AIR WAR COLLEGE

AIR UNIVERSITY

FEAR NO EVIL:

UNMANNED COMBAT AIR VEHICLES

FOR

SUPPRESSION OF ENEMY AIR DEFENSES

By

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“Yea, though I fly my aircraft through the valley of the shadow of death,
I shall fear no evil; for I am sipping a cappuccino in Vincenza

- *UCAV Operator, circa 2015*

Disclaimer

Abstract

American strategies for the employment of airpower are increasingly based on the presumption of rapidly attaining air superiority with minimal losses. Such strategies presume an ability to locate and destroy enemy air defenses, exploiting US advantages in intelligence collection, stealth, and precision strike. While stealth technology has given US forces a huge advantage over most adversaries, and enables unprecedented freedom of action, this "technology gap" is not an advantage that the US can take for granted. The proliferation of advanced air defenses, especially the so-called "double-digit" surface to air missiles, raises the specter of significant losses for manned platforms attempting to attack those defenses. Viability of current airpower strategies depends upon acquiring and maintaining a means to find, fix, track, target, and destroy those defenses, in order to permit the application of air power to other objectives. An unmanned combat air vehicle, properly integrated with proper sensors and capabilities, offers the potential to answer this need. Furthermore, the unique capability of such a vehicle to provide persistent intelligence, surveillance and reconnaissance over a battlefield makes it an even more attractive asset.

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PROLOGUE

It is a piercing, era-shattering sound. A high frequency tone interrupted at half-second intervals, it galvanizes the attention of any aviator who hears it. An Emergency Locator Beacon, transmitting on the international distress frequency, alerts every aircraft within radio range of a downed airman. Through modern communications links, an air commander hundreds of miles from the battlefield can hear it too, and it is a sound that fills the operations center with dread. Somewhere over the battlefield, a young American is hanging from the risers of a parachute, staring down into the inky blackness and wondering what went so horribly wrong.

CHAPTER 1

Introduction

> *"Now it is clear the military does not have enough unmanned vehicles. We're entering an era in which unmanned vehicles of all kinds will take on greater importance – in space, on land, in the air, and at sea"*
>
> *- President George W. Bush*
> *December 11, 2001*

On July 23, 1965, a US Air Force F-4C became the first aircraft to be destroyed by an SA-2 surface-to-air missile in the skies over North Vietnam.[1] Less than two weeks later, defense officials met with industry executives to launch the concept that came to be known as the "Wild Weasels": specially equipped aircraft tasked with the extraordinarily demanding mission of suppressing or destroying enemy air defense radars. For three and one half decades, the US military has wrestled with this challenge, as technological developments have shifted the balance back and forth. With the development of "stealth" aircraft in the early 1980s, many defense experts felt that American technology might have finally solved the problem of radar-guided threats. As the stealth aircraft fleet grew in numbers, it seemed the Wild Weasels might eventually fade into a distant memory.

The decade since Desert Storm, however, has seen steady improvements in enemy defenses, and a slow but discomforting proliferation of the most advanced surface-to-air missile systems. Even pilots of our stealthiest aircraft are reluctant to challenge these new systems. The smaller size of today's force structure means that any aircraft loss is a significant loss, especially if the downed aircraft is a modern, expensive platform produced in low numbers, such as the F-117 or B-2. Furthermore, the greatly increased sensitivity to casualties demands a careful assessment of aircraft survivability in the face of new threats. Consequently, the Air Force has begun to take stock of its capabilities in the Suppression of Enemy Air Defenses (SEAD) mission area, including serious consideration of unmanned vehicles. The rapid technological progress in the field of unmanned vehicles has to date focused mostly on "drone" aircraft for battlefield reconnaissance. But improvements in systems now point the way to a new and more capable generation of vehicles specifically designed to take on the "dull, dirty, and dangerous missions" that tax aircrews and put them at highest risk.[2] SEAD certainly qualifies as one of the most dangerous missions for modern air forces. Now, the US may be on the brink of another major restructuring of SEAD, to shift the mission from manned to unmanned aircraft.

The development and fielding of unmanned vehicles in significant numbers in the latter part of this decade will be a watershed event for the US Air Force. Unmanned vehicles have gained a prominent role in military operations by providing real-time intelligence, surveillance, and reconnaissance, and with the weaponization of the RQ-1B Predator for operations in Afghanistan, the Air Force has already embarked on a road that will undoubtedly lead to more sophisticated Unmanned *Combat* Air Vehicles – UCAVs. In fact, UCAVs may one day make up a significant portion of US strike assets. Senator John Warner, ranking minority member of the Senate Armed Service Committee, has stated that he expected that "within 10 years, fully one-third of the nation's deep-strike aircraft could be robot airplanes."[3] With such outspoken support for unmanned vehicles, airmen must make every effort to examine and understand the potential applications of these new weapons. The system currently in development has the potential to provide a powerful new tool for countering enemy air defenses.

In order to win favor, an unmanned vehicle should ideally offer a combination of lower risk and lower cost. The risk to human life is eliminated, and the advantages of that are immediately evident. One need only compare the shoot-down and rescue of Air Force Captain Scott O'Grady in early 1995 with the recent losses of Predator unmanned vehicles over Iraq and Afghanistan to see the enormous difference the human element imparts to military operations. Captain O'Grady's six days on the ground in Bosnia became an intense national drama making front-page headlines. The loss of the third Predator in as many months over Iraq was buried on page 30 of the October 11, 2001 Washington Post.[4] A senior Pentagon official summed it up well: "Thus far, we've had no missing-man flybys, no funerals, no Arlington burials – and no excitement in the E-ring – over the loss of a Predator."[5]

Eliminating risk to human life by removing the human from the vehicle has an obvious appeal. However, the vehicle itself must still fly in harm's way, and if it is a sophisticated and expensive vehicle, it must prove itself survivable enough to be cost effective. Striking the right balance between affordability and survivability will be a major challenge for the designers of a UCAV system.

The chapter that follows will examine how the evolution of air power strategies have come to depend upon rapidly attaining control of the air, and how SEAD plays a vital role in that task. Chapter 3 provides a closer look at the modern surface to air missile threat, and explores the implications of those threats to US air strategies. Chapters 4, 5 and 6 examine current SEAD capabilities and shortfalls, and alternatives for addressing those needs, including the UCAV. Chapters 7 and 8 explore the concept of operations for UCAV, and the way in which such a system would integrate within the command and control infrastructure. Finally, Chapter 9 concludes by examining the unique challenges and opportunities presented by this new technological advance.

Notes

[1] http://wildweasels.org/history.htm

[2] Office of the Secretary of Defense, Unmanned Aerial Vehicle Roadmap, 2000-2025, April 2001, p. ii.

[3] John A. Tirpak, "Send in the UCAVs", Air Force Magazine, August 2001, 63.

[4] Bill Sweetman first made this comparison to an earlier UAV loss in Popular Science. See Sweetman, "Fighters Without Pilots", Popular Science, November 1997, 96.

[5] Harry Disbrow, Deputy Director of Requirements, Headquarters United States Air Force, personal interview with the author, 28 Nov 2001.

CHAPTER 2

US Air Power Strategy and the Evolution of SEAD

"You can observe a lot just by watchin'."
-Yogi Berra

The introduction of radar-guided surface-to-air missiles into North Vietnam in 1965 forced the USAF to devote considerable resources to overcome the new threat. The need to "suppress" the SAM threat led to the development of both standoff jamming aircraft (the EB-66) and the "Wild Weasel" concept. The Wild Weasel role, begun with modified F-100 aircraft, migrated to the F-105, the F-4C, and finally to the F-4G.[1] The F-4G, a heavily modified version of the venerable Phantom II with specialized electronics, served as the primary SEAD platform for over two decades. The F-4G played a vital role in the Gulf War, but the high costs associated with it's aging airframe led to its retirement in the mid 1990s. With an increasing emphasis on stealth technology as a means of increasing aircraft survivability, and with scarce dollars funneled towards new acquisition programs, the Air Force was reluctant to fund expensive "legacy" platforms such as the F-4G. The role of Wild Weasel passed to the "Block 50" variant of the F-16, equipped with the HARM Targeting System, an external pod that serves as the electronic sensor for locating emitters. Originally intended as a gap-filler between the F-4G and a follow-on dedicated SEAD platform, budget constraints forced the USAF to rely exclusively on the F-16 and the US Navy's EA-6B for defense suppression missions. Throughout this thirty-seven year history, the role of SEAD in airpower strategy has ebbed and flowed as threats and tactics changed.

Roll Back – the Cold War paradigm

During the Cold War, the USAF developed SEAD tactics for the worst-case scenario of a major war with the Warsaw Pact forces in central Europe. The Soviet Integrated Air Defense System, or IADS, was a relatively sophisticated network of early warning radars, linked to target acquisition and tracking radars that fed a dense array of both fixed and mobile SAMs. USAF tactics relied upon the synergy of several different systems: radar jamming, communications jamming, and Wild Weasels carrying anti-radiation missiles. Standoff jamming would "take out the enemies eyes", while jamming radio communication links would prevent SAM sites from receiving target information from any other radar. Isolated SAM sites would thus be forced to use their own acquisition or tracking radars to acquire targets, turning on the radars sooner and keeping them on longer. This facilitated location and destruction of those sites by the Wild Weasel's missiles.

Because the forward edge of the battle area was expected to present an unbroken "wall" of SAM threats, large force tactics usually revolved around the use of SEAD assets to "punch a hole" through the defenses, allowing strike aircraft to funnel through and then fan out through less heavily defended territory to reach their targets. Strike aircraft attacking heavily defended target areas might require Wild Weasel escorts to accompany them.

Early in an air campaign, target selection would focus heavily on SEAD-related command and control targets, such as sector operations centers, to further disrupt the enemy defenses. Eventually, defenses would be "rolled back" sufficiently to permit relatively unhindered operations. This doctrine saw its most dramatic test in the June 1982 Israeli operations in the Bekaa Valley of Lebanon. The Israeli Defense Forces used largely American equipment and tactics, with the addition of some significant new capabilities, notably the extensive use of decoys and unmanned vehicles for surveillance. The Israelis succeeded in destroying 17 of 19 Syrian SA-6 sites within minutes.[2]

The success of the Israeli operation stunned many observers and captured the attention of the defense establishment. But half a world away a small number of people, working in extreme secrecy, were building an airplane that would revolutionize the American approach to warfare, built around a concept known as "stealth".

Parallel Warfare – the promise of DESERT STORM

The success of stealth technology, demonstrated so dramatically in Operation Desert Storm, had a profound effect on the views of an entire generation of airmen, and its magical allure had an equally profound effect on Air Force strategy and doctrine. The introduction of stealth aircraft provided the USAF with a capability to strike even the most heavily defended target at substantially reduced risk. Freed from the need to rollback air defenses before moving on to more lucrative target sets, airmen now had at their disposal a weapon that could strike at the heart of the enemy from the opening minutes of a conflict. At 0200 on January 17, 1991, the F-117 Nighthawk did exactly that.

Unfortunately, the success of Desert Storm may have lulled some airmen into a false sense of security. True, stealth did permit the US to attack the full range of targets from the outset of the war. This premise of “parallel warfare”, ardently advocated by a key campaign planner, then Lt Col Dave Deptula, quickly took hold. The popularity of this notion is hardly surprising; it is a good way to fight when circumstances permit. Indeed, this philosophy shaped the USAF’s outlook for the next two decades, as outlined in a newly unveiled “Concept of Operations 2020”: “Simultaneity will be the key to attack superiority—the aggressor is stunned by the simultaneous application of kinetic and non-kinetic means at strategic, operational, and tactical targets.”[3] However, this concept presumes the US will retain the capability to mount such attacks, with full freedom of action, even in the face of increasingly sophisticated defenses. The “CONOPS 2020” does not spell out the specific systems or platforms that will make up the force in 2020 and provide these capabilities. A more stealthy attack force is one possibility. But can the US afford a force large enough, and stealthy enough, to achieve this vision? And will new enemy strategies or tactics undermine that doctrine? The next major air operation after Desert Storm proved to be very different, and presented its own unique challenges.

Operation ALLIED FORCE – anomaly or wakeup call?

The Air Force entered Operation Allied Force, the 1999 air war over Serbia, with the same fleet of F-117s used during Desert Storm, and with the addition of a squadron of B-2 bombers. NATO’s fleet of legacy aircraft relied upon USAF F-16s and USN/USMC EA-6Bs for defense suppression and jamming. The Serbs, however, appeared to have learned a lesson from watching the destruction of Iraq’s air defenses eight years earlier.

