative assessment model during chapter four. The model will be broken down into its separate comparative categories to allow for the synthesis and detailed analysis of the raw data. As a result of this process, chapter 5 will allow this study to answer the primary question, As military technological advancements evolve toward *Joint Vision 2020*, should manned, fixed-wing aviation continue to conduct the preplanned interdiction mission?

¹U.S. Joint Chiefs of Staff, Joint Publication 3-03, *Doctrine for Interdiction Operations*, V-2.

²*Ibid.*, V-1.

³William D. Beydler, "Some Thoughts on Assessing Military Operations," *Marine Corps Gazette*, November 2000, 82-86. LtCol Beydler stresses that a MOE must be expressed in terms of progress in relation to a desired end state, and form the framework for the overall assessment. It is also essential that not only must MOE be measurable, quantifiable, and understandable, but they must, above all else, be relevant.

⁴Federation of American Scientists, *Joint Direct Attack Munition (JDAM) GBU-29, GBU-30, GBU-31, GBU-32* [database on-line] (Military Analysis Network, December 2000, accessed 10 February 2001); available from <http://www.fas.org/man/dod-101/sys/smart/jdam.html>; Internet.

⁵Periscope, *GBU-31 JDAM (Joint Direct Attack Munition)* [database on-line] (USNI Military Database, August 1998, accessed 13 September 2000); available from <http://www.periscope.ucg.com/docs/weapons/missrock/landatk/w0004483.html>; Internet.

⁶Federation of American Scientists, *AGM-154A Joint Standoff Weapon (JSOW)* [database on-line] (Military Analysis Network, June 2000, accessed 8 December 2000); available from <http://www.fas.org/man/dod-101/sys/smart/agm-154.html>; Internet. Additional information provided by the Naval Weapons Handbook, 73.

⁷Naval Air Warfare Center Weapons Division, *Naval Weapons Handbook* (China Lake, CA: Naval Air Warfare Center Weapons Division, 1999), 71.

⁸Federation of American Scientists, *AGM-154A Joint Standoff Weapon (JSOW)*.

⁹Periscope, *MGM-140 ATACMS (Army Tactical Missile System)* [database on-line] (USNI Military Database, April 2000, accessed 15 September 2000); available from <http://www.periscope.ucg.com/docs/weapons/missrock/landatk/w0003235.html>; Internet.

¹⁰Federation of American Scientists, *ATACMS Block II / Brilliant Antiarmor Technology (BAT)* [database on-line] (Military Analysis Network, February 2000, accessed 25 September 2000); available from <http://www.fas.org/man/dod-101/sys/land/atacms-bat.html>; Internet.

¹¹Andy Marshall, *A Strategy for a Long Peace* (Washington, DC: Center for Strategic and Budgetary Assessments, February 2001). Secretary of Defense Rumsfeld charged Mr. Andy Marshall with reviewing America's Armed Forces in January 2001. Mr. Marshall presented his "Quick Look" Assessment on 12 February 2001.

¹²Federation of American Scientists, *Land Attack Standard Missile (LASM)* [database on-line] (Military Analysis Network, December 1998, accessed 8 December 2000); available from <http://www.fas.org/man/dod-101/sys/missile/lasm.html>; Internet.

¹³Federation of American Scientists, *RIM-66 / RIM-67 Standard Missile* [database on-line] (Military Analysis Network, April 1999, accessed 10 February 2001); available from <http://www.fas.org/man/dod-101/sys/missile/sm-2.html>; Internet.

¹⁴Periscope, *LASM Land Attack STANDARD Missile* [database on-line] (USNI Military Database, October 2000, accessed 30 November 2000); available from <http://www.periscope.ucg.com/docs/weapons/missrock/landatk/w0004680.html>; Internet. Its IOC was pushed back from 2003 to 2004 (Troshinsky 2000, 2)

¹⁵Federation of American Scientists, *BGM-109 Tomahawk* [database on-line] (Military Analysis Network, December 2000, accessed 1 February 2001); available from <http://www.fas.org/man/dod-101/sys/smart/bgm-109.html>; Internet.

¹⁶Doug Detwiler, interview by author, 16 December 2000, telephonic and electronic mail, NAVAIR PMA-280, Patuxent River, MD. Mr. Detwiler is the Deputy Program Director for Tomahawk All-Up-Round at the Program Executive Office for Strike Weapons and Unmanned Aviation.

¹⁷Periscope, *BGM-109A Tomahawk Land-Attack Missile (TLAM)* [database on-line] (USNI Military Database, September 1998, accessed 13 September 2000); available from <http://www.periscope.ucg.com/docs/weapons/missrock/landatk/w0003236.html>; Internet. Block III with its improved accuracy and stand-alone GPS guidance was first used in the September 1995 Bosnia strike (Deliberate Force) and a year later in the Iraq strike (Desert Strike). The success rate for both strikes was better than 90 percent (Townes 1997, 18).

¹⁸Federation of American Scientists, *BGM-109 Tomahawk*.

¹⁹Periscope, *X-45 UCAV (Unmanned Combat Air Vehicle)* [database on-line] (USNI Military Database, September 1998, accessed 23 November 2000); available from <http://www.periscope.ucg.com/weapons/aircraft/rpv-dron/w0004702.html>; Internet.

²⁰Defense Advanced Research Projects Agency (DARPA), *Unmanned Combat Air Vehicle Advanced Technology Demonstration (UCAV ATD)* [database on-line] (March 1998, accessed 27 November 2000) available from <http://www.darpa.mil/tto/ucav/ucav-sol.html>; Internet.

²¹Periscope, *X-45 UCAV (Unmanned Combat Air Vehicle)*.

²²Osa E. Fitch, *Autonomy for Naval UAVs and UCAVs: Synergies Between the Autonomous Operations, Naval UCAV, and Multi-Role Endurance Naval UAV Projects* (Patuxent River, MD: Program Executive Office for Strike Weapons and Unmanned Aviation (PEO(W)), 1999. Additionally, Cdr Fitch (PMA-263) and the author have had several telephonic and electronic mail exchanges concerning the UCAV program.

²³Mark Black, interview by author, 19 December 2000, telephonic and electronic mail correspondence, NSAWC, Fallon, NV. LCDR Black is the carrier air wing training officer, N72, at NSAWC. He acknowledged that the targets selected were representative of real world tasking. Additionally, Maj Robert Charette, a recent tactics department head from MAWTS-1, concurred with NSAWC's determination (January 5, 2001).

²⁴Jerry Wyant, interview by author, 7 December, 2000, telephonic and electronic mail correspondence, NSAWC, Fallon, NV. Mr. Wyant is the weaponeering subject matter expert at NSAWC. The U.S. Marine Corps aviation schoolhouse, MAWTS-1, also uses a Pd of .7 as a general rule. For the respective target sets, the following weaponeering goals were set: (1) bunker – breach of wall and/or ceiling with possible contents detonation, (2) railroad bridge – drop a span, (3) radar – catastrophic kill, (4) tank – firepower kill, (5) building – penetration with catastrophic kill of contents.

²⁵Periscope, *BGM-109A Tomahawk Land-Attack Missile (TLAM)*.

CHAPTER 4

ANALYSIS

The manned fixed-wing aviation systems are compared with the other weapon systems to determine relative performance. This relative performance is assessed across several different categories. It is important to understand that the success of a system cannot be judged based on its performance in a single category. Rather, the cumulative result in the various categories must ultimately be assessed. This chapter will focus on each comparative category, discuss the ideal weapon type for each system, and assess manned, fixed-wing's relative performance. Chapter five will encompass the overall evaluation of manned fixed-wing performance across all categories.

Service schoolhouses and program offices provided assistance in acquiring performance data, to include weaponeering computations. Specifically, NSAWC provided assistance with JDAM, JSOW, and TLAM. The U.S. Army Field Artillery School provided detailed information on ATACMS. NAVAIR provided information concerning UCAVs and additional TLAM details while NAVSEA assisted with the LASM issues.

