# Strikestar 2025

A Research Paper
Presented To

Air Force ***2025***

by

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# Disclaimer

***2025*** is a study designed to comply with a directive from the chief of staff of the Air Force to examine the concepts, capabilities, and technologies the United States will require to remain the dominant air and space force in the future. Presented on 17 June 1996, this report was produced in the Department of Defense school environment of academic freedom and in the interest of advancing concepts related to national defense. The views expressed in this report are those of the authors and do not reflect the official policy or position of the United States Air Force, Department of Defense, or the United States government.

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# *Preface*

We examined unmanned aerial vehicles (UAV), knowing that similar research had produced naysayers and even some active hostility. However, we are genuinely concerned for future modernization efforts as budgets and manpower decrease. We came to an early conclusion that manned vehicles provide a flexibility and level of accountability far beyond that of unmanned vehicles. But considering our changing world, the use of unmanned vehicles for missions beyond reconnaissance is both technically feasible and cost-attractive. We envision the UAV proposed here to be a force multiplier for the air and space warrior—a new tool in the warrior's arsenal.

# *Executive Summary*

The United States military of the year 2025 will need to deal with a wide variety of threats in diverse parts of the world. It will be faced with budgetary restraints that will dictate system trades favoring those military elements that offer utility over a wide spectrum of conflict and add to the ability to project power over long distances. The United States military of the year 2025 will also exist in a social and political environment that will dictate the need to minimize United States personnel losses and enemy collateral damage.

An opportunity exists to exploit planned advances in intelligence, surveillance, reconnaissance, and the development of unmanned aerial vehicles (UAV) to address future military needs. Through all-source, coordinated intelligence fusion, it will be possible to supply the war fighter with all-weather, day or night, near-perfect battlespace awareness. This information will be of precision targeting quality and takes advantage of multiple sources to create a multidimensional view of potential targets. Early in the twenty-first century, reconnaissance UAVs will mature to the extent that reliable, long-endurance, high-altitude flight will be routine, and multiple, secure command and control communications links to them will have been developed.

The obvious extension of these developments is to expand UAV use to include lethal missions. In 2025, a stealthy UAV, we refer to as "StrikeStar," will be able to loiter over an area of operations for 24 hours at a range of 3,700 miles from launch base while carrying a payload of all-weather, precision weapons capable of various effects. Holding a target area at continuous risk from attack could result in the possibility of "air occupation." Alternatively, by reducing loiter time, targets within 8,500 miles of the launch and recovery base could be struck, thus minimizing overseas basing needs.

A concept of operations for this UAV will include various operation modes using the information derived from multiple sources to strike designated targets. In developing and fielding this type of a weapon system, a major consideration will be carrying weapons aboard unmanned vehicles. However, the StrikeStar

UAV concept has the potential to add new dimensions to aerial warfare by introducing a way to economically and continuously hold the enemy at risk from precision air attack.

# Chapter 1

# Introduction

The 2025 study was chartered to look at twenty-first century airpower needs and postulate the types of systems and capabilities that would be useful to future war fighters. This paper targets the potential contributions of unmanned aerial vehicles (UAV) to the future war fighter. Specifically, it looks at an expansion of the UAV's role from its present reconnaissance emphasis to encompass a multimission strike role. Although open-source literature speaks of using UAVs in combat support roles, less has been written about the use of such aircraft as lethal platforms. This paper helps to address this shortcoming and should stimulate the thinking necessary to make the organizational and cultural changes that will utilize UAVs in this new role.

The paper is organized to show where we are in the field of UAVs, delineate the need for this new capability, and discuss some nontechnical considerations that must be addressed before this capability is fielded. It then looks at the technology required to bring this concept to fruition, and, finally, shows the ways a lethal UAV could be employed.

It should be understood there is a variety of forms a lethal UAV could take as well as a variety of performance capabilities it could exhibit. The concept of lethal UAVs found in the Air Force Scientific Advisory Board's *New World Vistas: Air and Space Power for the 21st Century* is but one form a lethal UAV could take. Their concept of a high-speed, highly maneuverable UAV capable of performance far greater than current manned fighter aircraft offers one future capability. This paper looks at a different UAV capability emphasizing long-loiter and cost-effectiveness. This is a concept of "air occupation"—the ability to hold an adversary continuously at risk from lethal or nonlethal effects from the air.

# Chapter 2

## Historical Development and Employment

> *Unless you plan your strategy and tactic far ahead, unless you implement them in terms of weapons of tomorrow, you will find yourself in the field of battle with weapons of yesterday.*
>
> —Alexander de Seversky

The United States Air Force will remain actively engaged in all corners of the globe and at all levels of the conflict spectrum. Yet at the same time, the military budget is decreasing, overseas bases are closing, and there is political and social pressure to keep United States and adversary casualties to a minimum in any future conflicts. The situation, as described, is unlikely to change much in the future. As the Air Force adapts to this new set of realities and meets it commitments to the nation, it will need to look at new ways and methods of doing business. One of the most promising future possibilities is the increased use of unmanned aerial vehicles (UAV) to perform tasks previously accomplished by manned aircraft. Unmanned aircraft have the potential to significantly lower acquisition costs in comparison with manned alternatives, thus enabling the fielding of a more robust force structure within constrained budgets. Unmanned aircraft can also be tasked to fly missions deemed unduly risky for humans, both in an environmental sense (i.e., extremely high-altitude or ultra long-duration flight) as well as from the combat loss standpoint. The Department of Defense (DOD) recognized the potential value of the UAV through its support of the Defense Airborne Reconnaissance Office's (DARO) advanced concept technology demonstrations (ACTDs) of a family of long-endurance reconnaissance UAVs. However, the DARO UAVs, along with other improvements in reconnaissance and communications, will lead to even greater possibilities in the use of UAVs to project precision *aerospacepower*[1] to all parts of the world and to remain engaged at any level of conflict.

## The Early and Cold War Years

The use of UAVs is not a new experience for the United States armed forces or those of many other states. The German use of the V-1 in World War II showed that unmanned aircraft could be launched against targets and create a destructive effect.[2] Unfortunately, the V-1 was a "use and lose" weapon. Once launched, it was designed to destroy itself as well as the target. In the 1950s, the United States developed an unmanned intercontinental-range aircraft, the Snark. Designed to supplement Strategic Air Command's manned bombers in nuclear attacks against the Soviet Union, this unmanned aircraft also destroyed itself as it destroyed the target. In effect, these were precursors of today's cruise missile.

In the United States, the UAV has normally been associated with the reconnaissance mission and designed to be a recoverable asset for multiple flight operations. The remotely piloted vehicles (RPV) of the early 1960s were developed in response to the perceived vulnerability of the U-2 reconnaissance aircraft, which had been downed over the Soviet Union in 1960 and again over Cuba in 1962.[3] "Red Wagon" was the code name for a 1960 project by Ryan Aeronautical Company to demonstrate how its drones could be used for unmanned, remotely guided photographic reconnaissance missions.[4] As early as 1965, modified Ryan Firebee drones were used to overfly China with some losses experienced.[5]

In 1962, in conjunction with the development of the Central Intelligence Agency's manned A-12 (similar to the SR-71 Blackbird) reconnaissance aircraft, Lockheed began development of the D-21 supersonic reconnaissance drone (fig. 2-1). The D-21 (code-named "Tagboard") was designed to be launched from either the back of a two-seat A-12 (designated M-12 for this project) or from under the wing of a B-52H.[6] The drone could fly at speeds greater than Mach 3.3, at altitudes above 90,000 feet, and had a range of 3,000 miles.[7] At the end of the D-21's mission, the reconnaissance and navigation equipment as well as the exposed camera film could be parachuted away from the airframe and be recovered by a specially equipped aircraft.[8] The project was canceled in 1971 due to numerous failures and the high cost of operations.[9]

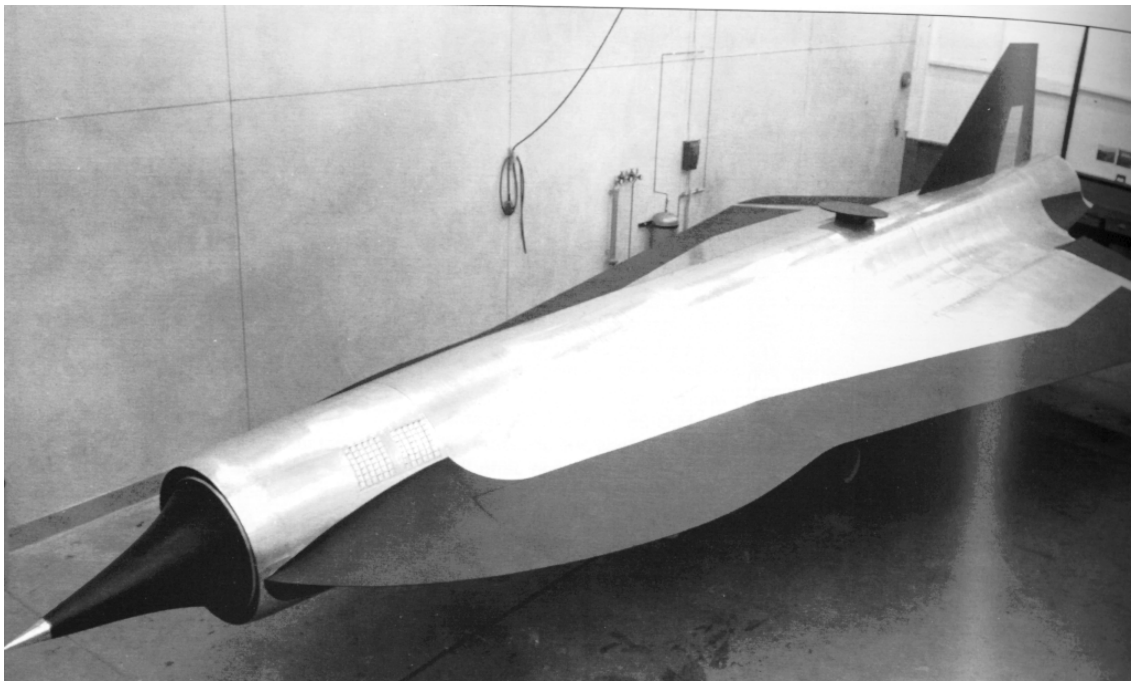

**Figure 2-1. D-21 Tagboard**

The best known United States UAV operations were those conducted by the United States Air Force during the Vietnam War. Ryan BQM-34 (Ryan designation: Type 147) "Lightning Bug" drones were deployed to the theater in 1964.[10] From the start of operations in 1964 until missions were terminated in 1975, 3,435 operational drone sorties were flown in Southeast Asia by the Strategic Air Command's 100th Strategic Reconnaissance Wing.[11] These air-launched UAVs flew both high (above 60,000 feet) and low (below 500 feet) altitude missions. Mission durations were as long as 7.8 hours. Types of missions flown included photo reconnaissance, leaflet dropping, signals intelligence collection, and the laying of radar-confusing chaff corridors to aid penetrating strike aircraft.[12] The average life expectancy of a drone in Southeast Asia was 7.3 missions with one aircraft, the Tomcat, flying 68 missions before being lost (fig. 2-2). Recovery rates for operational unmanned aircraft in Southeast Asia were approximately 84 percent with 2,870 of the 3,435 sorties recovered.[13]

**Figure 2-2. BQM-34 UAV, Tomcat**

In addition to the reconnaissance role, Teledyne Ryan also experimented with lethal versions of the BQM-34 drone. In 1971 and 1972, drones were armed with Maverick missiles or electro-optically guided bombs (Stubby Hobo) in an attempt to develop an unmanned defense suppression aircraft to be flown in conjunction with manned strike aircraft (fig. 2-3). The thinking behind this project was that an unmanned aircraft ". . . doesn't give a damn for its own safety. Thus every unmanned bird is a potential Medal of Honor winner!"[14]

The Israelis effectively used UAVs in 1973 and 1982. In the 1973 Yom Kippur War, the Israelis used UAVs as decoys to draw antiaircraft fire away from attacking manned aircraft. In 1982, UAVs were used to mark the locations of air defenses and gather electronic intelligence information in Lebanon and Syria. During the war, the Israelis used UAVs to continually monitor airfield activities and use the information that was gathered to alter strike plans.[15]

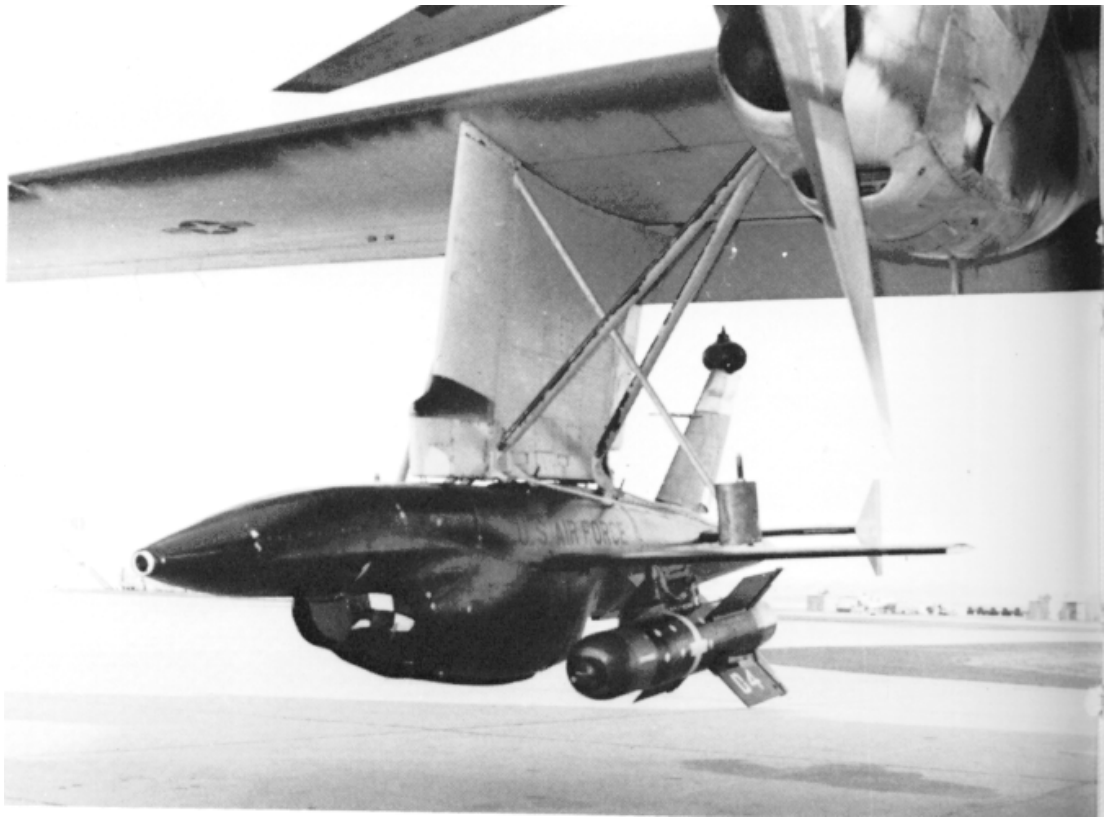

**Figure 2-3. BQM-34 UAV with Stubby Hobo**

## The Gulf War and Its Aftermath

The United States "rediscovered" the UAV in the Gulf War. The Pioneer UAV (fig. 2-4) was purchased by the Department of the Navy to provide inexpensive, unmanned, over-the-horizon targeting, reconnaissance, and battle damage assessment (BDA).[16] The Army purchased the Pioneer for similar roles and six Pioneer systems (three Marine, two Navy, and one Army) were deployed to Southwest Asia to take part in Desert Storm. During the war, Pioneers flew 330 sorties and more than 1,000 flight hours.[17]

In the aftermath of the Gulf War, the United States began to look more closely at the use of the reconnaissance UAV and its possible use to correct some of the reconnaissance shortfalls noted after the war. Space-based and manned airborne reconnaissance platforms alone could not satisfy the war fighter's desire for continuous, on-demand, situational awareness information.[18] As a result, in addition to tactical UAVs, the United States began to develop a family of endurance UAVs that added a unique aspect to the UAV program.[19] Three different aircraft comprise the endurance UAV family.

**Figure 2-4. Pioneer on Sea Duty**

The Predator UAV is an outgrowth of the CIA-developed Gnat 750 aircraft (fig. 2-5).[20] Also known as the Tier II, or medium altitude endurance (MAE) UAV, the Predator is manufactured by General Atomics Aeronautical Systems and costs about $3.2 million per aircraft.[21] It is designed for an endurance of greater than 40 hours, giving it the capability to loiter for 24 hours over an area 500 miles away from its launch and recovery base.[22] It is powered by a reciprocating engine giving it a cruise speed of 110 knots, loiter speed of 75 knots, ceiling of 25,000 feet, 450 pound payload, and a short takeoff and landing capability. The Predator carries an electro-optical (EO) and infrared (IR) sensor and was recently deployed with a synthetic aperture radar (SAR) in place of the EO/IR sensor. The Predator is also unique in its ability to collect full-rate video imagery and transmit that information in near real-time via satellite or line of sight (LOS) data link.[23] The Predator first deployed to Bosnia in 1994 and has since returned there with two combat-related losses (see appendix A).

**Figure 2-5. The Predator UAV**

A higher performance vehicle is the Teledyne Ryan Aeronautical Conventional High Altitude Endurance (CHAE) UAV (fig. 2-6). Referred to as the Tier II+, or Global Hawk, it is designed to fulfill a post-Desert Storm requirement of performing high-resolution reconnaissance of a 40,000 square nautical mile area in 24 hours. The Global Hawk is designed to fly for more than 40 hours giving it a 24-hour loiter capability over an area 3,000 miles from its launch and recovery base. It will simultaneously carry a SAR and an EO/IR payload of 2,000 pounds and operate from conventional 5,000 feet runways. The aircraft will cruise at altitudes above 60,000 feet at approximately 340 knots.[24] Tier II+ is scheduled to fly in late 1997 and meet a price requirement of $10 million per unit.

**Figure 2-6. The Global Hawk UAV**

The low observable high altitude endurance (LOHAE) UAV (Tier III- or DarkStar) is the final member of the DARO family of endurance UAVs (fig. 2-7). DarkStar is manufactured by Lockheed-Martin/Boeing and is designed to image well-protected, high-value targets with either SAR or EO sensors.[25] It will be capable of loitering for eight hours at altitudes above 45,000 feet and a distance of 500 miles from its launch and recovery base. DarkStar can be flown from runways shorter than 4,000 feet. DarkStar's first flight occurred in March 1996.[26] This UAV is also designed to meet a $10 million per aircraft unit fly-away price. DARO's new endurance UAVs, along with manned airborne reconnaissance aircraft, are designed to meet Joint Requirements Oversight Council (JROC) desires for the development of reconnaissance systems that are able to ". . . maintain near perfect real-time knowledge of the enemy and communicate that to all forces in near-real-time."[27] DARO's goal is "extended reconnaissance," which is "the ability to supply responsive and sustained intelligence data from anywhere within enemy territory, day or night, regardless of weather, as

the needs of the war fighter dictate."[28] The objective is to develop by the year 2010, a reconnaissance architecture that will support the goal of "extended reconnaissance."

