



Time-Critical Targeting

Predictive versus Reactionary Methods:
An Analysis for the Future

Lt Col Gregory S. Marzolf, USAF

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Marzolf

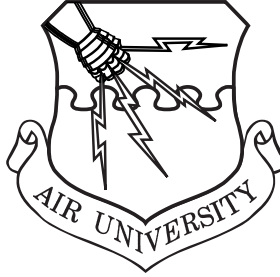
Predictive versus Reactionary Methods: An Analysis for the Future

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Time-Critical Targeting
*Predictive versus Reactionary Methods:
An Analysis for the Future*

GREGORY S. MARZOLF
Lieutenant Colonel, USAF

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Please send inquiries or comments to
Chief of Research
Airpower Research Institute
CADRE
401 Chennault Circle
Maxwell AFB AL 36112-6428
Tel: (334) 953-5508
DSN 493-5508
Fax: (334) 953-6739
DSN 493-6739
E-mail: cadre.research@maxwell.af.mil

Contents

<i>Chapter</i>		<i>Page</i>
	DISCLAIMER	ii
	FOREWORD	vii
	ABOUT THE AUTHOR	ix
	ACKNOWLEDGMENTS	xi
1	INTRODUCTION	1
	Notes	5
2	BACKGROUND	7
	Notes	23
3	REACTIVE APPROACH	27
	Notes	47
4	PREEMPTIVE APPROACH	51
	Notes	70
5	RESULTS AND CONCLUSIONS	75
	Notes	83
	GLOSSARY	85
	BIBLIOGRAPHY	89

Illustrations

<i>Figure</i>		
1	Kill chain	8
2	Preemptive kill chain	52
	<i>Photograph</i>	
	Low-cost persistent area dominance design	63
	Low-cost persistent area dominance's search constellation	66

Tables

1	Summary of sensor capabilities	14
2	Low-cost autonomous attack system search area for a fleeing vehicle	34

Foreword

Targeting has long been a primary concern for our air forces; it took a thousand plane raids in World War II to destroy a factory. The revolutionary gains in precision weapons of the last dozen years have eliminated the requirement for the air force armada and highlighted new areas of improvement, particularly a desire to destroy more difficult, fleeting targets of opportunity. As Lt Col Gregory S. Marzolf points out in this study of new targeting parameters, the Air Force became aware during Operations Desert Storm and Allied Force of its inability to find and destroy emerging targets before they disappeared. Marzolf sees the Air Force moving towards solutions, particularly with the concept of reactive methods, wherein identified targets are attacked by loitering aircraft. The Air Force is working to improve its persistent intelligence, surveillance, and reconnaissance platforms to identify the targets, its communications network to get the information to a shooter, and its weapons to quickly engage the target.

On the other hand, work in this area suggests some 15–20 years for implementation, and Colonel Marzolf advocates a temporary solution for engaging time-critical targets and suggests a methodology he calls a preemptive or predictive approach. He bases his idea on the need for an analysis of enemy activity to the point of accurate prediction and employment of a flying platform that has long-loiter capability and incorporates sensors to detect, locate, and identify targets that will be destroyed by miniature munitions that it carries. He identifies the low-cost persistent area dominance (LOCPAD) system, now under development, as the one that will tie intelligence with a kinetic mechanism to finalize the time-critical (or time-sensitive as it is called in 2004) targeting.

The author outlines the issue in an introduction and has a background chapter that explains the current system, which provides a useful description of sensors, fusion of information, shooters, and weapons. He explains the current reactive method and identifies various system weaknesses and strengths. His main theme of a preemptive approach describes in great detail the projected employment of LOCPADs as a very effective system

for time-critical targeting. Marzolf insists that persistence of surveillance is crucial, especially when Airmen directing the air war in Iraq used persistence surveillance to identify and effectively target the illusive Iraqi insurgents.

Time-Critical Targeting: Predictive versus Reactionary Methods, An Analysis for the Future was originally written as master's thesis manuscript for Air University's School of Advanced Airpower Studies—renamed School of Advanced Air and Space Studies in September 2002. The College of Aerospace Doctrine, Research and Education (CADRE) is pleased to publish this study as a CADRE Paper and thereby make it available to a wider audience within the Air Force and beyond.



DANIEL R. MORTENSEN

Chief of Research

Airpower Research Institute, CADRE

About the Author

Lt Col Gregory S. Marzolf (BSCE, University of Tennessee at Knoxville; MAS, Embry-Riddle Aeronautical University; MAAS, School of Advanced Airpower Studies; MMOAS, Air Command and Staff College) returned to active flying status in 2004 and currently serves as the chief of Safety, 388th Fighter Wing, Hill AFB, Utah. He is a senior pilot with more than 2,100 flying hours and earned his commission as a distinguished graduate from the Air Force Reserve Officer Training Corps, University of Tennessee at Knoxville in June 1988. Immediately preceding this position, he was chief of the Strategy and Concepts Branch, AF/XOX, Air Staff, Pentagon. Colonel Marzolf entered active duty as a student pilot in the European-North Atlantic Treaty Organization Joint-Jet Pilot Training Program at Sheppard AFB, Wichita Falls, Texas, earning a follow-on assignment to Luke AFB, Phoenix, Arizona, where he learned to fly the F-16 Fighting Falcon. After this tour Marzolf spent the next four years operational in the F-16 at Osan AB, Republic of Korea, and Spangdahlem AB, Germany. In Germany Colonel Marzolf flew and led 56 combat missions in Operations Northern Watch and Deny Flight. Leaving Germany in 1995 for Cannon AFB, Clovis, New Mexico, he helped the 522d Fighter Squadron (FS) transition from F-111s to F-16s and, after a short time, departed to attend the USAF Weapons Instructor Course (WIC) at Nellis AFB, Las Vegas, Nevada. Colonel Marzolf returned to Cannon AFB in June 1996 and served as chief of weapons in the 523d FS. Following this tour in 1998, he returned to WIC as a weapons instructor in the F-16 division. While at Nellis AFB, he specialized in weaponeering and mission attack planning, primarily using Joint Munitions Effectiveness Manuals.

Acknowledgments

I acknowledge several people for their support and help. My advisors, Dr. David R. Mets and Maj John Terino, were instrumental in providing guidance and much help on writing. Their efforts as advisors and readers many times go unnoticed at the School of Advanced Airpower Studies while working with many students who all need fast response to make the deadline. Thank you for your time and effort. Also, Colonel Leonpacker and his staff at the Air Force Research Laboratory, Munitions Directorate at Eglin AFB, Fort Walton Beach, Florida, were helpful in providing insight as to how advanced weapons work, their associated problems, and the acquisition process. I thank Gregory Jenkins and Ben Plenge, also at Eglin, for conceptualizing the idea of a persistence weapon and its associated concept of operations.

I thank my wife, Carole, and our four “butterflies” for their patience, love, and support during this trying time. They always provided me a reason to take a break, even when I was not ready for one. Their smiles, hugs, and tugs, while sometimes an annoyance, kept this project in perspective. To them this project is dedicated.

Chapter 1

Introduction

Thus, it is said, one who knows the enemy and knows himself will not be endangered in a hundred engagements. One who does not know the enemy but knows himself will sometimes be victorious, sometimes meet with defeat. One who knows neither the enemy nor himself will invariably be defeated in every engagement.

—Sun Tzu
The Art of War

Some 2,500 years after *The Art of War* was written, today's war makers continue to realize that knowing the enemy is essential to success in war. However, experience has shown that, while Sun Tzu's overused dictum is true, it certainly is no panacea. In his book, *On War*, Carl von Clausewitz asserted that "the general unreliability of all information presents a special problem in war: all action takes place, so to speak, in a kind of twilight, which, like fog or moonlight, often tends to make things seem grotesque and larger than they really are."¹ He further suggests that because of this uncertainty, the "only situation a commander can know fully is his own."² Compounding this problem is the fact that an enemy reacts and adapts to changing circumstances, so even if one had perfect information, its usefulness expires quickly with time. The solution to the problem is to recognize that while perfect information may be the desired goal, the realistic and essential goal is to have better information relative to that of the enemy.

Because of this fact, the United States has invested substantially in reconnaissance and surveillance platforms that allow military leaders and analysts to observe the enemy, select targets, and later destroy them through the application of force. However, in attempting to neutralize this capability, the enemy has learned to use a variety of techniques, some of which include hiding, deception, and movement. This behavior

highlights the adage, “If seeing a target is tantamount to killing it, then seeing others and staying hidden become [sic] the two reigning requirements of combat.”³

While there is nothing new to this adage, experiences in Operation Desert Storm and Kosovo have highlighted the need to nullify the enemy’s ability to become a chameleon. In Operation Desert Storm, Scud missile transporter-erector-launcher (TEL) vehicles constantly eluded coalition efforts to find them as they launched 40 missiles into Israel in an effort to destroy the alliance that President George H. W. Bush painstakingly constructed. Even though Gen Charles A. “Chuck” Horner, joint force air and space component commander (JFACC), prioritized the destruction of Scud TELs to a high level and dedicated more than 4,700 sorties to the effort, postwar intelligence showed no proof that a single Scud was destroyed.⁴

Later in Kosovo the problem became evident once again. Gen Wesley Clark, the joint force commander (JFC) for the operation, said, “Even with the intelligence, surveillance, and reconnaissance provided by the Air Force, it was still impossible to determine what was inside vehicles and buildings and under camouflage nets and bridges. Consequently, these ‘targets’ did not get bombed. High-tech delivery platforms were excellent, but intelligence on many targets was inadequate.”⁵ This difficulty was aggravated because of Kosovo’s mountainous terrain, which enabled mechanized forces to disperse and hide virtually anywhere.⁶ Even when targets were identified, many times aircraft could not respond fast enough to take advantage of the situation because the targets were located in or behind heavy air defenses that required air-to-air and suppression of enemy air defense (SEAD) aircraft to accompany the strike aircraft to the target. Unfortunately, some targets were left unscathed because support aircraft were not always available in sufficient numbers.⁷ General Clark stated, “Targeting time against time-urgent critical targets for F-15[E] missions was much longer than it should have been. Some progress was made in this area during the war, but the planning must minimize time to ‘reflex’ aircraft.”⁸

A RAND analysis highlights General Clark’s frustration and makes two recommendations for the coercive use of airpower

in future conflicts. One recommendation suggests that because the North Atlantic Treaty Organization's (NATO) attempts to systematically and progressively destroy Yugoslav military forces were largely unsuccessful, the United States and its allies must improve their capabilities to locate, identify, and rapidly strike mobile enemy targets.⁹ The RAND study emphasized that sensors, surveillance and reconnaissance platforms, target processing and dynamic control measures, weapon systems, and concepts of operation must be developed to improve the ability to attack enemy armor and artillery forces when dispersed, hidden, or in urban terrain.¹⁰ Fortunately, the USAF is heeding RAND's advice.

To overcome and destroy elusive surface targets, a reactive or preemptive method may be used.¹¹ Reactive methods attempt to detect, locate, and identify a target in real time and assign an aircraft or weapon to kill it. Since the targets are elusive, the faster one can proceed from detecting a target to killing it (oftentimes referred to as the kill chain), the greater the chance for success. The USAF is pursuing this reactive approach by adopting a "systems of systems" sensor-to-shooter architecture that eliminates many of the traditional barriers that slow down the kill chain.¹²

On the other hand, the preemptive method is enabled by persistence—the ability of an aircraft or munition to loiter over an area for a long time—and when discovering a target, to kill it quickly. Traditionally, this method was not viable for two primary reasons. First, aircraft could not loiter for long periods of time in enemy territory because of their limited fuel capacities.¹³ In addition, such missions promised to be long and dull, hardly an efficient use of aircraft, especially since support aircraft would also be required to suppress the threat. In the end, many aircraft would be needed to conduct even a small operation—all waiting for the enemy to move and, thereby, relinquishing the initiative unto the enemy.

Second, intelligence was not good enough to predict adequately where the enemy would act. Assets loitering over the wrong territory did not prove worthwhile, which resulted not only in wasted time and fuel but also in the forfeit of other operations. Today, however, with technological advances being

made that enable intelligence to predict the enemy's next move, along with stealthy aircraft, unmanned combat aerial vehicles (UCAV), loitering unmanned aerial vehicles (UAV), and miniaturized weapons with automatic-target-recognition (ATR) algorithms, a preemptive approach may be feasible.

This study investigates the feasibility of the preemptive method and determines whether or not the USAF should pursue the new paradigm through purchase of low-cost, miniature, persistent, air-to-ground weapons for use in engaging time-critical targets (TCT). To conduct the analysis, a four-step process is used. First, research is conducted to determine which future aircraft, spacecraft, and weapons are most promising for use in the 2010 time frame. This time frame is selected because it coincides with the projected completion of the USAF's Transformation Force. According to Maj Gen John L. Barry, the USAF's director for Strategic Planning, the Transformation Force is a "gap filler" that will provide critical capabilities until the Vision Force, which is heavily reliant on space assets, is implemented in the 2020 to 2025 time frame.¹⁴ Further, Gen Robert H. Foglesong, the USAF's vice chief of staff, said, "This midpoint, the first incremental leap in capability, would see a force that is a more dynamic and precise aerospace [air and space] force. The Transformation Force would have enhanced combat, airlift, and intelligence, surveillance, and reconnaissance (ISR) fleets, be lighter and more agile, and include a more robust space force."¹⁵ Because of this effort to transform the force into a more effective fighting force, Air Combat Command's (ACC) global attack mission area plan, which addresses USAF future force requirements, has identified precision munitions and combat or target identification as primary focus areas.¹⁶ The need for a flexible, time-critical architecture that includes rapid identification and continuous, real-time, sensor-to-shooter links are also embraced in the primary focus areas.¹⁷ Since these sources suggest that the USAF wants to correct the time-critical targeting problem by the year 2010, it follows that this study should also use a similar time frame. As a side benefit, the use of a 2010 target date reduces the need for speculation regarding future capabilities, thus keeping the assessment more realistic.

Second, after determination of the most promising aircraft, spacecraft, and weapons, they are categorized for use in the reactive or preemptive method. For example, while a hypersonic missile would probably be used for reactive targeting, a loitering munition would likely best fit preemptive use. Third, evaluation criteria include but are not limited to effectiveness, cost, ease of future integration, and adaptability. Because the areas of evaluation are qualitative in nature (except for cost), the study focuses not on whether preemptive systems can destroy 90 percent or only 50 percent of TCTs, but whether preemptive systems can enhance current and future capabilities, which helps to destroy TCTs at a reasonable cost. Fourth, based on the findings, a course of action will be recommended for the USAF to pursue.

To answer these questions, many sources were researched to find pertinent evidence. Some of these sources included current and proposed future joint and USAF doctrine, concepts of operations, books on technology and war fighting, periodicals, statements and speeches by senior military and government officials, interviews, articles written by established defense institutions, and USAF goals and long-range plans. After reading the source material and cataloging them, the pertinent evidence was organized by topic and evaluated by date and the reliability of source. Primary sources have priority over secondary sources. In addition, when evidence conflicts, the most recent evidence is used. Because technological advancements during the past few years sparked the advent of many new capabilities, most books written before 1998 are not very useful.¹⁸ For this reason, second-hand sources such as the Internet and current periodicals are referenced because they provide the most up-to-date information. To ensure accuracy, however, interviews, e-mail, and telephone calls were made to reputable sources to help confirm questionable evidence.

Notes

Most of the notes for this chapter and the following chapters appear in shortened form. For full details, see the appropriate entries in the bibliography.

1. Clausewitz, *On War*, 140.
2. *Ibid.*, 84.

3. Gompert, *1998 Strategic Assessment*.
4. Jamieson, *Lucrative Targets*, 49–50; Fox, “Dynamic Targeting,” 41; and Gordon and Trainor, *The General’s War*, 246–47.
5. Hutcheson, *Unified Aerospace Power in the New Millenium*, 13.
6. Metz, “Asymmetric Warfare.”
7. Fox, “Dynamic Targeting,” 35.
8. Hutcheson, *Unified Aerospace Power in the New Millenium*, 14.
9. Hosmer, *The Conflict over Kosovo*.
10. *Ibid.*
11. Air Force Joint Pamphlet 10-225, *Targeting: The Joint Targeting Process and Procedures for Targeting Time-Critical Targets*.
12. Fleming and Paone, “Air Force Developing New ‘Constellation’ of Integrated Capabilities.”
13. Air-to-air refueling would degrade the effort because persistence would be compromised when the aircraft left enemy territory to join with the tanker.
14. Correll, “The Vision Force.”
15. Butler, “The CONOPS with a Difference.”
16. Headquarters Air Combat Command, *Combat Air Force’s Global Attack Mission Area Plan—FY2002*, 4.
17. *Ibid.*, 18, 22.
18. Moore’s Law, named after Intel Corporation’s cofounder Gordon Moore, asserts that the capability to process data is doubling every 18 months. Most experts expect the law to remain valid for at least two more decades.

Chapter 2

Background

They [the enemy] will hide from detection, shield themselves, attack our weapons, and strive in every possible way to dislocate our fires. They will change the political context, disperse into cities, and dare us to apply our firepower into the midst of noncombatants. They will refuse to be detected, located, tracked, targeted, and assessed.

—Robert R. Leonhard
*The Principles of War for
the Information Age*

This chapter provides the necessary background to understand the complex nature of time-critical targeting, defines TCTs and their behavior, and gives an in-depth analysis of the kill chain. Throughout the analysis, time-critical targeting problems are examined and, for clarity, are summarized. Solutions to these problems are also emphasized.

Definitions

According to the Air Land Sea Application (ALSA) Center, a TCT is “a lucrative, fleeting, land, or sea target of such high priority to friendly forces that the JFC or component commander designates it as requiring immediate response.”¹ Sometimes these targets are also called flex targets, emerging targets, or time-sensitive targets.² ALSA separates TCTs into two categories, planned and immediate. Planned TCTs, normally fixed and immobile, are not addressed. On the other hand, immediate TCTs are mobile, require established procedures to seek and destroy, and are focused on in this study.³ Immediate targets limit their exposure time on the battlefield by moving quickly and using deception. Some examples are Scud missile TELs, surface-to-air missiles (SAM), mobile rocket launchers, and

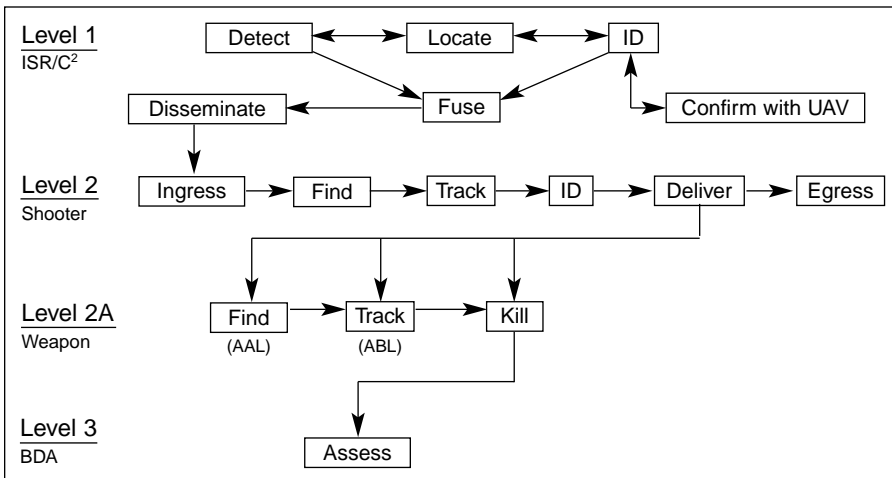
mobile command and control (C²) vehicles.⁴ For the remainder of this study, any reference to TCTs automatically implies immediate TCTs.

Kill Chain

Kill chain is the tooth-to-tail process that prescribes the sequence of events needed to find, engage, and destroy targets. Also included in the chain is the requirement for poststrike battle-damage assessment (BDA). For ease of discussion, the process has been segmented into four levels: ISR and C², shooter, weapon, and BDA (fig. 1).

Intelligence, Surveillance, and Reconnaissance and Command and Control

The TCT process begins by using various sensors and techniques to detect, locate, and identify a contact of interest (COI).⁵ Because clever adversaries have learned to minimize their sig-



AAL – acquire after launch
 ABL – acquire before launch
 C² – command and control
 BDA – bomb damage assessment
 ID – identify
 ISR – intelligence, surveillance, and reconnaissance
 UAV – unmanned aerial vehicle

Figure 1. Kill chain

natures and use tactics that can deceive certain sensors and because no one sensor can reliably detect in all environments, many different sensors with different capabilities are needed to obtain a high probability of detection and identification under varied conditions.⁶ In this study, sensors are categorized into two types—active and passive.

Active Sensors

Active sensors emit and collect energy reflected from an object. Processing and analyzing the returned energy obtains information about the object. Radar, a commonly used active sensor, typically uses three techniques to achieve this insight: synthetic aperture radar (SAR), moving target indicator (MTI), and foliage penetrating radar (FolPen).

SAR provides day and night, all weather, long-range surveillance and produces a photograph-like picture of the target area.⁷ Even with a picture containing a potential COI, experience has shown that in most cases full COI identification is not possible because of the picture's poor resolution.⁸ This fact and SAR's limited capability to quickly cover large amounts of territory because of the required advanced processing result in SAR being most useful for accurately pinpointing an object's position.

MTI detects vehicular movement by transmitting radar energy and measuring the shift in frequency of the reflected energy returning from an object.⁹ When a moving object is moving near or far from the radar, the reflected energy returning is compressed (higher frequency) or extended (lower frequency). This shift in frequency is called a Doppler effect and is easily measured. An advantage of MTI is that it can cover large amounts of territory in a small amount of time, which makes it ideal to detect unknown moving objects. MTI is also able to locate a moving vehicle accurately by creating a track on the object.¹⁰ Unfortunately, MTI has limited capabilities to identify. In Kosovo the Joint Surveillance Target Attack Radar System (JSTARS) could see vehicles moving, but it could not distinguish a tank from a tractor pulling refugees.¹¹ MTI adds a significant capability to detect and locate moving targets but not much else.