Destructive Capability

Five diverse targets, representative of actual strike taskings, are used in the first comparative category. In order to maintain uniformity, each weapon system is weaponeered for a single round across each target. A weapon's single round performance is compared with the Pd value of .7 (70 percent). Table 5 identifies with a hashed pattern, system performance below that mark, and in black, performance above. It is important to understand that this method of evaluation differs from operational

execution. Tactically, commanders and operators would employ multiple weapons to achieve the desired Pd. This study differs in that it focuses on the comparison of individual weapons, not cumulative effects.

Table 5. Probability of Destruction (Pd)						
		Bunker	Railroad Bridge	SA-2 Radar	T-80 Tank	Building
	Aircraft w/JDAM					
	Aircraft w/JSOW					
	AVMRL w/ATACMS					
	Ship w/ASM					
	Ship w/TLAM					
	UCAV w/JDAM					
Pd < .7 Pd > .7 MOE: A single weapon achieves no less than a Pd of .7 (70 percent).						

The GBU-31 JDAM delivers a 2,000-pound bomb to the target. Across all targets, the GBU-31 was selected over the GBU-32 (1,000-pound version). Weapon employment conditions include a release altitude of 22,000 feet above mean sea level (MSL) and 550 knots true airspeed (KTAS). The tailoring of different bomb bodies, Mk-84 and BLU-109, and fuzes (delay, instantaneous, and proximity) provide effective single bomb solutions against the majority of targets. The recent addition of the Direct Attack Munition Affordable Seeker (DAMASK) has significantly enhanced the JDAM's performance against point targets such as the T-72.¹

The three variants of the JSOW are optimized across the target sets. Weapon employment conditions are the same as for the JDAM. The unitary version of JSOW, AGM-154C, is not capable of singularly destroying the bunker, dropping a span of the railroad bridge, or destroying the building. This is due primarily to the relatively small BLU-111/B warhead, a variant of the Mk-82, 500-pound general-purpose bomb. The cluster munitions of the AGM-154A are effective against the Fan Song radar, while the BLU-108 Sensor Fuzed Weapon (SFW) submunitions associated with the AGM-154B are effective against armor.

As with the other systems, the ideal ATACMS warhead was selected for each target. A single ATACMS unitary round is effective against the Fan Song radar, and has some capability against the single story building. It is less effective against the bunker and the railroad bridge. The Pre-planned Product Improvement (P3I) BAT submunition associated with the ATACMS Block II/IIA is effective against "hot or cold" armored

combat vehicles, surface-to-surface missile transporter erector launchers, and multiple rocket launchers.²

Relative to the other weapons systems, LASM carries a small warhead of 75 pounds. It provides a single fuzing option of ground proximity and is designed to operate effectively against thin-skinned targets, such as the Fan Song radar.³ LASM's destructive capability against bunkers, bridges, armor, and buildings is significantly less. Although ideas, such as an Armor Piercing LASM (AP-LASM) and Extended Range LASM (ER-LASM), have been discussed, money has not been directed to develop those programs.

A single TLAM is effective against this set of targets. The Block III TLAM-D is the current TLAM weapon of choice for the SA-2 Fan Song radar while the Block III TLAM-C is ideal against the reinforced concrete building. The Tactical Tomahawk, Block IV, will be modified to incorporate the government-furnished hard-target penetrator warhead and the hard-target smart fuze.⁴ This missile will be effective against the bunker, the railroad bridge, and the armor target. Future TLAM deep strike requirements are in review with the possibility of developing a dedicated antiarmor variant with BAT-type submunitions.⁵

The UCAV has the same operating capabilities as manned aircraft and thus employs weapons at similar airspeeds and altitudes. The result is the employment of a single GBU-32 JDAM against the selected targets. It is generally less effective than its 2,000-pound relative because of the smaller quantity of explosive material and the limitations associated with the Mk-83 bomb body. The weapon's performance does not achieve the .7 Pd tasking when employed against the bunker and the bridge.

For the MOE associated with this category, only the GBU-31 JDAM and the TLAM achieved the prescribed tasking of .7 Pd or better across all targets. The relative comparison of this group of weapons results in the GBU-31 JDAM and the TLAM performing better than the average. The AGM-154 JSOW, ATACMS, and GBU-32 compose the average group, while LASM is least effective across this set of targets.

Weapon Accuracy

The selected weapons systems have a variety of means to guide themselves to the desired targets. These navigation systems include inertial, GPS, radar, and imaging. All of the weapons systems rely on a minimum of two such means and are mechanized to gracefully degrade if the primary means malfunctions. Additionally, all the systems require the programming of accurate target coordinates into the weapon. The factor of target location error (TLE), the inaccuracies associated with plotting a target, are not included in this study's circular error probability (CEP) calculations (table 6).

Table 6. Weapon Accuracy (CEP)	
JDAM	10' / 3m
JSOW	10' / 3 m
ATACMS	42' / 13 m
LASM	42' / 13 m
TLAM	10' / 3 m
MOE: A weapon's CEP is no greater than 15 meters (50 feet).	

Upon aircraft release, the JDAM relies upon its inertial navigation system (INS) to correct its course. The GPS provides periodic updates to further improve the bombs accuracy during the decent phase. A recent product improvement program resulted in the addition of an IIR focal plane-array to the front of the weapon. This DAMASK activates at approximately 1,600 meters from the target and provides further corrections to the INS/GPS solution. A standard JDAM has a circular error of probability of 13 meters when its GPS and INS are used. DAMASK potentially reduces this error to three meters.⁶ The GBU-32 JDAM associated with the UCAV has the same accuracy performance as the manned, fixed-wing weapon system.

The JSOW also relies upon on a tightly coupled INS and GPS system for navigation. The AGM-154C variant with the BLU-111 unitary warhead will have an IIR seeker to assist in accuracy at the terminal phase of the flight. Its CEP is three meters.⁷ The submunition versions of JSOW, AGM-154A and AGM 154B, do not include the IIR seeker. The dispersion pattern for the 145 BLU-97/B bomblets of the AGM-154A is approximately the size of a football field, 300 feet by 120 feet. The 24 antiarmor projectiles from the AGM-154B cover a search area of roughly 1,000 feet by 2,000 feet (305 meters by 610 meters).⁸ With both submunition variants having a CEP of well less than 36 meters (100 feet), these patterns effectively negate their less accurate performance. Arguably, the infrared-homing antiarmor variant is the most accurate.

The ATACMS Block IA, II, IIA, and unitary include a GPS receiver to provide in-flight updates to the inertial navigation system. This Improved Missile Guidance Set (IMGS) with an embedded GPS provides significant accuracy improvements over the

Block I variant. The accuracy generally accepted for the integrated INS and GPS navigation unit is 13 meters (42 feet). Block IA dispenses its 300 M-74 bomblets over a footprint of approximately 183 meter (600 feet) square. It can be expected that the six P3I BAT submunitions associated with Block IIA will ballistically cover an area larger than that of a Block IA.⁹ In fact, the instantaneous footprint of each BAT submunition, using its acoustic sensor, exceeds a four kilometer radius.¹⁰ Similar to the AGM-154B, the organic acquisition capability of the BAT submunition could arguably make it the most accurate variant.

The LASM relies upon a GPS-aided inertial navigation system (GA INS) for guidance. Similar to ATACMS, the accuracy accepted with this system is 13 meters (42 feet). The lethal radius of the LASM round is increased by detonating the high-explosive (HE) fragmentation warhead before impacting the ground. Its fragments are lethal to thin-skinned targets out to ranges greater than 100 meters.¹¹ This provides latitude in the weapon's accuracy requirement.