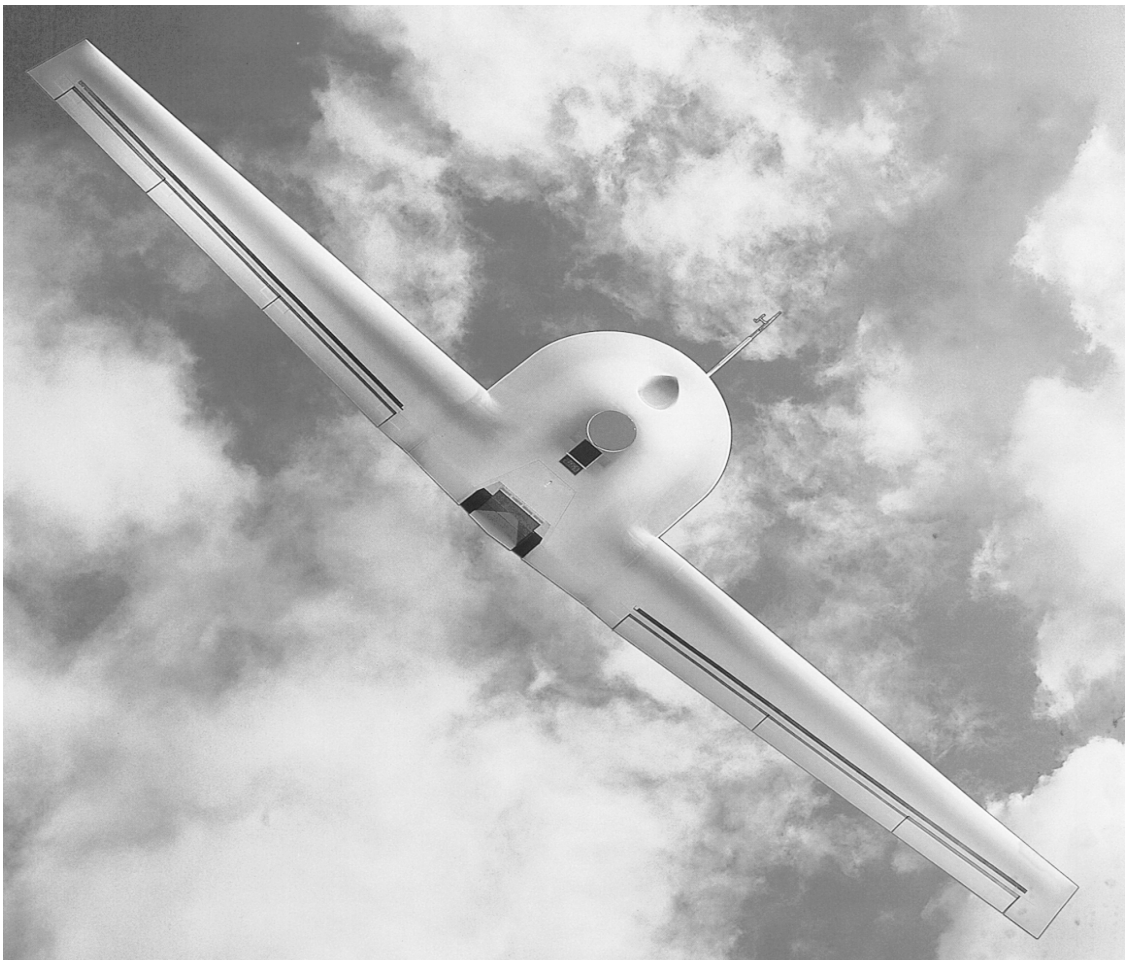

**Figure 2-7. The DarkStar UAV**

To do this, DARO will consolidate platforms, introduce endurance and tactical UAVs, emphasize all-weather sensors as well as multispectral optical sensors, improve information systems connectivity to the war fighter through robust line-of-sight and over-the-horizon communications systems, produce scaleable and common-use ground stations, and focus on the benefits of interdisciplinary sensor cueing.[29] In conjunction with spaceborne and other surveillance assets, this objective architecture will provide the war fighter and command elements with near-perfect battlespace awareness.

The seamless integration of airborne and spaceborne reconnaissance and surveillance assets, along with robust, on-demand communications links, coupled with the experience in long-endurance, high-altitude UAVs made possible by current DARO efforts, will lead to the next step in the development and employment of

unmanned aerial vehicles—the long-endurance, lethal, stealthy UAV. A possible name for this new aircraft could be "StrikeStar," and we will refer to it by that name throughout this paper.

StrikeStar will give the war fighter a weapon with the capability to linger for 24 hours over a battlespace 3,700 miles away, and, in a precise manner, destroy or cause other desired effects over that space at will. Bomb damage assessment will occur nearly instantaneously and restrike will occur as quickly as the decision to strike can be made. StrikeStar will allow continuous coverage of the desired battlespace with a variety of precision weapons of various effects which can result in "air occupation"—the ability of *aerospacepower* to continuously control the environment of the area into which it is projected. The next chapter explores the requirements that drive the StrikeStar UAV concept.

## Notes

[1] The term "aerospacepower" is used as one would normally use the word "airpower" and reflects the inseparability of air and space assets in 2025. In 2025, there will be no air and space power, only aerospacepower.

[2] Dr Michael H. Gorn, *Prophecy Fulfilled: Toward New Horizons and Its Legacy* (Air Force History and Museums Program, 1994), 28–35.

[3] Paul F. Crickmore, *Lockheed SR-71 - The Secret Missions Exposed* (London: Osprey Aerospace, 1993), 9,16.

[4] William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, Calif.: Aero Publishers, Inc., 1982), 15.

[5] Ibid., 115.

[6] Jay Miller, *Lockheed's Skunk Works: The First Fifty Years* (Arlington, Tex.: Aerofax, Inc., 1993), 134–135; Ben R. Rich, *Skunk Works* (N.Y.: Little, Brown and Co., 1994), 267.

[7] Miller, 141.

[8] Crickmore, Lockheed SR-71, 38.

[9] Rich, 269.

[10] Lt Col Dana A. Longino, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios* (Maxwell AFB, Ala.: Air University Press, December 1994), 3; Wagner, 52.

[11] Wagner, 52, 200.

[12] Ibid., 197.

[13] Ibid., 200, 213.

[14] Ibid., 185.

[15] Ibid., 6.

[16] *Unmanned Aerial Vehicles*, Defense Airborne Reconnaissance Office Annual Report (Washington, D.C., August 1995), 5.

[17] Longino, Role of Unmanned Aerial Vehicles, 9.

[18] U*nmanned Aerial Vehicles*, 7.

[19] Steven J. Zaloga, "Unmanned Aerial Vehicles," *Aviation Week and Space Technology*, 8 January 1996, 87.

[20] Ibid., 87.

[21] David A. Fulghum, "International Market Eyes Endurance UAVs," *Aviation Week and Space Technology*, 10 July 1995, 40–43.

[22] *Unmanned Aerial Vehicles*, 27.

[23] David A. Fulghum, "Predator to Make Debut Over War-Torn Bosnia," *Aviation Week and Space Technology*, 10 July 1995, 48.

[24] David A. Fulghum, "International Market, 43.

[25] Zaloga, Unmanned Aerial Vehicles, 90–91.

[26] "Tier III- DarkStar First Flight Video," *Lockheed-Martin Skunkworks*, 29 March 1996.

[27] *Airborne Reconnaissance Technology Program Plan - Executive Summary*, Defense Airborne Reconnaissance Office (Washington, D.C., February 1995), 2.

[28] *Unmanned Aerial Vehicles*, 1.

[29] Ibid., 4.

# Chapter 3

# The Need for A Strike Unmanned Aerial Vehicles

> *What we need to develop is a conventional deterrence force, similar to our nuclear triad, that we can project and sustain over long distances.*
>
> —Gen Ronald R. Fogleman

As 2025 approaches, the use of unmanned aerospace vehicles will be driven by sociocultural, geopolitical, and economic forces. Although it is impossible to see the future, some assumptions can be developed about the year 2025:

1. Americans will be sensitive to the loss of life and treasure in conflict.
2. The US economy will force its military to be even more cost-effective.
3. Technology will give potential enemies the ability to act and react quickly. [1]

These strategic assumptions create operational needs the US military must meet by 2025. UAVs are one cost-effective answer to those needs and have the potential for use across the spectrum of conflict. Although the need for advanced capabilities is continually emerging, this concept identifies constraints that create a demand for lethal UAVs in 2025 and a possible solution to that need. By 2025, limitations may cause gaps in US airpower and UAVs offer the ability to bridge them.

## Current Forces

Currently, the triad of conventional aerospace forces consists of carrier-based aircraft, land-based strike aircraft, and CONUS-based, long-range bombers. While proven very effective in Desert Storm, this triad has several limitations.[2] First, the aircraft carrier fleet is limited. Naval aviation lacks stealthy vehicles

and long-range systems.[3] Carriers will increasingly be called on for global presence missions, but cannot be everywhere at once.[4] Second, land-based fighters require forward basing, which could take days or even weeks to develop before employment. Finally, long-range manned bombers require supporting tankers, have limited loiter time over long distances, varying degrees of penetration capability, and can require up to 48 hours to prepare for strikes.[5] In 2025, these limitations will have a greater effect on US power projection as a result of two factors: the shrinking military budget and a smaller military force (fig. 3-1).[6]

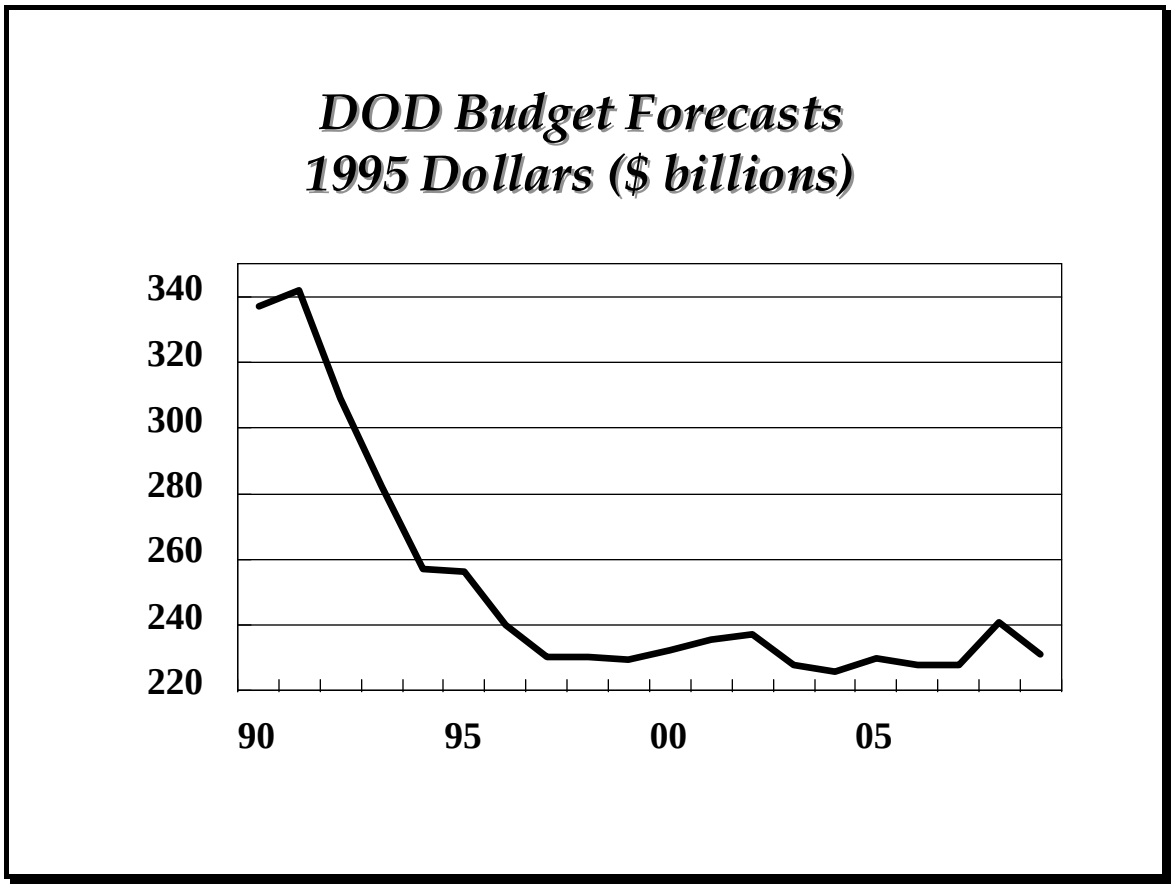


**Figure 3-1. The Shrinking Military Budget**

The ripple effects of current US government budgetary problems are just beginning to affect US military force levels and strength. Tighter military budgets will continue through 2010, or longer, and fewer new strike aircraft purchases will result as costs increase.[7]

Figure 3-2 represents a possible fighter force of 450 by the year 2025 and takes into consideration one of the alternate futures that might be faced.[8] It is likely that today's fighter force will be retired by 2018, the

F-22 will begin entering retirement in 2025, and that there will be further reductions in the bomber fleet. These actions will result in a 2025 triad of conventional aerospace strike forces one fourth of the size of the 1996 force.[9]

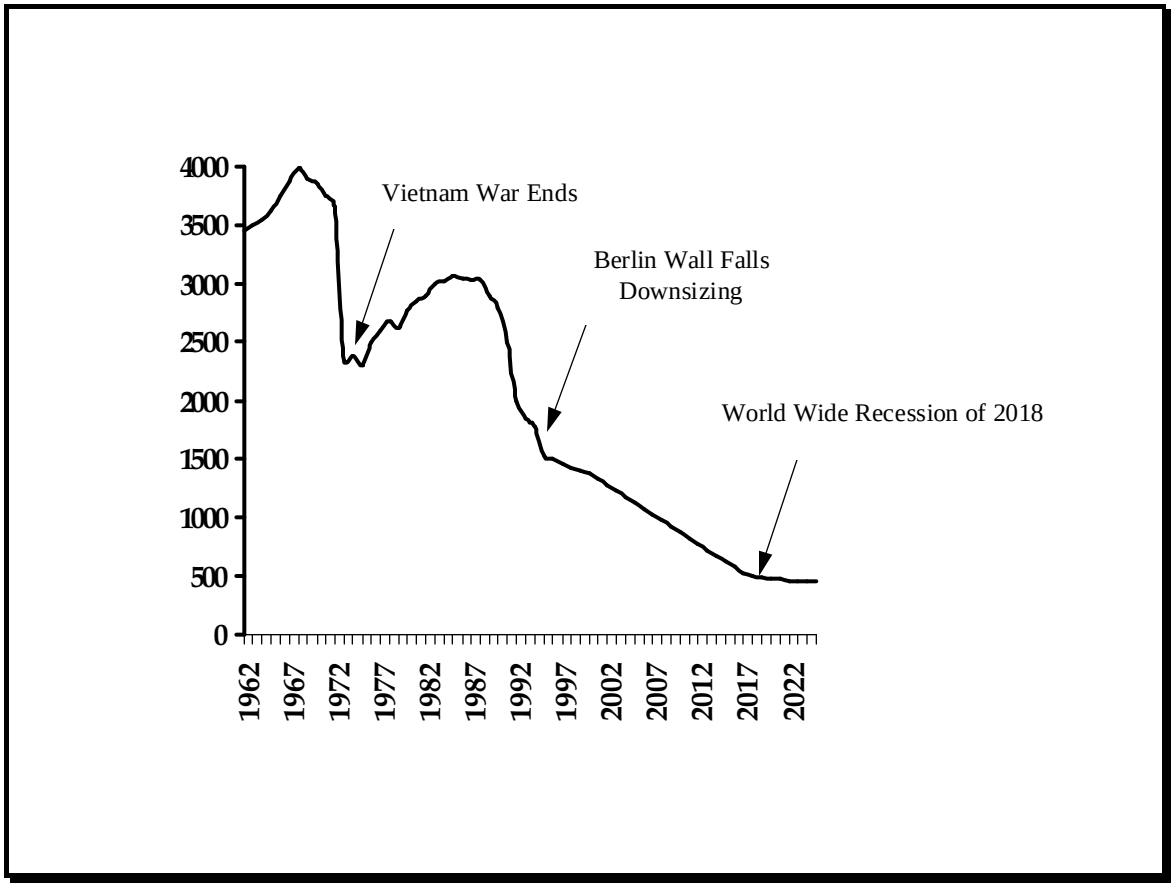


**Figure 3-2. Fighter Force Projection for 2025**

Unfortunately, the demands on this smaller force will not diminish. To be effective in 2025, our smaller conventional aerospace triad will require a force multiplier that will enable the US military to strike within seconds of opportunities. One way to achieve these results is to get inside our adversary's observation-orientation-decision-action (OODA) loop while reducing the time required for us to observe, and then act.[10] The advent of the capability for dominant battlespace awareness allows us the ability to significantly reduce our observation, orientation, and decision phases of the loop.[11] Unfortunately, our current triad of conventional aerospace forces are time-limited in many scenarios due to deployment, loiter, risk, and capability constraints. The concept of a long-loiter, lethal UAV orbiting near areas of potential conflict

could allow us to significantly reduce the OODA loop action phase. In fact, the entire OODA loop cycle could be reduced from days or hours to literally seconds.[12] The lethal UAV offers a variety of unique capabilities to the war fighter at the strategic, operational, and tactical levels of war.

The US strategic triad possesses the capability to hold other countries at risk with a very short (30 minute) response time, but unfortunately, this type of deterrence is only effective against forces similarly equipped. With the exception of current no-fly zones in Iraq and Bosnia, we normally do not have conventional aerospace forces posed for immediate precision strike, nor do we have the capability to exercise this option beyond one or two theaters. Although no-fly zones in Iraq and Bosnia are considered successful operations, the operations tempo and dollar cost of maintaining this deterrence is high. In 2025, a smaller, conventional aerospace triad will be expected to react within seconds over the broad spectrum of conflict from military operations other than war (MOOTW) to major regional conflict (MRC); overcome improved enemy air defense systems; and meet demands for fewer pilot and aircraft losses, all without requiring extremely high operational tempos.[13] These expectations will demand the development of a force multiplier to overcome the current, conventional aerospace triad limitations.

## Required Capability

The force multiplier required for 2025 conventional aerospace triad forces must be capable of exercising the airpower tenets of shock, surprise, and precision strike while reducing the OODA-loop time from observation to action to only seconds. Also, this force must possess the capabilities of stealth for survivability and reliability for a life span equivalent to that of manned aircraft. Many possibilities exist across the spectrum of conflict. This paper develops the concept of a stealthy, reliable UAV capable of precision strike. StrikeStar could act as a force multiplier in a conventional aerospace triad one fourth the size of the 1996 force structure.

The StrikeStar UAV could add a new dimension to the war fighter's arsenal of weapons systems. In a shrinking defense budget, it might be a cheaper alternative to costly manned strike aircraft if today's high altitude endurance UAVs are used as a target cost guide. StrikeStar must rely on a system of reconnaissance assets to provide the information needed for it to precisely and responsively deliver weapons on demand. To

save costs and minimize the risk of losing expensive sensors, StrikeStar itself should have a minimal sensor load. The robust, expensive sensors will be on airborne and space reconnaissance vehicles, feeding the information to the UAV. An air or ground command element located in the theater of operations or continental United States could receive fused reconnaissance data and use it to direct the StrikeStar to its targets. A secure, redundant, communications architecture would connect StrikeStar and the command element, but the communications suite could be rather minimal since the UAV would normally be in a receive-only mode to reduce detectability.

StrikeStar should have a minimum 4,000-pound payload so a variety of all-weather weapons could be employed by the UAV, depending on the target and the effect desired. Lethal weapons could include global positioning satellite (GPS)-guided, 250-pound conventional weapons that would have the effect of current 2,000-pound weapons. Nonlethal weapons such as "Stun Bombs" producing overbearing noise and light effects to disrupt and disorient groups of individuals could also be delivered. Target-discriminating, area-denial weapons, air-to-air missiles, and theater missile defense weapons could be employed to expand StrikeStar's potential applicability to other mission areas. Finally, the best lethal weapon for StrikeStar might be an all-weather directed energy weapon (DEW) which could allow hundreds of engagements per sortie.

StrikeStar would be designed for tremendous range, altitude, and endurance capabilities. Cruising at 400 knots true airspeed, StrikeStar would have an unrefueled range of almost 17,000 nautical miles, thus minimizing the historical problems inherent in obtaining overseas basing rights that have limited our strategic choices. Translated into a loiter capability, StrikeStar could launch, travel 3,700 miles to an orbit area, remain there for 24 hours and then return to its original launch base. With a cruise altitude above 65,000 feet and a maximum altitude of 85,000 feet, StrikeStar could fly well above any weather and other conventional aircraft. It would fly high enough to avoid contrails and its navigation would not be complicated by jet stream wind effects.

Such capabilities should easily be possible by 2025. Before the year 2000, today's Tier II+ UAV will have reached nearly the StrikeStar range/endurance and payload capabilities and the Tier III- will have demonstrated stealth UAV value. The issue then revolves around the use of such an unmanned capability and how such a capability could add value to *aerospacepower* of the twenty-first century. Ben Rich, a former president of Lockheed's "Skunk Works" saw the future of the unmanned strike vehicle:

> But even a leader able to whip up sentiment for "sending in the Marines" will find it dicey to undertake any prolonged struggle leading to significant casualties. . . . As we proved in Desert Storm, the technology now exists to preprogram computerized combat missions with tremendous accuracy so that our stealth fighters could fly by computer program precisely to their targets over Iraq. A stealthy drone is clearly the next step, and I anticipate that we are heading toward a future where combat aircraft will be pilotless drones.[14]

Coupled with the ability to reduce casualties, StrikeStar and its supporting reconnaissance and communications assets will add new meaning to what the Joint Chiefs of Staff call precision engagement:

> Precision engagement will consist of a system of systems that enables our forces to locate the objective or target, provide responsive command and control, generate the desired effect, assess our level of success, and retain the level of flexibility to reengage with precision when required. Even from extended ranges, precision engagement will allow us to shape the battlespace, enabling dominant maneuver and enhancing the protection of our forces.[15]

## Milestones

Currently, technology is being developed to accomplish this concept. While the technology will exist by the beginning of the twenty-first century, transferring this technology from the laboratory to the battlefield will require reaching three new milestones in aerospace thinking.

First, US military leadership must be willing to accept the concept of lethal UAVs as a force multiplier for our conventional aerospace triad of 2025. They should not deny the opportunity for continued growth in this capability.[16] The issue revolves around the use of an unmanned capability and how such a capability could add value to *aerospacepower* of the twenty-first century.

