U.S. UNMANNED AERIAL VEHICLES IN COMBAT, 1991-2003

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Executive Summary

Between 1991 and 2003, the United States used a variety of unmanned aerial vehicles (UAVs) in combat operations. These included the Pioneer, the Pointer, the Hunter, the Predator, the Global Hawk, the Dragon Eye, the Desert Hawk, and the Shadow. During those thirteen years the role of UAVs expanded from mere reconnaissance to target designation and attack. Advantages of UAVs over manned aircraft systems include eliminating pilot risk, saving money, providing long-term real-time video reconnaissance, and reducing the time between target identification and destruction. UAVs are especially useful for extremely long reconnaissance missions and for missions in areas of extreme danger. The percentage of unmanned aircraft sorties should continue to grow as UAV capabilities increase.

Table I: U.S. Unmanned Aerial Vehicles Used in Operations, 1990-2003

UAV Type	Operations	Years Used	Locations
RQ-2 Pioneer	DESERT STORM ALLIED FORCE IRAQI FREEDOM	1991 1999 2003	Kuwait, Iraq Serbia Iraq
FQM-151 Pointer	DESERT STORM IRAQI FREEDOM	1991 2003	Kuwait Iraq
RQ-5 Hunter	ALLIED FORCE IRAQI FREEDOM	1999 2003	Serbia Iraq
RQ-1 Predator	PROVIDE PROMISE, JOINT ENDEAVOR, JOINT GUARD SOUTHERN WATCH ALLIED FORCE ENDURING FREEDOM IRAQI FREEDOM	1995-1997 (1998)-2003 1999 2001- 2003	Bosnia-Herzegovina Iraq Serbia Afghanistan Iraq
MQ-1 Predator	ENDURING FREEDOM IRAQI FREEDOM	2001- 2003	Afghanistan Iraq
RQ-4 Global Hawk	ENDURING FREEDOM IRAQI FREEDOM	2001- 2003	Afghanistan Iraq
Dragon Eye	IRAQI FREEDOM	2003	Iraq
Desert Hawk	IRAQI FREEDOM	2003	Iraq
RQ-7	SHADOW	2003	Iraq

Table II: UAV and Manned Reconnaissance Aircraft Advantages

Unmanned Aerial Vehicles	Manned Aircraft
No casualties	Faster
Less expensive per aircraft (the cost of the original Predator was a fifth that of an F-16)	Direct control and more situational awareness allows greater flexibility
Can fly longer missions to provide near real-time reconnaissance (not subject to human endurance limitations)	Better performance in bad weather
Reduces time between target identification and destruction	Airframes incorporate more stealth technology
Space and payload for pilot and life support equipment available for other uses	Not as dependent on ground and satellite signals that may fail
Can fly into more hostile environments	More likely to return if hit
Smaller (more difficult to detect than manned aircraft without stealth)	Refuelable by aerial tanker
Easier to store and ship	Tolerates rougher runways

Table III: UAV and Satellite Advantages

Unmanned Aerial Vehicles	Satellites
Less expensive	Not subject to weather
Easier to launch (in long run uses less fuel)	Stays aloft much longer
Can carry weapon to destroy target	More difficult for enemy to detect
Can be retrieved more easily	More difficult for enemy to destroy
Can be replaced more easily	Little maintenance required
Can loiter over target area	More stable platform for cameras/sensors
Can fly much closer to target	Imagery generally of higher quality
Easier to repair	Does not need to be refueled

LESSONS LEARNED

- **UAV flights should be carefully synchronized with each other and with the flights of other systems.**
- **UAVs should be improved to reduce their vulnerability to weather, enemy air defenses, and mechanical and communication failures.**
- **UAVs should be specialized and used for a greater variety of missions.**
- **The Air Force should develop countermeasures to enemy UAVs.**

ELABORATIONS

- **UAV flights should be carefully synchronized with each other and with the flights of other systems.**

