STRATEGY RESEARCH PROJECT

UNMANNED AERIAL VEHICLES - PROMISES AND POTENTIAL

BY

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Abstract

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This paper reviews the background of Unmanned Aerial Vehicles (UAV), tracing UAV technology from its genesis through to the promising UAV systems in development today. It provides historical insight into the enabling technologies which make UAVs uniquely capable of a variety of missions beyond their traditional roles in aerial reconnaissance. Finally, the controversy over Manned vs. Unmanned Aircraft is raised to shake up the cultural inertia which seems to constrain UAV applications in the Revolution in Military Affairs. Regardless of the winner of that debate, UAV systems are politically and fiscally relevant to our military today and in the uncertain future.

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Chapter 1

"All the business of war, and indeed all the business of life, is to endeavor to find out what you don't know by what you do know; that's what I called guessing what was at the other side of the hill."[1]

Duke of Wellington quoted in John Wilson Croker, The Croker Papers (1884)

ASSESSING THE RISKS

The concept of Unmanned Aerial Vehicles (UAVs) began as an experiment with target drones in the 1940's. Shortly thereafter, a veil of secrecy fell over UAV research as their operational capabilities were developed covertly. Nearly fifty years later, during OPERATION DESERT STORM, UAVs truly came to the attention of the general public through reports from the war of Iraqi soldiers with arms held high, attempting to surrender to a circling UAV. The Gulf War became the newest proving ground to evaluate UAV capabilities in combat and their potential role on the modern battlefield. The abundance of open source information and increased media exposure of UAVs piqued my interest in this topic. In addition, the high cost associated with modernizing the combat aircraft inventories of each service component challenged me to consider the feasibility of unmanned systems on the battlefield of the future.

My training and experience as an Army Attack Helicopter Company Commander and Command Aviation Battalion Commander have taught me the value of aerial weapons platforms on the battlefield as a combat multiplier. The stream of after action reports from OPERATION DESERT STORM confirmed my academic peacetime lessons. This battlefield success was possible through the sustained efforts of a unique synergy of aviation crews and machines in cohesive units. These operations also underscored the vulnerabilities of the human and the machine in that equation. Machines can fail, but more often it is a human operator exceeding personal limitations that is responsible for turning aircraft into scrap metal. High stress mission conditions, fatigue, poor weather and night vision devices each increase pilot workload and risk. These factors create 'pilot errors' which are responsible for the majority of aircraft accidents.

The daunting task for aviation commanders is to determine which of the unit's aviators is at the "highest risk" and train to reduce that risk. It still takes less time to build a combat aircraft than to recruit, train and qualify the pilot(s) that will fly it on a combat mission. Encounters with enemy air defense systems and enemy air assets are predictable and potent threats when U.S. Forces deploy into a hostile theater of war. As risk increases, the potential for human errors increases, especially when fear influences judgment in the cockpit. Can we protect pilots from unacceptable risk? Which high risk missions can be performed by unmanned aircraft? What missions must be performed by manned aircraft regardless of risk?

In this information age, emerging electronic and aviation design technologies are melding in Unmanned Aerial Vehicles. These combined technologies increase mission capability and enhance aircraft & human survivability. The second and third order effects can dramatically alter wartime requirements and the conduct of future military operations. For purposes of this paper, I will restrict my remarks to unmanned systems except in those circumstances where a comparison to manned systems would be helpful for clarification.

Chapter 2

"Those who know when to fight and when not to fight are victorious. Those who discern when to use many or few troops are victorious. Those whose upper and lower ranks have the same desire are victorious. Those who face the unprepared with preparation are victorious." [2]

Sun Tzu, 400-320 BC

A BRIEF HISTORY OF THE UNMANNED FLIGHT

Unmanned aircraft may appear as a novelty concept to many people outside of the military community. This is hardly startling when the most early use of unmanned aircraft was classified. A civilian resident of Carlisle working at the War College observed several of my colleagues discussing their research papers. At a quiet moment he turned and asked me, "What are you researching?" "Unmanned Aerial Vehicles," I replied. This immediately drew a puzzled look and then my acquaintance said, "Oh yeah! My son has one of those. He flies it at a big field outside of town."

This chapter includes the political and military pressures that were the genesis for UAV development. I believe the potential of Unmanned Aerial Vehicles (UAVs) can be understood through the events that led to their development. The rapid progress and growth of the UAV program allows us to imagine all possibilities, improve current capabilities and explore new military applications for the future defense. It is in our national interest to prepare for that uncertain future.

The protection of American citizens is one of the stated vital interests of the United States. An American taken hostage or prisoner by a hostile foreign power, gives that government political leverage to push for concessions from the United States. Pressure for concessions can be substantial and humiliating. This was clearly demonstrated by the downing of a U-2 spy plane and capture of pilot Francis Gary Powers in 1960. The incident occurred only a few years after President Dwight D. Eisenhower had proposed mutual aerial surveillance, or "Open Skies," to ease tensions between the Soviet Union and the United States. When overflight privileges were denied by Soviet Premier Nikita Kruschev, President Eisenhower covertly authorized overflights of the Soviet Union to maintain surveillance on the growing Russian military. The United States drew harsh international criticism for this encroachment on Soviet airspace, fueled by the Communist Press. President Eisenhower was personally embarrassed by the incident and issued a public statement terminating the America's U-2 overflights of the Soviet Union.

Two months after the Powers shootdown, a similar incident occurred. The Soviets downed another US plane, an RB-47, over the Barents Sea. This incident occurred between Norway and Russia, 50 miles from the Russian Coast-- according to the United States. Two of those crew members survived and were taken prisoner. However, this shoot-down caused the loss of three American lives and caused another embarrassment for the United States Government before the international community. These incidents forced the United States to explore other alternatives to its manned reconnaissance program. Intelligence analysts believed the growth of Russian military power demanded regular surveillance to provide critical reaction time for U.S. Forces if needed. Aerial reconnaissance is the best means to satisfy this requirement. The threat from Soviet Air Defenses led to the initial feasibility study of UAVs.

"Red Wagon" was the code name for the first flight demonstration of target drone aircraft modified for reconnaissance use. The highly classified project began in July 1960, shortly after Powers' U-2 was shot down. The drone was developed by the Ryan Company, a manufacturer of target drone aircraft. In an effort to provide security, and screen the true intent of the project, a misleading cover story was prepared for release. It was advertised as "a ground controlled target flying at near sonic speed and at altitudes in excess of 60,000 ft. It was to be flying for more than six hours while being engaged by surface to air missiles in an Air Force Training program against high flying enemy aircraft."[3] It was hoped that this information plan could disguise the true purpose of the tests to preserve the U.S. technological edge.