The BGM-109 Tomahawk relies upon several guidance means to achieve accuracy on target. These include the inertial and terrain contour matching (TERCOM) radar guidance that compares a stored map reference to actual terrain as determined by the missile's position. The Digital Scene Matching Area Correlation (DSMAC) system compares a stored image of the target with the actual target image. The accuracy associated with the TERCOM and DSMAC capabilities is 10 meters (33 feet).¹² The Tomahawk TLAM Block III system upgrade includes the incorporation of GPS receivers. The Tactical Tomahawk is to have GPS receivers, a laser gyroscope INS, and a forward-

looking terminal sensor to autonomously attack targets.¹³ Due to these improvements, the expected CEP of these Block IV missiles is 3 meters (10 feet).

In the category of accuracy, all of the weapons systems performed within the prescribed MOE. Comparatively speaking, the JDAM and JSOW accuracies associated with manned and unmanned aircraft are above the group average. TLAM accuracy is similar to the air-delivered weapons while ATACMS and LASM performance is slightly less.

Response Time

The response time category focuses on the terminal phase of a strike. The time associated with mission planning and the majority of the command and control decisions are not included in this calculation. As a prerequisite, the aircraft, ships, and multiple rocket launchers are tactically deployed with all the planning and coordination issues resolved. Additionally, the INS associated with each weapon system requires time to acquire an alignment. Typically requiring about five minutes, this value will not be included. It will be assumed that each weapon has already established a good alignment before receipt of target coordinates. The terminal phase begins with the input of accurate target coordinates into the weapons system. Once this data input is complete, the weapon or host platform is launched. To ensure consistency, each of the weapons must travel 100 nautical miles from the launch point to the target. The time equation of “input of data + flight = response” is applied to each weapon system (fig. 9).

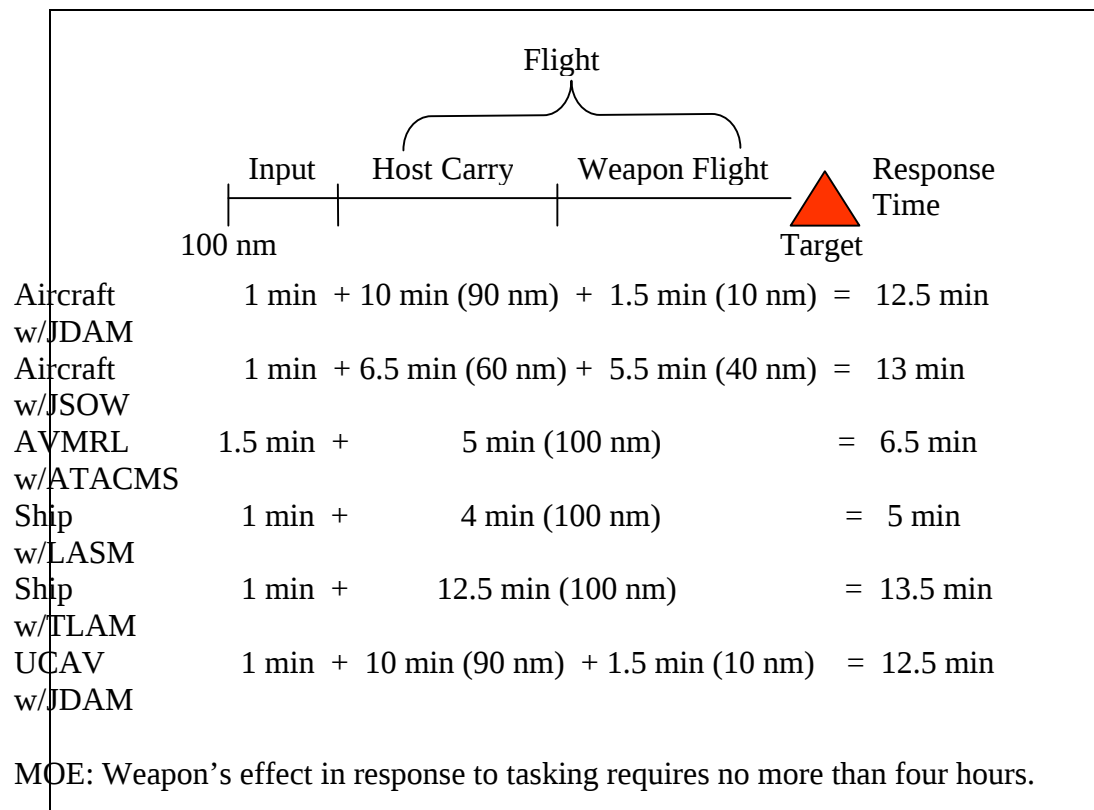


Fig. 9. Response Time.

The maximum range of both the JDAM and the JSOW is less than 100 nautical miles. A host aircraft is used to carry the weapon a portion of this required distance. For the “flight” portion of the time equation, it must be further subdivided into “host carry” and “weapon flight.” The tactical employment profile used for the manned, fixed-wing aircraft and the UCAV is 25,000 feet above mean sea level (MSL) and 550 knots.¹⁴ Employment ranges of 10 nautical miles for the JDAM and 40 nautical miles for the JSOW are used. The average glide speed for the JSOW is 420 knots, while the average speed for the JDAM is 480 knots. Aircrew input of target coordinates into each weapon requires less than 1 minute.

The ATACMS and LASM are both supersonic missiles. They reach speeds of 1,200 knots and 1,600 knots, respectively.¹⁵ The ATACMS operational time line requires a minimum of 1.5 minutes with the M270 AVMRL to input the coordinates into the missile and ready the system for launch. Under ideal conditions, the transferring of launch information from the Field Artillery brigade tactical operation center (TOC), through both the battalion TOC and the battery TOC, and ultimately arriving at the firing position would take an additional 1.3 minutes.¹⁶ The LASM fire control system requires less than 1 minute to load the coordinates into the system and be ready for launch from the Mk 41 VLS or the Mk 26 GMLS.

Although not currently available, the TLAM Block IV will use the Tomahawk Strike Network Loading (TSN) to uplink information to a loitering missile. With the TACTOM just prior to its next waypoint, the missile will require less than one minute to receive the information uplink, including GPS target coordinates, and act. The TLAM Block III expects upgrades resulting in the reduction of its preparation for launch process from several hours to less than one. The TLAM is capable of traveling from 331 to 496 knots.¹⁷ Four hundred and eighty knots has been selected for the calculations of this study.¹⁸

All of the weapon systems have a response time that is well within the MOE of four hours. The aviation-based systems and the ship with TLAM performed at the group average for responsiveness. The supersonic ATACMS and LASM responded more quickly.

Effective Reach

The effective reach of a weapon system relates to the flexibility in its employment. A system with a relatively short reach may require a commander to either increase the number of systems to cover his area of responsibility or move his system as required to facilitate ranging of the target sets. Table 6 identifies the maximum range of each weapon. Again, this is only part of the effective reach equation. The possible range of movement of a weapon's host platform is the second consideration. In practical application, the commander must also evaluate the time associated with this host platform movement.

Table 7. Reach		
	Weapon Range	Host Platform Range
Aircraft w/JDAM	15 nm	Global
Aircraft w/JSOW	45 nm	Global
AVMRL w/ATACMS	164 nm	Global
Ship w/LASM	175 nm	Sea-limited
Ship w/TLAM	1000 nm	Sea-limited
UCAV w/JDAM	15 nm	Global
Note: The maximum range of each weapon is significantly dependent upon the wind conditions. MOE: A weapon system's effective reach provides worldwide coverage.		

The range performance of aircraft and UCAVs extend the operational capabilities of the JSOW and JDAM significantly. A nominal strike-fighter aircraft has a combat radius of at least 300 nautical miles. Additional drop tanks and air refueling extend this range considerably, allowing manned, fixed-wing aircraft with the JDAM or JSOW to reach anywhere on the globe. The anticipated combat radius associated with the X-45 UCAV is 500 to 1,000 nautical miles.¹⁹ Because there is no planned in-flight refueling capability through 2020, the UCAV with the JDAM will be much more dependent upon launch location to achieve worldwide coverage.