Modern air component commanders lead an orchestra of air and space assets. Instruments include manned and unmanned aircraft, cruise and ballistic missiles, and satellites. Each instrument offers its own advantages and disadvantages. Familiarity with the strengths and weaknesses of various UAVs allows commanders to select them for the most appropriate missions depending on such factors as threat, weather, and time. Unmanned aircraft should supplement rather than replace manned systems and satellites.[1] Over Bosnia and Serbia in the 1990s, for example, satellites and manned airplanes provided reconnaissance from high altitudes, but UAVs were needed at lower altitudes where enemy air defenses increased risks to airborne pilots.[2]

Commanders have had more success with UAVs when they were flown in coordination with manned aircraft and satellites. For example, UAVs operated more successfully after air supremacy or at least superiority has been achieved. Moreover, armed UAVs and unarmed UAVs working together can enhance the utility of each.[3]

In high-sortie operations, the number of UAV sorties should rise with the number of manned aircraft strike sorties because of the need for more target imagery. During Operation ALLIED FORCE over Serbia in 1999, for example, there were sometimes as many as 300 manned aircraft strike sorties on a day on which only four UAVs were airborne at a time.[4] Not enough real-time imagery was available to accurately strike all the targets.

During the same operation, certain targets lacked UAV coverage, while others had too much. All UAV units posted liaison officers at the Combined Air Operations Center (CAOC). Despite this, USAF Predators and U.S. Army Hunter UAVs sometimes arrived over the same targets at the same time and ended up observing and recording each other. This duplication of effort demonstrated the need to centralize UAV control and to improve mission planning.[5]

UAVs offer real-time video simultaneously to decision-makers regardless of how far they are from the battlefield. Commanders far from the battlefield, and in some cases outside the theater, have sometimes diverted or preempted flights launched by local commanders.[6] Field commanders have complained that UAVs have encouraged micromanagement of the air battle. During Operation ALLIED FORCE in 1999, some

NATO pilots were angered because a commander in Italy using a UAV as his “eye in the sky” denied their requests to attack targets of opportunity. Such oversight was intended to limit civilian casualties. What appeared to a pilot of a high-flying attack aircraft to be an armored column might turn out to be a refugee convoy. At times the ground commander wanted to send a UAV over the target to verify it. By the time the relatively slow UAV arrived over the target area, the target sometimes disappeared. The delay meant lost opportunity.[7]

In Operations ENDURING FREEDOM and IRAQI FREEDOM in 2001-2003, the need to coordinate UAV flights with the flights of manned strike aircraft decreased because increasing numbers of Predators could strike the targets they found, firing air-to-ground missiles. Once they discovered an enemy asset, usually on a moving vehicle, they could destroy it before it got away. Sometimes calling in additional aircraft was not necessary.

In the future cruise missiles might take out most fixed targets while UAVs destroy mobile targets. Commanders will have to plan carefully to avoid collisions. Several UAVs might fly in cooperative groups or in formation. This will require enhanced mission control capabilities and automatic collision avoidance. The need to coordinate the flights of UAVs with other aircraft, manned or unmanned, is likely to increase.[8]

A warrior is more eager to shoot one of many arrows than to throw his only spear. More willing to lose is more willing to use. Theater commanders have been more willing to risk UAVs than manned aircraft at low altitudes over enemy territory because they have been more willing to sacrifice them. Being less expensive and having no pilots to preserve or rescue, UAVs sometimes flew where manned aircraft did not. The greater expendability of UAVs has encouraged theater commanders to use aircraft where they were not used before.

- **UAVs should be improved to reduce their vulnerability to weather, enemy air defenses, and mechanical and communication failures.**

In the years 1990-2003, UAV proved to be more vulnerable than manned aircraft to bad weather, enemy air defenses, and mechanical and communication failures. By 1998, the peacetime attrition rate for the Pioneer UAV was 17 times higher than that for manned aircraft.[9] By early 2002, 23 of 65 Predators built, or over a third, had crashed.[10] During combat operations between 1999 and 2003, at least 19 UAVs crashed. The exact cause of each loss over enemy territory is not always evident because there is no pilot to confirm why the craft went down. No doubt the enemy claimed to have destroyed some that went down because of weather or mechanical failure.