In light of the tragic loss of aircrews and the political problems associated with the manned (U-2) reconnaissance efforts, several studies were made by the Department of Defense. A report from Dr. Harold Brown, then Director of Defense Research and Engineering in 1961, neatly summarized the issues and requirements of aerial reconnaissance programs:

> The suspension of overflights (by US over Russia) and peripheral operations by U-2 aircraft is political in nature and has deprived the United States of its most effective aerial intelligence collection capability.
>
> The fact that Sino-Soviet Bloc capabilities, both offensive and defensive, are dynamic and aggressive, dictate that an almost constant surveillance be maintained to insure maximum US combat effectiveness. This requires high resolution (1 foot) photographic coverage of selected areas and of specific targets within these areas.
>
> Based on the preceding remarks, the following criteria are proposed for use in the selection of any future vehicle that will be used for overflights;
>
> **-Unmanned,** For political, diplomatic and public acceptability
>
> **-Operate independent of foreign and US overseas bases,** not dependent on a third country for support and/or policy. It could be recovered over international waters.

> **-Lead Time,** recommend that the study phase of a drone program be undertaken immediately.[4]

Clearly, a need existed for accurate aerial-photo intelligence data without the political liability of a dead or captured aviator. However, UAVs often lost in the fierce competition for DOD funding. This trend continued until the next crisis with Soviet expansion. In October 1962, Major Rudolph Anderson was killed when his U-2 was hit by a SAM missile over Cuba while photographing Soviet Missile Sites. At that time, only two UAVs were mission capable in the inventory. The Cuban Missile Crisis in 1962 prompted additional funding and renewed interest in UAVs for reconnaissance use.

The earliest combat use of UAVs was in Vietnam. The unmanned program consisted of over 28 different configurations of UAVs that flew from 1962 through 1975. During the Vietnam War, the United States flew over 3435 operational sorties using UAVs. (These are described in an abridged, tabular form in Appendix A of this paper. This table provides specific details on the UAV model size, numbers launched, most flights per bird and percentage of UAVs recovered.)

The Appendix (page 28) offers valuable insight into the general capability and intriguing missions which were flown by the early UAVs. These include both day and night photo reconnaissance missions, photo missions over the Hanoi Hilton, and other BDA photos of Hanoi from 2000-3000 ft.[5] However, there are also references to alternative special purpose UAV payloads used during the Vietnam War. For example, several 147NA/NC UAVs were maintained on standby for possible pre-strike ECM chaff-dispensing missions. An undetermined number of UAVs were launched for electronic intelligence or electronic countermeasures missions. Over twenty nine UAVs, called "bullshit bombers," were launched to drop leaflets. The Appendix also lists examples of unmanned systems serving as decoy aircraft.[6]

In the many lessons learned from Vietnam, available off-the-shelf-technology was successfully adapted to enhance the nation's requirement for aerial reconnaissance capabilities. This field experience is a proof of concept for UAVs, demonstrating creatively a potential for expanding their utilization for other missions. The UAV project engineers also evaluated many advanced technology concepts during the UAV development program which included;

- Prototype low observable (Stealth) designs to reduce radar signature[7]
- Radar altimeter low altitude control system to hug terrain[8]
- Implementation of LORAN navigation on UAV for position accuracy +200 feet[9]
- Unmanned Flight to 65,000 ft at nearly the speed of sound[10]
- UAV Suppression of Enemy Air Defenses (Air to Surface Missile)[11]
- UAV Bomber (1964) with 2ea 250lb bombs[12]

The second and third order effects of the UAV program could have begun to surface in the 1960s by spin-off research developments. Unfortunately, the doctrine and the culture were slow to adapt to the potential opportunities offered by UAVs. Advocacy for unmanned systems was likely seen as a vote against manned aircraft, tantamount to career suicide for senior aviators.

Are there any benefits of manned systems over unmanned systems? How much more costly would Vietnam have been if more missions had been flown by manned aircraft instead of UAV's? Is there any certainty that a manned system would have performed better? How many pilots and (more costly) aircraft could have been saved if more missions were performed by UAVs? These are rhetorical questions, yet it is the reduction of risk and the related cost to human lives that is really at the center of the issue. William Helmich, Ryan's Program Manager for their Air-to-Surface Missile Project, offered one prophetic opinion: "We wouldn't expect to replace manned aircraft….The drone runs about one-tenth the cost of a (1970 vintage) manned jet fighter, which carry one or two pilots each. And, everyone wanted to cut down on the number of guests in the Hanoi Hilton, and this (Ryan 234 armed UAV prototype) is one way to do it."[13] Clearly, many aviators were saved by the use of UAVs. Could there have been more?

Chapter 3

"To win one hundred victories in one hundred battles is not the acme of skill. To subdue the enemy without fighting is the acme of skill."[14]

Sun Tzu, 400-320 BC

THE PROMISES OF U.S. UNMANNED AERIAL VEHICLES TODAY

The previous chapter discussed the genesis of the Unmanned Aerial Vehicle Program from the early 1960s through the Vietnam War. It presented the political factors that support the unmanned concept and information about the capability of these airframes. The greatest vulnerability of the UAV program apparently was accounting for UAV losses. Morally, unmanned aircraft losses cannot not be compared by a cost accountant against the lives of the pilots that flew similar missions in more costly aircraft. Unmanned does not mean infallible, bulletproof or indestructible. It means no ejection seat required. Fortunately, the proof of concept was validated by the missions accomplished by these systems in high risk combat environments without risk to human life or related political consequences.

Unlike the Vietnam Era, the current Unmanned Aerial Vehicle Program is no longer solely an Air Force managed initiative. This is now a joint service program with participation by all services. As an Office of the Secretary of Defense, the Defense Airborne Reconnaissance Office (DARO) manages the Defense Airborne Reconnaissance Program and is a focal point for all airborne reconnaissance matters.[15]

The Joint Requirements Oversight Council (JROC) sets priorities for Department of Defense by allocating funds to key projects. The JROC allotted funds to UAV projects in this order. The Tactical UAV (TUAV) aircraft is the number one UAV program priority. The TUAVs are represented by two distinct systems called Pioneer and Outrider. The second and third priority projects respectively are the Predator and High Altitude Endurance UAVs[16]. These separate and unique UAV projects are the core of the Defense Airborne Reconnaissance Program (DARP). Each UAV system has the potential of being tasked for a variety of missions with each individual service component. A complete description of these unmanned systems is found in the Appendix of this paper[17].

The (TUAV) system will eventually support Army battalions, brigades and light divisions as well as deployed Navy units. The TUAV mission is to provide near real time, reconnaissance, surveillance, and target acquisition (RSTA) and battle damage assessment (BDA)[18]. Currently both the Pioneer and Hunter UAV systems are filling this role. An Advanced Concept Technology Demonstration (ACTD) design called Outrider is being evaluated as a replacement for Pioneer and Hunter. Outrider will fly over 200km on missions, nearly twice the range of the previous systems. Outrider is also more easily deployable than the earlier systems, requiring only a single C130. Both Hunter and Pioneer would require multiple C130 or C141 sorties. Each of these TUAV systems uses a Global Positioning System (GPS) for navigation and cruises at approximately 90 kts air speed (90 nautical miles/hr)[19].

The Predator is the Medium Altitude Endurance or Tier II UAV. This system was a ACTD and is now in production. It has a mission range of over 500nm, approximately five times the Tactical UAV Systems. Predator has a fuel endurance of over 20hrs, cruising at 70kts airspeed to achieve this range.

