AU/ACSC/0230D/97-03

UNMANNED AERIAL VEHICLES (UAVS)

AN ASSESSMENT OF HISTORICAL OPERATIONS AND FUTURE POSSIBILITIES

A Research Paper

Presented To

The Research Department

Air Command and Staff College

In Partial Fulfillment of the Graduation Requirements of ACSC

by

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March 1997

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Preface

I have supported the acquisition of this nation's intelligence collection, processing, exploitation, storage, and dissemination systems throughout my entire career. Three events during my career were sparks that ignited phenomenal changes in how we administer the U.S. military, including the reconnaissance business. Although they are all interrelated, they all caused different effects on the evolution in reconnaissance. The events were the demise of the Soviet Union, the shrinking defense budget, and the Persian Gulf War.

The collapse of the Soviet Union eliminated the primary requirement for the billions of dollars we spent on strategic intelligence systems and community infrastructure. The "new world order" that arose was not predictable, not traditional, and not suitable for appraisal by our strategic intelligence system. Gone were the requirements for intense monitoring of Soviet ballistic missile submarine activities, ICBM testing, aircraft development, and the status of Warsaw Pact ground forces. Now we are trying to monitor Tiananmen Square-like civil uprisings, ethnic cleansing, and refugee migration.

The shrinking defense budget is a fact of life. Gone are the hordes of intelligence analysts, the "stovepiped" architectures and disciplines, and classification "green doors" keeping critical intelligence data from the warfighter. The military is striving to find cheaper solutions to military needs and also provide more flexibility to dynamic, unpredictable, and unfamiliar situations. For example, what does a civil riot in Albania look like, and how can we assess its impact on U.S. national policies and objectives? How do we not only share that information with deployed U.S. forces but also our allies or even the Russians?

The last catalyst for change was Desert Storm, not from its military successes, but its intelligence failures. Many involved at the operational and tactical levels during that conflict assert that our Intelligence System broke-down and did not support the tactical commander. This is an incorrect assertion. Our Intelligence System did exactly what it was designed to do—support the National Command Authority and the CINC at the strategic and operational levels of war. Desert Storm, from an intelligence standpoint, was an unforeseen type of war. What was "broken" was in fact a realization of our lack of forethought for fielding intelligence support systems for the warrior fighting at the pointy end of the spear. Another outcome, probably with more consequence to the future of armed conflict than highlighting intelligence system failures, was the lack of U.S. casualties during the war. This nation, and in fact most western nations, have become extremely sensitive to conflict-inflicted human suffering.

All of these events ignited the fervor for unmanned aerial vehicles (UAVs) to perform critical missions without risk to U.S. personnel and to do it more cost effectively than comparable manned systems. But the most amazing aspect to the recent fervor for UAVs is that it's coming from the "fighter-minded" community of the Air Force. The Air Force has programmed significant funds to procure and field a highly capable UAV reconnaissance force. Prior to UAVs coming in vogue, the Air Force had shrunk its manned reconnaissance force, retiring the SR-71, moving the RF-4 to the reserves then retirement, and now considering the fate of the workhorse U-2. UAVs, and a new appreciation for space-based reconnaissance, are becoming part of the Air and Space Force mentality. It will be interesting to observe through the beginning of the next millennium how this fighter-mentality Air Force expands the role of UAVs into other manned domains of employing air power.

I must thank those who helped bring all this data and thought together. Thanks to go Maj Brian Bergdahl (USAF/XORR), Mr. Parr (OSD/DARO), Maj Steve Hargis (ASC/RAV), and my facility advisor LtCol Mark Barnhart. Also, thanks go to my family for allowing me, sometimes against their wishes, the time to complete this project. I hope those that may read this report can expand on some of my ideas and dream of things I haven’t even thought about.

Abstract

UAVs are not new; they have a long history in aviation. Pilotless aircraft, whether as aerial targets or for more belligerent purposes, have a history stretching back to the First World War. The annual *Jane's All the World's Aircraft* has described UAVs since the 1920s.[1] From early use as target drones and remotely piloted vehicles (RPVs), the U.S. employed UAVs for reconnaissance purposes during the Korean War, and then as highly classified "special purpose aircraft" during the conflict in Southeast Asia. UAV missions flew mainly to cover areas determined too hazardous for manned reconnaissance aircraft. Additionally, these missions occurred at a fraction of the cost of and risk to manned aircraft.[2] The Air Force also investigated the potential utility of expanding the UAV's role beyond reconnaissance, specifically in air defense suppression and strike missions, but never operationally fielded these possibilities. Interest in UAVs dwindled through the 1970s and 1980s.

General awareness and military-wide acceptance of the utility of UAVs for U.S. military operations did not emerge again until their use during Operations Desert Shield and Desert Storm. During Desert Storm, with most of the U.S.'s fleeting manned tactical reconnaissance assets committed, UAVs emerged as a critical source of intelligence at the tactical level. Recently, UN and NATO activities in the former Yugoslavia also brought international attention to the advantage of military UAVs. According to *Jane's Unmanned Aerial Vehicles and Targets*, at least fourteen countries are using or

developing over 76 different types of surveillance, target acquisition, electronic warfare, and expendable UAVs.

Currently, the U.S. DOD is aggressively developing two classes of UAVs to support the *Joint Vision 2010* quest for Information Superiority—tactical and high-altitude endurance (HAE) UAVs. The HAE UAVs will be theater-level assets controlled predominately by the Joint Task Force Commander and provide broad area surveillance over the battlefield. The tactical UAVs will come under the control of lower echelons, notionally battalion level commanders, and provide much more focused coverage.

The Air Force is now envisioning, as described in *New World Vistas*, other potential missions for UAVs beyond the traditional reconnaissance mission. Also, Micro UAVs, less than 15 cm long, could provide the basis for even more potential applications. It does seem clear that applications for UAVs will expand. Increased sensitivity to risking human life in combat is pushing the U.S. military towards expanding UAV applications. Also, the rapidly advancing technologies are pulling us towards the economic viability of expanding the role of UAVs in the future DOD force structure. As the U.S. military evolves to become a more flexible force across the spectrum of conflict, clearly UAVs will be an integral part of our ability to meet the challenges of the 21st century.

Notes

[1]Kenneth Munson, *Jane's Unmanned Aerial Vehicles and Targets*, (Surrey, UK, Jane's Information Group Limited, 1996).

[2]*Annual Report: Unmanned Aerial Vehicles (UAVs) - August, 1995*, n.p.; on-line, Internet, 18 February 1997, available from http://www.acq.osd.mil/daro/homepage/daro1.html.

Chapter 1

Introduction

> *It is only the enlightened ruler and the wise general who will use the highest intelligence of the army for purposes of spying, and thereby they achieve great results. Spies are a most important element in war, because on them depends an army's ability to move.*
>
> —Sun Tzu

Interest in the development of unmanned aerial vehicles (UAVs) in the United States has risen and fallen relative to aircraft encountered threat environments and political pressures. This is a typical pattern behind the motivation to fund many warfighting technologies and systems. History shows that it usually takes an international incident threatening our national security to highlight a military deficiency and to stir a desire for new, innovative methods to support national objectives.

The Cold War

The genesis event for the UAV was the downing of Francis Gary Powers' U-2 spy plane over the Soviet Union on 1 May 1960 by an SA-2 missile.[1] During this intense time of the Cold War, U.S. policy centered on our ability to stay abreast of the Soviet's strategic nuclear posture. This country did not want to experience a nuclear "Pearl Harbor." Of greatest concern was the Soviet intercontinental ballistic missile (ICBM) programs under development in the heart of the Soviet Union.

In 1954, President Eisenhower authorized the development of the long range U-2 reconnaissance airplane by Lockheed's Kelly Johnson in his secret 'skunk works.' Eisenhower had hoped to persuade the Soviet leader Khrushchev to adopt an "open skies" policy of mutual aerial surveillance as a deterrent to surprise attacks and a reduction of the tensions among the super powers. Khrushchev rejected Eisenhower's proposal during their meeting on 21 July 1955 in Geneva. Within months after the unsuccessful Geneva summit, President Eisenhower authorized U-2 overflights to collect photography of Soviet missile development and deployment activities. ICBMs became a real threat to this country after the Soviets launched "Sputnik-1" on 4 October 1957. For four years the U-2s flew through Soviet airspace without interference nor official objection. To have accused the U.S. of overflights would have been to admit the Soviet military's inability to defend the Soviet Union against U.S. planes.

Shootdown of Gary Power's U-2

Powers' intended U-2 flight on 1 May 1960 was from Pakistan to Norway to photograph the Soviet's Tyuratam missile test facility. Knowing only that Powers had not arrived in Norway, U.S. officials began a cover-up story by announcing on 2 May that a National Aeronautics and Space Administration (NASA) plane was missing on a routine weather reconnaissance flight over Turkey. On 5 May, Khrushchev announced that the Soviets had shoot down a U.S. airplane. On 6 May, NASA, continuing its cover-up story, said the plane was a U-2 on a high-altitude research flight. It said the pilot, identified as a Lockheed civilian employee, reported having trouble with his oxygen equipment and strayed off course over Turkey and drifted into Soviet airspace by mistake. The State Department followed by announcing there had been no deliberate attempt to violate Soviet air space. The event climaxed on 7 May when Khrushchev announced that the pilot, imprisoned since 1 May, was alive in Moscow and had confessed that he was on a spy mission across the heart of the Soviet Union, scoring a damaging propaganda blow against the U.S. Subsequently, President Eisenhower publicly announced that he shouldered all the blame, stating that he had personally approved the flights only because of their vital support to U.S. security.

The shoot-down of Powers' U-2 was a devastating blow to the U.S.'s international prestige. Therefore, this country became significantly sensitive to manned reconnaissance. After the Powers incident, the U.S. stopped all U-2 overflights of the Soviet Union. Subsequently, efforts increased on the development of satellite reconnaissance systems as well as the SR-71 and reconnaissance drones. Having promised to discontinue the offensive U-2 flights, the U.S. found itself critically unable to collect intelligence of Soviet missile and bomber developments. The first successful CORONA spy-satellite mission (KH-1 mission 9009) did not occur until August 18, 1960, 110 days after Powers' demise.[2] It was 18 months before the first U.S. photo-reconnaissance satellites provided intelligence on Soviet missile sites.[3] But satellite-based photography, because of much higher altitudes over the target area, could not provide one foot high-resolution photography as provided by airborne collectors.[4] In fact, the first CORONA satellites' (KH-1 through KH-4 series) best ground resolution was 25 feet. Starting in August 1963, KH-4A missions began providing 6 ft. resolution imagery.

Although some high-level officials in the Pentagon advocated funding the development of UAVs, neither DOD nor CIA provided any significant funding.[5] Support for unmanned reconnaissance drones quickly subdued again within the U.S. military. In fact, the first development effort by Ryan Aeronautical Company, code-named *Project Red Wagon*, started in July 1960 but terminated later that year by the Air Force. It is now evident that the Air Force's lessening interest in UAVs was because of the ongoing development of the SR-71 and spy satellite programs (e.g., CORONA). Also, because President Eisenhower's commitment to end overflights of the Soviet Union, there appeared little need for reconnaissance drones.

Shootdown of a U-2 During Cuban Missile Crisis

Development activities for reconnaissance drones solidified again after the downing of another U-2, this time while overflying Cuba on 27 October 1962 to determine the status of the Soviet nuclear missile sites. A Soviet SAM, protecting the ballistic missile sites, destroyed the aircraft. The pilot died in the crash, thus again fueling a national outcry for unmanned reconnaissance. Classified work began rapidly on the D-21 Tagboard and the AQM-34 Lightning Bug.

The Vietnam War

The Air Force's development of a new UAV reconnaissance system evolved from a target drone airframe (the BQM-34).[6] The Cuban situation vividly demonstrated the need for quick intelligence gathering while also demonstrating the political sensitivity with using manned collection platforms. As U.S. involvement in the Vietnam War broadened, the Air Force fielded this country's first operational photo-reconnaissance unmanned aircraft, the AQM-34 Ryan Aeronautical "Lightning Bug."

During the Vietnam War, Lightning Bug capabilities evolved to not only support photographic missions, but subsequent modifications also supported other missions: real-time video, electronic intelligence (ELINT) that increased the safety of manned aircraft flying over hostile areas, electronic counter measures (ECM), real-time communications intelligence (COMINT), and PSYOPS leaflet dropping. Some UAV missions, conducted at very low altitudes, provided critical battle damage assessments (BDA) to confirm that our strike aircraft had hit their assigned targets.[7] But as the Vietnam War wound down, so did interest in reconnaissance UAVs.

The Persian Gulf War

General awareness and military-wide acceptance of the value of UAVs for U.S. military operations did not emerge again until their use during Operations Desert Shield and Desert Storm. Prior operations in Grenada and Libya had identified the need for an inexpensive, unmanned, over-the-horizon (OTH) targeting, reconnaissance, and BDA capability for force commanders. In response to these earlier operations, the Navy started the Pioneer UAV program in the late 1980s. By the time Iraq invaded Kuwait in 1990, the Navy, Marine Corps, and Army operated UAVs. With 85% of the U.S.'s manned tactical reconnaissance assets committed, UAVs emerged as a "must have" capability. Six Pioneer systems (three with the Marines, two on Navy battleships, and one with the Army) participated. They provided highly valued near real-time reconnaissance, surveillance, and target acquisition (RSTA) and BDA, day and night. They often worked with the Joint Surveillance and Target Attack Radar System (JSTARS) to confirm high-priority mobile targets.[8]

Today's Preparation for Tomorrow

Currently, the U.S. DOD is aggressively developing two classes of UAVs to support *Joint Vision 2010* quest for Information Superiority—tactical and high-altitude endurance UAVs—with two systems in each class. Three of these UAV programs are utilizing a fast-paced acquisition strategy known as Advanced Concept Technology Demonstration (ACTD). The tactical class consists of the Tactical UAV (called Outrider) and the Tier II Medium-Altitude Endurance UAV (called Predator). These UAVs will be tactical assets, controlled at tactical echelons, and provide focused coverage close to the forward-line-of-troops (FLOT). The two high-altitude endurance (HAE) UAVs, Tier II Plus (Global Hawk) and Tier III Minus (DarkStar), be theater-level assets and primarily provide deep, long dwell, broad area surveillance over the battlefield.