SAR and MTI radars are currently used on the E-8 JSTARS, U-2R, RQ-1 Predator UAV, RQ-4A Global Hawk UAV, AC-130U, B-1, B-2, and various tactical fighters.¹² However, only the E-8 JSTARS, U-2R, and RQ-4A Global Hawk have radars with wide field of views that can adequately cover large amounts of terrain. One advantage of the E-8 JSTARS is its capability to process returning radar energy autonomously in real time.¹³ This capability allows operators to make faster decisions as the information is presented to them without delay. The U-2R's Advanced Strategic Airborne Radar System (ASARS-II) and the RQ-4A's radar system are near-real-time capable and require a ground station to process the data before sending it to users.¹⁴ While the Predator UAV is SAR capable, its narrow field of view (NFOV) sensor and limited sensor range are better used for locating and identifying the COIs.

FolPen uses ultrawide-band radars operating in the high frequency and very high frequency spectrum to penetrate foliage and detect and locate stationary enemy vehicles, equipment, buildings, and even buried objects such as land mines.¹⁵ One limitation of FolPen is that while it can see through foliage, it cannot see through tree trunks. For this reason, FolPen's ability to detect targets in heavily wooded areas is degraded. Since it uses advanced processing similar to SAR, FolPen is best used in detecting and locating targets in isolated areas of heavy foliage where the search area is minimized. FolPen is a relatively new technology and is not currently used on any USAF operational platforms, but it will be incorporated into Global Hawk in the future.¹⁶

Passive Sensors

Because of active sensor limitations, passive sensors are incorporated into the process. A passive sensor does not transmit; it only receives. Examples of passive sensors are electro-optical (EO) sensors, thermal imagers, and signals intelligence (SIGINT) equipment.

EO sensors are the most common type of airborne passive sensor and can be used to detect, locate, and identify COIs.¹⁷ EO sensors are camera-like devices that operate in the long-wave infrared (IR) through the ultraviolet region of the electromagnetic

spectrum.¹⁸ EO sensors offer higher resolution than other types of sensors, but they depend more on weather conditions.

EO sensors are routinely used on space vehicles and high-flying aircraft such as the U-2R and RQ-4A Global Hawk. One vehicle, the KH-11 satellite, gathers information and sends the image to a ground site where it is processed in near real time.¹⁹ Depending on atmospheric conditions and COI contrast, the KH-11 can detect objects as small as six inches.²⁰ For example, an EO sensor can distinguish between a truck with a 50-caliber machine gun on its roof and one without.²¹ However, one significant drawback of these platforms is their inability to deliver the imagery when needed.

Because most EO satellites are in low earth orbit flying between 60 and 600 miles above the surface to enable them to see small areas clearly, they are not continuously over a specific area on the earth's surface.²² This difference results in delays from when a COI is detected to when a satellite passing overhead can identify it. For this reason, the "USAF and the National Security Agency (NSA) have concluded [that] too much emphasis has been placed on low and medium orbit satellites that cannot watch a target for more than a few tens of minutes at a time."²³ The U-2R also faces similar problems due to required overflight and limited endurance. The U-2R's EO images are not down-linked to ground stations, and they must be downloaded from the aircraft upon landing, many times well after the critical COI identification was needed.²⁴ Although the RQ-4A Global Hawk is a long-endurance UAV with a loiter of up to 24 hours, it is just now coming online and has so far proven itself unreliable.²⁵ Another disadvantage of EO sensors is their dependency on favorable atmospheric conditions.

Rain, haze, clouds, humidity, smoke, and dust all work to degrade EO's ability to provide necessary resolution to identify a target accurately. Historical meteorological data shows that in three of the four primary theaters (Pacific Command, European Command, and Southern Command) poor weather is a factor 50 percent of the time; EO's ability to deliver imagery may be severely hampered.²⁶ EO sensors are also limited in identifying camouflaged targets. One technique that helps to alleviate EO's limitations is the use of multispectral imaging.

A multispectral approach overcomes atmospheric effects and camouflaged targets by combining the visible, IR, and other segments of the electromagnetic spectrum into a coherent picture. Because the approach uses several different spectral wavelengths, objects that are indistinguishable in one spectrum can now be easily detected and identified in one of the others. Unfortunately, US intelligence was slow to recognize the need for this technology and, running into budgetary roadblocks, was later forced to buy the service from commercial sources.²⁷

Another type of passive sensor uses IR imaging, and it detects differences in temperature between an object and its background. Because of the normal heating and cooling processes that occur from the rising and setting of the sun, objects heat up and cool down at different rates caused by their differences in specific heat.²⁸ For example, because armor has a higher specific heat value than foliage, an armored tank will stay hot well into the night while foliage will quickly cool with its surrounding environment. The resulting difference in temperatures allows a thermal imager to detect objects that EO systems cannot, which includes many camouflaged targets.

To increase resolution to allow discrimination between objects and their backgrounds, thermal imagers use NFOVs. For this reason, they are not good for detecting COIs but can locate a COI if cued. Thermal imagers can also identify COIs; again, they must be close to the object to get sufficient resolution to make an assessment. Factors that degrade thermal imagers are clouds, rain, humidity, snow, and wind. One sensor that overcomes many of these limiting factors is SIGINT.

SIGINT intercepts communications signals including voice, fax, telex traffic, and a variety of electronic signals such as the emanations of radar systems.²⁹ Since most signals have distinct signatures, SIGINT's main advantage is its ability to identify its source. For example, SAM radars operate in specific frequency ranges with unique operating characteristics. With some experience, it becomes easy not only to detect the SAM's radar emission but also to identify exactly what kind of radar (and, therefore, the kind of SAM) it is. SIGINT's two weaknesses are the requirement for an enemy to transmit over the

air to detect the signal and its inability to locate a system quickly and accurately.³⁰

SIGINT locates a target through a process of triangulating signals emanating from a COI. As the SIGINT platform moves in relation to the COI, it continually triangulates and refines its assessment of the COI's location. Over time the COI's location becomes more and more precise until the sensor's threshold is met, which is the best accuracy the sensor can deliver. From this point onward, regardless of how much time is spent triangulating a COI, no improvement in accuracy will result.³¹

Because SIGINT sensors do not need to be placed close to an object to obtain high resolution, such as required by EO sensors, they can be placed on satellites in high geostationary orbits that allow for continuous coverage of an area.³² SIGINT satellites placed into high orbits do not have the on-station problems encountered by EOs. SIGINT sensors are also placed on aircraft. Two aircraft specifically designed for collecting SIGINT are the USAF's RC-135V/W Rivet Joint and the Navy's EP-3 Aries. The Rivet Joint is a modified Boeing C-135 airframe that can fly for 11 hours at a time without air-to-air refueling (AAR), or 20 hours with AAR, while simultaneously collecting information. The EP-3 is a modified P-3 four-engine turboprop aircraft that has greater than 40-hour endurance, thus giving it a range of more than 3,000 miles.³³

Fusion

Fusion is the process of "combining data gathered during the detect, identify, and locate functions to develop targeting information."³⁴ While fusion can be done at the tactical level, such as a pilot flying along and detecting a tank, identifying it as hostile, and attacking it, the fusion necessary at the ISR and C² level involves the rapid exchange of information between platforms and sensors to gain an accurate picture of the battlespace. According to Joint Publication 3-55, *Doctrine for Reconnaissance, Surveillance, and Target Acquisition Support for Joint Operations*, "The better the interoperability of systems and the more robust and redundant the links, the better the cross-cueing, analytical exchange, and ability of the commander to work inside an opponent's decision loop."³⁵ Fusion is the key enabler that allows all

the different sensor capabilities to be used and integrated into a common picture. Unfortunately, many of the key ISR sensors and platforms discussed earlier do not communicate with each other, thereby leaving operators grasping to gather the bits of information single-handedly. This lack of communication is why Gen John P. Jumper, USAF chief of staff, wants a system of systems approach that will break down the tribal barriers and allow information to pass freely between platforms, which results in faster decisions and, therefore, a faster kill chain.³⁶

After analyzing the various active and passive sensor capabilities along with the problem of fusion, table 1 is deduced. A quick glance at table 1 reveals two potential problems. First, detecting a hidden, stationary target that does not emit is difficult. Other than using multispectral imagery, SAR, and EO techniques, all of which are inefficient at best, there is little that can be done to solve the problem. In most cases, the enemy must come out of hiding to effectively engage US forces, which allows MTI to detect it. In this case, one must detect, locate, and ID the COI as a target, but proceed through the rest of the kill chain to destroy it before it can act against friendly forces.

Table 1. Summary of sensor capabilities

<i>Type Sensor</i>	<i>Detect</i>	<i>Locate</i>	<i>Identify</i>
Active			
synthetic aperture radar	–	+	–
moving target indicator*	+	+	–
foliage penetrating radar**	o	+	–
Passive			
electro-optical	–	+	+***
multispectral	o	+	o
infrared	–	+	+***
signals intelligence	+	–	+

+ favorable
 – unfavorable
 o neutral
 * object must be moving
 ** isolated areas of heavy foliage
 *** requires favorable atmospheric conditions and close sensor range

As realized in Desert Storm, a Scud TEL can set up, shoot, scoot in 35–45 minutes, and make this a difficult task.³⁷ In cases where an enemy may not need to move, a Scud TEL may not be located until after its missile is launched and detected by a Defense Support Program (DSP) satellite or a Cobra Ball RC-135 aircraft.³⁸ With a Scud TEL capable of leaving its launch site within five minutes of firing, the rest of the kill chain must now be accomplished even faster than before, preferably within single-digit minutes.³⁹

The second revelation is that the timely identification of a non-emitting target will be difficult, especially in poor weather conditions. This fact is compounded because the enemy will try to avoid emitting any signals. One example of this is evidenced when enemy SAM systems minimize their emission times for fear of being detected and destroyed. Unlike most SAMs, however, not all TCTs have to emit to engage their prey, even when their traditional line of communications (LOC) are degraded.⁴⁰ One solution routinely used is to send manned aircraft into the area to identify the COI as hostile or friendly, and attack it if the rules of engagement (ROE) permit.⁴¹

While this method is an option, it is inefficient because it requires a commitment of valuable resources that may be futile if the COI, once identified, is not a target. All of the time and effort used in the operation is for naught, which serves only to squander and expose manned aircraft that could have been used for other missions. This is why General Clark, JFC in Operation Allied Force, said, “The US armed forces are unbalanced. They are overstructured in strike platforms and underresourced for the amount of ISR it possesses.”⁴² In an attempt to alleviate General Clark’s complaint, the USAF developed and integrated the RQ-1 Predator into the kill chain.

Because it is equipped with NFOV sensors that provide excellent resolution once cued, the RQ-1 Predator can locate and identify COIs.⁴³ To accomplish this, the Predator is flown to the COI’s location and peers down taking high-resolution video of the COI. The data is downlinked through the Joint Broadcast System in real time to the air operations center where the COI is identified.⁴⁴ Unlike times when manned air assets were tasked before knowing the probable outcome, now they are efficiently

used only against a confirmed target. This is why General Jumper stated, "We're now using our ISR sets more to confirm that which we predicted than for pure discovery."⁴⁵ The major flaw with this plan is the Predator's inability to fly quickly to the unidentified COI, which slows the entire process.

By using a pusher-type propeller and a Rotax 912 engine, the Predator flies at a blistering cruise speed of 70–90 knots.⁴⁶ At this speed, it takes the Predator more than one hour to fly only 100 miles. Since even small countries such as Afghanistan are several hundred miles across, many Predators that spread geographically across the area are required to provide timely information. Although this is not horrible in itself, it does raise cost and survivability concerns.

Although the Predator has a service ceiling of 25,000 feet (ft), it routinely loiters at 15,000 ft or lower to capture the high-quality video needed to identify targets accurately.⁴⁷ Thus, the Predator is vulnerable to ground fire, particularly antiaircraft artillery (AAA). This was demonstrated during the Predator's first European deployment in 1995 (Nomad Vigil) where AAA shot down two Predators.⁴⁸ Since then, the USAF has lost more than 19 Predators, with a rash of losses occurring in Operations Southern Watch and Enduring Freedom.⁴⁹ Previously, the USAF was procuring six to seven Predators per year to compensate for normal attrition, but with increase in losses, the USAF allocated \$161 million in the proposed 2003 budget to buy 22 Predators at a cost of about \$7.3 million each.⁵⁰ This fact is startling considering the Predator was originally designed to be a relatively low cost air vehicle of about \$3 million each.⁵¹ To reduce the losses, the USAF has considered changing flight routes to reduce the Predator's predictability and encrypting its communications links to make it harder to sever or disrupt the remote control of the aircraft.⁵² Even these modifications do not remove the root cause of the problem.

The Predator provides a needed capability that allows the JFACC to allocate air resources efficiently to kill confirmed targets, not COIs. With the Predator's cost increasing to more than \$7 million a copy, commanders may think twice before putting them into harm's way, especially since they fly low and slow and are vulnerable to ground fire. At the very least, com-

manders will most likely recognize that an underused Predator (staying out of known threat rings) is better than having no Predator at all (i.e., shot down), which reestablishes the problem of timely and accurate COI identification that the Predator was supposed to solve.

Dissemination

Dissemination is “the link between sensors and shooters and occurs when the final targeting information is passed to the C² agencies and the shooters for possible engagement.”⁵³ Five factors should be considered before disseminating targeting information to a weapons platform: effectiveness, responsiveness, range, accuracy, and threat.⁵⁴ The first four factors are dependent on the aircraft and its associated munitions; the last factor rests entirely on the target or COI’s location in regard to the enemy’s defenses. Effectiveness is the first consideration because there is little sense in attacking a target with a weapon that has a low probability of achieving damage. For example, tasking an F-15C air-to-air fighter equipped with a 20-millimeter gun to attack a tank would result in little or no effect. For this reason, the aircraft selected to engage the target must have munitions appropriate for the amount of damage desired.⁵⁵

Response and range are the next two factors and relate to how soon an aircraft can deliver ordnance onto the target. As mentioned earlier, speed of attack is the critical factor needed to successfully destroy the TCTs. For this reason, aircraft closer to the target are likely to be prioritized ahead of others located far away because they can strike sooner.⁵⁶

Accuracy is ability of the tasked platform to find the intended target and destroy it. For instance, an aircraft using an unguided general-purpose (GP) 500-pound (lb) bomb (i.e., an Mk-82) to attack a dug-in tank has a low probability of success in comparison to a laser-guided 500 lb weapon (i.e., a GBU-12) because the accuracy of the latter is much better.

The last factor to consider before disseminating target information to a strike package is the threat. Many times the TCTs are located behind heavy air defenses that require support assets such as SEAD, electronic attack, and offensive counterair air-

craft to accompany the strike aircraft.⁵⁷ After considering all of these factors, the targeting information is disseminated to the best asset(s) for the task.

Level Two—The Shooter

Unlike level one where detect, locate, and identification functions may occur simultaneously, level two is a sequential process that begins with ingress and ends with egress. Between these two boundaries are the tasks of finding, tracking, identifying, and delivering ordnance on a target. Before an aircraft can deliver ordnance, it first must find the target. For an aircraft to reliably find a specific target, target location error (TLE) must be minimized.⁵⁸ If an aircraft's sensors can scan a circular area of two nautical miles (NM) in diameter, then the TLE must be less than one NM to ensure it will be within the sensor's field of view (FOV). Because different tactical aircraft have different sensor FOVs, operators at level one must take the TLE into account when determining a suitable strike aircraft. Obtaining small values of the TLE is not normally a problem with stationary targets located with SAR or EO techniques, but it can be a huge problem with moving targets or those detected with SIGINT.

The problem stems from the time delay that occurs from when the target information is disseminated to when the strike aircraft arrives in the target area. Slow-moving targets can travel significant distances in relatively short periods of time and can be difficult to find, especially in a high-threat area that does not permit aircraft to loiter and search for the target. One method used to overcome this challenge is for level-one platforms to update the target's whereabouts to the strike aircraft in real time, thereby keeping the TLE in check and enabling successful target detection by the strike aircraft.

When an aircraft finds a target, the next steps are to track and identify it. To track a target, tactical aircraft use many different sensors, some include passive SIGINT receivers, IR pods, radar, and, of course, the pilot's vision. One advantage in using aircraft sensors to track a target is the ability for the pilot to cue a beyond visual range weapon to the track (i.e., an AGM-65 Maverick missile), lock it on to the target, and shoot without ever flying into harm's way. Because the ROE many

times require a pilot to identify a target before shooting, this advantage may be of little use.⁵⁹

Although SIGINT receivers can identify targets quickly, aircraft that use IR and radar sensors cannot accurately identify a target until at relatively close range, usually well inside the maximum engagement range of their air-to-surface missiles.⁶⁰ This limitation is magnified by ROE altitude restrictions that keep aircraft flying high above small arms fire and shoulder-fired SAMs. In Kosovo, for example, aircraft were usually required to stay above 15,000 ft above ground level (AGL), which made target identification difficult by day and virtually impossible at night, even with IR targeting pods and night vision goggles.⁶¹ After F-16CG forward air controllers (FAC) misidentified and bombed a Kosovar refugee column, the altitude was lowered to 5,000 ft AGL to help improve the chances of accurate target identification.⁶² According to General Barry, the requirement to identify targets accurately (to reduce collateral damage and fratricide) is going to persist in the future.⁶³

Level Two A—The Weapon

Although level two A, the weapon, is presented as its distinct level, notice there is no horizontal line on figure 1 that separates level two from level two A. This signifies that while the transition from level one to level two involved a major change requiring the tasking of strike and suppression aircraft, the transition from level two to two A is small and easy. It is simply the continuation of level two but now in regard to the weapon. The three steps in level two A are find, track, and kill, and they are dependent on the type of weapon used to engage the target.

If employing unguided bombs, where the bomb falls ballistically to the ground without further guidance, the kill chain proceeds from deliver directly to kill. As soon as the bomb comes off the aircraft, it free-falls through the air until impacting the ground. While the GP bombs are cheap and plentiful, they are inherently inaccurate and have little capability to hit moving targets. Similar to throwing a rock at a moving target, the successful engagement of moving targets with the GP bombs necessitates predicting the target's future location and bombing that location in hopes that the target cooperates. Although

such action may be simple for a target 20 yards away, the bomb range for an aircraft at 20,000 ft AGL is four to five miles, which results in a time of flight of almost a minute.⁶⁴ This fact makes hitting moving targets with unguided bombs a matter of luck, and it is a reason why acquire before launch (ABL) munitions were developed.

ABL munitions are those weapons that require target coordinates or a self-track of the target before releasing them from the aircraft. Some of these weapons, such as the joint direct attack munition (JDAM) and the conventional air-launched cruise missile (CALCM), are programmed to fly to a fixed point (i.e., latitude and longitudinal coordinates) on the ground. Once launched, these weapons guide to their point by using inertial navigation linked with Global Positioning System (GPS) updates.⁶⁵ Unfortunately, since there is no capability to change the weapon's flight profile once released, they, like GP bombs, are of little use in attacking mobile targets. Some other ABL munitions, such as the AGM-65D/G Maverick, specialize in attacking mobile targets.

The AGM-65D/G incorporates an IR tracking assembly on the front of the missile that allows it to track a target all the way until impact.⁶⁶ To employ the missile, the pilot simply locks the missile seeker onto the target and shoots the missile when in range. Because the missile continues to track the target from launch to impact, target maneuvering does not affect its accuracy. For this reason, the AGM-65 is the weapon of choice for moving vehicles, especially armor. The major disadvantage with the Maverick is its limited target acquisition range. Typical lock-on ranges are anywhere from four to eight miles, depending on atmospheric conditions and the target's temperature contrast. Strike aircraft employing Maverick will likely need suppression aircraft to accompany them into hostile enemy territory. Use of an acquire after launch (AAL) munition is one alternative to increase standoff.

AAL munitions fly long distances to the target area and perform a search of the area to find, track, and kill mobile targets. There is little theoretical difference between an ABL munition that flies to a fixed point and an AAL munition that performs the same function up to a point. Upon arrival at the fixed point, the AAL munition performs an area scan to find the target.

The problem with AAL munitions has not been their ability to find or track a target but to identify it.⁶⁷ In the past the ATR systems have not identified targets accurately and have stunted the development of AAL munitions.⁶⁸ One future AAL weapon, the low cost autonomous attack system (LOCAAS), will be discussed in chapter 3.

Killing the target is the final step in level two A. Targets are normally engaged to achieve levels of damage that range from a catastrophic kill (K-kill) to a mobility kill (M-kill) or to a firepower kill (F-kill).⁶⁹ Each level of damage is usually best achieved with a certain type of munition, and the probability of achieving that level of damage usually increases with the amount of ordnance delivered. For example, to achieve a K-kill against a tank, it is best to use big weapons (i.e., Mk-84 2,000 lb bombs) that can be delivered accurately. The Mk-84 is a good choice because it offers both fragmentation and blast effects that are well suited to destroy a tank. Up to a point of diminishing returns, the more weapons delivered, the greater the chance of achieving the desired ends. Unlike K-kills that require heavy blast and fragmentation, F-kills are best achieved with cluster bombs. Cluster bombs contain many submunitions that are expelled in flight and disperse to cover a large surface area. Because the submunitions are small, they usually have only enough explosives to lightly damage a tank. The light damage is frequently severe enough to disable the gun or targeting systems to such a degree that the result of the attack is an F-kill. Even though the vehicle may remain mobile or mostly functional, it is unable to engage. However, on other types of soft vehicles, cluster bombs may achieve K-kills. While this may seem difficult and puzzling considering the multitudes of weapons and targets, planners use computer programs within the Joint Munitions Effectiveness Manuals to help match the correct weapon to the target for the desired level of damage. The programs also provide estimates on the number of bombs (and the number of aircraft) required to achieve a specific probability of damage against a given target.

Level Three—BDA

The last step in the kill chain is the BDA, which is “the timely and accurate estimate of damage resulting from the application

of military force, either lethal or nonlethal, against a predetermined objective.”⁷⁰ The BDA is important because it supports the commander’s decision-making process and provides the necessary feedback to make adjustments in the operational plan.⁷¹ “When the decision to attack a particular enemy unit is tied to reducing it to a predetermined strength prior to our crossing the line of departure, the BDA estimates must be timely and accurate.”⁷² In Operation Desert Storm, the BDA sometimes took 12 days to obtain, which ultimately created a misunderstanding of how weak and ineffective Iraqi forces really were, and it “may have resulted in a concept of ground operations that allowed significant elements of the Republican Guard to escape.”⁷³ To avoid such problems in the future, prospective systems should incorporate the BDA into their processes.