Satellite communication (SATCOM) allows near real time transmission of reconnaissance and target acquisition data from over the horizon, beyond electronic line of sight. This system is the first to incorporate a de-ice capability, essential for flight operations in cold weather. The Air Force's 11th Reconnaissance Squadron at Nellis AFB was formed in August 1995 and was the first UAV unit equipped with Predator. The Predator system is called Tier II due to features that surpass the capabilities of its UAV predecessors.

The Global Hawk is a Tier II+ UAV. This is a conventional high altitude endurance system (CONV HAE) currently in testing and development. The first flight is planned this spring (March1997).[20] Its aft-mounted jet engine distinguishes it from the other UAV propeller driven systems. The jet engine allows Global Hawk to fly over 345 kts, almost 4 times the airspeed the previous systems and attain a range of 3000 nautical miles. This Teledyne Ryan built UAV resembles a U-2 in size and shape. Its transcontinental flight capability could recreate the Francis Gary Powers' U-2 flight easily, and because it is unmanned, it could do so without the same political consequences.[21] The payload is similar to the other systems which use electro-optical/infrared and synthetic aperture radar. These sensor systems provide day-night and all weather imagery capability. Survivability is achieved by its high altitude stand-off and its self-defense measures. The phrase "global" is well suited to this UAV; with its strategic range Global Hawk is self-deployable worldwide.

DarkStar is the Low Observable High Altitude Endurance (LO HAE) or Tier III(-) UAV. In this context, 'Low Observable' means 'stealth capable'. The Darkstar is the only US produced UAV with true stealth design. Due to its stealth focus, DarkStar will not achieve the same overall flight performance of the Global Hawk but should attain over 250kts airspeed for more than +8hrs endurance, reaching altitudes over 45,000 feet. The payload capacity, although not fully described in the available literature, appears to be less than Global Hawk as well. The DarkStar sensor payload includes either an electro-optical (EO) or synthetic aperture radar (SAR), not both systems like Global Hawk.[22] "DarkStar trades air vehicle performance and payload capacity for survivability against highly defended air defenses by minimized radar return. This UAV is still in the developmental and test flight stage with production scheduled to begin in the year 2000." [23] Larry Lynn, Director of Defense Advanced Research Projects states that, "DarkStar will demonstrate a warfighting capability that the US has not had since the early days of the SR-71 Blackbird and the U-2 Spyplane."[24]

Each modern UAV system possesses unique flight characteristics and capabilities to support the Joint Task Force Commander on the modern battlefield. Joint Command and Control of these assets requires rapid facilitation of in-flight handoffs of mission aircraft and seamless sharing of data. To accomplish this, DARO is developing two types of UAV Ground Control Systems (GCS). Two distinct types of ground control links will support the unique differences between the Tactical and the High Altitude Endurance UAVs. The Tactical Control System (TCS) is designed for tactical UAVs (TUAV) supporting the close battle without going beyond the horizon. The Common Ground Segment (CGS) for the relatively autonomous HAE UAVs provides high data exchange rates, and multi-payload functionality for significantly more complex missions beyond the horizon[25].

The nature of UAV missions is directly influenced by the threat environment, range to the area of interest and the payload components required. The current (FY97) UAV systems and payloads demonstrate significant improvements over their Vietnam Era remotely piloted vehicle (RPV) predecessors. These improvements cut UAV size and weight, upgraded electronics to smaller high efficiency integrated circuits, and achieved real-time data sharing via satellite (SATCOM) data linkages. Unmanned Aerial Vehicles provide responsive coverage of large geographic areas of responsibility, more quickly than by repositioning reconnaissance satellites. The UAV systems give the JTF Commander what he wants, when he wants it.

In an effort to expand the UAV flight mission, the DARO program managers are looking to the most promising technologies for new applications. What will these emerging technologies do for the UAV program? Will technology open new opportunities for UAVs or will these systems remain in a rut, relegated primarily to an aerial reconnaissance role?

Chapter 4

"It all started 93 years ago with two brothers from Ohio…Think where we will go in the next 93 years."[26]

-General Joseph W. Ralston, USAF
Vice Chairmen Joints Chiefs of Staff,

THE POTENTIAL IN UAV MISSION PAYLOADS

We examined the current UAV development program in Chapter Three, noting that several new UAVs are in development and testing. These systems represent significant product improvements over the Ryan (Teledyne) RPVs/UAVs used during Vietnam. In this chapter, we will examine the potential that technology offers for alternative payloads and expanded UAV roles and missions.

On 16 January 1996, Dr. Paul Kaminski, the Under Secretary of Defense (Acquisition and Technology), identified primary enabling technologies and architectural concepts that are vital to achieve battlefield dominance. One or more of these technologies are relevant to all high technology (military) systems. At least five of these will be applied on UAV system development:

- Advanced Processing
- Automatic Target Processing
- A Common Grid
- Distributed and Open Architectures

- Sequential Application of Off Board Collectors
- Data Compression
- Very Large, Dynamic, Object-Oriented Data Bases
- Data Storage
- Data Dissemination
- Planning Analysis Tools

Dr. Kaminski's emphasis on these specific technologies promotes the following conclusion; battlefield dominance relies heavily on automated information processes. Predictably, information requirements of battlefield commanders will vary in terms of quantity, quality and timeliness according to their role in the close, deep, or theatre fight. UAV systems will require an advanced C4I (Command, Control, Communication and Computers and Intelligence) infrastructure for collection, processing and dissemination to meet the unique needs of commanders at all levels. These enabling technologies will meld UAV systems into all aspects of information dominance to see the battlefield, rapidly share the imagery and adjust the battleplans accordingly.

UAVs are critically dependent on computer data processing, data compression, storage and high speed data transmission for navigation, and flight profile. The UAV mission equipment will also need a high speed data dissemination capability to feed the C4I infrastructure and serve its subscribers. Fortunately, the technology sectors that engineer multimedia microchip capacity, computer processing and high speed data modems, announce significant improvements with regularity in the private sector/civilian community. Private sector automation technology directly supports some

UAV development programs, creating the acquisition advantage of reduced cost. Readily available, sophisticated technology with military application also creates a potential threat from proliferation of that technology.

> In developing effective and affordable UAVs and ground control systems we need to prepare for both core and specific UAV missions. The core missions include day or night reconnaissance, surveillance and target acquisition (RSTA); combat assessment (CA); and battlespace management. As new payloads become available, more specific UAV taskings will evolve to include adjusting indirect fire: close air support; deception operations; search and rescue (SAR) and mine detection. Our list of potential "real time or near real time" UAV missions is growing[27].

The Defense Airborne Reconnaissance Office (DARO) approved over sixteen proof-of-principle demonstrations of UAV payloads described on the table below. This is a clear indication of the program managers to explore the potential of UAVs for missions beyond the (historical) aerial reconnaissance mission.