The ATACMS, LASM, and TLAM rely primarily on the propulsion of the missile to attain its tactical range. ATACMS Block IA and IIA, while carrying a smaller destructive payload than the Block I, is capable of delivering ordnance in excess of 164 nautical miles (300 kilometers). The Block I, II, and unitary are capable to a range of 82 nautical miles (150 kilometers). The baseline LASM is capable of 175 nautical miles. An unfunded Extended Range LASM (ER-LASM) program may extend that range considerably. The TLAM Block III, BGM-109C, can range 900 nautical miles due to its recent conversion to a lighter (700-pound or 318-kilogram) insensitive-munition PBXN 107 warhead.²⁰ This improved warhead change permits more fuel storage resulting in approximately 200 nautical mile greater range than the BGM-109D. The TLAM Block IV will be able to strike 1,000 nautical miles inland.²¹

For these three surface-launched systems, the range associated with their host platform must also be considered. The sea-based launch platforms are normally limited to a range of movement no closer than within 25 nautical miles of a hostile shore. This limitation, coupled with the size of some landmasses, does not allow the LASM or

TLAM weapon systems to reach the entire globe. The ATACMS weapon system does have the ability to cover the earth's surface and is simply dependent upon the placement of the M270 AVMRL. Although unconventional, the ATACMS weapon system could be placed on ships for employment at sea.

With regard to the effective reach of weapon systems, the manned, fixed-wing aircraft with JSOW and JDAM, the UCAV with JDAM, and the M270 AVMRL with ATACMS provide worldwide coverage. The practicality associated with the ease of host platform movement is a consideration for the commander. Generally, however, it can be said that the aviation-based host platforms will be a more feasible means of providing worldwide reach. In the relative performance analysis, the aviation weapon systems performed above the group average. Again, this is not due to the individual JDAM or JSOW range performance. Rather, the host aircraft's range of movement contribution is key to the overall effective reach of the weapon system. ATACMS and its associated AVMRL also fit in the above average group. The Ship with TLAM and Ship with LASM weapon systems are slated in the average and below average categories, respectively.

Survivability

A weapon system's survival can be challenged by atmospheric conditions, enemy electronic countermeasures, and enemy direct action against the weapon or its host platform (table 8). A direct action threat to a weapon system relies on the enemy's ability to detect that system. This detection can generally be achieved by two means, radar and visual. To counter radar detection, the weapon systems may use flight techniques including low altitude operations and terrain masking. Additionally, efforts in weapon

system construction can aid in reducing the radar cross-section and result in decreasing the detection probability by threat systems. A threat's ability to visually acquire one of the weapon systems is directly related to the system's size and is inversely related to its speed, and altitude. Regardless of a weapon system's performance in the other comparative categories, a weapon system will seldom be successful if weather or enemy actions deprive it from functioning properly.

The integrated GPS and INS in all the weapon systems allows for near all weather, day and night operations. GPS enhancements within the systems provide for operations in GPS jamming environments. As a passive defense, the GPS receivers are placed on the top of the weapons so that during flight, ground based jammers can have minimal effect. Actively, product improvement programs have resulted in the use of encrypted GPS signals. As an example, ATACMS and JSOW are expected to have a new security infrastructure that incorporates the Selective Availability Anti-Spoofing Module (SAASM). Its performance includes ensuring successful GPS operations in a high signal-jamming environment.²² The only weapon system that will not have a jam proof GPS system is the Block IA variant of the ATACMS. The fact that this is an area weapon may mitigate the requirement for 100 percent GPS connectivity.

The radar cross section (RCS) of a weapon system is important because it relates directly to the detection range by an enemy radar system. Ground-based tracking radars and their subsequent directing of antiaircraft artillery (AAA) and surface-to-air missiles (SAMs) can adversely affect the survivability of weapon systems. Geometrically, all of the individual weapons have a forward RCS of less than one square meter (10.8 square feet). It can be expected that by using design techniques and low observable materials,

Table 8. Survivability						
				Size (length x wingspan)	Speed	Employ- ment Altitude
Aircraft w/JDAM	Yes	Yes	$> 1 \text{ m}^2$ $< 1 \text{ m}^2$ (note 1)	10' x 1.7' 12.4' x 2' 12.8' x 2' (note 2)	480 kts	Low to High
Aircraft w/JSOW	Yes	Yes	$> 1 \text{ m}^2$ $< 1 \text{ m}^2$ (note 1)	13.3' x 8.4' (note 2)	420 kts	Low to High
AVMRL /ATACMS	Yes	Blk IA-No Blk II/IIA/ Unitary-Y	$< 1 \text{ m}^2$	13' x 3'	1,200 kts	Medium to Very High
Ship w/LASM	Yes	Yes	$< 1 \text{ m}^2$	26.2' x 5.1'	1,600 kts	Medium to Very High
Ship w/TLAM	Yes	Yes	$< 1 \text{ m}^2$	18.2' x 8.8'	475 kts	Low
UCAV w/JDAM	Yes	Yes	$> 1 \text{ m}^2$ $< 1 \text{ m}^2$ (note 1)	10' x 1.7' 12.4' x 2' 12.8' x 2' (note 2)	480 kts	Low to High
Note (1): The RCS of the JDAM and JSOW is less than 1 m^2. The RCS for the host aircraft is generally greater than 1 m^2. Note (2): The JDAM size numbers correspond to the GBU-32, GBU-31 (BLU-109), and GBU-31 (Mk-84), respectively. The manned, host aircraft vary in size with the smallest JSOW and JDAM capable aircraft being the AV-8B Harrier (30' wingspan x 46' length). The X-45 UCAV has a wingspan of 35' and a length of 27'. MOE: A weapon system is not denied successful mission execution because of hostile actions or adverse weather.						

the forward RCS of each of the weapons is less than .5 square meters (2.7 square feet). The relatively small radar size of the weapons makes it difficult for enemy systems to detect their presence. Following the same thought process, it can be expected that the smaller host manned aircraft and the X-45 UCAV have forward RCS values around one square meter (10.8 square feet). The cumulative RCS effect, host and weapon, is especially important when a strike is relying upon the element of surprise. The greater RCS, generally associated with the host, may be overcome by the aircraft and UCAV's active counterradar means and employment tactics. These attributes can help to reduce the enemy's radar detection and threat system employment ranges.

The visual employment characteristics of the weapon systems include its size, speed, and altitude. These characteristics are important because of their relationship to visual detection and enemy engagement by visually cued AAA and SAM systems. Obviously, the size of an object is directly related to range that it can be visually detected. On size alone, one would expect the TLAM to be visually detected at a greater range than any JDAM variant. More important, however, is the weapon system's employment speed and altitude. The higher the altitude and speed of a weapon, the more difficult it is to visually acquire. The LASM, for example, is considerably larger than the majority of the other comparative systems. Operating primarily at altitude and at supersonic speeds, it is much more difficult to visually detect than the lower and slower TLAM. Similarly, a low

flying JSOW could be expected to be more susceptible to visual engagement than an ATACMS or LASM.

