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UNMANNED AERIAL VEHICLES AND SPECIAL OPERATIONS: FUTURE DIRECTIONS

by

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Advances in computing, miniaturization, imaging, and data transmission technologies are precursors to a more important role for UAVs in warfare. UAVs are likely, first, to revolutionize the way reconnaissance and surveillance are conducted, second, to increase the capabilities of small units, third, to join manned platforms in the conduct of assault and attack missions, and finally help provide the numerous nodes necessary to facilitate both the digital connectivity and swarming forces envisioned in future network-centric formations.

This thesis focuses on answering six questions:

-What missions can UAVs perform?
-What missions should UAVs perform?
-What type of UAV is appropriate for each mission?
-How can SOF use UAVs?
-Who should own the UAV (from a SOF perspective)?
-What level of control is required and where?

Results include what UAV missions and types could support special operations, which of these should be performed by UAVs organic to special operations, and which should be performed by the Services' UAVs, as well as recommendations for future command and control of UAVs supporting special operations. Results are presented in matrix form for easy correlation of related factors. The thesis concludes with a twenty-year prognostication of UAV development and recommends areas for future study.

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UNMANNED AERIAL VEHICLES AND SPECIAL OPERATIONS: FUTURE DIRECTIONS

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ABSTRACT

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EXECUTIVE SUMMARY

UAVs have proliferated throughout the militaries of the world over the last twenty years. They have seen increasing use on the battlefield from Southern Lebanon to Iraq and from Bosnia to Kosovo. With all four of the military services in the U.S. already possessing their own organic UAVs, and developing future generations of UAVs, it is a valid question to ask what role UAVs could play in special operations.

The goal of this thesis is to answer six fundamental questions about UAVs and, in so doing, to determine how special operations forces (SOF) should employ UAVs in the future. These fundamental questions are first, what missions can UAVs perform? Second, what missions should UAVs perform? Third, what type UAV is appropriate for each mission? Fourth, how can special operations use UAVs? Fifth, who should own the UAV (from a special operations perspective)? And sixth, what level of control is required and where?

This study addresses these questions inductively—building knowledge from which we will derive our conclusions. Accordingly, the study begins with an investigation into the history of the development and use of UAVs. From that discussion, inherent advantages and disadvantages of UAVs as well as trends in technology, organization, and tactics are identified. Next the study uses the preceding conclusions to suggest how UAVs could be used to enhance special operations. Based on those suggested uses, the study recommends the types of UAVs that should be procured by U.S. Special Operations Command (USSOCOM) and which Service-owned UAVs should be used to support special operations. Based on these recommendations, the study addresses the issues of what echelons of command the UAVs should support and who should control the UAVs. In the final chapter, several issues, which are essentially implications arising from the preceding discussion, are raised and discussed—to include issues for further study.

This study arrives at the following conclusions:

- History is replete with uses of unmanned aerial vehicles, but their full potential has previously been hampered by insufficient technology.

- Recent technology breakthroughs have occurred and the real news is in payloads, efficiency, and miniaturization. Much of this is facilitated by exponential advances in computer technology.

- Three measures of effectiveness facilitate the comparison of plans using manned vehicles versus plans using unmanned vehicles. They are the probability of mission failure, the probability of friendly death or casualty, and the cost of the operation.

- Two trends in warfare will most effect the future demands for UAVs. First is the trend towards information dominance, because UAVs can provide cost effective, staring sensors and surrogate satellites. The second is the trend towards network-centric organizational designs, because UAVs can provide rapidly deployable, cellular networks that are capable of providing the required data transmission bandwidth. UAVs can also empower the numerous small units required for swarming.

- UAVs could provide support to all nine primary missions and five of the seven collateral activities of USSOCOM.

- USSOCOM should buy an organic UAV capability. It should do so in phases that correspond with the progress of UAV technology, beginning with tactical UAVs then adding micros, cargo carriers, and perhaps CSAR platforms as technology matures.

- USSOCOM should articulate its UAV support requirements to the military Services so that they will include our needs in their procurement plans. Two of the areas most appropriate for the Services to provide UAV support to special operations are strategic reconnaissance and C4I connectivity.

- Control of SOF UAVs should go to those best able to utilize them with the general goal to push them as far down in the chain of command as makes sense. In other words, commanders should seek to empower small units without unnecessarily burdening them.

- There are three future issues for UAVs. The first issue is the need to counter adversary UAVs. The second issue is the increasing autonomy of UAVs and the need to consider when and how humans should be in the loop. The third issue is the replacement of manned systems by UAVs and the missions and scenarios where that will most likely happen in the future.

- Even more so than in the case of manned aircraft, there is some danger that UAVs could be used against their original owners. Although UAVs are not likely to be captured and flown against their original owners, there is significant danger that UAVs could be captured and reverse engineered. There is also a remote but significant chance that UAV guidance signals could be intercepted and altered, thus allowing the UAV to appear to malfunction and present a danger to its owners.

- Manned aircraft will not become obsolete. This due to the vulnerability of guidance links, shortcomings of artificial intelligence, and the loss of a casualty-avoidance advantage caused when passengers are carried in an aircraft.

- For most applications, UAVs should be seen as complimenting a manned presence rather than as operating alone.

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I. INTRODUCTION

How might a Theater CINC utilize special operations forces and a family of unmanned aerial vehicles (UAVs) to conduct military operations that minimize the danger to U.S. personnel, while avoiding the collateral damage associated with high altitude bombing? The following scenario is designed to open the reader's mind to the possible future uses of unmanned aerial vehicles and to suggest how UAVs could be used to empower small units to out-perform larger units, do it more economically, and with far less risk to personnel. Beyond that, I intend to discuss how the dramatic increases of digitized information, available to military personnel and facilitated by UAVs and other sensors, suggest new ways of organizing for and conducting military operations.

A joint special operations task force (JSOTF) has been given the mission of protecting a United Nations-sponsored safe haven, which is surrounded by hostile forces. The safe haven is connected to friendly territory by a tenuous road through a rugged mountain pass. From well-concealed hide-sites, a handful of Special Forces NCOs control the important mountain pass and critical road junctions leading into the safe haven. At several two-man sites, whose general locations were chosen by operations analysts for most effective observation and further pinpointed by the team members themselves for reasons of field craft, these specially trained NCOs are monitoring movement through the pass and deciding what gets through and what does not. They are observing, on a continuous, real time basis, on and off-road movements through the valley and via a slow orbiting or stationary UAV which provides day, night, thermal, and radar imaging via secure, directional data link to durable, high-resolution, multipurpose screens which can fit in the operators' cargo pockets. All communications to and from the operators are relayed via a directional link through a surrogate satellite UAV to prevent adversary triangulation of the teams' locations.

When an operator sees activity of interest, he is able to slew one of the UAV's multi-sensor turrets to the object of interest, choose one or more imaging sources and zoom as desired. If he detects an activity or other target that fits the parameters of their search, they can choose to either engage the target or send a secure data burst message to his approval authority as specified in the rules of engagement. Once the decision to engage is made, the operators are able to call upon semi-autonomous attack UAVs launched from an orbiting mother ship. The operators designate their targets as well as the preferred order and/or method of attack by mouse clicks which in turn place tags on the objects on their viewing screens. Through imagery correlation and/or laser designation by the surveillance UAV, an electronic target hand off occurs between the surveillance UAV and the attack UAV. The SOF teams monitor the attack UAVs via the continuous image streams coming from their reconnaissance/surveillance UAVs and serve as men in the loop who can call off or modify the attacks if they begin to have undesired consequences such as damage to friendly forces or non-combatants.

In the event that hostile forces begin searching the hills where the SOF teams are hidden, the SOF teams stay safely concealed in their hide-sights while diverting some of their assets to their own defense. Not only are the SOF teams well hidden on difficult terrain, but they are also able to bring withering fire to bear on any would-be attackers. Not even nighttime is the enemy's friend, because the UAV's sensors see them at night just as well as daytime.

In order to keep these twenty-first century warriors healthy, SOF team resupply is facilitated by periodic electronic shopping lists that the teams send by secure data burst to the JSOTF J4. J4 builds their resupply bundles to order, places them on resupply UAVs, and sends the respective SOF team a message that their bundle is ready. The SOF team sends for the resupply UAV when time permits, preferably at night, and directs it to a designated cache site, where the bundle can be either air-landed or dropped by parachute.

Elsewhere in the theater, another SOF element is preparing to capture a suspected war criminal that the U.S. National Command Authority wants brought to justice. This is to be a classic building take down in a dense, non-permissive, urban setting. Once surprise is lost, the team will need a quick helicopter extraction, but since it is not known when the target will arrive at the take down site, the team has covertly infiltrated by ground vehicle to a nearby building where they have a room facing the target building. The team inconspicuously launches two electric-powered micro-UAVs that quietly fly over to and attach themselves to the outside walls of the target building overlooking the only two entrances. These micro-UAVs can transmit several hours of real-time video and audio from the target building, ensuring positive identification of the target person, as well as facilitate continuous, accurate situational awareness for the operation. The critical insertion and extraction of the SOF teams is conducted by manned, special operations aviation (SOA) helicopters. These SOA helicopters often fly in manned–unmanned teams with uninhabited combat aerial vehicles (UCAV) providing suppression of enemy air defense (SEAD), or serving as decoys, scouts, and fire support platforms—whatever the tactical situation calls for.

A. HISTORY OF UNMANNED AERIAL VEHICLES

1. UAVs Defined

Aerial vehicles can be classified according to their method of guidance and whether or not they are intended to be expendable. The first major differentiation for aerial vehicles is whether they are manned or unmanned. The next differentiation is whether they are recoverable or expendable. These groupings can be further divided into remotely controlled vehicles and automatically controlled vehicles. Although the letters in the acronym stand for unmanned aerial vehicle, the term UAV, as it is currently used, refers to reusable, unmanned, aerial vehicles and excludes missiles and rockets which, although they are unmanned, are more munitions than vehicles. The following three figures depict three different ways of categorizing unmanned aerial vehicles. Figure 1 illustrates the differentiation of air vehicles according to method of guidance and reusability. Figure 2 illustrates classification by purpose, which considers the mission and echelon that the vehicle is designed to support (Figure 2). Figure 3 illustrates classification by vehicle performance. To avoid confusion, I will only use the acronym UAV when referring to the current meaning of the term. When referring to the more general definition shown in Figure 1, I will write out the term "unmanned aerial vehicle."

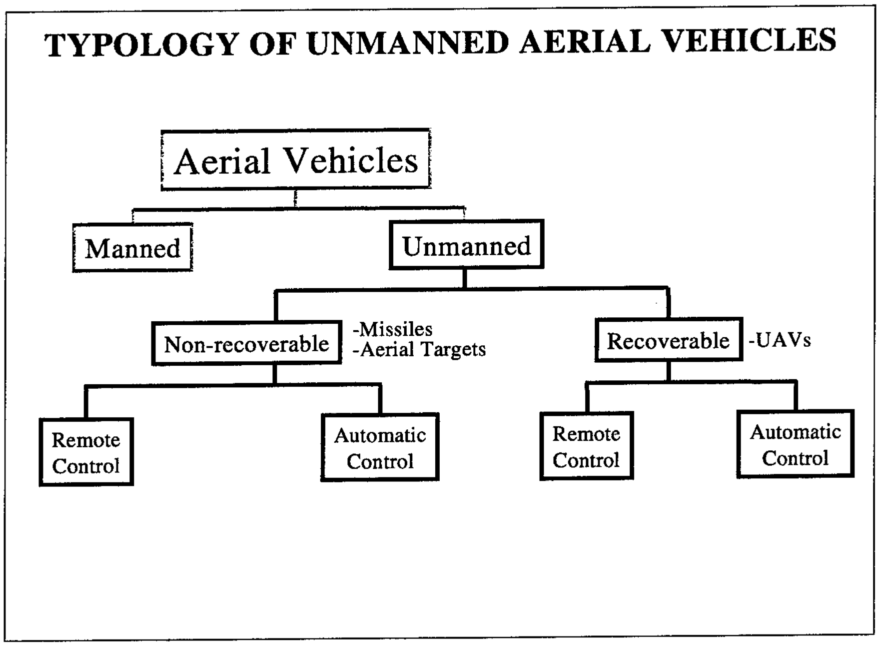

Figure 1: Typology of Unmanned Aerial Vehicles by Method of Guidance and Reusability (After Armitage, 1988, p. xi).

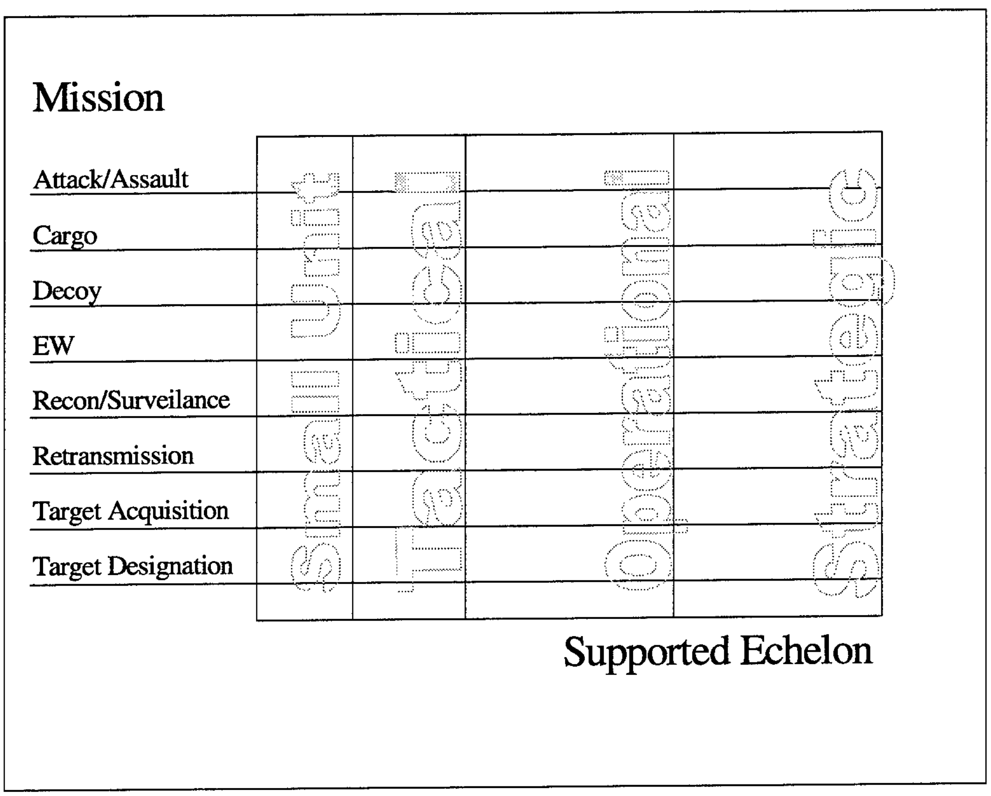

Figure 2: Typology by Mission and Supported Echelon.