Second, doctrinal and organizational changes need to be fully explored to ensure this new weapon system is optimally employed. In the context of a revolution in military affairs (RMA), developing a new weapon system is insufficient to ensure our continued prominence. We must also develop innovative operational concepts and organizational innovations to realize large gains in military effectiveness.[17]

Finally, a target date not later than 2022 should be set for this refined concept and supporting systems to be operational for combat employment. This will give the US military and contractors time needed to correct deficiencies, leverage new technological developments, and polish capabilities equivalent to or beyond the manned portion of the conventional aerospace triad.[18] The need will exist in 2025 for a cost-effective, reliable force multiplier for the US military aerospace forces. StrikeStar offers a unique combination of

these three requirements and now is the time to begin working toward these milestones to meet conventional aerospace triad needs in 2025.

## Notes

[1] Gene H. McCall, Chairman USAF Scientific Advisory Board, presentation to the AF 2025 Study Group, Maxwell AFB, Ala., 6 September 1995.

[2] Thomas A. Keaney and Eliot A. Cohen, *Gulf War Air Power Survey Summary Report* (Washington, D.C., 1993), 15.

[3] John T. Correll, "Deep Strike," *Air Force Magazine*, April 1996, 2.

[4] James A Lasswell, " Presence - Do We Stay or Do We Go?," *Joint Forces Quarterly*, Summer 1995, 84–85; Col Walter Buchanan, JCS/J3, "National Military Command Center," presentation to Air Command and Staff College, 27 February 1996.

[5] Maj David W. Schneider, "Heavy Bombers Holding the Line," *Air Power Journal*, Winter 1994, 45–52.

[6] Col William Jones, JCS/J8, "JROC and the Joint War fighting Capabilities Assessment Process," presentation to Air Command and Staff College, 12 February 1996.

[7] David R. Markov, "The Aviation Market Goes Global," *Air Force Magazine*, June 1995, 22–28. In this article Mr Markov paints a gloomy picture of total strike aircraft production worldwide due to lower defense budgets and rising costs.

[8] "AF 2025 Alternate Futures: Halfs and Have Naughts," April 1996.

[9] "A New Defense Industrial Strategy," *Air Power Journal*, Fall 1993, 18–22; Brian Green, "McCain's Rising Star," *Air Force Magazine*, April 1996, 9. In this article, Senator John McCain states, "It's obvious we're not going to maintain the force structure that was anticipated when the two-MRC scenario was designed."

[10] John R. Boyd, "The Essence of Winning and Losing," presentation to the AF 2025 Study Group, Maxwell AFB, Ala., October 1995.

[11] "Warfighting Vision 2010: A Framework for Change," (Ft. Monroe, Va: Joint Warfighting Center, 1 August 1995), 10–11.

[12] Maj James P. Marshall, *Near-Real-Time Intelligence on the Tactical Battlefield*, (Maxwell AFB, Ala.: Air University Press, January 1994), 100. In this report, Maj Marshall proposes a wide range of target lifetimes ranging from several hours to one minute.

[13] Clark A. Murdock, "Mission-Pull and Long-Range Planning," *Joint Forces Quarterly*, Autumn/Winter 94–95, 33. Mr Murdock identifies 12 operating environments, more than 60 military missions, and more than 200 critical tasks by the year 2011.

[14] Ben R. Rich, *Skunk Works* (N.Y.: Little, Brown and Company, 1994), 340.

[15] *Joint Vision 2010*, (Washington, D.C.: The Joint Chiefs of Staff 1995), 9.

[16] Jeffrey Cooper, Another View of Information Warfare: Conflict in the Information Age, SAIC, (Publication Draft for 2025 Study Group), 26. In reference to new technologies he states: "These changes, exactly because they are fundamental, threaten all the vested interests and military "rice bowls," from resource allocation, to roles and missions, to the very nature of command and how control is exercised"; Gene H. McCall, Chairman USAF Scientific Advisory Board, presentation to the AF 2025 Study Group, Maxwell AFB, Ala., 6 September 1995. Dr McCall stated in his presentation: "Most revolutionary ideas will be opposed by a majority of decision makers."

[17] Jeffrey McKitrick et al., "The Revolution in Military Affairs," in Barry R. Schnieder and Lawrence E. Grinter, eds., "Battlefield of the Future: 21st Century Warfare Issues" (Maxwell AFB, Ala.: Air University Press, September 1995), 71–75; Andrew F. Krepinevich, Jr., "The Military Technical Revolution:

A Preliminary Assessment," (Maxwell AFB, Ala., Air Command and Staff College, War Theory Course Book, Volume 3, September 1995), 163.

[18] Gene H. McCall, Chairman USAF Scientific Advisory Board, presentation to the AF 2025 Study Group, Maxwell AFB, Ala., 6 September 1995. Dr McCall stated in his presentation: "Early applications of revolutionary concepts should not be required to be complete and final weapon systems."

# Chapter 4

# Developmental Considerations

> *The end for which a soldier is recruited, clothed, armed, and trained, the whole object of his sleeping, eating, drinking, and marching is simply that he should fight at the right place and the right time.*
>
> –Carl von Clausewitz *On War*

Clausewitz's statement of the supremacy of purpose for all that we do in the military applies as much today as it did centuries ago. In his day, military leaders concerned themselves with tailoring, building, and sustaining their forces to "fight at the right place and the right time" with the purpose of winning wars. Today, our leaders are faced with a similar challenge. In our increasingly technological age, military leaders are challenged to develop weapon systems that enable our forces to determine the "right place" and move people, equipment, and supplies to be able to fight at the "right time."

Unmanned aerial vehicles offer military leaders the ability to use *Global Awareness* to more accurately apply *Global Reach* and *Global Power* when and where needed. For years, UAVs have had the capability to push beyond the realm of observation, reconnaissance, and surveillance, and assume traditional tasks normally assigned to manned weapon systems. However, several factors influenced decisions that favored manned aircraft development at the expense of UAVs. A 1981 Government Accounting Office report "alleged inefficient management in the Pentagon in failing to field new [UAV] vehicles. The GAO noted several explanations for the inertia: many people are unfamiliar with the technology, unmanned air vehicles are unexciting compared to manned vehicles, the limited defense budget, and user reluctance—the pro-pilot bias."[1]

Whether one accepts this assessment or not, there have been limited advancements in military UAV development, but not without prompting from external sources. Since 1981, the US Department of Defense has expended a much greater effort in developing, producing, and employing UAVs in the reconnaissance role. In fact, UAVs proved to be a viable force multiplier in the coalition military efforts in the 1991 Gulf War.[2] However, some of those problems identified by the 1981 GAO report continue to exist today and, without additional UAV research and education, may severely limit future development of UAV military potential.

Moreover, the "jump" from using UAVs in nonlethal reconnaissance roles to lethal offensive operations is a dramatic change, adding another consideration to deal with—public accountability. It is likely the American public and international community will demand assurances that unmanned UAVs perform at least as safely as manned aircraft. This requirement must be considered in designing, developing, and employing any lethal UAVs.

This section analyzes this accountability issue and two other considerations: (1) an alleged pro-pilot bias that favors development and employment of manned aircraft over UAVs and; (2) a reduced budget that forces choosing space-based or air-breathing systems in a zero sum battle for military budget dollars.

## Pro-Pilot Bias

> *Under the many challenges of their rapidly changing environment, the Air Force leadership may have become more focused on the preservation of flying and fliers than on the mission of the institution.*
>
> —Carl A. Builder
> *The Icarus Syndrome*

Nearly every research effort conducted on UAV development in the last 10 years has either referenced or implied the existence of a "pro-pilot bias." None of those studies, however, defines what constitutes that bias, except in one case where it is described as a "user reluctance."[3] Yet authors state or imply that this bias has been responsible for delaying or undermining efforts in developing and employing operational UAVs since their inception. In the future, to ensure optimization of combat UAVs, underlying concerns must be identified, validated, and dealt with as hurdles to be overcome, not biases.

There are three identifiable concerns that will be analyzed concerning "pro-pilot bias" and its effects on UAV development. First, there is a skepticism that current UAV technology provides the reliability, flexibility, and adaptability of a piloted aircraft.[4] Basically, this perception implies that UAVs are incapable of performing the mission as well as equivalent manned aircraft since they are unable to respond to the combat environment's dynamic changes. This incorrectly assumes all UAVs operate autonomously as do cruise and ballistic missiles. These latter systems do lack flexibility and adaptability, and only do what they are programmed to do. Other UAVs, like the Predator, are remotely piloted vehicles, and are as flexible and adaptable as the operator flying them. The operator's ability to respond to the environment is dependent on external sensors to "see" and "hear" and on control links to provide inputs to and receive feedback from the UAV. Future UAVs using artificial intelligence will respond to stimuli in much the same way as a human, but will only be as flexible and adaptable as programmed constraints and sensor fusion capabilities allow.

In 2025, technology will enable near-real-time, sensor-shooter-sensor-assessor processes to occur in manned and unmanned aircraft operations. The question is not whether either of these systems is flexible and adaptive but whether it is more prudent to have a human fly an aircraft into a hostile or politically sensitive environment, or have an operator "fly" a UAV from the security of a secure site.

Second, there is a perception that UAVs capable of performing traditional manned aircraft missions are a threat to the Air Force as an institution. This perception is deeply rooted in the Air Force's struggle with its own identity, a struggle lasting since the early Army Air Corps days. Carl Builder, in *The Icarus Syndrome*, describes how the Air Force sacrificed airpower theory ("the end") in exchange for the airplane's salvation ("the means") when challenged by arguably more capable "means."[5] Like the intercontinental ballistic missile (ICBM) and cruise missile, the Air Force has struggled against the development of UAVs only to accommodate it when faced with other services' infringement on traditional Air Force missions. Like the ICBM and cruise missiles before it, the UAV has been assigned a support role, primarily in reconnaissance. The problem, according to Builder, is that the Air Force, when faced with challenges to the "flying machine," tends to accommodate new systems instead of adapting doctrine to tie the new "means" to its mission and underlying airpower theory.[6] Thus, Builder asserts the Air Force has been myopic, seeing the "mission" of the Air Force in terms of airplanes, and therefore any system other than an airplane is relegated to mission support, or deemed a threat to the Air Force institution and dismissed. Ironically, the UAV is

following the same development path that the airplane took over 50 years ago when the Army culture relegated it to a reconnaissance and mission support role.

Finally, there is a concern among the Air Force's pilot community that UAVs pose a threat to their jobs and, ultimately, their future Air Force roles.[7] There is a perception that UAVs will replace the need for pilots to employ aerospacepower, and closely tied to this belief is the resultant threat to the power base and leadership role pilots have held in the Air Force since its birth. It is easy to rationalize an Air Force founded on flying airplanes led by those who fly them. For years, those who protected the preeminence of the airplane also protected the leadership of the pilots and operators, sometimes at the expense of the institution's well being.[8] If it is right for pilots to lead a "fly, fight, and win" Air Force, then would it be equally right for pilots to step down when the airplane is replaced by cruise missiles, space-based platforms, and UAVs? Pilots, who have held the leadership reins of the Air Force for more than 50 years, are now faced with being replaced with specialists and technologists. This threat and the reaction of today's pilot-laden Air Force leadership will play a major role in determining the UAV's development between now and 2025.

**Budget Competition — Space-Based, Air Breather, or Both**

> *Space warfare will likely become its own warfare area only when there is need to conduct military operations in space to obtain solely space-related goals (not missions that are conducted to support earth-based operations).*
>
> —Jeffrey McKitrick
> The Revolution in Military Affairs

The Air Force is looking to both space and the inner atmosphere for ways to meet future war fighting requirements. At the same time, budget constraints are forcing the Air Force to be selective in determining which system(s) will receive increasingly dwindling dollars. In the past, UAVs lost similar competitions to manned aircraft in the Air Force's constant attempt to modernize its manned aircraft. Future competitions will still face manned aircraft concerns, but the competition will also be between the UAV and an equivalent space-based platform. This section does not provide a thorough comparative analysis of space-based systems and the StrikeStar. It does provide those who will make the decisions that fund one or both of these

systems with (1) an understanding that a competition exists between space-based systems and a StrikeStar concept; (2) some considerations to be used in making those decisions; and (3) recommendations for using the StrikeStar in conjunction with a bolstered space-based system.

Several organizations associated with the Department of Defense's research and development circle are developing space-based systems that can deliver precision lethal and nonlethal force against ground-based targets. Like StrikeStar, these systems have the capability to project power to any point on the earth and do so with a minimal sensor-to-shooter time delay. As orbiting systems, these systems provide decision makers a near continuous coverage of all global "hot spots." In many respects, these systems parallel capabilities provided by a gravity-bound StrikeStar.

Unlike StrikeStar, space-based systems are expensive in research and development, and the space environment provides operational challenges. The budget dollars do not exist now and likely will not exist in the future to fund the simultaneous development of space-based and StrikeStar UAV systems. But more important than lack of money is the waste inherent in simultaneously developing systems that duplicate each other's capabilities without adding any appreciable value.[9] For years, the Navy and Air Force have done just this by developing very similar frontline fighters. Today, the services and Congress understand that this practice results in great waste and that they can reduce that waste by comparing space-based attack system and UAV development now and determining which strategy will best provide needed capabilities by 2025.

Decision makers must compare space-based and air-breathing systems and determine which will receive development funding. They must consider the capabilities, limitations, and implications of both systems and form a conclusion as to which system or combination of systems provides the needed war fighting capability in 2025. Probably the greatest limitations of space-based systems are the costs associated with transporting the vehicle from the surface to earth's orbit, maintaining it (in orbit or on return), and then transporting it back to the surface. Another significant space-based system limitation is the criticality of the vehicle(s) position or orbit. Space-based systems cannot currently loiter over a target area since orbital mechanics require constant movement around the earth. Therefore, a space-based system needs multiple vehicles to provide constant coverage as well as the ability to position a vehicle when and where needed.

Decision makers must also consider the sociopolitical implications of militarizing space. Some argue control of space is analogous to control of air and that this new frontier should be approached in the same

manner the military approached airpower.[10] But this new frontier is inherently different from the skies overlying the earth's nations, and space cannot be divided up in segments as the international community has done with airspace. In fact, space is rapidly being established as an international domain for commercial interests owned by a combination of nation-states and corporate conglomerates. Establishing space dominance will be costly and threatening to an increasingly interdependent international community. Placing an offensive-capable platform in space that continuously holds any nation or group of individuals at risk will undoubtedly be perceived as a direct threat to friendly or enemy nations.

A less threatening alternative for space is the enhancement of current military capabilities in the areas of reconnaissance, navigation, and communications with concurrent development of space-to-space weapon systems designed to protect our space-based assets. Also, challenges associated with projecting lethal and nonlethal force from space-to-surface targets may be too difficult and costly when compared with inner-atmosphere systems with similar capabilities. Offensive and defensive space-based systems are essential, but primarily for missions that support space requirements and not for direct attack against inner-atmosphere targets.

Probably the greatest limitation of air-breathing UAVs compared to an equivalent space-based system is the time delay required to mobilize and deploy it to a theater of operations. StrikeStar is designed to deploy-loiter-strike-loiter-redeploy from either CONUS or a forward base, but due to fuel limitations, the time required to deploy and redeploy are contingent on the distance to the area of operations and this also directly affects available loiter time. Because StrikeStar cannot stay airborne indefinitely, it may require advanced warning times or an increased number of vehicles to provide continuous coverage of the operations area.

Because of high costs to develop, operate, and maintain space-based systems that might deliver lethal force on the earth's surface, the armed forces should tailor development of space-based platforms to lethal missions that focus on space-only missions and nonlethal missions supporting earth-bound lethal weapon systems. StrikeStar and a new generation of UAVs capable of delivering lethal and nonlethal force provide a low cost, highly mobile platform that will enable the US military and civilian authorities to project power to any point on the globe in minimal time and hold an area at risk for days at a time. StrikeStar is not a threat to space, but simply provides an effective capability that when directed by air, land-based, or space-based command and control can reach out and touch enemies threatening our national interests throughout the world.

## Public Accountability

> *War is a human endeavor, fought by men and women of courage. The machines, the technology help; but it is the individual's skill and courage that makes the crucial difference.*
>
> —General Gordon R. Sullivan
> *Army Focus 1994: Force XXI*

The public will demand accountability for lethal UAVs and their operations and StrikeStar's lethal potential requires assurances that prevent inadvertent or unintentional death and destruction to both friendly and enemy troops.

### Imposed Limitations

Restrictions must be placed on lethal UAVs because of the potential consequences of an accident or malfunction. Recent history has proven that the American public and the international community hold individuals and organizations accountable for decisions to use force. The downing of two US helicopters supporting Operation Provide Comfort in Northern Iraq and the subsequent loss of 24 lives provide a vivid example of how the public will react to lethal force "accidents" or "mistakes." Today, accident-or mistake-justifications do not warrant death or destruction.

Even in war, use of legitimate lethal force will be questioned. Society has become more sensitive to death and destruction as the information age provides real-time, world-event reporting. Television presents images and political commentary, probing and demanding justification for using lethal force. The intent of those inquiries is to determine accountability when events result in questionable death or destruction. Also, technology has legitimized precision warfare, and "criminalized" collateral death and destruction resulting from the use of lethal force. The perception exists among many press and public that it is now possible to prevent nearly all types of accidents and mistakes and only shoot the "bad guy."

These perceptions place limits on using any system that could deliver lethal force. StrikeStar falls within this category and it is imperative that accountability be built into the system design and concept of operations.

But how do we create accountability? First, a human must be involved in the processes that result in lethal force delivery. Second, redundancy must be designed into the system to ensure a person can exercise control from outside the cockpit. Third, the system must be responsive to the dynamic environment in which it will operate. Finally, reliability must be designed into every StrikeStar system and subsystem to minimize the possibility of inadvertent or unintentional use of lethal force. In total, these measures place a human in the decision-making position when employing lethal force. Thus, when an accident or mistake occurs, a person, not a machine, is responsible and accountable. For claiming a system failure, or "it just blew," will not suffice.

**Man-in-the-Loop**

Accountability is not well suited for anything other than a person. When an aircraft crashes, the mishap board's task is to find causal reasons for the crash. Even when it becomes apparent a broken or malfunctioning part contributed to the crash, the board probes the processes involved in its production, installation, and even documentation. Since processes are created and normally managed by people, accountability is normally given to a person.

So humans must be involved in the decisions that could result in intentional or unintentional death and destruction. But human input is not required in all phases of flight and there are various ways to keep a person in the loop without putting a pilot in a cockpit. However, because of the potential consequences of mistakes or accidents, human input must be involved in target selection and weapons delivery decisions.

The man in the loop can be attained through nearly all of the potential controlling mechanisms available now and forecast into the future. UAV control mechanisms included manned, remotely piloted, semi-autonomous (combined RPV and programmed), autonomous (programmed/drone), and fully adaptive (artificial intelligence). StrikeStar control mechanisms allow for inflight human input, but an autonomous system preprogrammed to hit a prelaunch designated target or target area with minimum human intervention and not normally be changed in flight could be used. Also, a fully adaptive UAV using artificial intelligence could be programmed to mimic the decisions a pilot would make in reacting to environmental changes.

Although it can be suited to some missions, a lethal UAV with autonomous or fully adaptive controls pose significant accountability problems. First, decisions to target and strike are made without regard to a

rapidly changing environment. For example, a tomahawk land attack missile (TLAM) might hit a command post even though, in the time since it was launched, a school bus full of children stopped nearby. An autonomous system has no way of knowing current or real-time information that may affect the decision to target and strike. Second, autonomous UAVs cannot react to internal malfunctions that might affect their ability to perform their prescribed missions. A preprogrammed UAV told to deliver its weapon will do so even though its targeting system has malfunctioned and the result is a bomb dropped with unknown accuracy. The net effect in both situations is inadvertent or unintentional delivery of lethal force and an accountability question.

Obviously, 100 percent reliability is not guaranteed even with a human in the decision making process, but 100 percent accountability must be attempted. The further a person gets away from lethal force accountability, the easier the "fire" decision is and the greater the probability that the wrong target will be hit. As a result of this tendency and the severity of the consequences, our air-to-air rules of engagement favor visual identification over system interrogation and identification. A person must be kept in the loop when using UAVs to deliver lethal force.

**Redundancy**

To keep man in the loop and maintain this accountability, we must ensure the control links are sufficiently redundant. There are two potential centers of gravity that, if intentionally or unintentionally targeted, would remove or degrade the man in the loop. First, the control links are susceptible to MIJI (meaconing, intrusion, jamming, and interference). In this case, the "lines" between the UAV and the controller are severed or degraded to a point where the UAV is basically autonomous. Second, the controller or the controllers' $C^4I$ facilities are also susceptible to physical destruction, equipment malfunctions, and situational dis/misorientation. In this case, the source of the signals or an intermediary relay (e.g., satellite) would be physically incapable of sending or transmitting control signals to the UAV. In either case, the UAV is without a man in the loop.