Doubting NATO's resolve to carry on a long fight, the Serbs elected to forego a determined defense, and instead chose to hunker down and try to preserve their assets. The Serbs did not acquiesce completely; in fact, they launched over 700 missiles in the course of the 78-day conflict.[4] But the Serb SAM operators developed "shoot and scoot" tactics, attempting to ambush NATO planes in the hope that the loss of an aircraft and its pilot would weaken NATO resolve. The inability to destroy the air defense system was an enormous frustration to the airmen prosecuting the war. According to one analyst, "the Serbian tactic of carefully husbanding antiaircraft missile defenses throughout the campaign made those defenses a continuing threat to NATO's freedom to operate in Yugoslav airspace, undermining the effectiveness of many sorties as a result."[5]

Was Operation Allied Force an anomaly, or a wakeup call for SEAD planners? Certainly, it demonstrated that an adversary will not always follow the script that American planners have written. If the severity of bombing is not too punishing, a future adversary may choose a strategy similar to the Serbs, in order to buy time while still holding friendly forces at risk. By keeping air defenses at least partially intact, the adversary can significantly complicate the situation for the attacker. During Allied Force, the available windows for target attacks were frequently constrained by the limited availability of EA-6B standoff jamming aircraft and F-16 HARM shooters. In short, the availability of SEAD became a driving factor in the tempo of the campaign. These lessons were not lost on the Air Force. In its initial report on the war, the United States Air Forces in Europe concluded: "The Air Force could benefit from a renewed focus on future SEAD and electronic warfare capabilities and doctrine, as well as more capable, stealthy platforms…The Air Force should re-evaluate means of destroying, rather than merely suppressing, air defenses that do not emit or are otherwise 'uncooperative.'"[6]

An adversary who possessed more advanced defenses could exploit tactics similar to the Serbs to hold large numbers of aircraft at risk. This implies a need for a more persistent SEAD capability, in order to detect and target the "uncooperative" threats.

Operation Enduring Freedom – no war is like the last

Less than two and one half years after the end of Allied Force, the United States found itself engaged in a new conflict in Afghanistan, and Operation Enduring Freedom seemed tailor-made to demonstrate the wisdom that no war is like the last one. A country devastated by twenty years of war, Afghanistan had only a rudimentary air defense system. Within the first two days of the conflict, it had none. Air Force and Navy fighters roamed the skies at will, and B-52 bombers loitered for hours, dropping one bomb at a time at dug-in Taliban troop positions.

Although the experience of Operation Enduring Freedom hardly indicates that the US will never face a high-intensity conflict again, it did serve as a vivid reminder that the nation must be prepared to respond across a wide spectrum of conflict. As the USAF makes plans to spend its modernization budget and transform into a force for the future, it must consider more than just how systems will perform in fighting "the big wars." Systems that can offer capability in a wide variety of circumstances will have an advantage over niche systems designed solely for a certain threat environment. Operations in Afghanistan highlighted the ever-growing requirement for Intelligence, Surveillance, and Reconnaissance (ISR) capabilities; the Global Hawk high-endurance

UAV was pressed into service early to aid in the search for Osama bin Laden and his al Qaeda network. As future warfare becomes increasingly dependent on timely, high quality targeting information, systems that can collect information and integrate into the communications infrastructure will be especially attractive. The Air Force has already begun to outline this force of the future.

Global Strike Task Force – the wave of the future?

As the Air Force looks to the 21st Century and attempts to forecast the demands of future conflicts, the issue of access denial has moved to center stage. Future adversaries will have witnessed the combat power that the US and its allies can bring to bear given sufficient build up time and regional basing rights. Such adversaries, the argument goes, will seek to undermine the US power projection by acquiring so-called "anti-access" threat systems. The systems of primary concern to air forces include aircraft, cruise missiles, theater ballistic missiles, and advanced air defenses such as the "double-digit" SAMs, the SA-10, SA-12 and follow-on systems.[7]

The Global Strike Task Force, introduced in 2001 by General John Jumper while serving as commander of Air Combat Command, seeks to answer the challenge of access denial. The concept entails a rapidly deployable force of stealth aircraft, enabled by advanced Intelligence, Surveillance, and Reconnaissance (ISR) assets, that can "kick down the door" by locating, attacking, and eliminating these anti-access threats. The concept "hinges on precision weapons and stealth capabilities inherent in the B-2 and F-22."[8] But making those platforms effective, General Jumper contends, requires a thorough preparation using enhanced ISR platforms much more closely integrated than those of today. The hope is that "the power of machine-level integration will close the seams that currently delay our ability to precisely locate and identify critical targets."[9]

Some of those critical targets, no doubt, will be enemy air defenses, including the double-digit SAMs. But eliminating those threats without sustaining significant losses still presents problems, especially in a scenario in which the United States must operate from distant bases. Any follow-on SEAD capability must address the needs of GSTF. As Chapters 5 and 6 will show, some future SEAD options could also aid significantly in providing enhanced ISR.

To better understand the challenge of SEAD in the new century, Chapter 3 will closely examine the missile systems at the heart of a modern air defense network, and how those systems can complicate US strategies for employing airpower.

Notes

[1] http://wildweasels.org/history.htm

[2] Benjamin Lambeth, *The Transformation of American Air Power* (Ithaca, N.Y.: Cornell University Press, 2000), 92

[3] USAF/XO, Air Force CONOPS 2020 White Paper, Washington, DC, undated.

[4] Gen John Jumper, "Global Strike Task Force", Air Power Journal, Spring 2001, p. 27.

[5] Lambeth, 228.

[6] United States Air Forces in Europe, Studies and Analysis Directorate, *The Air War over Serbia: Aerospace Power in Operation Allied Force, Initial Report*, 30 September 1999, p 42. (Secret)

[7] Gen John Jumper, "Global Strike Task Force", Air Power Journal, Spring 2001, p. 28.

[8] GSTF, p. 30.

[9] GSTF, p. 30.

CHAPTER 3

Double-Digit SAMs: Capabilities and Implications for Strategy

"This is like déjà vu all over again."
- Yogi Berra

When American pilots first confronted surface to air missile in Vietnam, it required a major rethinking of tactics and equipment. Any of those veterans contemplating the challenge of systems like the Russian S-300 or S-400 (NATO designations SA-10 and SA-20) would certainly feel a sense of déjà vu. The newest Russian-made surface to air missile systems represent a significant advancement over older threats in several ways, and will require a similar reassessment. Without a clear understanding of the vastly improved capability these systems offer, it is impossible to appreciate the challenges for SEAD in the future.

The most obvious change is the newer system's maximum effective range, which varies from roughly 50 to 250 nautical miles depending on the specific missile.[1] Older SAMs were limited to 30 miles or less, and most mobile systems were limited to about 15 miles. The extended range of newer systems permits an adversary to defend a huge area with a small number of SAMs. Depending on the proximity of sites to a country's borders, the extended range of these new systems may force aircraft such as refueling tankers and reconnaissance assets to operate much further from the battlespace, reducing their effectiveness. In some cases, the enemy air defense umbrella may extend over friendly bases. For example, a single S-400 system positioned near the border of the southern no-fly zone in Iraq would cover almost the entire country, reaching all the way to Mosul in the north, and to the Kuwaiti border in the south. Far from being a point defense weapon, a relatively small number of these systems would enable an adversary to cast an air defense blanket over a huge area.

The speed of the newer missiles, roughly twice that of older ones, presents new challenges as well. Defensive tactics that help US and allied crews to survive against older SAMs will be far less effective against the much faster missile. In order to employ current or planned munitions (including standoff munitions such as the Joint Standoff Weapon, or even the rocket-boosted AGM-130), friendly aircraft will have to operate well inside the "no escape zone", the range at which the aircraft can no longer kinematically defeat the missile by turning away from the launch site and accelerating to top speed. In fighter pilot parlance, this is known as "showing up to a gunfight armed with a knife."

The high speed of the missile also means more maneuverability at intercept. Currently, fighter aircraft can often out maneuver a missile at intercept provided the pilot can visually acquire the missile in time. The pilot's best chance of acquiring the missile, however, is during the launch phase.[2] This is more easily accomplished with current threats when the launch site is relatively close to the targeted aircraft. Missiles launched from very long range are less likely to be detected, and the high speed gives the pilot far less reaction time to maneuver if he is lucky enough to visually acquire the missile later in flight.

This combination of high speed and long range makes modern missiles far more lethal than previous generations of SAMs, dramatically increasing the need for effective SEAD, while simultaneously making the mission much more difficult. Even if the precise location of all such threats were known, destroying them with present day systems would be difficult and costly. Complicating the problem further, the newer SAMs are also much more mobile.

The lessons of Desert Storm and Kosovo have taught potential adversaries that permanent fixed defenses will not last long in a conflict. Such sites are very vulnerable to attack by cruise missiles or other strike platforms. Consequently, some nations such as Iraq have taken to frequently moving even older systems from one site to another, trying to play a shell game to increase their survivability. The newer systems, purposely designed for such rapid relocation, make the enemy's job much easier, and make the SEAD mission substantially more difficult. By maintaining strict emissions control, and moving shortly after each known satellite overflight, the enemy may succeed in keeping the exact location of his defenses an unknown. By operating inside the friendly decision and targeting cycle, the enemy can keep his mobile defenses safe from many forms of attack.

Counter-Low Observable Capability

Perhaps the most daunting aspect of newer missile systems, however, is their improved capability to detect, track, and engage stealth aircraft. While low-observable technology has reduced aircraft radar signatures by many orders of magnitude, improvements in digital signal processing have narrowed the advantage. Even the best stealth design has some radar signature, and given sufficient transmitted power and advanced signal processing algorithms, any aircraft can be made vulnerable.[3]

In addition to the proliferation of advanced missile systems, the increasing integration of air defense radars poses a serious challenge. The United States is not alone in exploiting the advantages of real-time communications. Other countries are increasingly seeking to integrate their air defense systems into vast networks that can draw tracking data from a variety of sensors.[4] Iraq, for example, has attempted to upgrade its air defenses, with Chinese assistance, by installing a network of buried fiber optic cable. A missile equipped with "uplink guidance" (as opposed to one that uses semi-active homing) need not receive the target's position information from a radar associated with its own site. A distributed network of radars, linked through such secure means, presents a potential problem for both stealth aircraft and SEAD planners. Suppressing the threat under such circumstances would require near simultaneous attacks on multiple radars in order to "blind" the air defenses.

Implications for US Strategy

"The other teams could make trouble for us if they win."
– Yogi Berra

The increasing vulnerability of current aircraft, both stealth assets and the "legacy fleet" of non-stealth fighters and bombers, has serious implications for the US With a limited fleet of stealth aircraft, the loss of even one is a serious setback, and the US can not afford to wage a war of attrition against enemy defenses. Furthermore, the loss of an aircraft such as the B-2 could be an enormous blow to national prestige. Most importantly, the prospect of losing a significant number of manned aircraft in the first few days of a conflict would significantly raise the stakes for national decision-makers when contemplating the use of force. Political leaders will likely feel constrained when faced with an increased likelihood of aircraft losses, and aircrews captured or killed. Taken together, all these factors serve to raise the threshold for using airpower, making it a less useful tool for achieving national objectives.

Hesitancy on the part of national leaders would undoubtedly affect the enemy's calculus. If the enemy perceives increased reluctance, he may be more likely to resist diplomatic coercion. If the enemy can threaten a sufficiently high "blood price" by acquiring advanced defenses, the US may be less willing to commit forces for limited objectives. This in turn undermines US ability to coerce an adversary by holding high value targets at risk. An American unwillingness to sustain losses makes the threat of force considerably less convincing in the face of more capable air defenses.

If even stealth aircraft can be held at risk, obviously the entire fleet of legacy aircraft is even more vulnerable. Given current limitations in locating and targeting mobile defenses, a substantial portion of the friendly force can be held at bay by even a single SA-10 site. The US could choose to accept the risk and prosecute a campaign using only stealth assets, but the small inventory of such aircraft would seriously hamper the tempo on the campaign.[5] This undermines the effectiveness of parallel strategies, and could extend the time required to achieve campaign objectives, threatening to weaken public support.