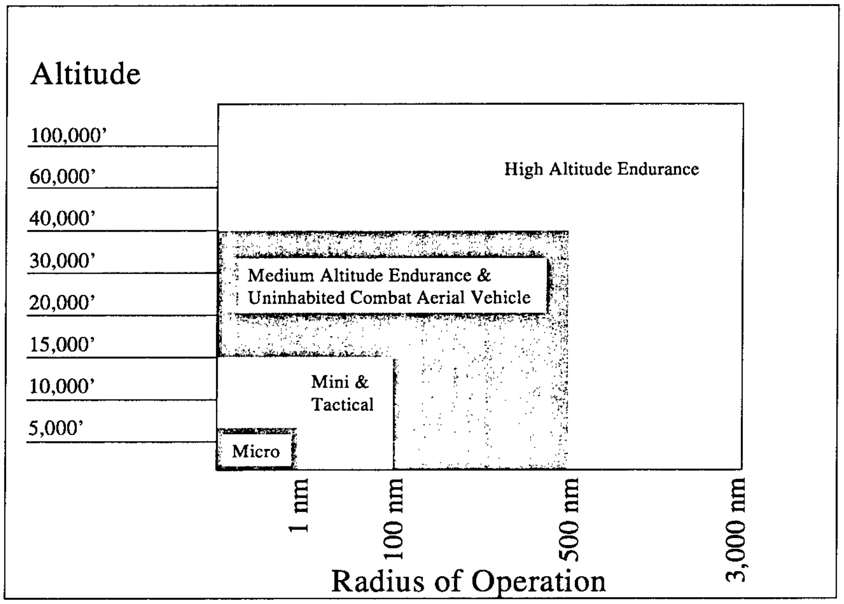

Figure 3: Typology of UAVs by Performance (After DARO, 1996).

2. Origins of the Unmanned Aerial Vehicle

The idea of sending an unmanned aircraft over an enemy's territory to attack him, or reconnoiter his disposition has been attractive to military thinkers since long before the Wright brothers even invented the airplane. Ancient mythologies tell of winged weapons being used by gods to gain an advantage over their enemies. According to ancient Chinese writings, a Chinese warlord used large kites to carry explosives over a walled city and fortress nearly 2,000 years ago, allowing him to attack his adversaries while keeping his own troops out of range. In 1818, a French scholar designed an aerial balloon that would use a time delay to float over enemies and launch rockets down on top of them. In America, U.S. Army researchers experimented with an aerial photography system hanging from a large kite as early as the 1890s (Shaker and Wise, 1988, p. 19-21). During the years from World War I through Korea, many development projects were undertaken to build unmanned aerial vehicles for military use, but none of them had much success. In order for unmanned aerial vehicles to become successful in operational use, three technologies would have to be developed: first, an aerial platform capable of maneuvering to an appropriate objective; second, a guidance system that would permit over-the-horizon unmanned aerial vehicle operations; and third, a payload that can perform a useful mission once the platform gets it to the objective. In the following discussion of the historical development of the unmanned aerial vehicle, I will periodically refer to the progress made in these three areas. Where numerous similar systems were being developed at the same time, my discussion will have a bias towards the historical development of U.S. systems. I will, however, note significant developments in other countries when they show particular innovation.

3. WWI

Although the idea behind the unmanned aerial vehicle had been around for a long time, the invention of the airplane was a major and required breakthrough in technology, which would bring it closer to being of practical use. The airplane brought about a level of directional mobility that kites and balloons do not have: not only can they go up like a kite, and horizontally like a balloon, they can be sent in any direction, not just the direction the wind happens to be blowing. This advance in technology satisfied the first of the three technological requirements I referred to previously in subparagraph 2—it was capable of maneuvering to an appropriate objective. However, the fundamental need for a more sophisticated guidance system for this new technology meant that, for the time being, the airplane would have little operational success without a man onboard. During World War I, both the U.S. and Britain developed aircraft filled with explosives designed to fly for a set distance, then crash--hopefully on the enemy. These designs had very crude guidance systems that included slaving the aircraft heading to a magnetic compass and its altitude to a barometric altimeter. In 1917, the British tried without success to use radio control in their unmanned aircraft experiments. Neither the U.S. nor Britain developed an operational unmanned aircraft before the end of the war. Shortly after the war, both countries cut their funding for these programs significantly, allowing only for a modest research capability. The Germans were also interested in developing unmanned aerial vehicles for the war. Among their more innovative ideas was a remote control technology for guided missiles, which used a thin copper wire that reeled out behind the vehicle and kept it in contact with a pilot on the ground—not unlike the wire-guided missiles of the 1970s. The Germans also had several flying bomb designs, including a glider that could carry 2,205 lb of explosive for about five miles. Just like the American and British designs, none of the German unmanned aerial vehicle designs made it to an operational status before the end of World War I (Armitage, 1988, pp. 1-2).

4. Interwar Years

During the period between World War I and World War II, development of unmanned aerial vehicles continued, albeit at a slower rate due to decreased funding. One of the more notable achievements by the British was the development of radio controlled target drones named Fairy Queens, many of which crashed shortly after launch. However, in April 1934, one survived over two hours of heavy naval gunfire by the British home fleet in the Mediterranean, thus proving both the ineffectiveness of the fleet's anti-aircraft weapons and the future feasibility of remotely piloted aircraft (Armitage, 1988, p. 6).

5. World War II

The desire to win World War II spurred countries on both sides to develop many new and more capable aircraft, including the first jet-powered airplane and America's first practical helicopter, the VS-300, built by Igor Sikorsky (Fardink, 2000, p. 28). Most significant and notorious among the unmanned aerial vehicles of World War II was the German V-1. The V-1 was a self-guided monoplane filled with explosives that would fly a pre-set heading and time, at which point the engines would cut off and the aircraft would go into a dive, exploding on impact. Following their loss in the Battle of Britain, the Germans could no longer afford to conduct strategic bombing against the Allies. They needed to save their relatively few remaining manned aircraft and seasoned pilots for the Russian front. Thus, it was due to a scarcity of resources that Hitler and the German high command looked to expendable unmanned aircraft to allow them to resume a strategic bombing campaign. Their campaign marked the first large-scale operational employment of unmanned aircraft. Although historians assert that the V-1 campaign had only negligible military effect, its successes bear some cost-benefit analysis. A study by the British Royal Air Ministry concluded that the V-1 campaign cost the Allies four times more than it cost the Germans to conduct. Allied expenses included the destruction and lost civil productivity caused by the V-1's attacks, as well as the cost of Allied military operations against the V-1s. The V-1 campaign also had a significant psychological impact. No fewer than 1.4 million people left the city of London by the second month of the V-1 campaign. Significant statistics from the V-1 campaign are listed in Table 1 (Armitage, 1988, pp. 7-19).

Campaign Length	7.5 mo.
Total V-1s Launched	10,492
# Ground Launched	8,892
# Air Launched	1,600
# Reaching Objective	2,419
Civilians Killed	6,184
Civilians Injured	17,981
Cost to Allies	£47,635,000
Cost to Germans	£12,600,000

Shoot downs:		
By Fighters	By Balloons	By AAA Guns
1,847	232	1,878

Table 1: Significant Statistics of the German V-1 Campaign (Armitage, 1988, p. 19).

In the area of guidance technology, both the U.S. and Britain had some success with radio-controlled aircraft as target drones (Shaker & Wise, 1988, p. 26-28). The requirement for the remote pilot to physically see the unmanned aerial vehicle he was controlling kept the radio controlled aircraft from having an over-the-horizon guidance capability at this point in history. Although an important facilitating technology for automatically controlled unmanned aerial vehicles, the electronic computer, was first demonstrated by IBM in the mid-1940s, a typical operational computer of that era consisted of 3,000 ft^3 of machinery and consumed 80 kW of electricity (Mayne & Margolis, 1982, pp. 127-130). For that reason computers were much too large for unmanned aerial vehicle use.

6. Post-World War II, Through Pre-Vietnam

During this period, there were many advances in unmanned aerial vehicle technologies and tactics as well as some notable operational uses of UAVs. This progress was fueled by the escalating Cold War and the associated competition between the Soviet Union and its allies on one side and the United States and its allies on the other. Many platforms were developed specifically for unmanned use and can be grouped into several categories of weapons:

a. Surface-to-surface Cruise Missiles

These were evolutionary improvements on the German V-1, which were developed for long-range infiltration and attack, using nuclear payloads. These systems were largely ineffective for the same reasons as the V-1 in World War II: the sophisticated guidance systems they required were beyond the technological capability of the day. Both the U.S. and USSR developed several cruise missile systems. Notable U.S. systems included the Mace, which saw operational deployment with the 38th Tactical Missile Wing from 1955 to 1969; the Snark, which eventually saw operational duty with the 702nd Strategic Missile Wing from May 1957 to June 1961; and the Navaho, which was never operational. The Mace was a subsonic nuclear-capable missile with a cruise speed of 650 knots and range of 620 miles. Its best Air Force reliability rating was 70% and had a 50 % probability of hitting within a 500-yard radius of its target (i.e., it had a 500 yard circle error of probability or CEP). The Snark could cruise at mach .9 for 5,000 miles, had a very poor reliability rating, and never met its required CEP of 8,000 yards. The Navaho could cruise at mach 3.25 for 5,500 miles, but it was very unreliable and, at the distances it was designed to travel, very inaccurate. These three cruise missiles were largely unsuccessful because they used new guidance technologies that were still not mature enough to provide the required accuracy. The Matador used LORAN, a long-range radio navigation system, and ATRAN (automatic terrain recognition and navigation). The Snark used a combination of automated stellar navigation, and INS (inertial navigation system). The Navaho used a variant of INS. Because of their continued inaccuracies, these first and second generation cruise missiles were pushed aside by ICBMs (intercontinental ballistic missiles) which proved much more reliable, more accurate, and impossible to shoot down with any weapons available during that era (Armitage, 1988, pp. 34-49).

b. Decoy Missiles

Decoy missiles designed to confuse enemy antiaircraft weapons into attacking the decoy while their host aircraft escaped, were developed on both sides of the Cold War to increase the survivability of strategic manned bombers. A notable U.S. design was the Quail. Designed to simulate the radar cross section of a B-52 and employ electronic countermeasures, the Quail could cruise at mach .9 for 445 nautical miles and make two preprogrammed heading changes and one preprogrammed speed change. Following the Quail's operational deployment in 1960, the B-52's standard weapon load included four Quails. By 1969 U.S. intelligence sources deemed Soviet radar systems capable of distinguishing the Quail from its B-52 host, so Quails were phased out of the inventory (Armitage, 1988, pp. 50-52).

c. Standoff Cruise Missiles

These vehicles, designed to allow strategic bombers to stay a safe distance away from heavily defended targets, were also developed by both sides in the Cold War. This tactic compensated for the inaccuracy of the long range cruise missiles such as the Snark by getting them closer to the objective so there was much less time for error to build within their guidance systems. A notable U.S design was the Hound Dog, two of which were carried as standard load on B-52 strategic bombers from 1959 to 1976. The Hound Dog had a range of 675 miles, a top speed of mach 2.0, and could deliver a four-megaton nuclear weapon (Armitage, 1988, p. 53).

d. Anti-ship Cruise Missiles

Anti-ship cruise missiles, designed most successfully by the Soviet Union and sold to their client states, were developed to counter the superior U.S. Navy. Most notable of the Soviet designs was the SS-N-2 Styx anti-ship cruise missile. One of the most important operational uses of an unmanned aerial vehicle during this era was during the 1967 war between Egypt and Israel when the Egyptians sank the Israeli destroyer Eilat with a single Soviet-built Styx missile. This demonstration had serious implications for navies around the world regarding the vulnerability of their expensive surface ships (Armitage, 1988, pp. 55-57).

e. Photo Reconnaissance UAVs

Due to the rapidly changing strategic military capabilities of the East Block countries, the U.S. was under great pressure to keep them under aerial surveillance. At the same time, the East Block's anti-aircraft capabilities were rapidly exceeding that of our manned spy planes. Several highly publicized shoot-downs of U.S. spy planes in the early 1960's, including that of Francis Gary Powers, led to the adaptation of target drones for photoreconnaissance. The best-documented vehicles in this emerging class of UAV were the 147 family of UAVs built by the Ryan Aeronautical Company. The first design criteria for the program, code-named Fire Fly was to build a vehicle capable of flying 1,200 nautical miles above 55,000 feet while taking photographs with 2-foot resolution. Ryan met this requirement with modified BQM-34 target drones redesignated as 147As. In addition to other modifications, they fitted the 147As with a high-resolution camera, preprogrammable autopilot, and radar suppression modifications. Their first air launches from a C-130 proved the feasibility of the system and interceptions attempted by F-106s verified the effectiveness of the new stealth technologies in increasing the 147A's survivability against air defense radar systems (Wagner, 1982; Armitage, 1988).

7. Vietnam Through Just Cause

The period between the Vietnam War and the Gulf War was characterized by continued evolutionary development of unmanned aerial vehicle capabilities and several significant and successful operational uses of unmanned aerial vehicles. All of these successful operational uses of unmanned aerial vehicles were due to the fact that technology had caught up with the three fundamental requirements: an aerial platform capable of maneuvering to an appropriate objective, a guidance system that permits over-the-horizon unmanned aerial vehicle operations, and a payload that can perform a useful mission.

a. Technology

Improvements in unmanned aerial vehicle technology included many new aerial platforms, and increased navigational accuracy. Unmanned target drones increased in performance with speeds all the way up to mach 4 and service ceilings of nearly 100,000 feet. These improvements closely paralleled the capabilities of manned systems (Taylor, 1981). In the U.S., Teledyne Ryan developed a family of unmanned vehicles that were used in a variety of missions including reconnaissance, signals intelligence collection, radar jamming, decoy for manned or other unmanned aircraft, and leaflet dropping. Some tests were even conducted where they successfully launched anti-radiation missiles to destroy anti-aircraft radar sites, and dropped 500 lb bombs on ships from wave skimming altitudes. They began as preprogrammed drones, but were later upgraded to receive guidance while in flight (Wagner, 1982). During this time also, Israel became a leader in the production and operational use of mini-UAVs—these are relatively small, inexpensive vehicles designed primarily to support echelons below the strategic. It should be noted that Israel is a tiny country, with limited resources, surrounded by mortal enemies. They owe their survival to the fact that they have always been able to find an advantage to offset their numerical inferiority. Accordingly, it was natural for them to be one of the first countries to realize the emerging potential of UAVs. As long-range guidance systems became more reliable, there was a reemergence of cruise missiles for strategic bombing platforms. The U.S. developed a new and effective generation of air and ground-launched cruise missiles with Terrain Contour Matching (TERCOM) and Digital Scene Matching Area Correlator (DSMAC) navigation systems, which achieved a circle, of error probability of from 100 to 600 feet after travelling intercontinental distances (Armitage, 1988, pp. 88-98).

b. Tactics

The technological advances of this period facilitated the use of new tactics. Vehicles no longer flew straight-line courses to their targets or reconnaissance objectives. Some vehicles used a hybrid autopilot that allowed their route's multiple waypoints to be reprogrammed in flight, or for a remote pilot to take over guidance during critical phases. Real-time telemetry and surveillance products could be sent back via wireless data links allowing over-the-horizon remote guidance. Many times vehicles were ultimately destroyed during a mission, but the value of the data they transmitted before destruction greatly outweighed the cost of the vehicle (Armitage, 1988, p. 74).

c. Demand

There was increasing demand for unmanned aerial vehicles to replace manned systems due to the increased relative effectiveness of anti-aircraft missiles and radar guided anti-aircraft artillery systems. As the world's leading producer and user of UAVs, the United States' effort was justified throughout the later 1960's and 1970's by the conflict in Vietnam where the U.S. Air Force was conducting a large and costly air campaign over the well-defended North Vietnam. Following Vietnam, America's need for UAVs for strategic reconnaissance decreased because of the launch of effective spy satellites and treaties between the U.S. and Both Russia and China prohibiting unauthorized over flights.

d. Operational Uses

(1) The longest sustained operational use of UAVs to date was in conjunction with the American reconnaissance gathering efforts, principally over North Vietnam, but over China, Cuba, and Russia as well. The platforms used were Teledyne Ryan's family of UAVs, based on the model 147, which proved to be quite easily modified as new technologies and missions evolved. These aircraft, flew 3,435 sorties with a 4% loss rate and, in the process, prevented many potential international

incidents and the loss of many much more expensive manned aircraft and crew (Wagner, 1982, Forward).