Controller backup systems need to be able to deal with contingencies that could threaten the UAV's ability to accurately hit its designated target. The StrikeStar should have triple redundancy built into the controlling system utilizing a ground source, airborne source, and an autonomous backup mode. Should the

UAV detect an interruption of controller signals, it could enter an autonomous mode and attempt to reconnect to its primary controller source. If unable to reconnect, it could search for a predesignated secondary controller input and establish contact with the backup controller. The final option available if the UAV can not regain controller input would be to follow the last known program or abort, depending on its prelaunch abort configuration.

**Responsiveness**

The StrikeStar system must be responsive to a dynamic environment and design must include flexible $C^4I$ systems, $C^2$ operations, and UAV guidance and fire control systems. It is imperative that a lethal UAV be able to assess its environment and adapt to it accordingly. This requires real-time data and assessment, high-speed data transmission capability, flexible $C^2$ procedures, reliable controller capability, and a real-time reprogramming capability.

An advantage of a manned aircraft is that the pilot can make the last-second decision to deliver the weapon, abort the delivery, or change targets as the situation dictates. At the last-second, a pilot can detect an unknown threat preventing him or her from reaching the target, and has the ability to change targets when the original target has moved. Simply, a pilot has the ability to assess and react to a environment characterized by fog and friction.

Lethal UAVs (and/or their controllers) must have the same ability to adapt to an unanticipated or dynamic environment. They must be able to discern the environment, consider the threat (in cost-benefit terms), confirm the intended target, and have the ability to deliver, abort, or change to a new target. The consequences of not having this ability relegates the UAV to an autonomous system and raises accountability questions in the event of an unintentional or inadvertent delivery. Real-time information and control is essential to protecting our accountability in lethal UAVs.

**Reliability**

The UAV and its many subsystems must have a high operational reliability rate to prevent accidental destruction and collateral damage. Unlike nonlethal UAVs, unmanned systems carrying lethal munitions

could have destructive effects in an accident or systems-related malfunction. Lethal UAVs must have a higher reliability confidence level than a manned system because UAV system malfunction effects could prove to be more disastrous.

### Summary

StrikeStar as well as other systems that deliver lethal force will be scrutinized when accidents occur, especially those that result in unintentional or inadvertent loss of life or treasure. The public will demand accountability for lethal UAVs and their operations. Therefore, design, development, and employment of the StrikeStar must integrate the concept of accountability. Humans must remain in the command and control loop, and the internal and external systems and links must be robust enough to keep that loop intact. The sociopolitical implications are too high to ignore these facts.

## Conclusion

Although the StrikeStar concept can be proven to meet an operational need, is technically feasible, and fits into a sound concept of operations, it may go the way of previous UAV concepts. Forces exist today that could slow or deny the development of a lethal UAV for use in 2025. Most prevalent are the historical bias for manned aircraft over UAVs, budget competition between space development and the UAV programs, and, finally, the public pressure that increasingly requires accountability when things go wrong. These forces need to be understood and met openly as we start developing a StrikeStar.

## Notes

[1] David H. Cookerly, *Unmanned Vehicles to Support the Tactical War* (Maxwell AFB, Ala.: Air University Press, May 1988), 25.

[2] Lt Col Dana A. Longino, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios* (Maxwell AFB, Ala.: Air University Press, December 1994), 9.

[3] Ibid., 25.

[4] Ibid., 28.

[5] Carl H. Builder, The Icarus Syndrome (New Brunswick, N.J., 1994), 200.

[6] Ibid, 205.

[7] Longino, 13.

[8] Builder, 200.

[9] Jeffrey McKitrick et al ., "The Revolution in Military Affairs," in Barry Schnieder and Lawrence E. Grinter, eds., *Battlefield of the Future; 21st Century Warfare Issues* Maxwell AFB, Ala.: Air University Press, September 1995), 78.

[10] McKitrick, 89.

# Chapter 5

# StrikeStar Technology

> The system was so swift that human beings simply could not handle the target volume without extensive automated support, and the system was designed to fight on full automatic, relying on its human masters for key decisions, for overall guidance, for setting or revising priorities, and for defining operational parameters. Technically, this most potent warfare machine ever built had the capability to carry on the fight indefinitely.
>
> –Ralph Peters
> *The War in 2020*

The war machine described above is fiction, but the technology is within our grasp to make it a reality. In the past, UAV systems have been plagued with reliability problems or by design flaws (see appendix A).[1] Recently, the joint tactical UAV Hunter was canceled due to continuing reliability problems.[2] Current efforts are producing mature technology that improves overall reliability and functionality. The first DOD UAV master plan was produced to consolidate requirements and integrate efforts across all DOD agencies.[3] The Global Hawk and DarkStar UAVs are excellent examples of how quickly UAV systems technology is advancing. Table 1 provides a summary of US UAV characteristics from a system capabilities perspective.

**Table 1**

**US UAVs, System Characteristics**

| Characteristic | Maneuver UAV | Interim Joint Tactical Pioneer | Joint Tactical Hunter | MAE Predator | CHAE UAV Global Hawk Tier II Plus | LOHAE UAV DarkStar Tier III Minus |
|---|---|---|---|---|---|---|
| Max Altitude (ft) | 13000 | 15,000 | 25,000 | 25,000 | >65,000 | 45,000 |
| Endurance (hrs) | 3 | 5 | 12 | > 24 | > 24 | > 8 |
| Rad. Action (nm) | 27 | 100 | > 108 | 500 | 3000 | > 500 |
| Max Speed (kts) | TDB | 110 | 106 | 129 | > 345 | > 250 |
| Cruise Speed | <90 | 65 | > 90 | 110 | 345 | > 250 |
| Loiter Speed | 60-75 | 65 | < 90 | 70-75 | 340 | > 250 |
| Payload Wgt(lbs) | 50 | 100 | 196 | 450 | 2,140 | 1287 |
| Max Wgt | 200 | 429 | 1700 | 1873 | 24,000 | 8,600 |
| Navigation | GPS | GPS | GPS | GPS/INS | GPS/INS | GPS/INS |

**Source:** *Unmanned Aerial Vehicles*, Defense Airborne Reconnaissance Office Annual Report (Washington, D.C., August 1995).

This family of UAVs capitalized on past accomplishments and started the evolutionary process of adapting technologies proven in manned aircraft to UAV platforms. Other countries are also involved in UAV technology and have recognized the roles UAV will have on future battlefields (see appendix B).[4] Trends indicate a wide range of anticipated technologies will support the StrikeStar concept and provide platform robusting. Some include:

1. airframe technology
2. avionics systems
3. propulsion technology
4. weapon systems
5. communications systems
6. mission control equipment
7. launch and recovery equipment

Sensor technologies are not critical to the construction and design of StrikeStar, but are critical to its operation. We expect reconnaissance efforts for both manned and unmanned aircraft and space platforms will continue to advance. StrikeStar will rely on other platforms for target identification, but could have the

capacity to carry reconnaissance sensors using modular payload approaches. This concept does not advocate combining expensive reconnaissance sensors on the same platform carrying a lethal payload, since separating sensors from the weapon platform lowers costs and lessens the risk of sensor loss.

The technologies noted above have to support the system characteristics shown in table 2 to ascertain current capabilities and identify enabling technologies that support the StrikeStar concept. Our baseline for the system characteristics is based on a melding of the Global Hawk and DarkStar performance attributes. The range and loiter improvements allow us to overcome the basing and response constraints mentioned in chapter 2. Adding stealth characteristics to a Global Hawk-size UAV reduces vulnerability and allows covert operation. Improved payload capacity allows the ability to carry both more and varied weapons. The envisioned altitude improvements allow for airspace deconfliction, self defense, and weapon range and dispersion performance.

**Table 2**

**StrikeStar System Characteristics**

| Characteristic | StrikeStar |
|---|---|
| Wingspan (ft) | 105 |
| Max Altitude (ft) | >80,000 |
| Endurance (hrs) | > 40 |
| Rad. action (nm) | 3700 w/24 hr loiter |
| Max Speed (kts) | > 400 |
| Cruise Speed (kts) | 400 |
| Loiter Speed (kts) | 400 |
| Payload Wgt (lbs) | 4000 |
| Max Wgt (lbs) | 24,000 |
| Navigation | GPS/INS |

## Airframe Technology

Past UAV systems have used both fixed and rotary wing configuration. Rotary wing systems overcome many of the problems associated with launch and recovery, and optimize sensory payload operations. The Sikorsky Cypher provides a recent, successful demonstration of rotary wing technology.[5] Unfortunately, most rotary wing systems have limited range and endurance capabilities. Most UAVs fall into the fixed wing category including all those currently in-service worldwide.[6]

Typical low performance fixed wing systems employ rear-mounted pusher propellers, such as the Predator UAV, or tractor propellers. Systems have single or twin tail booms and rely on their relative small radar cross section and low noise generation to avoid detection. The Hunter platform shown in figure 5-1 is a prime example of a UAV using push-pull engine technology on a twin boom airframe.

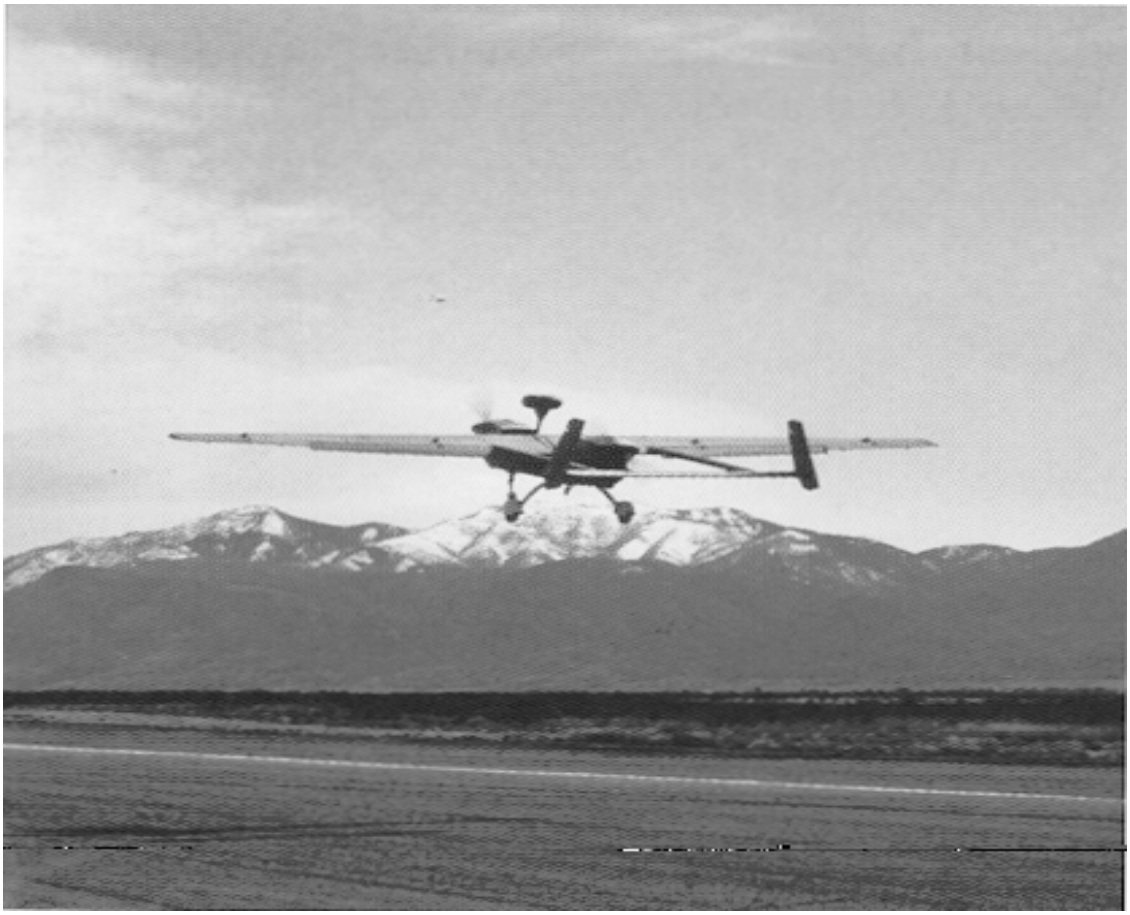

**Figure 5-1. Twin-Boom Hunter UAV**

Designs to date have focused on using existing manned airframe components or designs to minimize cost or produce operational platforms quickly. These systems support moderate payloads over various ranges despite known aerodynamic deficiencies. The advent of the DarkStar platform demonstrates an innovative approach to improve both aerodynamic efficiency, payload support, and operational radius.[7] DarkStar's use of a jet engine coupled with a composite flying wing structure will improve aerodynamic efficiencies and significantly decrease the radar cross section.

As currently designed, the DarkStar UAV consists of an internal payload bay capable of supporting a sensor payload which can be swapped in the field. The current payload capacity and platform configuration does not allow DarkStar to function as an efficient strike platform. Skunkworks designers are continuing evolutionary improvements on the DarkStar platform. Their conceptual design in figure 5-2 provides a look at a twin engine platform capable of increased range, speed, and payload capacity that has the potential to function as a UAV strike platform. This design could serve as the basis for future StrikeStar developments.

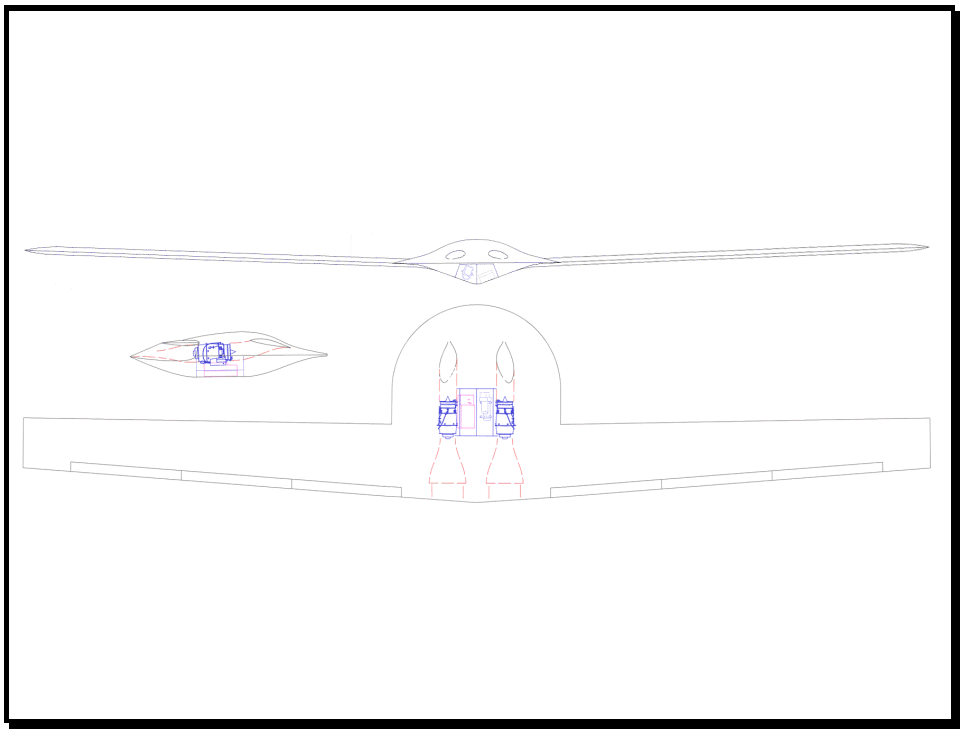

**Figure 5-2. Notional StrikeStar**

StrikeStar designers could capitalize on DarkStar payload swapping techniques as well as internal weapon carriage technology used for the F-117 and F-22 airframes. Future generations of StrikeStar

airframes would rely on larger payload bays and wider use of composite materials to improve payload capacity and stealthiness without increasing total weight. We anticipate that stealth technologies will mature to the point that cloaking or masking devices could be used to prevent detection or the employment of effective countermeasures.[8]

## On-Board Control Systems

The avionics system would support two modes of platform operation: command-directed and autonomous. In command-directed operation, the StrikeStar operator would transmit the desired strike mission way points, cruising speed, and flight altitude to the StrikeStar flight control system to perform normal flight operations. Preprogrammed operations would be possible if all known way points were entered prior to a mission. Default preprogrammed operations would commence if uplink communications were lost and not recovered within a user-selectable time frame. Defaults could include entering preplanned holding patterns or initiating preplanned egress maneuvers as determined by the on-board Virtual Pilot system described later.

The avionics system would be based on concepts embodied in the Pave Pace integrated avionics architecture. Pave Pace is a concept that uses a family of modular digital building blocks to produce tailorable avionics packages. Using this approach on the StrikeStar would allow for future growth and allows the UAV avionics to mirror manned platform components without adding additional avionics maintenance requirements. A notional avionics system, based on the Pave Pace integrated avionics architecture is shown in figure 5-3.

The StrikeStar flight control system would rely on an integrated system consisting of a global positioning system (GPS) receiver, an inertial navigation system (INS), autopilot, and various sensing and control functions. StrikeStar navigation would rely on GPS precision “P” code data. Eventually, as potential enemies develop GPS jamming capabilities to prevent GPS use in target areas, an INS could provide redundancy and allow limited autonomous operation in the event GPS countermeasures are encountered. Other UAVs could also be used to broadcast high power, synchronous broadband satellite signals over target areas to counter GPS countermeasures.[9]

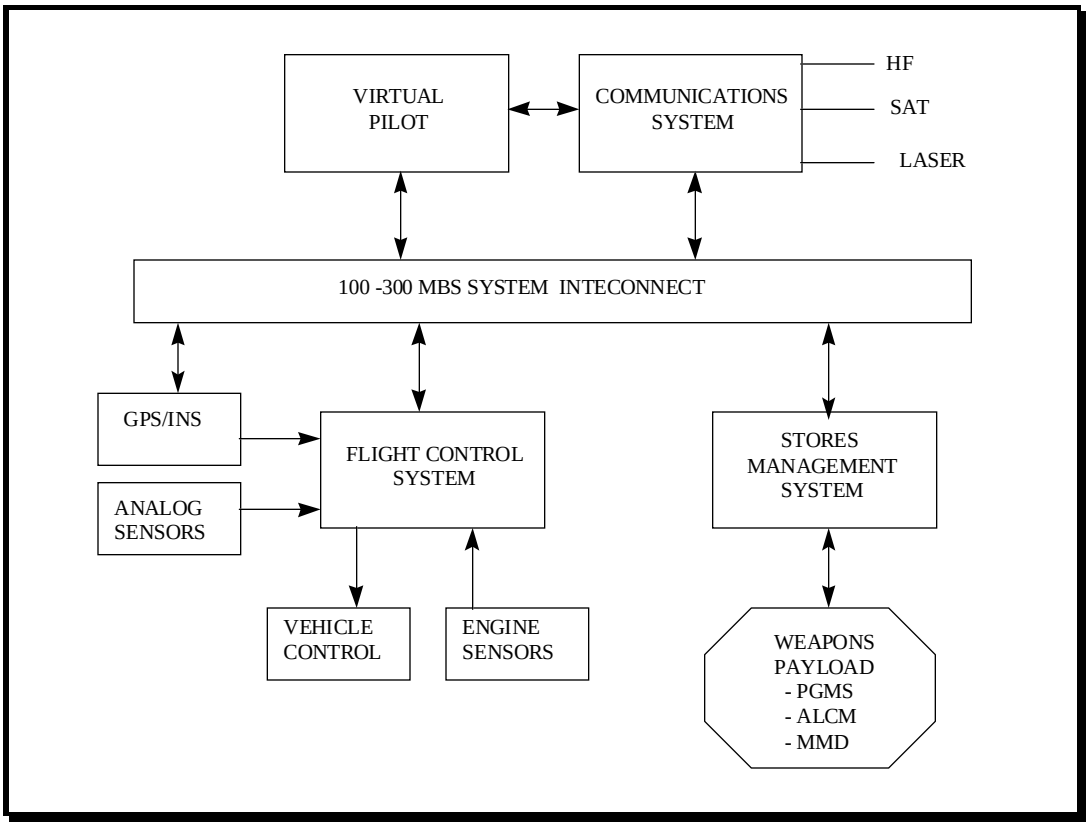


**Figure 5-3. StrikeStar Notional Avionics**

GPS location data could be transmitted to the control station at all times except in autonomous or preprogrammed operation. Components produced in the Tri-Service Embedded GPS/Inertial Navigation System (EGI) Program, which integrates GPS into the fighter cockpit for better navigation and weapon guidance, could be adapted for use in StrikeStar.[10] In addition to GPS data, StrikeStar would transmit altitude, airspeed, attitude, and direction to control station operators as requested.

The Virtual Pilot provides StrikeStar with a computational capability far exceeding current airborne central computer processing capabilities. Virtual Pilot would consist of an artificial intelligence engine relying on a massively parallel optical processing array to perform a wide range of pilot functions during all operational modes. In addition, the Virtual Pilot could perform self-diagnostic functions during all phases, flight operation phases, and maintenance checks. An antfratricide system would reside in the Virtual Pilot to ensure that combat identification of friendly forces is accomplished before weapon release. This would provide an additional fail-safe to any battlefield awareness systems present in the target area and allow

limited extension of a battlefield combat identification to future allies operating with US forces. StrikeStar would also be capable of interrogating and classifying identification friend or foe transponder-equipped platforms to facilitate use of that data in air-to-air engagements and identify potential airborne threats.