Ongoing operations in Bosnia by the Pioneer system and the developmental Predator system have highlighted the unique contributions that UAVs make to the warfighter. Thus, a new set of international dilemmas (the Persian Gulf War and recent experiences in Bosnia) have caused the DOD to step up and define requirements for UAVs to support an increasing variety of peace-through-war operations, and the need for different classes of UAVs to cover the operational envelope. Today, the Services are quickly accepting the unique and vital characteristics of UAVs and are envisioning other potential applications. The Air Force's *New World Vistas* describes many applications for UAVs beyond the traditional reconnaissance mission, such as uninhabited combat aerial vehicles (UCAVs) that could be more effective for particular missions than are their inhabited counterparts. Reusable UCAVs that deliver unguided or coordinate guided weapons may be more cost effective when compared to sophisticated missiles (e.g., AGM-86C cruise missiles) that cost $1 million each. Another vision is the potential viability of Micro Unmanned Aerial Vehicles (MicroUAV). These tiny drones, no more than 15 cm in span or length, could scout inside buildings, for example, collect biological-chemical samples, or attach themselves to structures and equipment to act as listening and/or video posts.

Notes

[1]William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, CA: Aero Publishers, 1982) 1.

[2]Remarks by Admiral William O. Studeman, Acting Director of Central Intelligence at the signing of the Executive Order Declassifying Early Satellite Imagery, 24 February 1995.

[3]Wagner, 1-4.

[4]Ibid., 19.

[5]Ibid., 19.

[6]Ibid., 23.

[7]*Annual Report: Unmanned Aerial Vehicles (UAVs) - August, 1995*, n.p.; on-line, Internet, 18 February 1997, available from http://www.acq.osd.mil/daro/homepage/daro1.html.

[8]*Annual Report: Unmanned Aerial Vehicles (UAVs) - August, 1995*.

Chapter 2

The Past

And ye shall know the truth, and the truth shall make you free.

—Bible; New Testament; John 8:32

As mentioned earlier, UAV employment has supported military reconnaissance needs since the First World War. Historically, most UAVs have been very small, some even hand-launched like toy radio-controlled airplanes, and mostly confined to the reconnaissance role. What follows are descriptions of the more capable U.S. UAV programs.

The AQM-34 Lightning Bug Drone

The Air Force's development of the "Lightning Bug" reconnaissance system evolved from a target drone airframe (the Ryan Aeronautical Company's FIRE FLY drone, DOD designation BQM-34) that had begun in 1962 under the streamlined and accelerated BIG SAFARI acquisition program.[1] The Cuban missile crisis early in the decade vividly demonstrated the need for quick intelligence gathering while highlighting the political sensitivity with using manned collection platforms. By 1964, this BIG SAFARI acquisition program fielded this country's first photo-reconnaissance unmanned aircraft, the AQM-34 Ryan Aeronautical Lightning Bug.

Figure 1. AQM-34 Lightning Bug

The Strategic Air Command (SAC) 100th Strategic Reconnaissance Wing (SRW) operated these drones, mostly employing them in Southeast Asia. Most missions involved photography and real-time video, electronic intelligence (ELINT), and communications intelligence (COMINT). Some UAV missions, conducted at very low altitudes necessitated by poor weather conditions, provided battle damage assessments (BDA) to confirm that U.S. strike aircraft had hit their assigned targets.[2] Flights over Communist China started in 1964, proceeding on to sorties over North Vietnam, Loas and Cambodia. With aircraft flying initially from Bien Hoa AB, South Vietnam, and later from U-Tapao, the program was a huge success. Not only did the UAVs provide photographs and ELINT on crucial enemy MiG and SAM defenses, they also acted as “clay pigeons” to determine the precise command codes used to detonate the enemy SAMs’ warheads. This intelligence kept U.S. strike and bomber aircraft safe from all but the worst ravages of the Soviet-supplied SAMs, affording U.S. aircraft the ability to jam the incoming missiles at opportune moments.[3]

Lightning Bug employment commonly used throughout the war called for an air launch from a specially modified C-130, the "mother ship." After flying the preprogrammed (although sometimes remotely piloted) route, the drones recovered using a parachute system automatically deployed over a designated area, bringing the drone softly to earth. A helicopter would retrieve the drone and return it to the unit operating center for film retrieval and vehicle refurbishment. In 1966 a new mid-air retrieval system (MARS), initially developed to capture satellite photographic "buckets," was adopted for the drones. A helicopter would snatch the drone's parachute and return to the recovery location with the drone hanging below the helicopter. The procedure was fairly successful in Southeast Asia.[4]

The intelligence community tasked the Lightning Bug under a classified operations order code-named *Buffalo Hunter*. The first operational flight for the Lightning Bug in Southeast Asia was 20 August 1964; the last flight was on 30 April 1975. In all, the 100th SRW flew 3,435 operational sorties in Southeast Asia.[5] During the course of the war the Lightning Bug provided some invaluable results. Some accomplishments were:

- Obtained the first photographic evidence of SA-2 missiles in North Vietnam.
- Took the first photographs of Soviet MiG-21D/E aircraft in North Vietnam.
- Obtained photographic evidence of Soviet helicopters in North Vietnam.
- Photographed an SA-2 missile detonation at close range (20 to 30 feet).
- Provided the only daily low altitude bomb damage assessment (BDA) of B-52 raids during "Linebacker II."[6]

Table 1. Different Types of Lightning Bugs

RYAN 147 MODEL	MILITARY MODEL	MISSION	DATES UTILIZED	NO. LAUNCH	PERCENT RETURNED
A		Fire Fly - First Recce Demo	4/62-8/62		
B		Lightning Bug First Big-Wing High Altitude Photo Bird	8/64-12/65	78	61.5%
C		Training & Low Altitude Tests	10/65		
D		Electronic Intelligence (ELINT)	8/65	2	
E		High Altitude ELINT	10/65-2/66	4	
F		Electronic Counter Measures (ECM)	7/66		
G		Longer B Model w/ Larger Engines	10/65-8-67	83	54.2%
H	AQM-34M	High Altitude Photo	3/67-7/71	138	63.8%
J		First Low Altitude Day Photo	3/66-11/77	94	64.9%
N		Expendable Decoy	3/66-6/66	9	0
NX		Decoy & Medium Altitude Day Photo	11/66-6/67	13	46.2%
NP		Interim Low Altitude Day Photo	6/67-9/67	19	63.2%
NRE		First Night Photo	5/67-9/67	7	42.9%
NQ		Low Altitude Hand Controlled	5/68-12/68	66	86.4%
NA/NC[a]	AQM-34G	Chaff & ECM	8/68-9/71		
NC	AQM-34H	Leaflet Dropping	7/72-12/72	29	89.7%
NC (M1)	AQM-34J	Day Photo & Training			
S/SA		Low Altitude Day Photo	12/67-5/68	90	63.3%
SB		Improved Low Altitude Day Photo	3/68-1/69	159	76.1%
SRE	AQM-34K	Night Photo	11/68-10/69	44	72.7%
SC	AQM-34L	Low Altitude	1/69-6/73	1,651	87.2%
SC/TV	AQM-34L/TV	SC Model w/ Real Time Video	6/72-	121	93.4%
SD	AQM-34M	Low Altitude Photo / Real Time Data	6/74-4/75	183	97.3%
SDL	AQM-34M(L)	Loran Navigation	8/72	121	90.9%
SK		Operations from Carrier	11/69-6/70		
T	AQM-34P	High Altitude Day Photo	4/69-9/70	28	78.6%
TE	AQM-34Q	High Altitude Real Time COMINT	2/70-6/73	268	91.4%
TF	AQM-34R	Improved Long Range	2/73-6/75	216	96.8%
		TOTAL		3,435[7]	83.9%

Source: William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, CA: Aero Publishers, 1982), 213.

[a]NA/NC Combat Angel drones, for possible prestrike ECM chaff-dispensing missions, operated on standby in the CONUS by Tactical Air Command.

Table 1 summarizes the employment of the Ryan Lightning Bug in Southeast Asia. It is easier to follow the numerous versions of the AQM-34 using the Ryan Aeronautical Co.

designation, which is the 147 model with letter suffix designations. The Lightning Bugs also photographed the prisoner of war camps, including the famous Hanoi Hilton within the deadly air-defense system around the capitol. Returning POWs considered the low-level overflights by these aircraft a real morale booster.[8]

The employment concepts for the drones evolved as operating techniques and technologies improved, allowing the system to mature. The percent returned column of the table indicates a significant improvement in system effectiveness during the span of AQM-34 operations. Another performance aspect the Air Force experimented with was the "stealthiness" of the vehicles, as a method to improve system success. Drone modifications included installation of a screen mesh over the engine inlet, special blankets, and radar absorbing paints.[9]

In July 1976 Tactical Air Command (TAC) took over the force, which was redeployed to Davis-Monthan AFB. Soon afterward, TAC had a major change of heart about the utility of these UAVs and retired the force within three years, most likely due to the revitalization of the TR-1/U-2R production run. Of the retired force, thirty-three refurbished "stealthy" AQM-34s went to Israel, but the bulk remained in storage.[10]

Other Applications for the Bug

In 1970, the Israeli government requested U.S. assistance in overcoming the Egyptian-Soviet air-defense system along the Suez Canal. Inquiries in to the DOD revealed that, short of close-in strafing attacks, there were no effective means of suppressing missile and anti-aircraft sites. Such attacks would, of course, be extremely hazardous to the pilots and their tremendously expensive aircraft. The attrition would be unacceptable in terms of lives, dollars, and assets.

Although the U.S. Air Force had purposely ignored drone weapons delivery, the Israeli dilemma highlighted a fact that NATO countries could face the same threat in Europe. In 1971 the Air Force received $14 million from Congress for the "Have Lemon" program to demonstrate new approaches to accurately delivery stand-off weapons. Within a year of contract initiation, an Air Force-Ryan Aeronautical team successfully demonstrated the launch of a Lightning Bug drone that subsequently launched an AGM-65 Maverick electro-optical seeking missile against a radar control van. The demonstration program also included the Lightning Bug dropping a electro-optical glide bomb, "Stubby Hobo," against a target. Although the demonstration program succeeded and was ready for deployment in early 1972, the drone weapon program never deployed operationally. In Vietnam, the enemy camouflaged their SAM sites very well, hindering the ability of the drone operator and the missile system to identify the targets. Even though the drone weapon delivery never deployed, the U.S. DOD began realizing the utility of using a UAV attack system to go in on the first wave and soften up the target so that manned aircraft could go in and finish the job.[11]