UAV Joint Program Office Payload Projects

Demonstration Payload	Potential Mission Application
Meterological Sensor	Systemic Atmospherc readings
Radiac Sensor	Plot suspected NBC contamination
Light weight Standoff Chem Detector	Detect & plot toxic agents
Light weight Comms (COMINT) payload	Find/ID ground comms emitters
Acoustic Wave Chem Detector	Detect/plot low level chem agents
Hyperspectral Sensor (HSS)	Detect hidden/difficult targets
Coastal Recon & Analysis	Detect mines (day/limited visibility)
Tactical Remote Sensor System	BLOS ground sensor data relay
Commumications Relay	BLOS comms relay for grd forces
Laser Designator/Rangefinder	Demonstration for UAV payload
Electronic Intell (ELINT) Payload	Locate/ID enemy ground forces
Radar Jammer Payload	Jam enemy ground radars
Light Weight COMINT Payload	Find/ID ground comms emitters
Communications Jammer Payload	Jam both radios and data links
HSS/FOPEN Radar/Air Traffic Control	Demo for SouthCom

DARO /Defense Airborne Recon Office, UAV Annual Report, 6 Nov 1996.[28]

The goal of each of these payload projects is to provide battlefield commanders with additional means to achieve battlefield dominance. At this time, results of these studies are unavailable. However, some initial information has been released via media reports.

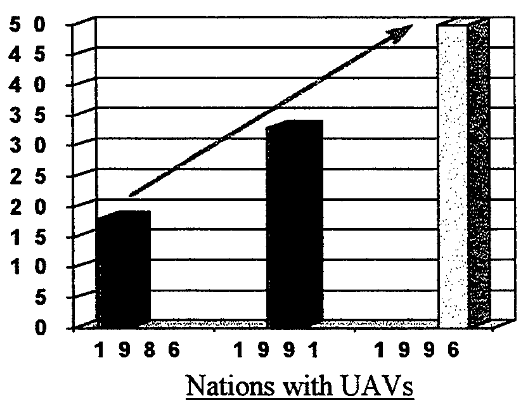
The Defense Advanced Research Project Agency reported promising results using ultra-wide band radar (UWB) to detect buried mines. According to the report, mine-detecting radar operating from a UAV at altitude will require significantly a higher power supply than used in ground tests. Furthermore, precise location of small mines is difficult with UAVs even with dual global positioning systems (GPS)[29]. Additional testing is planned.

A report in the Journal of Electronic Defense described testing of four different payloads installed in a UAV to test its potential for electronic warfare. One payload performed precision direction finding using HF,VHF and UHF bands. A second payload autonomously recognized and jammed 'enemy' VHF and UHF transmission. A third payload tested radar electronic warfare. The fourth payload was a tactical radar jammer to counter pulse, pulse-doppler and continuous-wave radar threats. All payloads performed well in the initial concept tests. "The services must now analyze the data and decide when or whether they will devise requirements and programs for UAV EW payloads."[30]

The concept of armed or lethal UAV systems is also being tested. One media report announced that a UAV flown laser targeting system successfully guided anti-armor missiles to four out of five targets.[31] In another report, GEN. Charles Krulak, Commandant of the Marine Corps, announced that the Marine Corps was assessing the development of UAV bombers in recent tests conducted at Aberdeen Proving Grounds.[32] Armed UAVs are not a new concept. The concept of using UAVs for a weapons delivery platform originated in 1953 and was tested in 1964 using two 250 lb. bombs from a Ryan Firebee RPV.[33] There are a variety of possible armed UAV prototypes.

The first launch of an air to ground weapon from a UAV was made 14 December 1971 by the USAF 6514th Test Squadron with a Maverick missile at Edwards Air Force Base[34]. The UAV, a Teledyne Ryan BGM-34 was recovered after the firing tests, confirming the concept as a proof-of-principle. This project was to originally designed to maintain the balance of power between Israel and Egypt by providing a low cost weapon system to counter the Russian SAM and AAA batteries in Egypt.[35] Anti-radar "harassment drones and decoys have a major role in efforts by the Israeli Air force to defeat hostile air defenses."[36] ARMADA magazine reports that Six nations presently have 'Attack UAVs'[37]. These nations include Iran, Israel, Germany, France, South Africa and the US.

Proliferation of UAV's



Source: UAVAnnual Report FY1996, 6 Nov 96, p6.

Many nations are realizing that UAVs provide cruise missile capability at a fraction of the cost. A hostile UAV, carrying a lethal payload, could reach the United States. Consider the domestic and international impact associated with chemical or biological agents dispensed by UAV. Suddenly, terrorism has an accurate, long range delivery means for weapons of mass destruction. Non-proliferation of UAV technology is clearly a national security issue for the United States.

The Missile Technology Control Regime (MTCR), is a voluntary agreement to prevent the proliferation of missiles capable of nuclear delivery which covers cruise missiles and related technologies.[38] The MTCR specifically prohibits the "export of unmanned aerial vehicle systems (including cruise missile systems, target drones, and reconnaissance drones) capable of delivering at least a 500kg payload to a range of 300 km."[39] The MTCR was first established in 1987 and now has 25 countries participating.

The United States is a charter member of the MTCR and has taken a strong stand in support of weapons control agreements and armed UAVs. The following statement appeared in the 1995 UAV Annual Report;

> We will continue to monitor advances in the arms control arena and ensure treaty compliance. In addition, to preclude any future misunderstanding about UAVs as weapon platforms, the DARO has made it clear that it has no plans to develop or test armed reconnaissance UAV's.[40]

Clearly there has been a major reversal in US Policy in the last two years which now allows concept tests of armed UAVs. Oddly, there is no mention of this significant change in policy in the 1996 UAV Annual Report.

The UAV program addresses the airworthiness of each system and the opportunities this technology offers to commanders at every level. Emerging technologies and over forty years of experience with UAVs led to a family of uniquely capable air vehicles that allows US Forces to dominate the battlefield without incurring unnecessary risks to aircrew members. However, the proliferation of UAV technology is tantamount to handing a cruise missile to a hostile nation as a delivery means for WMD. We have come far in those forty years, but did we come far enough? In the final chapter, we will consider what the future applications for UAVs could and should be.

Chapter 5

"UAVs are being used for more functions every day. The military UAV missions are obvious and have been addressed many times. The non-military government and commercial unmanned aircraft functions, will yield a yearly market exceeding $1 billion (US) by the turn of the century...(and) will likely exceed $2 billion by 2005-just ten short years away."

Richard T. Wagaman,
Past President , Association of Unmanned Vehicle Systems
Address at UV-95 Conference, Paris, France June 95

A SUMMARY OF RECOMMENDATIONS FOR THE FUTURE

In the first two chapters of this paper, I spoke of the value of versatile aerial platforms for military operations during the Cold War, which often placed aircrews at risk. As discussed, the loss or capture of aircrew members was exploited hostile nations and sensationalized by the international media, further increasing global tensions. In chapter three, I introduced the latest family of Unmanned Aerial Vehicles, created for high risk missions over hostile terrain. Finally in chapter four, alternative payload concepts were described that have the potential of expanding UAV mission scenarios beyond aerial reconnaissance. In this chapter, I will present some recommendations and concerns about UAVs for U.S. forces of the future.

My recommendations will cover three points. The first is to increase commitment on the part of all services, especially the Air Force to expand UAV mission capabilities. The second recommendation is to research UAV fighter aircraft. Lastly, I recommend monitoring international efforts for development and sale of UAVs and related technology.