Visual engagement can also be dependent upon the infrared spectrum. Visual shoulder-launched SAM systems generally rely on target infrared emissions to track and engage. Infrared detection of the JDAM and JSOW would be minimal due to their lack of organic heat generating sources. The ATACMS and LASM, although both are IR significant, operate with a speed and altitude sanctuary that denies the enemy's threat employment. Even with the TLAM, infrared detection is difficult because the turbofan engine emits little heat.²³

The survivability of the host aircraft and UCAV is challenged in the radar and visual spectrum. Suitable employment tactics in response to the enemy's threat capabilities is mandatory. The survival of a manned, fixed-wing aircraft in a non-threatening, standoff location can be expected to be better than operating within the threat's visual or radar engagement zone. Employment of counter radar tactics, as previously discussed, along with altitude, speed, and maneuverability considerations to counter the visual environment, will enhance survival within the threat envelopes. It is anticipated that through 2020, a manned, fixed-wing aircraft is going to be more responsive to the dynamics of the surface-to-air threat environment than a UCAV, especially in the visual arena. However, the X-45 UCAV is expected to be much more maneuverable, capable of exceeding G-forces that would kill a human. This increased maneuverability may eventually make the UCAV much harder for the enemy to destroy.²⁴

The comparative category of survivability is subjective. In response to the MOE, all of the weapon systems have, or eventually will have, an occurrence where atmospheric conditions or efforts by the enemy result in mission failure. Thus, none of the systems have a 100 percent guarantee of success. Historical accounts document the fact that aircraft and cruise missiles have been denied striking a target by the weather or the enemy. Technological advancements will continue to increase the probability of success for all of the weapon systems. However, as identified by the downing of a premier stealth aircraft, an F-117 over Serbia in 1999, there are no guarantees when the enemy or the weather has a vote.

General analysis of each of the weapon systems results in a relative performance ranking. Due primarily to their speed and altitude, the ATACMS and LASM are assessed as the most survivable systems. The second group, aircraft with JSOW and TLAM, is rated as the next most survivable. This determination is based primarily on the fact that only the relatively small weapon will be operating in hostile territory. Finally, the aircraft and UCAV with JDAM are assessed as the least survivable systems. This is based on the requirement to bring a relatively large weapon system, manned aircraft or UCAV with JDAM, into the enemy's threat environment.

Cost

"Average unit cost" is used to compare the weapons across a common standard. This value does not include host or launch vehicle operating cost. Additionally, this section will not consider the cost associated with the potential loss of a manned, fixed-wing aircraft or a UCAV. It only reflects the expenditure of the weapon (table 9).

The aviation-based weapons are relatively inexpensive. The "bolt on" JDAM

guidance kit is a low-cost adaptation to general purpose and penetrator unitary bombs.

Its initial production run fixed the unit price at \$18,000. With the recent product improvement program, including the DAMASK, the cost has increased accordingly.²⁵

The development and production of the JSOW round from the ground up is reflected in its higher cost. The three variants differ in complexity, resulting in the unitary version and its associated terminal seeker and man-in-the-loop data link costing the most.²⁶

Table 9. Cost	
Aircraft w/JDAM	\$42,200
Aircraft w/JSOW	\$246,585 (A) \$429,929 (B) \$661,013 (C)
AVMRL w/ATACMS	\$750,000 (Blk IA) \$3,508,000 (Blk II) \$1,460,000 (Blk IIA) \$750,000 (Unitary)
Ship w/LASM	\$700,000 (Note 1)
Ship w/TLAM	\$600,000 (Blk III) \$569,000 (Blk IV/TACTOM)
UCAV w/JDAM	\$42,200
Note (1): This is the total cost of a LASM round. The conversion cost of an existing Standard missile is \$291,000. A SM-2 Extended Range unit cost is \$409,000. MOE: Individual weapon's cost is no more than 1 million dollars.	

The surface-based weapons are markedly more expensive than the aviation-based. This is partially due to the costs associated with the requirement for an organic propulsion system. Of the three ATACMS variants, the Block II BAT is the most costly. The autonomous BAT submunitions, with their acoustic and infrared sensors for armor detection and tracking, are expensive. Similar in cost to the ATACMS Block IA and unitary is the LASM round. In 1998, the LASM missile conversion program was chosen over a naval version of ATACMS, the Naval Tactical Missile System (NTACMS), primarily due to price. The conversion of a Standard Missile (SM-2), at the cost of \$291,000 each, was sixty percent less than the NTACMS proposal.²⁷ The TLAM procurement process is continuing with the purchase of Block IIIs and IVs. The Tactical Tomahawks are cheaper to build new rather than converting old Block IIs. This was achieved primarily by technological component advancements, turbojet propulsion instead of a turbofan, and by removing the requirement to launch from a submarine torpedo tube. The building of these new TLAMs from the ground up, as opposed to remanufacturing old missiles, resulted in a sixty percent cost savings.²⁸

All of the weapons, except for the ATACMS Block II, IIA, have an average unit cost below the MOE of \$1,000,000. The result of the relative cost comparison is that the JDAM associated weapon systems are less than the average, equating to an above average rating. The AVMRL with ATACMS is rated as below the group average. The remaining weapon systems fall into the average category.

Redirect and Self-Destruct Capability

A weapon's redirect or self-destruct capability provides the commander additional options while the weapon is enroute to the target. The last human input to the weapon without these capabilities is when the weapon is launched or released from its host platform. For each of the weapon systems, the same weapon employment range used for the response time category is applied. The last man-in-the-loop adjustment time is relative to weapons impact on target, the time on target (TOT). The time depicted in table 10 identifies how close to the TOT a commander can change his decision.

The JDAM, LASM, and ATACMS do not have any organic redirect or self-destruct capabilities. Likewise, the AGM-154A, AGM-154B, and TLAM Block III do not have either capability. The last time the commander has the ability to change his decision is just before weapons release or launch. In the case of the JDAM with its

Table 10. Redirect and Self-Destruct Capability			
	Redirect capable	Self- Destruct capable	Last Man-In-The-Loop Adjustment Time
Aircraft w/JDAM	NO	NO	1.5 min
Aircraft w/JSOW	YES	NO	15 sec (AGM-154C) 5.5 min (AGM-154A/B)
AVMRL w/ATACMS	NO	NO	5 min (note 1)
Ship w/LASM	NO	NO	4 min (note 1)
Ship w/TLAM	YES	NO	15 sec (Block IV) 12.5 min (Block III) (note 1)
UCAV w/JDAM	NO	NO	1.5 min
Note 1: This time corresponds to 100 nm traveled. The actual time is purely a function of the distance from the launch site to the target. MOE: The commander can direct a mission abort within 5 minutes of weapon's time on target.			

relatively short time of flight, the decision to abort or launch a weapon can be made close to the TOT. The TLAM Block IV, Tactical Tomahawk, and the AGM-154C, JSOW-C, plan for incorporating a two-way data link capability. Although there are no plans for a self-detonation option, these weapons could be sufficiently steered away from their targets at a time no later than fifteen seconds before TOT. Additionally, these weapons can be directed to new targets if sufficient time of flight remains.

The JDAM, LASM, AGM-154C, and Tactical Tomahawk perform within the prescribed MOE. Relative to one another, the TLAM Block IV and AGM-154C provide the greatest flexibility to the commander. The JDAM, ATACMS, LASM, AGM-154A, and AGM-154B make up the average grouping, while the TLAM Block III provides the least flexibility. Weapon systems are ranked according to their best representation for this category of comparison.

Risk to Man

The aversion to losing a fighting man permeates through the military, political, and civilian sectors of American society. As a result, U.S. military equipment and tactics are developed to accomplish the mission while attempting to minimize the risk to man. For this study, man is a portion of each of these weapon systems. Specifically, he is the military personnel associated with the host platform. The threat to his safety is dependent upon whether the host platform is operating within the threat's engagement envelope and the countermeasures of the host platform. An enemy IADS will focus on engaging the air delivery vehicles while the counterbattery systems will focus on targeting the surface, land or sea, based host platforms. Based on current capabilities, the surface-to-air threat range is set at 30 nautical miles, the surface-to-surface threat range is set at 50 nautical

miles, and the counterbattery detection range is set at 40 nautical miles.²⁹ Enemy air threat will not be considered. With these category parameters established, the threat IADS and counterbattery systems are centered about the target (table 11).