(2) During the Israeli's operational uses of UAVs, the tactics they employed were by far more innovative and more responsible for their success than the technology of their UAVs. The first incident was during the Six-Day War in October 1973 when they used UAVs as decoys in their air raids against Egypt. The Israeli's sent numerous UAVs on mock raids against Egyptian facilities just ahead of the true attack forces. Because the UAVs appeared to be incoming attack aircraft, the Egyptian air defense forces fired on them and were consequently unable to reload in time to fire on the real attack aircraft (Armitage, 1988; Powers, 2000).

(3) Israel's second significant operational use of UAVs was in 1982 where they used Northrop Chukar target drones to draw fire from the Syrians' new SA-6 systems thereby learning vital information about the frequencies used by the missiles' search, tracking, and missile activity functions. Israel later used this information to effectively jam the same systems during air attacks into the Syrian-held Bekaa Valley. They also used their Mastiff and Scout mini-UAVs to fly hundreds of sorties a day in Southern Lebanon and the Bekaa Valley to include stationing UAVs over three Syrian airfields in the Bekaa valley. These UAVs transmitted real-time television images of hostile activities, such as aircraft launches and recoveries, to E2C command and control aircraft. Accordingly, some credit for the 95:1 aircraft kill ratio (Powers, 2000) in favor of Israel should go to these UAVs, because they helped Israeli air defense know when, where, and what type aircraft they would be engaging, in advance.

8. Desert Storm Through Present

a. Supply and Demand of Technology

The most significant advances in unmanned aerial vehicle development during the last ten years have been driven by the exponential increases in computer processing capability, data transmission rates, and miniaturization technology. There has also been an increased desire for detailed, near-real-time information about the location and disposition of enemy forces juxtaposed against the inability and/or unwillingness of national collection assets to distribute the desired information. Gulf War after action reports noted that intelligence gathered by national collection assets did not get to the commanders in the theater of operations that needed it. In contrast, many senior military commanders spoke high praise for the few UAVs available to operational commanders during the Gulf War. The reason senior leaders praised the UAVs was that they enabled decision makers in the theater of operations to have real-time or near real-time, unfiltered information about an area of interest. As a result, UAVs were in big demand during the United States' operations in Bosnia and Kosovo.

b. Operational uses

(1) The most prevalent system used in the Gulf War was the Pioneer. The U.S. Navy flew Pioneer for 213 hours and 64 sorties from the battleships U.S.S. Missouri and U.S.S. Wisconsin conducting target selection, naval gunfire support, battle damage assessment, maritime interception operations, and battlefield management. The information they collected was provided to both theater and component commanders resulting in the detection of numerous Iraqi patrol boats, a successful strike on two high-speed boats, location of two Silkworm anti-ship missile sites, 320 ship identifications, location of antiaircraft artillery positions, as well as pre- and post-assault reconnaissance of Faylaka Island. As the war progressed, Navy Pioneers sent back images of surrendering Iraqi troops, and the retreat of major armored units. The Army's Pioneers flew 155 hours and 46 sorties providing a quick-fire link that allowed the targets they identified to be quickly engaged by other systems. Army Pioneers also helped tactical commanders to conduct situation development, targeting, route reconnaissance, and BDA. Marine UAV companies flew 318 hours and 138 missions during Operation Desert Shield and 185 missions and 662 hours during Operation Desert Storm (Pioneer UAV Incorporated, 2000).

(2) During a U.S. Chief of Naval Operations-sponsored training exercise in 1997, level four control (all functions except landing and take-off) of a U.S. Air Force Predator UAV was given to a U.S. Navy submarine commander supporting a SEAL direct action mission. A mast-mounted c-band antenna and remote control station installed aboard the submarine allowed receipt of real-time video and aircraft control from the submarine. The Navy also installed a joint deployable intelligence support system (JDISS) in the submarine's radio room that allowed them to forward images from the Predator, via UHF satellite link, to the joint task force commander 3,000 miles away. The UAV provided continuous surveillance of the objective (a simulated Silkworm missile site) while the SEALs conducted their infiltration by combat rubber raiding craft (CRRC) allowing the SOF commander, aboard the submarine, to divert his team to an alternate landing site when an unidentified vessel was spotted near their primary landing site. When the sensors aboard the Predator detected a Silkworm being moved into launch position, the SOF commander instructed his team to laser-designate the target and passed it off to loitering precision strike aircraft, which then destroyed the missile site. The Predator recorded the successful strike with real-time imagery that was relayed to the joint task force commander, thus potentially making it simultaneously available to the National Command Authorities (Robinson, 1997, p. 18).

(3) At least three different UAV systems, Pioneer, Hunter, and Predator have seen action as part of U.S. operations in the former Yugoslavia. The most significant advance in UAV technology, however, was demonstrated by the combination of the Predator UAV; commercial satellite TV technology; and a wide bandwidth, secure tactical Internet connection through fiber-optic cables and commercial satellite transponders. The Predator and other components, known as the Bosnia Command and Control Augmentation (BC2A) initiative, transmitted live images to theater commanders via the Joint Broadcast Service. All that was needed to receive the broadcasts was a 20-inch receive antenna, cryptologic equipment, and authentication codes. Commanders could select the programming that they received over their 30 megabit-per-second down

links over direct broadcast satellites. Compared to the 9.6 kilobit-per-second modems available during the Gulf War, that is over 3,100 times more data per second (Kaminski, 1997).

B. SURVEY OF CURRRENT UAV TECHNOLOGY

1. Platform Technology

In the last 40 years, the ability to build a UAV of a given size, speed or service ceiling has not changed appreciably—we have had supersonic drones and remote-control bombers capable of flying in the stratosphere since the 1960's. The real advances in UAV platform technology have been in efficiency, and miniaturization. Figure 4, looks at six performance characteristics of UAVs at three different points in time, twenty years apart. The "largest UAV" figures are based on the unmanned aircraft with the heaviest gross weight for each year sampled. Conversely, the "smallest UAV" represents the unmanned aerial vehicle with the lowest maximum gross weight for each year sampled. This chart graphically illustrates the fact that the real significant advances in UAV platform technology have been in areas of efficiency: range, endurance, and smallness. This is an important point because, as we will see later in Chapter II, one of the most compelling reasons for using an unmanned aerial vehicle is because they are generally more economical than manned vehicles performing the same functions. Figures 5 and 6 show the range, endurance, and service ceiling envelopes of current UAV systems.

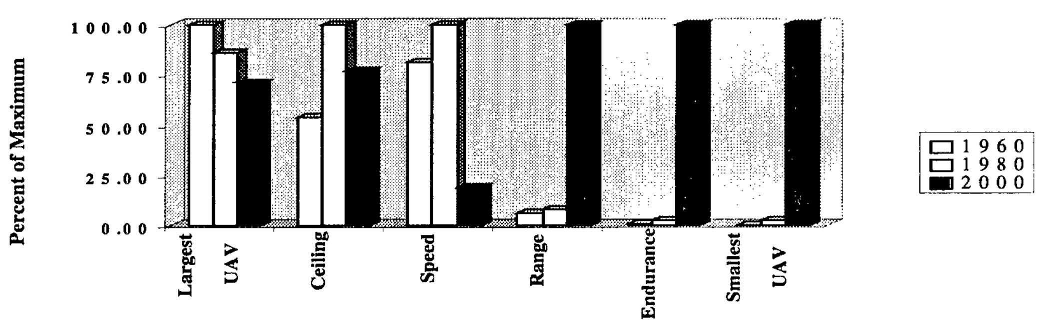

Figure 4: Changing Performance of UAVs Since 1960 (adapted from Taylor, 1961, Taylor 1981, and Munsan 1998).

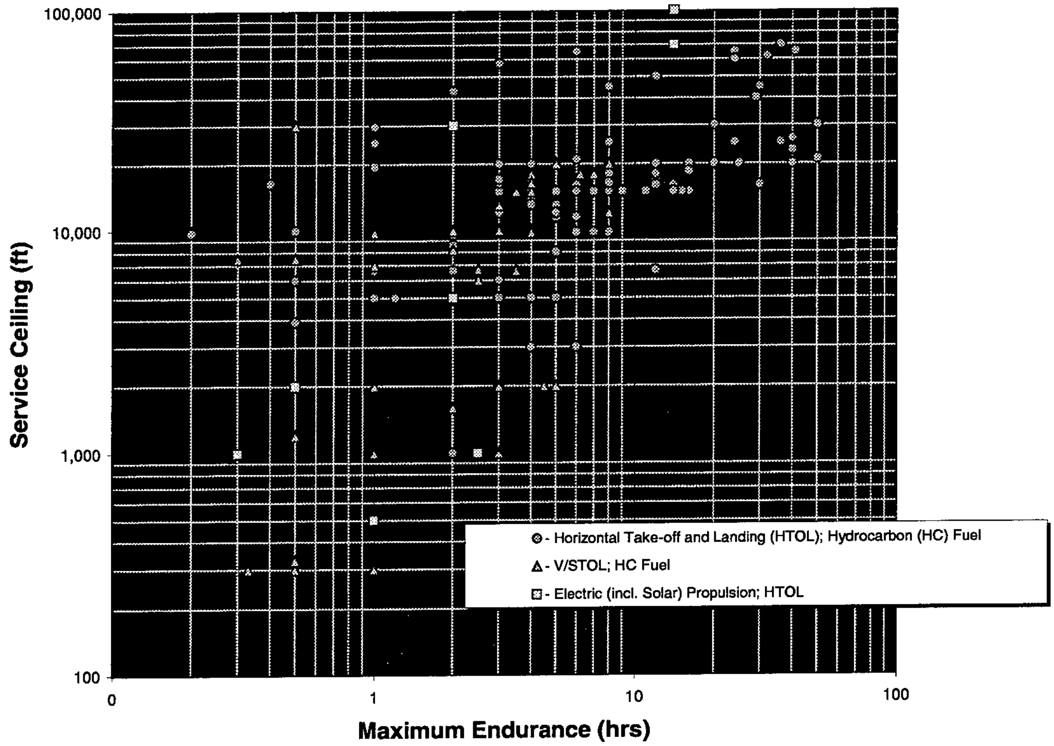

Figure 5: Current UAV Systems' Service Ceiling and Endurance (Papadales, 1999).

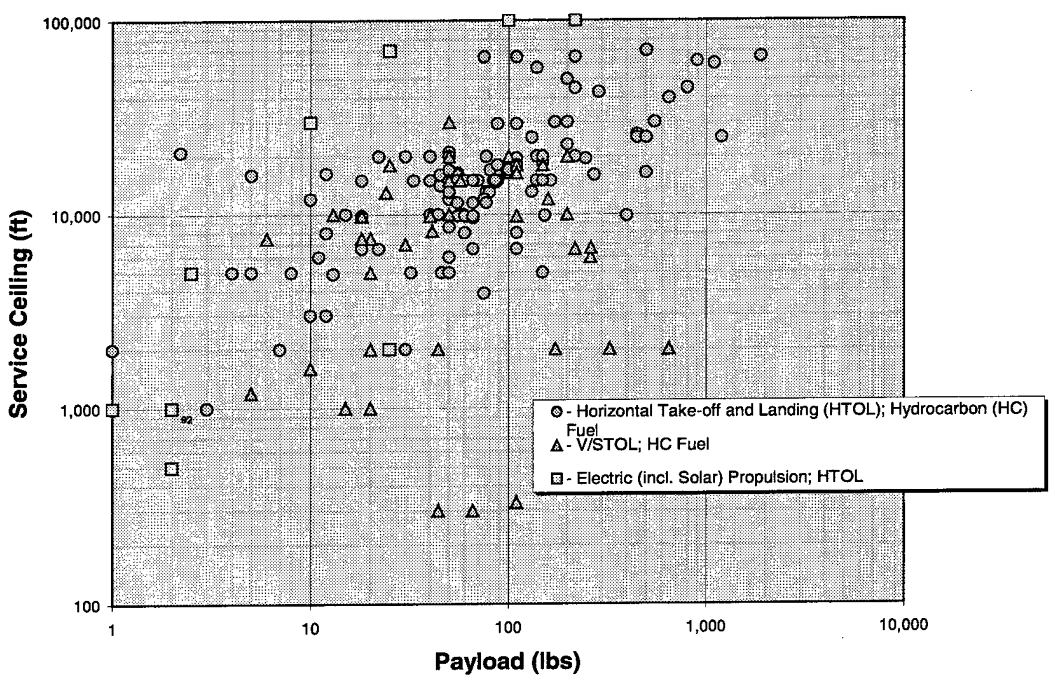

Figure 6: Current UAV Systems' Service Ceiling and Payload (Papadales, 1999).

2. Mission and Payload Technology

Another, perhaps counter intuitive, feature of UAV technology is that the most dramatic technological advances over the last forty years have not really involved the platforms at all. Facilitating technologies that contribute to a wide range of functions to include information collection, transmission, and synthesis, and increasingly autonomous navigation have caused the greatest advances for UAVs. The technological progress of computers and data transmission equipment has taken place at an astounding rate; its continued progress will undoubtedly drive the future capabilities of UAVs. What follows is a brief summary of the technological progress of computers and data transmission equipment.