I do not advocate a UAV Program as a panacea for airpower. There can be no replacement for strategic lift or tactical lift capability. UAVs are ill suited for strategic lift purposes. UAVs are better suited for aerial reconnaissance, communications relay, electronic warfare and radar jamming missions. I believe that UAV systems should have achieved greater integration into the military overall and the Air Force in particular.

The US Air Force has been involved over forty years with UAV systems and associated research. Given this experience, it amazes me that there is only one Air Force TUAV unit in existence. Furthermore, several of the payload concept tests mentioned in the preceding chapter merely repeat similar tests done conducted during the 1960s and early 1970s. The microchip and miniaturized on-board computers are providing the UAV with a virtual cockpit capability. This virtual cockpit and new alternative payloads will make new UAVs even more functional as aviation assets than in the past. It would be sad if the private sector realizes greater the potential of UAVs before the military. (See Mr. Wagamans remarks at beginning of this chapter). A spark is needed. It is time for a new generation of Hap Arnold's or Billy Mitchell's to lead a cultural revolution to further the unmanned revolution in military affairs.

My next point or recommendation is for the U.S. to research a concept UAV fighter. This concept offers some economy compared to manned systems. It is not my intent to conduct a detailed cost benefit analysis of manned vs. unmanned systems. I propose an alternative to large numbers of high technology manned fighter aircraft. A small number of UAV fighters could serve in the first wave of a high risk theatre campaign to attrite enemy air defenses. This would effectively preserve manned systems for future lower risk missions. Whether the future requires threat based or capability based systems to support U.S. National Security Strategy becomes irrelevant if UAVs can do the job cost efficiently. Consider the potential benefits of a UAV fighter in terms of cost avoidance (1-5) and the operational capabilities (6-9).

1. No Ejection Seat/No Oxygen System (low cost/less weight).
2. A Virtual Cockpit: No flight controls or pilot safety systems.
3. No ergonomic studies of cockpit design (low cost).
4. Potentially less time & cost to replace a combat UAV than replace a combat fighter and pilot.
5. If feasible convert current aircraft to UAV for testing.
6. Fly by Wire (F16 type) control system would connect through On-Board Computer to Ground Control System.
7. Extreme High G-Maneuvers (Exceeding human capacity).
8. Reduce fratricide: Real-time/Gun Camera slow-motion and stop-action imagery, to UAV 'pilot' improves target identification.
9. Precise Close Air Support: Combine gun camera targeting with laser guided munitions.

An ironic but significant justification for unmanned fighters (in lieu of manned versions) is to increase the aircraft's capability by removing the 'human' constraint. Pilots generally cannot sustain more than 6-7G's. In a tight turn, a fighter aircraft can easily develop G-Forces that will force the pilot into unconsciousness. UAVs are already capable of exceeding 8Gs, sufficient to outmaneuver manned systems in aerial combat. In 1971, this Air to Air concept was tested informally in mock dog fights, pitting an unarmed UAV against veteran Navy Pilots in two F4s with Sparrow and Sidewinder missiles. The UAV repeatedly outmaneuvered the F4s and was not hit.[41] This capability may be as significant as "stealth" in aircraft survivability, and may provide the best countermeasure against enemy UAVs.

My final point or recommendation is to monitor international development and sale of UAV technology. This will become increasingly difficult if Mr. Wagaman's assessment for the growth potential of the non-military market for UAVs is correct. He claims that the non-military UAV market will double to a $2B industry. For example, UAVs may be used as crop dusters, highway traffic surveillance, counterdrug operations, border surveillance, nuclear power plant or chemical plant discharge monitors. In each of the preceding examples, a common operational theme emerges. Extended, monotonous and high-risk hazardous operations are defining criteria that makes UAVs attractive to civilian application as well as military. The UAV is clearly a dual use technology, ultimately capable of crop dusting agricultural fields or delivering biological toxins and nerve agents. The United States must be prepared for a two-fold challenge:

- Prevent rogue nations from gaining a delivery means for weapons of mass destruction.
- Devise countermeasures for highly maneuverable, stealthy enemy UAV aircraft.

In conclusion, the United States Department of Defense must maintain a balanced military capability to protect national interests and project power. This must be done without eroding the national economy or vital domestic interests. I believe that UAV systems offer a unique, next step for a true revolution in military affairs and a cost effective alternative to a large, manned aircraft fleet without peer.

APPENDIX

RYAN RECONNAISSANCE MODEL DIRECTORY

Ryan 147 Model	Military Model	Length ' Span ' Area □'			Thrust (lbs.)	Mission	Month/Year Operated	Number Launched	% Return	Most Flights by a Bird
A		27	13	36	1700	Fire Fly — first recce demo drone	4/62-8/62			
B		27	27	80	1700	Lightning Bug — first big-wing high-altitude day photo bird	8/64-12/65	78	61.5%	8
C		27	15	40	1700	Training, and low-altitude tests	10/65			
D		27	15	40	1700	From C for electronic intelligence	8/65	2		
E		27	27	80	1700	From B for hi-altitude electronic intelligence	10/65-2/66	4		
F		27	27	80	1700	From B — electronic countermeasures	7/66			
G		29	27	80	1920	Longer B with larger engine	10/65-8/67	83	54.2%	11
H	AQM-34N	30	32	114	1920	Hi-alt. photo; more range	3/67-7/71	138	63.8%	13
J		29	27	80	1920	First low-alt. day photo (BLACS)	3/66-11/67	94	64.9%	9
N		23	13	36	1700	Expendable decoy (from BQM-34A)	3/66-6/66	9	0	
NX		23	13	36	1700	Decoy and medium-alt. day photo	11/66-6/67	13	46.2%	6
NP		28	15	40	1700	Interim low-alt. day photo	6/67-9/67	19	63.2%	5
NRE		28	13	40	1700	First night photo (from NP)	5/67-9/67	7	42.9%	4
NQ		23	13	36	1700	Low-alt. NX; hand controlled	5/68-12/68	66	86.4%	20
*NA/NC	AQM-34G	26	15	40	1700	By TAC for chaff and ECM	8/68-9/71			
NC	AQM-34H	26	15	40	1700	Leaflet dropping (Bullshit Bombers)	7/72-12/72	29	89.7%	8
NC(M1)	AQM-34J	26	15	40	1700	Interim low-alt. day photo and for training				
S/SA		29	13	36	1920	Low-altitude day photo	12/67-5/68	90	63.3%	11
SB		29	13	36	1920	Improved SA low-altitude bird	3/68-1/69	159	76.1%	14
SRE	AQM-34K	29	13	36	1920	Night photo version of SB	11/68-10/69	44	72.7%	9
SC	AQM-34L	29	13	36	1920	The low-altitude workhorse	1/69-6/73	1651	87.2%	68**
SC/TV	–34L/TV	29	13	36	1920	SC model with real-time TV	6/72-	121	93.4%	42
SD	AQM-34M	29	13	36	1920	Low-altitude photo; real-time data	6/74-4/75	183	97.3%	39
SDL	–34M(L)	29	13	36	1920	SD bird with Loran navigation	8/72	121	90.9%	36
SK		29	15	40		Navy operation from aircraft carrier	11/69-6/70			
T	AQM-34P	30	32	114	2800	Larger engine; high-alt. day photo	4/69-9/70	28	78.6%	
TE	AQM-34Q	30	32	114	2800	High-altitude; real time Comint	2/70-6/73	268	91.4%	34
TF	AQM-34R	30	32	114	2800	Improved long-range TE	2/73-6/75	216	96.8%	37
								3435 operational sorties by 100th SRW		