JDAM employment requires the manned host platform to operate within the 30 nautical mile IADS engagement envelope. In this environment, man's survival is challenged by visual, infrared, and radar-guided threat systems. These threats are expected to continue and possibly increase in intensity in the future. During Operation ALLIED FORCE in Kosovo, air crew were two-and-one-half times more likely to have had a surface-to-missile shot at them than during Operation DESERT STORM.³⁰

Table 11. Risk to Man		
	Threat	
	Counterbattery	IADS
Aircraft w/JDAM	None	High
Aircraft w/JSOW	None	Low
AVMRL w/ATACMS	Very Low	None
Ship w/LASM	Very Low	None
Ship w/TLAM	Very Low	None
UCAV w/JDAM	None	None
MOE: Man will not be lost because of the enemy's immediate reaction to the interdiction strike.		

JSOW has been designed to allow manned, fixed-wing aircraft to standoff from the threat. Although the aircraft may be detected by the threat IADS, the employment range of the JSOW allows weapons release outside the threat engagement envelope. Unlocated surface-to-air threat systems are the primary risk to man during JSOW operations. Again, the assumption is made that the air threat, enemy aircraft, is nonexistent for this study.

Although the risk to man continues, the loss of fixed-wing aircraft has significantly decreased during the past thirty-five years. From 1965 to 1968, ninety-seven aircraft were lost without bringing down the bridge at Thanh Hoa, North Vietnam.³¹ During the forty-three days of Operation DESERT STORM, thirty-two aircraft were lost to AAA, infrared, and radar threats.³² Finally, the war in Kosovo claimed a single U.S. aircraft to hostile fire, an F-117A Nighthawk. Although the loss of an aircraft was not unexpected, the fact that it was one of the most sophisticated was cause for surprise. In general, aircraft warning and reactive systems, along with employment tactics, have been effective in reducing the risk to man while operating in the threat envelopes.

The capabilities of the M270 launcher with ATACMS significantly reduce the counterfire threat to the personnel associated with the launcher. Due to employment ranges, the risk to man may be zero due to operations outside the enemy's counterbattery employment envelope. The mobility of the M270 launcher may make the targeting information from the enemy's weapons-locating radars (WLRs) a moot point. Although the launcher must be stationary for launch, it can quickly become mobile following ATACMS employment. The most significant survival factor of the host platform and its personnel is the system's random off-axis launch capability.³³ A WLR relies on the trajectory of a round to accurately determine the location of the host platform. This trajectory is based on the individual, ballistic profile that is associated with a specific artillery system. ATACMS does not fly a ballistic profile. Rather, ATACMS can be launched as much as thirty degrees off axis.³⁴ The missile is steered aerodynamically by electrically actuated control fins during the descent, modifying the flight path from a ballistic parabola. By offsetting the launch angle and descending in a semiballistic mode, it makes accurate targeting of the M270 host platform very difficult for the enemy.

A United States Navy ship is the common host platform for the LASM and the TLAM. The risk to man is associated with the personnel that are onboard the specific launch platform. Similar considerations as those made for the land-based weapon system, AVMRL with ATACMS, can be made with these sea-based systems. Rarely will a combatant ship operate inside the engagement envelope of a threat counterbattery system. Sea space allowing, the range capabilities of the LASM and TLAM will allow a range sanctuary for the operators. The movement of the host platform and the weapons' trajectory further complicate the counterbattery solution for the enemy. Both weapon

systems have the ability to be employed while the combatant ship is underway. Weapon launch can be off axis for both systems, including a vertical launch capability. The steering control section of the LASM allows for a semiballistic profile. The TLAM, powered by a turbofan or turbojet engine, flies a nonballistic profile. Following launch, the TLAM boosts and transitions to cruise, and then navigates along a preplanned route. These factors make targeting of the host platform very difficult for the enemy's counterbattery systems.

As the name implies, UCAV will not include a man in the host platform. Arguably, the nearest men at risk because of UCAV with JDAM operations are those at the UCAV launch site. Theoretically, a WLR could be employed to attempt to track the trajectory of the UCAV back to its origin to provide targeting information for the counterbattery fires. Effectiveness would be based upon whether the fires could range the launch site and the accuracy of the target location data. Obviously, and similar to manned aircraft, the UCAV does not fly a ballistic profile. This type of enemy immediate reaction would be unrealistic. Rather, the enemy would focus his efforts, by way of his IADS, to destroy the host platform. The possible destruction of the UCAV host platform by the enemy results in no risks to man.

The risk to man category requires subjective analysis. In response to the MOE, history has shown that aviators associated with manned, fixed-wing aircraft have been lost to the enemy's immediate reaction to an interdiction strike. It can be anticipated that as long as man continues to operate within an enemy's engagement envelope, there will be a substantial risk of losing both man and aircraft. Abiding strictly with the conditions set for this category, JSOW employment should always be outside the enemy's

engagement envelope. We should never lose a man during JSOW operations. The reality is that intelligence is never perfect, resulting in the possibility that some threat systems are unlocated. The possible loss of man as a result of employing the surface-based systems or UCAV with JDAM is extremely remote. Historically, there has been no host platform loss of man, because of the enemy's immediate reaction, associated with TLAM and ATACMS weapon employment. This trend is expected to continue and include the operators of the ship with LASM and the UCAV with JDAM weapon systems.

Relative to one another, the manned aircraft with JDAM poses the greatest risk to man. The risk associated with JSOW employment is substantially lower. Finally, the three surface-based systems' risk to man is very remote while the UCAV related risk is nonexistent. A common sense approach is used for the relative conclusions of this category. Man is either placed at risk by the immediate reaction of the enemy or he operates from an unassailable sanctuary. There is no average or middle ground.

Synopsis of Analysis

A synopsis of this analysis by comparative category is depicted in table 12. As emphasized initially with this study, the focus is on manned fixed-wing interdiction performance as compared to all of the other weapon systems. Conclusions from this analysis will be drawn in chapter five.

Table 12. Weapon Systems Summary								
	Pd	CEP	Response Time	Reach	Survival	Cost	Redirect Destruct	Risk to Man
Aircraft w/JDAM								
Aircraft w/JSOW								

ATACMS w/ATACMS								
LASM w/LASM								
TLAM w/TLAM								
JCAV w/JDAM								
Notes:  – Performed above the average of the weapons systems – Performed at the average of the weapons systems – Performed below the average of the weapons systems MOE (Pd): A single weapon achieves no less than a Pd of .7 (70 percent). MOE (CEP): A weapon's CEP is no greater than 15 meters (50 feet). MOE (Response Time): Weapon's effect in response to tasking requires no more than four hours. MOE (Reach): A weapon system's effective reach provides worldwide coverage. MOE (Survival): A weapon system is not denied successful mission execution because of hostile actions or adverse weather. MOE (Cost): Individual weapon's cost is no more than 1 million dollars. MOE (Redirect/Self-destruct): The commander can direct a mission abort within five minutes of weapon's time on target. MOE (Risk to Man): Man will not be lost because of the enemy's immediate reaction to the interdiction strike.								

¹Christian Bohmfalk, "New Seeker May Find A Home On JDAM Or Other Missiles And Bombs," *Inside the Navy*, 18 December 2000, 1. An F-16 test flight on 20 November 2000 dropped a JDAM equipped with the DAMASK several miles away from the target. The weapon, set in the GPS denied mode – punched a hole in a target nearly dead center, relying only on JDAM's inertial navigation system and DAMASK's template-matching capability.

²Federation of American Scientists, *ATACMS Block II / Brilliant Antiarmor Technology (BAT)*.

³Periscope, *LASM Land Attack STANDARD Missile*.

⁴Federation of American Scientists, *BGM-109 Tomahawk*.

⁵Ibid.

⁶Federation of American Scientists, *Joint Direct Attack Munition (JDAM) GBU-29, GBU-30, GBU-31, GBU-32*. This publication identifies the 3 meter accuracy requirement. The test on 20 November 2000, as reported by *Inside the Navy*,

demonstrated the DAMASK's template matching ability to achieve that accuracy. Additionally, USNI's database (Periscope) of the GBU-31 JDAM identifies non-DAMASK JDAM's accuracy as 13m, although actual test results are much better. In December 1996, two JDAM equipped Mk-84s were dropped from F-16s at the USAF test range at Eglin AFB, FL. The first Mk-84 was released from 20,000 ft at Mach .8, and impacted six meters from the target. The second Mk-84 had a miss distance of 3 meters.