UAVs proved to be fair weather aircraft. During Operation DESERT STORM in 1991, rain eroded the laminated wood propellers of Pioneer UAVs.[11] During the 1990s, precipitation, fog, and crosswinds often prevented safe takeoffs and landings. Lightweight UAVs such as the Predator, the Hunter, and the Pioneer were less able to cope with high winds than heavier manned aircraft. The Predator in Afghanistan during Operation ENDURING FREEDOM, for example, could not take off or land when crosswinds exceeded 17 knots.[12] The early Predator models were especially susceptible to wing icing and could not be used in freezing weather. In December 1998, commanders withdrew Predators from Hungary because of winter icing problems.[13] At least three Predators crashed in Afghanistan between October 2001 and February 2002 because of bad weather and ice.[14] A first-generation Predator could not be equipped with de-icing equipment without degrading its ability to carry a full complement of sensors or a full fuel load.[15] The larger and more powerful MQ-9 Predator B is equipped with de-icing equipment.[16] Even the faster, heavier, and more robust Global Hawk UAV demonstrated poor performance in bad weather. At least one of the two lost in Afghanistan during Operation ENDURING FREEDOM crashed because of poor weather.[17]

Heat was another UAV weather nemesis. Predators based in Pakistan and Kuwait during Operations ENDURING FREEDOM, SOUTHERN WATCH, and IRAQI FREEDOM endured temperatures as high as 113 degrees. Despite use of sunshades in front of hangars, mobile ground cooling units, shorter taxi distances, and streamlined ground checks, excessive heat threatened to cause structural damage to the aircraft and to degrade the critical electronic communication links that guided them. Launches became impossible during the middle of the day in the summer.[18]

Besides weather, enemy air defenses brought down many UAVs in the period between 1991 and 2003. In comparison with manned aircraft, they generally flew lower and slower, were less stealthy, were more fragile, and flew in areas of greater risk.[19] Enemy antiaircraft artillery, surface-to-air missiles, and interceptors brought down as many as 16 UAVs over Bosnia, Serbia, Afghanistan, and Iraq in the years 1995-2002. Iraqi air defenses downed no manned aircraft in those years but destroyed at least four Predators. In the Balkans, Serb machine gunners in helicopters downed a few UAVs while flying alongside them.[20] During its first overseas deployment between July and November 1995, the Predator system lost three airplanes, at least two to Serb ground fire.[21] The Air Force could improve the survivability of UAVs in a number of ways, such as making them faster, flying them higher, making them more durable, making them more stealthy, equipping them with chaff, and flying them only in areas in which air supremacy has already been attained.[22] Such efforts would make UAVs more costly, reducing one of their advantages over manned aircraft. Moreover, if UAVs flew only where risk was slight, they would not be needed in place of manned aircraft.

Table IV: USAF Manned Aircraft and UAV Operational Losses, March 1999-May 2003

Operation	Manned aircraft losses	UAV losses
ALLIED FORCE (Serbia)	2 (F-16 and F-117)	4 Predators
ENDURING FREEDOM (Afghanistan)	3 (B-1, 2 MC-130s)	9 (7 Predators, 2 Global Hawks)
SOUTHERN WATCH (Iraq)	0	5 Predators
IRAQI FREEDOM (Iraq)	2 (F-15, A-10)	1 Predator
TOTAL	7	19 (17 Predators, 2 Global Hawks)

Despite their vulnerability to enemy air defenses, UAVs were more often the victims of mechanical or communication failure. Many of the UAVs were so small and light that their mechanical systems lacked the redundancy and durability built as a matter of course into manned aircraft. Certain UAV models were rushed to the battlefield even as they were being developed and had not been tested extensively. Landing gear on some UAVs was lighter and more prone to fail than that on manned aircraft. Runways had to be especially flat and smooth for the generally delicate and fragile UAVs. The Predator RQ-1A, for example, demanded a 5,000 by 125-foot hard surface runway.[23] In 2001, the Pentagon's operational test and evaluation office argued that the Predator UAV system was "not operationally effective or suitable."[24] At about the same time, a RAND study questioned the Predator's operational suitability based on its maintainability, reliability, safety, and supportability.[25]