The possibility of encountering advanced defenses was a concern during Operation Allied Force. As General John Jumper, then Commander of United States Air Forces in Europe remarked in August of 1999:

> "I can tell you what I worried about every day, and I can tell you what General Clark worried about every day – that somehow Mr. Milosevic would find a way to float an SA-10 or an SA-12 up the Danube River, put it together and bring it to bear as a part of this conflict. If that had happened, it would have profoundly changed the balance of the threat and our ability to maintain air superiority."[6]

Asked what impact this would have had on the tempo of Allied Force, Lieutenant General Mike Short, the Combined Forces Air Component Commander for the operation, replied: "Obviously, that would become the top priority target. We'd try to take it out, with TLAM or CALCM [cruise missiles]. But no other sorties would fly into that "bubble" until the threat was eliminated."[7]

The improved capabilities of newer SAMs come at a price. A battalion of S-300 missiles, consisting of 16-20 missiles and the associated radars, costs over $US 70 million. A more comprehensive air defense system, made up of six battalions of S-400 with 200 total missiles, would cost approximately $US 1 billion.[8] The number of adversaries who can afford to buy such advanced systems will be quite limited.

Arms Control – limiting proliferation

At present, the source for the most worrisome defense systems is Russia. Given the high cost of the S-300 and S-400 systems, few have been exported outside Russia itself. According to the most recent Jane's Land-Based Air Defence journal, Belarus, Bulgaria, China, Croatia, Greece, Hungary, Iran, Russia, Syria, and the Ukraine[9] possess the S-300, but Russia has aggressively marketed these systems, along with other advanced military hardware.[10] India reportedly has ordered the S-300 as well. While relations between the United States and Russia suffer from frequent ups and downs, it is clearly in the United States' interest to use diplomatic leverage whenever possible to discourage Russia from exporting the system to nations that are likely to come into conflict with the

United States. This is by no means a reliable solution, given the sorry state of the Russian economy and its heavy reliance on defense exports as a source of hard currency. Nonetheless, efforts to limit proliferation of these systems are well worth pursuing.

Arms control not withstanding, the introduction of a double digit SAM on today's battlefield would have enormous consequences, and any future SEAD platform must have the ability to cope with both the "low-end" and the "high-end" of the threat spectrum. In the chapter that follows, we'll look at the current state of US SEAD capabilities and identify shortfalls that must be addressed to cope with emerging threats.

Notes

[1] John A. Tirpak, "The Double Digit SAMs", Air Force Magazine, June 2001, 49.

[2] Even with modern radar warning receivers, aircrews rely on the smoke and exhaust plume from a missile launch to visually acquire a missile in flight.

[3] While the focus of this paper is on the challenge presented by "double-digit" SAMs, it is important to note that older systems such as the SA-2 and SA-3, which are widely deployed around the world, can be upgraded with new technology to enhance their capability significantly. Although the range and speed of the system is unlikely to be enhanced appreciably, improve signal processing or the addition of new sensors such as infrared trackers may give an adversary a counter-low-observable capability at significantly less cost than a new SAM system. See John Tirpak, "The Double-Digit SAMs", Air Force Magazine, June 2001, 48.

[4] Christopher Hellman, "Joint Effort Needed to Defeat Enemy Air Defenses", Center for Defense Information Weekly Defense Monitor, January 4, 2001, available at: http://www.cdi.org/weekly/2001/issue01.html

[5] At present, the USAF operates approximately 55 F-117 and 21 B-2 aircraft. The exact number of F-22 aircraft is still subject to change, but as of May 2001 the planned production run was 339 aircraft. See USAF Almanac, "Gallery of USAF Weapons", Air Force Magazine, May 2001, 132-137.

[6] Gen John Jumper, speech to the Eaker Institute for Aerospace Concepts, Washington DC, Aug 16, 1999. Archived at http://www.aef.org/eak16aug99.html

[7] Lt Gen Mike Short (Ret), personal interview with the author, 13 Nov 2001, Maxwell AFB, Ala.

[8] Tirpak, "The Double Digit SAMs", 49.

[9] Jane's Land-Based Air Defence, Fourteenth Edition, 2001-2002

[10] The Russian Defense Export state trade agency even has its own English language website, http://www.rusarm.ru/exprod.htm

CHAPTER 4

Current SEAD Capabilities and Shortfalls

"You give 100 percent in the first half of the game, and if that isn't enough,
in the second half you give what's left."
- Yogi Berra

Modern conflicts tend to be a come-as-you-are affair. While US forces have occasionally developed innovative concepts during a conflict, for the most part a war must be fought with those resources in the inventory when the conflict begins. If US SEAD capabilities “give 100 percent” and fail to prove effective, there may not be a second half. Since the experience of Operation Allied Force, USAF leaders have frequently acknowledged the need to reexamine SEAD capability.

Suppression of enemy air defenses is a joint service problem. None of the services have sufficient resources to fully address this mission area, and cooperative efforts are essential. The Navy maintains the only standoff jamming aircraft, the EA-6B, although some of its squadrons are jointly manned with both Navy and Air Force personnel. Both services have “shooters” capable of employing anti-radiation missiles, and both have cruise missiles and other strike assets that may be pressed into the SEAD role.

SEAD is normally divided into two categories, preemptive and reactive. Preemptive SEAD is conducted before friendly strike aircraft arrive within range of enemy threats. Fixed SAM sites, for example, are often targeted with cruise missiles in the first wave of attacks. Preemptive SEAD, therefore, requires foreknowledge of the threat location. Reactive SEAD, on the other hand, implies operations against threats whose location is unknown or uncertain. As the term suppression implies, reactive SEAD is considered successful if it prevents an enemy missile site from engaging a target, even if the site remains fully operational. SAM sites often shut down their radars if they suspect an anti-radiation missile has been launched. While this eliminates the immediate threat, it means friendly forces must deal with the same threat repeatedly. In recent years the services have introduced the term DEAD, or *Destruction* of Enemy Air Defenses, to distinguish those missions that seek to achieve a "hard kill" using conventional ordnance such as laser-guided bombs or datalink-guided standoff weapons.

American strategies almost always seek to neutralize an enemy's air defenses early in a conflict, but as reactive SEAD assets are stretched thin, dealing a knockout blow is more and more vital. Eliminating the threat gives friendly forces more flexibility to adjust the timing and tempo of operations. Reactive SEAD is considered successful if the threat radar shuts down and is unable to complete an engagement. However, the same system may threaten another aircraft only minutes later. Destruction of threat radars, on the other hand, permits aircraft to operate with relative impunity. Such permanent destruction becomes even more vital in operations that require attack aircraft to loiter over the battlefield in search of mobile targets. In Operation Allied Force, the inability to permanently cripple the air defense net forced planners to limit strikes to time blocks in which traditional reactive SEAD assets could provide support. By contrast, in Operation Enduring Freedom, US forces were able to completely eliminate the very limited Afghan air defenses, permitting bombers to loiter over targets for hours at a time.

Reactive SEAD

The mainstay of the US Air Force's reactive SEAD capability is a variant of the F-16 equipped with the High Speed Anti-radiation Missile (HARM) and an externally mounted targeting pod. When the F-16 first succeeded the venerable F-4G as the USAF's primary SAM killer, many critics decried it as a poor substitute for the F-4G. The F-16's HARM targeting system lacks the 360-degree antenna coverage of the F-4G and obtaining an estimate of target location took much longer. The F-16's capabilities have improved with recent software upgrades, and in some respects it now has capability on par with its predecessor. However, the F-16 still has some significant shortcomings in countering modern air defenses.

The F-16 has a relatively large radar signature compared to stealth aircraft, especially when carrying external fuel tanks and missiles. The range of the HARM missile, impressive when first introduced, is less than even the shortest range SA-10 variant. And despite what the name implies the "high-speed" anti-radiation missile has a relatively long time of flight when launched from near its maximum range. Most newer SAMs are much faster missiles than the HARM. The HARM-equipped F-16 may quickly find itself in a "duel to the death" with a SAM site, which will be able to complete an intercept on the SEAD aircraft long before the HARM arrives. Increasingly, the F-16 is simply outgunned by modern long range SAMs. In order to cope with high-end conflicts in the decades ahead, the USAF must consider other options.

Preemptive SEAD

Over the past decade, the emphasis within the USAF has shifted from reactive SEAD to preemptive "hard kill" operations.[1] The availability of low-risk weapons such as cruise missiles made it logical to target air defenses very early in a conflict, and attempt to achieve a permanent kill against the system. As confidence in stealth technology increased, manned systems such as the F-117 joined in the first wave of attacks against SAM sites. These systems have some inherent limitations, however, as outlined below.

Cruise Missiles

Since the Gulf War, the cruise missile has been the weapon of choice for operations in very high threat environments. For fixed targets, they will no doubt continue to play an important role. However, enemy air defense systems are becoming increasingly mobile. Even systems designed for fixed sites, such as the SA-2 and SA-3, can be disassembled, relocated, and reassembled in a few hours time by experienced crews. As described in the previous chapter, countries such as Iraq have played a continuous shell game, relocating systems among a number of prepared sites in order to keep planners guessing about threat numbers and locations. Newer systems designed for mobility, such as the Russian SA-10, complicate the situation much more. Although modern cruise missiles equipped with GPS are capable of accuracy measured in feet, such accuracy is of little use if the exact target location is unknown. Cruise missiles have relatively small warheads, and if the target has moved by as little as one-half mile, a "kill" is very unlikely. The relatively long planning, launch, and time-of-flight cycle of cruise missiles exacerbates this situation. Finally, the cruise missiles themselves can be vulnerable to detection and destruction by a system such as the SA-10, or to other air defenses along the route of flight, especially in daytime.

While cruise missiles will remain a vital component of US military power, their high cost and low probability of kill against highly mobile air defenses makes them a poor option for killing SAMs. Given their high cost and limited inventories, they are better employed against fixed, high-value targets in heavily defended areas.

Stealth Aircraft

Stealth platforms seem the logical choice for destroying enemy missile sites. Indeed, the F-117 has proven itself sufficiently stealthy to operate with near impunity within the threat envelopes of older systems such as the SA-2 and SA-3. However, the downing of an F-117 during Operation Allied Force served as a vivid reminder that stealth aircraft are not invisible. Given the right set of circumstances, a determined adversary may succeed in tracking and destroying a stealth aircraft, even using Vietnam-era systems such as the SA-3. Furthermore, the latest generation of air defenses are substantially more capable against low observable targets.

Another liability of the F-117 in the 21st century SEAD role is that it was designed exclusively for attacking high-value, fixed targets. Consequently, the F-117 relies solely on passive infrared sensors for locating targets. Such sensors, while providing very precise weapons delivery, have a very narrow field of view, often equated to "looking through a soda straw". As such, they are poorly suited to searching for mobile targets. Off-board cueing would reduce this liability somewhat, but currently the only means of providing this cueing to the F-117 is voice communication. Adding a datalink capability could provide more seamless integration, but would require a substantial investment in an aircraft already regarded in some circles as a legacy platform.

Contrary to the public perception of an “invisible airplane”, the F-117 is not free to roam over the battlefield at will. The F-117 relies upon very careful mission planning to select a route that minimizes its vulnerability. Attacking mobile targets, which requires frequent inflight adjustments to route of flight and timing, is thus a poor match for the F-117.

Unlike the F-117, the B-2 features a radar warning receivers and a defensive avionics suite to warn crews of threat radars and permit the crew to select a route of flight that minimizes risk. Furthermore, a low-probability-of-intercept ground mapping radar permits the B-2 crew to search a relatively wide area and pinpoint a target. The B-2 has proven itself in combat operations in Kosovo against older SAM systems. However, with an operational inventory of only 16 aircraft, the B-2 represents too limited a capability to handle the SEAD challenge by itself. According to the Center for Strategic and Budgetary Assessments, "Sixteen operational B-2s, however impressively upgraded to carry small diameter bombs, will still constitute a 'risk fleet.' Such a force is too small to conduct sustained anti-access campaigns to strategic depths from standoff range against widely distributed targets (e.g., mobile missiles.) It is also far too small a force to provide a 'swiftly defeat' anti-access hedge force in one, let alone two, theaters."[2] Given its enormous cost – and the almost incalculable cost in national prestige if one were lost – it seems an unlikely choice for the extremely hazardous mission of attacking double digit SAMs. The F-22, which combines stealth with supersonic cruise speeds, seems better suited to the SEAD role. The next chapter provides a more detailed examination of the F-22 alternative.

Non-lethal SEAD

In order to evaluate the contributions of current and planned "lethal" SEAD platforms, it is essential to understand the contributions made by other, non-lethal systems. SEAD has traditionally relied on the synergistic effects of a spectrum of capabilities such as on-board and off-board radar jamming, decoys, and deception, in addition to "hard-kill" systems. The relative contributions of these non-lethal measures are often difficult to quantify, but an understanding of how they support the SEAD effort is essential.