Summary

This chapter laid the groundwork for the rest of the analysis. A few conclusions can be made:

- Inherent sensor limitations make detecting stationary targets difficult, especially if hidden. If such a target is detected, the remaining kill chain must be accomplished quickly, optimally in less than 10 minutes.
- Speeding through the kill chain is complicated by a lack of fusion to tie all the sensors together into a common architecture.
- The inability to obtain timely and accurate identification at the ISR and the C² level slows the kill chain down and tends to waste valuable manned aircraft on nonproductive missions.
- While the Predator helps obtain timely identification of the COIs, it is significantly limited due to speed and survivability concerns, and not cost-effective.
- Manned aircraft can be used to identify and strike the TCTs, but they may need support aircraft, updated target information to keep the TLE in check, and ROE that enable identification to occur.

- Use of manned aircraft lengthens the kill chain's timeline because of time and space factors.
- GP bombs and ABL munitions, such as the JDAM and CALCM, are of little use for engaging moving targets.
- Other ABL munitions, such as AGM-65 Maverick, have a good capability to engage moving targets, but they require relatively close ranges to enable them to track the target.
- AAL's ATR is not yet reliable, but it looks promising and could enable aircraft to standoff and still engage moving targets.
- The BDA should be incorporated into the process, if practical.

Looking to solve the revelations presented above, chapter 3 investigates reactive methods and their suitability for use.

Notes

1. The Air Land Sea Application Center is responsible for providing tactics, techniques, and procedures for the joint military forces. Air Force Joint Pamphlet (AFJPAM) 10-225, *Targeting: The Joint Targeting Process and Procedures for Targeting Time-Critical Targets*, II-1.

2. Joint Publication (JP) 1-02, *Department of Defense (DOD) Dictionary of Military and Associated Terms*, 435. The term *time-sensitive targets* is used.

3. AFJPAM 10-225, *Targeting*, II-2.

4. *Ibid.*, II-1.

5. Danskine, "The Time Critical Targeting Model," 14. A contact of interest is a potential target, detected and possibly located, but not yet identified as friendly or hostile.

6. Vick, *Finding Needles in Haystacks*.

7. Federation of American Scientists, "Joint Surveillance Target Attack Radar System."

8. Danskine, "The Time Critical Targeting Model," 72.

9. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 16.

10. JP 1-02, *DOD Dictionary of Military and Associated Terms*, 437. A track is a record of successive positions of a moving object.

11. Haun, "Airpower versus a Fielded Army," 84.

12. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 16.

13. JP 1-02, *DOD Dictionary of Military and Associated Terms*, 355. Real time means the data has only been delayed for electronic communication with no noticeable delays.

14. *Ibid.*, 292. Near real time means that the data or information has only been delayed for electronic communication and automatic data processing, implying no significant delays; and Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 17.

15. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 17.

16. Dimaggio et al., "Presence with an Attitude!"

17. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 21.

18. *Ibid.*, 20.

19. Richelson, "High Flyin' Spies."

20. *Ibid.*

21. Operations in Afghanistan highlighted this fact. Maj David Hathaway, US Central Command Air Force's chief of strategy, interview by the author, 30 November 2001.

22. Corcoran, *Higher Eyes in the Sky*, 14.

23. Fulghum, "New Air Force Recce Aircraft Takes Shape," 34.

24. Jack Jones, 36th Intelligence Squadron commander, interview by the author, 5 March 2002. Recent changes allow some U-2s to data-link digitized pictures in near real time to ground stations, but it still takes at least 15–20 minutes to get the information to the user (i.e., the air operations center).

25. Richter, "Global Hawk Crashes in Afghanistan in a Setback for High-Tech Drones."

26. Headquarters Air Combat Command (ACC), *Combat Air Force's Global Attack Mission Area Plan—FY2002*, 15.

27. Richelson, "High Flyin' Spies."

28. Specific heat is defined as the amount of heat needed to move one gram of a substance one degree Celsius.

29. Richelson, "High Flyin' Spies."

30. Since signals intelligence sensors listen only to enemy emissions, they cannot intercept messages or information sent via optical cable, normal telephone lines, or other methods where direct connectivity is used.

31. Danskine, "The Time Critical Targeting Model," 43.

32. Corcoran, *Higher Eyes in the Sky*, 14. Geostationary orbits are located approximately 22,300 miles from the earth, allowing them to orbit in constant relation to the earth's surface.

33. Federation of American Scientists, "Rivet Joint"; and Federation of American Scientists, "EP-3 Aries."

34. Danskine, "The Time Critical Targeting Model," 18.

35. JP 3-55, *Doctrine for Reconnaissance, Surveillance and Target Acquisition Support for Joint Operations*, II-5.

36. Jumper, address, 15 February 2001.

37. Lukes and McKenzie, "Theatre Missile Defense (Attack Operations) for Those Tactically Challenged," 7.

38. Defense Support Program satellites are located in geosynchronous orbit 22,300 miles above the earth and are capable of detecting missile launches by observing their heat signature during boost phase. The system, deployed in 1970, will soon be replaced by the Space Based Infrared System. USAF Space Command Fact Sheet, "Defense Support Program"; and Federation of American Scientists, "Joint Surveillance Target Attack Radar System." Cobra Ball is a modified RC-135 specifically designed to detect and track tactical ballistic missile during their boost phase. Within seconds of launch, the system provides estimates of launch, intercept, and impact points that can be data-linked to other combat and command platforms.

39. Jumper, address, 15 February 2001. General Jumper's goal is to destroy time-critical targets in single-digit minutes after detection.

40. Gordon and Trainor, *The General's War*, 247.

41. JP 1-02, *DOD Dictionary of Military and Associated Terms*, 371. Rules of engagement are directives issued by competent military authority that delineate the circumstances and limitations under which US forces will initiate and or continue combat engagement with other forces encountered.

42. Hutcheson, *Unified Aerospace Power in the New Millenium*, 13.

43. Haun, "Airpower versus a Fielded Army," 84.

44. JP 1-02, *DOD Dictionary of Military and Associated Terms*, 18. The air operations center is the joint force air and space component commander's command center for controlling his air assets; and Federation of American Scientists, "RQ-1 Predator."

45. Jumper, address, 27 June 2001.

46. Federation of American Scientists, "RQ-1 Predator."

47. Wall, "The Devastating Impact of Sensor Fuzed Weapons," 61.

48. Federation of American Scientists, "RQ-1 Predator."

49. Wall, "The Devastating Impact of Sensor Fuzed Weapons," 61.

50. *Ibid.*

51. *Ibid.*

52. *Ibid.*

53. Danskine, "The Time Critical Targeting Model," 19.

54. Normally this is a manned aircraft, but it could be any platform capable of delivering ordnance on the target. AFJPAM 10-225, *Targeting*, II-5 and II-6.

55. AFJPAM 10-225, *Targeting*, II-5.

56. *Ibid.*

57. *Ibid.*

58. Air Force Pamphlet 14-210, *Intelligence*, 98. Target location error is the difference between the target's actual location and the expected location.

59. Haun, "Airpower versus a Fielded Army," 82. Pilots in Kosovo were required to visually identify targets before engaging them. The same rules of engagement are used in most air campaigns where fratricide and collateral damage are issues.

60. Signals intelligence receivers used on tactical aircraft are normally designed for suppression of enemy air defense, shooting high-speed anti-radiation missiles at emitting surface-to-air missiles systems, and have no use for nonemitting time-critical targets. Headquarters ACC, *Combat Air Force's Global Attack Mission Area Plan—FY2002*, 22.

61. Haun, "Airpower versus a Fielded Army," 82.

62. Ibid.

63. Hutcheson, *Unified Aerospace Power in the New Millenium*, 42.

64. Bomb range is the horizontal distance across the ground the bomb must travel, measured from the bomb's release point to the target. 27th Fighter Wing Attack Guide, Cannon AFB, N.Mex., May 1995, 54.

65. Federation of American Scientists, "Joint Direct Attack Munition."

66. Federation of American Scientists, "AGM-65 Maverick."

67. Defense Advanced Research Projects Agency Special Projects Office, "Jigsaw Project Concepts."

68. Hathaway, "Germinating a New SEAD," 51.

69. A catastrophic kill means the target is inoperable and beyond repair. A mobility kill means the target cannot move on its own accord for a given length of time. A firepower kill means the target is incapable of delivering ordnance for at least four hours.

70. JP 1-02, *DOD Dictionary of Military and Associated Terms*, 50.

71. Harris, "Counterfire and Predictive BDA," 42.

72. Ibid.

73. Nowland, *Eliminating the Rhetoric*, 60.

Chapter 3

Reactive Approach

We need a robust, time-critical targeting capability that turns our response to emerging targets from hours today into minutes in the future.

—Gen John P. Jumper
Chief of Staff, USAF

This chapter focuses on the kill chain sequence where one detects a COI and reacts to it by going through the rest of the chain as fast as possible. This reactive approach does not endorse predictive targeting where one would employ weapons before detecting a COI (i.e., place loitering weapons over an area prior to detecting a COI). The reactive approach does not attempt to reduce or consolidate the number of steps in the kill chain but instead attempts to speed through them by eliminating the previously discussed bottlenecks. This chapter evaluates the efficacy of this approach regarding the TCTs, which answers these questions: Are there new ISR platforms that can detect, locate, and identify the TCTs more efficiently? What can be done to fuse sensor data into a common battlespace picture? What future platforms and weapons are best suited to attack the TCTs reactively?

Future Intelligence, Surveillance, and Reconnaissance Capability to Detect and Identify

As mentioned in chapter 2, progressing quickly through the kill chain is currently hindered because ISR platforms (JSTARS, Rivet Joint, and space assets) cannot identify nonemitting TCTs or efficiently detect stationary COIs, thus resulting in the use of manned aircraft or the Predator to fill the void. Previous evidence shows neither of these options is efficient. While this approach is necessary due to the lack of other

means, must the ill-suited approach continue to be used based on ISR's prognosis to detect and identify TCTs in 2010? According to the Aerospace C² and ISR Center (AC²ISRC), ISR's prognosis is dependent on three programs the USAF is attempting to solve this issue: the Multi-Platform Radar Technology Insertion Program (MP-RTIP), Global Hawk, and the Space-Based Radar (SBR).¹

Multi-Platform Radar Technology Insertion Program

The MP-RTIP evolved from the JSTARS preplanned product improvement (P³I) effort to design, develop, install, and test advanced radar systems that could be integrated into the JSTARS.² After looking ahead and seeing a need for advanced radars on Global Hawk and a NATO medium-sized ISR platform (still in development), the USAF redesigned the program to develop advanced radar for use on a variety of platforms. In December 2000, Northrop Grumman received a three-year \$303 million contract to design the MP-RTIP system.³ Upon completion of work, the next phase is to develop and test the system. According to the AC²ISRC, the advanced radar should be ready for implementation about FY2008.⁴

Although little is known about the specifications and how it will work, the new radar will dramatically increase the USAF's ability to detect, track, and identify stationary and moving ground vehicles from standoff orbits.⁵ If the new radar follows the techniques planned for the original JSTARS P³I, enhanced SAR (ESAR), inverse SAR (ISAR), and high-range resolution MTI, at least a sixfold enhancement of the current radar's resolution would be obtained for stationary and moving targets, and it will significantly improve the identification capability.⁶ However, to take full advantage of MP-RTIP's capabilities, it needs to be placed in orbits that minimize obstructions to its line of sight (LOS).

Radar cannot look through terrain; therefore, standoff platforms such as the JSTARS cannot observe enemy movement behind mountains or in rough terrain where deep gullies and culverts exist. However, if the radar is placed high overhead, obstructions to the radar's LOS are nullified because the radar

now peers straight down to the ground without hindrance. One high-flying platform well suited to this task is the Global Hawk.

Global Hawk

Global Hawk is the second avenue the USAF is pursuing to detect, locate, and identify TCTs, and although currently unreliable, it should prove itself capable in time.⁷ Global Hawk is a high-altitude, long-range, long-endurance, unmanned platform that carries a 1,950 lb payload for up to 36 hours.⁸ LOS problems are minimized because Global Hawk operates at ranges up to 3,000 NM from its launch area and cruises above 60,000 ft AGL close to an area of interest (AOI).⁹ In scanning for prey, Global Hawk uses a multitude of sensors that include EO, IR, SAR, and MTI which enable it to detect, locate, and identify COIs in real time or near real time. As the data is collected, it is distributed via LOS communication links to the mission control element by X-band or, if LOS is not available, by satellite communication.¹⁰ By using its radar and EO and IR sensors, Global Hawk can search up to 40,000 square NM per mission at one-meter resolution and up to 1,900 spot images per mission at 0.3-meter resolution.¹¹ Another sensor that promises to dramatically assist in identifying the COIs is hyperspectral imaging, and because of this fact, the USAF desires to incorporate it into Global Hawk.¹² Hyperspectral imaging measures the reflected energy from objects on the ground that use hundreds of different frequencies in the spectrum.¹³ Once the energy is collected, mathematical algorithms are used to process, differentiate, and combine the data into a coherent picture.¹⁴ The technique is especially useful to find hidden objects and to discriminate between actual targets and decoys. To develop this technology, the Air Force Research Laboratory (AFRL) is working on project Spectral Infrared Remote Imaging Transition Testbed (SPIRITT). Its purpose is to develop hyperspectral imaging sensors which was scheduled for testing the technology in 2003 using National Aeronautics and Space Administration's WB-57 high-flying aircraft.¹⁵ Another program is the MightySat II.1 Space-Based Experimental Platform. The satellite, built by Spectrum Astro, Inc., of Gilbert, Arizona, weighs 300 lbs and incorporates a hyperspectral space-imaging

instrument built under contract by the Kestrel Corporation. This is the Department of Defense's only space-based hyperspectral imager to use a Fourier Transform technique to discriminate between spectrally unique objects.¹⁶ Provided neither program encounters any major setbacks, hyperspectral imaging for military applications should be available for use by the end of the decade.¹⁷

Because it flies at high altitudes, one of the advantages of Global Hawk over the Predator is its ability to avoid hostile ground fire. Since most AAA and shoulder-fired SAMs can only engage targets up to about 20,000 ft AGL, an area where the Predator routinely flies, the Global Hawk operates well above this threatening region and is unhindered by such weapons. Only radar-guided SAMs and high-altitude interceptors have the capability to reach Global Hawk at 60,000 ft, and to help account for them, it uses electronic jammers and decoys for self-protection.¹⁸ Nevertheless, with an estimated price of \$50 million each and considering that Global Hawk's electronic jammers and decoys will not be 100 percent effective in defeating all SAMs and air-to-air missiles, some degree of air superiority will most likely be required before flying Global Hawk in the face of such threats, especially since it is not stealthy.¹⁹ In the end, based on its ability to loiter, detect, locate, and identify the COIs, Global Hawk may prove to be a worthwhile asset but only commensurate with its ability to avoid enemy fighters and the SAMs. A better approach that currently promises to practically eliminate all hostile fire is the use of space.

Space-Based Radar

The third avenue the USAF is pursuing to solve current ISR limitations is the SBR. Given the advantages of space, namely free overflight, lack of obstructions to hinder the LOS, and continuous coverage if enough satellites are used, space is the ultimate high ground.²⁰ Unfortunately, satellites also have disadvantages such as predictability due to their orbits, little flexibility to move or change orbits, a lifespan of about 10 years (much shorter than airborne vehicles), and the requirement of more sensor power since they are farther away from targets than are

air-breathing assets.²¹ When considering studies have shown that from 24 to more than 100 satellites would be required for continuous coverage, the cost would almost certainly be astronomical.²² Nevertheless, with Dr. Daniel Hastings, the USAF's chief scientist, reporting that to migrate the JSTARS to space is technically feasible in the near term, and with the cancellation of the Discoverer II technology demonstration program, the secretary of defense jumpstarted the acquisition of the SBR by formulating the 2001 multitheater target tracking capability (MT³C) Mission Needs Statement (MNS).²³

The MT³C MNS sets the stage to develop and implement a space-based system that would enable multitheater detecting, tracking, identifying, and targeting of ground moving targets by FY2010.²⁴ To accomplish this feat, the radar will incorporate MTI, SAR, and digital terrain elevation data techniques, and it promises to cover most of the earth.²⁵ To develop the system, the SBR program will buttress on maturing technology and leverage advances made in the Discoverer II program. While the advantages of the SBR are obvious, can it be operational by 2010?

According to General Barry, the SBR is part of the USAF's Vision Force that will not be operational circa 2020.²⁶ He says that because placing fully capable ISR platforms into space will not occur until after current ISR platforms wear out in 2014, the USAF will need an intermediate platform to serve in the meantime.²⁷ To fill this need, the USAF has proposed the multisensor C² aircraft (MC²A), a modified Boeing 767-400 that will serve as a "battle management aircraft that would also take on missions now performed by the E-3 AWACS [Airborne Warning and Control System], E-8 JSTARS, and the EC-130 Compass Call."²⁸ To develop and acquire the MC²A by 2010, the FY2002 house defense appropriations bill added an additional \$354 million over the budget request for production of two test aircraft and other related research.²⁹ With substantial investments pouring into the MC²A program, it is obvious that General Barry's foresight is correct; the SBR will not be fully operational by 2010, and until it is, the MC²A will help fill the C²ISR requirement.

Fusion—Can It Be Done Better?

Chapter 2 illustrated that because no one sensor is fully capable in all operating environments, many different sensors are used to detect, locate, and identify the COIs. With the current lack of communication between sensor platforms, operators are left to gather dispersed information single-handedly, which hampers their ability to make quick decisions. Because decisions are not timely, progressing rapidly through the kill chain is difficult. Fusion solves this problem by combining vast amounts of data, sorting it, identifying the essential information, and providing the pertinent information to the right operator quickly and efficiently.³⁰ To implement fusion into its future ISR systems, the USAF is planning to use a concept called the multisensor C² constellation that will fuse together all the ground, air, and space multiintelligence (human, signals, communications and measurement, and signature intelligence) platforms. The constellation referred to as multisensor C² constellation (MC²C) will tear down the barriers between individual systems and erect a horizontal architecture that allows sensor platforms to talk to each other. To develop the MC²C, Maj Gen Jerry Perryman, a previous commander of the AC²ISRC, stated, "This complex task of creating the MC²C will require an aggressive, total team effort to meet the goal of having a flying prototype in 2008 with aircraft production beginning in 2009."³¹

The components of the constellation are the MC²A, high- and low-altitude UAVs, and space UAVs (when operational), and they will replace the current capabilities delivered by the AWACS, JSTARS, Rivet Joint, U-2, and the airborne battlefield command and control center (ABCCC). As the battle management component, the MC²A will serve as the hub of the constellation and will use the multiplatform common data link (MP-CDL) to connect all peripheral platforms into a common, horizontal architecture.³²

The MP-CDL's goal is to provide a seamless and transparent global grid of information that all users can access. To achieve this goal, the MP-CDL will transcend today's point-to-point data links with a multipoint connectivity system that allows a multitude of active (transmit and receive) users and an indefinite number of passive (receive only) users. To ensure maximum participation, the MP-CDL is scalable and modular, so it can fit on

many different sized air and ground vehicles. To keep the information flowing freely without compromise, the network is jam-resistant and secure. If the system, design, and development phase and flight tests go as planned, the MP-CDL should be ready for production and implementation in FY2006.³³

Based on the above discussion, there are a few tentative conclusions that can be made for ISR's capability in 2010:

- New MP-RTIP sensors will most likely detect, locate, and identify COIs, but they will be limited in covering all the AOIs due to standoff range limitations, LOS obstructions, or Global Hawk's inability to loiter because of the threat.
- Because of these limitations, other sensor platforms will be needed to cover the AOIs deep within enemy territory, behind terrain obstructions, or in high-threat areas until the SBR becomes operational.
- Improved fusion and streamlined battle management architecture will result in faster decision making, increasing the speed of progression through the kill chain.

Future Time-Critical Target Attack Capability

Based on evidence and conclusions from chapter 2, the ideal strike vehicle for engaging emerging TCTs would have the following characteristics and capabilities: fly and strike targets autonomously without the need for support aircraft (i.e., stealth); fly fast to cover distance quickly (i.e., be reactive); find, track, and identify targets accurately (when applicable); deliver munitions capable of attacking and killing mobile targets; integrate easily with existing and planned systems; and be reasonably priced. The USAF is investigating a myriad of approaches to best satisfy these requirements. The most promising approaches are the LOCAAS munition, hypersonic delivery vehicles, the UCAV, and the affordable moving surface target engagement (AMSTE).

Low-Cost Autonomous Attack System

The LOCAAS is a small miniature missile that was designed specifically for emerging TCTs. Its genesis stemmed from the elusive behavior of Scud TELs that systematically evaded coalition attempts to detect, locate, identify, and destroy them. During Operation Desert Storm, the first detection of a Scud sometimes did not occur until a launch was observed by a DSP satellite or an RC-135 Cobra Ball. Once a launch was detected, these platforms calculated and predicted not only the Scud's intended target but also the missile's launch point. With this information available, the conceptualization for the LOCAAS was forged.³⁴

In forging a design for the LOCAAS, one hurdle to overcome was how to locate a fleeing target with a munition that cannot be redirected after launch. Because a Scud TEL could leave its firing location within five minutes of shooting a missile, well before a LOCAAS would likely reach the Scud's firing site, the munition would need to perform an area search to find and kill its prey.³⁵ The size of the search area depended on the speed of the TCT fleeing its launch site and the time elapsed before the LOCAAS arrived on station. Table 2 displays the areas as a function of elapsed time for 20 miles per hour (mph) and 35 mph vehicles.³⁶

Table 2. Low-cost autonomous attack system search area for a fleeing vehicle

<i>Elapsed Time^a in Minutes</i>	<i>20 mph^b in Square Miles</i>	<i>35 mph^b in Square Miles</i>
10	35 (2)	107 (5)
15	79 (4)	240 (10)
20	140 (6)	427 (17)
30	707 (29)	962 (39)

^a Elapsed time is measured when the vehicle starts moving (normally within five minutes after launch).

^b The number in parenthesis indicates how many LOCAAS are required to search the area assuming each munition covers a 25-square-mile area with no overlap.

Based on table 2, the size of the search area increases with the square of how far the vehicle travels during the elapsed time. While it only takes four LOCAAS to adequately search for a 20 mph vehicle in 15 minutes (79 square miles), it takes 29 LOCAAS at 30 minutes (707 square miles), more than seven times the previous number. The search area continues to grow even after the LOCAAS arrives on station. For example, even if a LOCAAS arrives 10 minutes after a 20 mph vehicle departs, more than two LOCAAS are required because they cannot search the entire area instantaneously, and in 10 additional minutes, the search area has quadrupled in size. It appears that for the LOCAAS to be effective and cost efficient, the required number need to arrive at the launch site either before launch (if we can detect, locate, and identify it) or soon after.