In 1965 Gordon Moore, an Intel employee, predicted that computer complexity would double every eighteen months. In the last 35 years, the number of transistors on an integrated circuit (IC) chip has doubled twenty-two times; the dimensions of features on these silicon chips are now smaller than the wavelength of the light that is etching the features on them. Ten years from now, engineers expect that IC chips will have 64 times more transistors on them than today, and still cost about the same. Over these same 35 years, IC complexity has increased by 1,000 times, yet their reliability has remained constant at one failure per billion device hours and their quality coming off the production line has increased dramatically--less than 0.001 percent are defective. As far as our ability to store digital information is concerned, the storage capacity of dynamic random access memory (DRAM) chips has quadrupled every four years while maintaining the same price. As far as size is concerned, every five years, IC geometry shrinks fifty-percent; and every seven to eight years, personal computer mother board minimum trace width shrinks by fifty-percent (Alfke, 2000, pp. 3-10). Another important characteristic of this rapid growth of technology is the ability to transmit data long distances. The rate of wireless data transmission by digital radio frequency (RF) link has doubled twenty-one times since the 1970's when the transmission standard was 75 bits per second (Boyd, 2000, p. 5). These advances in electronics are greatly improving the effectiveness of UAV guidance systems (both remote control and autonomous guidance systems) and remote sensors, and enabling it to transmit real-time imagery streams.

C. HOW WILL THE CHANGING NATURE OF MODERN WARFARE INCREASE THE DEMAND FOR UAVs?

1. Increased Speed of Modern Warfare

The increased speed of modern warfare has increased the size of military commanders' areas of interest (Sullivan and Brouillette, 1998). This fact is causing commanders at lower and lower levels to need dedicated over-the-horizon scouting capabilities. Accordingly, the demand for organic UAVs at the tactical level will increase. As the speed of warfare increases, SOF will have to become even faster in order to maintain a decisive advantage over a larger or well-defended enemy—a concept called relative superiority in William H. McRaven's theory of special operations (1995). UAVs can enhance small units' situational awareness during mission execution, making them even faster.

2. Emergence of Casualty-intolerant Mission Profiles

The phenomenon of casualty intolerance or aversion (Bowman, 2000) is not new, but the types of missions that bring it on seem to be increasingly common in the post-Cold War era. One of the more notable examples of casualty aversion in action is President Clinton's 1993 withdrawal of Task Force Ranger from Somalia following the death of 18 U.S. servicemen (Bowden, 1999). An increase in missions lacking significant national urgency to warrant the death of U.S. servicemen will tend to increase the demand for military options that keep servicemen out of harms way. Unmanned aerial vehicles are a natural choice for these operations.

3. Increased Precision of Modern Weapons Systems and Targeting

Increasing desires to keep U.S. military personnel out of harms way, and to reduce collateral damage are causing decision makers to favor military courses of action that use standoff precision munitions. This increased use of stand-off precision munitions, and its accompanying need for precision targeting information, are increasing the demand for unmanned vehicles that can gather precision targeting information, as well as deliver precision munitions, and conduct battle damage assessment. Along with these basic missions, there will be a multitude of supporting missions that they will be called on to conduct: escort, suppression of enemy air defense, decoy, electronic warfare, and resupply to name a few. In fact, as the technology becomes available for unmanned vehicles to do new missions, they will tend to force the manned vehicles that used to do those missions out of business, because UAVs are inherently more economical, and more politically usable. SOF missions are affected by many of these same forces.

4. Need for Higher-leverage Forces Caused by Downsizing

The trend over the last ten years has been one of reduced military budgets and manpower. An even longer trend has been towards more careful scrutiny of military spending. Compounding the matter is the fact that the number of operational deployments has increased dramatically over the last ten years. In short, the U.S. military is required to do more with less. This fact suggests the need to have more efficient systems, and UAVs are inherently more efficient than manned aircraft. Not only are they less expensive monetarily, but the loss of a UAV has historically been less expensive politically as well. Compare for example the difference in publicity between the shoot down of Francis Gary Powers over the Soviet Union as compared to the several Ryan UAVs shot down over China: Francis Gary Powers' name is etched in history, but few know about the shoot-downs over China, in spite of Chinese propaganda efforts (see Figure 7). UAVs could increase the effectiveness of manned special operations aviation assets by allowing aircrews to view the route and target, in real-time, before mission execution; by acting as a decoy to draw enemy attention away from the manned aircraft; and acting as radar jammers. In the near future, UCAVs will be able to conduct suppression of enemy air defense (SEAD) missions, thus obviating the need to put an expensive manned aircraft and crew at risk.

Figure 7: One of Several UAVs Shot Down Over China in 1968 (from Teledyne Ryan Aeronautical Corporation, 2000)

D. WHY ARE UAVS IMPORTANT TO SOF?

1. The Changing Nature of Modern Warfare and Improvement of UAVs

As seen above, the changing nature of modern warfare is increasing the need for what UAVs can provide. At the same time, the capabilities of UAVs are increasing making them an even more attractive asset for SOF. Two emerging capabilities in particular should make UAVs more attractive to SOF:

a. Increasing Autonomy and Decreasing Size of UAVs

The increasing autonomy of UAVs and their decreasing size make them increasingly suitable for launch and/or control by small units such as SOF. The increasing autonomy of UAVs makes them easier to fly, thereby allowing special operators to successfully employ them without having to specialize in UAV operations. Small units, by their nature, are less able to afford dedicating personnel to UAV operation; therefore, the increasing autonomy of UAVs has a much greater implication for small units than large units. The same is true of the decreasing size of UAVs. Small, units which depend on being light for agility, can ill afford to transport bulky yet fragile

UAV systems. That suggests that the decreasing size of the UAV and associated control systems will have a much more important impact on small units such as SOF than large units.

b. Smaller, Lighter Displays

Smaller and lighter means of receiving and displaying tactical information, such as palm-top computers, suggest the ability to let operators in the field view images from and even control the payloads of UAVs when appropriate. Again, because small units are the most sensitive to the size and weight of the technology they must transport, smaller displays will be a much greater advantage to small units like SOF than larger units.

2. The Worldwide Proliferation of UAVs

Not only are UAVs becoming more important to SOF because of how SOF can use them, but also the sheer numbers of UAVs and the numbers of countries developing them will make them increasingly a feature of the modern battlefield. Figure 8 shows how the number of countries with UAVs and the types of UAVs have increased dramatically over the last forty years (Taylor, 1961; Taylor, 1981; Munsan, 1998).

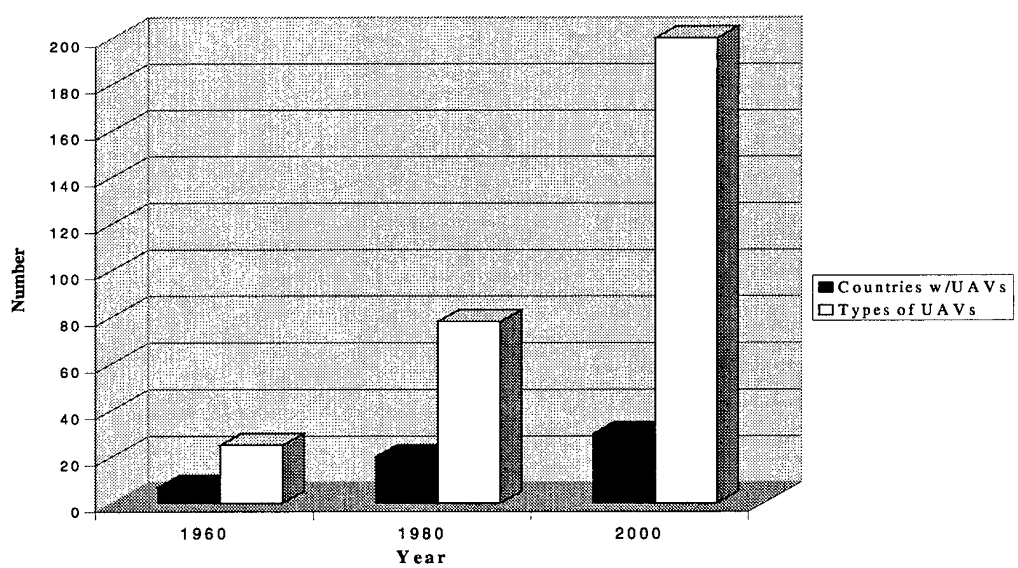

Figure 8: Worldwide Proliferation of UAVs Since 1960.

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II. WHAT MISSIONS CAN AND SHOULD UAVS PERFORM?

A. MISSIONS UAVS CAN PERFORM

From its name you can deduce some general conclusions about what an unmanned aerial vehicle can do. Because it is aerial, it can bypass terrestrial obstacles, fly with or pursue other air vehicles, and provide over-the-horizon line of sight for sensors and communications equipment. Because it is unmanned, it can operate without risk of crewmembers being killed or captured; it can be made smaller, cheaper, more maneuverable, and have longer endurance than manned aircraft. Because it is a vehicle, it can carry aloft and/or transport things to include, among other things, weapons, sensors, communications equipment, and cargo. Theoretically, UAVs can be designed to do any task that a manned aircraft does, and some that no manned aircraft will ever do, like flying around inside of a building. But UAVs should not be thought of as just another aircraft, because their size, relative economy, and expendability give them the potential to do missions not previously done by aircraft—missions for which manned aircraft would be inappropriate or impractical systems. Table 2 presents a partial list of missions that UAVs could logically do. They represent all of the different missions currently being considered for UAVs as well as any other mission that seemed to follow from the inherent advantages and disadvantages of UAVs in general. Some of these missions are possible with current systems and some of the missions listed would require years of research and development and new designs in order to complete. For missions where a system is already doing the mission, I list it as a "present" capability. For missions where there are operational systems that could be adapted to do the mission I list it as possible in 2003, allowing for a three-year period of test and evaluation. If a system is in development to do a particular future mission, I list the mission as possible in 2010 unless there is a more accurate date available. Missions for which there are no specific systems being developed, but which are either under research and development or could theoretically be done by a UAV, I list as possible in 2020+. I think the most important thing to know here is not exactly when a particular capability will be fielded, but to get a qualitative feel for when we should plan on integrating these capabilities.

UAV MISSIONS			UAV Types					
			HAE	MAE	UCAV	Mini/Tactical	Micro	Meso
UAV MISSIONS	Assault	Deliberate Insertion of Combat Troops			20			
		Deliberate Extraction of Combat Troops			20			
		Emergency Extraction/CSAR			20			
	Attack, Air -to-Air	Anti-Airplane or Anti-helicopter			20			
	Attack, Air-to-Ground	Close Air Support (CAS)			20			
		Mine Destruction			10	3		
		Mine Emplacement			10	3		
		Precision Strike			10			
		Suppression of Enemy Air Defense (SEAD)			10			
		Manned-Unmanned Teaming			10			
		Strategic Bombing			20			
	Cargo Transport	Surface-Deliver Payloads				0		
		Air-Drop Payloads				3		
		Air-Drop Non-lethal Weapon				3		
	Decoy	Decoy		0	10	0		
	Electronic Warfare	Electronic Attack (EA), Jamming or Deception	0	0		0		
		Electronic Support Measures (ES), ELINT	0	0		3		
	Reconnaissance	Air Sample, Meteorological	0	0		0		
		Air Sample, NBC Detection	0	0		0	10	20
		Combat Search and Rescue (CSAR) Support	0	0	10	0	10	20
		Mine Detection	3	3		3		
		Manned-Unmanned Teaming	3	3	10	0		
		Manned-Unmanned Teaming, Forward Air Controller				0		
	Reconnaissance/Surveillance	Enclosed Space (e.g. inside building)						20
		Linear, Border	0	0		0		
		Strategic, IMINT	0	0				
		Theater, IMINT	0	0				
		Tactical, Area, IMINT		0		0	10	
		Tactical, Point, IMINT		0		0	10	
		Strategic, SIGINT	0	0				
		Theater, SIGINT	0	0				
		Tactical, Area, SIGINT		0		0		
		Tactical, Point, SIGINT		0		0		
	Retransmission	Ground or Airborne Sensor	0	0		0		
		Data/Communications	0	0		0		
		GPS Pseudolite	0	0		0		
	Target Acquisition	Enclosed Space (e.g. inside building)						20
		Target Acquisition, Specific Target	0	0	10	0	10	
		Target Acquisition, Target of Opportunity	0	0	10	0	10	
	Target Designation	Enclosed Space (e.g. inside building)						20
		Moving Target	0	0	10	0	20	
		Stationary Target	0	0	10	0	20	

Key:
0 = Current Capability
3 = Possible by 2003
10 = Possible by 2010
20 = Possible by 2020+

Table 2: Partial List of Missions that UAVs Could be Designed to Conduct.

B. RELATIVE ADVANTAGE OF UAVs OVER OTHER SYSTEMS

1. Before I answer the question of what missions UAVs should do, let us look at some of the inherent advantages and disadvantages of the UAV. First, here are some of the advantages of being able to move through the air:

a. Inherent Advantages of Being an Aerial Vehicle:

- Can bypass terrestrial obstacles.
- Can extend the line of sight beyond that of surface-based sensors and provide immediate answers to "what is going on" type questions.
- Can get closer to and therefore better resolution of surface objects than space based sensors.
- Can exploit the natural tendency of humans to scan in the horizontal plane, thereby escaping visual detection.
- Able to physically intercept or block adversary air vehicles.
- Able to travel with, join and separate from other friendly air vehicles.
- Can rapidly carry a variety of objects (e.g., sensors, weapons, communications equipment, cargo, or troops) to remote locations and loiter over the area if desired and/or drop off objects and depart.
- Less affected by weather than surface systems (applies to high altitude endurance (HAE) UAVs only).

b. Inherent Disadvantages of Being an Aerial Vehicle:

- More susceptible to adverse weather than surface systems (does not apply to HAE UAVs).
- Vulnerable to attack if acquired.
- Not well suited to carrying very heavy objects like bulk cargo or armored vehicles.

- Can inadvertently carry sensitive technology deep into enemy territory (e.g., F-117 Stealth Fighter shot down and captured by Yugoslavia).

2. Now consider the inherent advantages and disadvantages of being unmanned:

a. Inherent Advantages to Being Unmanned:

- Can be made smaller and cheaper.
- Can be less detectable.
- Can be disposable.
- Can be designed to maneuver beyond the physical capabilities of a human pilot (i.e., g-load).
- Can have longer endurance.

b. The Inherent Disadvantages to Being Unmanned:

- Autopilots are still less capable than human pilots.
- Remote pilots lack the situational awareness of pilots in the vehicle.
- Digital radio frequency (RF) links to remote control vehicles are vulnerable.

When the environment is too complex for existing technology to allow for autonomous operation, then there must be a remote human pilot making decisions. Accordingly, when there is relevant information in the cockpit, and that information is not, or can not be, reliably transmitted to a remote pilot, the unmanned vehicle is at a disadvantage over the human-piloted aircraft. Examples of information that either is not or can not be reliably transmitted with current technology are noise, vibration, visibility and other factors that normally improve a pilot's situational awareness. In addition, the link between the remote control station and the UAV is potentially vulnerable to being severed, altered, monitored or triangulated. All three of these disadvantages could eventually be eliminated by future technological advances; however, in the meantime we must compare the current and near future (now through 2020) advantages and disadvantages when determining when a UAV is the appropriate system to fulfill a particular need.