Radar jamming

Since the Vietnam War, the United States has employed standoff jamming aircraft as a means of reducing the effectiveness of radar guided SAMs. Search, acquisition or target-tracking radars all share at least some vulnerability to jamming. Any radar must achieve a certain minimum signal-to-noise ratio in order display a target. While stealth technologies attempt to reduce the level of the target return by minimizing the amount of radar energy reflected back to the radar, standoff jamming attacks the other side of the equation, by raising the background noise level. The effectiveness of standoff jamming varies greatly depending on the power output of the jammer, the range of the jammer from the radar, the geometry of the jamming aircraft orbit, and the countermeasures employed by the radar. Newer SAM systems present a number of challenges. First, they typically have very high output power. More significantly, the greatly increased aerodynamic range of the newer missiles forces jamming aircraft to operate much further away from the threat radar.[3] If the new S-400 system proves to be as capable as advertised, with a maximum range of almost 250 miles, it would render current standoff jamming platforms virtually useless, since aircraft would be forced to standoff well outside their effective jamming range.

In order to regain effectiveness, the jammer output power must increase, or the jammer must move closer to the target radar. Higher power standoff jamming would probably require a large aircraft in order to generate sufficient power. While penetration/escort jamming is theoretically possible, the speed and survivability of today's EA-6B platform render it unsuitable for such a mission. Escort jamming would have to be performed by a new aircraft.

Radar jamming has a complementary relationship to stealth. To an enemy radar operator, 10 decibels of radar jamming produces the same net effect as 10 decibels of signature reduction. However, even modern aircraft cannot achieve stealth characteristics in all parts of the radio frequency spectrum. Stealth aircraft are generally designed to minimize radar signature in the higher frequency ranges where terminal threats, such as surface to air missile tracking radars, operate. Lower frequency radars, of the type used for early warning or target acquisition, are generally more capable of detecting low observable aircraft. Fortunately, these radars do not provide position information as accurately as terminal threat radars. Standoff radar jamming in this lower frequency range helps to prevent the adversary from detecting stealth aircraft.

Whatever platform the US selects to deliver ordnance on SEAD targets, standoff jamming offers benefits. Whether it is cost effective to build a large aircraft jammer that can operate effectively outside the range of advanced systems like the S-400 remains to be seen.

Decoys

Aerial decoys have been a part of warfare for decades. The Israeli Air Force used a combination of decoys and unmanned surveillance drones to great effect during the 1982 Bekaa Valley operation. The Syrian air defenses took the bait, and within hours their air defenses lay in ruins.[4] The United States staged a similar gambit in the opening moments of the Persian Gulf War, sending BQM-74 ground-launched drones to stimulate the Iraqi radar network. Once the radars began transmitting, they became easy targets for HARM missiles.[5] But as the Kosovo conflict demonstrated, not every adversary will cooperate in the destruction of his air defense network. While the Serbian SAM operators were mostly ineffective in defending their nation's airspace, their strategy of minimal radiation time and frequent movement kept allied planners guessing for the duration of the conflict.

The USAF's current decoy program, the Miniature Air-Launched Decoy, or MALD, uses an extremely small turbojet engine to enable the decoy to fly at fighter-like speeds, while performing climbs, dives, and high "g" turns. The vehicle also features a signature augmentation system, permitting operators to select from a range of radar signatures to mimic various types of aircraft.[6] The USAF projects a unit cost of $70,000 for the system.[7] If each decoy encourages the enemy to launch a SAM, the economics seem to favor such an approach, especially if the engagement permits the friendly force to target the radars with HARMs or geo-locate the radars for attack with other assets. However,

$70,000 isn't an insignificant cost, considering hundreds of decoys may be required. And as the name states, the MALD is an *air*-launched decoy, meaning it takes up a weapon station on the launching aircraft, reducing that aircraft's mission payload.

The Serb strategy highlights one weakness of decoys: they might prove completely ineffective if the enemy is willing to ride out an initial wave of attacks. If an adversary detects what appears to be a large raid on radar, and suspects use of decoys, he may elect to wait until bombs begin to fall before committing missiles – especially if those missiles are expensive and a limited resource. Future adversaries may follow the Serb model, attempting to test US or coalition resolve by downing a few aircraft, rather than mounting a determined resistance and risking the complete loss of air defenses.

Aircraft self protection

Historically, the American reaction to the introduction of new radar-guided threats has been to develop new electronic warfare capabilities. Although such aircraft self-protection is not doctrinally a part of SEAD, its effectiveness is obviously a key factor in aircraft survivability. Modern electronic countermeasures systems are designed to allow for software reprogramming to deal with new or modified threats. Unfortunately, hardware limitations such as computer processing speed or memory size can hamper the ability of many systems to provide reliable protection. Furthermore, countermeasure developers must often rely upon computer "fly-out" simulations to estimate the effectiveness of a jamming technique. While ideally electronic countermeasures should deny detection or prevent enemy radar from tracking an aircraft, often the more realistic goal of jamming is to induce tracking errors that can increase "miss distance" during an intercept. Without actual "live fly" tests using unmanned drone targets and actual missiles (which are not always available for exploitation), the effectiveness of electronic jamming can only be known for certain in actual combat.

The quest to insure increased miss distance has led to the development of active towed decoys, which are deployed in-flight and trail behind the aircraft, emitting a jamming signal to decoy the missile away from the aircraft. Towed decoys have been credited with saving several aircraft, including the B-1B bomber, in SAM engagements during Operation Allied Force.[8] An improved version of the system currently fielded is planned for use on the Navy's F/A-18E/F and the USAF's F-15.[9]

Improvements in aircraft self-protection will certainly enhance survivability, but relying on systems that only operate in the end game of a SAM engagement puts aircrews at increased risk. Furthermore, aircraft from other nations operating in a coalition with the United States are far less likely to have such sophisticated countermeasures. These factors point to a need to maintain a robust capability to suppress or destroy enemy air defenses. As the USAF looks to the future, what are the alternatives for the US in order to maintain its current advantage?

Notes

[1] John A. Tirpak, "Dealing With Air Defenses", Air Force Magazine, November 1999.

[2] Adam J. Hebert, "Air Force, OSD Near Resolution in Battle Over the Merit of New B-2s", Inside The Air Force, September 28, 2001, available at: http://www.freerepublic.com/focus/fr/534666/posts

[3] Since radar energy dissipates according to an inverse square law, doubling the range from the jamming orbit to the threat radar reduces jamming effectiveness by 75%. Tripling the range reduces jamming effectiveness by almost 90%.

[4] Benjamin Lambeth, *The Transformation of American Air Power* (Ithaca, N.Y.: Cornell University Press, 2000), 94.

[5] Tom Clancy and Gen Chuck Horner, *Every Man a Tiger*, G.P. Putnam's Sons, New York, NY, 1999, p. 351.

[6] Defense Advanced Projects Agency News Release, "DARPA Transitioning Miniature Air Launched Decoy to Air Force", January 22, 2001.

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[7] Lt Col Don Lundie, …., Interview with author.

[8] Martin Streetly, "Radar and Electronic Warfare Systems 2000-2001", Jane's, April 2000, available at http://www.janes.com/defence/market_review/jrew_2000_2001/radar_and_electronic_warfare_2000-2001_06.shtml

[9] Christopher Bolkcom, "Airborne Electronic Warfare: Issues for the 107th Congress", CRS Report for Congress, Feb 9, 2001, 16.

CHAPTER 5

Alternatives

"When you come to a fork in the road, take it"
-Yogi Berra

The USAF cannot afford to fully fund every potential solution to the SEAD challenge. Resource-driven tradeoffs are an inevitable part of military planning, and any new system must prove its worth relative to existing or planned capabilities. In some cases, a system originally developed for a different mission area, such as the F-22, may have the capability to make significant contributions to SEAD. On the other hand, there may be viable lower-cost options more readily available. While a sophisticated unmanned vehicle is one possible solution for the demanding SEAD mission, it must be weighed against the costs and benefits of these other alternatives.

Information warfare

Advocates of Information Warfare have often argued that rather than attempting to counter every air defense system on the battlefield, the US should focus its efforts on achieving a high-payoff result by attacking the integration of those assets with Information Warfare tools. The thought of inserting a computer virus into the enemy's computers that renders his defenses harmless – in the words of one senior officer, making the SA-10 think it's a Maytag washer – is certainly appealing. While the US will no doubt continue to aggressively pursue such capability, relying on it in the near term doesn't seem realistic, for several reasons.

The most daunting challenge for most information warfare efforts is access. Unlike conventional electronic warfare that attacks the "front door" of a radar system through antennas, information warfare attacks on computers lack such convenient points of entry. As air defenses become more sophisticated, using secure means of communication such as buried fiber optic cable, the problems increase. In some cases, recruiting an "insider" may be the only means of delivering a virus weapon. Furthermore, designing an effective computer network attack mechanism requires a detailed knowledge of that network. While the US often obtains detailed knowledge of adversary systems through intelligence collection or exploitation of captured systems, determining the exact way in which a given adversary has networked those systems together may exceed our intelligence capabilities.

Finally, assessing the effectiveness of an information warfare attack presents unique problems. Satellite imagery offers no clue as to the effectiveness of a computer system. If the adversary practices good radar emissions discipline to avoid attacks on missile sites, the lack of radar signals from a site doesn't necessarily mean the site has been rendered ineffective. Accurate "battle damage assessment" may require human intelligence from a carefully placed source. These types of sources can take years to develop – recruiting one after a conflict has begun would be extraordinarily difficult.

None of these hurdles should be regarded as a reason to ignore the promise of information warfare. By 2020, the US may have developed revolutionary capabilities that far exceed the current state of the art. But for the foreseeable future, Information Warfare applications should be regarded as essential “arrows in the quiver” along with other capabilities, not a “silver bullet” to count on exclusively..[1]

Low Cost Unmanned Combat Air Vehicles

General Mike Short’s concerns about air defenses in Operation Allied Force were complicated by the lack of a long dwell SEAD capability. To overcome this limitation, General Short requested deployment of the Israeli-made “Harpy”, a ground-launched system that could loiter over the battlefield.[2] The Harpy is a “fire and forget” lethal UAV, designed to autonomously attack radar emitters.[3] This request was denied, based on legal concerns that the Harpy violated arms control treaties.

A low-cost UAV such as the Harpy suffers from several drawbacks. First, the low-cost systems are not stealthy. While they might be cost effective in lower threat environments against older tactical missile systems, the lack of stealth means the drone might not be able to get close enough to advanced SAM systems to achieve a kill.

Secondly, the lack of a communications capability on rudimentary systems like Harpy means SEAD planners would have no feedback on the success or failure of a mission. Anticipating this drawback, Israel Aircraft Industries has teamed with Raytheon Systems to create a more sophisticated drone known as Cutlass, which it is marketing to the US Navy. Cutlass incorporates more advanced sensors and a datalink capability, giving it capability against a wider range of targets.[4]

Third, drones such as Harpy and Cutlass are not recoverable, and therefore can only be used once. If an adversary chooses to maintain radar silence, friendly forces could expend large numbers of drones without ever achieving a hard kill. Admittedly, this may meet the objective of suppressing the threat, but it could prove expensive over a long campaign.

Finally, such "one time use" systems present legal challenges. Under the 1987 Intermediate-range Nuclear Forces (INF) Treaty, the United States and the Soviet Union prohibited the deployment of ground-launched cruise missiles with ranges between 500 kilometers and 5,500 kilometers. Non-recoverable UAVs are virtually indistinguishable from cruise missiles, and therefore systems such as the Harpy, with a range of 600 kilometers, are likely to face legal entanglements. Such concerns were a factor in the decision not to employ Harpy during Operation Allied Force.[5] Systems such as Cutlass are more attractive to the US Navy, since the INF Treaty does not address sea-launched missiles.[6]

F-22 SEAD variant

> *"The F-22 will bring us not only the air superiority that we traditionally think of in the air-to-air role, but that total air superiority of a first-in capability that takes out the airplanes and those most potent surface-to-air defenses that would otherwise limit our access to targets."*[7]
>
> *- General John Jumper, CSAF*

Any examination of options for next-generation SEAD must consider the role of the F-22 Raptor air superiority fighter in future force structure. The F-22 is a likely candidate for both technological and political reasons. Its stealthy design greatly reduces the range at which radar can detect the aircraft, and supersonic cruise speeds permit the F-22 to transit that detection zone more quickly, shrinking the lethal engagement zone for defenses to a fraction of that for conventional aircraft. Because of its enhanced survivability, it is a logical candidate for a secondary SEAD role. And despite the fact that the F-22 is the Air Force's highest priority modernization program, it has endured countless assaults by budget-cutters who question its relevance in future conflicts, arguing it is a relic of the cold war, designed for scenarios in which US fighters would fight outnumbered by ratios of four to one or more. Whether it is the right platform for SEAD or not, it is the platform the USAF is most likely to want to protect from any future budget cuts.