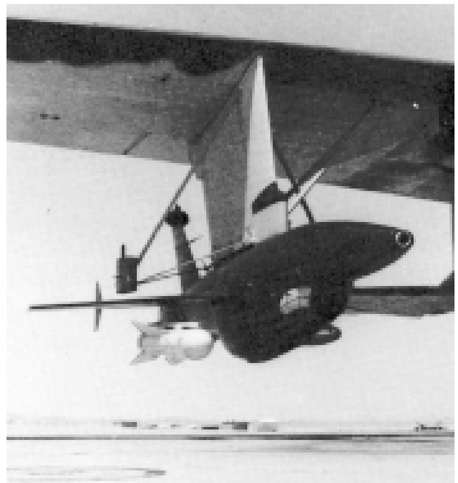

Figure 2. AQM-34 with PGM

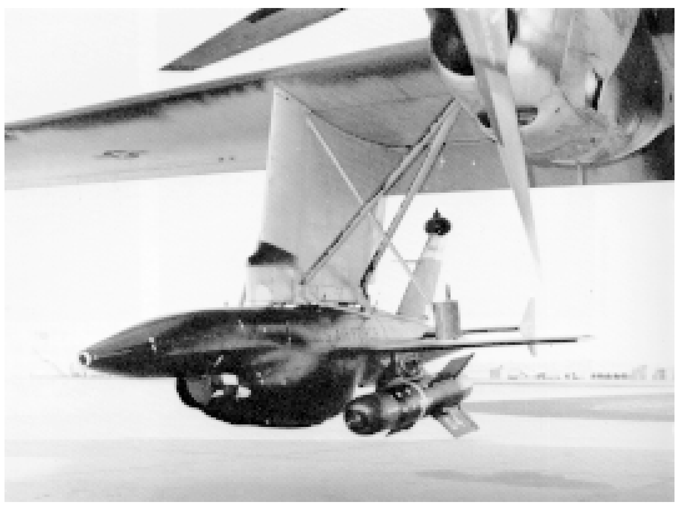

Figure 3. AQM-34 with Maverick Missile

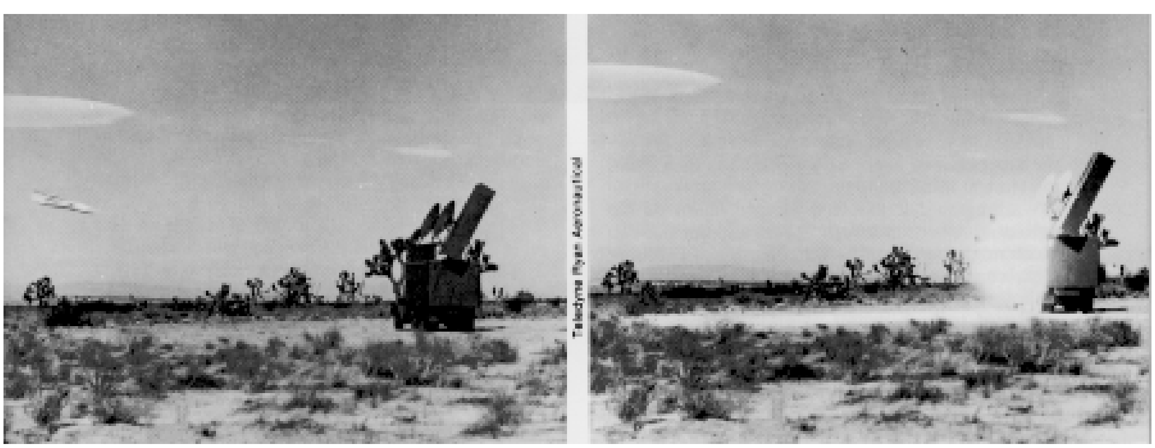

Figure 4. Maverick Striking Target

The D-21 Tagboard Drone

Mindful of the Gary Powers U-2 shootdown aftershocks and the inevitable political sensitivities concerning manned overflight of large expanses of denied territory, the Lockheed 'Skunk works' designed a tri-sonic, air-launched, reconnaissance vehicle designated the D-21 (code-named *Tagboard*). By June 1963 the engineers mated a D-21 to its launch aircraft. The launch platform was a modified A-12 called the M-12, the predecessor to the SR-71. Built primarily from titanium, the D-21 had a range of 1,250 nautical miles, cruised at Mach 3.3 and could reach an altitude of 90,000 ft. Once released from the M-12 by a Launch Control Officer (LCO) riding in the M-12, the drone flew its sortie independently. The D-21 inertial navigation system (INS) was programmed to fly the desired track and flight profile and execute camera on and off operations, allowing it to satisfactorily execute the perfect photo-recce sortie. After completing its camera run, the drones' INS commanded the auto-pilot system to descend the vehicle to its 'feet-wet' film collection point. The entire palletized camera unit then ejected and parachuted towards the surface. As the drone continued it descent, barametrically activated explosive charges would destroy the vehicle. A C-130 equipped with a Mid-Air Recovery System (MARS) would retrieve the camera unit containing its valuable film and fly it to a base for processing and analysis.

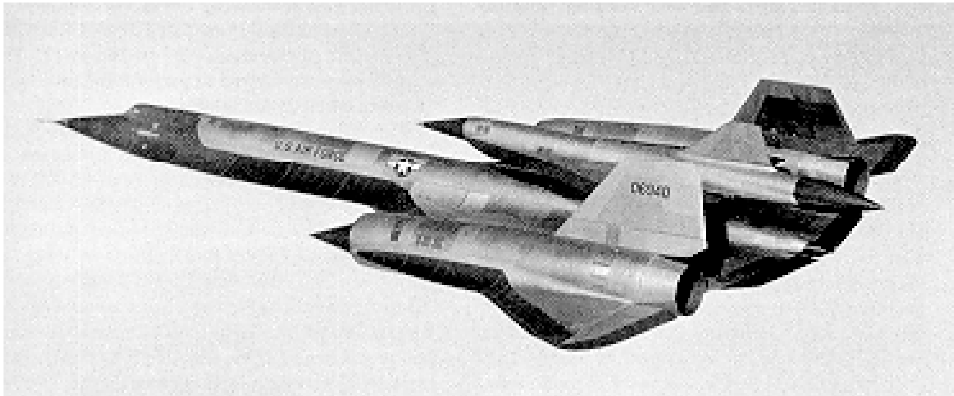

Figure 5. D-21 Drone Riding M-12

By 1966 the program had progressed and was ready to perform vehicle separation. The mission profile called for the M-12 to fly at Mach 3.2 and commence a slight pull up at 72,000 ft, then push over to maintain a steady 0.9 g. With controllability checks completed and its ram-jet burning, the LCO initiated vehicle separation by throwing the switch that fired off a blast of compressed air from a cylinder fitted in the M-12's pylon. This pioneering work achieved its first successful separation on 3 July 1966. But the third launch, on 31 July 1966, resulted in disaster. After drone separation, a combination of factors caused a ram-jet stall on the D-21, which slammed down onto the aft launch pylon of the M-12. The impact caused the M-12 to violently pitch-up, exposing the large underside chine area of the aircraft to the immense pressure of a Mach 3.2 airstream, which quickly ripped the M-12 in half. Miraculously, both crewmen survived the aircraft's disintegration, but the LSO drowned upon entering the water. As a result of this mishap, Lockheed canceled the M-12/D-21 program.

Instead, Lockheed modified the D-21s to incorporate a less sensitive inlet and allow launch from B-52s of the 4200th Test Wing at Beale AFB. This new operation, code-named *Senior Bowl*, produced its own array of problems. Launched from a slower, lower platform, the D-21 was accelerated to its operational speed and altitude by a booster rocket fitted to the underside of the drone, which separated from the vehicle at cruising speed. Only five B-52/D-21 operational sorties took place. The collection areas for these highly classified missions were targets in China. During one such mission a D-21 drone malfunctioned and crashed in a remote mountainous region of China. The incident resulted in China, thinking this was an SR-71 overflight, protesting to the U.S. that SR-71s were violating their sovereign airspace. On another operational flight, problems arose during the recovery of the vital reconnaissance camera pallet. While descending by parachute, the MARS-equipped recovery aircraft failed to capture the unit. In the subsequent water recovery attempt, a U.S. Navy destroyer snagged the floating parachute and keel-hauled the reconnaissance package, thus, destroying the film.

The Air Force canceled *Senior Bowl* due to operational difficulties, political concerns and the high cost of these limited-duration flights.[12] After the Air Force retired the Lightning Bug fleet in 1975, the U.S. DoD was not involved in any notable UAV programs until the late 1980s.

The Pioneer Tactical UAV

Another international crisis again highlighted the utility of UAVs at enhancing our warfighting capabilities. During Operation Desert Storm, coalition commanders could see across the entire battlespace, understand infinite details of the enemy, and lead coalition forces to a new level of precision engagement never seen before. A wide spectrum of collection platforms; satellites, Joint STARS, AWACS, UAVs, and others, collected reconnaissance. The U.S. Army, Navy, and Marine Corps capitalized on their use of

UAVs to help accomplish the task of battlefield-intelligence gathering, sometimes referred to as intelligence preparation of the battlefield.

The employment of UAVs clearly demonstrated their ability to complement other information systems, providing a total battlespace view to all commanders, from the tactical battlefield commander to the operational-level decision makers.[13] According to the interim DOD report to Congress on Desert Shield and Desert Storm, UAVs performed "direct and indirect gunfire support, day and night surveillance, target acquisition, route and area reconnaissance and BDA." The Pioneer system "appears to have validated the operational employment of UAVs in combat." [14]

Figure 6. Pioneer Tactical UAV

The Pioneer system was the primary UAV employed by the U.S. during the conflict. Ironically, it was the Israelis that originally developed the Pioneer system. Because of the Israeli success with UAVs and identified U.S. military needs for an unmanned penetrating reconnaissance platform, the Navy started the Pioneer Program in 1985. The Pioneer UAV provides imagery intelligence (IMINT) for tactical commanders on land and at sea (originally launched from Navy Iowa-class battleships, today from LPD-class ships).[15]

The Israeli company Israel Aircraft Industries (IAI) teamed with the U.S. company AAI to form Pioneer UAV, Inc. and produce the Pioneer UAV for the U.S. military. The Army also procured Pioneer systems from the Navy and received its first Pioneer system in 1990. The following table outlines the characteristics of the Pioneer UAV.

Table 2. Pioneer UAV System Characteristics

Cost	Average $875k per vehicle; $400k for IR sensor; $100k for TV
Dimensions	Wingspan - 16.9 ft.; Length - 14.0 ft.
Weight	Max. Gross Weight - 447 lb. (includes 66 lb. fuel)
Runway	Rail, Runway, Rocket Assist Takeoff; Recovers in to a net or with arresting gear
Payload	35-60 lb.
Range	185 km (maximum)
Duration	5 hr.
Airspeed	95 knots maximum, 65 knots cruise
Altitude	Ceiling - 15,000 ft.; Normal ConOps - 5,000 ft.
Survivability	No ECM or low observable technologies
Deployment	two C-141s or five C-130s
C2 Link	C-band & UHF uplink / C-band downlink
Sensors	EO or IR
Total System	5 Air Vehicles, 1 Ground Control Station (GCS), 1 Portable GCS, 4 Remote Receiving Stations, 1 Truck Mounted Launcher

The U.S. deployed forty-three Pioneers to the theater that flew 330 sorties, completing over 1,000 flight hours. During the “left hook” maneuver, UAVs enabled the U.S. Army to take out every piece of enemy artillery that could have threatened friendly forces, then maneuver to cut-off and destroy Iraqi forces in the Kuwaiti Theater of Operations (KTO). The Navy used UAVs to monitor the Kuwaiti coastline and Iraqi naval facilities. UAVs helped search for mines and spotted every 16-inch round fired by U.S. battleships. The ability to spot each round real-time allowed a significant increase in the accuracy of the big guns. The Marine Corps used the Pioneer to fill the gap created by the retirement of their RF-4s. Although the imagery resolution provided by Pioneer did not match that provided by the retired RF-4s, the information did significantly support Marine air power in the Gulf, providing target information and BDA.[16]

In ten years, the U.S. Pioneer system has flown nearly 14,000 flight hours and supported every major U.S. contingency operation to date. Since 1994, it has flown over Bosnia, Haiti, and Somalia. Currently, there are nine systems in the active force: five Navy, three Marine Corps, and one assigned to the Joint UAV Training Center at Ft. Huachuca, AZ. The Pioneer system will begin drawdown and phase-out in FY2000 as its replacement, the Outrider Tactical UAV, enters the inventory.[17]

The Hunter Tactical UAV

The U.S. Army envisioned the Hunter Joint Tactical UAV to provide both ground and maritime forces with near-real time imagery within a 200-km radius of action, extendible to 300+ km by using another Hunter as an airborne relay. The system can operate from unimproved airfields to support the ground tactical force commanders at the FLOT. Although the prime contractor is TRW, the Hunter system is a derivation of a UAV developed by Israel Aircraft Industries (IAI), Israel.

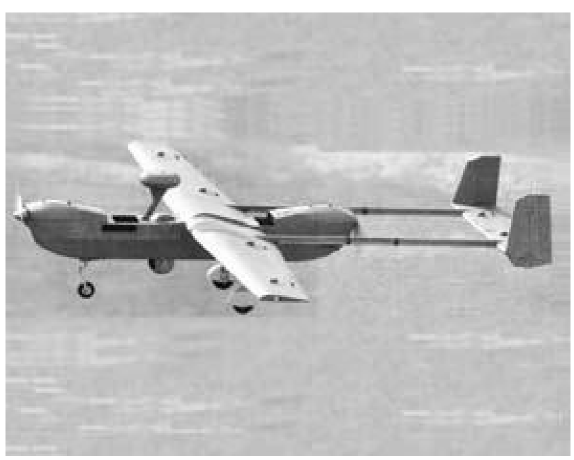

Figure 7. Hunter Tactical UAV

Following an October 1995 JROC recommendation, the USD (A&T) decided to let the Hunter contract expire after delivery of only seven systems, ending the acquisition program. Currently, the Army is operating the Hunter systems in the CONUS to support contingency operations, UAV doctrine and concept development, and exercises and training. For example, at the August 1996 live-fire demonstration at Eglin AFB, a Hunter was a testbed for a laser designator demonstration. The UAV illuminated the target for a PGM from a manned weapon system, thereby, limiting operator risk.

Table 3. Hunter UAV System Characteristics

Cost	N/A, program canceled
Dimensions	Wingspan - 29.2 ft.; Length - 22.6 ft.
Weight	Max. Gross Weight - 1,546 lb. (includes 300 lb. fuel)
Runway	Unimproved runway
Payload	185 lb.
Range	200 km (maximum)
Duration	8-12 hr.
Airspeed	110 knots maximum, 90 knots cruise
Altitude	Ceiling - 15,000 ft.
Survivability	No ECM or low observable technologies
Deployment	sixteen C-130s
C2 Link	C-band LOS
Sensors	EO or IR
Total System	8 Air Vehicles, 3 Ground Control Station (GCS), 4 Remote Receiving Terminals, 2 Ground Data Terminals, 1 Launcher & Recovery System

Notes

[1] William Wagner, *Lightning Bugs and Other Reconnaissance Drones* (Fallbrook, CA: Aero Publishers, 1982), 23.

[2] Ibid., 5.

[3] Anthony M. Thornborough, *Sky Spies: Three Decades of Airborne Reconnaissance* (London, England: Arms and Armor Press, 1993), 35.

[4] Dana A. Longino, LtCol, USAF, *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios* (Air University Press, Maxwell AFB, AL, 1994), 5

[5] Wagner, 200.

[6] Ibid., 24-25.

Notes

[7]Although this column only adds up to 3,423 sorties, multiple sources indicate the total sorties were 3,435. No reason for this discrepancy was identified in the source documents.

[8]Longino, 3.

[9]Ibid., 5.

[10]Thornborough, 36-38.

[11]Wagner, 180-185.

[12]Crickmore, Paul F., *Lockheed SR-71: The Secret Missions Exposed* (Osprey Aerospace, 1993), 36-41.

[13]Longino, 9.