C. MISSIONS UAVs SHOULD PERFORM

Considering the preceding discussion of the UAV's relative advantages and disadvantages, it is preferable to use a UAV when one or more of the unique characteristics of the UAV result in its advantages out-weighing its possible disadvantages. Or more appropriately, UAVs should be used when a course of action that incorporates UAVs is preferable to all other courses of action. Making the decision of what method and what tools to use in prosecuting a military mission is critical to a successful outcome. Accordingly, the decision of what course of action to pursue—and whether to use a particular UAV system—for a particular mission must be made by the commander in the field who considers all of the potentially unique aspects of his mission. However, the nature of modern war is that commanders must fight with the systems that they currently have and train with; there will not be time for new procurement, training, or changes in force structure. Therefore, decisions about research and development priorities, procurement plans, future force structure, and training must be made in advance and based on historical trends and guidance from the National Command Authority and articulated in documents such as the National Military Strategy, Defense Planning Guidance, and Presidential Decision Directives. So there is a need to evaluate the relative advantages of UAVs at two levels—the level of the commander in the field and the level of the Joint Planning, Programming and Budgeting System (JPPBS). Again, this decision is not just a choice between using manned or unmanned aircraft, it is between one course of action that utilizes UAVs perhaps in combination with other systems (humans, ground vehicles, satellites etc.) and one that does not.

One tool that has been useful to military decision makers for years is the decision matrix. It normally utilizes only a limited amount of analysis and works best when the advantages between courses of action are fairly distinct. I have adapted this venerable tool for use in judging when a course of action including the use of UAVs might be appropriate. Figure 9 shows a logical decision process which could be used to compare courses of action with and without UAVs. The first step is to screen out missions for which the use of a UAV is obviously not appropriate, such as digging a defensive position for an armored vehicle. The second step is to develop and compare courses of action that do and do not incorporate UAVs. For this step, I will use a simple decision matrix. Organizations with more time and resources will probably choose to use more sophisticated techniques. The last step is to decide which course of action is best,

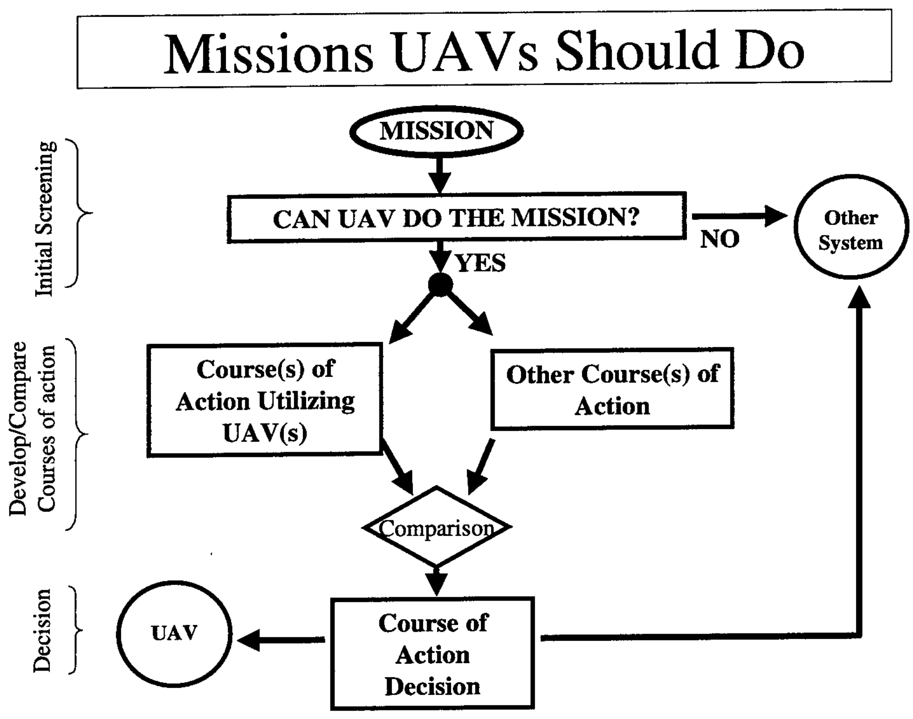

Figure 9: Comparing Courses of Action With and Without UAVs.

based on the comparative advantages of each course of action.

When using a decision matrix, you should choose measures of effectiveness that will highlight the comparative advantages and disadvantages of the particular courses of action, and then define grading thresholds. Figure 10 shows part of a rudimentary decision matrix that I developed to compare courses of action with and without UAVs. With this matrix, I have combined the inherent advantages and disadvantages of the UAV into three negative measures of effectiveness:

- **Probability of mission failure.**
- **Probability of friendly death or casualty.**
- **Cost of operation.**

In all three areas, lower figures are better.

				Weights			
				I_{ms}	A_{dc}	I_c	
		Unweighted		Weighted			
Courses of Action	P_f	P_{dc}	C_o	$P_f \times I_{ms}$	$P_{dc} \times A_{dc}$	$C_o \times I_c$	**Total**
							Lower is Better

Figure 10: Example Decision Matrix for Comparing Courses of Action With and Without UAVs.

An explanation of the notation in Figure 10 follows:

- **Probability of Failure (P_f)** is the probability that a particular course of action will not result in mission success. I have modeled it as a function of the vehicle's performance when unopposed by an enemy, and its survivability (Ball, 1985).
- **Importance of Mission Success (I_{ms})** allows the decision maker to subjectively weight how important it is to have a successful mission in relation to the other criteria being evaluated.
- **Probability of Friendly Death or Casualty (P_{dc})** the probability that there will be a friendly death or casualty as a result of the particular mission. For this, I

consider the probability that a system will be killed (from the survivability estimate made earlier) the probability that a system kill would result in a friendly death or casualty, and the probability that there will be a death or casualty unrelated to a system kill (e.g., Rangers that were killed during street fighting in the Battle Mogadishu, or hostages killed at the 1972 Munich Olympics).

- **Aversion to Friendly Death or Casualty (A_{dc})** allows the decision-maker to subjectively weight the degree to which a friendly death or capture might adversely impact the mission's real or perceived success.

- **Cost of Operation (C_o)** is a measure of the aircraft and/or ordinance procurement cost on a per-mission basis. I make rough calculations of this based on the most expensive items that would be expended during the mission in question. For an example, let's preview of one of the scenarios I will discuss later. In this scenario, I compare the cost of conducting a strike mission with Tomahawk cruise missiles or with F/A-18C/Ds. Tomahawk cruise missiles cost about $1 million each (Aerospace Industries Association of America [AIAA], 1998; Friedman, 2000) and each one does only one mission before it is destroyed. In comparison, the F/A-18C/D costs about $40 million (AIAA, 1997; Friedman, 2000) and at the 0.05% attrition rate experienced for Navy F/A-18s in Desert Storm (Ball, 2000), the average aircraft will complete 2 thousand sorties before it is destroyed. In addition, the F/A/-18 carries two Maverick missiles that cost $120 thousand apiece (AIAA, 1990; Friedman, 2000). Assuming both mavericks are launched on every mission and one aircraft is lost every 2000 missions, the F/A-18's per-sortie procurement cost will be $260 thousand. As we know, the Tomahawk procurement costs are $1 million per sortie. In order to get the per-mission procurement costs, we need to know how many F/A-18s per Tomahawk are required to do the mission. Based on the General Accounting Office's Report on Aircraft Ammunition Effectiveness in Desert Storm (1997a, p. 4), you need 1.2 F/A-18s to achieve the same level of mission success as one Tomahawk. Based on that ratio, the Tomahawk's per-mission procurement cost is still about 3.2 times greater than that of the F/A-18 ($1 million divided by the product of $260 thousand and 1.2 equals 3.2).

- **Importance of Cost (I_c)** allows the decision-maker to subjectively weight the importance of cost in the choice between courses of action. Examples of things to consider are the length of the conflict and the friendly force's ability to replace expended assets.

Before listing the results for some example scenarios, I must stress two facts: first that the quality of the results using this tool are dependent on the judgement of the person or persons making the estimates about relative advantages or disadvantages; second, that more accurate comparisons can be made using operations research techniques which are beyond the scope of my study. At this point I am going to briefly discuss four scenarios and then show how I used my decision matrix to compare courses of action with and without UAVs.

1. Scenario 1: U-2 vs. Global Hawk Conducting Strategic Reconnaissance

This scenario will use the 1999 air campaign against Serbian forces in Kosovo as a backdrop. Although the Global Hawk was not operational in 1999, I will assume that it was and compare the choice of using the U2 or the Global Hawk to conduct strategic reconnaissance over Yugoslavia. Remember that the three factors that I am comparing

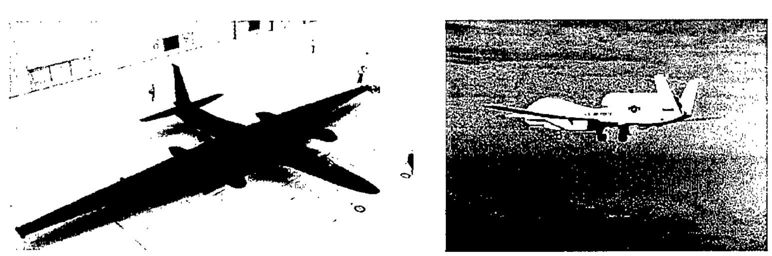

Figure 11: U-2 (From Harkin, 2000) Versus Global Hawk (From U.S. Air Force, 2000).

are the probability of mission failure, probability of friendly death of capture, and cost of operation.

Because this mission is part of a routine ongoing operation and the element of surprise is not particularly important, a one-time failure is of little importance and will not affect the national prestige. Therefore, the overall importance of mission success is low. Since neither aircraft was designed for radar stealth, both are about the same size and operate at similar altitudes, and both have similar counter-measures, I assume they are equally susceptible to being engaged by enemy air defenses. Because they are both slow, single-engine aircraft they are about equally likely to be killed if hit by an air defense weapon. The likelihood of poor weather interfering with their mission is low, because both planes fly above the weather and could be equipped with synthetic aperture radars (SAR). Neither aircraft is likely to fail its mission under ideal conditions. All of these factors result in a similar probability of mission failure for both aircraft.

Because this campaign lasts more than a month, but less than a year, the importance of cost is medium; however, since I assume that both systems' operating costs are about the same, there is no advantage to either system as far as cost is concerned.

Because the probability of a shoot down is low, and there are no personnel at risk except the pilot on the U-2, the probability of a friendly death or capture is low for the U-2 and non-existent for the Global Hawk. I assume that the American public knows we are in a shooting war with Serbia and that, just as in Bosnia, we may have servicemen killed or captured. However, since the conflict is perceived mostly as a humanitarian effort on our part, I assume that the aversion to death or casualties is medium. Since a death or capture is possible, this ends up being the deciding difference between the two systems. Accordingly, the Global Hawk UAV is the best system for this particular mission.

2. Scenario 2: F/A-18C/D vs. Tomahawk Conducting Ground Attack

This scenario uses the 20 August 1998 attack by the U.S. on a terrorist training facility in Afghanistan and a suspected chemical weapons facility in Sudan as a backdrop. I will compare the use of Tomahawk cruise missiles versus a carrier-launched air armada of F/A-18's and related support aircraft for the attacks.

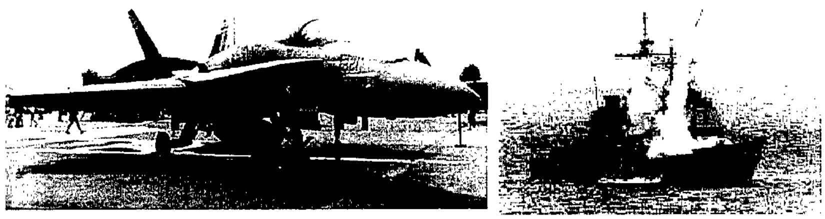

Figure 12: F/A-18 (From Harkin, 2000) Versus Tomahawk (From Federation of American Scientists, 2000).

I assume that due to its smaller size, the Tomahawk is harder to detect and hit than the F/A-18. I assume that the Tomahawk is less likely to survive a hit, neither system is likely to fail in poor weather, and both courses of action are equally likely to succeed if unopposed. Overall the probability of failure is low for both systems and the importance of success is high due both to the importance of surprise and the level of national prestige at stake.

The aversion to death or capture is very high for this mission. If forces allied with Ben Laden capture an American hostage or publicly desecrate an American serviceman's body, the mission would be a political failure. The probability of a death or capture is low, but possible using manned aircraft. There is no probability of death or capture using Tomahawks.

As discussed earlier in defining cost of operation, the Tomahawk's per-mission procurement cost is 3.2 times greater than the F/A-18's. However, since the attack is very short and the Tomahawks can be replaced fairly quickly, the importance of cost is low.

In this scenario, each course of action is favored in one of the three measures of effectiveness and they tie in the third. It would be a tie overall except the advantage of an unmanned attack, given the political importance of no deaths or captures, outweighs the added cost of the Tomahawk strike, making the Tomahawk guided missile attack the preferred course of action.

3. Scenario 3: OH-58D vs. Shadow 200 Conducting Tactical Reconnaissance

This scenario uses Operation Desert Storm as the backdrop. I will compare the use of manned OH-58D scout helicopters (not Kiowa Warrior) versus the Shadow 200 UAV for all route reconnaissance in support of division-level ground forces prior to the ground invasion into Iraq. As in scenario 1, this is a hypothetical situation since the Shadow 200 was not fielded during Desert Storm.

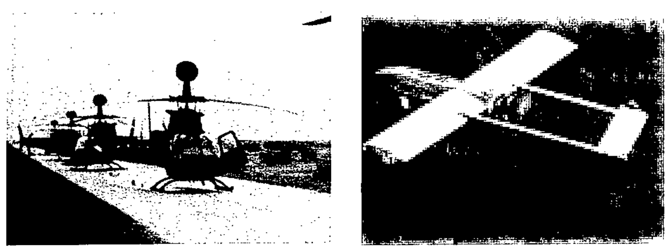

Figure 13: OH-58D's (photo by Tim Gowen, 1991) Versus Shadow 200 (From AAI Corporation, 2000).

Given that the Shadow 200 is smaller than the OH-58D, I assume it is harder to detect, however, I assume that it is slightly easier to hit than the OH-58D because the OH-58D can more than offset its larger size with its greater maneuverability and its pilots' better situational awareness. Although both systems have the capability to transmit live video, have both forward looking infrared (FLIR) and television sensors, and both can be equipped with laser designator/range finders, OH-58D's human pilots are generally better trained at road and bridge classification and will have better visibility than their remote-control counterparts. Weighing all these factors contributing to the probability of mission failure, I believe that the OH-58D has a lower probability of mission failure than the Shadow 200. Given that the reconnaissance mission is important to the ground force, but will probably not result in a change of outcome in the war, I assume the importance of mission success is medium.

The probability of death or capture is lower for the Shadow 200. I assume that the aversion to death or casualties is low due to the fact that the American people are willing and prepared to accept casualties in this conflict.