Assigning the F-22 a secondary SEAD mission would bolster its role in the future force and help to insulate it further from the budget axe. Faced with the choice of funding other initiatives for SEAD or expanding the role of the F-22, the Air Force may seek to preserve the aircraft it has long argued is essential to air dominance in the decades ahead. At his Senate confirmation hearing for his new position as Air Force Chief of Staff, General John Jumper made the case for the F-22, expanding on its utility outside the traditional air-to-air role: "Many have characterized the F-22 as strictly an air-to-air fighter, but the main strength of the F-22 will be its unique ability to combine stealth and supercruise to penetrate and precisely bomb future surface-to-air missile systems. The leverage of the F-22 will allow us to bring stealth into the daytime. The F-22, combined with the B-2 and F-117, will provide 24 -hour stealth as the F-22 both protects the force and suppresses the most difficult threats."[8] That would seem to imply a leading role for the F-22 in the future SEAD mission. But is the F-22 equipped for the task?

Filling the SEAD role would require the F-22 to employ some type of precision ordnance, in order to achieve a permanent kill against a SAM site. The F-22 weapons bay accommodates two one thousand-pound class air-to-ground weapons, such as the

Joint Direct Attack Munition.[9] However, the current trend within the Air Force is towards a family of smaller weapons, permitting aircraft to carry more weapons and attack more targets. The Small Diameter Bomb program seeks to procure a 100-250 pound weapon to fill this need, and the plan calls for the new weapons on F-22s by fiscal year 2006.[10] An F-22 would be able to carry at least eight of the small bombs, although that number could increase to 12 or more depending on the actual design selected.[11] Early versions of the bomb will employ Global Positioning System guidance, but later variants might include autonomous seekers.[12]

Accurately delivering those bombs requires some means of determining precise target coordinates. Especially when faced with highly mobile threats, weapons must either employ an autonomous seeker or receive accurate, updated target location just prior to weapons delivery. When initially fielded, the F-22 will not include any ground-mapping radar modes to provide such information to air to ground weapons, although planned upgrades will provide a capability by the 2007-2009 timeframe.[13] Such an upgrade would possibly include synthetic aperture radar modes with resolution of one foot or less. When combined with off-board cueing provided by datalink, the F-22 pilot would have the capability to locate, identify, and target SEAD targets. However, given the high cost of the F-22 and the limited numbers projected for future force structure, planners must carefully consider the survivability of the aircraft against advanced defenses.

Although the F-22 may yet find itself in a SAM-killer role, it seems unlikely that it will bear sole responsibility for eliminating advanced defenses such as double-digit SAMs. Instead, the Raptor force will likely want assistance in this demanding task. That vision has received recent support from the Air Force's senior leadership. The blueprint for the Global Strike Task Force concept leans heavily on both the F-22 and the B-2. It proclaims: "F-22s will pave the way for the B-2 and other bombers by providing initial local air superiority through the traditional "sweep" role and through air-to-ground targeting of the enemy's air defense network."[14] But a few paragraphs later, the same paper projects a need for a new air vehicle: "Small, armed UAVs, present throughout, will provide a hunter-killer platform for finding and killing threats in the highest-risk areas."[15]

Is an unmanned vehicle an inevitable development for SEAD? Certainly the future looks bleak without some new capability to meet the challenge of double-digit SAM systems. Current SEAD platforms were stretched thin in Operation Allied Force, even without having to deal with threats such as the SA-10. Increasingly frequent references to the SEAD capabilities of the F-22 highlight a growing recognition among Air Force leaders that future campaigns against a sophisticated adversary will require new technological solutions to prevent significant losses of aircraft and aircrews.

With the daunting lethality of modern defenses like the SA-10, the thought of sending manned aircraft into threat zones in the early stages of a conflict will become less and less attractive in the decades ahead. Although operations in Afghanistan have demonstrated a greater American willingness to risk casualties than other operations in the past decade, it is unlikely that the US will accept a return to the loss rates of the Vietnam era. Likewise, it is difficult to justify risking very high cost manned platforms such as the B-2 and the F-22 to accomplish a mission that might be accomplished as well or better with an unmanned vehicle. As technological advances make unmanned vehicles more capable, the idea of such a platform for the SEAD mission deserves serious consideration. Such a vehicle could potentially eliminate the most worrisome threats, paving the way for manned stealth aircraft and the legacy fleet to prosecute an extended campaign. Furthermore, an unmanned vehicle may offer unique capabilities unmatched by any other current or planned system. Understanding the full potential of a UCAV requires a detailed look at exactly what the Air Force has on the drawing board.

Notes

[1] Maj Gen Bruce Wright, Commander, Air Intelligence Agency, personal interview with the author, 20 Nov 2001, Maxwell AFB, Ala.

[2] Short, interview with the author.

[3] Israel Aircraft Industries Ltd. website, http://www.iai.ci.il/dows/Serve/level/Engligh/1.1.4.2.7.3.html

[4] Sandra I. Erwin, "Loitering, Smart Cruise Missiles Marketed to U.S. Navy"", *National Defense* website, available at http://www.nationaldefensemagazine.org/article.cfm?Id=509

[5]Bryan Bender, "Pilotless combat vehicle awaits legal green light", *Jane's Intelligence Digest*, September 19, 2000, available at http://www.janes.com/aerospace/military/news/jdw/jdw000919_2_n.shtml

[6] Erwin.

[7] General John Jumper, remarks to the Air Force Association Air Warfare Symposium, Orlando, FL, 24 February 2000.

[8] General John Jumper, remarks to U.S. Senate Confirmation Hearings, Washington, DC, 1 August 2001.

[9] USAF Almanac, "Gallery of USAF Weapons", Air Force Magazine, May 2001, p. 137.

[10] Sandra I. Erwin, "New Smart Weapons Are High On Air Force Chief's Agenda", National Defense, available at http://www.nationaldefensemagazine.org/article.cfm?Id=611

[11] Robert Wall, USAF Targets Larger Numbers, Smaller Bombs for F-22's Future, Aviation Week and Space Technology, available at: http://www.aviationnow.com/content/publication/awst/20010827/f22.htm

[12] The inclusion of radar or ladar (laser detection and ranging) seekers could be coupled with automatic target recognition software to permit weapons to seek out and destroy targets of known shape and dimensions, such as missile tracking radars.

[13] Lt Col Burt Wiggins, (title?), Air Combat Command F-22 Program Office, telephone interview, 6 Dec 2001.

Notes

[14] Gen John Jumper, "Global Strike Task Force", Air Power Journal, Spring 2001, p. 31.

[15] Ibid, p. 31.

CHAPTER 6

The Unmanned Combat Air Vehicle

"The Army Air Forces must go to guided missiles for the initial heavy casualty phases of future wars"
– General Curtis LeMay

The USAF's developmental UCAV program is an Advanced Technology Demonstration[1] conducted jointly with the Defense Advanced Research Projects Agency (DARPA). The goal of the program, begun in 1997, is to "demonstrate the technical feasibility for a UCAV system to effectively and affordably prosecute 21st century SEAD/Strike missions within the emerging global command and control architecture."[2] The program objectives include development of the air vehicle, the mission control station, and secure command, control, and communication links. The project hopes to demonstrate a human-in-the-loop process of detection, identification, location, real-time targeting, weapons authorization, weapons delivery, and target damage indication. Boeing, the contractor selected for the program, has already rolled out the X-45 air vehicle. With a wingspan approximately that of an F-117, but only half as long and with a very sleek cross section, the X-45 is a stealthy platform designed to fly at high subsonic speeds and high altitude.[3]

Concept Overview

The life-cycle of a UCAV is projected to be very different than that of an aircraft. The all-electric UCAV system is designed to be kept in storage, with its wings removed, during most of its lifetime. The storage containers are designed for a shelf life of ten years or more, and to enable "health-monitoring" and reprogramming of the vehicle without removal from storage. When needed in a contingency, the UCAV would be shipped in its storage container to the area of operations, where the vehicle would be reassembled and readied for flight. When no longer needed, the UCAV is repacked into its shipping container and returned to storage.[4]

The evolving concept of operations calls for UCAVs operating in cooperative formations of three to four vehicles. Off-board cueing, if available, would be transmitted via datalink to optimize positioning of UCAVs over the battlefield. The vehicles would employ on-board electronics to detect signals from enemy radars. By comparing time and direction of signal arrival among two or more vehicles, the formation of UCAVs rapidly estimates the threat's location. One of the vehicles then uses its synthetic aperture radar to obtain a high-resolution radar image of the target area. The vehicle then transmits the radar image back to the mission operator, who confirms the target identification and location, and grants consent to release weapons. One or more of the UCAVs then maneuvers to a weapons release point to deliver ordnance on the target. Eventually, more sophisticated automatic target recognition software and on-board processing may permit increased levels of autonomy. For example, if technology matures sufficiently, it may be possible to entrust the UCAV to attack any target whose emitter and radar signature matches the characteristics programmed for the particular mission (a particular SAM radar system, for example).

To better understand the UCAV system, the section that follows will examine its characteristics in seven key areas. These include range, radar signature, sensors, communications, weapons, cost, and supportability.

Range

Like any aircraft, a new unmanned vehicle must meet certain parameters in order to support US strategies for employing airpower, which have increasingly focused on projecting power over long distances. The design for the X-45 calls for thirty minutes of loiter capability at a range of 650 miles from the launch base.[5] While these parameters would enable a UCAV based in Saudi Arabia, for example, to reach central Iraq, it falls short of that needed to fully support the Global Strike Task Force concept. Countering "anti-access" threats implies a capability to operate from well outside an enemy's defenses, including systems such as theater ballistic missiles that may make forward bases unusable in the early stages of a conflict.

Obviously, including an air refueling capability could extend the deployment range of the vehicle almost indefinitely, and permit it to loiter longer over the battlefield. In some scenarios with a limited number of threats, it is conceivable that several formations of UCAVs with refueling support could stay over the battlefield for days at a time, returning to base only when their ordnance runs low.

Although the current X-45 vehicle does not have an air-refueling receptacle, the design permits one to be added at a later date.[6] From the standpoint of risk-reduction, it makes good sense to delay exploration of this capability until the program is more fully developed. But conceptually, air refueling is essential if the UCAV is to have a role in emerging employment concepts. The very premise of GSTF is founded on the idea that an adversary's denial of access requires a "kick down the door" capability from long range. If the UCAV is to contribute to this capability, it must operate from significant distances, well outside its unrefueled range specification. Many aviators (and more than a few boom operators) may recoil at the suggestion of "autonomous aerial refueling", but technologically it should be achievable in the near future.[7] While such a system would probably require modifications to at least a portion of the tanker fleet, the cost might be justified in order to increase the survivability of GSTF manned assets.

Radar Signature

The UCAV air vehicle is a low observable, or "stealth" design. One look at the X-45 prototype (Fig. 1) reveals the now familiar angular lines and curved surfaces of previous stealth designs such as the F-117 and B-2. While roughly comparable to the F-117 in wingspan and about half its overall length, its profile view shows a much thinner, sleeker shape. The head-on view is more reminiscent of the B-2, characterized by the lack of a vertical tail. All these features hint at a radar signature similar to or even less than previous stealth designs. The lack of a cockpit and canopy may significantly enhance the stealthiness of the UCAV. This permits its very thin profile, and the lack of a seam where a canopy would open eliminates a problem for designers and maintainers.

How much stealth is enough? As much as engineers would like to build an invisible aircraft, stealth involves an inevitable series of tradeoffs of signature, performance, and cost. Unlike the F-22, which must retain the capability for high "g" close in maneuvering in a visual air-to-air engagement, the UCAV can make some performance tradeoffs. Positioning the engine inlet on top of the airframe masks it from the view of ground based radars. This limits the ability of the vehicle to attain high angles of attack (which could interrupt airflow to the inlet and cause an engine stall), but the UCAV should have little need to fly in that regime.