⁷Periscope, *AGM-154 JSOW (Joint Standoff Weapon)* [database on-line] (USNI Military Database, April 1998, accessed 13 September 2000); available from <http://www.periscope.ucg.com/docs/weapons/missrock/landatk/w0004368.html>; Internet.

⁸Ibid.

⁹Federation of American Scientists, *M39 Army Tactical Missile System (Army TACMS)* [database on-line] (Military Analysis Network, February 2000, accessed 12 December 2000); available from <http://www.fas.org/man/dod-101/sys/land/atacms.html>; Internet.

¹⁰Leighton Duitsman, interview by author, 21 February 2001, telephonic and electronic mail correspondence, U.S. Army Field Artillery School, Fort Sill, OK. Mr. Duitsman is responsible for the ATACMS Block II and IIA programs.

¹¹Raytheon Missile Systems, *Land Attack Standard Missile: Ready for EMD*, (Tucson: Sound & Sight Media, 1998), video.

¹²Periscope, *BGM-109A Tomahawk Land-Attack Missile (TLAM)*.

¹³Federation of American Scientists, *BGM-109 Tomahawk*.

¹⁴Periscope, *X-45 UCAV (Unmanned Combat Air Vehicle)*. The performance capability of the X-45 UCAV is to include a high subsonic speed and medium to high operating altitude.

¹⁵Periscope, *LASM Land Attack STANDARD Missile*.

¹⁶Timothy Hossack, interview by author, telephonic and electronic mail correspondence, 18 January 2001, U.S. Army Field Artillery School, Fort Sill, OK. Maj Hossack is responsible for the ATACMS Block I, IA, and unitary programs. Additional information: 7 variables affect the total mission time: (1) time at the Common Ground Station (CGS), best 2.2 min, worst 4.2 min, (2) Airspace Coordination, best 0 min, worst 21.5 min, (3) FA BDE TOC, best 5 min, worst 1.5 min, (4) BN TOC, best .4 min, worst 1.4 min, (5) BTRY TOC, best 4 min, worst 1.4 min, (6) M270, best 1.5 min, worst 7.9

min, (7) time of flight for missile, best 1.4 min, worst 8.9 min. 8.9 minutes equates to a 300 km shot and a resultant average velocity of 1080 kts.

¹⁷Periscope, *BGM-109A Tomahawk Land-Attack Missile (TLAM)*.

¹⁸John F. Moran, interview by author, electronic mail correspondence, 15 February 2001, Science Applications International Corporation, Patuxent River, Md. Mr. Moran, as an employee of SAIC, works directly with the U.S. Navy's Tomahawk Program Office at Naval Air Station Patuxent River, MD.

¹⁹Periscope, *X-45 UCAV (Unmanned Combat Air Vehicle)*.

²⁰Periscope, *BGM-109A Tomahawk Land-Attack Missile (TLAM)*.

²¹Lisa Troshinsky, "Navy's Surface Fire Support Lacking," *Navy News & Undersea Technology*, 11 December 2000, 2.

²²Alliant Techsystems, Inc., *ATK Family of SAASM GPS Receivers* [database on-line] (September 1999, accessed 26 January 2001); available from <http://www.atk.com/defense/descriptions/products/smart-weapons/saasm-gps/default.html>; Internet.

²³Federation of American Scientists, *BGM-109 Tomahawk*.

²⁴J. F. Murphy, *Replacing Combat Pilots With Joysticks* [database on-line] (Special to PlanetGov.com, December 4, 2000, accessed 12 December 2000); available from <http://ebird.dtic.mil/Dec2000/s20001204replacing.html>; Internet.

²⁵Federation of American Scientists, *Joint Direct Attack Munition (JDAM) GBU-29, GBU-30, GBU-31, GBU-32*.

²⁶Federation of American Scientists, *AGM-154A Joint Standoff Weapon (JSOW)*.

²⁷Periscope, *LASM Land Attack STANDARD Missile*.

²⁸Michael A. Dornheim and David A. Fulghum, "New Tomahawks To Be Retargetable." *Aviation Week & Space Technology*, 31 August 1998, 35.

²⁹James Hicks, ST 100-7, *OPFOR Battle Book* (Fort Leavenworth, KS: TRADOC Threat Support Directorate, 2000), 3-15 through 3-19. Although these numbers do not replicate the forces of a particular nation, they do signal a robust defensive order of battle. One of the largest of the multiple rocket launchers, the 300 millimeter SS-80 has a range of 49 nautical miles. The SA-2 Guideline, although an old surface-to-air missile system, has one of the longest ranges at 27 nautical miles. The AN/TPQ-37 WLR has an effective detection range of rockets and cannon artillery out to 50 kilometers (27 nautical miles). The SS-1C Scud range capability was not included

because its employment requires a sixty minute reaction time. This time delay is not within the category intent of “immediate reaction to the interdiction strike.”

³⁰Michael E. Ryan, Gen. Chief of Staff U.S. Air Force, *Chiefs of Staff Status of Forces to House Armed Services Committee (HASC)*, testimony, 21 October 1999. Each year at the end of the Congressional Session, HASC holds hearings with the Chiefs of Staff on Status of Forces, an update to the MilDepts Testimony in March at the beginning of the annual budget process.

³¹U.S. Army Command and General Staff College, *Advanced Operational Warfighting*, ed. Phillip B. Davidson, *Totus Porcus (The Whole Hog 1972)* (Fort Leavenworth, KS: U.S. Army Command and General Staff College, 2000), L7-1-15.

³²National Security and International Affairs Division, *Operation Desert Storm Evaluation of the Air Campaign* (Washington, DC: United States General Accounting Office, 1997), 94. Ten aircraft were lost to radar SAMs, 13 to IR SAMs, and 9 losses were attributed to AAA.

³³David L. Johnson, “ATACMS Block IA Fires Deep and Deadly,” *Field Artillery*, March-April 1997, 37.

³⁴Periscope, *MGM-140 ATACMS (Army Tactical Missile System)*.

CHAPTER 5

CONCLUSIONS

The requirements and considerations of a preplanned interdiction mission are important elements of the commander's targeting decision-making process. This study focused on eight of the most significant points, or categories, to compare various interdiction weapon systems. The comparative categories can be broken down into two distinct groups. The first group encompasses the fundamental capabilities of a weapon system to accomplish the mission. In selecting the possible weapon systems, the commander must first look at the essential categories of probability of destruction, reach, and survival. The second group is composed of accuracy, response time, cost, and redirect and self-destruct ability. This group is not fundamental to the successful functioning of a weapon system, rather, it comprises the additional considerations a commander must make. The risk to man category does not fit cleanly into either group and will be discussed separately.

A weapon system's probability of destruction, reach, and survival elements are critical to its success. If any one of these three results in failure or is unattainable, the interdiction mission is a failure. By equally weighting these three fundamental categories, the weapon systems can be ranked (table 13). The manned, fixed-wing aviation-based weapon systems rank in the upper half of the grouping. The ship with TLAM and the AVMRL with ATACMS also share this ranking. This implies that although manned, fixed-wing aviation can conduct the preplanned aviation mission, there are other weapon systems that are just as capable.

Table 13. Fundamental Categories Summation					
	Pd	Reach	Survival	Value	
 Aircraft w/JDAM				7	
 Aircraft w/JSOW				7	
 AVMRL w/ATACMS				8	
 Ship w/LASM				5	
 Ship w/TLAM				7	
 UCAV w/JDAM				6	
 Notes:	– Performed above the average of the weapons systems – Performed at the average of the weapons systems – Performed below the average of the weapons systems A value of three is given for above average, two for average, and one for below average.				