UAVs fell not only to mechanical but also to communication failures. Because pilots at remote ground stations guided them in flight, UAVs depended more than manned aircraft upon ground stations and satellite links. In the years through 2003, such communications were often broken or interrupted by such factors as bad weather, electronics failures, or enemy jamming.[26] During Operation DESERT STORM in 1991, friendly electromagnetic interference caused a Pioneer UAV to crash.[27] To control the aircraft, the ground station had to have a direct line-of-sight connection with the aircraft, preventing the UAV from descending behind mountains, buildings, or trees without losing the link.[28] The Predator was the first operational UAV to use the global positioning system (GPS) for navigation, eliminating the need for a direct line of sight connection with a ground station, but communications remained a problem.[29] In September 2002, a Predator flying in the southwest Asia theater flew into a cloud and lost contact with its operator. The pilot reestablished communication with it twice, but the UAV would not respond to his signals and failed to return.[30]

The absence of an on-board pilot with situational awareness able to compensate for unexpected aircraft movements contributed to UAV losses. Generally, UAV pilots with experience flying manned aircraft controlled UAVs more effectively than those without such experience. They were more familiar with the behavior of aircraft in various situations and were more likely to respond appropriately.[31]

- **UAVs should be specialized and used for a greater variety of missions.**

UAVs began only as reconnaissance instruments. During Operation DESERT STORM in 1991, the U.S. Marine Corps, Navy, and Army had as much success with the Pioneer UAV as a reconnaissance drone as the U.S. Air Force with the Lightning Bug in Vietnam. For example, a Pioneer flying over northeastern Saudi Arabia detected the Iraqi attack on Khafji, enabling U.S. air strikes to decimate the invaders. Pioneers also served as artillery spotters for a battleship in the Persian Gulf.

The Air Force acquired the Predator UAV from its joint Defense Department developers after it demonstrated its reconnaissance capability over Bosnia in the mid-1990s, but that role was not enough.[32] During Operation ALLIED FORCE over Serbia in 1999, the Air Force equipped some of its Predators with laser designators so that they could mark armored targets for manned attack aircraft, but the war ended before they could be used.[33] During Operations ENDURING FREEDOM and IRAQI FREEDOM, Predators and Global Hawks supplied real-time imagery directly to airborne AC-130s, fighter, and bombers so that the strike airplanes could concentrate on hitting rather than finding their targets.[34]

In Serbia, Predators sometimes detected targets such as tanks and enemy troop formations that moved before manned aircraft could arrive to strike them. This delay between discovery and destruction of a target encouraged the Air Force to arm the Predator with missiles.[35] In 2001, the Air Force successfully test-fired Hellfire air-to-surface missiles from Predators against armored vehicles on the ground in Nevada. This allowed the Predator to destroy a target almost immediately after finding it. In 2002 during Operation ENDURING FREEDOM, armed Predators serving the Central Intelligence Agency destroyed human targets on the ground, performing as attack aircraft in combat for the first time. In Afghanistan, Predators fired some 40 Hellfire missiles by the end of 2002.[36] The Air Force used Predators for both reconnaissance and attack over Iraq during the last full year of Operation SOUTHERN WATCH in 2002, targeting mobile air defense systems. On March 22, 2003, a Predator found and destroyed a radar-guided antiaircraft artillery site in southern Iraq, firing an AGM-114K "Hellfire II" missile. It was the first Predator strike of Operation IRAQI FREEDOM.[37]

The Air Force's attack version of the Predator is called the MQ-1. A larger Predator attack aircraft called the MQ-9 is under development.[38] The newer, larger Predators have more powerful turboprop engines, higher ceilings, strengthened wings, greater payload capabilities, and wing de-icing systems. They can carry up to eight Hellfire missiles.[39] In addition, the Air Force and the Defense Advanced Research Projects Agency is developing a new unmanned combat aerial vehicle (UCAV) designed from the start as a strike aircraft. Called the X-45, it will work with manned systems to suppress enemy air defenses, and might eventually take the place of the F-117.[40] Large and fast, the X-45 will incorporate stealth technology and possibly an in-flight refueling capability.[41] It might even use directed radiation as a weapon.[42] Another experimental UAV called the X-47 is also being developed for use on ships.