For the LOCAAS to perform an area search for the target, the original glider design that was flight-tested in the 1990s was scrapped, and a 5 lb turbojet engine that produces 30 lbs of thrust was added.³⁷ With this addition, the LOCAAS flies about 200 mph for 30 minutes or about 100 miles in distance.³⁸ To give the LOCAAS enough time to search for its target, LOCAAS is air delivered by aircraft or missiles (e.g., a hypersonic delivery vehicle) within 50 miles of the target area where it cruises for 15 minutes (or less) to reach the target's expected location. Upon reaching the location, LOCAAS spends the rest of its time searching the area for the target. With 15 minutes of search time, the LOCAAS can cover about 25 square miles of territory.³⁹ If the target is not found, the LOCAAS self-destructs so "the enemy cannot get its hands on the technology."⁴⁰

To incorporate LOCAAS into its inventory, the USAF granted \$33 million to Lockheed Martin in December 1998 to build a prototype munition.⁴¹ The prototype munition's flight occurred on 28 March 2003.⁴² If the flight tests are successful, the USAF plans to buy 12,000 of these munitions at a cost of about \$33,000 each.⁴³

Unlike most air-to-surface munitions that contain hundreds of pounds of explosives, the LOCAAS uses a small multimode warhead not much bigger than a soup bowl. Because the warhead is small, LOCAAS is only 31 inches long and weighs a meager 85 lbs.⁴⁴ The warhead has three different modes of op-

eration: fragmentation for a soft kill on soft vehicles, an aerostable slug for standoff, and a stretching rod for hard armor, and it is selected based on the type of target engaged.⁴⁵ The key enabler that allows LOCAAS to determine the type of target and select the proper mode of kill is advanced ATR software.

To detect and identify targets accurately, the LOCAAS uses light detection and ranging (LADAR) in conjunction with advanced algorithms. Although LADAR has not been commonly used in the past, the technology is not new and has been used extensively in medical instruments and bar-code scanners.⁴⁶ LADAR works by emitting light and capturing the returning image to form a three-dimensional (3D) image of the area. Once a picture is captured, advanced processing is done to scan the picture for potential targets. If a potential target is identified, it is compared to stored target templates in the ATR's software database. If a match occurs, the LOCAAS dives down upon its prey, selects the appropriate warhead mode based on the target type, and delivers the fatal blow.⁴⁷ Although seemingly simple, one problem with ATR technology is its inability to find and identify targets that are fully or partially hidden by foliage or other debris.⁴⁸

Since LADAR is light energy, it cannot adequately penetrate through foliage or other obscurations to detect targets. While there is little that can be done to alleviate this problem with fully obscured targets, the Defense Advanced Research Projects Agency (DARPA) is working on a solution for partially obscured targets. The program, called Jigsaw, attempts to solve the problem by taking several pictures of a potential target from different viewing angles, by peering down through holes in the foliage, and by fusing the data together.⁴⁹ The end result is an enhanced 3D image that increases the probability for successful target identification. Another problem with ATR technology is its lack of ability to discriminate between real targets and objects that look like targets.

This phenomenon, often called a systems constant false alarm rate, is the rate at which a system misidentifies objects as targets.⁵⁰ Because there are many naturally occurring objects that look like targets when viewed with LADAR, current versions of ATR programs have difficulty in discriminating real targets from

look-alike targets, especially in cluttered terrain. Needless to say, probably few commanders will want to assume responsibility for a munition that cannot be trusted to kill only valid targets, especially since the political ramifications of fratricide or collateral damage are often unbearable. "All bombs are becoming political bombs, and air commanders must be aware of their emerging constraint—hundreds of millions of people will judge [via the Cable News Network] the appropriateness of everything an air commander does."⁵¹ This aspect of warfare must be part of a commander's decision process, and it may drive him to wage war through the delicate application of force instead of mass destruction to create shock and awe.

Two solutions are possible to increase an ATR program's ability to identify targets precisely. First, create a stringent target template in the ATR algorithm so that an object is only declared a target when an exact match occurs between the template and the 3D image. The obvious drawback to this approach is the lack of efficiency. In this case, the LOCAAS enjoys 100 percent assurance of its target, but many targets are bypassed because of match inadequacies. The result is a LOCAAS that seldom finds what it is looking to kill, even when encountering valid targets. The second solution is to incorporate man-in-the-loop (MITL) guidance.

MITL guidance enables a human operator to view the target and decide whether to engage it. This approach has two distinct advantages. First, it keeps the question of accountability solidly answered at all times. Second, the MITL allows increased flexibility and risk reduction. Because of these reasons, one study asserted that any LOCAAS-type autonomous weapon should incorporate a MITL capability.⁵² Unfortunately, the LOCAAS is not currently planned to use MITL guidance, mainly to limit the munition's cost.

LOCAAS's strength is its low cost and ease of integration. Each LOCAAS, estimated to cost \$33,000, is roughly equivalent in cost to two JDAMs. This fact assumes a UCAV or manned aircraft as the delivery platform. The cost of using LOCAAS rapidly skyrockets when delivering them via expensive hypersonic or stealthy cruise missiles. Considering that an AGM-158 joint air-to-surface standoff missile (JASSM) is projected to cost \$300,000

and carries only three LOCAAS, efficiency of operation quickly deteriorates.⁵³ While hypersonic vehicles are much faster than the JASSM, they are projected to cost \$200,000 and carry only two LOCAAS.⁵⁴ Nevertheless, a faster delivery increases efficiency because the search area is decreased and results in fewer LOCAAS required to detect, identify, and engage a moving target. It appears that in regard to cost-effectiveness, delivering LOCAAS by reusable aircraft is the most efficient means, followed by hypersonic delivery, and, finally, the JASSM.

Hypersonic Missiles

Decreased response time is one advantage of hypersonic missiles. Decreased response time is derived directly from the missile's speed. Most hypersonic missiles fly at speeds ranging from Mach 5 to Mach 8, which translates to about 50 to 80 miles per minute.⁵⁵ Considering that a supersonic Mach-1 aircraft covers about 10 miles per minute or 50 miles in five minutes, a hypersonic missile traveling at Mach 8 can cover 400 miles in the same time. The difference is staggering. Hypersonic missiles enable them to be launched well outside any threat envelopes and still impact the target with the same timeliness of an aircraft loitering close to the target.

Another advantage of hypersonic missiles is their survivability. Similar to the well-known Patriot system that is capable of engaging inbound missiles, the highly exported Soviet SA-10 Grumble can do the same. The SA-10 is difficult to destroy even with high-speed antiradiation missiles (HARM) because the SA-10 engages and shoots down the incoming missiles before they can reach the system's components. Other double-digit SAMs are equally difficult to engage. The benefit of a hypersonic missile is that enemy SAM systems cannot adequately engage them because they are traveling too fast for successful intercept. Hypersonic missiles are difficult to negate and, because of this fact, are useful in attacking targets protected by highly capable, double-digit SAMs.

While hypersonic vehicles offer these two advantages, their development has been plagued by several technological problems. First, reliable engines are expensive and difficult to manufacture.⁵⁶ Research into ramjets dates back 50 years,

but relatively few hypersonic vehicles have been developed because of the engine's inability to sustain adequate thrust to maintain hypersonic speeds.⁵⁷ Today, the supersonic combustion ramjet (scramjet) is being perfected and has propelled missiles above Mach 5 for long periods of time.⁵⁸ Unlike solid fuel engines that burn out quickly, long-burning scramjet engines allow for greater range and increased payloads.⁵⁹

The second problem plaguing hypersonic missile development is airframe heating. Aerothermic heating occurs by the friction of the air passing over the missile's body and, at Mach 4, results in a temperature of about 1,200 degrees Fahrenheit (F). As the speed increases to Mach 6 and Mach 8, the temperature increases to a whopping 2,800 and 5,600 degrees F, respectively.⁶⁰ Titanium and Inconel materials can handle temperatures in the Mach-4 range, but the main problem is keeping the missile's internal payload (i.e., the warhead) cool so it does not explode.

Another technological problem incurred is fitting a warhead of adequate size into the slender body of a hypersonic missile.⁶¹ One proposed solution is to negate the warhead altogether and use the missile itself as a kinetic kill vehicle. Since kinetic energy varies directly with the square of the missile's velocity, a missile striking a target at Mach 8 generates 64 times the energy as the same missile striking the target at Mach 1. For this reason, hypersonic vehicles with inert, kinetic kill warheads are ideal for hardened or deeply buried targets such as C² bunkers. Although this approach is adequate for fixed targets, it is not suited to attack moving targets because the missile is not redirectable in flight. Once the missile is launched, it attacks a predesignated, fixed target. To overcome this limitation, LOCAAS is used.

To eject LOCAAS munitions successfully without injuring them, the hypersonic missile must slow to subsonic speed.⁶² While this feat seems simple, a slender missile body traveling at Mach 8 descending at a steep angle towards the earth has little desire to slow down on its own accord. Boeing recently explored nine different dispense concepts, but the follow-on program to test their viability went unfunded. Tom Grady, an expert in the field, believes that getting the dispense technology perfected by 2010 will be expensive, and it will likely result in decreased missile payload and more stability problems that will

require even more effort to overcome.⁶³ This is a difficult task, not to mention the need to self-destruct the expended hypersonic missile before it impacts the earth to minimize collateral damage.

To find solutions to some of these problems, several programs are currently in place, which include the Affordable Rapid Response Missile Demonstrator (ARRMD), HyTech, the Low Cost Missile, and the High Speed Strike System (HiSSS). The first program, DARPA's ARRMD, is developing a \$200,000, Mach 6–8, rapid-response missile that can engage TCTs or deeply buried hardened targets.⁶⁴ To propel the missile, DARPA is formulating a ramjet that burns hydrocarbon fuel and is capable of sustaining a missile at Mach 6 for 600 miles with 250 lbs of payload.⁶⁵ Another hypersonic program is HyTech.

The HyTech program was initiated by the USAF in 1995 to design and test technologies for successful hypersonic flight of missiles, aircraft, and transatmospheric vehicles. It is funded at about \$20 million per year and is currently concentrating on developing a scramjet propulsion system that will operate from Mach 4 to Mach 8. The program's focus is to develop an air-to-surface hypersonic missile that can travel 750 NM in less than 12 minutes.⁶⁶

The third hypersonic program, the Low Cost Missile—sometimes referred to as Fast Hawk—has been in development since 1997 when Boeing received an \$8 million contract from the US Navy. The initial contract called for a 36-month program to develop and demonstrate hypersonic technologies for the Navy's next generation land-attack system.⁶⁷ One interesting feature of Fast Hawk is its wingless design. The missile changes direction by bending its airframe. The specifics on how the technology works are puzzling and is not discussed in this study.

The purpose of the HiSSS—the final program that looks promising and sponsored by the Office of the Chief of Naval Operations (OPNAV)—is to merge the new technologies developed in the aforementioned hypersonic programs to produce a common-use hypersonic missile by 2010.⁶⁸ The missile is expected to fly at Mach 3½ to 7 for 600 NM. The HiSSS missile will not carry the LOCAAS or attack moving targets but will rely on a kinetic kill warhead that penetrates up to 36 ft of

concrete. To obtain buy-in from the various services, the OPNAV wants the missile to be capable in all weather conditions, day or night, and employable from USAF strike platforms, naval air, surface, and subsurface forces, and the Army's Multiple Launch Rocket System.⁶⁹ Provided procurement proceeds as planned, the missile is slated to field in 2010 with the purchase of 1,200 missiles by 2015.⁷⁰

Unmanned Combat Aerial Vehicles

Although perceived as a new technology, the development and use of unmanned air vehicles can be traced to World War I with the production of the US Army's Kettering Bug. This unmanned aircraft traveled at 55 mph and carried a 180 lb bomb 40 miles where it nosed-over and crashed into the intended target.⁷¹ Since this genesis, unmanned aircraft development has been slow to progress because of technological deficiencies, political resistance, and lack of cooperation between services.⁷² Even in times when an operational UCAV was greatly needed, spurring developmental programs into action, the programs were soon abandoned when the need subsided, mostly due to high program costs with minimal returns.⁷³ However, with the success of the UAVs in Desert Storm, Bosnia, and Kosovo, the story has changed, and the USAF is now fully committed to developing and integrating UCAVs into their warfighting strategy.⁷⁴ General Jumper stated, "We plan to pursue this [UCAV] program once the [advanced technology demonstrations (ATD)] are over. I don't think there's any doubt about that . . . UCAVs will come, and we will work the concept of operations to include them."⁷⁵

To jumpstart the development of an operational UCAV, the X-45, the USAF and DARPA established a three-phased ATD program in October 1997. Phase one granted awards to four companies to provide competing designs that would meet the X-45's specifications. In March 1998 Boeing's Phantom Works won the competition, which prompted the beginning of phase two. The end of FY2002 scheduled phase two for completion. During that phase, development and demonstration of the X-45 was supposed to validate its technology and feasibility.⁷⁶ Phase three is projected to culminate with the demonstration of a

fully operational X-45B UCAV in FY2007. If the program proceeds as planned, operational UCAVs could be fielded by 2009.⁷⁷ In October 2001 the X-45A was undergoing taxi tests at Edwards AFB, California.⁷⁸

The X-45A is a stealthy, tailless, 10,000 lb aircraft that is about two-thirds the size of an F-16. Once loaded with fuel and ordnance, the X-45A tips the scales at 19,000 lbs and uses a Honeywell F124 Turbofan to propel it to operating altitudes above 40,000 ft at speeds in excess of Mach 0.8. The X-45 is practically impossible to track with radar and operates at high altitudes where optical AAA and SAM systems cannot engage it; these characteristics give the X-45 autonomy of operation. The only threats capable of shooting down a stealthy UCAV are enemy interceptors where the pilot visually acquires the UCAV and employs heat-seeking missiles or bullets to engage it. While this is possible, experience has shown that the Big Sky theory makes it improbable.⁷⁹

One of the big advantages of the X-45 is its ability to carry diverse ordnance loads and incorporate the MITL into its guidance. With two 168-inch weapon bays, the X-45 is capable of carrying four HARMs, 12 small-diameter bombs (SDB), 12 LOCAASes, and two 1,000 lb JDAMs or two Joint Standoff Weapons (JSOW). Because the weapon bays are split, the X-45 can mix its munitions (e.g., one JDAM and six LOCAASes).⁸⁰ The end result is a flexible platform tailored for a wide variety of applications.

The other big advantage is MITL guidance, which allows for human interaction in the engagement process. The X-45 incorporates this guidance by using a high-resolution SAR sensor that produces a target image that is relayed via data link back to the operator. Once the operator confirms the target, it is attacked. One additional benefit of the on-board SAR sensor is that the UCAV may be used in an ISR role to augment other sensors such as Predator and Global Hawk.

The planned missions for UCAVs are dull, dangerous, and dirty.⁸¹ Dull missions are those requiring long endurance such as reconnaissance and surveillance patrols. Dangerous missions are those where conventional manned aircraft face risk incommensurate with the gain or situations where the political environment does not warrant the possible loss or capture of

an American pilot. Dirty missions result when biological or chemical contaminants are used. Commensurate with the idea of dangerous missions, the USAF has determined the first UCAVs will accomplish the SEAD.

The USAF's choice is logically based on one study that evaluated the UCAVs, manned aircraft, and a space-based option in regards to life-cycle cost, risk to human life, feasibility, and mission effectiveness to perform the SEAD mission. The study concluded that UCAVs were the best option of the three platforms investigated.⁸² Since the ACC has determined that the combat air forces will be deficient in SEAD in 2015, the UCAV may help alleviate the problem.⁸³ However, one area of concern is the UCAV's lack of range.

The X-45 has a range radius of about 650 NM.⁸⁴ A 1997 RAND study specifically addressed needed range requirements for the next generation attack fighter. The study investigated several scenarios. One scenario considered Iran, Iraq, and North Korea as enemy theaters of operation and, using favorable bases, found that only 70 percent of the targets could be attacked with a 650 NM-range radius aircraft.⁸⁵ When the range radius was decreased to 600 NM, some AAR was required in the Iran and Iraq theaters to reach 70 percent of the targets. Another scenario evaluated the same enemy states but with less favorable basing.⁸⁶ In this case, either an 800 NM-range radius aircraft or significant AAR was needed to hold the same percentage of targets at risk (70 percent). The results of the study are disturbing because the X-45 is not currently projected to perform AAR, and with a range of only 650 NM, it appears that the X-45 may not be useful in performing the missions it was designed to accomplish. If the UCAV is best suited for dull, dangerous, and dirty missions, its range must allow it to penetrate deep into enemy territory and attack those targets where manned aircraft fear to tread or to loiter for long periods on patrol. It appears that if the UCAV is going to be adequately suited to perform these types of missions, some serious modifications need to be made.

Even if the range modification was made and even with the UCAV's advantages of reusability, invulnerability to attack, and incorporation of MITL guidance, the UCAV still has difficulty engaging emerging targets quickly. Since there are limits to how

many UCAVs will be available to loiter while waiting for tasking, they will not be able to be every place at one time. While they might be positioned in likely target areas, they still will not be able to respond quickly to targets emerging outside expected areas. The UCAVs suffer from the same time and space problems that prevent traditional aircraft from achieving fast response times. Unfortunately, there is little that can be done to rectify the problem. However, one benefit the UCAV has over manned aircraft is its relatively low cost of procurement and operation.

The UCAV is expected to cost about one-third that of a Joint Strike Fighter (JSF), about \$10 million, and its operations and support costs are estimated at only 25 percent of a manned fighter unit.⁸⁷ The operations and support savings stem from the operators training in simulators vice flying real aircraft. Few UCAVs will ever fly daily sorties since they are crated and stored in special boxes where they remain for up to 10 years or until needed. When the need arises, the UCAV is loaded onto a transport, delivered to its operating area, assembled, fueled, and ready to fly. Of course the UCAV can self-deploy if airlift is in short supply. While still in storage, software changes are made directly through the UCAV's box via a receptacle. This action allows the programmer to access the UCAV's memory to change software without breaking open the sealed container. Since the UCAV's flight controls are powered entirely by electricity, leaking hydraulic fluid or dry-rotting rubber seals are of no concern. The UCAV is a tidy and efficient platform that promises to deliver many advantages, but only if its range is extended.

Affordable Moving Surface Target Engagement

The AMSTE is a program awarded to Northrop Grumman Corporation and Raytheon Systems for \$23.3 million used to develop a methodology engaging moving surface targets with long-range precision standoff weapons.⁸⁸ To achieve this, the program will network and integrate sensors and weapons without expensive modification to existing and future planned systems.⁸⁹ AMSTE's methodology to engage TCTs is to track them with radar from standoff systems and relay the track data (i.e., the target's location) directly to a precision-guided

weapon in flight. Instead of using an area search munition such as LOCAAS to scan an expected target area, AMSTE continuously updates the target's location to the weapon, which eliminates the need to search. Two tests have proven that the concept is feasible.

The first test occurred on 15 August 2001 when three MTI radars—an ASARS-II, a Global Hawk radar, and a test-bed radar—were used to generate a precise track of a target. The target's location was relayed via data link to a modified Maverick missile. The missile, continuously updated to the target's position, scored a hit on the moving target.⁹⁰ The other test occurred on 28 August 2001 when two MTI radars—a JSTARS and a surrogate radar—tracked a moving target and relayed its location to a guided-glide weapon. This weapon also scored a hit.⁹¹ However, there are limitations to the concept.

First, the LOS obstructions are a concern. Radar must have an unobstructed view of the vehicle to see and track. Targets in deep or rugged terrain pose particular difficulties since targets may only be seen intermittently as they weave in and out of culverts. Just when one thinks a valid track is obtained and a weapon is launched, there is no way to know when the target will soon disappear behind some intervening terrain or will cause the radar to break lock and result in an unsuccessful engagement. While Global Hawk and manned aircraft minimize LOS obstructions by flying close to the AOI, standoff is greatly compromised. Space is perhaps the best platform for AMSTE to use, but it will not be fully operational until about 2020 and will need powerful target tracking radars because of the increased ranges involved.⁹²

Second, because accurately tracking moving vehicles demands high radar update rates, radars used with AMSTE will not likely be capable of performing other tasks when busy tracking a target. Considering that a limited number of radars are available to perform all of the ISR functions, dedicating even a few of these radars to AMSTE will most likely degrade the overall ISR effort.⁹³ If only a few radars are dedicated to AMSTE, the system will be capable of engaging only one target at a time. One solution is to time-share the radars between

collection and engagement, and this might offer a reasonable compromise provided it could be implemented.

Third, this last limitation is the need for a vehicle to deliver the weapon. Most munitions other than cruise missiles and LOCAAS are delivered within 10 miles of the target. If an aircraft must come so close to deliver the munition, why invest in AMSTE when the aircraft could use a Maverick-type munition and perform the entire engagement on its own? Therefore, for AMSTE to have any value, it must use long-range weapons that are delivered from standoff orbits. Cruise missiles such as JASSM or hypersonic missiles will hardly prove cost efficient. One likely munition is the SDB with a bolt-on wing kit. This munition flies more than 30 miles when dropped from high altitude, and because it is relatively inexpensive, it might provide a reasonable exchange between standoff and cost.⁹⁴

Summary

This chapter investigated and evaluated the USAF's proposed approach to eliminate bottlenecks in the kill chain. It was found that while ISR's capabilities in 2010 will be improved, discrepancies would still exist, specifically in areas outside sensor coverage. Many vehicles are being developed to engage TCTs, but all have limitations. The LOCAAS is cheap, but unless its ATR feature is improved, it may be of little use with today's high concern for collateral damage. Hypersonic missiles offer great advantages in speed but cannot engage moving targets without incorporating in-flight updates or delivering LOCAAS munitions. The UCAV is perhaps the best option, but it lacks the required range and speed of response to perform all of its proposed dull, dangerous, and dirty missions. The last proposal, AMSTE, promises to overcome the need for a LOCAAS-type munition, but it will require many radars to engage even a few TCTs. Radar LOS problems are still incurred with AMSTE's long standoff distances, and some type of cheap munition such as the SDB with wing kit will need to be used.

Notes

1. Guilbeaux and Connor, *Multi-Sensor C² Constellation Team Effort*, slide 9; and Djuric, "Future Command and Control of Aerospace Operations," 6. The USAF created the Aerospace Command and Control and Intelligence, Surveillance, and Reconnaissance Center (AC²ISRC) in 1998 to pursue technology and systems that would eliminate chokeholds and speed up the kill chain.