## Propulsion System

Many current UAV systems are based on inefficient, propeller-driven airframes powered by internal combustion engines, relying on highly volatile aviation gasoline, which causes military forces significant safety and logistics issues. Propeller improvements are progressing, but the desire for stealthy platforms steers many designers away from these systems with the exception of the Predator. Gas turbine engines have been demonstrated for rotary wing applications and the use of jet engines has been widely demonstrated and proven highly effective in combat operations.[11] Significant research has been conducted on electrically powered platforms that rely on expendable and rechargeable batteries. Recently, fuel cell application research increased, as evidenced by demonstrations of the solar rechargeable Pathfinder.[12] Unfortunately battery and fuel cell systems exhibit low power and energy densities relative to hydrocarbon fuels. For that reason, internal combustion engines will continue to be the mainstay for less sophisticated UAV propulsion systems.

Jet engine design is a trade-off between airflow and fuel to maximize performance. Engine designers either enlarge the size of engine intake to increase airflow or provide more fuel to the jet engine combustion chambers to produce the desired propulsion characteristics. Since most jet engines rely on conventional fuels, designers increased intake size to maximize fuel efficiency and improve range and endurance. However, increasing UAV intake size is not desirable since this impacts the stealth characteristics and overall aerodynamic efficiencies of small airframes. Exotic or alternative fuels hold much promise for powering future aircraft and extensive research has been conducted on potential new aircraft fuels. Table 3 provides some potential aircraft fuel characteristics.

**Table 3**

**Fuel Characteristics**

| Fuel | Btu/lb | Btu/cu ft | lbs/cu ft | Btu/lb of fuel |
|---|---|---|---|---|
| JP | 18,590 | 940,000 | 50.5 | 0.47 |
| Hydrogen | 51,500 | 222,000 | 4.3 | 3.20 |
| Methane | 21,500 | 570,000 | 26.5 | 0.49 |
| Propane | 19,940 | 720,000 | 36.1 | 0.65 |
| Methanol | 8,640 | 426,000 | 49.4 | 0.60 |
| Boron | 30,000 | 1,188,000 | 39.6 | 0.57 |
| JP from coal | 18,830 | 996,000 | 53.0 | 0.47 |

**Source:** Senate, Hearings before the Subcommittee on Aerospace Technology and National Needs of the Committee on Aeronautical and Space Sciences, 94th Congress, 2nd sess., 27-28 September 1976.

Exotic fuels have been used for manned platforms in the past, but only in isolated cases because of the risks associated with them. Risk to man is minimized on UAV platforms except during launch and recovery cycles, and while storage of exotic fuels remains a concern, storage technology is improving. Still, exotic fuels represent a viable option for improving enthalpy on UAV platforms. Hydrogen-based fuels provide significant increases in energy density over conventional hydrocarbon fuels, and such fuels could be widely employed in UAVs by 2025 if current research advances continue and a nationwide manufacturing and distribution network emerges.

## Weapon Systems

Weapons with current, precision-guided-munitions characteristics, new nonlethal weapons, and directed-energy weapons could provide StrikeStar with the capability to strike at all levels of conflict from military operations other than war to full-scale war. The key to producing a StrikeStar that can hold the enemy at risk is to deploy weapon systems that have all-weather and extremely precise aimpoint capabilities.

Precision-guided munitions are widely accepted as demonstrated during the Persian Gulf War. The family of Launch and Leave Low-level Guided Bombs (LLLGB), Maverick, and homing anti-radiation missiles (HARM) all represent current weapons that could be integrated into a UAV strike platform. Unfortunately, these weapons lack range and poor weather capability. New all-weather seekers are needed to provide desired battlefield dominance. New studies to produce long-range hypersonic PGMs are also underway, which if employed on a StrikeStar could significantly extend the weapon employment zone.[13] Efforts underway on the should produce weapons technology that not only discriminates against ground targets, but operates in adverse weather conditions.[14]

Stores management systems (SMS) used in modern attack aircraft could be integrated into UAV avionics packages to provide required weapon control and release functions. Tight coupling between sensor platforms, the Virtual Pilot and SMS could allow for autonomous weapon selection, arming , and release without operator intervention under certain scenarios. Unfortunately, the weight and large size of current PGMs and limited functionality of current SMS suites could limit conventional weapon employment.

Recent developments on an enhanced 1,000-pound warhead proved that blast performance of 2,000-pound MK-84 is obtainable.[15] Improved explosives are an enabling technology that would reduce weapon size without decreasing blast performance. Guidance and warhead improvements envisioned in the Miniaturized Munitions Technology Demonstration (MMTD) effort could produce a new class of conventional weapons. The MMTD goal is to produce a 250-pound class munition effective against a majority of hardened targets previously vulnerable only to 2,000-pound class munitions.[16] A differential GPS/INS system will be integral to the MMTD munition to provide precision guidance, and smart fusing techniques will aid in producing a high probability of target kill. The kinetic energy gained by releasing these weapons at maximum StrikeStar altitudes would also help improve explosive yield. Improving bomb accuracy, focusing on lethality, and providing an all-weather capability are all technology goals which, when coupled with a StrikeStar platform, could produce a potent strike platform. MMTD advances would significantly improve weapons loading on StrikeStar. Unfortunately, conventional explosives technology has the limitation that once all weapons are expended, the UAV must return to base for replenishment. However, StrikeStar directed energy weapons would allow more strikes and reduce replenishment needs.

Directed energy weapon (DEW) technology is undergoing rapid advances as demonstrated on the Airborne Laser program. The goal to produce a laser capable of 200 firings at a cost of less than $1,000 per shot is realizable in the near future.[17] The ability for rapid targeting, tracking, and firing of a UAV-mounted DEW could deny enemy forces the ability to maneuver on ground and in the air. If initiated now, expanded research efforts could produce a smaller, more lethal, directed-energy weapon suitable for a StrikeStar platform in 2025.

Capabilities in present air-to-air weapons provide a level of autonomous operations, which if employed on StrikeStar could revolutionize offensive and defensive counter air operations. A StrikeStar loaded with both air-to-ground and air-to-air missiles could be capable of simultaneous strike and self-defense. Additional survivability could be provided by using towed decoys cued by off-board sensors. Advanced medium range air to air missile (AMRAAM) and air intercept missile (AIM-9) weapons are proven technologies already compatible with stores management systems that could be employed on StrikeStar. Internal carriage and weapon release of these missiles from a StrikeStar could rely on experiences gained in the F-22 program. Eventually, a new class of air-to-air missiles could be developed which are significantly smaller and more lethal to allow additional weapon loading.

Nonlethal weapons also present some unique possibilities for use on the StrikeStar. Nonlethal weapons are defined as:

> discriminate weapons that are explicitly designed and employed so as to incapacitate personnel or material, while maintaining facilities.[18]

Nonlethal weapons that disorient, temporarily blind, or render hostile forces or equipment impotent, provide alternative means for neutralizing future opponents without increasing the political risk death and destruction can bring.[19] Employing these weapons from StrikeStar platforms could be used in prehostility stages to demonstrate resolve and the dominant presence of orbiting weapon platforms with instantaneous strike capabilities.

## Communications Systems

"What the warrior needs: a fused real-time, true representation of the Warrior's battle space—an ability to order, respond, and coordinate horizontally and vertically to the degree necessary to prosecute his mission in that battle space."[20] To provide continuous battlefield dominance, information dominance is critical for StrikeStar operations. Battlespace awareness as envisioned under the *$C^4I$ for the Warrior Program* will provide the information infrastructure required for command and control ($C^2$) of the StrikeStar platforms. UAV communications systems function to provide a communications path, or data link, between the platform and the UAV control station, and to provide a path to pass sensor data. The goal of the $C^4$ system is to have the head of the pilot in the cockpit, but not his body.[21]

StrikeStar communications would provide a reliable conduit for status information to be passed on a downlink and control data to be passed on the uplink in hostile electronic environments. The uplink and downlink data streams would be common datalinks interoperable with existing $C^4$ datalinks to maximize data exchange between sensors, platforms, and their users. Status and control information would be continually transferred between StrikeStar and its controller in all cases except during autonomous operation or implementing preprogrammed flight operations. The data link would need to be impervious to jamming, or even loss of control, to ensure weapon system integrity. User-selectable, spread spectrum, secure communications in all transmission ranges would provide redundancy, diversity, and low detection and intercept probability. Both beyond line-of-sight and line-of-sight communications methods would be supported to a variety of control stations operating from aerospace, land, and sea platforms.[22]

Command and control of UAVs via satellite links has been demonstrated to be highly reliable.[23] The MILSTAR constellation or its follow-on could serve as the primary $C^2$ communications network for StrikeStar platforms. MILSTAR's narrow-beam antennas coupled with broad-band frequency hopping provides isolation from jammers and a very low probability of detection.[24] The Defense Satellite Communications System (DSCS) constellation and Global High-Frequency Network could provide alternate paths for connectivity and redundancy depending on mission profiles. The vast HF network provides nearly instantaneous coverage and redundancy under adverse environmental conditions (fig. 5-4).[25] High-Frequency can provide commanders with useful, flexible, and responsive communications while reducing the demand on

overburdened satellite systems.[26] The continued proliferation of commercial satellite networks may allow StrikeStar platforms to exploit these networks as viable communications paths as long as $C^2$ integrity of on-board weapons is assured.

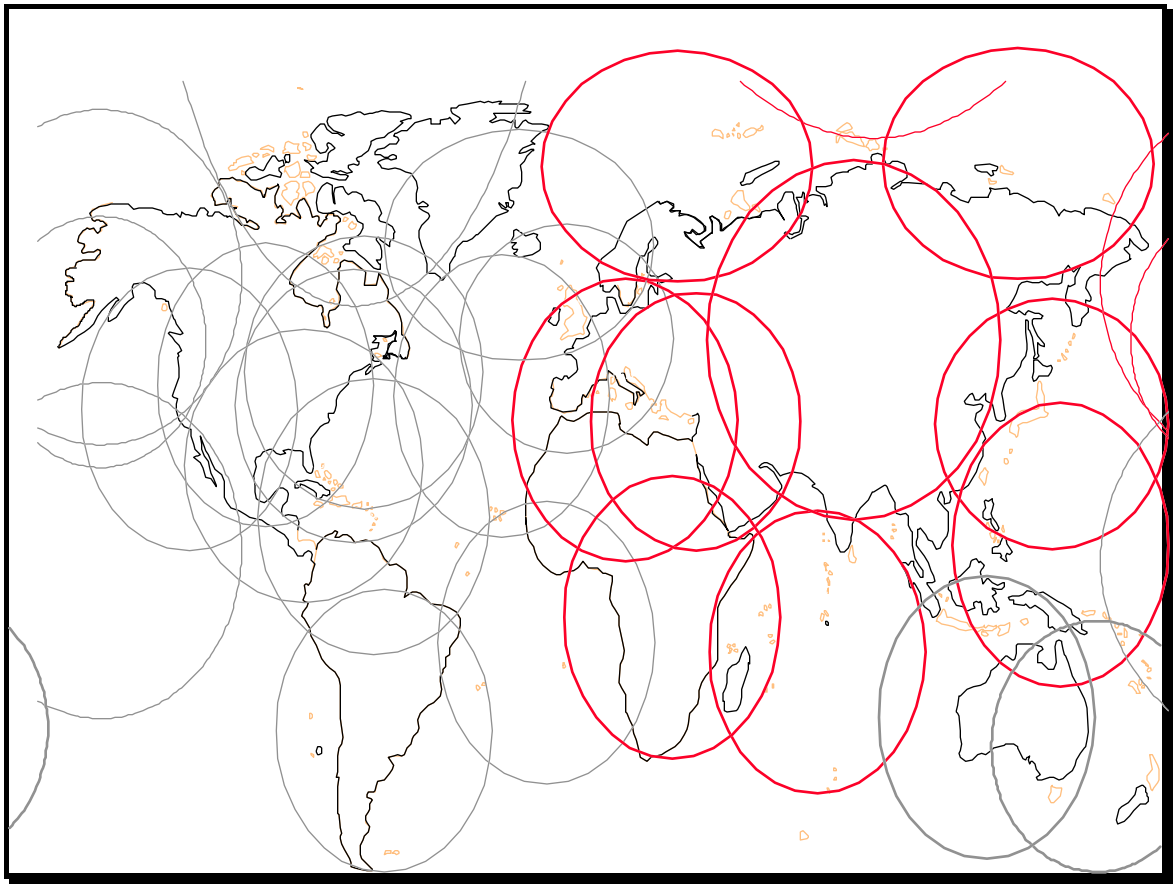

**Figure 5-4. Global HF Network Coverage**

StrikeStar would rely on other platforms, like Predator, DarkStar, Global Hawk or ground, airborne, or space reconnaissance, to detect and locate potential targets. The StrikeStar could team with any or a combination of all these assets to produce a lethal hunter-killer team. Once geolocated, the target coordinates would be passed to StrikeStar along with necessary arming and release data to ensure successful weapon launch when operating in command-directed mode. In autonomous mode, StrikeStar would function like current cruise missiles, but allow for in-flight retargeting, mission abort, or restrike capabilities. Communications for cooperative engagements with other reconnaissance platforms require minimum bandwidth between StrikeStar and its control station since the targeting platforms already provide the large bandwidth necessary for sensor payloads.

As with any $C^4$ system, we anticipate StrikeStar's requirements would grow as mission capabilities and payloads mature. It is possible StrikeStar follow-ons could be required to integrate limited sensing and strike payloads into one platform, thus significantly increasing datalink requirements. In this event, wideband laser data links could be used to provide data rates greater than 1 gigabit per second.[27] In addition, a modular payload capability could allow StrikeStar platform to carry multimission payloads such as wideband communications relay equipment to provide vital $C^4$ links to projected forces.[28]

## Mission Control Equipment

As mentioned, StrikeStar will be controllable from a multitude of control stations through the common data link use. Control stations could be based on aerospace, ground, or sea platforms depending on the employment scenario. A control station hierarchy could be implemented depending on the employing force's composition and the number of StrikeStars under control. The StrikeStar $C^2$ hierarchy and control equipment would allow transfer of operator control to provide $C^2$ redundancy. Current efforts by DARO have established a common set of standards and design rules for ground stations.[29] This same effort needs to be accomplished for aerospace and sea based control stations.

Significant efforts to miniaturize the control stations would be needed to allow quick deployment and minimum operator support through all conflict phases. Man-machine interfaces would be optimized to present StrikeStar operators the ability to sense and feel as if they were on the platforms performing the mission. Optimally, StrikeStar control could be accomplished from a wide variety of locations ranging from mobile ground units to existing hardened facilities. The various control stations would be capable of selectively controlling StrikeStars based on apriori knowledge of platform $C^2$ and identification procedures.

## Launch and Recovery Equipment

Launch and recovery are the most difficult UAV operations and are the greatest factors inhibiting wider acceptance.[30] A variety of launch and recovery systems are used worldwide. Launchers range from simple hand launchers to sophisticated rocket-assisted take-off systems (fig. 5-5). Recovery systems range

from controlled crash landings to standard runway landings. StrikeStar would launch and recover like manned aircraft, and carrier-based operations could be considered as another viable option to improve loiter times and mission flexibility.

**Figure 5-5. Rocket-Assisted Hunter UAV Launch**

The goal for StrikeStar launch and recovery would be autonomous launch and recovery via an enhanced landing system (ELS), although it could operate with the current instrument landing system (ILS) and microwave landing system (MLS) equipment under operator control. ILS is prone to multipath propagation and MLS is susceptible to terrain variations and the presence of nearby objects; thus both would not be acceptable for truly autonomous recovery of StrikeStar platforms.[31] The ELS would overcome these deficiencies by using GPS, high resolution ground mapping techniques, and optical sensing to land without operator control.

Technologies to support the StrikeStar do not appear to represent significant challenges. In most cases proven technologies can be expected to evolve to a level that will overcome all hurdles by the year 2025. Determining the doctrinal and operational changes required to integrate a StrikeStar capability presents more significant challenges, considering the aversion our service has had with UAVs in the past.[32] Technology for StrikeStar is evolutionary where as organizational acceptance and employment will be revolutionary.

## Notes

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[2] Defense Daily, 2 February 1996, 162.

[3] Maj William R. Harshman, Army UAV Requirements and the Joint UAV Program, DTIC Report AD - A228149 (US Army Command and General Staff College Thesis, June 1990), 4.

[4] K. Cameron, *Unmanned Aerial Vehicle Technology* (Melbourne Australia: Defense Science and Technology Organization, February 1995).

[5] *Janes Unmanned Aerial Vehicles, Launchers and Control Systems, 1994* (Surrey, UK: Janes Information Group Limited), 253.

[6] Cameron, 21.

[7] *Air Progress*, September 1995, 47-49.

[8] David A. Fulghum, "McDonnell Douglas JAST Features Expanding Bays," *Aviation Week and Space Technology*, 19 February 1996, 52. In this article a smart-skin-type experimental coating is discussed. This coating attenuates radar reflections with customized carbon molecules. When activated by an electric charge it can also change the skin's color from sky blue to earth and foliage-colored hues to fool optical sensors.

[9] Ibid., 66.

[10] ARPA Technical Abstract, (Internet: December 1995).

[11] Longino, 2.

[12] Lawrence Livermore National Laboratory Technical Abstract, *Solar-Electric Aircraft* Internet: January 1996.

[13] Mr Wayne A. Donaldson, WL/POPA, Fuels Engineer, E-mail, 2 February 1996; AF 2025 Assessor comments, 28 March 1996.

[14] "Smart Bombs get their Ph.D.," *CNN Interactive Technology*, Internet, 1 February 1996.

[15] "Energetic Materials Branch/High Explosives Research and Development Facility Home Page," (Eglin AFB, Fla., January 1995).

[16] "Miniaturized Munition Technology Demonstration Abstract," January 1995, 2.

[17] Suzanne Chapman, "The Airborne Laser," *Air Force Magazine* January 1996, 54–55.

[18] E. E. Casagrande, *Nonlethal Weapons: Implications for the RAAF* (RAAF Base Fairbarin, Australia: Air Power Studies Center, November 1995), 6.

[19] Peter Petre and H. Norman Schwarzkopf, *It Doesn't Take a Hero* (N.Y.: Bantam Books, 1992), 468. Considering the death and destruction on the Highway of Death, General Powell informed General Schwarzkopf that the White House was getting nervous: "The reports make it look like wanton killing."

[20] Adm Richard C. Macke, *C4I for the Warrior*, 12 June 1992.

[21] Robert K. Ackerman, "Tactical Goals Encompass Sensors, Autonomous Arts," *Signal*, December 1995, 27.

[22] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 27.

[23] Joint Precision Strike Demonstration (JPSD) Beyond Line of Sight UAV Demonstration, JPSD Program Office, March 1994, vi–viii.

[24] Adm James B. Busey IV, "MILSTAR Offers Tactical Information Dominance," *Signal*, July 1994, 11.

[25] AFC$^4$A Briefing, Global HF Consolidation, November 1994.

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[27] "Optical Space Communications Cross Links Connect Satellites," *Signal*, April 1994, 38.

[28] Col Dale W. Meyerrose, HQ USAFE/SC, E-mail, 21 January 1996. In this E-mail Col Meyerrose explained how a long-loiter UAV capable of relaying combined air operations center communications to pilots over Bosnia would have been a much better solution than building the line-of-sight communications system in enemy territory; Kenneth L. Gainous and William P. Vaughn, *Joint Warrior Interoperability Demonstration 1995 After Action Report for the MSE Range Extension Repeater*, 16 November 1995. In this effort, a UAV was used to extend voice and data communications for US Army Deep Strike Assault Mission.

[29] Defense Airborne Reconnaissance Office Annual Report *Unmanned Aerial Vehicles*, (Washington, D.C., August 1995), 28.

[30] Cameron, 28–30.

[31] Aubrey I. Chapman, *Remotely Piloted Vehicle Technology*, DTIC AD-B131985 (Radar Guidance Inc., San Antonio, Tex., 17 April 1989), 17–18.

[32] Harshman, 17; Longino, 27–31.

# Chapter 6

# StrikeStar Concept of Operations

*We're getting into UAVs in a big way. We understand they have enormous potential.*

—General Joseph W. Ralston

The purpose of the StrikeStar concept of operations is to define the operational application of the StrikeStar by highlighting system advantages, defining future roles and missions, and illustrating interrelationships between intelligence, command and control ($C^2$), the weapon, and the war fighter.

## The Dawn of a New Era for Airpower

Historically, America has held expectations for airpower just beyond the limits of available technology, and now a new national expectation is emerging. Today, airpower application is expected to equate to cost-effective, precise, and low-risk victory.[1] These inexorable expectations could be a reality in 2025 because a StrikeStar could hold strategic, operational, and tactical targets at risk with relative immunity to enemy defenses. This platform could operate in high risk or politically sensitive environments, perform its mission, and return to fly and fight again. The StrikeStar would enable the United States military to meet the national expectations and the threats of a changing world.