Note: *NA/NC Combat Angel birds were operated on standby in U.S. by Tactical Air Command for possible pre-strike ECM chaff-dispensing missions.*

**68 missions by Tom Cat
63 missions by Budweiser
52 missions by Ryan's Daughter
46 missions by Baby Buck



	CHARACTERISTICS	Pioneer	Hunter	Tactical UAV Outrider
Operational	ALTITUDE: Maximum (km, *ft*) Operating (km, *ft*)	4.6 km *15,000 ft* ≤4.6 km *≤15,000 ft*	4.6 km *15,000 ft* ≤4.6 km *≤15,000 ft*	4.6 km *15,000 ft* 1.5 km *5,000 ft*
	ENDURANCE (Max): (hrs)	5 hrs	11.6 hrs	>4 hrs (+ reserve) @ 200 km
	RADIUS OF ACTION: (km, *nm*)	185 km *100 nm*	267 km *144 nm*	≥200 km *≥108 nm*
	SPEED: Maximum (km/hr, *kts*) Cruise (km/hr, *kts*) Loiter (km/hr, *kts*)	204 km/hr *110 kts* 120 km/hr *65 kts* 120 km/hr *65 kts*	196 km/hr *106 kts* >165 km/hr *>89 kts* <165 km/hr *<89 kts*	204 km/hr *110 kts* 167 km/hr *90 kts* 111-139 km/hr *60-75 kts*
	CLIMB RATE (Max): (m/min, *fpm*)	[N/A] [N/A]	232 m/min *761 fpm*	488 m/min *1,600 fpm*
	DEPLOYMENT NEEDS:* *Depends on equipage & duration	Multiple* C-130, C-141, C-17 or C-5 sorties Ship: LPD	Multiple* C-130 sorties	Single C-130 (drive on/drive off) Ship: LHA/LHD (roll on/roll off)
Air Vehicle	PROPULSION: Engine(s) – Maker – Rating – Fuel – Capacity (L, *gal*)	One Recip; 2 cylinders, 2-stroke – Sachs & Fichtel SF 2-350 19.4 kw *26 hp* AVGAS (100 octane) 42/44.6 L *11/12 gal*	Two Recips: 4-stroke – Moto Guzzi (Props: 1 pusher/1 puller) 44.7 kw *60 hp* MOGAS (87 octane) 189 L *50 gal*	One Recip; pusher prop – McCulloch 4318F Short Block/Diesel 37.3 kw *50 hp* Heavy Fuel (JP-8) 48 L *12.7 gal*
	WEIGHT: Empty (kg, *lb*) Fuel Weight (kg, *lb*) Payload (kg, *lb*) Max Takeoff (kg, *lb*)	125/138 kg *276/304 lb* 30/ 32 kg *66/ 70 lb* 34/ 34 kg *75/ 75 lb* 195/205 kg *430/ 452 lb*	544 kg *1,200 lb* 136 kg *300 lb* 91 kg *200 lb* 726 kg *1,600 lb*	136 kg *300 lb* 39 kg *85 lb* 27 kg *60 lb* >227 kg *>500 lb*
	DIMENSIONS: Wingspan (m, *ft*) Length (m, *ft*) Height (m, *ft*)	5.2 m *17.0 ft* 4.3 m *14.0 ft* 1.0 m *3.3 ft*	8.9 m *29.2 ft* 7.0 m *23.0 ft* 1.7 m *5.4 ft*	3.4 m *11.0 ft* 3.0 m *9.9 ft* 1.5 m *5.0 ft*
	AVIONICS: Transponder Navigation	Mode IIIC IFF GPS	Mode IIIC IFF GPS	Mode IIIC IFF GPS and INS
	LAUNCH & RECOVERY:	Land: RATO, Rail; Runway, (A-Gear) Ship: RATO; Deck w/Net	RATO, Unimproved Runway (200 m)	75m x 30m x 10m "box" (dependent on weight and altitude)
	GUIDANCE & CONTROL:	Remote Control/Preprogrammed	Remote Control/Preprogrammed	Prepgmd/Remote Con/Autopilot & -land
Payload & Links	SENSOR(S):	EO or IR	EO and IR	EO and IR (SAR growth)
	DATA LINK(S): Type	Uplink: C-band/LOS & UHF Downlink: C-band/LOS	C-band/LOS	C-band/LOS (Digital growth)
	Bandwidth: (Hz)	C-band/LOS: 10 Mhz UHF: 600 MHz	20 MHz	4.4–5.0/5.25–5.85 GHz
	Data Rate: (bps)	C-band/LOS & UHF: 7.317 kbps	7.317 kbps	Full Duplex: 9,600 baud
	C2 LINK(S):	Through Data Link	Through Data Link	Through Data Link
System & Support	SYSTEM COMPOSITION:	5 AVs, 9 payloads (5 day cameras, 4 FLIRs), 1 GCS, 1 PCS, 1–4 RRSs, 1 TML (USMC units only)	8 AVs, 8 MOSPs, 4 ADRs, 4 RVTs, 3 GCSs/MPSs, 2 GDTs, 1 LRS, 1 MMF	4 AVs, 2 GCSs, 2 GDTs, 1 RVT, 4 MMPs, LRE, GSE
	PRIME/KEY CONTRACTOR(S):	Pioneer UAV, Inc.	TRW Avionics & Surveillance Group	Alliant Techsystems
	MAJOR SUBCONTRACTORS: – Air Vehicle, Propulsion, Avionics, Payloads, Information Processing, Communications, Ground and Support Systems	AAI Corp; Computer Instrument Corp; General Svcs Engrg; Humphrey; Israel Aircraft Industries (IAI); Sachs; Trimble Navigation	Alaska Ind.; Burtek; Consolidated Ind.; Fiber Com; Gichner; IAI/Malat; IAI/Elta; IAI/Malat/Tamam; ITT/Cannon; Lopardo: Mechtronics; Moto Guzzi	Bendix King; BMS; Cirrus Design; CDL; FLIR Systems; GS Engineering; IAI Tamam; IntegriNautics; Lockheed Martin; Mission Technologies; Phototelesis-TI; Rockwell International; SwRI; Stratos Group; Teftec Inc.
	Column Notes:	*AV weights: Option 2 / Option 2+*		*Developmental estimates*