2. Federation of American Scientists, "Joint Surveillance Target Attack Radar System."

3. Northrop Grumman, "Northrop Grumman Team Awarded \$303 Million Contract for Multi-platform Radar Technology Insertion (MP-RTIP) Program," news release, 11 December 2000.

4. Guilbeaux and Connor, *Multi-Sensor C² Constellation Team Effort*, slide 9.

5. Northrop Grumman, "Northrop Grumman Team Awarded MP-RTIP Contract," news release, 19 February 2000.

6. Federation of American Scientists, "Joint Surveillance Target Attack Radar System."

7. Office of the Secretary of Defense (OSD), *Unmanned Aerial Vehicles Roadmap*, 4. The Global Hawk was not expected to become operational until FY2005. Because of the opportunity to use Global Hawk in Afghanistan, the USAF opted to exercise the technology before it fully matured, which resulted in some setbacks.

8. *Ibid.*

9. Federation of American Scientists, "RQ-4A Global Hawk."

10. OSD, *Unmanned Aerial Vehicles Roadmap*, 4.

11. *Ibid.*

12. Behler, address, 13 December 2001.

13. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 16.

14. "The Warfighter's Edge."

15. "That's the SPIRITT," *Beyond 2000*.

16. Weisstein, "Books about Fourier Transform Spectroscopy." "Fourier transforms were originally developed as an engineering tool to study repetitive phenomena such as the vibration of a stringed musical instrument or an airplane wing during flight. A Fourier transform spectrometer (FTS) is a Michelson interferometer with a movable mirror. By scanning the movable mirror over some distance, an interference pattern is produced that encodes the spectrum of the source. FTSes have a multiplex advantage over dispersive spectral detection techniques for signal, but a multiplex *disadvantage* for noise"; and Air Force Research Library (AFRL) Fact Sheet.

17. "That's the SPIRITT."

18. Lamb and Stone, *Air Combat Command Concept of Operations for Endurance Unmanned Aerial Vehicles*; and Hathaway, "Germinating a New SEAD," 17.

19. OSD, *Unmanned Aerial Vehicles Roadmap*, 22. The DarkStar Unmanned Aerial Vehicle (UAV) program was to incorporate stealth, but it was cancelled in favor of the Global Hawk.

20. Corcoran, *Higher Eyes in the Sky*, 1.

21. *Ibid.*, 2.

22. *Ibid.*, 20.

23. *Ibid.*, 45; and Steinhardt, *Discoverer II Space Based Radar Concept*, slides. The Discoverer II program was to design, fabricate, and launch two prototype moving target indicator (MTI)/synthetic aperture radar satellites to conduct a one-year effectiveness study on MTI, tracking, imaging, and digital terrain elevation data.

24. Research, Development, Test, and Evaluation (RDT&E) Budget Justification Sheet, "Space-Based Radar EMD."

25. US Air Force Fact Sheet, "Space-Based Radar."

26. Hutcheson, *Unified Aerospace Power in the New Millenium*, 20.

27. Corcoran, *Higher Eyes in the Sky*, 2; and Correll, "The Vision Force."

28. Wall, "Recce Plans Bolstered in Terror's Wake," 61.

29. Global Security, "E-767 Multi-Sensor Command and Control Aircraft."

30. Murphy et al., "Information Operations."

31. Fulghum, "New Air Force Recce Aircraft Takes Shape," 34; and Fleming and Paone, "Air Force Developing New 'Constellation' of Integrated Capabilities."

32. *Ibid.*

33. Pierce, "Draft Rev 4 Systems Requirements Document for the MP-CDL."

34. Defense Support Program satellites are located in geosynchronous orbit 22,300 miles above the earth and are capable of detecting missile launches by observing their heat signature during boost phase. The system, deployed in 1970, will soon be replaced by space-based infrared system. USAF Space Command Fact Sheet; and Federation of American Scientists, "Joint Surveillance Target Attack Radar System." Cobra Ball is a modified RC-135 specifically designed to detect and track tactical ballistic missiles during their boost phase. Within seconds of launch, the system provides estimates of launch, intercept, and impact points that can be data-linked to other C² platforms; and Tom Grady (AFRL), interview by the author, 19 November 2001.

35. Lukes and McKenzie, "Theatre Missile Defense (Attack Operations) for those Tactically Challenged," 28.

36. *Ibid.*, 33. A MAZ 543 Scud TEL can travel at a maximum speed of 60 kilometers per hour (35 miles per hour).

37. Cheung, "Mini-missile Has Mind of Its Own."

38. Goodman, "Tank Eradicators," 38.

39. *Ibid.*

40. Barela, "Anti-armor Einstein."

41. Erwin, "Technologists Chasing Mobile Target Hunters."

42. AFRL, "ACC Applied Technology Council Meeting"; and Bowie et al., *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns*, 16.
43. Erwin, "Technologists Chasing Mobile Target Hunters."
44. Goodman, "Tank Eradicators," 38.
45. Hathaway, "Germinating a New SEAD," 50.
46. Richardson, "Casting Light on a Target." One exception is the AGM-129A advanced cruise missile, which uses light detection and ranging for terminal guidance; and Erwin.
47. Goodman, 38.
48. Grady, interview.
49. DARPA Special Projects Office, "Jigsaw Project Concepts."
50. The constant false alarm rate is normally associated with the rate of false target indications in a radar system, caused by interference or noise levels that exceed the established detection threshold.
51. Meilinger, *10 Propositions Regarding Air Power*, 46–47.
52. Kosan, *United States Air Force Precision Engagement against Mobile Targets*.
53. Federation of American Scientists, "AGM-158 Joint Air to Surface Standoff Missile."
54. Fernandez, address, 11.
55. Kevin L. Zondervan (senior project engineer for the Aerospace Corporation), interview by the author, 13 December 2001.
56. Grady, interview.
57. Wiencek, "Hypersonics."
58. DARPA, "Hypersonic Scramjet Projectile Flies."
59. *Ibid.*
60. Correll, "The Vision Force."
61. Grady, interview.
62. *Ibid.*
63. *Ibid.*
64. Fernandez, address, 11.
65. Wiencek, "Hypersonics."
66. *Ibid.*
67. Correll, "The Vision Force."
68. *Ibid.*
69. *Ibid.*
70. Wiencek, "Hypersonics."
71. Shaker and Wise, *War without Men*, 22.
72. Clark, *Uninhabited Combat Aerial Vehicles*, 28–32.
73. *Ibid.*, 32.
74. Barry and Zimet, "UCAVs."
75. Tirpak, "Send in the UCAVs."
76. Hathaway, "Germinating a New SEAD," 53.
77. Wyatt, *DARPA/USAF UCAV*, slide 9.
78. Wall, "X-45A UCAV Poised for First Flight," 97.

79. The Big Sky theory asserts that because the atmosphere is so big and vast, there is little chance of two or more airplanes engaging each other from pure happenstance.

80. Fulghum and Wall, "Mini-Bombs Dominate U.S. Weapons Plans." The small-diameter bomb (SDB) is a 250-pound Global Positioning System-guided munition that is designed for use in the UCAV, F-22, and other air vehicles. Although not as big as other air-to-surface munitions, it promises to service 85 percent of the targets currently taken out with 2,000-pound bombs by its extremely high accuracy—95 percent of the SDBs will land within 3 meters of its intended target. The Joint Standoff Weapon is a glide munition that can carry a unitary warhead or submunitions.

81. Clark, *Uninhabited Combat Aerial Vehicles*, 39.

82. Hathaway, "Germinating a New SEAD," 70.

83. Clark, *Uninhabited Combat Aerial Vehicles*, 47.

84. Mark E. Garner (AFRL UCAV program manager), interview by the author, 13 December 2001.

85. Stevens et al., *The Next-Generation Attack Fighter*, 24–29. Favorable bases are the closest existing military bases to the theater of operation.

86. *Ibid.* Less favorable bases are existing bases safe from theater ballistic missile attack or from being overrun.

87. Tether, address, 7.

88. Welby, "Networked Targeting Technology."

89. Tether, address, 7.

90. DARPA, "DARPA Demonstrates Affordable Moving Surface Target Engagement."

91. *Ibid.*

92. Corcoran, *Higher Eyes in the Sky*, 2.

93. Grady, interview.

94. Fulghum and Wall, "Mini-Bombs Dominate U.S. Weapons Plans."

Chapter 4

Preemptive Approach

Opponents will take advantage of delays or shortcomings in US quick reaction targeting capabilities to shelter threat systems. Therefore, Future Battlespace Dominance requires the ability to hold opposing forces at risk any time, in any weather, stationary, or moving.

—Stephen Welby
Defense Advanced Research Projects
Agency Special Projects Office

This chapter investigates the feasibility of using a preemptive approach for engaging TCTs and begins by defining the approach with the introduction of its associated kill chain. Future methods of accomplishment are investigated to include ground mines and the low-cost persistent area dominance (LOCPAD) miniature munition. This chapter proposes that perhaps there is a better approach to solving the problems associated with TCTs.

Defining the Approach

Unlike the reactive approach that speeds through the kill chain after detecting a TCT, the preemptive approach uses intelligence to predict where the enemy will act and employs persistent aircraft or weapons to patrol the area. As soon as the aircraft or weapon detects a COI, it is located, identified, destroyed, and assessed in one fell swoop. The bulk of the traditional kill chain's process is consolidated and integrated into the aircraft or weapon loitering over the target area. Figure 2 displays the kill chain in two levels, predictive measures and integrated ISR weapons systems.

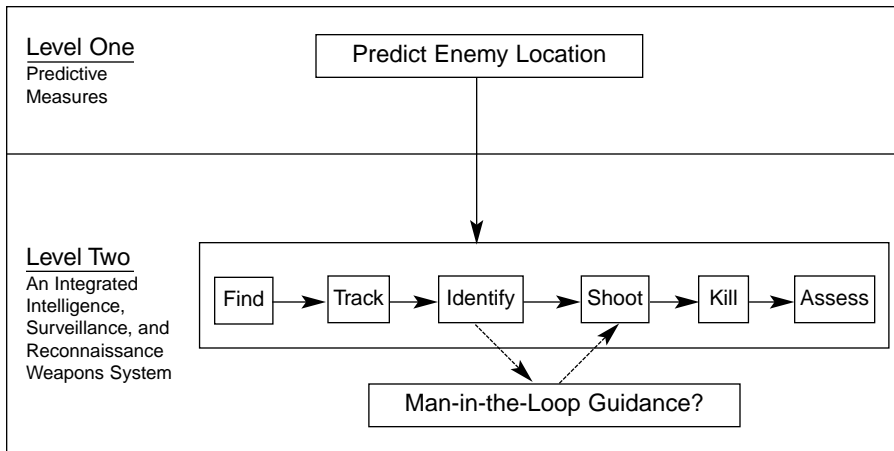


Figure 2. Preemptive kill chain

Predictive Measures

The primary enabler of preemptive employment is having the means to predict the enemy’s location. Since it is unlikely that a commander will ever have perfect intelligence to accurately predict where a TCT will emerge in all cases, the question of using aircraft or weapons in a preemptive role relies on the commander’s willingness to take some degree of risk. While there is no question that tasking aircraft or munitions to loiter over unproductive territory is inefficient and wasteful, if some degree of probability exists that a TCT is in the area, the payoff may be worth the risk. Payoff is determined by the value gained by destroying the TCT and is calculated by the threat it imposes on friendly forces. For example, if enemy Scud missiles are known to carry nuclear, biological, or chemical warheads, a commander may risk wasting some of his resources to ensure the missiles are located and destroyed before they can be launched against friendly forces. In this situation, a commander will most likely opt to preemptively employ forces even with a poor intelligence estimate of the Scud’s location.

This fact was evidenced in Operation Desert Storm when General Horner dedicated more than 4,700 sorties to preemptively hunt for Scuds.¹ Part of the effort used A-10s to “scour

the roads that mobile Scuds were likely to travel from their storage areas to launch sites.”² At night AC-130s patrolled expected Scud-operating areas in hopes of scoring a kill. Since planners knew the ranges of the Scud missiles and their potential targets such as Tel Aviv, Riyadh, or Dhahran, they were able to predict Scud-launch areas. Once the areas were identified, F-15Es flew combat air patrols directly over these launch areas in an effort to find and destroy the Scuds.³ In all of these cases, General Horner did not wait to detect a Scud before using his forces. Instead, he preemptively employed forces based on intelligence prediction to seek out and kill them. While General Horner’s approach might have been inefficient, the political ramifications of Iraqi Scuds landing in Israel mandated the effort.⁴ General Jumper promoted General Horner’s approach of limiting TCT search areas by analyzing terrain features, “If you provide rules such that tanks can’t sit on the sides of cliffs and SA-3s can’t be on mountain peaks, you quickly take away 60 percent of the terrain that is of consequence to any maneuver on the battlefield.”⁵ While General Jumper’s suggestion may vary based on the battlefield’s topography, his approach will reduce the needed search requirements based on fewer possible enemy locations.

Cost is another factor that influences the amount of risk a commander will accept and relates directly to the number of excess aircraft or munitions available for use. Commanders who harness an overabundance of aircraft or munitions can likely afford to squander some assets, but an overabundance of assets is seldom the case. Most commanders are limited in resources and do not have all the aircraft, space platforms, or munitions they desire. This fact is especially true for high-tech weaponry such as stealth aircraft and precision-guided munitions. One example that proves this point occurred in Operation Enduring Freedom (OEF) where limited stockpiles and production of JDAMs led to a serious shortage. The coalition was using approximately 40 JDAMs per day, but only 40 were being produced each month. The shortage became extreme in only a few months, and the commander had no choice but to slow down JDAM expenditure.⁶ A similar problem occurred in the Persian Gulf War and Bosnia when the limited production

and development of cruise missiles could not keep pace with requirements.⁷ Although greater stockpiles and better procurement strategies could ensure more stocks on hand, shortages in assets will likely continue. Thus, better prediction is critical to help increase efficiency and preserve resources. The predictive battlespace awareness (PBA) intelligence concept promises to increase successful prediction.

PBA is the process of analyzing enemy activities to the point where they can be accurately predicted.⁸ However, to predict the enemy's actions, one must understand the enemy accurately. Therefore, intelligence must continuously be collected, analyzed, and studied. General Jumper states, "We [the USAF] collect and we observe and we have a nice info briefing about this, but who's the person out there who's pulling that information out of the system, studying it down to the most minute detail, and figuring out how to go after that thing, and finding out what the most vulnerable point is, or part is, and figuring out how to keep that SA-10 from getting where it's supposed to be? Who's doing it? We don't do that."⁹ General Jumper has a point. If one is to understand the enemy, one must not only gather information but must also analyze it to gain understanding. Unfortunately, since the bulk of the information is collected with reconnaissance platforms that sporadically observe the enemy, only a few pieces of information are obtained at a time, which makes it difficult to combine all of the pieces over a continuum and gain the understanding General Jumper desires. One way to relieve this difficulty is to surveil.

Surveillance is the "systematic observation of aerospace [now air and space], surface, or subsurface areas, places, persons, or things, by visual, aural, electronic, photographic, or other means."¹⁰ While reconnaissance takes snapshots of enemy activity through time, surveillance watches the enemy continuously and observes movement and processes. Greater insight into the enemy's mind is gained that helps solidify the foundation for accurate prediction. Close and continuous observation of enemy behavioral patterns leads to understanding, and understanding is the key enabler of prediction. Surveillance is difficult to achieve with air and space platforms.

Surveillance requires persistent observation and necessitates that a sensor remain over an area for a long period of time. Since most satellites are over an area for only short periods of time, surveillance is usually not possible from space.¹¹ While manned aircraft could surveil in permissive environments, they usually suffer from fuel limitations and the threat of enemy air defenses.¹² The result is that the majority of USAF ISR platforms provide reconnaissance with few (such as SIGINT satellites in geosynchronous orbits) surveilling. To overcome this limitation, ground-based intelligence sources such as the Special Operations Forces (SOF), spies, or unattended ground sensors are used.

To conduct surveillance operations, the SOFs are normally inserted deep behind enemy lines where they secretly observe enemy actions. In Desert Storm SOFs used dune buggies inserted deep in Iraq to surveil Scud missiles. To remain covert, the dune buggies were specially designed to fold completely so they could be hidden during the day.¹³ After the war SOFs reported destroying seven Scuds and called in air strikes on five more to claim a total of 12 kills.¹⁴ Although their claims were unsubstantiated and disdained by American intelligence sources, it is undisputed that SOFs' surveillance contributed to the overall Scud-hunting campaign. One factor that limits SOFs' ability to surveil in populated or secure enemy areas is their need to remain hidden.

Spies overcome the SOFs' limitation by infiltrating an enemy's organization and attempting to gain access to sensitive information. Because spies work undercover, they can oftentimes provide information about the enemy's future intentions, grand scheme of maneuver, and center of gravity. Spies have difficulty transmitting the information to outside agencies before the information perishes. Working inside the enemy's camp, spies cannot reveal their true allegiance and may have to wait inordinate lengths of time before passing the information. When this occurs, the value of the intelligence is degraded and may be of little use. Unattended ground sensors were used in the past to alleviate problems incurred with the SOFs and spies.

Unattended ground sensors are airdropped devices that measure acoustic, seismic, magnetic, radio frequency, EO, or

chemical emissions.¹⁵ In Vietnam Operation Igloo White used seismic, acoustic, and radio frequency unattended ground sensors to detect movement of vehicles and men on the Ho Chi Minh Trail. When one of the sensors detected movement, it sent a code to an orbiting EC-121 aircraft that relayed the information to the infiltration surveillance center (ISC). The ISC correlated the code to the sensor's location and contacted ABCCC to request an air strike. While there were problems with some sensors malfunctioning, Igloo White was credited with the real-time location of more than 20 percent of the attacked targets. Moreover, almost 38 percent of the truck parks and 15 percent of the trucks attacked were located with Igloo White.¹⁶

With the success of Igloo White, the Remote Battlefield Acoustic and Seismic System (REMBASS) was developed in the late 1970s and used acoustic, seismic, and magnetic sensors to detect and classify targets.¹⁷ The system classified targets into four broad categories: personnel, wheeled vehicles, tracked vehicles, and unknown. Like its Vietnam-era predecessor, the system can transmit its findings to a central facility where the information is analyzed.¹⁸ In 1982 the improved REMBASS (I-REMBASS) was fielded and, other than offering a few slight enhancements in a smaller device, was not significantly modified from its original version.¹⁹ REMBASS and I-REMBASS were primarily designed to help SOFs surveil or to allow division, brigade, and battalion army commanders track enemy movement beyond the forward line of troops. One disadvantage of both REMBASS systems is the need for them to be hand placed. Special REMBASS teams are required to infiltrate hostile territory, place the sensors, and evade back out.²⁰ One future system that promises to overcome this limitation is the internetted unattended ground sensor (IUGS).

The IUGS system is deliverable by aircraft or artillery and employs the GPS along with acoustic, magnetic, seismic, environmental, and chemical sensors to detect enemy movement.²¹ "Advances in digital signal processing and smaller computer chips have enabled the technology and result in a more robust and reliable system. Since the system is internetted, it is expected to enhance the Army's Future Combat Systems program."²² Because the IUGS decreases delivery dif-

difficulties and corrects many of the traditional problems of unattended ground sensors like high false-alarm rates and power failures, the IUGS will likely be more influential in providing surveillance than the other previously used ground sensors.²³

Successful prediction is difficult but may be achieved by knowing the enemy's equipment capabilities, terrain delimitation, and surveillance. While all three methods should be used, surveillance is the best means to gain an understanding of the enemy because it continuously monitors enemy action and provides minute detail about the enemy's behavior. Most air and space assets are not adept at surveillance because they lack persistence. Ground-based sensors such as the SOFs, spies, and unattended ground sensors help to overcome the problem of persistence and were used successfully in the past. It appears that predicting the enemy's TCT locations may be possible to some degree in the future. Since it is unlikely to be perfect, the JFACC will still need to weigh expected benefits and risks to determine whether preemptive employment is a viable option.

Integrated Intelligence, Surveillance, and Reconnaissance Weapons Systems

The preemptive kill chain's second level requires a loitering integrated ISR weapons system that can detect, locate, identify, shoot, kill, and assess a target. Because the integrated platform performs the majority of functions found in the traditional kill chain, attack is possible immediately after a COI is detected and identified. Both manned aircraft and the Predator UAV have accomplished this task.

In Vietnam FACs were used to find targets and to direct strike aircraft to attack them. When the enemy discovered FACs circling overhead, they quickly disappeared beneath the jungle canopy before strike aircraft could arrive and deliver ordnance. One study found that in a four-month period during 1970, 54 percent of fleeting targets were not struck because firepower was not available.²⁴ To overcome this difficulty, the FACs began carrying ordnance that allowed them to attack a target as soon as it was identified. The OV-10, one of the first aircraft designed for this specific purpose, carried machine guns and four rocket pods.²⁵ With the integration of

weapons and surveillance platforms, the entire kill chain could now be accomplished with only one aircraft, and consequently, opportunities to kill elusive targets were no longer lost.

A similar situation occurred 20 years later in Operation Desert Storm that rekindled the concept. Because Iraq's armor was dug-in and difficult to distinguish from decoys by traditional ISR methods, General Horner adopted the Killer-Scout concept that sent pairs of F-16s into designated kill boxes to locate and destroy targets of opportunity.²⁶ By tasking the same pilots to conduct the operation each day, a pilot could readily detect any changes on the ground and either attack the target or mark it for another fighter to attack. Through systematic observation, the Killer Scouts achieved a level of surveillance that led one F-16 veteran assigned to the operation to say, "The Iraqis could not make a move without the Killer Scouts knowing about it."²⁷ After the war, General Horner praised the Killer-Scout effort, stating, "They [Killer Scouts] kept pressure on Saddam during the daytime. He could not move his forces. He just had to sit there and absorb punishment during the daytime."²⁸ In this example, prediction determined the kill-box locations; once the Killer Scouts arrived therein, the kill chain was quickly completed with little or no help from other platforms.

While the above examples demonstrate the effectiveness of the preemptive method using manned aircraft, certain contextual elements allowed manned aircraft to succeed. Traditionally, manned strike aircraft lack persistence and require support aircraft to accompany them into hostile airspace. However, in the examples presented, manned aircraft enjoyed autonomous operations because the majority of enemy air defenses were negated. Enough assets were available to replace low-fuel aircraft loitering over an area with others to gain a degree of persistence over the area. History shows that these contextual elements occur, and many other historical examples (some referred to in earlier chapters) provide evidence where they have not. One should not view using manned aircraft for preemptive employment as a panacea but only where favorable circumstances are present. The Predator-carrying Hellfire missile is another air vehicle used as an integrated ISR weapons system.