Underpinning the StrikeStar concept is the platform's ability to deliver increased combat capability with reductions in vulnerability and operating cost. The StrikeStar's 8,000 nautical mile combat radius would have the potential to keep vulnerable logistics and maintenance support far from hostile areas. Also, dramatic savings would be possible in operations, maintenance, personnel, and deployment costs.

Logistically the StrikeStar could be handled like a cruise—missile; stored in a warehouse until needed and then pulled out for a conflict. The potential savings over conventional aircraft could range from 40 percent to as much as 80 percent.[2] Training could be conducted using computer simulation with actual intelligence, surveillance, and reconnaissance inputs. While potential savings are impressive, the most attractive aspects of this platform and its supporting elements are the capabilities the StrikeStar System could deliver to tomorrow's commanders in chief (CINCs):

1. The StrikeStar could be configured to perform a variety of missions as diverse as surveillance to the delivery of precision weapons.

2. Operating altitudes could make it a true all-weather platform capable of remaining on-station regardless of area of operations (AO) weather.

3. Battlespace presence: depending on the weapons carried, a handful of StrikeStars could equate to continuous coverage of the AO.

4. Power projection: StrikeStar operations need not compete for ramp space with other theater assets. The combat radius would normally facilitate operations from coastal Continental United States locations or strategically located staging bases to improve loiter time (fig. 6-1).

5. Such an aircraft could accelerate the CINC's Observe, Orient, Decide, Act loop (OODA Loop) with immediate battle damage assessment (BDA) and restrike capability.

6. The employment concept of operations could shorten the chain of command, simplifying accountability and improving operations security.

7. A StrikeStar could enable a CINC to operate in environments where casualties, prisoners of war, or overt United State military presence are politically unacceptable.

8. A StrikeStar and its supporting systems could be tailored to have utility across the across the spectrum of conflict.

9. A StrikeStar in a combat environment could "buy back" battlespace flexibility.[3]

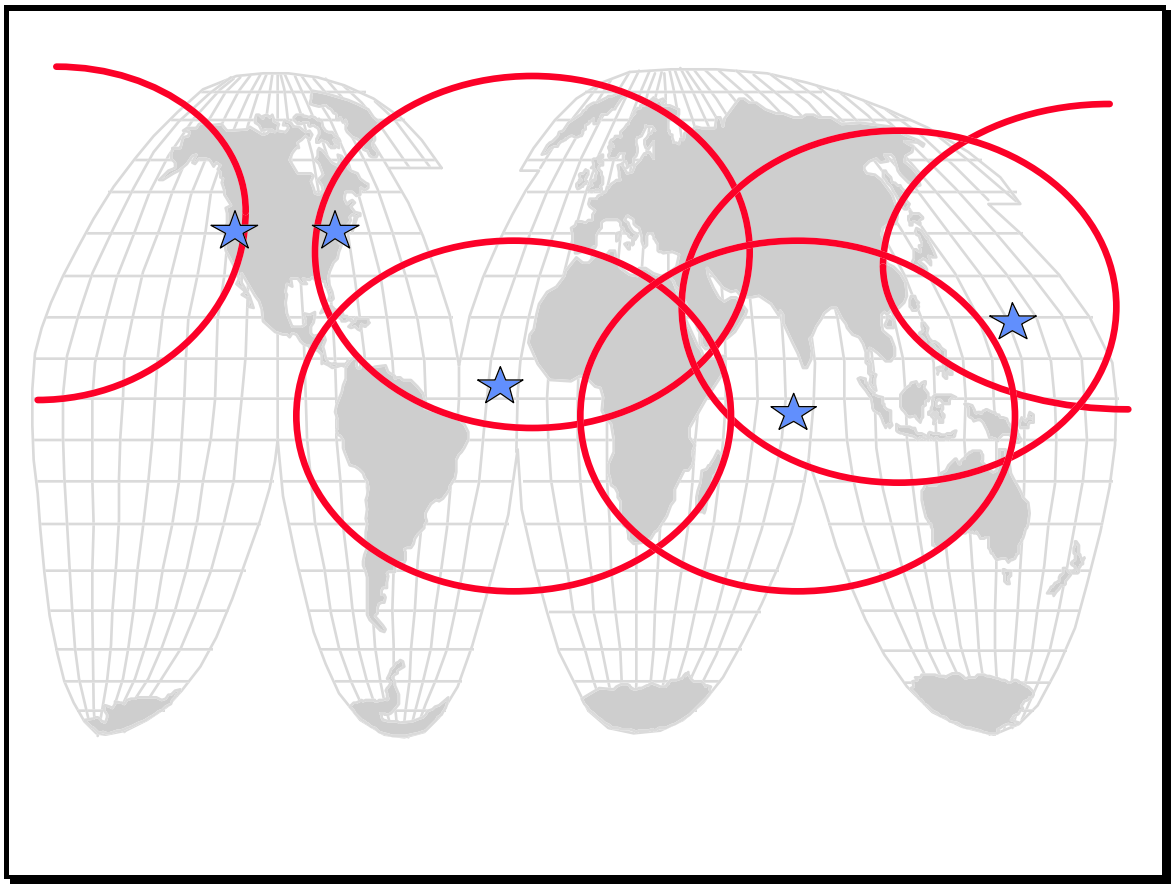

**Figure 6-1. StrikeStar Coverage**

## Roles and Missions

Aerospacepower roles and missions in 2025 are difficult to predict, yet we know they will be tied to the nature of future conflict. Desert Storm has been touted by many as the first modern war and a clear indicator of the nature of future conflict. Others believe that the conflict was not the beginning of a new era in warfare but the end of one, perhaps the last ancient war.[4] In terms of posing aerospace forces for the future, it is imperative we look for discontinuities in the nature of future war as well as commonalties to past conflicts. It is a fact that our future roles and mission will be a reflection of our technological capabilities and most significant centers of gravity as well as those of our enemies.[5] It is safe to say the missions that are the most challenging today will be the core requirements of aerospacepower tomorrow.

The StrikeStar complements the current understanding of air roles and missions and could provide a technological bridge to accomplish future roles and missions. The platform's most natural applications would be in aerospace control and force application roles; however, planned versatility also makes it a force multiplier and a force enhancer.[6] A payload and communications package swap could enable a StrikeStar to perform electronic combat, deception, or reconnaissance missions. A StrikeStar could act as a stand-alone weapons platform or it could multiply combat effectiveness by working in conjunction with other air and space assets. StrikeStar's utility in the performing any future missions would be limited only by its combat payload capacity and this limitation will be offset by revolutions in weapons technology that include light-weight, high-explosive, and directed-energy technology.[7] Yet, even by today's standards a StrikeStar could match the planned payload capacity of the Joint Strike Fighter (JSF).[8] Revolutions in conventional warfare will be driven by rapidly developing technologies of information processing, stealth, and long-range precision strike weapons.[9] A StrikeStar's relative invulnerability, endurance, and lethality would force redefinition of roles and missions and revolutionary doctrinal innovation for airpower employment.

For centuries war fighters labored to find the weapon that gave them a panoptic effect on the battle field.[10] The inherent flexibility and lethality of airpower provided us with great gains toward this long-sought goal. However, limitations in technology, airframes, and the national purse have led to a less than ubiquitous presence over intended areas of operations. A StrikeStar could be the conduit to achieving this goal. The "kill boxes" of Desert Storm would give way to 24-hour "air occupation" of the AO. Airpower theorist Col John Warden states that the primary requirements of an air occupation platform in the future are stealth, long endurance, and precision.[11]

Not only could a StrikeStar hold the enemy at risk, it could produce unparalleled psychological effects through shock and surprise. In the words of Gen Ronald Fogleman, Chief of Staff, United States Air Force, "So, from the sky in the aerospace medium, we will be able to converge on a multitude of targets. The impact will be the classic way you win battles—with shock and surprise."[12] A StrikeStar could produce physical and psychological shock by dominating the fourth dimension—time.[13] Future CINCs could control the combat tempo at every level. Imagine the potential effect on enemies who will be unable to predict where the next blow will fall and may be powerless to defend against it.

The possibilities for joint force combat applications of this system are enormous. A StrikeStar could be a multiplier used to increase the tether of naval fleet operations or as a strike platform with marine expeditionary applications. It could be used as a high-value asset (HVA) escort or in combat air patrol (CAP), allowing assets normally tasked for these roles to be retasked for other missions. An example of a StrikeStar force enhancement capability is its potential use in tactical deception. A possible employment scenario could include a StrikeStar releasing air-launched decoys over an area of suspected surface-to-air missiles, and as enemy radars come on line to track the approaching decoys, the StrikeStar would destroy them.[14] It could then follow the strike package of F-22s or JSFs, loiter over the battle area, and perform near real-time restrike as directed.

## Concepts of Employment

In this section, concepts of employment describe the architecture required to employ the StrikeStar and detail the concept of operations in two notional operating modes. The final areas covered are critical tasks and weapons employment.

### The System Architecture

The StrikeStar is inextricably linked to reconnaissance and command and control systems. The system architecture depicted in figure 6-2 illustrates how a StrikeStar is tied and integrated into the larger battle space systems. Keep in mind that it is the entire architecture, or the system of systems, which enables mission accomplishment.[15] The StrikeStar is a relatively dumb system: it carries few sensors, and it is not designed for a great deal of human interface. The viability of the StrikeStar concept in 2025 depends on its ability to plug into the existing battlespace dominance and robust $C^2$.

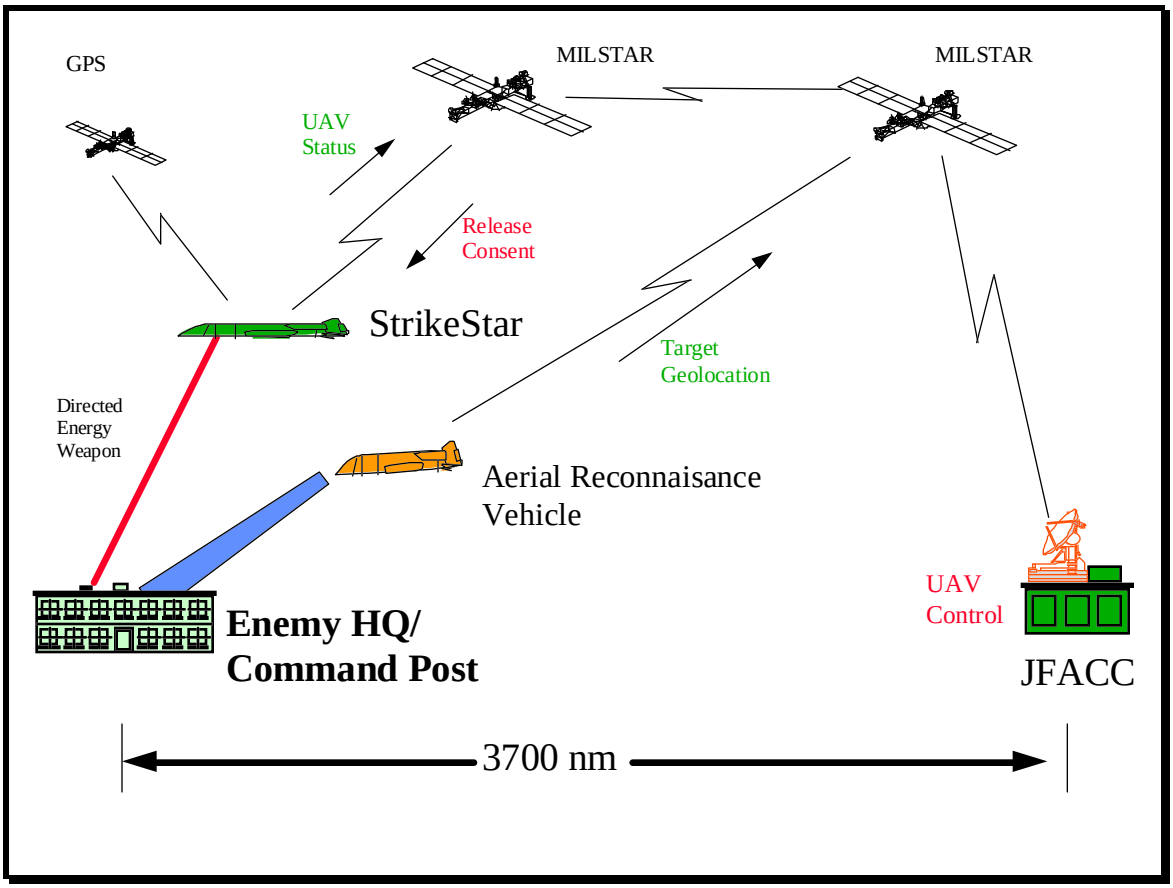


**Figure 6-2. StrikeStar $C^2$ Architecture**

Former Vice Chairman of the Joint Chiefs of Staff Admiral Owen's prediction that the United States military will enjoy dominant battlefield awareness by 2010 is a prerequisite to this concept.[16] Dominant battlespace awareness in 2025 must include near real-time situational awareness, precise knowledge of the enemy, and weapons available to affect the enemy.[17] This intelligence must be comprehensive, continuous, fused, and provide a detailed battlespace picture. The intelligence-gathering net will utilize all available inputs from aerospace assets, both manned and unmanned sensors.[18] The StrikeStar would rely on this integrated information for employment, queuing, and targeting. A StrikeStar in this architecture adds value since it enables an aerospace platform to provide dominating maneuver with lethal and precise firepower in a previously unattainable continuum of time. A pictorial representation of this concept is presented in figure 6-3.

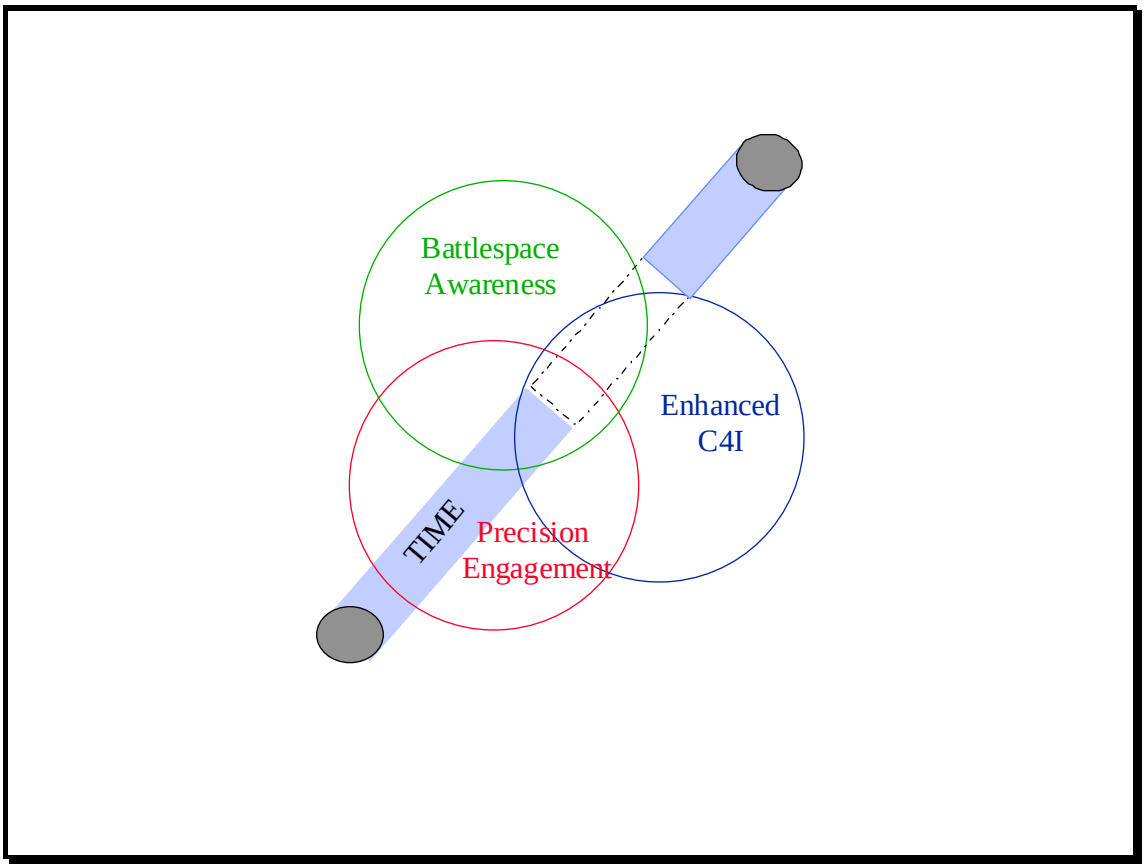


**Figure 6-3. A System of Systems Over Time Continuum**

Command and control capabilities in 2025 are the defining element in the StrikeStar concept. A StrikeStar would need to be fully integrated into a common $C^2$ element that manages all aspects of the air battle in 2025.[19] A StrikeStar places several unique demands on the command and control element. $C^2$ personnel would employ a StrikeStar by nominating targets, pulling down required intelligence, and selecting the platform and weapon to be used against them. The command element could then command weapons release or tie the StrikeStar directly to an AO sensor in an autonomous mode. In the autonomous mode intelligence is collected, sorted, and analyzed and then forwarded to a StrikeStar positioned to attack immediately a target by-passing the $C^2$ element (sensor-to-shooter).[20] To reduce vulnerability of the command center and StrikeStar, data-link emissions should be held to a minimum.

The type and location of the command center used in 2025 will depend on the nature of the conflict. Missions of the most sensitive nature, clandestine operations, or retaliatory strikes are best served by a short and secure chain of command. Therefore, these StrikeStar applications would be best served by a direct link

to the platform from a command center located in the hub of political power. Similarly, if a StrikeStar is utilized in extremely hostile theaters, a command and control center located far from hostilities is most advantageous. In low-intensity conflicts, peace enforcement, or domestic urban applications, the $C^2$ center could be moved to the vicinity of the conflict as a mobile ground station, an airborne platform, or even a space-based station.

**Autonomous Strike Mission**

The strike mission highlights the utility of a potentially autonomous mode of operation. This operating mode could free command and control center personnel to manage other assets. In the strike mode a StrikeStar would capitalize on the principles of simplicity, surprise, offensive, and objective.[21] The following details an autonomous strike mission (fig. 6-4).

**Ground operations.** A StrikeStar is tasked from Continental United States or a forward operating location to strike specific AO target(s). Mission specifics including target coordinates, time-on-target, takeoff time, and abort criteria are loaded directly into the aircraft computer via a physical link from the mission-planning computers. (The use of ground crew personnel is possible, however this option introduces potential for human error).

**Launch.** StrikeStar performs premission diagnostic checks, starts, and taxis to meet its designated takeoff time. The aircraft would require improved taxiways and runways to support a notional, maximum gross operational weight of 24,000 pounds. Taxiways and runways must provide adequate obstacle clearance to accommodate a StrikeStar's 105 feet wing span. The runway length required will be approximately 4,000 feet for takeoff, landing, and abort distances. The StrikeStar would taxi via global positioning and airfield information. Mission support personnel would deconflict operations with ground control and tower or sanitize the airfield during ground operations and takeoff.

**Climb Out.** When operating in congested or controlled airspace it would be necessary to deconflict a StrikeStar with potential air traffic. In these cases the aircraft would be programmed to perform a spiral climb over the field until above the future equivalent of positive controlled airspace. (This may require coordination for airspace above and around the aerodrome for operations within the United States).

**Enroute.** The StrikeStar would proceed to the target as programmed unless updated information is passed from the command center. Integrated engine and airframe function indicators would be constantly monitored and adjusted automatically for peak performance by the Virtual Pilot. Engine anomalies will be compared against pre-programmed go/no-go criteria, and in the event an abort criterion is discovered, a message would be automatically passed to the $C^2$ center for action.

**Ingress.** A StrikeStar would proceed to the target via the programmed flight path. Although stealthy technology and altitude reduces vulnerability, flight path programming should integrate intelligence preparation of the battlefield (IPB) to optimize this technology and avoid obvious threats. Once in the AO the StrikeStar would release its weapons or recognize its assigned sensor and establish a "kill box." The kill box is a block of space where the StrikeStar releases weapons on threats identified by coupled sensors.[22]

**Egress.** StrikeStar would egress the AO using preprogrammed information or remain on-station in a preprogrammed orbit awaiting battle damage assessment (BDA) and potential retargeting information until egress was required.

**Recovery.** StrikeStar would fly to the airdrome's vertical protected air space, and execute a spiral descent unless otherwise directed. The aircraft would perform a precision approach and landing, taxi clear of the active runway, and return to parking, using the enhanced landing system (ELS) discussed earlier.

**Regeneration.** Maintenance time would be kept to a minimum through computer diagnostics provided to ground personnel on landing, and blackbox swap technology. The aircraft could be refueled, rearmed, reprogrammed, and "turned" quickly after landing.