[14]Secretary of Defense Dick Cheney, *Conduct of the Persian Gulf Conflict, An Interim Report to Congress,* July 1991, 6-8.

[15]Department of Defense, *UAV Annual Report FY 1996* (Washington, DC: Defense Airborne Reconnaissance Office, 6 November 1996), 14.

[16]Longino, 9-10.

[17]*UAV Annual Report FY 1996*, 14.

Chapter 3

The Present

> *I was looking at Predator [imagery displays] yesterday.…It was flying over an area…at 25,000 feet. It had been up there for a long time, many hours, and you could see the city below, and you could focus in on the city, you could see a building, focus on a building, you could see a window, focus on a window. You could put a cursor around it and [get] the GPS latitude and longitude very accurately, remotely via satellite. And if you passed that information to an F-16 or an F-15 at 30,000 feet, and that pilot can simply put in that latitude and longitude into his bomb fire control system, then that bomb can be dropped quite accurately onto that target, maybe very close to that window, or, if it's a precision weapon, perhaps it could be put through the window… I'd buy a lot of UAVs in the future.*
>
> —Admiral William A. Owens
> Vice Chairman of the Joint Chiefs of Staff
> June, 1995

Until the time frame of the Gulf conflict, basically two types of assets provided reconnaissance: manned airborne platforms and satellites. Both of these classes of collectors have positive and negative aspects. Manned platforms (U-2, SR-71, JSTARS, AWACS, Guardrail, ES-3, ATARS on F-16 and F/A-18 aircraft, etc.) provide high resolution data, are extremely flexible at adapting to multiple mission scenarios, and can loiter (with air refueling) within the conflict region up to the limitations of the crew (about eight hours). Crew limitations also limit their ability to react quickly to global conflicts. Additionally, manned platforms have extra costs and weight allowances associated with crew requirements. But the most significant limitation of manned platforms is the risk to the crew. The American populous and government leaders are becoming increasingly sensitive to loss of life scenarios.

Satellite reconnaissance, because of the principles of orbital mechanics, can see virtually anywhere in the world every day. They also collect information across wide areas and at no risk to human life. Orbital mechanics also limit a satellite's coverage of a conflict area to about 20 minutes each orbit pass, with only about three to four passes a day, depending on target latitude. Continuous coverage of a conflict region from space would require a large satellite constellation (similar to the Global Positioning System constellation) costing billions of dollars. Also, satellite orbits are constant, enabling an enemy to easily predict when the satellites will observe the region and, therefore, conceal activities and forces. Satellites also tend to be expensive and considered "national assets," primarily used by the national decision makers on strategic and operational issues. Dissemination of satellite-derived intelligence to the tactical battlefield commander was a major fault of the national systems during the Gulf conflict.

UAVs have demonstrated their ability to fill the gap between manned airborne and satellite reconnaissance platforms. UAVs provide complimentary capabilities to the commander by conducting day or night reconnaissance, surveillance, and target acquisition (RSTA), rapid battle damage assessment (BDA), and battlefield management in high-threat or heavily defended areas where the loss of a high-value, manned system is likely but near-real-time information is required.[1] As mentioned earlier, the Pioneer UAV system did provide critical support to coalition forces during the Gulf conflict. But significant gaps still existed among all the reconnaissance platforms. Theater commanders perceived an intelligence shortfall during the Persian Gulf conflict. A memorandum from the Under Secretary of Defense (Acquisition and Technology) (USD (A&T)) outlined the need and characteristics for a system to fill this need.

> *Current national, theater, and tactical intelligence collection assets are insufficient to provide for urgently needed, critical, worldwide, releasable near real time intelligence on fixed and mobile targets for the in-theater Commander-in-Chief (CINC), Joint Forces Commander (JFC), and the National Command Authority. No system exists which can provide continuous all-weather coverage of worldwide targets. National assets cannot provide long dwell coverage of small mobile or fixed targets. Existing theater airborne assets are limited by endurance of less than 8-12 hours, limited numbers, and possible loss of air crew over hostile areas. Ground based systems cannot operate in denied and/or hostile areas without the possibility of loss/capture of personnel.*
>
> —USD (A&T) Memorandum, 12 July 1993

Although UAVs were successful in providing critical information during the Gulf conflict, they could not provide high resolution data covering large areas. The Pioneer system was basically a video camera flying about 5,000 feet above the battlefield. But the true success of the Pioneer system was not in the quality of intelligence it provided to the battlefield commander, rather its greatest success was that of changing opinions and attitudes of military officials about the role of UAVs in future reconnaissance architectures. UAVs are a critical element of the U.S. forces' ability to obtain and retain dominant battlefield awareness (DBA), crucial aspects of supporting *Joint Vision 2010* and the Air Force's concept of *Global Engagement*.

The Yugoslavian Civil War

Again an international crisis brought the UAV back into the spotlight. This time the crisis was the civil war in the former Yugoslavian republics. The DOD's UAV programs got a real boost from the impressive performance of the Predator UAV during the crisis.

MajGen Kenneth Israel, director of the Pentagon's Defense Airborne Reconnaissance Office (DARO), recently stated that: "Predator has done a remarkable job. It helped the general impression about UAVs in the Services and in the Department in a very positive way. Because it's been so successful, I think there's been an awakening. It has sparked support for UAVs across the board and for our planned family of UAVs."[2]

The Defense Airborne Reconnaissance Office

In FY 1994, DOD created the DARO to unify airborne reconnaissance architectures and enhance the acquisition of manned and unmanned airborne assets and associated ground systems. Since its conception, the DARO built an Integrated Airborne Reconnaissance Strategy for a comprehensive defense-wide airborne reconnaissance capability that will work in concert with the National Reconnaissance Office (NRO) space-based assets. The DARO oversees the Defense Airborne Reconnaissance Program, which consists of U-2, RC-135, and EP-3 aircraft programs, non-lethal tactical and endurance UAVs, the Distributed Common Ground System (DCGS), advanced reconnaissance technology and sensors, and the Common Data Link (CDL). DARO develops, demonstrates, and acquires improved airborne reconnaissance capabilities, and performs system-level tradeoffs for manned aircraft and UAVs, sensors, data links, data relays, and associated processing and dissemination systems. The DARO also establishes and enforces commonality and interoperability standards for airborne reconnaissance systems.

The DARO is utilizing the Advanced Concept Technology Demonstrations (ACTDs) process to demonstrate and evaluate promising UAV concepts through early user involvement in realistic operational scenarios. ACTDs started in FY 1994 for the Medium

Altitude Endurance UAV (Tier II or Predator), the Conventional High Altitude Endurance (HAE) UAV (Global Hawk), and the Low Observable HAE UAV (DarkStar). In FY96 the DOD terminated the Hunter UAV program and initiated a Tactical UAV (TUAV or Outrider) ACTD.

The DARO envisions that the future DOD family of UAVs will consist of two classes —tactical and high-altitude endurance UAVs—with two systems in each class. The tactical class consists of the Outrider UAV and the Predator UAV. The UAV Joint Program Office (JPO), under the Navy Service Acquisition Executive, manages both programs. The two HAE UAVs are the Global Hawk (Tier II Plus) and the DarkStar (Tier III Minus). Both programs are being developed by the Defense Advanced Research Projects Agency (DARPA).

The HAE UAVs will be theater-level assets controlled predominately by the Joint Task Force Commander. The tactical UAVs will come under the control of lower echelons. The HAE UAVs will provide broad area surveillance over the battlefield, while the tactical UAVs will provide much more focused coverage. The HAE UAVs will provide high-resolution digital (still frame) imagery, while the tactical UAVs will provide predominately video. The HAE UAVs will provide extremely high bandwidth data; the tactical systems will provide data at much lower bandwidths. The HAE UAV systems, designed to be relocateable, will usually operate from fixed bases. The tactical systems will be fully deployable.[3]

The Outrider Tactical UAV

Alliant Techsystems is the prime contractor for the Outrider UAV Program, with the contract awarded in May 1996. Alliant's offering is a derivative of the dual-winged Hellfox UAV, built by Mission Technologies, Hondo, Texas. During the initial two-year, $52.6M ACTD program, the DARO plans to procure six Outrider systems (each with four air vehicles and two Humvee trucks with trailers) and an additional eight attrition air vehicles.

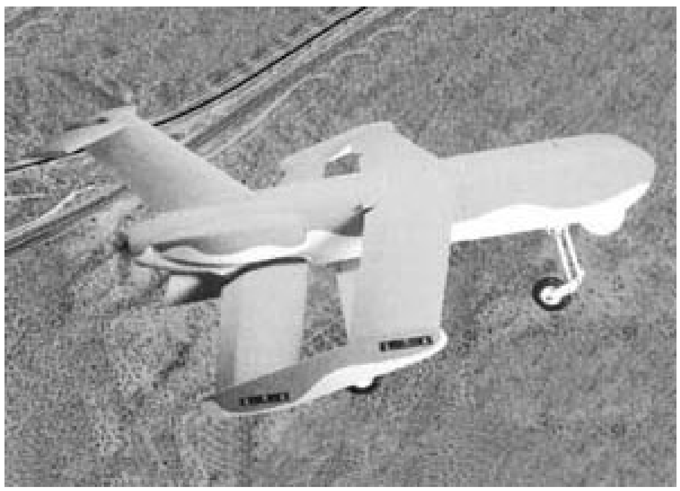

Figure 8. Outrider Tactical UAV

The Outrider system is designed to support Army maneuver brigade and armored cavalry regiment commanders, Marine Corps regimental/battalion levels, and Navy task forces. It will ultimately replace the Pioneer UAV. The Outrider will initially carry a day and night electro-optical (EO) and infrared (IR) sensor for reconnaissance, intelligence, surveillance, and target acquisition (RISTA) missions. In time, the Outrider may carry a moving target indicator (MTI) and synthetic aperture radar (SAR), electronic warfare, and communications and data relay capabilities. This system will likely see its first use in 1997 with the 4th Infantry Division (Mechanized) at Fort Hood, Texas.[4] If the ACTD program succeeds, the DOD may eventually procure as many as 61 systems, a total of 244 air vehicles.[5]

Table 4. Outrider UAV System Characteristics

Cost	Average $350k per vehicle
Dimensions	Wingspan - 11.1 ft.; Length - 9.9 ft.
Weight	Max. Gross Weight - 385 lb. (includes 85 lb. fuel)
Runway	300 ft. unprepared strips or shipdecks, automatic landing system
Payload	80 lb. internal, 100 lb. on centerline pod
Range	200 km (maximum)
Duration	4.9 hr. @ 200 km; 7.2 hr. @ 50 km
Airspeed	35 - 110 knots; cruise @ 90 knots
Altitude	Ceiling - 13,000 ft.; Normal CONOPs - 5,000 ft.
Flight Control	Programmable autopilot and GPS navigation with inertial back-up, reprogrammable in flight to loiter waypoints
Survivability	No ECM or low observable technologies
Deployment	one C-130
C2 Link	line-of-sight (LOS)
Sensors	EO or IR (potential SAR)
Total System	4 Air Vehicles, 4 Modular Mission Payloads, 2 Ground Control Station (GCS), 1 Remote Video Receiving Station, Launch & Recovery and Ground Support Equipment

The Predator Medium Altitude Endurance UAV

The Predator UAV was DOD's solution to an intelligence collection shortfall that the warfighters encountered during the Persian Gulf conflict. The Theater CINCs and JTF Commanders demanded an intelligence collection asset that could provide near real-time information, continuous coverage, and interoperability with C4I structures without endangering human life or sensitive technologies. Predator, also identified as the Medium Altitude Endurance (MAE) or Tier II UAV, is a derivative of the Gnat 750 (Tier I) UAV used by the Central Intelligence Agency (CIA).

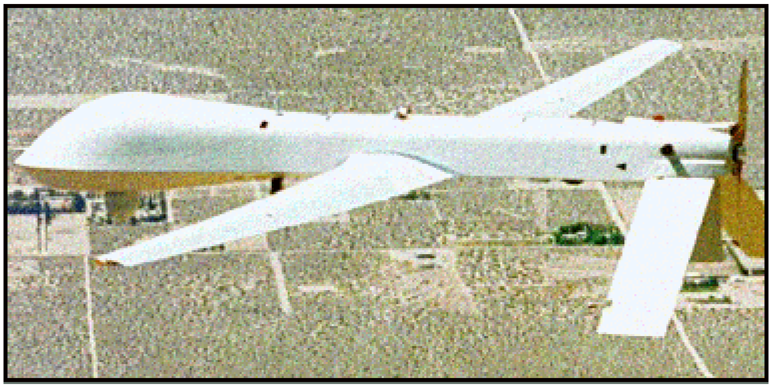

Figure 9. Predator Tactical UAV

In July 1996, Predator completed its 30-month ACTD program and began transitioning to low-rate initial production (LRIP) in the formal acquisition arena. The system provides long-range, long-dwell, near-real-time imagery intelligence (IMINT) to satisfy reconnaissance, surveillance and target acquisition (RSTA) mission requirements.

The Predator system has three parts: The air vehicle with its associated sensors and communications equipment, the ground control station (GCS), and the product or data dissemination system. The air vehicle carries EO (still frame and video), IR (still frame) and SAR (still frame) sensors which enable the system to acquire and pass imagery to ground stations for beyond-line-of-sight (BLOS) use by tactical commanders. The command link to the vehicle from the ground station allows the operator to dynamically retask the sensors and vehicle as requested by the field commander. Recent addition of de-icing equipment now allows transit and operation in adverse weather conditions. The "commercial off-the-shelf" (COTS) sensor hardware does not compromise sensitive technology if lost over enemy territory. The data provided is also unclassified, greatly easing releasability to coalition partners. The GCS consists of a pilot position, a payload operator position, and two data exploitation and communications positions. The notional system, to maintain continuous 24 hour coverage, comprises three or four air vehicles, one GCS and 28 personnel.