A similar ranking can be conducted with the categories that the commander must take into consideration. Again, with equal weight being given to each category, it can be seen that manned, fixed-wing aviation is well suited, relatively, to conduct the interdiction mission. Other weapon systems, such as the Ship with TLAM and the UCAV with JDAM perform similarly well in the “commander’s considerations” grouping (table 14).

Risk to man has historically been a contentious issue. It is expected, by both military and civilian leadership, that U.S. military operations will continue to include the management of risk to its service members. This is not to say that operations will be terminated, or significantly changed, if there is an element of risk to man. It is an assessment by the commander of risk versus return. Policy makers continue to ponder

Table 14. Consideration Categories Summation					
	CEP	Response Time	Cost	Redirect Destruct	Value
 Aircraft w/JDAM					10
 Aircraft w/JSOW					10
 AVMRL w/ATACMS					8
 Ship w/LASM					9
 Ship w/TLAM					10
 UCAV w/JDAM					10
	Notes: – Performed above the average of the weapons systems – Performed at the average of the weapons systems – Performed below the average of the weapons systems A value of three is given for above average, two for average, and one for below average.				

the American public's capacity to absorb lethal casualties. The public's real question is not if Americans will serve and die, but if policy formulators make wise decisions when intervening. The worthiness of the cause for sacrifice is paramount to this issue.¹

"Casualties, although abhorrent, become acceptable to the extent that they're viewed as accomplishing something important within an appropriate period of time."²

The blanket assumption that Americans will not tolerate casualties collapses upon close scrutiny. Americans have shown their willingness to sustain high casualties if they believe the risk is worthy. Americans are not risk adverse, but they recoil from the notion that the lives of their service personnel might be sacrificed in vain. If a decision to intervene militarily is based on vital national security interests, or to avert a preventable humanitarian disaster, then public anger over American deaths will be directed toward the adversary. But if the intervention rationale is suspect then ire will turn against the policy makers responsible for putting U.S. troops in danger.³

With this understanding of the American public's demand of its policy makers, a similar expectation can be deduced at the operational level. This study has reinforced the fact that manned, fixed-wing aviation is capable of conducting the preplanned interdiction mission. The comparative assessment has also revealed that other weapon systems are capable, or soon will be capable, of executing the mission just as effectively. The American public will support senior leadership foreign intervention decisions as long as the sacrifice is worthwhile. The possible loss of aircrew has been the main potential sacrifice while conducting the interdiction missions. Historically, this has been accepted by society because manned, fixed-wing aviation has been the only means of striking all types of preplanned interdiction targets. However, due to technological evolution of weapon systems, it can be expected that the American public is going to scrutinize the selection of preplanned interdiction means. Why put a man in harms way when an unmanned system can be just as effective? The "cause for the sacrifice" is an issue that must be handled at the strategic level. Operationally, the military commander's responsibility is to select a weapon system that achieves the tasking and minimizes the risk of sacrificing a warfighter.

Manned, fixed-wing aviation should not expect to continue to conduct the preplanned interdiction mission into the second decade of the twenty-first century. The most promising replacements are the Ship with TLAM and the UCAV with JDAM weapon systems. The TLAM may nearly replace the requirement for manned, fixed-wing aviation in the preplanned interdiction mission by 2005. Its shortcoming will be primarily in its lack of global reach, and to a lesser extent, its cost. The limitation of only affecting targets within approximately 1000 nautical miles of the coastline will require a

global reach system to cover the remainder. The TLAM weapon cost, although significant when compared with a JDAM, is well within the average of other precision-guided munitions. By including the operational costs of the manned, fixed-wing aircraft, the TLAM's cost could also be significantly mitigated.

The UCAV provides the most promise to fully replace manned, fixed-wing aviation in the preplanned interdiction mission. The X-45 is expected to IOC in 2010. From the probability of destruction comparative category, the UCAV with JDAM performs below manned, fixed-wing aircraft with JDAM due to limited weapons capacity. The 2,000-pound GBU-31 is not expected to fit in the X-45. However, the development of new weapons is expected to resolve this shortcoming. The UCAV designers expect that research into smaller munitions will bear fruit by 2010, leading to much smaller weapons with as much explosive power as today's 1,000- and 2,000-pound bombs.⁴ Survivability of the UCAV can be expected to be better than a manned, fixed-wing aircraft because of the design benefits associated with removing the man and the cockpit from the platform. Additionally, acquisition officials estimate that if the average UCAV lasts for 8-9 missions it will pay for itself.⁵ "UCAVs offer more flexibility than a cruise missile while still affording no risk to human life, and the potential affordability is significantly greater than operating manned aircraft."⁶

With the focus on the mission, what are the benefits of using manned, fixed-wing aviation-based systems over other weapon systems? The most obvious reason is familiarity. Historically, manned fixed-wing aviation has been the primary preplanned interdiction means. It is comfortable and familiar mission for aviators. Likewise, it is difficult for the services to adjust from a mind-set that has been engrained for several

generations. Additional benefits of manned, fixed-wing aviation may include the issues of situational awareness, reconnaissance, and bomb damage assessment (BDA) while conducting the preplanned interdiction mission. However, counterarguments could be made that the sensors associated with cruise missiles and UCAVs can provide just as good information, if not better. Likewise, that the fog of war may be less intense when the human element is not physically located in the middle of the fight. As for accurate BDA, there are currently better sensors available than those associated with manned, fixed-wing aircraft. These issues, while beyond the scope of this project, are worth additional investigation and study.

Dangerous missions for manned, fixed-wing aircraft are numerous and growing. The execution of a preplanned interdiction mission is no exception, as the loss of an F-117 during Operation ALLIED FORCE made painfully aware. Technological advancements in the U.S. military are reducing the need for manned, fixed-wing aircraft to conduct the preplanned interdiction mission. The American public demands that leaders make wise decisions. With weapon systems of similar capabilities, they expect commanders to select and employ those weapon systems that execute the mission and minimize the risk to their Soldiers, Sailors, Airmen, and Marines. By 2010, the commander will not have a good reason to risk manned, fixed-wing aviation to conduct the preplanned interdiction mission. It is the responsibility of the services to determine the future mission focus and future mission priorities of manned, fixed-wing aviation. The determination from this study is that, in light of *Joint Vision 2020*, manned, fixed-wing aviation should expect to be phased out of the preplanned interdiction mission. This process began in 1991 during Operation DESERT STORM with the introduction of

TLAM. It will be complete in about 2010 when the X-45 becomes fully operational capable. UCAVs and missiles will become the principal elements of the U.S. military's preplanned interdiction effort. Obviously, there is an element of risk associated with change, any change. However, "Victory smiles upon those who anticipate the changes in the character of war, not upon those who wait to adapt themselves after the changes occur."⁷

¹Richard K. Kolb, "Will America Accept Casualties in Peacekeeping Operations?" *VFW*, March 2001, 28.

²Tom Bowman, "Cost of War: A New Accounting," *Baltimore Sun*, 22 March 2000, 21.

³James H. Anderson, "The Low Casualty Dogma," *Semper Fi* (Marine Corps Commemorative booklet) 2000, 178.

⁴Richard M. Clark, *Uninhabited Combat Aerial Vehicles, Airpower by the People, For the People, But Not with the People* (Maxwell Air Force Base, AL: Air University Press, 2000), 49. Cadre Paper No. 8 at the College of Aerospace Doctrine, Research and Education.

⁵David A. Fulghum and Robert Wall, "Long Hidden Research Spawns Black UCAV," *Aviation Week & Space Technology*, 25 September 2000, 28.

⁶Richard M. Clark, 47. Quotation from LtCol Clarke's interview of Colonel Leahy at DARPA.

⁷ Richard M. Clark, 77. Quotation from airpower pioneer Giulio Douhet.

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