Ideally, the vehicle should be sufficiently stealthy to fly close enough to an advanced SAM like the S-400 to deliver weapons without the SAM system maintaining track long enough to guide a missile to intercept. Of course, there are a number of variables in this equation, including the standoff range of the UCAV's weapons and the capabilities of the tracking radar. Equipping the UCAV with a long-range standoff weapon decreases the degree of stealth required, however, if the weapon itself is not stealthy (and very few current weapons are) the system may be able to engage and shoot down the bomb on its way to the target.

The actual radar signature of the X-45 (or its successor) will remain highly classified. It is safe to assume the Air Force will buy as much stealth for the UCAV as it can afford, and any plans to move to a full scale acquisition of the UCAV system will likely be contingent on meeting both signature and cost goals. The Air Force has made clear its plans to evolve to an all-stealth force, and the UCAV will need to support that strategy.[8]

Sensors

In order to suppress or destroy enemy air defenses, the UCAV must have a means of locating these highly mobile threats. While some off-board information from other intelligence, surveillance, and reconnaissance assets may be provided to the formation of UCAVs, the key to their effectiveness will lie in their combination of on-board sensors. The sensor suite consists of a passive radar receiver capable of determining the time and direction of a signal's arrival with high accuracy, and synthetic aperture radar capable of mapping small areas with resolution of one foot or less.[9] DARPA intends to transfer technology from another of its programs, known as Advanced Tactical Targeting Technology (AT3), to support UCAV. This technology seeks to exploit time and direction-of-arrival information from multiple cooperating platforms to ascertain threat position inside a 50-meter ellipse within 10 seconds, from a distance of 50 nautical miles. The system requires three or more collectors to optimize accuracy; hence the need for UCAVs to operate in multi-ship formations.[10]

Deploying several formations of UCAVs equipped with such passive sensors over a battlefield represents a major step forward in the ability to counter mobile defenses. At present, only a few systems, such as the U-2 and RC-135, can detect and locate radar signals. Even these systems do not provide location sufficiently accurate for delivery of weapons, unless they are operating together in very carefully orchestrated scenarios. Both the U-2 and the RC-135 are regarded as "low-density, high-demand" assets, meaning there are seldom enough platforms available to meet worldwide needs. A fleet of UCAVs would substantially improve the ability of US forces to monitor the battlefield for fleeting targets.

The AT3 goal of 50-meter accuracy is still not adequate for delivering air to ground weapons. GPS-guided munitions are capable of 3-meter accuracy, so precise target location information is critical. Synthetic aperture radar has shown great promise in this area. The B-2, equipped with such a radar and GPS weapons, achieved remarkable accuracy in Operation Allied Force against fixed targets such as buildings, airfields, and bridges. The UCAV faces a tougher challenge in locating targets such as mobile radars. Advances in digital processing have now made resolution of less than one foot a reality, and such high resolution is vital if an operator (or eventually, a software routine) is to recognize tactical targets and discriminate them from other radar returns. The state of the art in radar technology can determine highly accurate target location information. Whether it will be sufficiently accurate for decision-making is an issue addressed in Chapter 8.

While both the passive electronic and active radar sensors are vital, it is the ability of the two sensors to operate in conjunction with one another that is crucial to the system's ability to rapidly locate targets. Multiple sensors on the same platform will enable machine-level integration to more rapidly process information, far faster than today's rudimentary architecture allows. The additional sensors UCAV offers, distributed over the battlefield, could vastly increase the situational awareness of those directing the air war, and those flying in harm's way. This capability may well prove to be one of the UCAV's most attractive features.

For the UCAV system to function efficiently, however, the information collected by the air vehicles' sensors must be shared through a robust communications network. Fitting the UCAV into the burgeoning information infrastructure is a significant challenge.

Communications

> "The most fundamental, technology-driven decision facing UAV planners early in the 2000-2025 timeframe is whether to migrate towards an air-centric (processor based) or a ground centric (communications based) architecture. In the case of the former, relatively autonomous UAVs with minimal ground infrastructure and direct downlinks to users will be the norm. For the latter, UAVs will be remoted "dumb" sensors feeding a variety of data into a centralized ground node which builds a detailed, integrated picture for users."[11]

This statement, taken from the Department of Defense's UAV Roadmap, highlights one of the dilemmas confronting designers of future unmanned systems: the rapid advance of computer technology will probably enable unmanned vehicles to perform tasks that humans are unwilling, at least initially, to trust to a machine. Relying solely on vehicle avionics to make target selection and potential collateral damage decisions, which might one day prove technologically feasible, is nonetheless politically unthinkable in today's climate, in which military operations are mercilessly scrutinized. Rules of Engagement, for example, usually require "positive identification" of the target by some means prior to weapons release.[12] Until confidence in automatic target recognition software has increased, this will demand a human decision-maker in the loop, so for the near future, the ground centric architecture is the only palatable choice. The UCAV program clearly follows this model, using the Mission Control Segment (ground station) as the central node for fusing information from a "flight" of up to four vehicles.

The ground station will transmit commands to the flight, for such purposes as route changes or new search area assignments. Unlike the RQ-1B Predator, the actual flight operations of the UCAV will be mostly automated, and will not require "stick and rudder" inputs in the traditional sense. Since the vehicle operator is only monitoring flight information, and focusing primarily on mission tasks, a single operator can control a formation of four vehicles. The vehicles themselves will share an interflight datalink, which permits spatial deconfliction (ie, prevents the vehicles from colliding) and allows the sensors on all the vehicles to share information, a vital requirement for rapid target location. The frequency bandwidth requirements for these tasks should be relatively low. Transmitting large quantities of sensor information back to the ground station, however, will require much more bandwidth, and will drive the UCAV communications architecture.

The human decision-maker will require radar imagery displayed at the ground station. Factors such as the size and resolution of the image, and the time constraints for transmitting it, drive the size of the datalink "pipe" required. DARPA's plans for the UCAV call for using a well-established datalink system known as the Joint Tactical Information Distribution System, more commonly referred to as Link 16. In order to prevent imagery transmissions from UCAVs from overwhelming the available bandwidth, designers may elect to employ some degree of onboard processing to eliminate unnecessary image segments. For example, if the UCAV radar produces an image of a one square mile area of terrain, but automatic target recognition software determines that the only man-made objects are in the lower right half of the picture, the remainder of the image need not be transmitted to the ground station.

In some cases, decision-makers may require a wider area image to evaluate collateral damage potential. Again, on-board processing can significantly reduce bandwidth demands. For example, if the vehicle obtains both medium and high resolution images of a given area, on-board processing can merge the two images, transmitting higher resolution imagery only in those areas where the radar detects man-made returns.[13] This type of on-board processing will be critical in order to prevent bandwidth requirements from spiraling out of control, especially as the size of the unmanned vehicle fleet increases.[14] As technology such as automatic target recognition matures, it seems logical that UCAVs would eventually migrate to a more air-centric architecture. This is even more essential if UCAVs eventually join the force structure in greater numbers, as a replacement for manned strike aircraft, for example. Under such circumstances, bandwidth demands could become overwhelming in a ground-centric architecture.

Nonetheless, the USAF is still a long way, both culturally and technologically, from trusting lethal force decisions to a computer. For the foreseeable future, UCAV demands for bandwidth are a serious concern. The ability to establish a secure, robust, over-the-horizon communications architecture that can support the rapid transfer of information is crucial if UCAV is to succeed.[15]

Weapons

Because the UCAV is still in an early stage of development, it stands to benefit from the rapid acceleration of precision weapons programs in the aftermath of the Kosovo conflict and operations in Afghanistan. The Air Force is currently moving ahead with the Small Diameter Bomb, with first hardware deliveries in the 2006 timeframe.[16] The first phase of the program is focused on a GPS-guided munition for fixed targets; later variants are expected to incorporate automatic target recognition and wide-area, autonomous search. The planned payload for the UCAV is twelve of these small bombs. While the UCAV weapons bay is compatible with larger munitions, the smaller bomb permits the UCAV to carry a greater number of weapons, and strike more targets per sortie. Although the actual size of the bomb has not been finalized, a 250-pound warhead is probable. Unclassified program goals call for a weapon standoff range of up to 35 miles, and accuracy of less than 13 meters.[17]

The small diameter bomb does have some significant limitations for reactive SEAD. Since it is an unboosted, gravity-fall weapon, it has a relatively long time-of-flight, typically 40 to 60 seconds at medium altitudes, even when released from minimum range. Longer release ranges for gliding weapons result in correspondingly longer times-of-flight. True reactive SEAD mission normally requires some type of high-speed weapon, since the objective is to force the radar operator to shut down before completing an engagement. Unfortunately, the high speed of newer missiles, up to Mach 6, makes this increasingly difficult. Ground-based SAM systems with large missiles have an inherent advantage over smaller, air-launched weapons.

While a future anti-radiation missile could conceivably be integrated with the UCAV, such a weapon would significantly increase complexity. USAF planners will have to carefully consider whether the increase in capability warrants the increased cost. In fact, cost will be one of the most important considerations in the viability of UCAV.

Cost

Despite the surge in defense spending associated with America's war on terrorism, defense budgets will significantly constrain major acquisition programs. With many other modernization programs already in development, any new program such as full-scale production of UCAVs will face extraordinary scrutiny. If UCAV can be shown to be more cost-effective than other alternatives, it is far more likely to win supporters. In fact, DARPA's stated goal for the UCAV program is to demonstrate the technical feasibility to perform SEAD/strike missions *effectively* and *affordably*.[18]

DARPA estimates that the UCAV will cost less than one-third the cost of a Joint Strike Fighter (JSF), or about $12 million per vehicle, and projects a 75% reduction in operations and maintenance (O&M) costs compared to a present day F-16 squadron.[19] Unmanned vehicles offer some inherent cost savings, since they do not require life support systems, ejection seats, and cockpit instrumentation. The reduced size means less surface area and savings on low observable coatings. And since the vehicle is intended to spend much of its service life in storage, the airframe need not be as robust as a typical aircraft.

The major cost savings for a UCAV come from reduced O&M, using the cold storage concept. The cost of daily flying operations accounts for a substantial portion of the life-cycle cost of a weapon system. Maintaining most of the vehicles in storage not only reduces this cost, it also reduces the risk of losses in training mishaps. A small number of vehicles would have to be kept in active service for operator training missions and maintenance training. If UCAVs are to eventually integrate seamlessly with manned platforms, they must participate in major exercises such as Red Flag.[20] This would require at least one active squadron, but for the remaining squadrons, DARPA estimates 80 percent of the manning could be maintained in the Reserve component.

This raises a cautionary note, however. If the UCAV were to take over some missions, such as patrolling no-fly zones, costs could rise dramatically. Such steady-state operations could accumulate a large number of flight hours in a relatively short time, requiring replacement of the air vehicle much earlier than planned. Operating the squadrons in those circumstances, at a deployed location, would require activating a reserve unit at considerable cost. In this case, the vehicle's affordability may be considerably less than that postulated for scenarios in which the UCAV is only used to "fight the big wars."

Supportability

Like every other system in the military's inventory, the UCAV must "get to the fight". Although it would be possible to pre-position a limited number of UCAVs in certain theaters of operation, the need to conduct periodic maintenance checks and reprogramming of the systems, and the desire to use reserve manpower, will probably dictate storing most of the air vehicles in the United States. The vehicles are projected to have a self-deployment range of 3600 NM when fitted with external tanks.[21] This is well short of that required for an overseas deployment, which argues in favor of adding an air refueling capability.

Alternatively, UCAVs may be airlifted to a theater in the storage container. A C-17 could deliver up to four UCAVs; a full squadron of 24 vehicles and a mission control station would require six C-17s. This increases the airlift requirement over that of a conventional fighter squadron, but eliminates the air refueling requirements associated with fighter deployments.

The key areas of range, radar signature, sensors, communications, weapons, cost, and supportability provide a glimpse at the physical characteristics of the UCAV system. The driving force behind all these characteristics, however, should be a clear understanding of how the UCAV will operate within a larger force structure, and within the future information architecture. Understanding that requires an in-depth look at concepts of operation. As the next chapter will show, the UCAV offers a great deal of promise not just as a "shooter" platform, but as an integral part of the total ISR network.

Notes

[1] ATDs are a technology transition mechanism sponsored by the Office of the Secretary of Defense. ATDs are used to demonstrate the maturity and potential of advanced technologies for enhanced military operational capability or cost effectiveness, and reduce technical risks and uncertainties at relatively low cost.

[2] Col Mike Leahy, DARPA UCAV Program Overview briefing, Washington DC, 28 Nov 2001.

[3] Ibid.

[4] Ibid.

[5] Leahy

[6] Leahy interview.