For strategic reconnaissance and surveillance, the Air Force developed Global Hawk. Designed as an alternative to the U-2, the Global Hawk can fly faster, higher, and farther than the Predator. It is also much larger to accommodate more sensor equipment and fuel. After test flights from the west coast to Alaska and Australia, the Global Hawk entered combat during Operation ENDURING FREEDOM in Afghanistan after the terrorist attacks on the United States on September 11, 2001, supplementing Predator missions.

During Operation ENDURING FREEDOM, the Air Force first used a new Force Protection Airborne Surveillance System (FPASS) involving small UAVs nicknamed Desert Hawk. They provided local surveillance around the perimeter of U.S. controlled air bases in Afghanistan. Desert Hawk UAVs also protected air bases in Kuwait during the last stages of Operation SOUTHERN WATCH and in Iraq during Operation IRAQI FREEDOM.[43]

Table V: Comparison of Predator and Global Hawk

Category	**Predator (RQ-1)**	**Global Hawk (RQ-4)**
Cruise Speed	84 miles per hour	400 miles per hour
Altitude	Up to 25,000 feet (RQ-1A) Up to 45,000 feet (RQ-1B)	Up to 65,000 feet
Range	454 miles (for 24 hour loiter)	1,380 miles (for 24 hour loiter)
Payload	450 pounds (RQ-1A) 750 pounds (RQ-1B)	2,000 lbs.
Length	27 feet	44 feet
Wingspan	48.7 feet	116 feet
Sensors	Television, infrared, synthetic aperture radar	Electro-optical, infrared, synthetic Aperture radar
Use	Tactical reconnaissance (RQ-1B adds missile capability)	Strategic reconnaissance And surveillance

The X-45, Global Hawk, Predator, and Desert Hawk were designed for different purposes. They were not interchangeable. Each UAV had its own advantages and disadvantages for certain missions. The same was true for UAVs of the other services. Centralized UAV development during the period 1993-1998 convinced the Department of Defense that each service should be allowed to develop its own UAV types because one design could not satisfy all the services.[44] The U.S. Navy, for example, desired UAVs capable of being launched from ships and hovering over one spot, and the Marine Corps favored small man-portable UAVs. The X-47 Pegasus, that flew experimentally in 2003, was designed to launch from and land on an aircraft carrier. [45] The Hummingbird UAV will fly like an Army helicopter, taking off and landing vertically.[46] During Operation IRAQI FREEDOM the Marines used a very small surveillance UAV called Dragon Eye. The Air Force's 46th Test Group at Holloman AFB, New Mexico, teamed up with New Mexico State University's Physical Science Laboratory to create an Unmanned Aerial Vehicle Test Center (UTEC) to evaluate various new models of USAF UAVs.[47]

- **The Air Force should develop countermeasures to enemy UAVs.**

Although the United States currently leads the world in the development of UAVs for combat, that was not always the case. In the 1970s, Israel led the world in UAV development. In the future, enemies of the United States might develop their own UAV capabilities, partly because they are less expensive and do not risk pilots. Whatever weapon the United States uses successfully against other countries might one day be used against the United States.

When Secretary of State Colin Powell presented the case against Iraq at the United Nations before Operation IRAQI FREEDOM, he warned that Iraq was developing its own unmanned aerial vehicles to dispense chemical and biological agents.[48] The

Anglo-American invasion of Iraq removed the threat, but terrorists might consider the use of unmanned aerial vehicles as a cheap alternative to the use of manned aircraft. For that reason, the United States should not only be developing UAVs but also developing countermeasures to them.