**System compromise.** A StrikeStar is intended to be a durable platform, however system degradation due to battle damage or malfunction could compromise the platform. To ensure that classified programming information remains secure, preprogrammed information will be altitude volatile. Additionally, to prevent reverse engineering or endangerment of friendly forces, the airframe could be destroyed by on-board weapons or another StrikeStar in the event of an inadvertent landing or errant behavior.

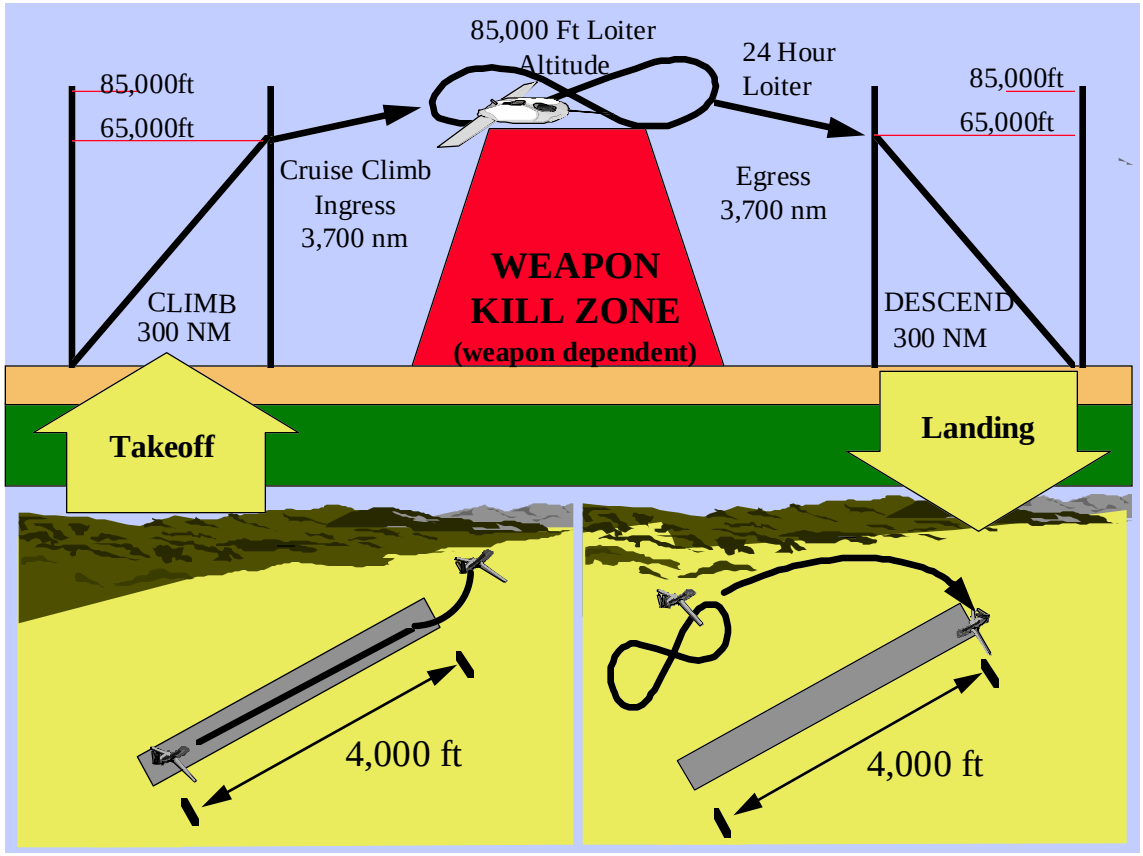


**Figure 6-4. StrikeStar Mission Profile**

**Command Directed Mission**

The specifics of the command-directed mission overlap many of the aspects of the autonomous mission. The fundamental distinction between the two operating modes is that the command directed mission requires command center inputs. In this operating mode, the StrikeStar could exploit the principles of unity of command, maneuver, mass, and economy of force. While the StrikeStar employment would naturally mesh with the tenets of aerospace power, this platform would define new limits to the tenets of persistence, flexibility, and versatility.[23] The objective of the command-directed mission is to provide continuous presence over the battle-field and maximize flexibility. Mission areas unique to command-directed missions are delineated below.

**Ingress.** A StrikeStar would be preprogrammed to a specific orbit where it would await closure of the $C^2$ elements OODA loop. This closure would provide the platform with the required information on optimum positioning and targeting commands.

**Egress.** A StrikeStar would remain on-station until fuel or weapons expenditures require a return to base. Fuel and weapons status will be provided to the command element on request. A return to base message will be transmitted at a predesignated navigation point. Due to the long loiter time in the AO, the planned recovery location may have changed, so updated landing information will be passed to the aircraft as situations dictate.

**Critical Tasks and Weapons Employment**

The 2025 battle space will have both unique and familiar features. The StrikeStar could leverage available weapons technology to perform many critical tasks. As noted in the *New World Vistas*, there will be a number of tasks that must be accomplished. Among the most pressing tasks in 2025 will be the destruction of short-dwell targets, and theater ballistic missile defense.[24] Additionally, the potential of air occupation must be explored. A final task, well suited to a StrikeStar, would be covert action against trans-national threats located in politically denied territory or in situations were plausible deniability is imperative.

The ability of a StrikeStar to loiter over an area for long periods and exploit information dominance with precision weapons, would make it a natural Theater Missile Defense (TMD) platform, particularly in boost phase intercept. A StrikeStar could be employed in the AO in a sensor-to-shooter mode looking for ballistic missiles in the first 180 seconds of flight. Intercepting missiles from high altitudes early in the boost phase increases the chances that dangerous debris would fall on enemy territory.[25] The weapon employed against TBMs or other short-dwell targets could be directed-energy weapons or hypersonic interceptor missiles.[26] The optimum weapons selection for a StrikeStar would match weapons availability to loiter capability. A StrikeStar offers the advantages of a space-based TBM defense weapon in terms of operational reach, a vast distance over which military power can be concentrated and employed decisively, and it extricates the military from the issues of the militarization of space.[27]

The StrikeStar approach to systems lethality and loiter capability could enable the Air Occupation concept. Because of a StrikeStar's endurance, altitude, and stealth characteristics, it could wait, undetected, over a specific area and eliminate targets upon receiving intelligence cues. If required for plausible deniability, specialized weapons could be used to erase any US finger-print. Uniquely suited to a StrikeStar would be delivery of high-kinetic-energy penetrating weapons. Firing kinetic weapons at StrikeStar's operational altitudes would allow engagements at longer ranges.[28]

Countries conform to the will of their enemies when the penalty of not conforming exceeds the cost of conforming. The cost can be imposed by destruction or physical occupation of enemy territory. In the past, occupation was conducted by ground forces—because there was no good substitute.[29] In 2025, a StrikeStar could send a lethal or nonlethal message to US enemies and enforce the imposition of our national will through air occupation across the battle space continuum.

It is estimated that over half the nations of the world have active UAV programs.[30] Because of the proliferation of UAV technologies, the United States may face enemy UAVs similar to StrikeStar in the future. Although beyond the scope of this paper, consideration must be given to how a StrikeStar will fit into, and possibly shape the 2025 battlespace. The broad influence that UAVs could have on military roles and missions will drive evolutionary changes in service doctrine. The issues of how best to employ strike UAVs, the details of the human-system interface, and potential countermeasures must be explored before this weapon system can fulfill its potential.

## Notes

[1] USAF Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century*, summary volume (Washington, D.C.: USAF Scientific Advisory Board, 15 December 1995), 60.

[2] David A. Fulghum, "New Priorities Refocus Ballistic Missile Defense," *Aviation Week and Space Technology*, 19 February 1996, 25.

[3] Ibid., 25.

[4] Gen Merrill A. McPeak, *Selected Works 1990-1994* (Maxwell AFB, Ala.: Air University Press, August 1995), 230.

[5] Col Phillip S. Meilinger, *10 Propositions Regarding Air Power* (Maxwell AFB, Ala.: Air Force History and Museums Program, 1995), 60.

[6] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, 2 vols., March 1992, 7.

[7] John Boatman, "Highly Energetic Bomb Studies," *Jane's Defense Weekly*, March 1995, 81.

[8] David A. Fulghum, "Mcdonnell Douglas JAST Features Expanding Bays," *Aviation Week and Space Technology*, 19 February 1996, 52.

[9] James R. Fitzsimuonds and Jan M. Vantol, "Revolution in Military Affairs," *Joint Force Quarterly*, Spring 1994, 27.

[10] Col John Warden, USAF Retired, address to Air Command and Staff College, Maxwell AFB, Ala., October 1995. The panoptic effect refers to the power that continuous surveillance and presence has in the ability to control large numbers of people. People begin to react to the pressure of constant surveillance even when it is not present.

[11] Col John Warden, USAF Retired, video address to Air Command and Staff College, Maxwell AFB, Ala., War Termination, January 1996.

[12] Gen Ronald R. Fogleman, chief of staff, United States Air Force, address to the Air Force Association, Orlando, Fla., 24 February 1995.

[13] Col Phillip S. Meilinger, 1, 30.

[14] David A. Fulghum, "DarkStar First Flight Possible in March," *Aviation Week and Space Technology*, 19 February 1996, 55.

[15] Lt Col Michael R. Mantz, *The New Sword: A Theory of Space Combat Power* (Maxwell AFB, Ala.: Air University Press, May 1995), 17.

[16] Adm William A. Owens, USN, Vice Chairman, Joint Chiefs of Staff, address to the AF 2025 Study Group, Maxwell AFB, Ala., 13 August 1995.

[17] "Warfighting Vision: 2010 A Framework for Change," (Ft Monroe Va: Joint War fighting Center, August 1995),10.

[18] "Surveillance and Reconnaissance, Real-Time Integration," 2025 concept briefing, Maxwell AFB, Ala., 19 January 1996.

[19] Unmanned Aerial Vehicle Technology Report, 2.

[20] Warfighting Vision: 2010 A Framework for Change, 10.

[21] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, 7.

[22] Richard P. Hallion, *Storm over Iraq Air Power and the Gulf War* (Washington. D.C.: Smithsonian Institution Press, 1992), 155.

[23] AFM 1-1, *Basic Aerospace Doctrine of the United States Air Force*, 9.

*New World Vistas*, summary volume, 36.

[25] William B. Scott, "Kinetic-Kill Boost Phase Intercept Regains Favor," *Aviation Week and Space Technology*, 4 March 1996, 23.

[26] Fulghum, 53.

[27] Joint Pub 3-0 *Doctrine for Joint Operations*, 1 February 1995, III–16.

[28] William B. Scott, "Kinetic-Kill Boost Phase Intercept Regains Favor," *Aviation Week and Space Technology*, 4 March 1996, 23.

[29] Jeffrey Mckitrick et al., "The Revolution in Military Affairs," in Barry R. Schneider and Lawrence E. Grinter, eds., *Battlefield of the Future: 21st Century Warfare Issues*. (Maxwell AFB, Ala.: Air University Press, September 1995), 121.

[30] Air and Missile Threat to the Force," Air and Missile Threat Briefing, Fort Bliss Threat Office, 1996, 14.

# Chapter 7

# Conclusions

*There will always be men eager to voice misgivings, but only he who dares to reach into the unknown will be successful. The man who has been active will be more leniently judged by the future.*

—General Heinz Guderian
*Armored Forces*

Many important issues face our military's leadership over the next 30 years. Continuing to build a reliable force structure amidst shrinking budgets is a challenge that must be met head-on. Recognizing the opportunity for growth beyond the UAV's reconnaissance mission is a must if the US military is to be ready for all aspects of the conflict spectrum. While there are other near-term priorities for military spending, UAV development beyond reconnaissance requires specific funding for research and development, and operations and maintenance. Estimating seven years for development and three years from initial fielding to a full operational capability, the lethal UAV concept should be supported and funded no later than 2015. In reality, this milestone should be achieved earlier, but we live in an imperfect world and funding for our future force is only growing smaller.[1]

The technologies discussed here are realizable by 2025. Current UAV advanced concept technology demonstration (ACTD) efforts by Defense Airborne Reconnaissance Office's (DARO) will provide the leverage we need to take the next step in UAV missions. Current efforts to improve conventional weapons and produce an airborne-directed energy weapon will provide the required precision and lethality needed to operate across the full spectrum of conflict. An interconnected, highly distributed infosphere that produces ultimate battlespace awareness will provide the $C^2$ reins to provide the conventional deterrence desired.

Conventional fuel sources can provide the desired platform performance between now and 2015, but continued research to provide cleaner fuel sources and improved fuel efficiencies is desirable. StrikeStar technology is a small hurdle—a challenge that can be overcome by funding and support from visionary leaders.

UAVs have a great potential for the strategic and operational commander in the pursuit of national interests. To optimize that potential, the apparent pro-pilot bias that favors manned aircraft over UAVs must be overcome. In addition, leaders must finds ways to fund lethal UAV development and support the research and development of doctrine to support it. While doing so, leaders must also ensure that lethal UAVs and their concept of operations comply with the wishes of a public that demands safety and accountability.

Based on these conclusions, the following are recommended:

- Add a budget line in the FY00 POM, or sooner, that provides adequate funding for the ACTD. Based on the ACTD results be prepared to dedicate funding for lethal UAVs.
- Initiate an ACTD effort that picks up where the current DARO ACTDs end. The ACTD will focus on integrating components produced in the Miniaturized Munitions Technology Demonstration, LOCASS, and Pave Pace avionics architecture, with an enlarged variant of the DarkStar platform.
- Investigate a multimission modular payload configuration for UAV use that will allow a quick and economical reconfiguration from strike to reconnaissance missions.
- Continue work on an airborne laser, focusing on miniaturizing the weapon.
- Investigate possible TMD weapons for boost-phase intercept or attack operations for carriage on a long endurance stealthy UAV.
- Initiate a study to determine what doctrinal changes are needed to effectively employ StrikeStar across the conflict spectrum.
- Accelerate efforts to fuse all-source national and theater intelligence technologies .
- Initiate a study to determine how lethal UAVs can be integrated into force structure and the cost benefits of this concept versus alternatives.
- Continue strong support of a global information infrastructure that can provide secure, reliable communications.

The long-endurance multimission lethal UAV offers the war fighter of the Twenty-first century a capability to enforce the concept of "air occupation." Applicable for use over a wide variety of scenarios and levels of warfare, the StrikeStar would be an affordable power projection tool that overcomes many of the political and social issues that will hinder force projection and force employment in the next century.

## Notes

[1] Maj Gen John R. Landry, USA, Retired, National Intelligence Officer for General Purpose Forces, Central Intelligence Agency, address to the AF 2025 Study Group, Maxwell AFB, Ala., 14 February 1996.

# Appendix A

## Unmanned Aerial Vehicle Reliability

UAV reliability constantly comes up as a major factor when conducting cost performance trade-offs between manned and unmanned aircraft. The sporadic interest in UAVs has resulted in missing reliability data or insignificant data collections due to small UAV test sets, and various measurement techniques. The propensity to link payload performance to UAV platform reliability also led to misconceptions on overall reliability.

Table 4 shows the first data collected on the Air Force's first widespread use of UAVs during the Vietnam War and its aftermath.

**Table 4**

**Ryan Model 147 UAV Flight Statistics**

| RYAN 147 Model | MIL Model | LT | SP | Mission | Date Opr | Number Launch | Percent Returned | Msn Per Uav |
|---|---|---|---|---|---|---|---|---|
| A | | 27 | 13 | Fire Fly-first recce demo | 4/62-8/62 | | | |
| B | | 27 | 27 | Lightning Bug First Big-Wing High Alt PhotoBird | 8/64-12/65 | 78 | 61.5 | 8 |
| C | | 27 | 15 | Trng and Low Alt Tests | 10/65 | | | |
| D | | 27 | 15 | Electronic Intelligence | 8/65 | 2 | | |
| E | | 27 | 27 | High Alt Elect Intel | 10/65-2/66 | 4 | | |
| F | | 27 | 27 | ECM | 7/66 | | | |
| G | | 29 | 27 | Long body/larger engines | 10/65-8/67 | 83 | 54.2 | 11 |
| H | AQM-34M | 30 | 32 | High Alt Photo | 3/67-7/71 | 138 | 63.8 | 13 |
| J | | 29 | 27 | First Low Alt Day Photo | 3/66-11/77 | 94 | 64.9 | 9 |
| N | | 23 | 13 | Expendable Decoy | 3/66-6/66 | 9 | 0 | |
| NX | | 23 | 13 | Decoy and Med Alt Day Photo | 11/66-6/67 | 13 | 46.2 | 6 |
| NP | | 28 | 15 | Interim Low Alt Day Photo | 6/67-9/67 | 19 | 63.2 | 5 |
| NRE | | 28 | 13 | First Night Photo | 5/67-9/67 | 7 | 42.9 | 4 |
| NQ | | 23 | 13 | Low Alt Hand Controlled | 5/68-12/68 | 66 | 86.4 | 20 |
| *NA/NC | AQM-34G | 26 | 15 | Chaff and ECM | 8/68-9/71 | | | |
| NC | AQM-34H | 26 | 15 | Leaflet Drop | 7/72-12/72 | 29 | 89.7 | 8 |
| NC (m1) | AQM-34J | 26 | 15 | Day Photo / Training | | | | |
| S/SA | | 29 | 13 | Low Alt Day Photo | 12/67-5/68 | 90 | 63.3 | 11 |
| SB | | 29 | 13 | Improved Low Alt Day Photo | 3/68-1/69 | 159 | 76.1 | 14 |
| SRE | AQM-34K | 29 | 13 | Night Photo | 11/68-10/69 | 44 | 72.7 | 9 |
| SC | AQM-34L | 29 | 13 | Low Alt Workhorse | 1/69-6/73 | 1651 | 87.2 | 68 |
| SC/TV | AQM-34L/TV | 29 | 13 | SC with Real-time TV | 6/72- | 121 | 93.4 | 42 |
| SD | AQM-34M | 29 | 13 | Low Alt Photo/Real-time Data | 6/74-4/75 | 183 | 97.3 | 39 |
| SDL | AQM-34M(L) | 29 | 13 | Loran Navigation | 8/72 | 121 | 90.9 | 36 |
| SK | | 29 | 15 | Operation From Carrier | 11/69-6/70 | | | |
| T | AQM-34P | 30 | 32 | High Alt Day Photo | 4/69-9/70 | 28 | 78.6 | |
| TE | AQM-34Q | 30 | 32 | High Alt Real-time COMINT | 2/70-6/73 | 268 | 91.4 | 34 |
| TF | AQM-34R | 30 | 32 | Improved Long-range | 2/73-6/75 | 216 | 96.8 | 37 |
| | | | | | | 3435 | | |
| | | | | | | | | |

Source: William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, Calif.: Aero Publishers, Inc., 1982).

The percent returned varied significantly from model to model. The fact these UAVs were flying in a war zone probably accounts for many of the losses, but the inability to recover downed UAVs prevented an exhaustive analysis. Using the AQM-34L as the largest statistical data set, it is easy to assert that the percent returned represents a reliability approximation that is good, but does not meet the reliability rates seen in manned aircraft.

Data on the Pioneer UAVs shows the accident rate is still higher than manned aircraft, but some improvement is noted since 1986 as the system matured (table 5).

**Table 5**

**Pioneer UAV Flight Statistics**

| Year | # Mishaps | Flight Hours | Sorties | Percent Sorties Loss | Percent Sorties Accident |
|---|---|---|---|---|---|
| 1986 | 5 | 96.3 | 94 | 2.1 | 5.3 |
| 1987 | 9 | 447.1 | 279 | 2.5 | 3.2 |
| 1988 | 24 | 1050.9 | 577 | 1 | 4.1 |
| 1989 | 21 | 1310.5 | 663 | 1.2 | 3.1 |
| 1990 | 21 | 1407.9 | 668 | <1 | 3.1 |
| 1991 | 28 | 2156.6 | 845 | 1.3 | 3.3 |
| 1992 | 20 | 1179.3 | 676 | 1 | 2.9 |
| 1993 | 8 | 1275.6 | 703 | 1 | 1.1 |
| 1994 | 16 | 1568.0 | 862 | 1 | 1.8 |
| 1995 | 16 | 1752/0 | 692 | 4 | 2.3 |

**Source**: Cmdr Davison, US Navy's Airborne Reconnaissance Office, 15 March 1996.

Data on the Hunter UAV is shown in table 6. The percentage return rate was 99.7 percent when human error is excluded and only hardware/software causes are used. The data reflects results from both early technical and user testing as well as follow-on early training for the Hunter System. There were a total of 12 strikes (UAVs damaged such that they will never return to flight) out of the total 1,207 sorties flown. Human error was assessed as the primary cause for 66 percent (8) of the 12 strikes/losses. Hardware/software was assessed as the cause for the remaining 34 percent (4) strikes. Of the 12 losses, 66 percent (8) occurred during training flights while 34 percent (4) were lost during the early technical or demonstration tests. [1]

**Table 6**

**Early Hunter UAV Flight Statistics**

| Date of Operations | Number of Sorties | Percent Returned | Average Flight Duration |
|---|---|---|---|
| 1/1/91-2/20/96 | 1207 | 99.0 | 2.97 flight hours |

The latest Predator UAV data is shown in table 7. The Predator has been supporting reconnaissance missions in Bosnia and two UAVs have been lost: one to ground fire (Predator 8) and one to an engine malfunction (Predator 1). Used for training now, the GNAT-750 was originally developed for the Central Intelligence Agency and was also used in Bosnia.