The Predator UAV was modified to carry Hellfire missiles because of lessons learned in Kosovo. Similar to the experiences found in Vietnam and Operation Desert Storm, targets detected often disappeared before strike aircraft could arrive and attack.²⁹ To solve this problem, the USAF redesigned and strengthened the Predator's wings to carry two Hellfire-C laser-guided antitank missiles. After the modifications were completed in February 2001, the USAF tested the innovation and successfully scored several hits on stationary tanks.³⁰ Currently, the armed Predator is used in Afghanistan to attack emerging targets.³¹ The Predator's attacks have been successful in some respects, but its poor accuracy and limited carriage capacity have hindered the effort.³²

Evidence in OEF showed the Predator's inability to hit small objects. Many times after a Predator missed its target—such as a vehicle carrying Taliban soldiers—the vehicle would stop, and its occupants would get out and run away.³³ Hellfire has little capability to target personnel in the open, so once this happened, little could be done to rectify the situation. On other occasions when the Hellfire hit its intended target, little damage was done because the missile's small, shaped-charge warhead lacked the required blast and fragmentation to kill the vehicle and its occupants.³⁴ Another limitation is the number of Hellfire missiles carried by the Predator. With a loiter capability of more than 24 hours, two missiles do not provide much firepower, and once expended, the Predator reverts to an ISR asset without the capability to complete the kill chain autonomously. Since reloading the Predator quickly is seldom an option because of the time it needs to return to base and re-deploy, there is little that can be done to rectify the problem. Because of these reasons, the Predator is not a viable integrated ISR weapons system.

Future Methods

Because manned aircraft and the Predator are inept in serving as integrated ISR weapons systems, other platforms with better capabilities are needed. Two candidates for consideration are ground mines and the LOCPAD miniature munition.

Ground Mines

Ground mines are not regarded as integrated ISR weapons systems, but they should be considered because they can detect, classify, locate, and attack enemy targets. Since ground mines simply sit on the ground and wait, they offer levels of persistence that airborne platforms cannot offer. For these reasons, ground mines are investigated. Since Gator mines are the only deep-attack mines that will be available in 2010, they will be the focus of consideration. Another system, the Army's Block II (Ultimate) Raptor, is expected to become operational around FY2011, but it will not be discussed for two reasons.³⁵ First, it will not become operational in time to meet the needed requirements. Second, upon initial analysis, the Raptor system does not appear to offer many advantages over Gator.³⁶ While the Raptor system is more technologically advanced and capable in some respects, an in-depth analysis is not warranted.

Gator Mine

Gator mine, sometimes referred to as CBU-89, is a 1,000 lb cluster munition that can be delivered by practically any of today's fighter or bomber aircraft and contains 72 antitank (AT) and 22 antipersonnel (AP) mines that are housed inside a casing called a tactical munitions dispenser (TMD).³⁷ When dropped from an aircraft, the TMD falls ballistically until it senses a certain height above the ground where it then blows apart and dispenses the mines.³⁸ On average, the mines in each TMD will cover an area of about 200 x 650 meters.

Once deployed, the 22 AP mines deploy trip wires that, when disturbed, detonate the mine and send high-velocity shrapnel into the horizontal plane that serves not only to injure enemy personnel traversing the area but also to protect the minefield from being cleared. The other 72 AT mines are specifically designed to kill armor. They consist of microelectronics that detect targets, discriminate armored vehicles, and detonates an explosive charge into the belly of the vehicle once it is over the mine.

One of the advantages Gator offers over other types of land mines is its ability to self-destruct at a predetermined time.

Users can select from one of three options, which include intervals of four or 48 hours and 15 days, and this feature was designed to allow friendly forces to traverse the area later without the need for mine-clearing equipment. Operational use has proven that the self-destruct mechanism is not 100 percent reliable, so mine-clearing equipment is still needed (or at least recommended) for friendly forces to cross predisposed Gator minefields.³⁹

Scatter mines such as Gator were first used by US forces in Desert Storm to deny Iraqi forces access to airfields and to create choke points along main roads.⁴⁰ On 27 February 1991, B-52 bombers scattered Gator mines along the Rumayla bridge, which helped prevent the escape of Iraqi forces before they could be attacked by coalition aircraft.⁴¹ The mines were also used extensively in areas where Scud TELs were likely to be operating such as culverts, overpasses, bridges, and staging. Based on the *Gulf War Air Power Survey (GWAPS)*, these efforts only served to discourage road movement and did little to destroy the Scuds or prevent them from launching missiles.⁴²

The Gator mine was not effective in engaging Scud TELs primarily because the Scuds dispersed months before the war began and the MAZ-543 Scud vehicle travels off road and can operate in a variety of environments. According to the *GWAPS*, the majority of Scud TELs dispersed from their central bases by the end of August 1990, approximately four months before Operation Desert Storm was initiated.⁴³ The Scuds were already in hiding when the war began, and with so many places to hide, they were practically impossible to find. Iraqi Scuds did not follow Soviet doctrine as coalition forces expected, which introduced even more fog and friction into the calculus. Clearly, while Gator was used on expected Scud operating locations, one could not possibly mine all of the areas. Gator is useful for preventing or discouraging movement, but if enemy vehicles do not have to move, Gator is of little value. Such was the case with the Iraqi Scuds.

On occasions when the Scuds moved to shoot or regenerate, they did not have to travel on primary road surfaces. The MAZ-543 Scud transport vehicle incorporates an eight-wheel

drive chassis with a 525 horsepower diesel engine, which easily traverses unprepared surfaces.⁴⁴ With this capability, Scuds tend to travel on secondary, tertiary, or primitive roads located away from primary LOC. Since it is difficult to effectively mine obscure areas where few if any natural choke points occur, employing Gator mines to stop Scud operations are difficult at best.

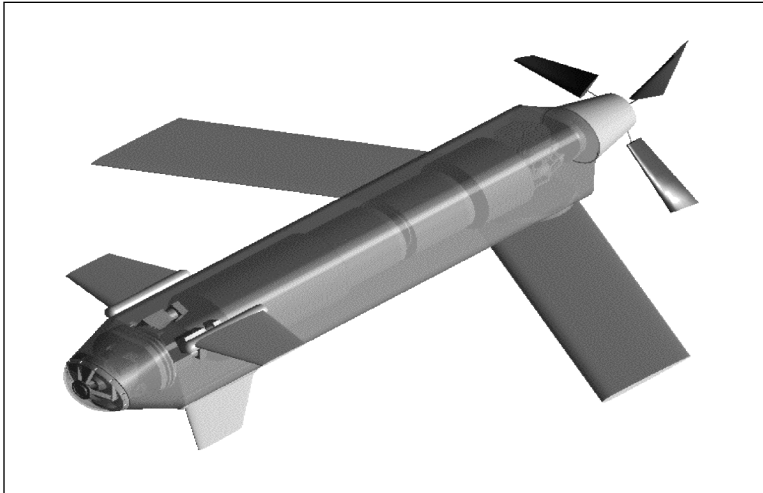
Because of recent developments in the political scene, Gator mines may not be used regardless of their military effectiveness. In May 1997, President William "Bill" Clinton pledged that the United States would sign the Ottawa Mine Ban Treaty that outlaws the use, production, stockpiling, and transfer of AP land mines. Even though the United States hoped that Gator mines would escape the treaty because of their self-destruct mechanism, the other signatories disagreed stating that the self-destruct mechanism was unreliable. Thus far, the treaty has been signed by 140 nations, and while the United States is the only NATO country that has not condemned the use of AP mines, the United States plans to join the treaty and ban AP mines by 2006 if alternative weapons are adopted. Considering that some experts are already touting that alternative weapons exist, the ban may become a reality much sooner.⁴⁵

Moreover, the political pressure to prevent fratricide and collateral damage may also prevent the use of Gator. Experience in Operation Desert Storm showed that coalition ground forces sometimes stumbled unknowingly into Gator mines. Because pilots sometimes missed their targets, Gators ended up in locations unexpected by ground forces and hindered their movement. Consequently, when Gator was considered for use in Operation Deliberate Force, it was quickly abandoned to prevent fratricide and collateral damage.⁴⁶

Gator has value in situations where the enemy is committed to movement along well-known LOC. Since the TCTs are elusive, disperse early into hiding, and traverse unprepared surfaces, engaging them with Gator is difficult. Considering that their future use will likely be banned, or at least restricted by political pressure, Gator does not offer a reasonable solution to the problem.

Low-Cost Persistent Area Dominance, Miniature Munition

Because manned aircraft, the Predator, and ground mines have significant limitations in providing the USAF with an integrated ISR weapons system that can effectively engage TCTs, another platform with better capabilities is needed. To do this, personnel at AFRL's Armament Product Directorate conceptualized the LOCPAD, and with sufficient funding, it could be operational by 2009.⁴⁷ The LOCPAD (shown in photo) is specifically designed for preemptive targeting and holds targets within a defined area at risk for long periods of time. Because each LOCPAD can search only a small area (i.e., NFOV search), multitudes of the LOCPADs are needed to cover larger areas. The LOCPADs must achieve an adequate revisit rate over the search area so that if a target emerges, it is detected and destroyed before it can escape the area or engage friendly forces. To achieve these ends, the LOCPAD has a long-loiter capability, incorporates an ISR suite to detect, locate, and identify targets with either MITL guidance or ATR algorithms, integrates weapons that can destroy a variety of vehicles, and uses a full duplex data-link architecture that allows for communication and control.



Low-cost persistent area dominance design. Photograph courtesy of USAF Armament Product Directorate.

By using a light, composite six-inch treated fuselage, low-drag wings, and a small gasoline engine, the LOCPAD is capable of flying for more than 12 hours before exhausting its fuel supply.⁴⁸ LOCPAD's long-loiter capability is primarily achieved by an engine-propeller combination that is much more efficient than miniature jet turbines like those used in the LOCAAS, sometimes by as much as eightfold.⁴⁹ The trade-off for efficiency is speed. The LOCPAD travels at about 70 knots, and although it can fly long distances to its designated search area, the LOCPAD is best delivered directly to the area by aircraft, UCAVs, or missiles. This delivery method avoids wasting LOCPAD's fuel and increases its loiter time in the search area. One favorable feature of the LOCPAD is that unlike reusable platforms that must return to base before exhausting their fuel, the LOCPAD is expendable and continues searching for targets until all of its fuel is exhausted. When fuel is consumed, the LOCPAD is programmed to either attack the nearest target of opportunity or self-destruct at altitude.⁵⁰

LOCPAD's ISR suite detects, locates, and identifies targets using several different sensors and processes. To detect targets, the LOCPAD uses IR imaging and passive millimeter wave radar located in its wing's leading edge. Because it uses IR and radar sensors, the system is capable of detecting targets in rain or light fog.⁵¹ When the system detects a potential target, a flash LADAR located in the munition's nose takes a 3D picture of the object.⁵² After this, the image is either data-linked to a ground station where a human operator identifies and confirms the target, giving consent for attack, or the LOCPAD uses its on-board ATR algorithms to decide for itself (as shown in fig. 2).⁵³ Because ATR software may not be reliable in all cases, LOCPAD's ability to use MITL guidance is a big advantage over other purely autonomous weapons such as the LOCAAS.⁵⁴ Nevertheless, the LOCPAD incorporates ATR technology so it can operate autonomously in those environments where the risk of fratricide or collateral damage is minimal.

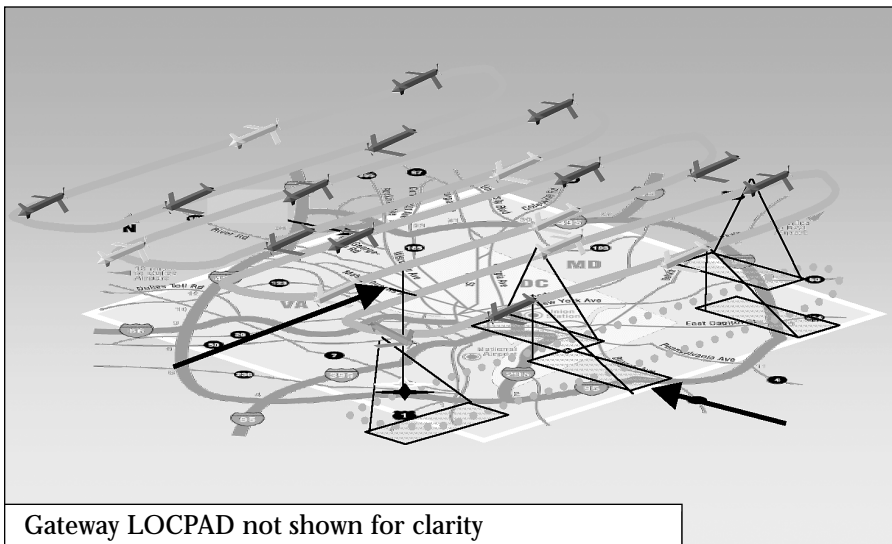
To kill its prey, the LOCPAD employs either sensor-fused weapons (SFW) or a 5 lb, blast-fragmentation warhead similar to a combined-effects bomblet.⁵⁵ The LOCPAD carries two SFWs internally, and because they are better optimized to kill vehicles

and armor than the 5 lb warhead, SFWs are the preferred kill method.⁵⁶ LOCPAD flies over the target and ejects an SFW. Once ejected, the SFW spins up, senses ground elevation, searches for a heat source, and fires an explosively formed projectile into the target at 4,500 ft per second.⁵⁷ While complex, these SFWs were used operationally in 1997 when two B-1Bs carrying CBU-97/B—a wide area cluster munition containing multitudes of SFWs—were dispatched to Bahrain.⁵⁸ After the two SFWs are expended, the 5 lb, blast-fragmentation warhead can be delivered via a suicide mode where the LOCPAD crashes into the intended target.⁵⁹ While this mode is an option, a different LOCPAD (with unexpended SFWs) is selected to attack the target and preserve the overall integrity and effectiveness of LOCPAD's constellation.

To allow control of the LOCPADs, a full duplex data link (4-watt S-band type) is used.⁶⁰ Although the data link is limited to LOS, a gateway LOCPAD operating above 5,000 ft AGL is used to transfer the information to other platforms such as Global Hawk or Predator that can relay the information to LOCPAD's command module.⁶¹ This relay capability is important because one of LOCPAD's strengths is its ability to operate deep inside enemy territory well beyond where standoff airborne sensors can detect emerging targets. As information is received and assessed at the command module, the operator can shift the entire LOCPAD constellation to a new location, order a specific LOCPAD to attack a specific target, or gather the BDA by tasking a LOCPAD to take LADAR imagery of previously attacked targets. The collected imagery allows the BDA to occur in real time and, if necessary, enables the operator to order an immediate restrike. The data-link architecture adds a robust capability to the LOCPAD, and it gives the operator the needed flexibility to respond quickly to emerging targets, even when operating deep inside enemy territory.

Another area that is enhanced through the use of data link is LOCPAD's constellation search coverage. The LOCPADs must search an area continuously to ensure detection of emerging targets, and the data link and LOCPAD must communicate with one another and set up an optimized systematic search pattern. One simplified pattern (shown in photo) illustrates

the possible appearance of the spacing and deconfliction between the LOCPADs. Each LOCPAD station uses a data link for communication that keeps and makes corrections to its orbit to optimize the constellation's coverage. For convenience, the corrections occur automatically and do not require any operator input. However, it is envisioned that a plethora of LOCPADs, orbiting at low altitudes over enemy territory, might be detected and engaged. Each LOCPAD pattern is periodically changed in altitude and cross range to reduce predictability and increase survival.⁶²



Low-cost persistent area dominance's search constellation. Photograph courtesy of USAF Armament Product Directorate.

While altering LOCPAD's flight profile will likely increase survivability, it is still exposed to enemy air defenses. LOCPAD's optimum altitude is about 1,500 ft AGL, and because flying lower decreases its search area coverage and flying higher degrades its ability to detect and identify targets, the LOCPAD is limited in the amount of altitude it can vary and still be effective.⁶³ For these reasons, the LOCPAD remains in the heart of many enemy threat systems.

While design experts assert that man-portable air defense systems, radar-guided SAMs, and radar-guided AAA cannot successfully engage the LOCPAD because of its extremely small radar cross section and virtually undetectable heat signature, small arms fire and optically aimed AAA may be able to effectively engage the LOCPAD.⁶⁴ Experience has shown that the key to minimizing losses to small arms fire and optically aimed AAA is to avoid visual detection, and because of this fact, the USAF now normally employs the majority of its strike aircraft at altitudes above 15,000 ft.⁶⁵ This altitude works well for aircraft. Testing is yet to be done to determine if an adversary can visually detect a small LOCPAD loitering at 1,500 ft AGL. Although somewhat imprecise, a comparison can be made on a basis of scale. Since manned fighter aircraft operating at or above 15,000 ft normally remain visually undetected, a miniature munition loitering over the enemy at 1,500 ft undetected would need to be approximately one-tenth the size.⁶⁶ Using the dimensions of an F-16 for comparison, the munition would need a wingspan of less than 3.3 ft and an overall length of less than 5 ft to avoid detection. Engineers who are currently designing the LOCPAD confirm that it will likely measure no more than 48 inches long with a wingspan under 3 ft.⁶⁷

One option that may help further prevent the enemy from visually detecting the LOCPAD is to use camouflage paint so the munition blends into the sky. With less contrast, the LOCPAD would be more difficult to see and may even prevent an enemy using optical devices with magnification (i.e., binoculars) from detecting it. Because no one camouflage pattern works in all environments, changing weather conditions will be a concern and most likely negate the camouflage's effectiveness. For example, cloud and haze backgrounds are ideal for visually detecting overhead flying objects (regardless of camouflage) because they appear as dark objects moving against a light background. While painting the LOCPADs will help them avoid enemy detection, the tactic will not work in all environments, possibly causing the LOCPADs to face enemy fire.

Another concern is LOCPAD's ability to survive enemy barrage AAA fire, which is designed to fill a volume of space rather

than aimed specifically at a given target.⁶⁸ Fire is usually not initiated until attack is either impending or under way. This reservation helps ensure that aircraft are at least overhead before expending ammunition. Rather than occupying large volumes of airspace that is difficult to achieve by shooting individual bullets, shells are used that explode at predetermined altitudes and send bits of shrapnel (called flak) blitzing through the air. Each exploding shell covers a much larger volume of airspace than an individual bullet, which results in a more effective and efficient defense system. As evidenced in the Second World War, this type of barrage fire has both damaged and fatally wounded attacking aircraft. In regard to the LOCPAD, it appears that using barrage fire with explosive shells may not be a likely option.

Since the LOCPAD flies at roughly 1,500 ft AGL, shells would need to detonate at approximately the same altitude. If this were to happen, not only would the LOCPAD be subject to the blast but also ground troops (to include the AAA operators) located in the vicinity. The smallest Soviet AAA round that incorporates a self-destruct option is 37 millimeter, and its minimum detonation altitude is 3,700 meters or about 11,000 ft, well above where the LOCPAD operates.⁶⁹ Larger shells offering more blast only serve to compound the problem. For this reason, it is unlikely that the LOCPAD will face exploding shells; if they are not used, it will be difficult at best to achieve the required concentration of AAA fire to engage a LOCPAD effectively. While the enemy may score an occasional golden BB and shoot down a LOCPAD without explosive shells, random firing with unitary bullets will probably not prove all that effective. For those cases where the enemy successfully engages the LOCPAD, replenishing munitions will be required to replace attrition and keep the constellation effective.

The number of LOCPADs required to hold an area at risk depends on the size of the area, the target's maximum travel speed, the target's engagement speed, LOCPAD's rate of coverage, and the rate of attrition. As with the LOCAAS, the number of LOCPADs needed to cover an area varies with the square of its radius. The target's speed is a concern because enough LOCPADs must cover the area fast enough so that if a target

emerges, it cannot escape the area before a LOCPAD detects it. Target engagement speed is also important because the LOCPAD must detect an emerging target before it can set up and engage friendly forces. LOCPAD's rate of coverage varies with its speed and altitude and remains relatively constant. Attrition will need to be factored into the equation once further study is accomplished and accurate data is obtained. Taking into account these factors, tentative calculations show that a 14 kilometers (km) x 14 km area (roughly equivalent to 70 square miles) requires 32 LOCPADs to keep a 60 km per hour target (e.g., a Scud TEL) from escaping detection for a 12-hour period.⁷⁰ With so many LOCPADs required to hold even a small area at risk, cost becomes a big concern.

Originally, each LOCPAD was estimated to cost about \$33,000 or roughly equivalent to a LOCAAS. However, with LOCPADs advanced-sensor suite and data-link communications, the experts now predict each LOCPAD will cost about \$100,000, which equates to approximately six JDAMs.⁷¹ Furthermore, if the JASSM, conventional cruise missiles, or hypersonic missiles deliver the munition instead of aircraft or the UCAVs, the price of employment increases dramatically. While the LOCPAD offers increased capability over other munitions, unless manned or unmanned aircraft employs it, the LOCPAD will not likely prove cost-effective for prolonged employment scenarios or where multitudes of the LOCPADs are needed to cover large target areas.

The USAF is developing several platforms that will be able to employ the LOCPADs. The F-22 is capable of carrying at least nine LOCPADs internally along with a complement of air-to-air missiles.⁷² The JSF will also have the capability to deliver the LOCPAD, but current data does not state how many. With two 168-inch weapon bays, the stealthy X-45 UCAV will also be able to carry the LOCPADs and, because of its ability to operate autonomously, may be the perfect choice to deliver the munitions to their areas of operation. Evidence suggests that delivering the LOCPADs with manned aircraft or the UCAVs may not be a concern.

Summary

The preemptive approach offers an alternative approach to the traditional reactionary kill chain and relies on one's ability to successfully predict enemy target locations and use integrated weapon platforms to continuously survey the area for emerging targets. By using different intelligence techniques such as area delimitation, PBA, and surveillance, it appears that successful target prediction may be possible in future conflicts. Because it will not likely be perfect, future combatant commanders will need to assess the level of risk acceptable versus the cost of preemptive weapon employment.