The Future

The history of UAVs in combat has revealed much about their weaknesses and strengths and has given insight into how their utility can be improved. Between 1991 and 2003, UAVs proved to be useful for only part of the spectrum of air roles and missions. They were not yet capable of shooting down enemy airplanes, airlifting troops or equipment, dropping heavy bombs, or refueling other aircraft. They complemented and supplemented manned airplanes but did not yet make them obsolete. UAVs probably will never replace manned aircraft or satellites completely, but they will provide a commander with more tools. The continued development of the attack UAV as an instrument of strategic bombardment, interdiction, or close air support will no doubt produce new lessons about how and when they should be employed with other manned and unmanned systems.

UAVs will increasingly take the place of manned aircraft, assuming some of the roles they fulfilled in the past. Future unmanned combat air vehicles (UCAVs) can conceivably **outmaneuver manned jets** because the latter have reached the limits of the human body to turn and accelerate. Some day UAVs might even dogfight, controlled by remote pilots on the ground who can direct their craft without concern for how many Gs they can tolerate.[49]

Technological improvements in UAV performance are already underway. Newer UAVs under development should have **more autonomous control** so that they need less pilot correction. This will include automatic collision avoidance. **Improved mission control** capabilities should allow multiple UAVs to fly in a cooperative groups and formations. Improved coordination of UAV flights with the flights of manned aerial vehicles, satellites, cruise missiles, and other UAVs would further enhance their utility. **More unitized structures**, with fewer parts, joints, and fasteners, should reduce weight, cost, and repairs.[50] Future UAV airframes will increasingly **incorporate antennas and sensors** as wing and fuselage components. **Active flow control** technology should reduce propulsive volume, allowing UAVs to be smaller, lighter, and carry more payload. **Increasing UAV fuel efficiency** or increasing fuel capacity will allow unmanned aerial vehicles to fly farther, conduct more complex missions, and loiter longer. It would also allow commanders to require fewer UAVs. Weaponized UAVs of the future might employ not only heavier and more advanced precision guided munitions but also **directed energy weapons** such as destructive laser beams.[51]

Making UAVs **faster** would decrease their vulnerability to enemy fire and increase their ability to confirm the hostility of potential targets in time for manned aircraft strikes. Increasing UAV **stealthiness** and the variability of UAV flight paths would also make them harder for an enemy to knock down. Giving them more **all-weather capability** by the addition of more effective deicing equipment would also improve their utility in the winter. Increasing the **quality of UAV sensors** through miniaturization would reduce the need for U-2 and satellite reconnaissance. Real time video imagery could be enhanced. UAVs might have to sacrifice some of their small size and lightness to accommodate some of the additional equipment necessary for effectively **countering enemy air defenses**. For example, UAVs might dispense flares and chaff like manned aircraft. Reducing the ability of enemy defenders to jam UAV **communications** would also enhance the vehicles' performance.[52] Adding an **inflight refueling** system would allow UAVs to loiter longer over enemy territory without having to return all the way to home base. Improving landing gear and increasing weight to counter crosswinds would allow UAVs to take off and land on more airfields and at more times. In a December 11, 2002 speech, President George W. Bush commented, "Now it is clear that the military does not have enough unmanned aerial vehicles."[53] As the percentage of combat aircraft that are unmanned increases, the roles they fill will also increase.

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[1] There are some exceptions. Air Force Chief of Staff General Ryan envisioned the Global Hawk as a replacement for, and not a complement to, the U-2. Thomas P. Ehrhard, A Comparative Study of Weapon System Innovation: Unmanned Aerial Vehicles in the United States Armed Services (Washington, DC: Johns Hopkins University Dissertation, 2000) 558.
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[5] Ibid, 2.
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[7] Ibid, 4.
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[9] Ehrhard, 375.
[10] Marc C. Herold, "The Problem With the Predator," (http://www.cursor.org/stories/dronesyndrome.htm) 3-4.
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[26] Newman, 4.
[27] Ehrhard, 374-375.
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[32] Ibid, 539-541.
[33] UAV Forum, News 1999 (http://www.adroit.com/uavforum/library/news99.htm) 5. Newman, 2.
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