Table 5. Predator UAV System Characteristics

Cost	$3.2M per vehicle (with EO/IR/SAR), $2.2M for Trojan Spirit, $2.9M for Ground Control Station. ***Total*** system cost $28.3M
Dimensions	Wingspan - 48.7 ft.; Length - 26.7 ft.
Weight	Max. Gross Weight - 2,100 lb. (includes 650 lb. fuel)
Runway	2,500 ft.
Payload	450 lb.
Range	925 km (maximum)
Duration	24 hr. on station, total mission duration up to 35 hr.
Airspeed	60 - 110 knots; cruise @ 70 knots
Altitude	Ceiling - 25,000 ft.
Flight Control	Manual take-off/landing, fully autonomous or remotely piloted, dynamically retasked in flight
Survivability	No ECM or low observable technologies
Deployment	five C-130s, two C-141s, one C-5/17 for equipment only, operational six hours after arrival on site
C2 Link	UHF MILSATCOM (16 KBs), Ku-Band commercial (1.5 MBs), LOS (4.5 MBs)
Sensors	simultaneous EO/IR (0.5 ft. resolution) and SAR (1.0 ft resolution) capable; SAR only via Ku-Band or LOS
Total System	4 Air Vehicles, 4 Modular Mission Payloads, 2 Ground Control Station (GCS), 1 Remote Video Receiving Station, Launch & Recovery and Ground Support Equipment

Sensor data from the Predator vehicle integrates into the current theater-level C4I architectures through the TROJAN SPIRIT II (TS II) satellite communications (SATCOM) system. To provide near-real time broadcast of Predator video to numerous theater and national users simultaneously, the dissemination system uses either the Joint Broadcast System (JBS) or the TS II switch at Fort Belvoir, Virginia, or both.

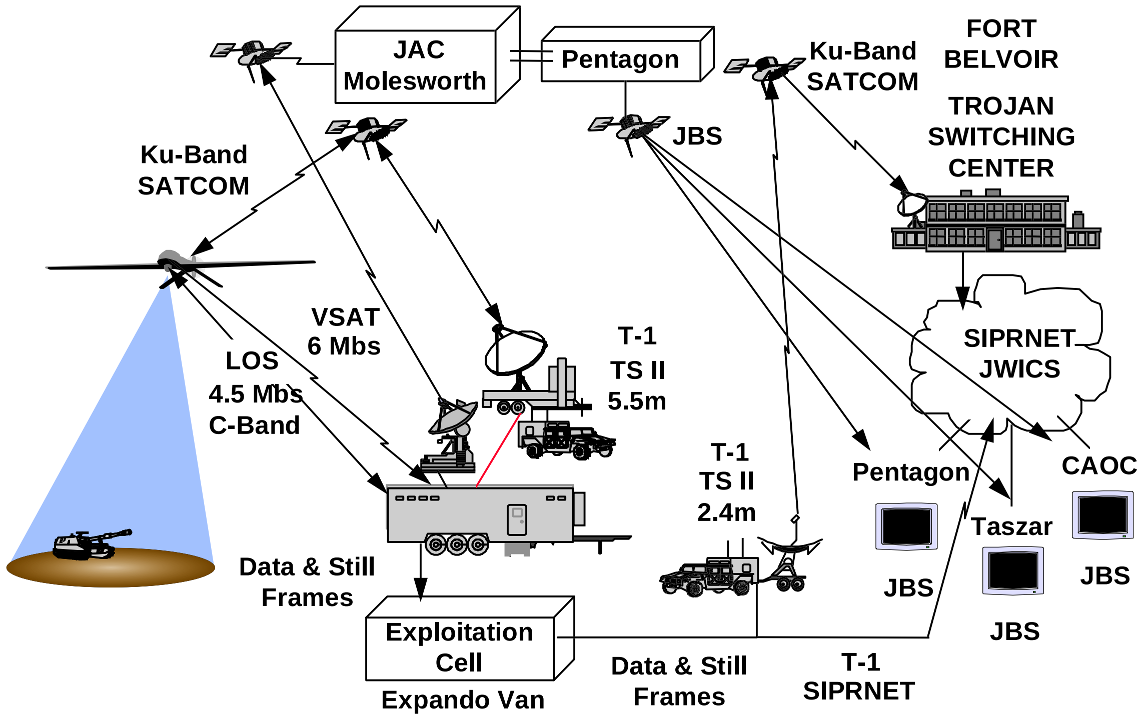

Figure 10. 1996 Predator EUCOM Deployment C^{4}I Architecture.

As production assets augment ACTD assets, Predator will be the operational endurance UAV workhorse by the end of the decade. General Atomics, San Diego, California builds the Predator System. The Air Force's 11th Reconnaissance Squadron at Nellis AFB, operationally controls and maintains the existing systems, with USACOM exercising COCOM. The Navy's Joint UAV Program Office in Crystal City, Virginia performs development and fielding efforts.

UAVs Over Bosnia

As part of its ACTD development activities, the Predator has successfully deployed twice to the Balkans supporting NATO, UN and U.S. forces. The first deployment, from July through November 1995, involved three Predators with only EO/IR sensors and the LOS and UHF SATCOM data links. The system operated from a base in Gjader, Albania. Despite two early losses (one to hostile fire, the other to engine failure) the Predator system and its operators showed steady improvements in operational utility to the theater commanders. The system's unique live video and dynamic retasking capabilities increased the commander's battlefield awareness and allowed him to focus his assets at the right place and time. Many credit the Predator with providing NATO commanders with the critical intelligence to begin a bombing campaign that, in turn, led to the Dayton Peace Accord signed in December 1995. Adverse weather was the principle limitation to system abilities. In-flight icing, high winds, precipitation and cloud cover limited Predator's ability to perform planned missions.

The Predator system deployed again to the Bosnian AOR in March 1996, this time based out of Taszar, Hungary. This time the vehicles included a SAR sensor, the commercial SATCOM link, active de-icing capabilities for the wings, and an expanded information dissemination infrastructure. Another Predator vehicle crashed in November 1996 due to engine failure.

During the two operational deployments to the Balkans, three CONUS exercises, and one demonstration, weather caused the cancellation of 17 percent of the planned missions and early return to base (RTB) in 19 percent of the missions flew. Weather limited Predator's value to the commanders more than any other factor.[6]

Also during the operational deployments to the Balkans, the system successfully integrated into a complex C4I architecture. However, the system operators experienced reluctance from airspace managers to integrate it with manned aircraft. The resulting restrictions on Predator employment hampered its ability to contribute to the intelligence collection missions.[7] Although Joint Pub 3-55.1 *(Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles,* 27 August 1993) outlines the procedures for the JFACC's airspace control authority (ACA) to control UAV operations, it is clear from all the Predator deployments that more effort is needed to familiarize the JFACC staff with UAV operations within controlled airspace.

The High Altitude Endurance Unmanned Aerial Vehicles (HAE UAV)

The DarkStar and Global Hawk air vehicles, with their Common Ground Segment (CGS), form the HAE UAV system. The two air vehicles are complementary: DarkStar will provide a capability to penetrate and survive in areas of highly defended, denied airspace, while Global Hawk's even greater range, endurance and multi-sensor payload will provide broad battlefield awareness to senior command echelons. The CGS will ensure interoperability between the air vehicles and transmission of their sensor products to the C4I infrastructure, as well as provide common launch and recovery and mission control elements (LRE and MCE). Thus, the HAE UAV system will provide the joint warfighter with an unprecedented degree of broad reconnaissance-surveillance coverage and flexibility. The systems are being designated for pre- and post-strike, standoff and penetrating reconnaissance missions, cost-effectively complementing other reconnaissance assets.[8]

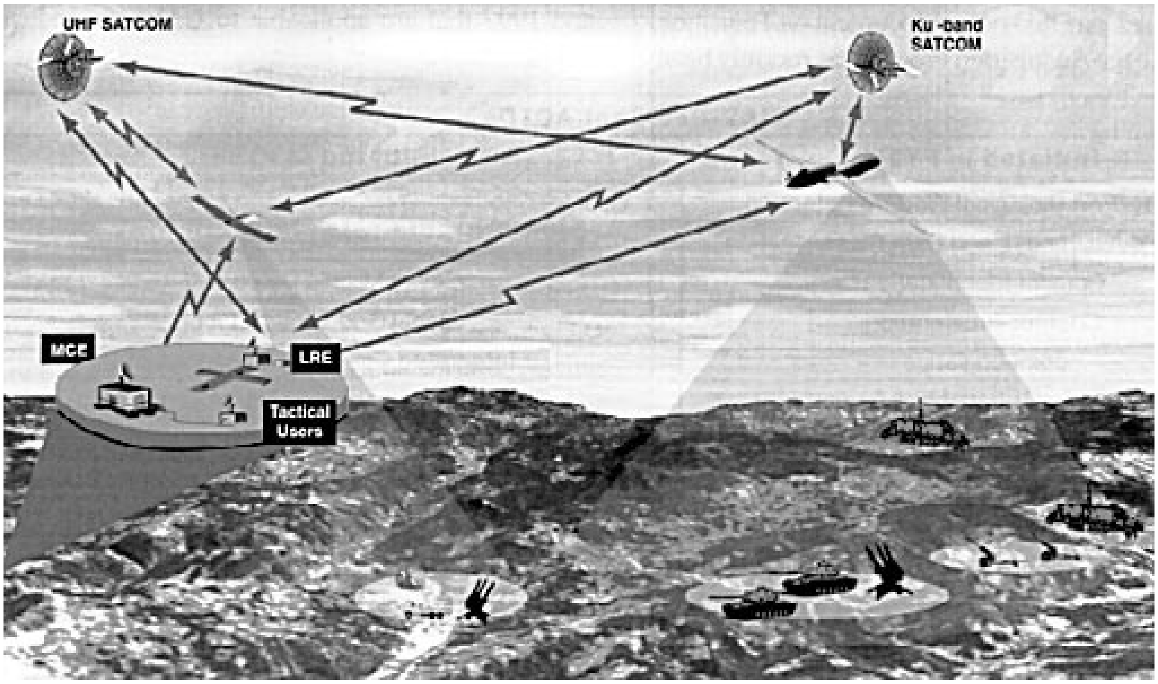

Figure 11. High Altitude Endurance UAV CONOPs

The DOD began a revolution in UAV reconnaissance by initiating the HAE UAV Program in 1994. The DARO designated the DARPA as the executive agent for the initial phases (Phases I and II) of these two ACTDs. After demonstration of acceptable flight and sensor performance, the Air Force will become the executive agent for the final ACTD demonstration (Phase III) and any follow-on acquisition activity (Phase IV). Currently, both programs plan to transition from Phase II to Phase III in January 1998. The decision to begin production will occur in FY2000. It is noteworthy that the same Air Force BIG SAFARI program office that procured the Lightning Bug UAV in the 1960s will be responsible for the HAE UAVs.

The HAE UAV performance objectives come from three Mission Needs Statements (MNS): Long Endurance Reconnaissance, Surveillance, and Target Acquisition (RSTA) Capability[9]; Broad Area Coverage Imaging Capability[10]; and Assured Receipt of Imagery for Tactical Forces.[11] The ACTD program objectives include demonstrating military utility within the constraint of a $10M Unit Flyaway Price (UFP) and developing a concept of operations (CONOPs) addressing operational control, airspace management, tasking, and data dissemination. The program management approach is revolutionary in that it allows the contractors the flexibility to adjust system specifications to meet the overriding requirement of achieving a $10M UFP. Also implemented is the use of Integrated Process Teams (IPTs) that emphasize new and innovative ways of doing business. This management approach allows maximum user involvement from the outset. The users, led by USACOM, are refining program objectives and assessing system operations and CONOPs. The users may identify recommendations or shortfalls that impact long-term system capabilities. Of course, any recommended configuration changes to the Global Hawk or DarkStar during the ACTD are constrained by the $10M UFP requirement. Simply put, all system capabilities are within the "trade space," as long as the UFP does not exceed $10M.

The program employs an innovative acquisition approach by using DARPA's Other Transaction Authority (OTA) for contractual agreements. This OTA provides broad and flexible authority, granted within the constraints of public law, allowing DARPA to enter into contractual agreements without the normal statutory and regulatory requirements of the Federal Acquisition Regulations (FAR) procurement system. The OTA permits DARPA to field and conduct technology demonstrations of military systems authorized under Section 845 of the National Defense Authorization Act (Public Law 103-160, enacted November 1993),[12] allowing DARPA to side-step most of the DOD acquisition bureaucracy.

The Global Hawk High Altitude Endurance UAV

Global Hawk, also identified as the Conventional High Altitude Endurance (CONV HAE) or Tier II Plus UAV, will be the HAE UAV "workhorse" for missions requiring long-range deployment and wide-area surveillance or long sensor dwell over the target area. It will be directly deployable from well outside the theater of operation, followed by extended on-station time in low- to moderate-risk environments. There, the system can look into high-threat areas with EO/IR and SAR sensors that provide both wide-area search and spot imagery. Because of Global Hawk's tremendous range capability, theater coverage is available at H-hour (vice days to weeks for deployment and initiation of operations for tactical assets). The vehicle achieves a high degree of survivability by its very high operating altitude and self-defense measures. The prime contractor is Teledyne Ryan Aeronautical (TRA), San Diego, California; the same company that built the AQM-34 Lightning Bug.