While manned aircraft have been used successfully in this role, notably in benign threat environments or where commanders have had a preponderance of assets, they are usually not well suited to perform the role of an integrated weapons platform in high-threat areas or with limited assets because of the incurred costs. Predator offers a reasonably cheap solution but is hardly effective due to Hellfire limitations and lack of carriage capacity. Although Gator offers the advantage of persistence, its effectiveness is marginal because targets disperse early and travel on unprepared surfaces, thus eliminating choke points that would normally serve to funnel them into minefields. Also, the Ottawa Mine Ban Treaty creates political pressure that will likely negate, or at least limit, its future use. The LOCPAD offers a promising alternative to a commander because of its long-loiter capability, MITL guidance, and relatively cheap cost (provided either manned or unmanned aircraft deliver it). Future study will be required to fully analyze the LOCPAD's survivability, but it appears possible that it will meet needed requirements.

Notes

1. Fox, "Dynamic Targeting," 41.
2. Jamieson, *Lucrative Targets*, 50.
3. *Ibid.*
4. *Ibid.*, 49.
5. Jumper, address, 15 February 2001.
6. David Hathaway (Central Command Air Force chief of strategy), interview by the author, 30 November 2001.

7. Buchan, *Information War and the Air Force*, 2.
8. Fulghum, "New Air Force Recce Aircraft Takes Shape," 34.
9. Jumper, address, 27 June 2001.
10. Joint Publication (JP) 1-02, *Department of Defense Dictionary of Military and Associated Terms*, 413.
11. One exception is signals intelligence satellites located in geosynchronous orbits.
12. This limitation was evidenced when Gary Powers was shot down in his U-2 over the Soviet Union by an SA-2 Guideline missile.
13. Gordon and Trainor, *The General's War*, 245.
14. *Ibid.*
15. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 26.
16. *Ibid.*, 27.
17. Srour, "Unattended Ground Sensors."
18. Since the monitoring device is mobile, this facility can be located in the field, even at the platoon level.
19. Federation of American Scientists, "AN/GSQ-187 REMBASS."
20. Beckman, "Intelligence Scouts," newsletter 01-15.
21. Vick et al., *Enhancing Air Power's Contribution against Light Infantry Targets*, 17.
22. Tether, address. The future combat systems program is a collaboration of mobile, networked, command and control communications, autonomous robotic systems, precision indirect fires, air and ground organic sensors, and intelligence, surveillance, reconnaissance capabilities that will enable and support future Army forces.
23. Srour, "Unattended Ground Sensors," 4.
24. Cooling, *Case Studies in the Development of Close Air Support*, 437-38.
25. *Ibid.*, 546.
26. A kill box was one-half degree latitude by one-half degree longitude or about 30 miles on each side.
27. Jamieson, *Lucrative Targets*, 75-76.
28. *Ibid.*, 78.
29. Federation of American Scientists, "RQ-1 Predator."
30. "Innovative Acquisition Approaches Lessons Learned from the HAE UAV Program," 2.
31. Barry, "A New Breed of Soldier."
32. Hathaway, interview.
33. *Ibid.*
34. Federation of American Scientists, "AGM-114 Hellfire."
35. The Raptor system is composed of the Hornet wide area munition and a sophisticated array of sensors and communications. When it detects a target inside 100 meters, the Hornet fires a sublet over the vehicle where it detonates, explodes, and sends a molten slug into the vehicle. The operator, usually located at a remote site, can control how a constellation of Hor-

nets engages its prey. Because the Hornet can only classify vehicles, not identify them, the operator's decisions are based on rudimentary information. The system was originally devised to stop the invasion of Europe by the Russian hordes.

36. This statement centers exclusively on engaging elusive vehicles deep in enemy territory. The author realizes the Raptor system offers many capabilities that Gator does not, but in regard to the limitations of land mines in general (i.e., spatial concerns and area coverage), a combatant commander employing the Raptor system is faced with many of the same dilemmas as Gator.

37. Federation of American Scientists, "CBU-89 Gator Mine." The Navy's version of Gator is designated CBU-78 and weighs 490 pounds. Each canister carries 45 antitank and 15 antipersonnel mines.

38. Height is predetermined based on the desired density of mines to cover an area. The higher the tactical munitions dispenser opens, the mine density becomes less because of increased mine dispersion.

39. Dupuy Institute, "Land Mines in the 1991 Gulf War."

40. Ibid.

41. Keaney and Cohen, vol. 2, pt. 2, 178.

42. Ibid., vol. 4, 291-92.

43. Ibid., vol. 2, pt. 2, 333.

44. Lukes and McKenzie, "Theatre Missile Defense (Attack Operations) for Those Tactically Challenged," 27, 32, 33.

45. Vietnam Veterans of America Foundation.

46. Human Rights Watch, "Descriptions of Cluster Bomb Types."

47. Gregory Jenkins, "Low Cost Persistent Area Dominance (LOCPAD) Miniature Missile," 4.

48. Jenkins (chief of advanced concepts, plans and programs, Armament Product Directorate, Eglin AFB, Fla.), interview by the author, 9 October 2001.

49. Ben Plenge (Air Force Research Laboratory LOCPAD project engineer, Eglin AFB, Fla.), interview by the author, 19 November 2001.

50. Jenkins, "LOCPAD Miniature Missile," 3.

51. Jenkins, interview.

52. Ibid. While light detection and ranging imaging does not work in all types of weather, it successfully imaged an object obscured by heavy fog at 1.2 kilometer (km). While using unaided vision, the object was lost at 0.7 km.

53. Jenkins, "LOCPAD Miniature Missile," 3.

54. A detailed discussion of automatic target recognition technology limitations is presented in chapter 3.

55. Combined-effects bomblets are used in CBU-87 cluster bombs to attack soft vehicles and personnel. The bomblets are effective against armor when a sufficient number of bomblets hit the target, normally eight to 10 bomblets per 1,000 square feet will suffice.

56. Public Domain at Yahoo.com.

57. Jenkins, "LOCPAD Miniature Missile," 2.

58. Wall, "The Devastating Impact of Sensor Fuzed Weapons," 28.
59. Jenkins, interview.
60. Jenkins, "LOCPAD Miniature Missile," 2.
61. At 1,500 feet above ground level, line of sight (LOS) is achieved out to 250 miles provided the terrain is relatively flat. Beyond this distance, the earth's curvature prevents unobstructed LOS—most likely located in the air operations center.
62. Jenkins, "LOCPAD Munition Missile," 2.
63. Plenge, interview.
64. Optically aimed antiaircraft artillery (AAA) normally uses a magnified aiming device such as a wide-area telescope to detect and track a target. Man-portable air defense systems are shoulder-launched surface-to-air missiles that lock on and track the heat emitting from an object.
65. Jumper, address, 15 February 2001.
66. Another consideration is the LOCPAD's acoustic footprint. If enemies can hear the LOCPAD, they might spend more time trying to engage it.
67. Plenge, interview.
68. JP 1-02, *DOD Dictionary of Military and Associated Terms*, 47.
69. Federation of American Scientists, "M1939, 37 millimeter AAA."
70. Jenkins, "LOCPAD Munition Missile," 3.
71. Plenge, interview.
72. Jenkins, "LOCPAD Munition Missile," 2.

Chapter 5

Results and Conclusions

Having investigated the different methods and techniques that can be used for future time-critical targeting, this chapter condenses and analyzes the evidence and recommends the best course of action. The chapter is separated into two sections. Section one determines if there is a future need for persistent area dominance munitions based on future ISR capabilities and weapons, offering several conclusions based thereon. Section two capitalizes on section one's results and investigates the feasibility of persistent area dominance munitions in meeting any shortfalls.

Is There a Need?

The USAF is aggressively pursuing ways to reactively engage the TCTs through the development of sophisticated ISR platforms that can find and cue strike platforms to emerging targets. Two problems are associated with this approach: (1) achieving continuous ISR coverage over areas of enemy territory with enough fidelity to accurately detect, locate, and identify emerging targets and (2) possessing the capability to quickly kill the target before it hides. Based on all the evidence currently available, it is not likely that the USAF will solve these problems by 2010.

The first problem will continue to plague the process because the SBR will not be operational until about 2020, and until it is, the ISR sensors will not be capable of providing persistent coverage deep inside enemy territory (beyond where standoff sensors can look—typically 100–150 miles behind enemy lines) where many TCTs will likely exist.¹ Even with Predator and Global Hawk UAVs that have the capability to loiter deep beyond the enemy's borders, evidence shows that their vulnerability to enemy air and surface threats will limit employment opportunities or necessitate manned assets to support their operations. Manned aircraft are poorly used in

this role because of efficiency constraints. For these reasons, high-threat areas beyond the range where standoff ISR sensors can search present a unique challenge, one that UAVs are not likely to solve. Because little or no continuous ISR coverage is available in these areas to cue strike platforms to emerging TCTs, the reactionary method of detecting and striking falls flat.

The result is if the USAF remains fully reliant on the reactionary approach, little or no capability to engage TCTs deep inside enemy territory will be likely, even if strike platforms are available. For this reason alone, the USAF needs to seriously consider a way to bridge this gap. The predictive approach using persistent area dominance munitions might be an attractive option, at least until the SBR comes online circa 2020. Furthermore, the acquisition of persistent munitions such as LOCPAD may serve to increase a much needed ISR capability while also acting as a safety net in case future budgetary constraints delay either SBR operations or projected ISR upgrades.

The second problem is devising a weapon with the ability to strike an emerging target before it hides. Evidence suggests that future ISR platforms will be capable of finding and identifying emerging targets within their search areas. Reactionary strike platforms that quickly and effectively engage emerging targets are needed. Based on the future weapons investigated in chapter 3, it appears that meeting this requirement will be difficult at best, especially against TCTs in high-threat areas or deep inside enemy territory.

All the systems investigated (AMSTE, UCAVs, hypersonic missiles, and LOCAAS) have significant drawbacks that hinder their ability to quickly engage emerging targets. The AMSTE suffers from a variety of setbacks, which include LOS obstructions to distant targets (or close targets located behind mountains), the necessity for multiple radars to track a single target, and the need for a delivery platform to encroach the target area. Due to the inadequacy of using the UAVs in high-threat areas, the LOS problem will not likely be resolved until the SBR is operational, and until then, LOS obstructions will likely remain a boundary that prevents AMSTE from engaging TCTs in deep or hostile areas. Because the number of ISR tar-

get tracking radars in 2010 will be limited, using the few available radars for target engagement hinders the entire ISR effort. Because AMSTE requires an aircraft or UCAV to fly relatively close to a target to deliver a weapon, evidence suggests that AMSTE does not deliver significant advantages over current capabilities. AMSTE's projected capabilities are somewhat encouraging, but they will not come to fruition until beyond 2010.

The UCAV also has its share of problems. Although billed by the USAF as the answer to dull, dangerous, and dirty missions, evidence suggests that the UCAV will not only falter in meeting these claims but will also fail to meet the single-digit TCT timeline for two fundamental reasons: range limitations and responsiveness. With a 650-mile range and no air-refueling capability, the UCAV is only capable of striking 70 percent of the targets located within enemy territory.² While the stealthy UCAV enjoys autonomy of operation against enemy threat systems, it hardly matters if it cannot reach emerging targets. Because the UCAV's limited range translates to a limited loiter capability, it cannot orbit for long periods while waiting for the TCTs to emerge in forward areas. While one answer may be to cycle UCAVs routinely in and out of orbits, these types of operations are hardly efficient and have traditionally been avoided. These two limitations, in conjunction with the UCAV's moderate speed that further restricts its ability to respond to emerging targets, result in a strike platform that has difficulty accomplishing not only the dull, dangerous, and dirty missions but also in meeting the required timelines for engaging the TCTs. Evidence suggests that the UCAV will offer little help in solving the TCT problem.

The next system is hypersonic vehicles, and while they solve the range, survivability, and timeliness problems incurred with AMSTE and UCAVs, they have other limitations that plague their development and use. The first problem involves finding a way to fit explosive munitions into a slender hypersonic missile that heats up to extremely high temperatures. After this feat, one must find a way to expel munitions such as LOCAAS without causing undue harm; this means slowing a Mach 5 to 8 missile down to subsonic speed before ejecting the munitions. Because these problems result from the hypersonic mis-

sile's inability to track moving targets while in flight, necessitating the use of an AAL munition (i.e., LOCAAS), both problems could be solved immediately by using a system such as the AMSTE, which will not be ready until after 2010. Another overriding problem of hypersonic missiles is their high cost. Considering that only two LOCAAS type munitions will likely fit into a hypersonic missile and that a minimum of four to 10 LOCAAS are required to search a target area, many missiles will be required to deliver the munitions.³ At about \$200,000 each, cost will likely limit the number of missiles acquired and, therefore, their potential for use.

The last system is LOCAAS, and while it holds great promise, it too will not likely solve the TCT problem because it lacks a reliable target recognition capability and a cost-effective vehicle that can quickly deliver it to deep or hostile areas. ATR algorithms used by LOCAAS in 2010 will not likely be accurate enough to ensure military commanders that collateral damage and fratricide will not occur, and because of this limitation, commanders will likely shy away from employing LOCAAS. This does not imply all cases of conflict because in large wars where the stakes are high, politics may allow commanders to accept increased risk. Unfortunately, recent wars have asserted the need to avoid collateral damage and fratricide, and according to leading scholars and military commanders, the requirement will likely persist in the future. LOCAAS's ATR program only recognizes those targets preprogrammed into its memory, and the enemy will likely take advantage of this limitation and slightly alter the shape of their vehicles (with a piece of plywood, etc.), causing the LOCAAS to misidentify a hostile vehicle as an unknown.⁴ Without MITL guidance to further analyze and clarify the situation, the LOCAAS might be ineffective.

The second problem with LOCAAS is achieving a timely response because of delivery delays. Either manned aircraft or UCAVs to keep costs minimized best deliver LOCAAS. However, UCAVs lack range, persistence, and responsiveness, and while manned aircraft overcome the range limitation, they suffer from the traditional problem of needing support assets to accompany them to the target. It appears that delivering LOCAAS

quickly to deep or hostile areas with aircraft and UCAVs is a limitation not easily solved.

These findings strongly suggest that none of the reactionary weapons currently being pursued by the USAF will likely meet the needed requirements to quickly and effectively strike TCTs, especially those residing deep inside enemy territory or in high-threat areas. In situations where the enemy's integrated air defenses are negated, history has clearly demonstrated that while UAVs and legacy strike platforms can operate freely and contribute to the effort, they are only marginally effective in such roles. This is why the USAF is pursuing so many different types of systems to alleviate the problem. The end result in 2010 is that if the USAF continues to solely pursue reactionary weapons, it is likely that the USAF will still operate under the old paradigm that it desperately seeks to correct. Here, LOCPADs may provide the means to fill this gap while there is still time to perfect the technology.

It is important to note that just because ISR and reactionary weapons will not likely be adequate in 2010 to engage all TCTs in single-digit minutes, it does not imply that they should not be pursued. The crux of the matter is that the reactionary approach is inherently efficient from a weapons perspective because they are not employed until a target is confirmed; as a result, fewer weapons are used per target. The approach's inefficiency results from tasking delivery platforms to loiter while waiting for TCTs to emerge, and in many cases, still not able to respond fast enough. If hypersonic vehicles and the AMSTE can be perfected and incorporated in the post-2010 era, stand-off ISR platforms could also serve as hypersonic missile delivery platforms by greatly enhancing efficiency and reaction time in one fell swoop. While the reactionary approach may be broken in 2010, long-term technological advancements and ISR upgrades could render the approach cheap, effective, and efficient.

Can Persistent Area Dominance Weapons Alleviate the Shortfalls?

This section investigates whether or not persistent area dominance weapons (such as the LOCPAD) can help solve the problems presented in section one. It is important to remember

that the question is not whether persistent area dominance weapons can destroy 90 percent or only 50 percent of TCTs but whether preemptive systems can enhance future capabilities at a reasonable cost. To answer the question and make a recommendation two areas are investigated: (1) predictive capability and (2) effectiveness, cost, and ease of integration. After analyzing these areas, results are presented that recommend whether or not the USAF should pursue the approach.

Predictive Capability

The key enabler to the preemptive approach is a robust intelligence network that allows one to predict when and where to use preemptive weapons. If one can get this part of the equation correct, killing TCTs in single-digit minutes is easily accomplished provided enough munitions are orbiting over the area. Evidence suggests that the art of prediction will be easier in 2010, but it will not be perfected and will still require a commander to calculate the costs and benefits of employing preemptive weapons. Furthermore, because the limitation of the ISR continuously observing the enemy deep inside his territorial boundaries will continue in 2010, it will be difficult to obtain the necessary intelligence levels to employ preemptive munitions in these areas.

One method that may help alleviate the difficulty is to use a few LOCPADs in a surveillance role by orbiting them over an area to gain information. By using only a few LOCPADs at a time, costs are kept low. If the collected information warrants the use of an entire LOCPAD constellation, a combatant commander can easily up the ante and fully invest in the effort. While this technique still requires PBA and analysis to determine where to initially place the surveillance LOCPADs, it does prevent using multitudes of munitions without first investigating the situation. LOCPADs can increase ISR collection, help increase the odds of successful prediction, and may propagate further LOCPAD employment if warranted.

Effectiveness, Cost, and Ease of Integration

This section discusses some possible problems with LOCPAD, determines their importance, and decides whether they can be

overcome.⁵ Specifically, it addresses LOCPAD's target recognition and identification capabilities, delivery methods, and cost. Like LOCAAS, LOCPAD uses LADAR and ATR technology as a basis for target identification, and some fear that it will not discriminate real targets from others. While LOCPAD has an ATR capability, its primary method of identifying targets is by using MITL guidance where a human operator looks at a suspected target and makes a determination. Unlike the LOCAAS where the ATR process is entirely automated by computer, MITL guidance helps prevent collateral damage and fratricide by inserting a human operator who can decide whether or not to attack targets on a case-by-case basis. The associated accountability allows combatant commanders to employ LOCPADs with less fear of political disaster. Small structural changes to targets are less likely to deceive a trained human operator than a computer "match-making" ATR algorithm that cannot reason and make selective judgments. Evidence shows that combatant commanders have little reason to fear that LOCPAD will attack an improper target.

LOCPAD delivery is also a concern because, like the LOCAAS, manned aircraft and UCAVs to keep costs minimized best deliver it. The main difference between the two delivery requirements is that while the LOCAAS requires a fast response time, LOCPAD does not. LOCPADs are preemptive munitions that have a long-loiter capability of about 12 hours, and because of this, LOCPAD constellations only need servicing twice a day. Since manned aircraft already successfully operate deep within enemy territory by forming strike packages, LOCPAD deliveries can be tasked on the daily air tasking order and incorporated into preplanned strike operations. The end result is that while some inefficiency is brought into the system because delivery aircraft are employing weapons that may not find a target, it is much more efficient than tasking strike and support aircraft to loiter continuously while waiting for an emerging TCT, even if dump targets are used.⁶ Once the constellations are serviced, the strike assets operate freely against other target sets as usual. Most of the preemptive approach's inefficiency results from the number of the LOCPADs used without guarantee of success—not by tying up more valuable strike and support

assets. The net result is that LOCPAD integrates easily into strike operations, can be employed in deep enemy areas, and offers increased efficiency of delivery assets in comparison to the reactionary approach. However, cost is a concern that hinders LOCPAD employment.

The overriding inefficiency occurs when the LOCPADs are used in areas where TCTs do not exist. With a price tag of \$100,000 each and requiring at least 32 LOCPADs to cover a 70-square-mile area for a 12-hour period, LOCPADs are not a cheap option. In cases where TCTs are weapons of mass destruction or threaten coalition cohesiveness, such costs might not only be acceptable but may be a bargain. In other cases where the threat is less, LOCPAD's cost may not be justified. Perhaps in these situations, LOCPADs can be used in an ISR role. When considering the high cost of operating manned platforms that require highly trained aircrew, expensive aircraft, and a robust support network, LOCPAD is a cheap option in relative terms. Nevertheless, a cost-benefit calculus is needed before employing multitudes of LOCPADs.

Conclusions

Based on the above analysis, a few conclusions are formulated. First, the road the USAF is currently traveling contains large potholes that need filling. The potholes primarily stem from a lack of ISR and weapons capabilities that fail to quickly engage the TCTs in deep or hostile areas. Second, the LOCPAD is a viable option that can fill these potholes by integrating easily into today's strike operations, accessing deep target areas, and increasing delivery vehicle efficiency. Third, a robust intelligence network is needed to enable the preemptive method, and the LOCPAD may help fulfill this requirement by increasing ISR collection. Fourth, because the LOCPADs quickly become expensive when used en masse, commanders will need to prioritize where and when to use LOCPADs based on a cost-benefit calculus. Fifth, the LOCPADs will complement reactionary weapons after 2010. By employing both reactionary and preemptive methods in the future, predictive intelligence can better align reactionary forces, and reactionary ISR platforms can move LOCPAD constellations to target rich areas as

they appear. The resulting synergy will enhance the overall efficiency of the effort. Sixth, the USAF should continue pursuing the reactionary approach because it promises a cheap, effective, and efficient solution to engaging TCTs once the technology is perfected. As the approach becomes feasible, LOCPAD force structure will need reassessing.

The USAF should further investigate and pursue persistent area dominance munitions as an answer to the TCT problem. LOCPAD is a munition already under study by the AFRL and would most likely be easy to develop, incorporate, and operationalize into USAF doctrine. Further study should be accomplished to determine how many munitions are required based on future projections of conflict.

Notes

1. Gordon and Trainor, *The General's War*, 247. In the Persian Gulf War, Iraqi Scuds moved deep behind enemy lines once aware of their vulnerability to detection by coalition standoff intelligence, surveillance, and reconnaissance platforms.

2. See chapter 3 for unmanned combat aerial vehicle details.

3. This is based on 15-minute time delay with a target speed ranging from 20 to 35 kilometer/hour.

4. Byman, Larson, and Waxman, *Air Power as a Coercive Instrument*, 131. The coercive paradox asserts that the more formidable airpower or any other instrument of coercion, the more likely adversaries are to be prepared for it.

5. Since Gator mine did not fulfill the needed requirements, it will not be discussed further.

6. A dump target is normally a low-priority target located outside known enemy threats that can be attacked if (in this case) a time-critical target does not emerge. The commander is able to get some use out of the sortie but very little because the destruction of dump targets typically achieves little effect.