The final consideration is cost. Based on the 0.2% non-battle loss rates of similar UAVs (Congressional Budget Office [CBO], 1998, p.9), 0.96% UAV battle loss rates in Operation Desert Storm (A. Lafferty [Office of the Deputy Assistant Secretary of Defense for C3I], personal communication, July 20, 2000), and $300 thousand per-vehicle procurement cost goals for the Army's new UAV system (CBO, 2000, p.12), I estimate the per-mission procurement cost for the Shadow 200 to be approximately $3,500. Using Vietnam helicopter loss rates of 0.1% (Ball, 2000) and the OH-58D per-airframe procurement costs of $7.6 million (AIAA, 1991; Friedman, 2000), I estimate the per-mission procurement cost for the OH-58D to be approximately $7,600, or 2.2 times greater than the Shadow 200—this assumes that the OH-58Ds will cover about the same area per sortie as the Shadow 200s. The importance of cost is medium, due to the fact that the entire operation is over seven months long, the nation's finances will be stretched, and most or all of the available resources have been deployed meaning losses will be hard to replace.

My final analysis is that the Shadow 200 is the preferred system to the unarmed OH-58D because although it is slightly more likely to fail the mission, it is cheaper to operate and does not put a human at risk.

4. Scenario 4: AH-64 vs. AH-64 Teamed with Unmanned Scout Helicopters Conducting Anti-armor Deep Attack

This scenario uses the 1999 air campaign against Serbian forces in Kosovo as a backdrop. I consider how teaming AH-64 attack helicopters with unmanned scout helicopters, such as the Navy's Fire Scout vertical/short take-off and landing tactical unmanned aerial vehicle (VTUAV), could have enhanced the probability of mission success, and reduced the probability of death or capture for our pilots. As in scenarios 1 and 3, this is a hypothetical scenario—neither the appropriate manned-unmanned (MUM) tactics, techniques, and procedures (TTPs) nor the VTAUV systems were available to Task Force Hawk in Kosovo.

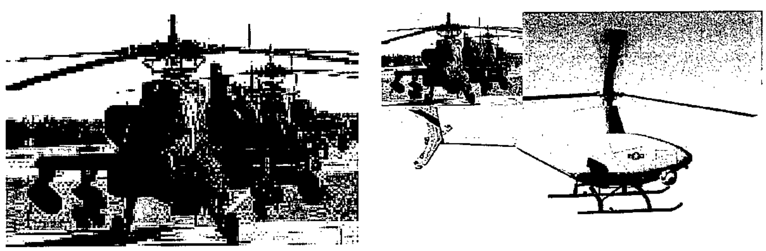

Figure 14: AH-64 Alone (From Boeing, 2000) Versus AH-64 with VTUAV (After Boeing, 2000 and U.S. Navy, 2000).

Given recent research into manned-unmanned teaming of helicopters and UAVs both in the U.S. and United Kingdom (Watson, 1999; Waddington, 2000), this is a scenario worth investigation. If the attack helicopters deployed to Kosovo had been previously equipped and trained with unmanned scout helicopters equipped with suitable guidance systems allowing the air mission commanders to control them, their chances for success against Serbian armor could have been significantly enhanced. The exact tactics to be used are still under study, but the unmanned helicopters could be used to extend the range of the AH-64s' sensors allowing them to positively identify targets without having to get within their target's weapons range. The unmanned helicopters could fly ahead of the manned helicopters, thereby drawing fire and exposing the location of air defense threats. These are much the same tasks as traditionally performed by manned scout helicopters, but the unmanned scouts would be potentially more effective because their sensors could be linked to the manned aircraft. Instead of getting a verbal description of what the scout sees, the attack helicopter crew could actually see what the scout sees.

In considering probability of failure, I assume that the unmanned scout helicopters are much more expendable than the manned attack helicopters and therefore I only consider the probability of loosing manned helicopters. I assume that the attack helicopters are less likely do be detected when accompanied by unmanned scouts because the unmanned scouts will warn them of enemy threats before the manned helicopters are detected, allowing them to avoid or destroy the threat. However, I assume that if detected, the attack helicopters are just as likely to be engaged, hit, and killed as without the unmanned scouts. Because the unmanned scouts will be able to get a closer look at the enemy armor and better designate targets, the chance of mission failure is lower with unmanned scouts. Although the AH-64 deployment to Kosovo has high visibility and the level of national prestige at stake is fairly high, mission failure will not necessarily mean overall failure of the campaign. Therefore, I assume the importance of mission success is medium.

The probability of death or capture with unmanned scouts is reduced significantly over the course of action without because the probability of a shootdown is reduced, as discussed earlier. Just as in scenario 1, the other Kosovo scenario, I assume that the aversion to death or capture is medium.

I assume that the importance of cost is medium due to the length of the campaign being more than a month, but less than a year. I also assume that the cost of manned-unmanned teaming is actually lower. Assuming that when the AH-64s encounter significant threats (23mm and above), there are more helicopters than threat systems shooting at them, and that they have a 1:1 mix of manned and unmanned helicopters when teamed, the attrition rate should be cut in half when they operate in manned-unmanned teams. Based on that assumption, using a .5% attrition rate for the un-teamed AH-64s (Ball, 2000), and a per-aircraft procurement cost of $18.5 million (AIAA, 1995; Friedman, 2000), their per-mission procurement costs are $93 thousand. In the case of the teamed aircraft, both the AH-64s and VTUAVs will have an attrition rate of .25% and their procurement costs are $18.5 million and $300 thousand per vehicle respectively. That results in a per-mission procurement cost of approximately $47 thousand—roughly one-half the cost of the un-teamed course of action. Based on my assumptions, the increased effectiveness, reduced probability of death or capture, and lower cost of manned-unmanned teaming make it the clear winner in this scenario.

Although I purposely chose four scenarios where I believe we should consider using UAVs in the future, the degree to which the three measures of effectiveness contributed to the decision varied. Table 3 shows how each measure of effectiveness was weighted and how each course of action was graded by effectiveness. Note that the only scenario where weighting the measures of effectiveness made a difference to the outcome was course of action 2.

#	Description	I_{ms}	A_{dc}	I_c	P_f	P_{dc}	C_o
1	**Global Hawk**	Low	Medium	Medium	Similar	**Lower**	Similar
	U-2						
2	**Tomahawk**	High	**High**	**Low**	Similar	**Lower**	
	F/A-18						**Lower**
3	**Shadow 200**	Medium	Low	Medium		**Lower**	**Lower**
	OH-58D				**Lower**		
4	**AH-64 w/ MUM**	Medium	Medium	Medium	**Lower**	**Lower**	**Lower**
	AH-64						

Table 3: Summary of Scenario Analysis with Best Score for Each Category Highlighted.

D. FUTURE POTENTIAL OF THE UAV

To assess the future potential of the UAV, we must refer back to Chapter I: the two factors most affecting the future potential of UAVs are the increased demand for the services they can provide, due to the changing nature of modern warfare; and the increasing capabilities of UAVs, mostly due to the explosion of information technology.

1. Trends of the Modern Battlefield

The most far-reaching trends for the future battlefield and therefore the trends most affecting the future demand for UAVs are in the areas of information technology and organizational design.

a. Information Technology

At the Unmanned Vehicles 2000 conference, Rear Admiral Robert Nutwell, Deputy Secretary of Defense for Command, Control, Communications and Intelligence (C3I) stated that victory on the future battlefield would require what he referred to as "dominant battlefield awareness." He also said that to achieve a dominant battlefield awareness requires "staring" sensors. Staring sensors are sensors that continuously monitor a point or area of interest, unlike near earth orbit (NEO) satellites that only get to look at a point on the ground for a short period every ninety minutes or so. The geosynchronous earth orbit (GEO) satellites can stare at an area of interest, but are almost impossible to move if the item of interest moves or you become interested in something else. Manned aircraft can orbit near an objective, but the crews need food, exercise and rest, among other needs, so you have to have enough of these manned aircraft to allow for a rotation schedule in order to stare at an area of interest, not to mention the fact that manned aircraft tend to be more expensive than UAVs designed for the same mission. Most ground-based sensors have to have line of sight visibility with the area of interest, requiring them to be very close, in order to sense anything. That means not only are they particularly susceptible to detection, but their range is short and they take longer to self-deploy than airborne vehicles. All of these factors point to the fact that UAVs will become the preferred platforms for reconnaissance, surveillance, and target acquisition (RSTA) for most applications.

b. Organizational Design

During an August 1999 appearance at the Naval Postgraduate School, Vice Admiral Arthur K. Cebrowski, former J6 (head of command control communications and computers (C4) for the Joint Staff) and current President of the Naval War College, asserted that network-centric warfare is, and should be, the future goal for the U.S. military (1999). His announcement resonated with calls from academia for more network-like military organizations to deal with emerging sub-state threats (Arquilla and Ronfeldt, 1997) as well as the U.S. military's increasingly interdependent system-of-systems architecture. But in order to attain this network-centered military organization, there must be a method of freely passing information between members (in this case military units) of the network. Because military units are and must be mobile, an appropriate network will have to be wireless with over-the-horizon capability. In order to determine how UAVs could be called upon to facilitate this connectivity, we need to consider how such systems work. Current over-the-horizon wireless systems include those that utilize satellite-based repeaters, atmospheric scattering (e.g., short wave and HF radios), or a network of ground-based antennas (e.g., cellular telephone networks). The problem with broadcast signals is that there is a limited number of frequencies in the electromagnetic spectrum which are suitable for long distance data transmission and only one station can transmit at a time within a given broadcast range. That means the stronger the transmitter, the larger the area, and potentially the more people, that must share the same set of frequencies. If the transmitter and receiver are close, signal strength may be reduced and the same frequencies can be reused by other stations beyond the range of the first stations. If we call each broadcast area a cell, then we can say that the number of stations that can be in a wireless network is dependent on the number of cells. Accordingly, cellular telephone systems that must handle hundreds of thousands of calls simultaneously, over a limited number of frequencies work only because there are lots of antennas. One way to create small cells without having more repeaters is to have directional antennas, thereby splitting a repeater's area into sectors. Two more advantages to having numerous cells of communications are an enhanced resistance to jamming and more options for rerouting signals during system outages, hence a more robust system.

With that background in mind, what are the characteristics of UAVs that may make them good repeaters for the future network-centric architecture? UAVs are cheaper and can be more rapidly moved than satellites; they have better line-of-sight visibility than ground antennas and are quicker to put in place. The main disadvantages of UAVs are that they do not have a global reach like satellites and, if used for a long period of time, would probably be more expensive than just putting in ground-based repeaters. Therefore, UAV repeaters should be used to establish or reestablish network connectivity in a theater to consolidate local transmissions, and route them to a satellite or fiber-optic cable if they have to go outside of the theater. This type of use could include acting as global positioning system (GPS) pseudolites or to help overcome enemy RF jammers. When operations are going to be extended, and as time permits, more permanent infrastructure can be put into place such as ground-based radio repeaters, fiber optic cables, or another satellite (the length of most contingency operations do not allow time for this kind of infrastructure improvement). The most appropriate UAV systems for this mission would seem to be those with very long endurance such as the HAE systems or lighter-than-air ships.

2. Trends in UAV Technology

The most significant trends in UAV technology, as discussed in Chapter I, are in the areas of miniaturization and increased autonomy. Let us see how that may impact the future potential of UAVs.

a. Miniaturization

As UAVs become smaller and more economical, they will be more suitable for use by smaller sized units who could conceivably hand-launch them as short-range reconnaissance tools, decoys, communications repeaters, or even as an offensive weapon (e.g., a precision, guided hand-grenade). Micro and meso-scale UAVs could be developed to operate inside of enclosed areas such as ships, buildings, bunkers, or caves and conduct missions such as reconnaissance, surveillance, or even attach beacons for tracking or targeting.

b. Autonomy.

Increasingly autonomous UAVs will be more easily operated by personnel lacking extensive UAV-specific training. This is another feature that will facilitate small unit use of UAVs, because small units are less able to dedicate one or more of their people to being UAV specialists. When operating a UAV requires no more skill than playing a simple video game, they weigh no more than a pair of binoculars, and are just as durable, they will be suitable to operations at the small unit level.

III. USE, OWNERSHIP, AND CONTROL: A SOF PERSPECTIVE

A. THE NATURE OF SOF

The U.S. special operations community is comprised of Army Special Forces, the 75th Ranger Regiment, the 160th Special Operations Aviation Regiment (Airborne), psychological operations units, and civil affairs units; U.S. Navy Sea-Air-Land forces (SEALs), special boat units and SEAL delivery units; and U.S. Air Force special operations squadrons (fixed and rotary wing), special tactics squadrons, a foreign internal defense squadron, and a combat weather squadron (Schoomaker, 1998). Theses units are specially configured and trained to conduct "special operations."

The following excerpt from the USSOCOM Posture Statement (ASD SO/LIC, 1998, pp. 3, 4) defines the principle missions and collateral activities of SOF.

SOF Principle Missions:

Counterproliferation (CP) — The activities of the Department of Defense across the full range of U.S. government efforts to combat proliferation of nuclear, biological, and chemical weapons, including the application of military power to protect U.S. forces and interests; intelligence collection and analysis; and support of diplomacy, arms control, and export controls. Accomplishment of these activities may require coordination with other U.S. government agencies.

Combatting terrorism (CBT) — Preclude, preempt, and resolve terrorist actions throughout the entire threat spectrum, including antiterrorism (defensive measures taken to reduce vulnerability to terrorist acts) and counterterrorism (offensive measures taken to prevent, deter, and respond to terrorism), and resolve terrorist incidents when directed by the National Command Authorities or the appropriate unified commander or requested by the Services or other government agencies.

Foreign internal defense (FID) — Organize, train, advise, and assist host nation military and para-military forces to enable these forces to free and protect their society from subversion, lawlessness, and insurgency.

Special reconnaissance (SR) — Conduct reconnaissance and surveillance actions to obtain or verify information concerning the capabilities, intentions, and activities of an actual or potential enemy or to secure data concerning characteristics of a particular area.

Direct action (DA) — Conduct short-duration strikes and other small-scale offensive actions to seize, destroy, capture, recover, or inflict damage on designated personnel or materiel.

Psychological operations (PSYOP) — Induce or reinforce foreign attitudes and behaviors favorable to the originator's objectives by conducting planned operations to convey selected information to foreign audiences to influence their emotions, motives, objective reasoning, and ultimately the behavior of foreign governments, organizations, groups, and individuals.

Civil affairs (CA) — Facilitate military operations and consolidate operational activities by assisting commanders in establishing, maintaining, influencing, or exploiting relations between military forces and civil authorities, both governmental and nongovernmental, and the civilian population in a friendly, neutral, or hostile area of operation.

Unconventional warfare (UW) — Organize, train, equip, advise, and assist indigenous and surrogate forces in military and paramilitary operations normally of long duration.

Information operations (IO) — Actions taken to achieve information superiority by affecting adversary information and information systems while defending one's own information and information systems.

SOF Collateral Activities

Coalition support — Integrate coalition units into multinational military operations by training coalition partners on tactics and techniques and providing communications.

Combat search and rescue (CSAR) — Penetrate air defense systems and conduct joint air, ground, or sea operations deep within hostile or denied territory at night or in adverse weather to recover distressed personnel during wartime or contingency operations. SOF are equipped and manned to perform CSAR in support of SOF missions only. SOF perform CSAR in support of conventional forces on a case-by-case basis not to interfere with the readiness or operations of core SOF missions.