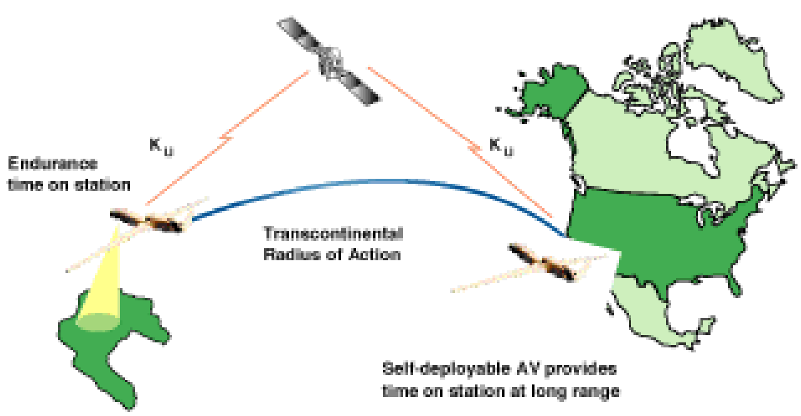

Figure 12. Global Hawk Employment Concept

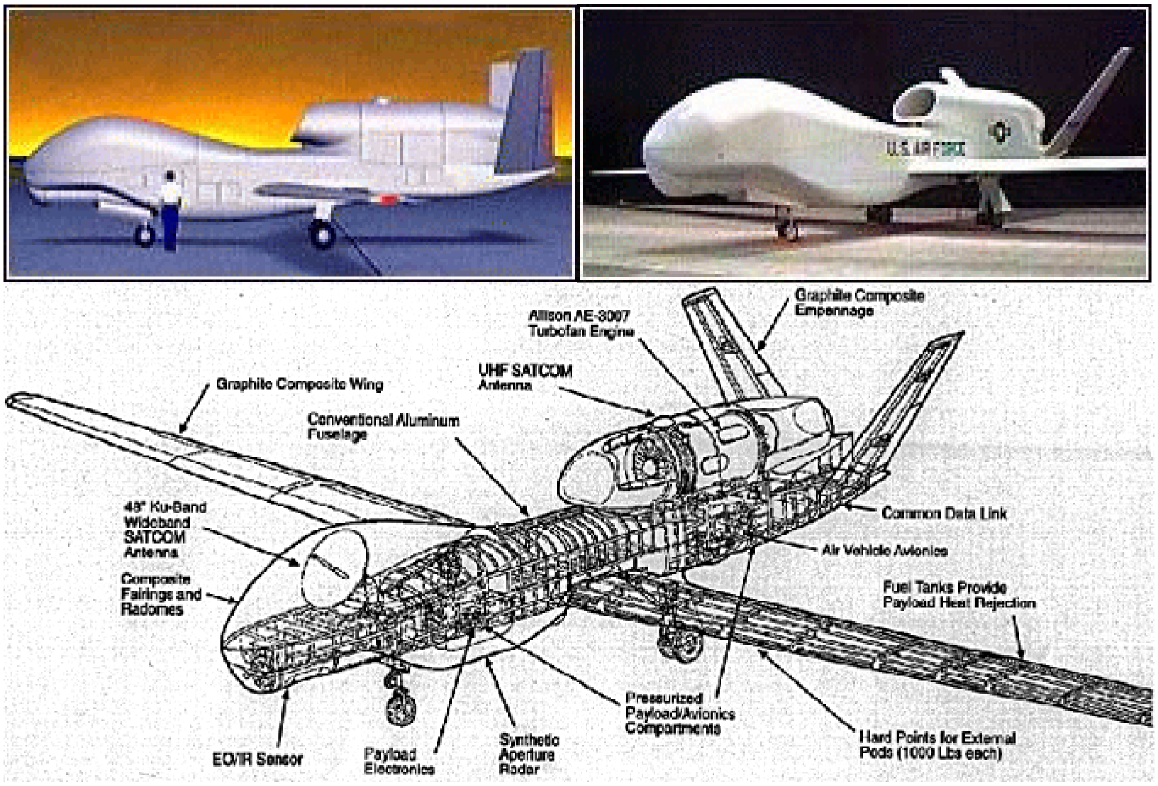

Figure 13. Global Hawk UAV

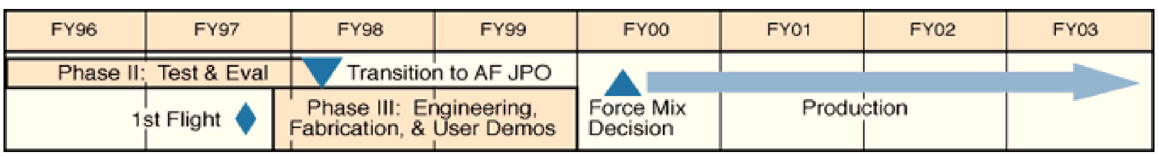

Figure 14. Global Hawk UAV Development Schedule

DOD completed the final Global Hawk aircraft design review in May 1996. Full air vehicle assembly completed in September 1996. Subsystem checkout is on-going as of this report. DARPA planned for the first flight in the Spring 1997 but slipped it to late 1997. After that the system will perform a series of aircraft flight and system tests and initial user demonstrations. The operational demonstrations of the full HAE UAV system should begin in mid-FY 1998. Program management should transition from DARPA to

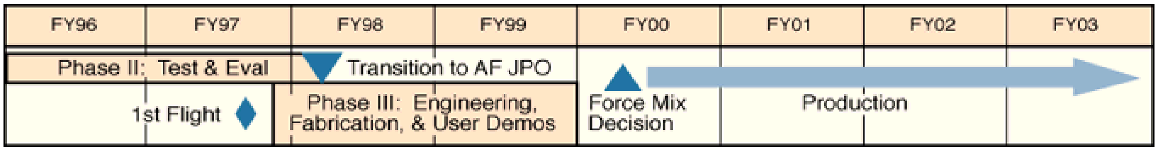

Figure 15. Global Hawk UAV Development Schedule

an Air Force-led joint program office at the end of December 1997. But program slips may also delay program management transition as well.

Table 6. Global Hawk UAV System Characteristics

Cost	$10M per vehicle (with EO/IR/SAR), $20M Ground Control Segment.
Dimensions	Wingspan - 116 ft.; Length - 44 ft.; Height - 15 ft.
Weight	Max. Gross Weight - 25,600 lb. (includes 14,700 lb. fuel)
Runway	<5,000 ft., automatic take-off and (with differential GPS) landing
Payload	2,000 lb. (4,000 lb. total using wing hardpoints)
Range	5,500 km (27,000 km ferry range)
Duration	24 hr. on station, total mission duration up to 40 hr.
Airspeed	350 knots
Altitude	Ceiling - 65,000 ft.
Flight Control	Vehicle can self-deploy from CONUS to overseas locations and land, fully autonomous, DGPS for takeoff/landing, retaskable in flight
Survivability	very high altitude and ECM and Radar Warning Receivers (RWR)
Deployment	one C-141s or one C-5/17 for equipment and personnel only
C2 Link	UHF MILSATCOM (16 KBs), Ku-Band commercial (1.5 MBs), LOS (274 MBs)
Sensors	simultaneous EO/IR (1.0 ft search, 0.5 ft. spot) and SAR (3.0 ft search, 1.0 ft spot) capable; SAR only via Ku-Band or LOS; capable of 40,000 sqnm or 1,900 spot images per 24 hr mission with 20M CEP accuracy

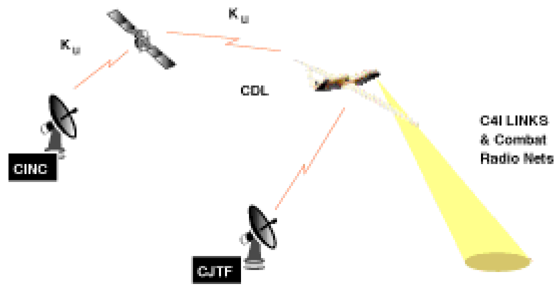

Figure 16. Global Hawk Airborne Communications Node Concept

In light of Predator's successful wide dissemination of imagery via JBS satellites during its second Bosnia deployment, comparable scenarios are being examined for this longer-range UAV under a Global Hawk-Airborne Communications Node (ACN) system concept. The ACN concept envisions a communications node payload for the UAV to provide gateway and relay services to surface and air forces. This capability would specifically enhance the commander's Dominate Battlefield Awareness (DBA) and Information Superiority.

The DarkStar Low Observable HAE UAV

Figure 17. DarkStar UAV

DarkStar will provide critical imagery intelligence from highly defended areas. The vehicle design trades performance and payload capacity for survivability features against air defenses, such as its use of low observable technologies to minimize the air vehicle's radar return. The air vehicle will self-deploy over intermediate ranges and carry either a SAR or EO payload. DarkStar's prime contractor is a Lockheed Martin/Boeing team.

Following its 1 June 1995 rollout and a series of ground tests, DarkStar flew successfully on 29 March 1996, the first fully autonomous flight using differential GPS. On its 22 April 1996 second flight, however, its "wheel-barrowing" characteristic during takeoff roll increased to uncontrollable oscillations causing the aircraft to stall nose-high and crash. Corrective action from the accident will include "hiking" the nose gear at rotation during takeoff, simplifying flight control laws, and adding the capability to abort takeoffs. Software testing and reconfiguration of aircraft #2 should allow the Phase II flight test program to resume in FY1997. Meanwhile, extensive radar cross-section tests validated DarkStar's low-observable design.

Table 7. DarkStar UAV System Characteristics

Cost	$10M per vehicle (with EO/IR/SAR), $20M Ground Control Segment.
Dimensions	Wingspan - 69 ft.; Length - 15 ft.; Height - 3.5 ft.
Weight	Max. Gross Weight - 8,600 lb. (includes 3,000 lb. fuel)
Runway	<4,000 ft., automatic take-off and (with differential GPS) landing
Payload	1,000 lb. SAR; 800 lb. EO
Range	925 km
Duration	>8 hr. on station, total mission duration up to 12 hr.
Airspeed	250 knots
Altitude	Ceiling - 45,000 ft.
Flight Control	Vehicle can taxi, take-off, climb, cruise, descend, and land fully autonomously using DGPS, dynamically retasked in flight
Survivability	very low observable
Deployment	seven C-130s, three C-141s, two C-17 or one C-5 for five aircraft, one GCS and 43 personnel
C2 Link	UHF MILSATCOM (16 KBs), Ku-Band commercial (1.5 MBs), LOS (137 MBs)
Sensors	EO (0.5 ft. spot) or SAR (3.0 ft search, 1.0 ft spot) capable; capable of 14,000 sqnm or 620 spot images per 8 hr mission with 20M CEP accuracy

Of significant interest to this UAV is its ability to radiate a SAR sensor but remain stealthy. The SAR sensor uses a low power, low probability of intercept (LPI) waveform and a low radar cross section, sidelobe suppression antenna. In the search mode, this SAR will provide strip images about 5.6 NM wide. Also, both the SAR and EO sensors only look-out the left side of the aircraft. The current DarkStar UAV development schedule is below:

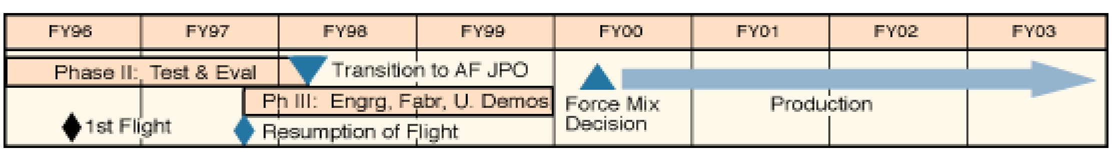

Figure 18. DarkStar UAV Development Schedule

Advanced Concept Technology Demonstrations (ACTD)

Except for the Pioneer and Hunter UAV programs, all recent DoD UAV developments are (or have been) ACTDs. The Predator program was the first ACTD to transition to a formal acquisition program, and its lessons learned are being applied to the other UAV programs. ACTDs, an acquisition philosophy started in 1994, are intended to be quick-development programs designed to get mature technologies into the hands of users for early evaluation of operational utility. These programs should complete development and demonstrations within two to three years; compared to the routine ten equivalent years for the traditional acquisition program. ACTDs are unique in that they focus on demonstrating warfighter determined essential capabilities and mission potential. The three possible outcomes of an ACTD effort are 1) user deems lack of demonstrated utility and cancels program, 2) system shows some utility and user modifies demonstrators for operational suitability, or 3) program succeeds and the system enters the normal Service acquisition process.

The advantageous aspects to an ACTD program are the shortened development cycle and proving system utility before a Service commits enormous funds to a full-rate procurement; a "try before you buy" philosophy. This concept also has its drawbacks, as being experienced with the Predator program. For instance, ACTD unit costs may be low (often representing off-the-shelf components), but militarizing these systems and instituting logistics, maintenance, and training increase program acquisition costs. For example, while an ACTD Predator demonstration system costs about $15M, a combat-ready production system (with configuration changes, added payload and communication subsystems, and full integrated logistical support provisions) requires about twice that sum.[13] Taking lessons learned from the Predator ACTD program, the Outrider ACTD includes funding for transition plus out-year procurement funds. Also, OSD recently published a policy document on Transition of ACTDs to the Acquisition Process as a guide to all ACTDs.

Near Term Demonstration Payloads

The UAV JPO is conducting proof-of-principle demonstrations of mature payloads to evaluate their suitability and utility for tactical UAV applications. Currently, the JPO is utilizing the Pioneer and Hunter UAVs to test several different payload reconnaissance sensor packages, as well as a few non-reconnaissance payloads. The potential missions that these payloads could support are: meteorological, nuclear/biological/chemical (NBC) detection, ELINT, COMINT, hyperspectral imaging, foliage penetration SAR imaging, mine detection, laser designator/rangefinder, and radar and radio/data link jamming. None of these demonstrations are outside the "box" of the traditional reconnaissance mission areas, for two reasons. First, its charter limits the DARO, that funds all these efforts, to the oversight of *non-lethal* tactical and endurance UAVs only. Secondly, employing lethal UAVs runs counter to current doctrine, attitude, and beliefs.