[7] Boeing and the NASA Dryden Flight Research Center are currently engaged in a program to outfit two NASA F-18 aircraft with flight control systems capable of resolving relative positions between aircraft to less than 10 centimeters. Such technology would be more than adequate for the relative positioning of a UCAV and an air refueling aircraft.

[8] John A. Tirpak, "Two Decades of Stealth", Air Force Magazine, June 2001, p. 33.

[9] By comparison, the F-15E's APG-70 radar, the best fighter ground-mapping radar in today's inventory, has a maximum resolution of 8.5 feet.

[10] Mark Hewish and Charles Gibson, "Into the Valley of Death", Jane's International Defense Review, Oct 2001.

[11] Office of the Secretary of Defense, Unmanned Aerial Vehicle Roadmap, 2000-2025, April 2001, p. 55.

[12] Although the US does employ weapons such as cruise missiles and GPS-guided bombs against fixed targets without such "positive identification" at the time of weapons release, rules are generally more stringent for attacks against mobile targets, which often carry a much higher risk of target misidentification.

[13] Such reductions in resolution can reduce the size of an image file by several orders of magnitude. For example, and area 1000' x 1000", imaged with one-foot resolution, comprises one million pixels of image data. The same area, imaged with ten foot resolution, comprises only ten thousand pixels.

[14] Michael O'Hanlon, *Technological Change and the Future of Warfare*, Brookings Institution Press, Washington DC, 2000, p. 58

[15] Lt Col Richard Clark, "Uninhabited Combat Aerial Vehicles: Airpower by the People, For the People, But Not with the People", CADRE Paper No. 8, (Air University Press, Maxwell AFB, Ala.; Center for Aerospace Doctrine, Research, and Education), 50.

Notes

[16] Adam J. Hebert, "Smaller Bombs for Stealthy Aircraft", Air Force Magazine, July 2001, p.43.

[17] Ibid, p. 44.

[18] DARPA Brief

[19] DARPA Brief

[20] Clark, 52.

[21] Leahy

CHAPTER 7

Concept of Operations

"We are big on getting the concepts of operations right before we decide on anything"[1]

- General John Jumper

Purchasing new hardware does not guarantee a successful transition to unmanned vehicles for the SEAD mission. Too often, the acquisition of new defense hardware leaps ahead of the thought process of how to coherently integrate that hardware into warfighting. As the Air Force begins to move more seriously to greater reliance on unmanned systems, it is determined not to fall into that trap. Air Combat Command already has the tasking to begin developing the future concept of operations for UCAV.

The UCAV system will need to support two distinctly different types of operations – preemptive destruction and reactive suppression. Preemptive destruction missions are carried out before strike packages attempt to penetrate hostile airspace. The UCAV would operate alone or in conjunction with a small number of stealth assets, with the objective of permanently destroying enemy radars. In the case of reactive suppression, the UCAV would integrate with manned assets, providing a persistent force to target radars that threaten the strike package. In this case, timing and positioning relative to the strike package are crucial, although permanent destruction is not essential, provided the UCAV's attack can force the radar to shut down before guiding a missile to intercept.

Preemptive SEAD

If intelligence assets can fix the location of air defenses before hostilities begin, attacking them is a straightforward matter. But recent experience suggests this task will be anything but simple. In reality, attacking mobile SAMs is a subset of the larger problem of time sensitive targeting, a term which includes attacks on other high-priority target sets such as theater ballistic missiles and weapons of mass destruction. The USAF's 1999 *Initial Report on the Air War over Serbia* addressed the challenge of such targeting, asserting: "Seamless integration of Intelligence, Surveillance, and Reconnaissance [ISR] information is critical to rapid target destruction." "Fundamental to this capability is the ability of ISR platforms – whether space-based or airborne – to transition between traditional collection tasks and the urgent requirements of real time targeting."[2] The UCAV may offer significant advantages in this respect. Appreciating the unique possibilities of the UCAV requires an examination of the time-sensitive targeting (TST) process in some detail.

The Time Sensitive Target Problem

Although the steps in the time-sensitive targeting process can occur linearly, that is not necessarily the most efficient approach. According to an article by Major William Danskine, the TST process can be better understood by organizing the "kill chain" into a model rather than linear steps. The first three steps in the process – detection, location, and identification – can occur in parallel, using a combination of active and passive sensors.[3] While either type of sensor can perform the detection function, precise location of an emitter is best accomplished by the use of an active sensor such as radar.

Identification, however, is currently best accomplished by passive sensors such as an electronic signals intelligence package or imagery sensor, either electro-optical or infrared.[4] At present, accomplishing all three of these functions requires close coordination among multiple platforms, especially when attempting very short response times.

The advantage of the UCAV for TST lies in its unique combination of two types of sensors and weapons. A flight of UCAVs could *detect* and *identify* an emitter using their electronic signals package, and determine the threat's approximate location. The UCAVs can then cue their radar systems to precisely *locate* the emitter. Because both sensors are on-board the UCAV, very rapid machine-level exchange of information can reduce the detect-locate-identify cycle from minutes to seconds. The next steps in the process, information fusion and dissemination take place at the ground station. Danskine defines dissemination as passing "the complete targeting information to decision-makers and shooters."[5] Since the UCAV "shooter" is already in relatively close proximity to the target, the dissemination function can be very rapid once the decision-maker authorizes release of weapons. The flight of UCAVs would be the logical choice to deliver ordnance (provided they had not already expended their full payloads), and the operator need only select one or more vehicles for the task. Once the UCAV received approval, it could employ ordnance as soon as it maneuvered within range of the target. The UCAV's stealth characteristics also give it an inherent advantage over conventional platforms in the TST role, since it can loiter closer to the battlefield and reduce the time required to get weapons to the target.[6]

The UCAV currently under development is essentially a system optimized for a particular type of TST: mobile surface-to-air missiles. However, not every future conflict will require an intensive SEAD effort. In situations where the air defense threat is low or quickly neutralized, extending the UCAV's mission to encompass other time sensitive targets, such as theater ballistic missiles or weapons of mass destruction, is a logical step. Those other targets, however, present some additional challenges. Air defense radars emit a very specific signal that aids in both detection and identification. By contrast, a trailer truck carrying chemical weapons emits no such signal, and the UCAV would have to rely on some external source to cue its radar search. Careful intelligence preparation of the battlefield using predictive analysis tools would aid this process, permitting use of ISR assets for "confirmation instead of discovery."[7] Of course, these tools would prove equally useful for hunting SAMs in situations where the enemy maintains radar silence to preserve his assets.

The time-limiting step for the UCAV's targeting cycle will most likely be obtaining consent for weapons release. For the foreseeable future (certainly when UCAVs are initially fielded), commanders will insist on a human in the loop for lethal force decisions, and the human decision maker will require some type of high resolution imagery to make this determination. The imagery serves multiple purposes: it provides a "sanity check" that the contact of interest is a military target, it permits the operator to select a precise aimpoint for weapons delivery, and it permits the operator to examine the area around the target to assess the chances of collateral damage. Getting the right kind of imagery to the right person is a key step in the process.

The time required for weapons authorization can be broken down into three segments: time required to transmit imagery from the air vehicle(s) to the operator, time required for human evaluation and decision making, and time required to transmit aiming corrections and authorization to the air vehicle(s).[8] The time for imagery transmission will depend directly on available datalink bandwidth. High-resolution images constitute a huge quantify of data, and system designers will have to make tradeoffs between image size and image resolution in order to minimize bandwidth demand. For example, confirming target identification will require very high (one foot or less) resolution, but only of the contact of interest - an area perhaps 100' x 100'. Assessing collateral damage potential demands an image of a much larger area, a circle of up to one-mile diameter centered on the target. This image, however, need not be of maximum resolution. Assessing the proximity of other buildings or vehicles could be accomplished with ten-foot resolution imagery. Transmitting lower resolution imagery for this wider area would considerably reduce bandwidth requirements.

The time for human decision making is a major unknown. It rests in no small measure on the key question: who is authorized to make the decision? The fastest decision cycle would occur if the UCAV operator could grant authorization. This is analogous to the present day situation in which aircrews are trusted to make the final decision on weapons release. However, the nature of UCAV operations, in which a remote operator can make the lethal force decision, may tempt commanders to elevate the decision making level, simply because they *can*. Requiring a decision from someone other than the operator adds an unknown delay. Obviously, target images from the ground station could be transmitted to the AOC or some other location via landlines. In cases where collateral damage concerns gain paramount importance, senior officers may insist on having "eyes on" the TST process. The "CNN effect", in which every instance of collateral damage makes headlines, has made it increasingly difficult for senior leaders to entrust such decisions to lower echelons. But will the UCAV radar imagery satisfy the "eyes on" requirement?

Unfortunately, the future UCAV community may have to overcome a significant obstacle to achieve maximum effectiveness against fleeting targets. Today's senior-level decision-makers are most comfortable with "visible spectrum imagery" - in other words, good old fashioned pictures. Moving pictures, or video, are considered even better.[9] However, there are no plans to include electro-optical sensors on the UCAV. The rapid advance of technology makes it reasonable to project that by the 2010 timeframe, radar systems will provide sufficient resolution for targeting decisions. However, senior decision-makers who are not familiar with radar images may be uncomfortable allowing lethal force decisions without the reassurance that visual sensors provide today.[10] Requiring a UAV with visual sensors to "confirm" the targeting decision would sacrifice many of the advantages of the UCAV. As radar imagery improves and offers ever-increasing resolution, tomorrow's senior leaders will need direct exposure to this type of imagery in exercises and war games if they are to trust it in war time to make lethal force decisions.

The TST construct, under current rules of engagement, involves inherent delays for human decision making. The extent of that delay might vary from seconds to hours, but in the context of preemptive SEAD such delays may be perfectly acceptable. However, time constraints will present a much greater challenge for reactive SEAD.

Reactive SEAD

Adapting the UCAV to a reactive SEAD role will be much more difficult than using it for preemptive destruction of defenses. Reactive SEAD is conducted by forces imbedded in a strike package, in an effort to suppress threat radars that attempt to engage aircraft in the package. This requires very precise timing and coordination between strike and SEAD aircraft. Such close coordination between manned and unmanned platforms would be difficult; in fact, such operations might be best avoided in the early stages of UCAV implementation.[11] Eventually, of course, such integration is inevitable. As a minimum, the UCAV operator would need to share a common datalink picture with manned strike aircraft in order to provide adequate situation awareness. Currently, in-flight coordination between strikers and SEAD aircraft is accomplished by means of voice communication. Shifting this coordination to datalink would allow more automation, for example, aircraft that received radar warning receiver indications of enemy missile activity could instantly relay information such as threat azimuth and radar parametrics to the SEAD platform.

As outlined in Chapter 6, a significant limitation of the UCAV for reactive SEAD is the lack of a high-speed weapon. Unless the UCAV is eventually armed with a missile of some sort, it will be unable, in most cases, to provide true reactive suppression. In essence, the USAF may be forced to move to a tactic of "reactive destruction", in which the primary objective is to achieve a hard kill against an emitter once it has revealed its position by attempting to engage another aircraft.[12] In this case, the targeted aircraft would have to rely on some combination of maneuver and defense countermeasures for survival. It is possible, of course, that the UCAV's presence over the battlefield will have a powerful psychological effect on enemy SAM operators, who may elect not to turn on their radars out of fear of giving away their position to the UCAV. This type of "suppression by presence" has always been an element of the Wild Weasel mission, and could be equally valid for UCAV. Although the UCAV will have a low radar signature, it is virtually impossible to make an aircraft invisible from all angles at all radar frequencies. Therefore, a sophisticated enemy would probably be able to determine that UCAVs were operating over the battlefield, even though they might be unable to target them successfully. This capability to loiter over the battlefield may be one of UCAV's most attractive features, both for SEAD missions and other possible roles.

An Intelligence, Surveillance, and Reconnaissance Role for UCAV?

As American strategies for employing air power place increasing emphasis on precision application of force, the need for ISR information to feed to "shooters" has stretched current assets thin. Commanders desire persistent ISR capability, to monitor the battlefield and look for patterns that can reveal an enemy's plans.[13] Global Hawk, a high-altitude, long endurance UAV, was deployed to support operations in Afghanistan before its testing was even complete, a clear sign of this insatiable appetite for timely intelligence information. Even in an environment in which there is little or no air defense threat, the UCAV could offer a great deal of utility as a dedicated ISR asset to help satisfy these demands. Although the UCAV's radar is intended for spot imaging rather than wide area surveillance, it could be very useful to maintain surveillance of specific areas of interest, such as enemy command and control facilities, or weapons cantonment areas. With air refueling, UCAVs could be kept on orbit for very long periods, even days. Conceivably, UCAVs could operate cooperatively with systems such as Global Hawk. Collection managers might use the Global Hawk's wide area surveillance capability to cue and position UCAVs for more continuous observation of areas of interest. In this role, UCAVs would offer useful capability across the spectrum of conflict.