Counterdrug (CD) activities — Train host nation CD forces and domestic law enforcement agencies on critical skills required to conduct individual and small unit operations in order to detect, monitor, and interdict the cultivation, production, and trafficking of illicit drugs targeted for use in the United States.

Humanitarian demining (HD) activities — Reduce or eliminate the threat to noncombatants and friendly military forces posed by mines and other explosive devices by training host nation personnel in their recognition, identification, marking, and safe destruction. Provide instruction in program management, medical, and mine awareness activities.

Humanitarian assistance (HA) — Provide assistance of limited scope and duration to supplement or complement the efforts of host nation civil authorities or agencies to relieve or reduce the results of natural or manmade disasters or other endemic conditions such as human pain, disease, hunger, or privation that might present a serious threat to life or that can result in great damage to, or loss of, property . . .

Security assistance (SA) — Provide training assistance in support of legislated programs which provide U.S. defense articles, military training, and other defense-related services by grant, loan, credit, or cash sales in furtherance of national policies or objectives.

Special activities — Subject to limitations imposed by Executive Order and in conjunction with a Presidential finding and congressional oversight, plan and conduct actions abroad in support of national foreign policy objectives so that the role of the U.S. government is not apparent or acknowledged publicly.

B. HOW CAN SOF UTILIZE UAVs?

To answer this question, let us consider how UAVs could contribute to the primary SOF missions and SOF collateral activities defined above. For this discussion, it will be useful to separate SOF activities into two basic types—*coup de main*, and persistent—for this discussion. *Coup de main* special operations are typified by such historical examples as the Italian mini-sub raid on the British fleet in Alexandria Harbor and the rescue of Benito Mussolini from the top of Gran Saso Mountain during World War II, the raid on Son Tay Prison during Vietnam, and the Israeli raid to free hostages at Entebbe in 1976 (McRaven, 1995). All of these missions were raids conducted by specially trained and equipped special operations forces against larger military forces in order to achieve strategic advantages. Persistent special operations missions, according to Dr. John Arquilla (1996, p. xvi), include ". . . more protracted campaigns in which small forces are used, either independently, or in concert with regular (or other irregular) forces to achieve larger aims." Examples of protracted special operations campaigns include T. E. Lawrence's contributions to the Arab nationalist campaign against the Turks during World War I, the work of OSS agents in support of resistance movements such as the French Underground and Yugoslav Partisans during World War II, and U.S. advisor teams in El Salvador during the 1980s.

Table 4, located on the next page, uses the same format as Table 2 of the preceding chapter but correlates UAV missions with SOF primary missions and collateral

UAV MISSIONS			SOF Primary Missions									SOF Collateral Activities						
			Counterproliferation [1]	Combatting Terrorism [2]	Foreign Internal Defense [3]	Special Reconnaissance [4]	Direct Action [5]	Psychological Operations [6]	Civil Affairs [7]	Unconventional Warfare [8]	Information Operations [9]	Coalition Support [10]	CSAR [11]	Counter Drug Activities [12]	Humanitarian Demining [13]	Humanitarian Assistance [14]	Security Assistance [15]	Special Activities [16]
	Assault	Deliberate Insertion of Combat Troops			X					X								
		Deliberate Extraction of Combat Troops			X					X								
		Emergency Extraction/CSAR																
	Attack, Air -to-Air	Anti-Airplane or Anti-helicopter	X	X						X								
	Attack, Air-to-Ground	Close Air Support (CAS)	X	X	X					X								
		Mine Destruction			X					X					X			
		Mine Emplacement			X					X								
		Precision Strike																
		Suppression of Enemy Air Defense (SEAD)																
		Manned-Unmanned Teaming	X	X						X								
		Strategic Bombing																
	Cargo Transport	Surface-Deliver Payloads			X	X		X	X	X		X			X	X		
		Air-Drop Payloads			X	X		X	X	X		X	X		X	X		
		Air-Drop Non-lethal Weapon			X											X		
	Decoy	Decoy						X										
	Electronic Warfare	Electronic Attack (EA), Jamming or Deception																
		Electronic Support Measures (ES), ELINT																
	Reconnaissance	Air Sample, Meteorological														X		
		Air Sample, NBC Detection																
		Combat Search and Rescue (CSAR) Support																
		Mine Detection			X					X					X			
		Manned-Unmanned Teaming																
		Manned-Unmanned Teaming, Forward Air Controller	X	X	X					X								
	Reconnaissance/Surveillance	Enclosed Space (e.g. inside building)						X										
		Linear, Border			X			X										
		Strategic, IMINT						X										
		Theater, IMINT						X										
		Tactical, Area, IMINT						X										
		Tactical, Point, IMINT						X										
		Strategic, SIGINT						X										
		Theater, SIGINT						X										
		Tactical, Area, SIGINT						X										
		Tactical, Point, SIGINT						X										
	Retransmission	Ground or Airborne Sensor						X				X						
		Data/Communications						X	X			X				X		
		GPS Pseudolite						X										
	Target Acquisition	Enclosed Space (e.g. inside building)																
		Target Acquisition, Specific Target																
		Target Acquisition, Target of Opportunity																
	Target Designation	Enclosed Space (e.g. inside building)																
		Moving Target																
		Stationary Target																

Key:
X = UAV missions and the SOF missions which they can contribute to

Conducted By:
Persistent SOF

Notes:
1 Includes SOF raids to capture or destroy WMD as well as SOF activities to find, track and determine intentions.
2 Includes raids to free hostages or retaliate against terrorist organizations (e.g., Iran Hostage Rescue).
3 Assumes U.S. in advisory/support role (e.g., El Salvador and Philippines), not active role (e.g., Greece or Viet Nam).
4 SR team needs insertion/extraction, possible emergency extraction and possible UAV to get a closer look of items of interest (e.g., SR in Desert Storm).
5 Includes pre-attack intelligence support and assets for possible contingencies.
6 Leaflet drop, commercial broadcast, loudspeaker, and deception.
7 Humanitarian assistance, command and control assistance, reestablishing basic governmental functions.
8 Similar to FID in that U.S. is in advisory/support role but it occurs in a country whose government is hostile to the U.S. (e.g., WWII Jedbergs and Partisans).
9 C4I attack and defend.
10 Liaison between U.S. and coalition forces, facilitate C3I connectivity, linguists.
11 In support of SOF as well as theater CINC's CSAR plan.
12 Assumes permissive environment where SOF train host nation forces to conduct counter drug activities.
13 Permissive environment where SOF both conduct demining and train host nation forces to conduct demining.
14 Emergency relief assistance: distribute supplies and assist host nation, interagency, and non-governmental organizations.
15 Similar to counter-drug activities; assume SOF conduct training of host nation personnel in a permissive environment.
16 Most salient difference from other special operations is the need to conceal the identity of the sponsor, thereby limiting the use of overtly U.S. systems.

Table 4: Summary of Missions UAVs Can and Should Do for SOF.

activities. An "X" in a particular cell denotes that the UAV mission listed to its left would contribute to the SOF mission or collateral activity listed above it. Cells are color coded to signify whether the mission in question supports *coup de main* missions, persistent missions, or both. The reader may find it helpful to reference this table periodically throughout the following discussion. Another table with this same format will appear later in this chapter to show what capabilities the Services are planning to procure. Chapter IV will present a consolidated table, which will contain all of the data from Tables 2, 4, and 5. At this point, let us turn our attention to discussing the analysis presented in Table 4 in greater detail.

1. Counterproliferation

Coup de main counterproliferation operations include raids to seize and destroy weapons of mass destruction (WMD) or react to similar attacks directed against the U.S. or its allies. SOF *coup de main* counterproliferation missions will generally include the insertion and extraction of SOF raiding parties or precision weapon strikes aided by SOF. Most deep insertions and extractions of SOF as well as most precision munitions deliveries will be conducted by airborne platforms. In the future, UAVs could be used to provide insertion and extraction and precision strike. For the foreseeable future, these platforms will be manned, but they can still benefit from manned-unmanned teaming with UAVs, thereby reducing their susceptibility to shoot down. *Coup de main* counterproliferation forces will often require suppression of enemy air defense (SEAD), electronic jamming, radio relay, and all types of reconnaissance support, all of which can be provided by UAVs. Pre-raid reconnaissance missions may require UAVs with the ability to acquire and track targets, thereby allowing the UAV operator to guide the SOF raiding party to the (possibly moving) target. Finally, because GPS satellite transmissions can be jammed, no-fail missions may often require GPS Pseudolites be in place to insure the local integrity of GPS signals.

Persistent counterproliferation operations can include operations to track the abilities and intentions of rogue states to develop WMD as well as extended campaigns to find and destroy possible WMD. This could also include military support to diplomatic efforts such as embargo enforcement or military engagement programs. A hypothetical example of a persistent counterproliferation operation would be a variation on the actual SOF SCUD hunting operations during Operation Desert Storm (USSOCOM, 1999a, pp. 42,43). In the hypothetical example, Iraq has armed their SCUDs with biological weapons and is threatening to launch them at Israel and Saudi Arabia. Because these SOF forces would operate beyond the forward line of own troops (FLOT), they would be without organic air assets, and relatively vulnerable to enemy air-to-ground attack. Mission success would depend on their not being detected; however, if they were detected, their survival would depend on having responsive anti-aircraft or close air support (CAS) assets to protect them long enough to allow for an emergency extraction. These are all functions that could be performed by UAVs in the future.

2. Combating Terrorism

Coup de main SOF operations include raids to free hostages—for example the 1979 attempt to rescue U.S. hostages in Iran—or raids to retaliate against terrorist organizations such as the 1998 U.S. attack on terrorist camps in Afghanistan in retaliation for the bombing of U.S. embassies in Kenya and Tanzania. These missions are likely to need the same types of support as counterproliferation *coup de main* SOF operations.

Persistent SOF missions to combat terrorism would benefit from the same types of UAV support as the persistent counterproliferation SOF.

3. Foreign Internal Defense

Coup de main SOF FID operations are most likely to be emergency extractions of U.S. personnel engaged in persistent FID operations. These forces would require assault platforms—mostly manned aircraft that could be teamed with decoy UAVs—as well as supporting assets to include, a full range of surveillance and reconnaissance assets, and radio retransmission platforms.

Persistent SOF will continue to play a central role training host nation personnel to prevent lawlessness, subversion, and insurgency. They will most likely be able to utilize commercial or military airlift transportation into theater, but could still require assault platforms to deliver them to tactical sites. As stated earlier, these will be manned platforms for the foreseeable future, but those manned platforms could benefit from manned-unmanned (MUM) teaming in order to reduce their susceptibility to enemy shootdown. UAVs could also be used to provide combat support to host nations in the form of reconnaissance and surveillance. Given that criminals, insurgents, and subversives often take advantage of international borders, border surveillance is another important combat support function that UAVs could provide by patrolling borders. Another area where many countries fighting insurgencies may request help is in the area of mine and countermine support. Since UAVs mounted with sensitive infrared cameras have demonstrated the ability to see anti-personnel mines beneath 2-6 inches of earth (Waddington, 1999), there is much potential for UAVs to play a role in this area. Finally, in the event that SOF tactical locations come under heavy attack, they may need CAS and FAC support to break contact prior to an emergency extraction.

4. Special Reconnaissance

Special reconnaissance missions conducted as *coups de main* include short duration intelligence gathering operations to achieve strategic advantages. *Coup de main* SRs can include operations where SR teams are sent to gather information about hostile weapons thereby allowing the exploitation of hostile technologies; they can be SR teams sent to reconnoiter facilities or hostile organizations for future targeting or news media exposure. It will usually be imperative that the subjects of *coup de main* SR never know how they were observed. Depending on the specific mission, these teams will probably need assault insertion and extraction by air as well as a wide range of reconnaissance and retransmission assets. If they are compromised, or to prevent compromise, they may need CAS and FAC, anti-aircraft, and non-lethal weapon dispersal support on call. Another type of *coup de main* operation in support of SR would be emergency extraction of SR teams. Forces conducting emergency extraction of SR teams may need SEAD, manned-unmanned teaming, ESM, and GPS pseudolite support in addition to the other assets already mentioned.

Persistent SOF SR will rely more on a long-term presence to achieve strategic and operational advantages. Historical examples of persistent SOF SR operations are the coast watchers operating on Pacific islands during WWII, whose mission was to watch Japanese ship movements and relay that information back to allied forces (Arquilla, 1996, pp. 256-274), and more recently the SR teams sent to report vehicle movements on Highway 8 in Iraq during Operation Desert Storm (USSOCOM, 1999a). These forces require periodic aerial resupply and most of the same supporting assets as the *coup de main* SR SOF; however, in the event that they needed emergency extraction, that would be a *coup de main* SOF operation.

5. Direct Action

Direct action missions are, by nature, *coup de main* operations. They also include many of the most high-visibility special operations missions in history. First time success is often the requirement and the National Command Authority (NCA) may be involved in their planning and execution. Commensurate with their strategic importance, these missions often have all required assets at their disposal. The larger DA missions are likely to require support from almost every category of the possible UAV missions with the exception of mining and countermining, strategic bombing, linear border reconnaissance, and acquisition of targets of opportunity (special operations require surgical application of force and excellent fire discipline precluding engagements of targets of opportunity).

6. Psychological Operations

By their nature, psychological operations are persistent SOF missions. UAVs could be used to distribute leaflets, retransmit civil-band radio broadcasts, and deliver supplies—either to resupply PSYOP forces or as part of a PSYOP campaign. Decoy UAVs could also be used, either to enhance the survivability of PSYOP forces like the Commando Solo aircraft or as part of a PSYOP deception. According to Joint Publication 3-53, Doctrine for Joint Psychological Operations (1996, p. I-4), PSYOP support requirements include intelligence; counterintelligence; command, control, communications, and computers (C4); and logistics. UAVs can help here as well. In addition to the cargo and retransmission functions already mentioned, which speak to the logistics and C4 requirements, UAVs can contribute greatly to the intelligence and counterintelligence requirements by conducting reconnaissance and surveillance missions.

7. Civil Affairs

Similar to PSYOPs, civil affairs are inherently persistent SOF missions. They may be able to utilize UAVs to resupply themselves or the host nation entities they are seeking to build up and support. Like all military forces in a theater, CA will also benefit from the flexible C4I connectivity which virtual satellite UAVs can provide.

8. Unconventional Warfare

At the risk of oversimplification, unconventional warfare is the flip side of foreign internal defense; forces conducting UW could use most of the same types of UAV support as those conducting FID. SOF supporting UW will, in general, be more isolated from support than those conducting FID because they will be supporting an insurgent or partisan force that is fighting against an established government or occupying power. Therefore, they are more likely to be attacked by enemy aircraft and could benefit from having an anti-aircraft capability on call. In the event of an emergency extraction, the extraction force is more likely to need SEAD, decoy, and/or manned-unmanned teaming to increase their survivability. Finally, SOF conducting UW are more interested in crossing borders at discreet locations than in keeping entire borders under surveillance like their FID counterparts so they will not need UAVs for linear border reconnaissance as in FID.