**Table 7**

**Predator UAV Flight Statistics**

| Model | Date OPR | Total Flights | Total Flight Hours | Bosnia Flights | Bosnia Flight Hrs | Percent Returned |
|---|---|---|---|---|---|---|
| GNAT-750 | 9/94 - 2/96 | 73 | 161 | | | 100 |
| Predator 1 | 6/94 - 8/95 | 74 | 328 | 10 | 60 | 94 |
| Predator 2 | 9/94 - 8/95 | 87 | 452 | 23 | 145 | 100 |
| Predator 3 | 11/94 - 10/95 | 50 | 205 | 29 | 128 | 100 |
| Predator 4 | 9/95 - 2/96 | 47 | 132 | | | 100 |
| Predator 5 | 2/95 - 11/95 | 99 | 301 | | | 100 |
| Predator 6 | 3/95 - 2/96 | 28 | 90 | | | 100 |
| Predator 7 | 5/95 - 2/96 | 18 | 42 | | | 100 |
| Predator 8 | 7/95 - 8/95 | 11 | 41 | 4 | 20 | 92 |
| Predator 9 | 8/95 - 2/96 | 74 | 476 | 49 | 371 | 100 |
| Predator 10 | 8/95 - 10/95 | 19 | 147 | 15 | 127 | 100 |
| | | 580 | 2375 | 140 | 851 | |

Source: Manny Garrido, Director of Advanced Airborne Systems, Battlespace Inc., Arlington, Va., 22 February 1996.

[1] Mr Bill Parr, US Army Joint UAV Office, Redstone Arsenal, Ala., provided the Hunter data and crash data on 2 April 1996.

# Appendix B

## Worldwide Unmanned Aerial Vehicles

Steven J. Zaloga's article "Unmanned Aerial Vehicles" in the 8 January 1996 issue of Aviation Week and Space Technology provides a comprehensive listing of ongoing efforts in UAV production (table 8). Thirty-four companies, including 16 US companies, are represented here. Nine countries besides the United States are involved in UAV design and production. Included in this group are many peer competitors or nations involved in arms exports.

**Table 8**

**Worldwide UAV Systems**

| Manufacturer | Type | Mission | Weight | Payload | Speed | Endurance | Max. Alt |
|---|---|---|---|---|---|---|---|
| AAI, | | | | | | | |
| Hunt Valley, MD, USA | Shadow 200 | Multimission | 250 | Various | 100+ | 3+ hr. | 15,000 |
| | Shadow 600 | Multimission | 600 | Various | 100+ | 12+ hr. | 17,000 |
| Adv Tech & Engr Co. | | | | | | | |
| (Pty) Ltd.,South Africa | UAOS | Multimission | 275 | Optronic Day Sight | 100 | 3 hr. | 16,400 |
| Aero Tech | | | | | | | |
| of Australia Pty, Ltd. | Jindivik Mk. 4A | Target | 4,000 | — | M 0.86 | 115 min. | — |
| Aerovironment Inc. | | | | | | | |
| Simi Valley, CA, USA | C. 22 | Target | 1,210 | Radio cmd (R/c) | M 0.95 | 2.5 hr. | — |
| | HILINE | HALE Recce | 770 | Autop. datalink, | 120 | 1-2 days | 40,000 |
| | | | | nav. computer | | | |
| | Pathfinder | HALE Recce | 480 | Comm. relay, | — | — | 75,000 |
| | | | | environ. sensing | | | |
| | Pointer | Multipurpose/Recce | 8 lb. | R/c | 25-50 | 2 hr. | 2,000 |
| | SASS-LITE | Multimission | 800 lb. | Autop. | 27 | 4 hr. | 5,000 |

| Manufacturer | Type | Mission | Weight | Payload | Speed | Endurance | Max. Alt |
|---|---|---|---|---|---|---|---|
| Aurora Flight Systems | | | | | | | |
| Manassas, VA, USA | Chiron | Marine Science | 4,630 | Scientific | 100 | 24 hr. | 10,560 |
| | Perseus A | Atmo. Science | 1,750 | Atmospheric | 80 | 5 hr. | 74,000 |
| | | | | sampling | | | |
| | Perseus B | Atmo. Science | 2,500 | Atmospheric | 80 | 36 hr. | 63,000 |
| | | | | sampling | | | |
| | Theseus | Atmo. Science | 8,800 | Scientific | 50 | 48 hr. | 90,000 |
| CAC Systems | | | | | | | |
| Vendomôise, France | ECLIPSE T1 | Target | 300 | IR & RF equip. | M 2.5 | ballistic | 42,000 |
| | ECLIPSE T2 | Target | 450 | IR & RF equip. | M 4.3 | ballistic | 70 mi. |
| | FOX AT1/AT2 | Recce/surv. | 160/250 | R/c, program., track. | 160 | 22 hr./5hr. | 10,500 |
| | FOX TS1 | Target | 160 | Autop., GPS | 190 | 1 hr. | 10,500 |
| | FOX TS3 | Target | 240 | Autop., Nav., GPS | 280 | 1 hr. | 15,800 |
| | FOX TX | Electronic warfare | 250 | Autop., Nav., GPS | 160 | 5 hr. | 10,500 |
| Canadair, Bombardier Inc. | | | | | | | |
| Montreal, Quebec, Canada | AN/USD-501 | Surv./target acq. | 238 | Programmed | 460 | 75 nm. | — |
| | AN/USD-502 | Surv./target acq. | — | Programmable | — | — | — |
| | AN/USD-502 | Surv./target acq. | — | Programmed | — | — | — |
| | CL-227 | Surv./target acq. | 502 | R/c, prog. | 92 | 4 hr. | — |
| | CL 289 | Recce and surv. | 529 | Optical camera, | 460 | 1,242 mi. | 1,970 |
| | | target acquisition | | | | | |
| Daimler-Benz Aerospace | | | | | | | |
| Dornier, Germany | DAR | Antiradar | 264.5 | Pass. radar seeker | 155 | 3 hr. | 9,840 |
| | Seamos | Maritme surv. | 2,337 | Radar, EO | 103 | 4.5 hr. | 13,125 |
| | SIVA | Recce, surv., | 441 | Flir, CCD, TV | 92 | 8 hr. | 8,200 |
| | | target acq. | | | | | |
| Flight Refueling Ltd. | | | | | | | |
| Winborne, Dorset, UK | Raven | Surv./Recce | 185 | Video, Flir | 75 | 3 hr.+. | 14,000 |
| Freewing Aerial Robotics | | | | | | | |
| College Park, MD, USA | Scorpion 60 | Multipurpose | 110 | Various 25 lb. | 100 | 3-4 hr. | 5,000 |
| | Scorpion 100 | Multipurpose | 320 | Flir, EO, 50 lb. | 172 | 4 hr. | 15,000 |
| General Atomics | | | | | | | |
| San Diego, CA, USA | BQM-34A | Target | 2,500 | R/c | 690 | 692 nm. | — |
| | J/AMQ-2 | Target | 519 | R/c | M 0.9 | 15.6 min | — |
| | Altus | High alt. research | 1,600 | — | 130 | 48 hr. | 50,000 |
| | GNAT 750 | Recce/surv./target | 1,126 | Day TV, Flir | 150 kt. | 40 hr. | 25,000 |
| | I-GNAT | Recce/surv./target | 1,140 | Day TV, Flir | 175 kt. | 60 hr. | 32,000 |
| | Predator | Recce/surv./target | 2,085 | Day TV Flir, SAR | 120 kt. | 60 hr. | 25,000 |
| | | | | | | | |
| | Prowler-CR | Recce/surv./target | 200 | Day TV, Flir | 160 kt. | 8 hr.+ | 20,000 |
| Honeywell, Defense | | | | | | | |
| Avionics Systems Div | QF-104J | Target | 23,690 | — | M2.2 | — | — |
| Albuquerque, NM, USA | QF-106 | Target | 35,411 | — | M2.2 | — | — |
| | QR-55 | Target | 7,000 | — | 133 | — | — |
| Israel Aircraft Industries, | | | | | | | |
| Malat Div. Tel Aviv, Israel | Eyeview | Recce, surv., | 174 | Varies | 120 kt. | 4-6 hr. | 10,000 |
| | | & target acq. | | | | | |
| | Helistar | OTH target acq., | 2,450 | computer | 100 kt. | 4.5 hr. | — |
| | | Recce, & surv. | | | | | |
| | Heron | Multipurpose | 2,400 | — | 125 | 52 hr. | 32,000 |
| | Hunter | Recce/surv. | 1,600 | — | 110 | 12 hr. | 15,000 |
| | Pioneer | Recce/surv. | 430 | Computer | 90 kt. | 6.5 hr. | — |
| | Searcher | Recce/surv. | 700 | Computer | 110 kt. | 24 hr. | — |

| Manufacturer | Type | Mission | Weight | Payload | Speed | Endurance | Max. Alt |
|---|---|---|---|---|---|---|---|
| Kaman Aerospace Int.Corp. | | | | | | | |
| Bloomfield, CT, USA | QUH-1B,C,E,M | Target | 9,500 | Radar command | 126 | 155 min. | — |
| | | | | Digital control | | | |
| Kamov Design Bureau | | | | | | | |
| Moscow, Russian Fdr | Ka-37 | Recce, comm. | 550 | Preprog or r/c | 59 kt. | 4.5 min. | 5,200 |
| Lear Astronautics Corp. | | | | | | | |
| Santa Monica, CA, USA | Skyeye R4E-50 | Multipurpose | 780 | 125 | 8+ hr. | 15,000+ | — |
| Lockheed Martin Skunk | | | | | | | |
| Works Palmdale, CA, USA | Dark Star | Acq./Recce/surv. | 8,600 | SAR | 288+ | 8+ hr. | 45,000+ |
| Lockheed Martin | | | | | | | |
| Electronics & Missiles | AQM-127A | Target, SLAT | 2,400 | Inertial, radar | M 2.5 | 55 nm. | — |
| Orlando, FL, USA | | (Super Sonic Low) | | | | | |
| Meteor Acft & Electronics | | | | | | | |
| Rome, Italy | Mirach 20 | Surv./target/acq. | 374 | R/c, prog. | 120 | 240+ | — |
| | Mirach 26 | Surv./target/acq. | 440 | R/c, prog. | 135 | 420+ | — |
| | Mirach-70 | Target | 525 | R/c | 195 | 60 | — |
| | Mirach-100/4 | Target | 594 | R/c, prog. | M 0.8 | 60 | — |
| | Mirach-150 | Recce | 748 | R/c, prog. | M 0.7 | 80 | — |
| Mission Technologies | | | | | | | |
| Hondo, TS, USA | Hellfox | Multimission | 240 | Flir, TV, other | 80 kt. | 4 hr. | 15,000+ |
| Northrop Grumman Corp. | | | | | | | |
| Los Angeles, CA, USA | BQM-74E | Target | 595 | R/c | 530 kt. | — | — |
| People's Rep of China | | | | | | | |
| | B-2 | Target | 123.5 | R/c | 149 | 1 hr. | — |
| | Changkong IC | Target | 5,401 | R/c | 565 | 45 min. | — |
| | D-4 | Target | 308 | R/c | 106 | 2.6 hr. | — |
| Raytheon Acft Co., (Beech) | | | | | | | |
| Wichita, KS, USA | AQM-37 | Target Variant | 620 | Radio cmd./prog. | M 4.0 | 120 nm. | — |
| | AQM-37A | Target | 560 | Programmed | M 0.7-2 | 120 nm. | — |
| | AQM-37C | Target | 581 | Radio cmd./prog. | M 1.0-3 | 120 nm. | — |
| | AQM-37EP | Target | 600 | Radio cmd | M 3.0-4 | 120 nm. | — |
| | | | | preprog. autopilot | | | |
| | MQM-107B/D | Target | 977/1012 | Radio cmd./prog. | M 0.80 | 90m/100m | — |
| | MQM-107D | Target | 977/1012 | Radio cmd./prog. | M 0.80 | 100 min. | — |
| | Upgrade | | | | | | |
| | MQM-107E | Target | 977/1012 | Radio cmd./prog. | M 0.85 | 100 min. | — |
| SAGEM | | | | | | | |
| Paris, France | Crecerelle | Recce/surv./target | 265 | Flir, EW | 155 | 5 hr. | 15,000 |
| | Marula | Recce/surv./target | 165 | Flir, EW | 155 | 5 hr. | 15,000 |
| Scaled Composites | | | | | | | |
| Mojave, CA, USA | Raptor 2 | Environ. research | 2000 | Environt. sensors | 92 | 10 hr. | 65,000 |
| Sikorsky | | | | | | | |
| Stratford, CT, USA | Cypher | Recce | 250 | EO, Flir, etc. | 60 | 3 hr./2,500 | 7,900 |
| Silver Arrow | | | | | | | |
| Rishon-Lezion, Israel | Colibri | Pilot training | 50 | — | 31-100 | 2 hr. | 10,000 |
| | Hermes 450 | Multipurpose | 1000 | Various up to 350 lb. | 57-115 | 25 hr. | 23,000 |
| | Micro-Vee | Tactical UAV | 100 | Video camera | 50-126 | 5 hr. | 15,000 |
| STN Atlas Electronik | | | | | | | |
| Bremen, Germany | Brevel | Recce/surv./target | 330 | Thermal Imaging | 136 | 5.5 hr. | 11,500 |
| | | | | camera | | | |
| | Luna | Optical Recce | 44 | TV, Flir | 124 | 2 hr. | 3,300 |
| | Tucan-95 | Recce/surv./target | 330 | TV, Flir | 155 | 10 hr. | 13,100 |

| Manufacturer | Type | Mission | Weight | Payload | Speed | Endurance | Max. Alt |
|---|---|---|---|---|---|---|---|
| Strela Production Assn. | | | | | | | |
| Orenberg, Russian Fed | La-17MM | Target | 5,070 | Transponder | 560 | 1 hr. | — |
| | La-17R | Recce | 6,835 | Camera | 560 | 1 hr. | — |
| | Dan | Target | 760 | Transponder | 440 | 40 min. | — |
| Tadiran Israel Electronic | | | | | | | |
| Industries Ltd., Israel | Mastiff Mk. 3 | Recce/surv. | 254 | R/c; prog. | 100 | 7+ hr. | — |
| | | & target acq. | | | | | |
| Target Technology Brux, | | | | | | | |
| France & Ashford, UK | Banshee 1 | — | 190 | Flares | 54-200 | 1.5 hr. | 23,000 |
| | Banshee 2 | — | 190 | Flares | 57-236 | 1.5 hr. | 23,000 |
| | IMP | Operator Training | — | — | 15-90 | 0.5 hr. | — |
| | Petrel | Ballistic Target | — | — | M 3.0 | 104 mi. | — |
| | Snipe Mk 5 | Aerial Target | 145 | Flares | 180 | 1.2 hr. | 18,000 |
| | Snipe Mk 15 | Aerial Target | — | Flares | 130 | 0.5 hr. | 5,000 |
| | Spectre | Surveillance, EW | — | CCD camera | 77-150 | 3-6 hr. | 23,000 |
| Teledyne Ryan Aero. | | | | | | | |
| San Diego, CA, USA | 324 | Recce | 2,374 | Program command | M 0.80 | 1,400 nm. | — |
| | Teledyne 410 | Recce/surv. | 1,800 | Program command | 169 kt. | 14 hr@10K | — |
| | BQM-34A | Target | 2,500 | RPV Trk Cntrl Sys. | M 0.97 | 692 nm. | — |
| | BQM-34S | Target | 2,500 | Integ. Trk Cntrl Sys. | M 0.97 | 692 nm. | — |
| | MQM-34D | Target | 2,500 | DTCS | M 0.97 | 692 nm. | — |
| | BQM-145A | Recce | 2,000 | Programmable | M 0.91 | 700 nm. | — |
| | Tier 2+ | Recce | 24,000 | — | 395 | 42hr | 67,300 |
| | YBQM-145A | Recce | 2,000 | Program command | M 0.91 | 700 nm. | — |
| Tupolev Design Bureau | | | | | | | |
| Moscow Russian Fed | DBR-1 Jastreb | Recce | 84,875 | Camera or Elint | 1,740 | 1.5 hr. | — |
| | VR-2 Strizh | Recce | 15,400 | Camera | 685 | 1 hr. | — |
| | VR-3 Reys-D | Recce | 3,110 | Camera or TV | 595 | 15 min. | — |
| Westinghouse Electronic | | | | | | | |
| Huntsville, AL, USA | Star-Bird | Recce, surv., | 280 | Flir, TV | — | 6.5 hr. | — |
| | | C101& target acq. | | | | | |
| Yakolev Design Bureau | | | | | | | |
| Moscow Russian Fed | Shmel | Surv., EW | 286 | R/c uplink | 97 kt | 2 hr. | 9,850 |
| | Yak-060 | Recce, EW | 225 | TV or EW jammer | 110 | 2 hr. | — |
| | Yak-061 | Recce | 285 | TV | 110 | 2 hr. | — |

**Source**: Tim H. Storey, Director of Operations, Teal Group Corporation, Fairfax Va.

# Appendix C

# Contributors

**Lt Col (Colonel select) Bruce W. Carmichael** is a command pilot with more than 4,300 flying hours in T-37, T-38, B-52, and U-2 aircraft. He has a Bachelor of Arts degree in government from Colby College and a Masters in Public Administration degree from Golden Gate University. He is a distinguished graduate of Squadron Officer School and received a National Defense University award as a student at Armed Forces Staff College. Lieutenant Colonel Carmichael is a 1996 graduate of the Air War College. He has commanded the 99th Reconnaissance Squadron (U-2 aircraft) and served on the staff of the United States Pacific Command and on the staff of the Office of the Secretary of Defense in the Defense Airborne Reconnaissance Office.

**Maj Troy E. DeVine** is a senior pilot with more than 3,000 flying hours in the T-37, T-38, and U-2. She is a United States Air Force Academy graduate with a Bachelor of Science degree in engineering mechanics. Major DeVine is a distinguished graduate of Squadron Officer School and is a 1996 graduate of Air Command and Staff College. She has served as the director of combat operations in the 99th Reconnaissance Squadron (U-2 aircraft) and will be attending the School of Advanced Air Power Studies next year.

**Maj Robert J. Kaufman.** Major Kaufman received his USAF commission through ROTC upon graduating Clemson University in 1982 with a degree in electrical engineering. He received a Master of Systems Analysis degree from University of West Florida in 1984 and completed postgraduate work in electrical engineering in 1992 at University of Colorado at Colorado Springs. He has served in a variety of positions to include: electronics engineer and program manager at the USAF Armament Laboratory, section chief and commander of an operational test and evaluation detachment, and USAF Academy instructor and coach. Prior to attending ACSC, he served a tour at Headquarters USAFE where he was a branch chief in the MAJCOM's Computer Systems Field Operating Agency and executive officer for the Directorate of Command, Control, Communications, and Computers. Upon graduating from ACSC, he will be assigned as commander, 509th Communications Squadron, Whiteman AFB, Missouri.

**Maj Patrick E. Pence.** Major Pence graduated from the United States Air Force Academy in 1983 with a degree in electrical engineering. He also holds a Master in systems management degree (1988) from Troy State University in Alabama. After attending pilot training at Laughlin AFB, Texas, Major Pence completed initial F-4 training at Homestead AFB, Florida, and flew the F-4E operationally at Taegu AB, Korea, and Moody AFB, Georgia. After Wild Weasel training at George AFB, California, in 1988, Major Pence flew the F-4G operationally at Clark AB, Philippines; Spangdahlem AB, Germany; and Nellis AFB, Nevada. He flew 37 combat missions in Operation Desert Storm and has flown 118 combat missions in support of Operations Southern Watch, Provide Comfort, and Vigilant Warrior no-fly zones. During this time he served as chief of scheduling and flight commander 81st Fighter Squadron, and as chief of weapons and flight commander 561st Fighter Squadron.

**Maj Richard S. Wilcox** Major Wilcox earned a Bachelor of Science in computer information systems from Arizona State University in 1983. He is a senior pilot with more than 1,500 hours of fighter time in F-111A, D, E, and F aircraft. Major Wilcox is a distinguished graduate from Air Force ROTC, undergraduate navigator training, undergraduate pilot training, and Squadron Officers School. His assignments have included mission-ready flying duties at Royal Air Force Upper Heyford, United Kingdom and Cannon Air Force Base, New Mexico, where he held every qualification available to an F-111 pilot. As a member of Cannon's 524th Fighter Squadron, Major Wilcox flew 19 combat sorties in support of Operation Provide Comfort II. His last assignment was advisor to the 27th Operations group commander in development of Quality Air Force initiatives for six fighter squadrons and two base-hosted detachments.

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