Notes

[1]Joint Publication 3-55.1, *Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles*, 27 August 1993, I-1.

[2]Glenn W. Goodman, Jr., "New Eyes in the Sky," *Armed Forces Journal International*, July 1996, 32.

[3]"New Eyes in the Sky", 32

[4]Col Ronald W. Wilson, "Eyes in the Sky," *Military Intelligence,* July-September 1996, 16

[5]"New Eyes in the Sky", 34.

Notes

[6]Defense Evaluation Support Agency, *ACTD Assessment Summation for the Medium Altitude Endurance Unmanned Aerial Vehicle* (Washington, DC: 29 July 1996), 7.

[7]Ibid., 7-8.

[8]Department of Defense, *UAV Annual Report FY 1996* (Washington, DC: Defense Airborne Reconnaissance Office, 6 November 1996), 23.

[9]Joint Requirements Oversight Council Memorandum (JROCM) 003-90

[10]JROCM-037-95

[11]JROCM-044-90

[12]Defense Advanced Research Projects Agency, *High Altitude Endurance UAV Program Advanced Concept Technology Demonstration Management Plan (DRAFT)* (Washington, DC: 16 August 1996), 1

[13]*UAV Annual Report FY 1996*, 28-29.

Chapter 4

The Future

You see things; and you say "why?" But I dream things that never were; and I say "why not?".

—George Bernard Shaw

Clearly the US government and the American populous are becoming increasingly sensitive to potential loss of life of military personnel, looking unfavorably on using manned assets to achieve military objectives. Navy Tomahawk and Air Force AGM-86C cruise missiles, used extensively in Desert Storm, offer only a partial solution to the need to strike targets without risk of pilot loss or capture. Although the effects of cruise missile strikes are highly favorable, the $500k to $1M per airframe cost is a significant limitation to massive use of these weapons. Manned fighters, on the other hand, can deliver bombs and missiles (e.g., Joint Direct Attack Munitions costing less than $15k each) at a much lower cost per pound of payload. This is possible because the manned fighter retains the most critical aspects of delivering weapons, the navigation, targeting, and propulsion systems, while these same expensive components on a cruise missile are lost on impact. Also, manned systems provide more flexibility and timeliness over cruise missiles. Cruise missiles require exacting flight path and targeting information before weapons launch. Manned systems can loiter over a target area, waiting for a targeting opportunity.

However, it is this loiter over denied area that presents the dilemma of employing manned systems.

Unmanned Tactical Aircraft (UTA)

According to an article in the 3 July 1996 issue of "Jane's Defence Weekly," the U.S. Air Force and UK Royal Air Force are assessing the possibility of unmanned fighter aircraft. This military interest has sparked both Lockheed Martin and McDonnell Douglas to study the feasibility of Unmanned Tactical Aircraft (UTAs). DARPA is also demonstrating interest in this concept. Senior RAF officials revealed recently that they are considering a UTA as an option for replacing the Tornado GR4 strike aircraft in early part of the next century.[1]

A UTA, with substantial C4I connectivity to its operator safely outside the denied area, can loiter and target its weapons like a manned system, but provide a level of safety to friendly forces similar to cruise missiles but with a more cost effective approach. According to a 1993 Lockheed study, the UTAs had a cost-effective niche that fell between cruise missiles and manned fighters. Lockheed Martin is advocating a phased program approach, representing a low-risk path to the development of a UTA. The starting point would be to adapt an existing platform, such as the F-16, both to test technologies and operational doctrine. If the Air Force modifies a line aircraft, it could operate in either manned or unmanned modes, depending on the targeting and threat scenarios of individual missions. Similarly, the Air Force Material Command started planning a UTA-like demonstration program using the existing F-16 Advanced Fighter Technology Integration (AFTI) aircraft.

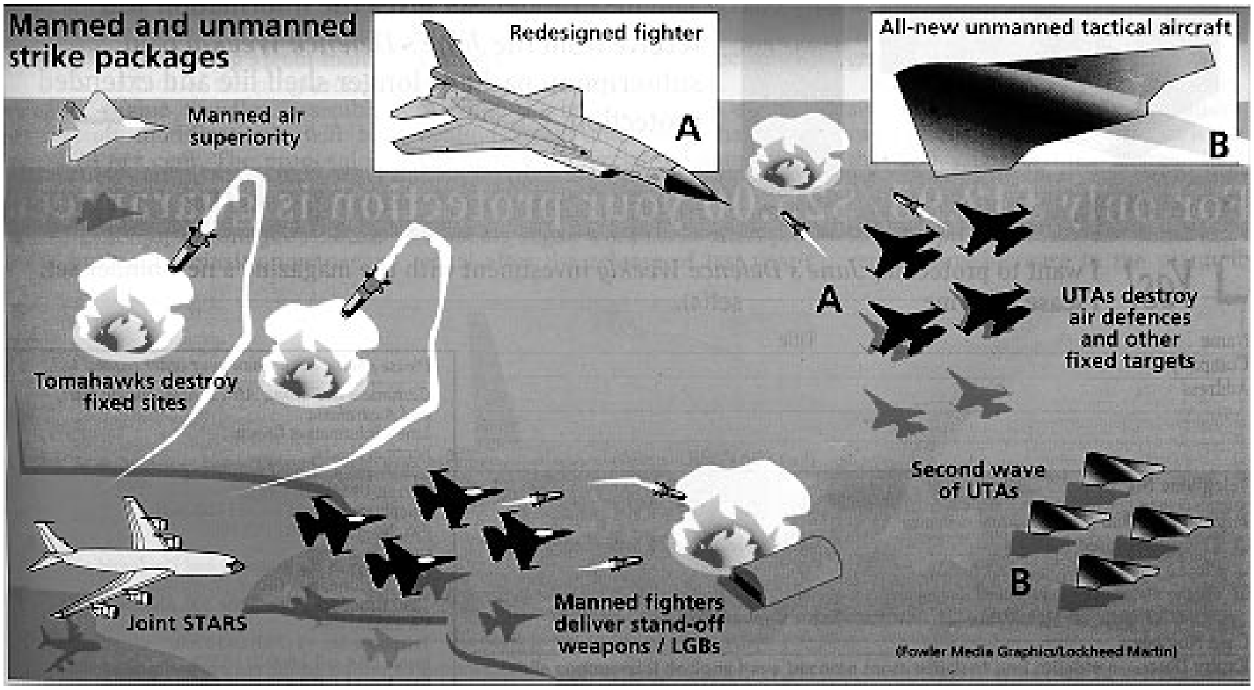

Figure 19. Unmanned Tactical Aircraft within Strike Packages

To fly a UTA to its target, an operator would first plan the attack on a mission support computer (like the Air Force Mission Support System) and load the strike profile into the vehicle. During the mission, changes could be data-linked via a secure communications system. Sitting at a control station hundreds of kilometers from where the attack is taking place, an operator would be able to coordinate not just one vehicle's action, but those of an entire package of UTAs. Illustrated below is a potential future attack scenario utilizing all three weapons platform types.

Manned systems, with their ultimately flexible human-in-the-loop design, are best suited for employment against highly mobile targets, uncertain targeting scenarios, and low-to-mid threat environments. Cruise missiles, with minimal threat to friendly forces, excel at attacking well defined, fixed targets but usually limited in numbers employed because of cost. UTAs provide the best of both extremes, the cost efficiency of manned systems and the low risk environment to its operators like the cruise missile. If the UTA has significant on-board sensor and communications capability, UTAs could provide the same flexibility in unanticipated scenarios like manned systems.[2]

Uninhabited Combat Aerial Vehicles (UCAVs)

The U.S. Air Force recently formalized its vision of its future in publishing *New World Vistas: Air and Space Power for the 21st Century*. Included in this report was the assertion that the Air Force will employ a mix of inhabited and uninhabited aircraft. The report uses the term "uninhabited" rather than "unpiloted" or "unmanned" to distinguish the aircraft enabled by the new technologies from those now in operation or planned. The "unmanned" aircraft of the present have particular advantages, such as cost or endurance, but are either cruise missiles or reconnaissance vehicles. The "uninhabited" combat aircraft (UCAV) will be new, high performance aircraft that are more effective for particular missions than their inhabited counterparts. The enabler for viable UCAV employment is the constantly evolving information technologies, allowing the use of new aircraft and weapons' technologies unavailable for use in inhabited aircraft.

The report asserts that there will be missions during the next three decades that will benefit from having a human present, but for many missions the uninhabited aircraft will provide capabilities far superior to those of its inhabited cousins. For example, shape and function will not be constrained by a cockpit, a human body, or an ejection seat. The design freedom generated should allow a reduction in radar cross section by at least 12 dB in the frequency bands currently used for air defense, compared to existing aircraft. A 12 dB reduction in aircraft cross section will reduce the effective range of enemy radar by a factor of two and area coverage by a factor of four. There is also the possibility of extending UCAV performance into the hypersonic range to enable global strikes from the CONUS in minutes (true Global Engagement) on high value targets. Also, small UCAVs carried aboard and launched from large "mother-ship" aircraft could provide an intercontinental standoff capability,[3] enabling what some define as true "air occupation."

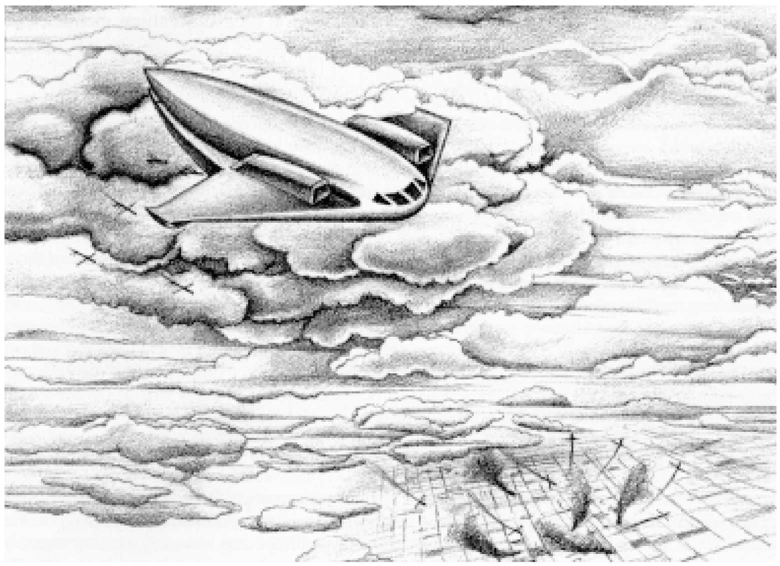

Figure 20. Attack by UCAVs Deployed by Airlifter

It is the improvements in sensors, processors, and information networks that make the UCAV possible. Information, critical to today's precision weapon systems, are increasingly derived from sensors outside the air vehicle itself. Current concepts call for transmitting information derived from many sources over a satellite or ground-based data-link to the pilot of a high performance combat aircraft. The amount of information available for display in the cockpit is enormous, quickly saturating the human pilot with more data than can be effectively absorbed.

In the New World Vistas concept, information gathered from many sources, including from the UCAV itself, will be brought to the Execution Control Center (ECC), located in the CONUS, over high speed, massively redundant fiber and satellite communications routes. A permanent, environmentally controlled ECC will permit extensive use of state-of-the-art commercial equipment. While on the UCAV, the absence of displays, pilot life support equipment, and manual controls will reduce vehicle cost and weight. Correspondingly, volume, area, and weight of displays, processors, and controls in the ECC is unrestricted. Well-rested mission specialists will be available to provide support for one or more UCAVs, and a cadre of expert maintenance technicians will also be available. Subsequently, the Services can reduce the number to support personnel in the theater and the necessity to transport a large number of shelters, workstations, and environmental control units to the theater to support these personnel.

The extremely low observability of the UCAV will also result in the reduction of standoff distance at the weapon release point; meaning the UCAV can be closer to the target at weapons release. This will, in turn, allow employment of less expensive PGMs with less sophisticated weapon sensors and guidance systems and lower propulsion costs than longer range stand-off weapons. In other words, a UCAV could employ JDAM-like weapons very close to the target, vice a manned platform positioned farther away from the target and required to utilize JSOW or JSSAM-like weapons.

UCAV maneuverability levels, beyond that of human pilot tolerance, will also increase system survivability. Acceleration limits for inhabited aircraft are typically +9g and -3g. A UCAV design can symmetrically accelerate in any direction immediately. In comparison, anti-aircraft missiles are usually designed with a factor of three margin in lateral acceleration over that of the target aircraft, although a few missiles have acceleration capabilities as high as ±80g. A UCAV with a ±10g capability could outfly many missiles, and an acceleration capability of ±20g will make the UCAV superior to nearly all missiles.[4]

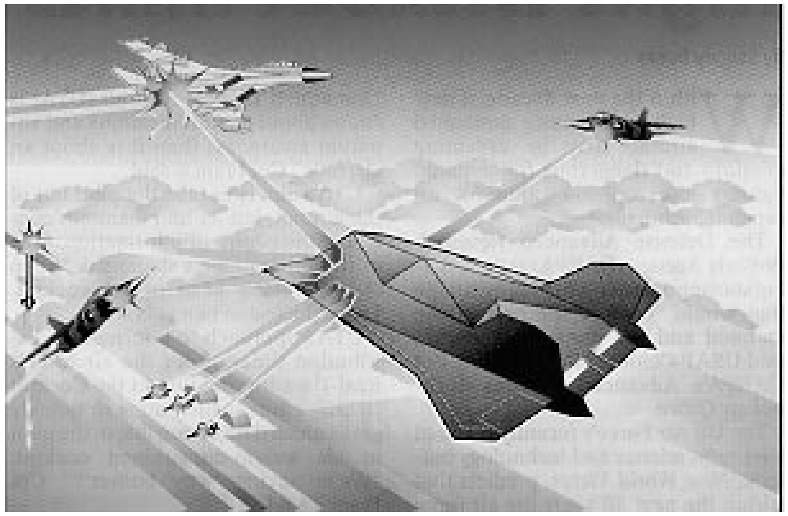

Figure 21. UCAV Attacking Air & Land Targets with High Power Laser

New World Vistas asserts that an effective UCAV will be possible in the next century as the result of the simultaneous optimization of information flow, aircraft performance, and mission effectiveness. The UCAV will not completely replace inhabited aircraft for decades, but the presence, or absence, of a pilot is now an available design trade. The advances in weapons systems, particularly the Air Force's Airborne Laser Program, could add completely new dimensions for employing UCAVs.