Although the concept of operations for UCAV is still in an early stage of development, the fact that it is underway now, before the vehicle has even flown, means the USAF has an important head start. The final design of the vehicle will no doubt benefit enormously from answering some of these questions early in the program. The UCAV program stands to benefit from the lessons learned with other unmanned systems such as Global Hawk and Predator, but there will be many new challenges because of the UCAV's unique design and capabilities. Warfighters must ask themselves now how they would control this unique asset.

Notes

[1] Gen John Jumper, media video teleconference, Sep 7, 2000, Hurlburt AFB, Fla, available at http://afeo.langley.af.mil/newslink/00_releases/jumper_vtc.pdf

[2] United States Air Forces in Europe, Studies and Analysis Directorate, *The Air War over Serbia: Aerospace Power in Operation Allied Force, Initial Report*, 30 September 1999, p 5. (Secret)

[3] Maj William B. Danskine, "Time Sensitive Targeting Model", available at http://www.airpower.maxwell.af.mil/airchronicals//cc//Danskine.html, p. 5.

[4] As the quality of synthetic aperture radar imagery improves, it may reach the level of fidelity required for target identification. Current SAR systems can achieve resolution of six inches or less.

[5] Danskine, p.6.

[6] A fighter loitering 80 miles from a target, outside the range of enemy missiles requires 8-10 minutes to put weapons on target. A UCAV loitering 30 miles away could deliver weapons within 4 minutes.

Notes

[7] Gen John Jumper, "Global Strike Task Force", Air Power Journal, Spring 2001, p. 30.

[8] Depending on the situation, multiple vehicles might be tasked to attack the same target from different axes, in order to increase probability of kill.

[9] Short interview

[10] This tendency is likely to be exacerbated if the decision-making process is elevated to a non-airmen or non-military individual, who may have little or no appreciation for radar capabilities.

[11] Clark, 74.

[12] The author is indebted to Lt Col Don Lundie for his insights on this issue.

[13] Mark Thompson, "The Lessons of Afghanistan", Time, February 18, 2002, 28.

CHAPTER 8

Command and Control

The first air component commander to grapple with the question "how do I use this thing?" will hopefully have the benefit of some forethought and planning from within the UCAV community. Understanding the ways in which a UCAV is like a traditional manned aircraft, and the ways in which it differs, will aid in making the right decisions on how to integrate such a new capability into existing command and control structures.

UCAVs will probably be deployed in a traditional squadron organization, much like a present day expeditionary fighter squadron. They will require runways, ramp space, refueling support, weapons loading areas and maintenance facilities. Operators will require mission planning facilities and a means of receiving the daily Air Tasking Order. However, since the operator need not see the vehicle he or she controls, the UCAV raises the possibility that maintainers and operators could be deployed to entirely different locations. While this is not necessarily the preferred option, it is a distinct possibility. Deciding a beddown location for the air vehicles will follow a familiar process of evaluating tradeoffs involving vehicle range vs. distance to the area of operations, available ramp space, runway length, and so forth. The optimum location for the ground station, however, revolves around other factors.

The location for UCAV operations (the Mission Control Segment, or MCS) will hinge on the availability of wide bandwidth communications. Although the UCAV will takeoff and fly to the area of operations autonomously, the MCS will employ a datalink to permit retasking of vehicles in-flight[1], and to provide the "human-in-the-loop" to authorize weapons release. By using satellite communications relays, operators could control UCAVs almost anywhere in the world from the United States. However, other requirements may dictate keeping the ground stations in theater.

Integration of the UCAV with manned assets will probably require operators to have real-time situational awareness of other aircraft – in practical terms, they will need access to the "tactical air picture" provided by AWACS or ground radars. This may prove a powerful argument for co-locating ground stations with the Air Operations Center (AOC) whenever possible. Most tactical units do not have the communications links to receive the air picture, but co-locating the UCAV ground station with the AOC would permit easy access to this critical information.

Co-locating with the AOC may also increase the utility of the UCAV in the intelligence collection role. A loitering, stealthy platform that puts sensors over the battlefield would be a lucrative source of information for the JFACC and his staff. The US currently lacks any type of penetrating ISR capability, and has this shortfall ever since the retirement of the SR-71 Blackbird. The Darkstar UAV was to have filled this role, but the cancellation of that program left this need unmet.[2]

Maximizing the UCAV's usefulness for ISR would require careful theater-wide planning, and the capability to rapidly re-task vehicles as the situation dictated. Currently, airborne re-tasking is typically accomplished via voice communications, a slow, laborious process that is prone to human errors. While UCAVs could be re-tasked via voice communications to the operators, next-generation technology should attempt to accelerate operations through "machine to machine" communications. For example, if a U-2 carrying a signals intelligence package detects threat radar emissions, personnel in the AOC should be able to hand off that new threat location to a flight of UCAVs without having to copy down and retransmit coordinates. Rather, the AOC should be able to pass the data over machine level links, to permit more rapid and accurate flow of information.[3] Co-locating UCAV operations with the AOC would permit these types of links through secure landlines, reducing bandwidth requirements within the theater.

Bandwidth availability will most likely be the biggest constraint in exploiting the ISR capability of the UCAV. In theory, while the UCAV is loitering over the battlefield and listening for radar emissions with its passive sensors, its high-resolution radar could be actively mapping yesterday's targets for battle damage assessment, or tomorrow's targets for updated imagery. However, high-resolution imagery demands a great deal of bandwidth for transmission. At times when demands on datalink nets are high, the UCAV might have to store images in memory for downlink when bandwidth permits, or even for download on the ground. Again, this favors locating the UCAV facilities near the AOC, where imagery downloads could be routed to planners in the AOC via dedicated landlines.

Pitfalls

If the UCAV mission control station is situated near the AOC, or collocated, then it could easily become part of the AOC. The USAF has long advocated centralized control and decentralized execution, but the introduction of a system like UCAV could sound the death knell for the latter. Up until now, decentralized execution has been essential because nothing else was technically feasible.[4] But if future communications systems can satisfy the bandwidth demands, senior decision-makers in the AOC could easily yield to the temptation to make tactical level decisions. In fact, there have been numerous press reports of exactly such a phenomenon in Operation Enduring Freedom.[5] With live video feeds from the Predator UAV, Central Command Headquarters in Tampa, Florida has made near-real time targeting decisions for an operation halfway around the world. Under such circumstances, keeping higher echelons of command focused on operational and strategic level tasks may become more and more difficult.

The dual-use possibilities for the UCAV, as both a strike asset and as an ISR platform, will also present significant challenges for command and control. Both the combat operations and ISR constituencies within the AOC may press for direct tasking authority over the UCAV fleet. In any environment other than complete air supremacy, its SEAD role will probably take priority, but in later stages of a conflict, some vehicles could conceivably be allocated specifically for ISR tasks.

Establishing command and control procedures for the UCAV system will undoubtedly require considerable experimentation to find appropriate solutions, and no set of procedures can cover every possible circumstance. Nonetheless, any future UCAV community will have to develop a workable doctrine that permits commanders to gain maximum utility from the system, while avoiding the pitfall of dragging the AOC into tactical level decisions that could overwhelm the AOC staff.

Notes

[1] John Tirpak, "Send in the UCAVs", Air Force Magazine, August 2001, 63.

[2] Maj David Hiltz, UCAV Program Manager, Advanced Programs Office, Directorate of Requirements, Headquarters Air Combat Command. Personal interview with the author, Langley AFB, VA, Nov 29, 2001.

[3] GSTF, p. 30.

[4] Dr. Phillip S. Meilinger, lecture to the Air War College, 11 Feb 2002.

[5] Thomas Ricks, "Beaming the Battlefield Home", The Washington Post, Mar 26, 2002, p 1.

CHAPTER 9

Conclusions

It's tough to make predictions, especially about the future.

-Yogi Berra

The growing proliferation of highly advanced air defenses has ensured that the SEAD missions of tomorrow will probably be as dangerous as the first Wild Weasel missions flow in Vietnam over thirty years ago. The capabilities of systems like the SA-10 and SA-20 can potentially hold an entire US campaign strategy hostage until those threats are eliminated. An unmanned vehicle for this demanding "first day" mission reduces risk and makes a great deal of sense. In fact, a UCAV for SEAD appears to fill an important niche in US defense strategy.

Unfortunately, niche capabilities can be prohibitively expensive. Advanced SAM systems are expensive, and only a few countries can afford to acquire them. Not every future conflict will feature advanced air defenses, and a capability only useful for high-intensity conflict in high threat environments may not pass the budget test of cost-effectiveness. Fortunately, the UCAV concept offers the potential to be far more than a "one-trick pony." A unique combination of sensors and communications links would permit the UCAV to fill a number of roles across the spectrum of conflict, as an ISR platform for persistent surveillance, as a specialized strike platform for time sensitive targets, or as a hunter-killer of deadly SAMs. With so much potential, what could possibly undermine the UCAV's seemingly bright future?

As Colonel Mike Leahy, DARPA's UCAV program manager has said, "Until you fly, you're nothing but PowerPoint," referring to the ubiquitous briefing slides used to pitch programs in the Pentagon. His point is well taken. As of this writing, the X-45 prototype has only accomplished high-speed taxi tests; it has yet to get off the ground. The UCAV will have to demonstrate success in early flight testing if it is to prove itself and garner additional support within the military bureaucracy. But if the UCAV results are promising, the program may quickly win new converts, despite dire predictions for unmanned vehicles in the past.

Many commentators have insisted that unmanned vehicles face a tough challenge because of a perceived bias by Air Force leaders towards piloted aircraft, a phenomenon known as "the white scarf syndrome." However, the successful employment of the armed Predator in Afghanistan has been widely hailed as marking a fundamental shift in military attitudes towards unmanned systems. Indeed, many Air Force senior leaders, including Chief of Staff General John Jumper, have expressed considerable enthusiasm for unmanned vehicles and their potential applications. The cautionary tone sometimes adopted in regard to UCAVs reflects a normal tendency to proceed carefully when moving into new technological territory. As Lieutenant General Joseph Wehrle, Air Force Director of Plans and Programs puts it: "We need to walk before we run on UCAVs. We need to develop the concept of operations first. However, I don't see any institutional resistance. The Air Force is constantly transforming and as technology allows it, UCAVs are a logical next step for us"[1]

One thing is certain: for the UCAV to earn a spot in the Air Force's future force structure, it *must* have air-refueling capability. Adding air-refueling poses engineering challenges, but the added range and endurance is vital if the UCAV is to support future US strategy. The extended range would enable UCAV to augment the Global Strike Task Force in scenarios where early access to friendly bases is denied by enemy threats, a scenario the USAF regards as increasingly likely in the 21st century. The nearly unlimited endurance offered by air refueling, indeed, the potential to keep UCAVs aloft for days instead of hours, vastly expands their usefulness in an ISR role.

The success or failure of UCAV will also depend to a large extent on the ability to operate a fleet of such vehicles within the inevitable communications bandwidth constraints. Bandwidth requirements are directly related to the number of vehicles deployed within a given theater, so the size of any UCAV fleet is an issue of major concern. Congress has urged the Air Force to move towards a force structure relying on unmanned vehicles for one third of its strike capability, and achieving that goal would demand innovative solutions to the bandwidth problem, such as improvements in on-board processing.

The UCAV for SEAD presents an opportunity for the Air Force to take the first steps into the realm of unmanned strike assets, using a small fleet and a well-defined mission area. The small numbers introduced for SEAD will make bandwidth requirements more manageable, while awaiting technical advances that will permit a larger number of vehicles to operate within a communications infrastructure. The concept of operations developed for SEAD will lay the groundwork for a larger fleet with a broader mission area, and allow the Air Force to grapple with the vital issue of command and control for this new type of platform.

The United States Air Force has a pressing need to improve its SEAD capability if it is to retain the freedom to project power in any theater in the world. The UCAV program offers the promise of fulfilling this vital requirement, while enhancing situational awareness over the battlefield, and paving the way for a future fleet of unmanned strike vehicles.

Notes

[1] Lt Gen Joseph Wehrle, Director of Plans and Programs, Headquarters United States Air Force, Washington, DC. Personal interview with the author, 27 Nov 2001.