	CHARACTERISTICS	Tier II, MAE UAV *Predator*	Tier II+, CONV HAE UAV *Global Hawk*	Tier III–, LO HAE UAV *DarkStar*
Operational	**ALTITUDE: Maximum** (km, *ft*) **Operating** (km, *ft*)	7.6 km *25,000 ft* 4.6 km *15,000 ft*	19.8 km *65,000 ft* 15.2–19.8 km *50,000–65,000 ft*	>13.7 km *>45,000 ft* >13.7 km *>45,000 ft*
	ENDURANCE (Max): (hrs)	>20 hrs	>40 hrs (24 hrs at 5,556 km/*3,000 nm*)	>8 hrs (at 926 km/*500 nm*)
	RADIUS OF ACTION: (km, *nm*)	926 km *500 nm*	5,556 km *3,000 nm*	>926 km *>500 nm*
	SPEED: Maximum (km/hr, *kts*) **Cruise** (km/hr, *kts*) **Loiter** (km/hr, *kts*)	204-215 km/hr *110-115 kts* 120-130 km/hr *65- 70 kts* 111-120 km/hr *60- 65 kts*	>639 km/hr *>345 kts* 639 km/hr *345 kts* 630 km/hr *340 kts*	>463 km/hr *>250 kts* >463 km/hr *>250 kts* >463 km/hr *>250 kts*
	CLIMB RATE (Max): (m/min, *fpm*)	168 m/min *550 fpm*	1,036 m/min *3,400 fpm*	610 m/min *2,000 fpm*
	DEPLOYMENT NEEDS:* *Depends on equipage & duration	Multiple* C-130 sorties	AV: Self-Deployable GS: Multiple* C-141, C-17 or C-5 sorties	Multiple* C-141, C-17 or C-5 sorties
Air Vehicle	**PROPULSION: Engine(s)** **– Maker** **– Rating** **– Fuel** **– Capacity** (L, *gal*)	One Fuel-Injected Recip; 4-stroke – Rotax 912/Rotax 914 63.4/75.8 kw *85/105 hp* AVGAS (100 Octane) 409 L *108 gal*	One Turbofan – Allison AE3007H 32 kN *7,050 lb static thrust* Heavy Fuel (JP-8) 8,176 L *2,160 gal*	One Turbofan – Williams FJ 44-1A 8.45 kN *1,900 lb static thrust* Heavy Fuel (JP-8) 1,575 L *416 gal*
	WEIGHT: Empty (kg, *lb*) **Fuel Weight** (kg, *lb*) **Payload** (kg, *lb*) **Max Takeoff** (kg, *lb*)	544 kg *1,200 lb* 295 kg *650 lb* 204 kg *450 lb* 1,043 kg *2,300 lb*	4,055 kg *8,940 lb* 6,668 kg *14,700 lb* 889 kg *1,960 lb* 11,612 kg *25,600 lb*	1,978 kg *4,360 lb* 1,470 kg *3,240 lb* 454 kg *1,000 lb* 3,901 kg *8,600 lb*
	DIMENSIONS: Wingspan (m, *ft*) **Length** (m, *ft*) **Height** (m, *ft*)	14.8 m *48.7 ft* 8.1 m *26.7 ft* 2.2 m *7.3 ft*	35.4 m *116.2 ft* 13.5 m *44.4 ft* 4.6 m *15.2 ft*	21.0 m *69 ft* 4.6 m *15 ft* 1.5 m *5 ft*
	AVIONICS: Transponder **Navigation**	Mode IIIC IFF GPS and INS	Mode I / II / IIIC / IV IFF GPS and INS	Mode IIIC IFF GPS and INS
	LAUNCH & RECOVERY:	Runway (760 m/*2,500 ft*)	Runway (1,524 m/*5,000 ft*)	Runway (<1,219 m/*<4,000 ft*)
	GUIDANCE & CONTROL:	Prepgmd/Remote Control/Autonomous	Preprogrammed/Autonomous	Preprogrammed/Autonomous
Payload & Links	**SENSOR(S):**	EO, IR, and SAR	EO, IR, and SAR	EO or SAR
	DATA LINK(S): Type	C-band/LOS; UHF/MILSATCOM; Ku-band/SATCOM	Ku-band/SATCOM; X-Band CDL/LOS	Ku-band/SATCOM; X-Band CDL/LOS
	Bandwidth: (Hz)	C-band/LOS: 20 MHz UHF/MILSATCOM: 25 kHz Ku-band/SATCOM: 5 MHz	UHF/SATCOM: 25 kHz Ku-band/SATCOM: 2.2-72 MHz X-band CDL/LOS: 10-120 MHz	UHF/SATCOM: 25 kHz Ku-band/SATCOM: 2.2 MHz X-band CDL/LOS: 10-60 MHz
	Data Rate: (bps)	C-band/LOS: 20 MHz Analog UHF/MILSATCOM: 4.8 kbps Ku-band/ SATCOM: 1.544 Mbps	UHF/SATCOM: 19.2 kbps Ku-band/SATCOM: 1.5-50 Mbps X-band CDL/LOS: 274 Mbps	UHF/SATCOM: 19.2 kbps Ku-band/SATCOM: 1.5 Mbps X-band CDL/LOS: 137 Mbps
	C2 LINK(S):	UHF/MILSATCOM	UHF MILSATCOM: Ku-band/SATCOM; UHF/LOS; X-band CDL/LOS	UHF MILSATCOM: Ku-band/SATCOM; UHF/LOS; X-band CDL/LOS
System & Support	**SYSTEM COMPOSITION:**	4 AVs, 1 GCS, 1 Trojan Spirit II Dissemination System, GSE	AVs (TBD); HAE CGS	AVs (TBD); HAE CGS
	PRIME/KEY CONTRACTOR(S):	General Atomics-Aeronautical Systems	Teledyne Ryan Aeronautical	Lockheed Martin Skunk Works/ Boeing Military Aircraft Division
	MAJOR SUBCONTRACTORS: – Air Vehicle, Propulsion, Avionics, Payloads, Information Processing, Communications, Ground and Support Systems	Boeing Defense & Space; Litton; LMTCS (Ku-band SATCOM); Magnavox/ Carlyle Gp; Northrop Grumman (SAR); Rotax Cp; Versatron Cp	Allison Engine/Rolls Royce; Raytheon E-Systems; GDE Systems/Tracor; Héroux; Hughes Aircraft; Lockheed Martin Wideband Systems; Rockwell International; Aurora Flight Sciences	ABS Cp; Advanced Composites; Aydin Vector; CI Fiberite; Hexcel; Honeywell Avionics; Litton G&C; Lockheed Martin Wideband Systems; Recon/Optical; Rockwell Collins; Rosemount Aerospace; Northrop Grumman; Williams International
	Column Notes:		*Developmental estimates*	

ENDNOTES

[1] Jay M. Shafritz, Words on War, Simon & Schuster, NY, 1990, p208.

[2] Samuel B. Griffith, Sun Tsu-The Art of War, Oxford University Press, 1963, p82.

[3] William Wagner, Lightning Bugs and Other Reconnaissance Drones, Armed Forces Journal and Aero Publishers, 1982, p17.

[4] Ibid., p19.

[5] Ibid., p202.

[6] Ibid., p213.

[7] Bill Sweetman, The Invisible Men, Air & Space Smithsonian, April/May 1997, p19.