Micro Unmanned Aerial Vehicles (MicroUAV)

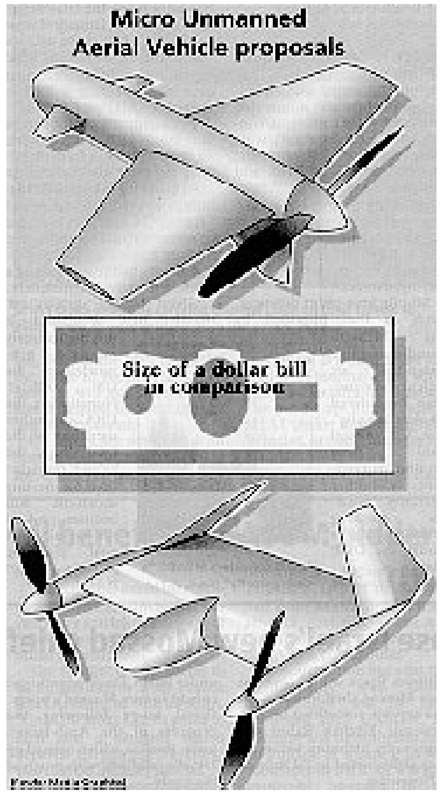

Figure 22. Micro UAVs

DARPA is also investigating the viability of Micro Unmanned Aerial Vehicles (MicroUAV). The development of the MicroUAV would be a technological feat so radical that it would push the state of the art in flight control, navigation, communications and propulsion. These tiny drones, no more than 15 cm in span or length, could scout inside buildings, for example, collect biological-chemical samples, or attach themselves to structures or equipment and act as listening and/or video posts. No specific application has drawn engineers to the project, but DARPA is confident that technologies, like micro-sensors and micro-electro-mechanical systems, being developed for other programs will provide the necessary capabilities to make a small-scale aircraft fly.[5] If this effort comes to fruition, MicroUAV employment could vary widely, but possible uses could be for surveillance, clogging aircraft engine inlets, jamming artillery and AAA gun barrels, dislodging the tracks on mechanized vehicles, and others. MicroUAV technology could also further reduce the possibility of collateral damage, since the weapon is only six inches across. Reducing collateral damage, even to enemy forces, is another trend of our society.

Notes

[1]Michael J. Witt, "Britain Ponders UAV Alternative," *Defense News*, vol. 12, no. 1 (6-12 Jan 97), 1.

[2]Nick Cook, "Leaving The Pilot On The Ground," *Jane's Defence Weekly*, 3 July 1996, 34-35.

[3]Air Force Scientific Advisory Board, *New World Vistas: Air and Space Power for the 21st Century, Summary Volume* (Washington, DC: December 1995), 8-9.

[4]Air Force Scientific Advisory Board, 34-35.

[5]Stacey Evers, " ARPA Pursues Pocket-Sized Pilotless Vehicles," *Jane's Defence Weekly*, 20 Mar 96, 3.

Chapter 5

Conclusions

> *High ground offers three strategic assets: greater tactical strength, protection from access, and a wider view.…The occupation of high ground can thus mean genuine domination. Its reality is undeniable.*
>
> —Carl von Clausewitz
> *On War*

So why are UAVs becoming popular, especially in this fighter-mentality Air Force? There are a few trends that are pushing UAVs to the forefront of the military reconnaissance force structure. First, as mentioned at the beginning of this report, our society is becoming more and more adverse to human suffering, even in war. The American public and media will probably frown on commanders that utter statements like "damn the torpedoes, full speed ahead." Therefore, it is becoming harder to envision sending manned reconnaissance assets into denied, hostile airspace, even if the intelligence data needed is critical to saving many lives in actual battle.

Another reason for the swell of UAV interest is that current technologies have finally overcome some significant limitations to the flexibility of previous UAVs. Until recently, most UAVs flew pre-programmed flight paths because of limited navigation capabilities and command and control links to the UAV operator. This limited the responsiveness of the systems to changes on the battlefield. The available technology for past UAVs also limited sensor performance. For example, the Lightning Bug used a film-based camera to provide high quality photography. This limited its role to performing BDA after pre-planned air strikes. This camera system was not applicable to the dynamic nature of target acquisition because of the time it took to recover the UAV, then remove the film for processing and exploitation. Although many variants of the Lightning Bug included a video link to the operator, the camera was an analog system and, therefore, limited in the quality and resolution of the image. Of course, these film and video systems were degraded by weather and camouflage. Until recently, SAR sensor technology was not mature enough to allow cost effective payloads small enough for UAV employment. Therefore, only manned reconnaissance platforms (e.g., U-2, SR-71, JSTARS, etc.) provided the flexibility, responsiveness, and quality needed on the dynamic battlefield.

The electronics revolution of the 1990s has provided the technology that enables cost effective UAVs to perform most, if not all, of the battlefield reconnaissance missions. Today's electronics, micro-processors, and communications networks allow the Predator UAV, using GPS navigation, to fly autonomously or be dynamically retasked in flight, to loiter over an area of interest for up to 24 hours while collecting high-quality EO, IR, and SAR imagery, then transmit that imagery over commercial satellites to warfighters at all echelons throughout the world. Therefore, today we have the technology to employ imagery collecting UAVs with as good or better capabilities than manned platforms. Soon, the Global Hawk will loiter over a theater for up to 40 hours, far exceeding a U-2's loiter time. If the Global Hawk program successfully demonstrates its predicted capabilities, the Air Force will probably retire the U-2 fleet by the middle of the next decade. Clearly the current Air Force leadership is very supportive of increasing our involvement in UAVs. At the Fall 1996 Air Force Corona Conference, the leadership decided to establish a UAV Battle Lab at Eglin AFB, to explore emerging areas of warfare for the next century. The Air Force already experimented with the possibility of lethal UAVs in the 1970s; are we willing to try it again? It will be interesting to see if the Air Force's attitude towards UAVs wavers after a change of top leadership.

Towards the end of this decade it will be clear that UAVs are more capable of performing the RSTA mission, especially in the IMINT domain, better than manned platforms, and at lower costs and less risk to human life. It is still unclear when UAV platforms will match or exceed the SIGINT and MASINT sensor capabilities of today's manned platforms (e.g., Rivet Joint, EP-3, ES-3, etc.). But at the rate technology is advancing, it should not be long. Probably by the end of the next decade the Global Hawk will carry SIGINT payloads on its wing hardpoints and use its existing communications payload to transmit the raw data to SIGINT processors and human exploiters that are safely away from the battlefield.

Similar technology advances will occur within satellite reconnaissance and surveillance programs and systems. Eventually, this nation could possess the ideal intelligence architecture, that of global satellite coverage for regular global surveillance and deployable UAVs for sustained and focused theater reconnaissance. Such an architecture will provide the Global Eyes and Global Ears to truly perform the Global Reach, Global Power, and Global Engagement of tomorrow's Air Force.[1]

So what does all this renewed interest and investments in UAVs mean for the future of warfighting? Clearly, theater RSTA will significantly improve. It is also clear that the same technology that is propelling advances and improving attitudes in UAVs could drastically change how the military employs force. As mentioned earlier, the Air Force's

New World Vistas report envisioned UCAVs, flown by operators in the CONUS, taking the fight to any enemy. UAV-like technologies, allowed to mature to fruition, could completely take the human out of actual combat. UCAVs from CONUS, theater airfields, and/or carriers could fly into denied airspace, supporting armies of unmanned ground vehicles (UGVs) moving into denied territory, to impress U.S. political will upon an adversary. The Navy is also applying these same technologies in their "Manta" concept, an unmanned underwater vehicle (UUVs) deployed from a submarine to operate in shallow water and through minefields to track and destroy enemy submarines.[2] The technologies to realize these capabilities are inevitable. The issue is whether we have the political and military will to accept this path and invest in it, even in these fiscally constrained times.

The Industrial Revolution provided rifles and cannons with lethal range that began separating fighting forces away from hand-to-hand combat. The Information Revolution, still in its infancy, continues this trend, providing intercontinental-ranged aircraft and missiles. Will the U.S. decide to fully exploit the Information Revolution and revolutionize our military by employing humanless weapons to quickly conclude conflicts? Or will we just selectively exploit new technologies and evolve our forces to quickly bring the human to the conflict? The choice is ours to make now.

Notes

[1]Credit for the concept of Global Eyes and Global Ears goes to Brigadier General Donald R. Walker, USAF (ret) while he was the Director of Special Projects (SAF/SP) in 1992.

[2]Robert Holzer, "U.S. Navy Manta May Expand Sub Combat Power," *Defense News*, vol. 12, no. 11 (17-23 Mar 97), 1.

Glossary

AAA	anti-aircraft artillery
ACA	airspace control authority
ACC	Air Combat Command
ACN	airborne communications node
ACTD	Advanced Concept Technology Demonstration
AFTI	Advanced Fighter Technology Integration
ARPA	Advance Research Projects Agency (now DARPA)
ATARS	Advanced Tactical Airborne Reconnaissance System
AV	air vehicle
BDA	bomb/battlefield damage assessment
C2	command and control
C4I	command, control, communications, computers and intelligence
C4ISR	command, control, communications, computers, intelligence, surveillance, and reconnaissance
CDL	common data link
CEP	circular error of probability
CGS	common ground station
CIA	Central Intelligence Agency
CINC	Commander-in-Chief
CJTF	Commander Joint Task Force
COCOM	combatant command
COMINT	communications intelligence
CONOPS	concept of operations
CONUS	Continental United States
CONV HAE	conventional high altitude endurance
COTS	commercial of-the-shelf
DARO	Defense Airborne Reconnaissance Office
DARPA	Defense Advance Research Projects Agency (formally ARPA)
dB	decibels
DBA	dominant battlefield awareness
DCGS	Distributed Common Ground Station
DGPS	differential Global Positioning System
DOD	Department of Defense
ECC	Execution Control Center

ECM	electronic countermeasures
ELINT	electronic intelligence
EO	electro-optical
EO/IR	electro-optical/infrared
GCCS	Global Command and Control System
GCS	ground control station/segment
GPS	Global Positioning System
HAE	high altitude endurance
IAI	Israel Aircraft Industries
ICBM	intercontinental ballistic missile
IMINT	imagery intelligence
INS	inertial navigation system
IOC	initial operational capability
IPT	integrated process/product team
IR	infrared
JDAM	Joint Direct Attack Munitions
JBS	Joint Broadcast System
JFACC	Joint Forces Air Component Commander
JFC	Joint Forces Commander
JPO	Joint Program Office
JROC	Joint Requirements Oversight Council
JROCM	Joint Requirements Oversight Council Memorandum
JSOW	Joint Stand-Off Weapon
JSSAM	Joint Service Surface Attack Missile
JSTARS	Joint Surveillance Target Attack Radar System
JTF	Joint Task Force
KBs	kilobits per second
KH	Keyhole (formally a classification control channel for satellite imagery)
KTO	Kuwaiti Theater of Operations
LCO	Launch Control Officer
LO	low observable
LOS	line of sight
LPI	low probability of intercept
LRE	launch and recovery element
LRIP	low-rate initial production
MAE	medium altitude endurance
MARS	mid-air retrieval system

MASINT	measures and signatures intelligence
MBs	megabits per second
MCE	mission control element
MNS	Mission Need Statement
MRC	major regional conflict
MTI	moving target indicator
NASA	National Aeronautics and Space Administration
NATO	North Atlantic Treaty Organization
NCA	National Command Authority
NRO	National Reconnaissance Office
OSD	Office of the Secretary of Defense
OTA	other transaction authority
OTH	over the horizon
PGM	precision guided munitions
POW	prisoner of war
PSYOPS	psychological operations
RISTA	reconnaissance, intelligence, surveillance, and target acquisition
RPV	remotely piloted vehicle
RSTA	reconnaissance, surveillance, and target acquisition
RTB	return to base
SAC	Strategic Air Command
SAM	surface-to-air missile
SAR	synthetic aperture radar
SATCOM	satellite communications
SEAD	suppression of enemy air defenses
SIGINT	signals intelligence
SRW	Strategic Reconnaissance Wing
TAC	Tactical Air Command
TRA	Teledyne Ryan Aeronautical
TS II	Trojan Spirit II
TUAV	tactical unmanned aerial vehicle
UAV	unmanned aerial vehicle
UCAV	uninhabited combat aerial vehicle
UFP	unit flyaway price
UGV	unmanned ground vehicle
UHF	ultra-high frequency
UN	United Nations
USACOM	United States Atlantic Command

USD(A&T)	Under Secretary of Defense for Acquisition and Technology
USEUCOM	United States European Command
UUV	unmanned underwater vehicle
VHF	very high frequency
VSAT	very small aperture terminal

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