Glossary

AAA	antiaircraft artillery
AAL	acquire after launch
AAR	air-to-air refueling
AARMD	affordable rapid response missile demonstrator
ABCCC	airborne battlefield command and control center
ABL	acquire before launch
ACC	Air Combat Command
AC ² ISRC	Aerospace C ² and ISR Center
AFRL	Air Force Research Laboratory
AGL	above ground level
ALSA	Air Land Sea Application Center
AMSTE	affordable moving surface target engagement
AOC	air operations center
AOI	area of interest
AP	antipersonnel
ARRMD	Affordable Rapid Response Missile Demonstrator
ASARS	advanced strategic airborne radar system
AT	antitank
ATR	automatic target recognition
AWACS	Airborne Warning and Control System
BDA	battle damage assessment
BVR	beyond visual range
C ²	command and control
CALCM	conventional air-launched cruise missile
CAP	combat air patrol
CFAR	constant false alarm rate
COI	contact of interest
CONOPS	concept of operations
DARPA	Defense Advanced Research Projects Agency
DOD	Department of Defense
DSP	Defense Support Program
EA	electronic attack
EO	electro-optical
ESAR	enhanced synthetic aperture radar
F	Fahrenheit
FAC	forward air controller
F-kill	firepower kill

FolPen	foliage penetrating radar
FOV	field of view
FPS	feet per second
ft	feet
GP	general purpose
GPS	Global Positioning System
HARM	high-speed antiradiation missiles
HiSS	High-Speed Strike System
IR	infrared
I-REMBASS	improved REMBASS
ISAR	inverse SAR
ISC	infiltration surveillance center
ISR	intelligence, surveillance, and reconnaissance
IUGS	internetted unattended ground sensor
JASSM	joint air-to-surface standoff missile
JDAM	joint direct attack munition
JFACC	joint force air and space component commander
JFC	joint force commander
JSF	Joint Strike Fighter
JSOW	Joint Standoff Weapon
JSTARS	Joint Surveillance Target Attack Radar System
K-kill	catastrophic kill
LADAR	light detection and ranging
lb	pound
LOC	lines of communication
LOCAAS	low-cost autonomous attack system
LOCPAD	low-cost persistent area dominance
LOS	line of sight
MAP	mission area plan
MC ² A	multisensor C ² aircraft
MC ² C	multisensor C ² constellation
MITL	man in the loop
M-kill	mobility kill
MNS	Mission Needs Statement
MP-CDL	multiplatform common data link
mph	miles per hour
MP-RTIP	multiplatform radar technology insertion program
MRL	mobile rocket launchers
MT ³ C	multitheater target tracking capability

MTI	moving target indicator
NATO	North Atlantic Treaty Organization
NFOV	narrow field of view
NM	nautical mile
NSA	National Security Organization
OEF	Operation Enduring Freedom
OPNAV	Office of the Chief of Naval Operations
PBA	predictive battlespace awareness
P ³ I	preplanned product improvement
REMBASS	Remote Battlefield Acoustic and Seismic System
ROE	rules of engagement
SAM	surface-to-air missile
SAR	synthetic aperture radar
SBR	Space-Based Radar
SDB	small-diameter bomb
SEAD	suppression of enemy air defense
SIGINT	signal intelligence
SOF	Special Operations Forces
SPIRITT	Spectral Infrared Remote Imaging Transition Testbed
TCT	time-critical target
TEL	transporter-erector-launchers
3D	three-dimensional
TLE	target location error
TMD	tactical munitions dispenser
UAV	unmanned aerial vehicles
UCAV	unmanned combat aerial vehicles
US	United States
WFOV	wide field of view

Bibliography

- Air Force Joint Pamphlet 10-225. *Targeting: The Joint Targeting Process and Procedures for Targeting Time-Critical Targets*, July 1997.
- Air Force Pamphlet 14-210. *Intelligence*, 1 February 1998.
- Air Force Research Laboratory. "ACC Applied Technology Council Meeting." Briefing, 31 October 2001.
- Air Force Research Library Fact Sheet. "MightySat II Satellites." <http://vs.afrl.af.mil/factsheets/msat2.html> (accessed 20 February 2002).
- Barela, Timothy P. "Anti-armor Einstein." *Airman Magazine*, September 1996. <http://www.af.mil/news/airman/0996/armor.htm> (accessed 7 April 2002).
- Barry, Charles L., and Elihu Zimet. "UCAVs—Technological, Policy, and Operational Challenges." *Defense Horizons*, October 2001. <http://www.ndu.edu/inss/DefHor/DH3/DH3.htm> (accessed 6 February 2002).
- Barry, John. "A New Breed of Soldier." *Newsweek International*, 5 December 2001. <http://bulletin.ninemsn.com.au/Bulletin/EdDesk.nsf/All/BBA635DF740BBA32CA256B17000CB0D0> (accessed 10 December 2001).
- Beckman, William T. "Intelligence Scouts: REMBASS and Battlefield Surveillance." *Joint Readiness Training Center Newsletter* 01-15.
- Behler, Maj Gen Robert F. Commander Aerospace Command Control and Intelligence, Surveillance, and Reconnaissance Center (AC²ISRC), US Air Force. Address. Fifth President's Forum, Electronic Systems Center, Hanscom AFB, Mass., 13 December 2001.
- Biass, Eric H. and Roy Braybrook. "Guided Submunitions." *Armada International*, 2000. <http://www.proquest.com/umi> (accessed 13 October 2001).
- Bowie, Christopher J., et al. *The New Calculus: Analyzing Airpower's Changing Role in Joint Theater Campaigns*. RAND Report prepared for the US Air Force. Washington, D.C.: RAND, 1998.

- Briefing at Air Force Research Laboratory (AFRL). Subject: Air Combat Command (ACC) Applied Technology Council Meeting, 31 October 2001.
- Buchan, Glenn. *Information War and the Air Force: Wave of the Future? Current Fad?* RAND Research Brief, IP-149. Washington, D.C.: RAND, March 1996.
- Butler, Amy. "The CONOPS with a Difference." *Air Force Magazine* 84, no. 10 (October 2001). <http://www.afa.org/magazine/Oct2001/1001conops.html> (accessed 28 November 2001).
- Byman, Daniel L., Eric Larson, and Matthew C. Waxman. *Air Power as a Coercive Instrument*. RAND Project Air Force. Washington, D.C.: RAND, 1999.
- Chandler, Doug. "MP-RTIP/WAS & Joint STARS MP-CDL Vision." Briefing, 1 May 2001. http://www.pixs.wpafb.af.mil/pixslibr/mp-cd/was_js_overview.ppt (accessed 20 February 2002).
- Cheung, Lance. "Mini-missile Has Mind of Its Own." *Airman Magazine*, March 2001. <http://www.proquest.com/umi> (accessed 14 October 2001).
- Clark, Richard M. *Uninhabited Combat Aerial Vehicles: Airpower by the People, For the People, But Not with the People*. Maxwell AFB, Ala.: Air University Press, August 2000.
- Clausewitz, Carl von. *On War*. Edited and translated by Michael Howard and Peter Paret. Princeton, N.J.: Princeton University Press, 1976.
- Cooling, Benjamin Franklin, ed. *Case Studies in the Development of Close Air Support*. Washington, D.C.: Office of Air Force History, 1990.
- Corcoran, Kimberly M. *Higher Eyes in the Sky: The Feasibility of Moving AWACS and JSTARS Functions into Space*. Maxwell AFB, Ala.: Air University Press, January 2000.
- Correll, John T. "The Vision Force." *Air Force Magazine*, November 2000. <http://www.afa.org/magazine/june2001/0601vision.asp>.
- Danskine, William B. "The Time Critical Targeting Model." Master's thesis, Air Command and Staff College, Maxwell AFB, Ala., April 2000.

- Defense Advanced Research Projects Agency (DARPA). "DARPA Demonstrates Affordable Moving Surface Target Engagement." News release, 31 August 2001.
- . "Hypersonic Scramjet Projectile Flies." News release, 27 August 2001.
- DARPA Special Projects Office. "Jigsaw Project Concepts." <http://www.darpa.mil/baa/baa01-15mod.htm> (accessed 30 November 2001).
- Dimaggio, Kathy, et al. "Presence with an Attitude!" *Proceedings*, October 2000. <http://www.usni.org/proceedings/proceedings.html> (accessed 15 October 2001).
- Djuric, Teresa A. H. "Future Command and Control of Aerospace Operations." Strategy Research Project. Carlisle Barracks, Pa.: Army War College, 15 March 2001.
- Dupuy Institute. "Landmines in the 1991 Gulf War: A Survey and Assessment." <http://www.dupuyinstitute.org/pdf/m-4minesgulfwar.pdf> (accessed 5 May 2002).
- Erwin, Sandra. "Technologists Chasing Mobile Target Hunters." *National Defense*, June 2000. <http://www.proquest.com/umi> (accessed 15 October 2001).
- Federation of American Scientists. "AGM-65 Maverick." <http://www.fas.org/man/dod101/sys/smart/agm-65.htm>.
- . "AGM-114 Hellfire." <http://www.fas.org/man/dod-101/sys/missile/agm-114.htm>.
- . "AGM-158 Joint Air to Surface Standoff Missile (JASSM)." <http://www.fas.org/man/dod101/sys/smart/jassm.html>.
- . "AN/GSQ-187 REMBASS." <http://www.fas.org/man/dod-101/sys/land/rembass.htm>.
- . "CBU-89 Gator Mine." <http://www.fas.org/man/dod-101/sys/dumb/cbu-89.htm>.
- . "EP-3 Aries." http://www.fas.org/irp/program/collect/ep-3_aries.htm.
- . "HyStrike, High Speed Strike Missile, Fast Hawk, Low-Cost Missile." <http://www.fas.org/man/dod-101/sys/smart/hystrike.htm>.
- . "Joint Direct Attack Munition (JDAM)." <http://www.fas.org/man/dod-101/sys/smart/jdam.htm>.

- . “Joint Surveillance Target Attack Radar System.” <http://www.fas.org/irp/program/collect/jstars.htm>.
- . “M1939, 37 Millimeter AAA.” <http://www.fas.org>.
- . “Rivet Joint.” http://www.fas.org/irp/program/collect/rivet_joint.htm.
- . “RQ-1 Predator MAE UAV.” <http://www.fas.org/irp/program/collect/predator.htm>.
- . “RQ-4A Global Hawk (Tier II+HAE UAV).” http://www.fas.org/irp/program/collect/global_hawk.htm.
- Fernandez, Frank, director, DARPA. Address to Subcommittee on Emerging Threats and Capabilities. Committee on Armed Services, US Senate, Washington, D.C., 21 March 2001.
- Fleming, Todd, and Chuck Paone. “Air Force Developing New ‘Constellation’ of Integrated Capabilities.” *Hansconian*, 18 May 2001. <http://www.hanscom.af.mil/Hansconian/Articles/2001Arts/05182001-1.htm>.
- Fox, Kevin L. “Dynamic Targeting: Are We Ready?” Master’s thesis, Air Command and Staff College. Maxwell AFB, Ala., April 1999, 41.
- Fulghum, David A. “New Air Force Recce Aircraft Takes Shape.” *Aviation Week & Space Technology*, 26 November 2001, 34.
- Fulghum, David A., and Robert Wall. “Mini-Bombs Dominate U.S. Weapons Plans.” *Aviation Week & Space Technology*, 25 September 2000. <http://www.proquest.com/umi> (accessed 13 October 2001).
- Global Security. “E-767 Multi-Sensor Command and Control Aircraft.” <http://www.globalsecurity.org/military/systems/aircraft/e-767-mc2a.htm>.
- Gompert, David C. *1998 Strategic Assessment: Engaging Power for Peace*. Edited by Hans Binnendijk and David C. Gompert (Washington, D.C.: National Defense University, 1998). <http://www.ndu.edu/inss/strategic%20assessments/sa98/sa98cont.htm> (accessed 10 January 2002).
- Goodman, Glenn W., Jr. “Tank Eradicators.” *Armed Forces Journal*, August 2000, 38.
- Gordon, Michael R., and Bernard E. Trainor. *The General’s War*. New York: Little, Brown and Co., 1995.

- Guilbeaux, Wilson, Jr., and Gary Connor, *Multi-Sensor C² Constellation Team Effort*, AC²ISRC's C²ISR Legacy Roadmap, slides.
- Harris, H. Brock. "Counterfire and Predictive BDA." *Military Intelligence*, April–June 1998, 42.
- Hathaway, David C. "Germinating a New SEAD: The Implications of Executing the SEAD Mission in a UCAV." Master's thesis, Maxwell AFB, Ala.: School of Advanced Airpower Studies, June 2001.
- Haun, Phil M. "Airpower versus a Fielded Army: A Construct for Air Operations in the Twenty-First Century." *Aerospace Power Journal* XV, no. 4 (Winter 2001): 81–88.
- Headquarters ACC. *Combat Air Force's Global Attack Mission Area Plan–FY2002*. Langley AFB, Va., 1 October 2000.
- Hosmer, Stephen T. *The Conflict over Kosovo: Why Milosevic Decided to Settle When He Did*. RAND Research Brief. Washington, D.C.: RAND, 2001.
- Human Rights Watch. "Descriptions of Cluster Bomb Types." <http://www.hrw.org/reports/1999/nato2/nato995-04.htm> (accessed 8 May 2002).
- Hutcheson, Keith, ed. *Unified Aerospace Power in the New Millennium*. Conference Report. Alexandria, Va.: Future Concepts Division, Headquarters USAF, 7–8 February 2001.
- "Innovative Acquisition Approaches Lessons Learned from the HAE UAV Program." RAND Research Brief. Washington, D.C.: RAND, 1999.
- Jamieson, Perry D. *Lucrative Targets: The U.S. Air Force in the Kuwaiti Theater of Operations*. Washington, D.C.: Government Printing Office (GPO), 2001, 49–50.
- Jenkins, Gregory. "Low Cost Persistent Area Dominance (LOC-PAD) Miniature Missile." Concept Paper. Eglin AFB, Fla.: Air Armament Enterprise, 2001.
- . "TCT Timeline & Persistent Area Dominance 2010." Eglin AFB, Fla.: Air Armament Enterprise, 9 July 2001.
- Johnson, Stuart, and Martin Libicki, eds. *Dominant Battlespace Knowledge*. Institute for National Strategic Studies, October 1995. <http://www.ndu.edu/inss/books/books%20-%201990%20to%201995/Dominant%20Battlespace%20>

- 20Knowledge%20-%20Oct%2095/dbk1.html (accessed 13 September 2001).
- Joint Publication (JP) 1-02. *Department of Defense Dictionary of Military and Associated Terms*, 12 April 2001.
- JP 3-55. *Doctrine for Reconnaissance, Surveillance and Target Acquisition Support for Joint Operations*, 14 April 1993.
- Jumper, Gen John P., chief of staff, US Air Force. Address. National Defense Industry Association Breakfast, Langley AFB, Va., 27 June 2001.
- Jumper, Gen John P., commander, ACC, US Air Force. Address. Air Force Association 17th Annual Air Warfare Symposium, Orlando, Fla., 15 February 2001.
- Keaney, Thomas A., and Eliot A. Cohen. *Gulf War Air Power Survey*. Vol. 2, *Operations and Effects and Effectiveness*. Vol. 4, *Weapons, Tactics, and Training and Space Operations*. Washington, D.C.: GPO, 1993.
- Kosan, Keith J. *United States Air Force Precision Engagement against Mobile Targets: Is Man In or Out?* Maxwell AFB, Ala.: Air University Press, November 2001.
- Lamb, Greg S., and Tony G. Stone. *Air Combat Command Concept of Operations for Endurance Unmanned Aerial Vehicles*. ACC Concept of Operations, 3 December 1996. http://www.fas.org/irp/doddir/usaf/conops_uav/toc.htm (accessed 28 November 2001).
- Leonhard, Robert R. *The Principles of War for the Information Age*. Novato, Calif.: Presidio Press, 2000.
- Lukes, Mike, and Eugene McKenzie. "Theatre Missile Defense (Attack Operations) for those Tactically Challenged." Concept paper on knowing your enemy, 30 September 1997.
- Meilinger, Phillip S. *10 Propositions Regarding Air Power*. Air Force History and Museums Program, 1995.
- Metz, Steven. "Asymmetric Warfare: Strategic Asymmetry." *Military Review*, July/August 2001, 23–31. <http://leavenworth.army.mil/milrev> (accessed 16 October 2001).
- Murphy, Edward F., et al. "Information Operations: Wisdom Warfare For 2025." Research paper presented to Air Force 2025. <http://www.au.af.mil/au/2025/volume1/chap01/v1c1-1.htm> (accessed 12 October 2001).

- Naval Air Warfare Center Weapons Division. *OPNAV High Speed Strike System (HiSSS) Roadmap*, slides.
- Northrop Grumman. "Northrop Grumman Team Awarded Multi-platform Radar Technology Insertion Program (MP-RTIP) Contract." News release, 19 February 2000. http://www.northgrum.com/news/rev_mag/review11/busfocus/mprtip.html.
- . "Northrop Grumman Team Awarded \$303 Million Contract for MPRTIP." News release, 11 December 2000.
- Nowland, Mark C. *Eliminating the Rhetoric: An Evaluation of the Halt-Phase Strategy*. Maxwell AFB, Ala.: Air University Press, February 2001.
- Office of the Secretary of Defense. *Unmanned Aerial Vehicles Roadmap*. Washington, D.C.: Department of Defense, April 2001.
- Pierce, Rick. "Draft Rev 4 Systems Requirements Document for the MP-CDL," 25 January 2002. http://www.pixs.wpafb.af.mil/pixslibr/mb-cdl/draft_mp_cdl_Rev%204_25Jan02%20.doc (accessed 23 February 2002).
- Public Domain at Yahoo.com. "Smart Munitions, The Next Generation." <http://www.vectorsite.tripod.com/arbomb9.html> (accessed 12 October 2001).
- Research, Development, Test, and Evaluation (RDT&E) Budget Justification Sheet. "Space-Based Radar EMD," June 2001. <http://www.dtic.mil/descripivesum/Y2002/AirForce/0604251F.pdf> (accessed 22 February 2002).
- Richardson, Doug. "Casting Light on a Target." *Armada International*, June/July 1999. <http://www.proquest.com/umi> (accessed 16 October 2001).
- Richelson, Jeffrey T. "High Flyin' Spies." *Bulletin of the Atomic Scientists* 52, no. 5 (September–October 1996), 48–54. <http://www.thebulletin.org/issues/1996/so96/so96richelson.html> (accessed 9 January 2002).
- Richter, Paul. "Global Hawk Crashes in Afghanistan in a Setback for High-Tech Drones." *Los Angeles Times*, 1 January 2002. <http://www.globalsecurity.org/org/news/2002/020101-attack01.htm> (accessed 14 February 2002).
- Satterly, Mark T., et al. "Intelligence Preparation of the Battlespace—An Airman's Introduction." *Air Chronicles*, 26 July

1999. <http://www.airpower.maxwell.af.mil/airchronicles/cc/Satterly.html> (accessed 10 September 2001).
- Sawyer, Ralph D. *The Art of War*. Boulder, Colo.: Westview Press, 1994.
- Shaker, Steven M., and Alan R. Wise. *War without Men*. New York: Pergamon-Brassey's, 1988.
- Srour, Nino. "Unattended Ground Sensors: A Prospective for Operational Needs and Requirements." North Atlantic Treaty Organization Land Group 6, October 1999. <http://www.arl.army.mil/sedd/acoustics/UGS%20for%20NATO%20Land%20Panel%206.pdf> (accessed 20 March 2002).
- Steinhardt, Allan. *Discoverer II Space Based Radar Concept*, DARPATech 2000, slides.
- Stevens, Donald, et al. *The Next-Generation Attack Fighter: Affordability and Mission Needs*. RAND, Project Air Force. Washington, D.C.: RAND, 1997.
- Tether, Tony, director, DARPA. Address. Subcommittee on Emerging Threats and Capabilities, Committee on Armed Services, US House of Representatives, Washington, D.C., 26 June 2001.
- "That's the SPIRITT." *Beyond 2000*, 1 January 2001. http://www.beyond2000.com/news/Jan_01/story_988.html (accessed 18 February 2002).
- Tirpak, John A. "Send in the UCAVs." *Air Force Magazine* 84, no. 8 (August 2001). <http://www.afa.org/magazine/Aug2001/080lucav.asp> (accessed 5 December 2001).
- 27th Fighter Wing Attack Guide, May 1995.
- US Air Force Fact Sheet. "Space-Based Radar," June 2001. http://www.losangles.af.mil/smc/pa/fact_sheets/sbr.htm.
- US Air Force Space Command Fact Sheet. "Defense Support Program Satellites." <http://www.af.mil/factsheets/factsheet.asp?fsID=96> (accessed 25 February 2002).
- Vick, Alan. *Finding Needles in Haystacks*. RAND Research Brief. Washington, D.C.: RAND, 1996.
- Vick, Alan, et al. *Enhancing Air Power's Contribution against Light Infantry Targets*. Project Air Force. Washington, D.C.: RAND, 1996.
- Vietnam Veterans of America Foundation. "Vietnam Veterans of America Foundation Urges President Bush to Ban

- Landmines Immediately." http://www.vwaf.org/media/pr_022502.shtml (accessed 2 May 2002).
- Wall, Robert. "The Devastating Impact of Sensor Fuzed Weapons." *Air Force Magazine*, March 1998, 28.
- . "X-45A UCAV Poised for First Flight." *Aviation Week & Space Technology*, 29 October 2001, 97.
- . "Recce Plans Bolstered in Terror's Wake." *Aviation Week & Space Technology*, 29 October 2001, 61.
- "Warfighter's Edge, The: First Hyperspectral Images from Space." *Space Daily*, 8 September 2000. <http://www.spacedaily.com/news/radar-00e.html> (accessed 20 February 2002).
- Weisstein, Eric W. "Books about Fourier Transform Spectroscopy," Wolfram Research. <http://scienceworld.wolfram.com/physics/FourierTransformSpectrometer.html> (accessed 27 April 2002).
- Welby, Stephen. "Networked Targeting Technology." DARPA Special Projects Office. http://www.darpa.mil/darpatech2000/presentations/spo_pdf/3welbynetworkedtargetingb&w.pdf (accessed 28 November 2001).
- Wiencek, David G. "Hypersonics: A New Age Dawns." *Global-Defence Missile Systems Index*. http://www.global-defence.com/missiles/missile_core.html (accessed 10 October 2001).
- Wyatt, Earl. *DARPA/USAF UCAV: Accelerating UCAV Capability to the Field*, Unmanned Combat Aerial Vehicle Brief, 28 January 2002, slide 9.

Time-Critical Targeting
Predictive versus Reactionary
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