[8] William Wagner, Lightning Bugs and Other Reconnaissance Drones, Armed Forces Journal and Aero Publishers, 1982, p175.

[9] Ibid., 194.

[10] Ibid., 166.

[11] Ibid., 182.

[12] Ibid., 174.

[13] Ibid., p185.

[14] Samuel B. Griffith, Sun Tsu-The Art of War, Oxford University Press, 1963, p77.

[15] Defense Airborne Reconnaissance Office, UAV Annual Report FY96, 6 Nov 1996, p1.

[16] Ibid., p1.

[17] Ibid., p31.

[18] Ibid., p14.

[19] Ibid., p31.

[20] Ibid., p20.

[21] As referred to in Chapter 1 of this text.

[22] Defense Airborne Reconnaissance Office, UAV Annual Report, 6 Nov 1996. p31.

[23] Ibid., p22.

[24] Ibid., p22.

[25] Ibid., p24.

[26] Defense Airborne Reconnaissance Office, UAV Annual Report, 6 Nov 1996. p21.

[27] Rear Admiral Barton Strong, Testimony before Senate Armed Forces Service Committee on UAV Programs, 29 Mar 1996.

[28] Defense Airborne Recon Office, UAV Annual Report, UAV Annual Ported.

[29] Bruce D. Nordwall, Ultra-Wideband Radar Detects Buried Mines, Aviation Week & Space Technology, 31 March 1997, p63.

[30] Demo Done, UAV EW Payload Players Await Report, Journal of Electronic Defense, Vol. 20, January 1997, p.27.

[31] Pat Cooper, New Battlefield Tasks Eyed for UAVs, Army Times, 28 Oct 1996, p12.

[32] Ibid, p12.

[33] William Wagner, Lightning Bugs and Other Reconnaissance Drones, Armed Forces Journal and Aero Publishers, 1982, p174.

[34] William Wagner, Lightning Bugs and Other Reconnaissance Drones, Armed Forces Journal and Aero Publishers, 1982, p181.

[35] Ibid., p180.

[36] W. Seth Carus, Cruise Missile Proliferation in the 1990s, Published with the Center for Strategic and International Studies, Washington DC, Praeger Publishers, 1992, p86.

[37] Doug Richardson, Technology Section, Armada International, Oct/Nov 1996, p20.

[38] Most international weapon agreements do not include UAVs, the Missile Technology Control Regime is a noteworthy exception.

[39] Carus, Cruise Missile Proliferation in the 1990s, p89.

[40] Defense Airborne Reconnaissance Office, UAV 1995 Annual Report, August 1995, p8.

[41] William Wagner, Lightning Bugs and Other Reconnaissance Drones, Armed Forces Journal and Aero Publishers, 1982, p186.

GLOSSARY

ACTD- Advanced Concepts Technology Demonstration. i.e. New equipment prototype test design.

BDA-Battle Damage Assessment.

BLOS-Beyond Line of Sight.

C4I-Command, Control, Communications, Computers and Intelligence.

DARO-The Defense Airborne Reconnaissance Office chartered to manage the DARP.

DARP-The Defense Airborne Reconnaissance Program includes the UAV program.

HAE-High Altitude Endurance. Refers to UAV systems capable of over 15,000 feet with over 10 hours fuel duration.

JATO-Jet Assisted Take-Off. A technique to rapidly accelerate and launch aircraft using drop-off "rockets" or (JATO) bottles.

JTF-Joint Task Force. A military force consisting of more than one service component.

JROC-Joint Requirements Oversight Council.

kts-knots, a measure of airspeed equivalent to nautical miles per hour.

RPV-Remotely Piloted Vehicle, a term synonymous with Unmanned Aerial Vehicles.

RSTA-Reconnaissance, Surveillance, and Target Acquisition.

SAM-Surface to Air Missile.

Sortie-A single flight mission from takeoff to landing.

UAV -Unmanned Aerial Vehicle. This powered, aerial vehicle that does not carry an operator, uses aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable and can carry a lethal or non-lethal payload. Ballistic or cruise missiles are not considered UAVs.

WMD-Weapons of Mass Destruction.

BIBLIOGRAPHY

Armitage, Sir Michael. *Unmanned Aircraft*, Vol 3. Brassey's Defence Publishers, 1988.

Carus, Seth W. *Cruise Missile Proliferation in the 1990s*, Published with the Center for Strategic and International Studies, Washington DC, Praeger Publishers, 1992.

Cooper, Pat. *New Battlefield Tasks Eyed for UAVs*, Army Times, 28 Oct 1996.

Cooper, Pat. *Study: Mass Power Rather than Forces/Smart Missiles and Drones could Replace Attack Aircraft*, Air Force Times, 20 January 1997.

Cooper, Pat. *UAVs Readied for New Battlefield Roles/Unmanned Systems to be Used to Achieve Blanket Coverage*, Army Times, 27 January 1997.

Department of the Air Force, *Air Force 2025 "Americas Vigilant Edge,"* Compact Disk, Air University, Maxwell AFB, AL, 1996.

Goodman, Glenn W, Jr. *New Family of U.S. Military UAVs Takes Shape*, Sea Power-Navy League of the United Sates, December 1966.

Griffith, Samuel B., *SUN TZU-The Art of War*, Oxford University Press, New York, 1963.

Headquarters Department of the Army, *FM 100-5 Operations*, 14 June 1993.

Heber, Charles E. Director of the High Altitude Endurance Unmanned Air Vehicle Program Office, *Statement before the Subcommittee on Airland Forces of the Senate Armed Services Committee on Unmanned Aerial Vehicles*, 29 March 1996.

Longino, Dana A. *Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios*, Air University Press, Maxwell Air Force Base, Alabama, December 1994.

Lum, Z. *Demo Done, UAV EW Payload Players Await Report*, Journal of electronic Defense, Vol 20, Jan 1997.

Nordwall, Bruce D. *Ultra-Wideband Radar Detects Buried Mines*, Aviation Week & Space Technology, 31Mar 1997.

Oliveri, Frank. *UAV: Poor Man's Weapon*, Air Force Times, 9 November 1995.

Richardson, Douglas. *Unmanned Aerial Vehicles Stretch their Wings*, Armada International Magazine, Volume 5. October/November 1996.

Strong, Barton D. Program Executive Officer, Cruise Missile and Joint Unmanned Aerial Vehicles, *Statement before the Subcommittee on Airland Forces of the Senate Armed Services Committee on Unmanned Aerial Vehicle Programs*, 29 March 1996.

Sweetman, Bill. *The Invisible Men*, Air & Space Smithsonian, Vol. 12, April/May 1997.

The UAV Annual Report FY1995, Defense Airborne Reconnaissance Office, August 1995.

The UAV Annual Report FY1996, Defense Airborne Reconnaissance Office, 6 November 1996.

Wagner, William. *Lightening Bugs and Other Reconnaissance Drones*, Armed Forces Journal & Aero Publishers, Fallbrook, CA. 1982.

Weigley, Russell F. *The American Way of War, A History of United States Military Strategy and Policy*, Indiana Press, Bloomington, IN. 1973.