9. Information Operations

SOF's role in information operations may include computer network attack (CNA) and computer network defense operations. SOF teams could be directed to disable, destroy, or seize critical, ground-based computer nodes. These teams might place demolitions directly on their targets or clandestinely preposition jammer transmitters nearby for use in future operations. They might use UAVs to laser-designate their targets for precision weapon systems, or they could temporarily assume guidance of UCAVs to conduct precision strikes. SOF could also use organic TUAVs, loaded with EW payloads to interrupt enemy C4I. Because many of these missions are really just specialized direct actions, the types of UAV assets they could benefit from are similar to the direct actions with the exception that they are unlikely to require an NBC detection capability.

10. Coalition Support

Coalition support activities are inherently persistent SOF missions. SOF conducting coalition support activities can benefit from C4I connectivity, which can be provided by UAVs with radio-retransmit capabilities and/or UAV surrogate satellites. They may also benefit from aerial resupply UAV support.

11. Combat Search and Rescue

Servicemen behind enemy lines trying to avoid capture could conceivably be rescued by autonomous vehicles in the future. The advantage to an autonomous vehicle for combat search and rescue, provided the evader is not too badly injured to get himself to a suitable landing zone and into the aircraft, is that you do not risk getting several more servicemen shot down while trying to rescue one or two others. For the foreseeable future though, the technology to reliably find and bring a downed pilot or other evader home safely by remote control or autonomous vehicles is not available. Therefore, SOF CSAR teams on manned assault helicopters or tilt-rotor aircraft, perhaps accompanied by decoy UAVs or using manned-unmanned teaming with UAVs, will have to do the job. CAS and FAC UAV support or even non-lethal weapon delivery could be useful if required to separate the evader from hostile pursuers. UAVs can provide the SEAD support that is normally required whenever assault helicopters have to penetrate a sophisticated air defense network, and of course, reconnaissance UAV products will help ensure proper pre-mission preparation and situational awareness during mission execution.

CSAR is inherently a *coup de main* SOF mission; however, some persistent SOF missions may be required to in order to sustain an evading serviceman until a rescue can be mounted. For example, radio retransmission may be required in order to allow the evading serviceman to transmit his location and disposition and, if suitable CSAR forces are not immediately available, UAVs could provide aerial resupply to sustain him until he can be recovered.

12. Counter Drug Activities

Provided that SOF personnel conducting counter drug activities remain in a teaching and advising role—as USSOCOM defines the mission—they will generally not require UAV support. However, if the mission changes to a more active role, their potential UAV needs may be better represented by thinking of it as a FID or DA mission.

13. Humanitarian Demining

Humanitarian demining is inherently a persistent type of SOF mission. UAVs can be useful in detecting mines, mapping minefields, and destroying mines. Because SOF may have to conduct these missions in remote locations with little or no infrastructure, they could benefit from aerial resupply UAVs.

14. Humanitarian Assistance

Humanitarian assistance is another inherently persistent SOF mission. For this type mission, attack, assault, decoy, EW, and targeting UAVs would not be required; however, UAVs would be very useful for conducting retransmission and satellite surrogate type operations to establish or restore C4I connectivity. There will obviously be a great need for cargo transport capabilities, but meteorological support will also play a role, both in helping predict how the weather will impact operations on the ground and in making up for a lack of weather reporting stations available to support air operations.

15. Security Assistance

Similar to counter drug activities, if SOF are solely there to train host nation personnel, there is probably little application for UAV support; however, as with counter drug activities, if the mission begins to look more like one of the other SOF missions, then they may be able to benefit from the requisite UAV support of whatever mission it is more similar to (e.g. coalition support, FID, DA etc.).

16. Special Activities

These missions may be conducted as *coup de main* operations or persistent operations. The main distinguishing feature of this mission is the fact that it will be covert (i.e., the identity of the sponsoring organization must be concealed and the government must have plausible deniability). That means that UAV systems that are only operated by the U.S. must not be used unless there is either a very low probability of their being identified or the nature of their activities will not be apparent. That would probably rule out infiltration or exfiltration of SOF by assault platforms, because both their origin and intent would be too obvious. The same is probably true of the attack platforms. In the future, meso-UAVs—dime sized micro-electro mechanical devices capable of flying inside buildings—could probably be used to conduct covert reconnaissance, target acquisition and designation, but for now, probably the most useful UAVs for special activities will be the HAE reconnaissance UAVs—which can look at many areas of interest from inside a neighboring country's airspace—and those UAVs that provide retransmission capabilities, thus allowing covert SOF to establish reliable communications with smaller, more easily concealed transmitters.

It is appropriate at least in passing to recognize that SOF can also support UAV operations. Let us consider two areas in particular: advance queuing and downed aircraft recovery.

1. Advance Queuing

The field of view for most UAV sensors can be compared to looking through a soda straw; sensors with wider fields of view lack sufficient resolution to distinguish relevant features. Accordingly, UAV units normally benefit greatly from being told in advance where to focus their efforts. The commander of the Army Hunter UAV company operating in Kosovo claimed that his UAV systems were much better at confirming suspected activities than randomly detecting them in previously unknown locations (Cook, 2000). The larger, wide coverage UAVs such as those operated by the Air Force collect detailed images of large swaths of terrain; however, relevant information can only be gleaned through many man-hours of analysis. If the analysts know what they are looking for and where to look, the process is greatly streamlined. In short, UAVs benefit greatly from advance queuing to a target or object of interest.

It so happens that SOF are ideal forces for providing advance queuing to UAVs. SOF elements conducting any of the SOF primary missions or SOF collateral activities could recommend targets of interest or help guide UAVs to relevant targets.

2. Recovery of Downed Air Vehicles

One of the main advantages of the UAV is that when one is shot down or crashes, there is no pilot, crew, or passengers aboard to be killed or captured. That does not necessarily mean that all UAVs are disposable. To the contrary, many UAVs will not be considered disposable and some of them will be worth putting a team at risk to either recover or destroy it in place. For example, suppose a UAV is conducting a mission in support of a special activity. If that UAV crashed where it could be discovered, recovery (or destruction) may be considered in order to conceal the mission. If a UAV contains classified technology, a recovery (or destruction in place) may be considered to prevent that technology from falling into enemy hands. If a particularly expensive UAV, such as a Global Hawk or UCAV lands outside of its base of operations and can be recovered intact, a recovery operation may be considered to protect the investment.

Given that combat search and rescue is already a SOF collateral activity and a mission for which SOF are well-suited, downed vehicle recovery would be a natural mission for SOF. SOF have organic cargo airplanes and helicopters capable of conducting deep clandestine penetrations into denied areas as well as teams capable of rapidly securing downed UAVs, and recovering or setting demolitions on sensitive components. SOF can also escort UAV recovery teams to landing sites where the recovery teams can conduct battle damage assessment and either repair the UAV on site or transport it back for repairs.

C. WHO SHOULD OWN UAVs?

1. Major Considerations

a. Cost

Cost is an important consideration for any defense acquisition. Although U.S. Special Operations Command (USSOCOM) has its own budget to be used for SOF-peculiar items, it is small compared to that of the Services; USSOCOM's annual budget for 1999 was approximately 1.2 percent of the DOD budget (ASD SO/LIC, 2000, p. 93; CBO, 2000). Because any SOF-peculiar UAV systems, components, or payloads would have to be paid for by USSOCOM, it is in their interest to leverage, to the extent practical, the UAV systems already being developed and purchased by the Services. All other things being equal, the lower the cost of the UAV system, the more suitable it will be for USSOCOM.

b. Access

Another feature of the resource-constrained environment that we operate in is that demand for UAV access already exceeds the supply. There are essentially three access issues related to the ownership of UAVs: access to the UAV itself (i.e., the ability to assign tasks to the UAV), access to the appropriate airspace for the UAV to operate in, and access to the products produced by UAVs. When determining the best way to get access to UAVs, the first place we should turn is to the Services, to see if they have the UAV capability we are looking for. Next, if they have the capability, we need to assess if we can get the desired support from them. Historically, the Air Force in particular has shown that it wants to maintain control of both its UAVs and its airspace (CBO, 1998, Ch 1 pp. 10, 14). Accordingly, they are not likely to take mission requests from SOF unless the theater CINC or JTF commander puts the SOF mission priority above that of the Air Force's other theater-level missions. That means that SOF will probably receive dedicated support from Air Force UAVs when the SOF elements are conducting vital missions and have a high priority for assets, but when conducting lower priority operations, they are unlikely to receive (dependable) Air Force UAV support. For example, if the Air Force had had Predator UAVs during Desert Storm it is not likely that SOF would have received any UAV support except in the case of SOF elements conducting SCUD hunting operations. With respect to the other Services: in most cases, SOF will only get dedicated UAV support when they are participating in a high priority mission, or when they are working in close proximity to conventional forces with organic UAVs. SEAL operations in support of conventional Navy or Marine Corps operations may be the best example of where SOF could expect to receive UAV support from conventional units. SOF conducting unconventional warfare, foreign internal defense, or any of the SOF collateral missions are good examples of when it is not likely that UAV support will be available from the Services.

Access to Air Force managed airspace—consisting, in general, of airspace above the coordinating altitude or beyond the fire support coordination line (FSCL)—seems to be a little easier to get than access to their UAVs. The conventional Army frequently operates Hunter UAVs in Air Force managed airspace, but the units that control them must put liaison officers at the joint force air component command (JFACC) to ensure that their routes and missions are integrated into the air tasking order (ATO).

SOF commanders will probably have adequate access to intelligence products produced by Air Force UAVs through their intelligence representatives at the JTF headquarters. Moreover, as intelligence products become increasingly network-centric, access for those who have a need to know should become even easier. With that said, one should keep in mind that unless the intelligence products are specifically intended for the SOF commander's use, they may or may not provide answers to his priority intelligence requirements. The theater and higher assets may or may not be looking at areas of interest to SOF and, if they are, they may not be looking at the right time, right frequency, or with sufficient resolution. Products produced by Army, Navy, and Marine tactical UAVs (TUAVs) will typically have narrower scopes, because their systems are designed to support tactical commanders. However, unless SOF and conventional tactical forces have significant overlap of their missions and/or areas of interest (AI), the conventional tactical products will be of little use. Furthermore, access to products produced by TUAVs in support of maneuver brigades and battalions, and ships afloat may require that SOF representatives be pre-positioned at those tactical headquarters, just as at the JTF, so they can get copies of pertinent products and forward them to the JSOTF.

c. Security

In order to keep the mission at a high level of security, knowledge of the mission must be restricted. This raises a couple of challenges: how to ensure that the UAV operators have the appropriate clearances, and how to get tasking authority over the UAVs without raising the profile of your mission. For missions with high security classifications, it will be appropriate to have UAV units that routinely work with the special operations forces that conduct these types of missions. There will be no appreciable difference, in such cases, between training operations and real-world missions to those without a need to know. Accordingly, missions with high security classifications require either SOF-organic systems, or habitual support relationships.

2. What UAV Capabilities are the Services Already Purchasing?

Table 5 and the following discussion summarize the military Services' current and planned future capabilities. The table and discussion are limited in scope to systems that the services have articulated an intent to develop and field, not to those for which only basic research is being conducted.

Current and Planned Future Service Missions [17]

UAV MISSIONS		Army-Hunter TUAV	Army-Shadow 200 TUAV	Navy-Pioneer TUAV	Navy-Fire Scout VTUAV	Navy-Canard/Rotor	Air Force-Predator MAE UAV	Air Force-Global Hawk HAE UAV	Air Force-UCAV	Marines-Pioneer TUAV	Marines-Fire Scout VTUAV	Marines-Dragon Warrior-VTUAV	Marines-SURSS Micro-UAV
Assault	Deliberate Insertion of Combat Troops												
	Deliberate Extraction of Combat Troops												
	Emergency Extraction/CSAR												
Attack, Air -to-Air	Anti-Airplane or Anti-helicopter												
Attack, Air-to-Ground	Close Air Support (CAS)												
	Mine Destruction				3	10			10		3		
	Mine Emplacement				3	10			10		3		
	Precision Strike					10			10				
	Suppression of Enemy Air Defense (SEAD)					10			10				
	Manned-Unmanned Teaming					10			10				
	Strategic Bombing												
Cargo Transport	Surface-Deliver Payloads												
	Air-Drop Payloads												
	Air-Drop Non-lethal Weapon												
Decoy	Decoy												
Electronic Warfare	Electronic Attack (EA), Jamming or Deception	0	3	0	3	10	0	3	10	0	3		
	Electronic Support Measures (ES), ELINT						0	3	10				
Reconnaissance	Air Sample, Meteorological				3						3		
	Air Sample, NBC Detection	0	3	0	3	10	0	3	10	0	3	3	10
	Combat Search and Rescue (CSAR) Support	0	3	0	3	10	0	3	10	0	3	3	10
	Mine Detection	3	3	3	3		3			3	3	3	
	Manned-Unmanned Teaming	0	3	3	3	10	3		10	3	3	3	
	Manned-Unmanned Teaming, Forward Air Controller	0	3	0	3					0	3	3	
Reconnaissance/Surveillance	Enclosed Space (e.g. inside building)												
	Linear, Border	0	3	0	3		0	3		0	3		
	Strategic, IMINT						0	3					
	Theater, IMINT						0	3					
	Tactical, Area, IMINT	0	3	0	3		0			0	3	3	10
	Tactical, Point, IMINT	0	3	0	3		0			0	3	3	10
	Strategic, SIGINT						0	3					
	Theater, SIGINT						0	3					
	Tactical, Area, SIGINT	0	3		3		0	3			3		
	Tactical, Point, SIGINT	0	3		3		0	3			3		
Retransmission	Ground or Airborne Sensor	0	3	0	3		0	3		0	3	3	
	Data/Communications	0	3	0	3		0	3		0	3	3	
	GPS Pseudolite	0	3	0	3		0	3		0	3	3	
Target Acquisition	Enclosed Space (e.g. inside building)												
	Target Acquisition, Specific Target	0	3	0	3	10	0	3	10	0	3	3	10
	Target Acquisition, Target of Opportunity	0	3	0	3	10	0	3	10	0	3	3	10
Target Designation	Enclosed Space (e.g. inside building)												
	Moving Target	0	3	0	3	10	0	3	10	0	3	3	20
	Stationary Target	0	3	0	3	10	0	3	10	0	3	3	20

[17] Lists the current and planned programs for each Service along with the missions for which they are being developed.

Key:
0 = Current Capability
3 = Possible by 2003
10 = Possible by 2010
20 = Possible by 2020+

Table 5: Current and Planned Future UAV Capabilities of the Military Services.

a. Army

The Army has two Hunter UAV systems in use with another five systems in storage. Each system consists of eight air vehicles (CBO, 2000). The mission they were designed for was to provide corps and division level ground and maritime forces with near-real-time imagery intelligence (IMINT) within a 144 nautical miles radius of action that could be extended to over 200 nautical miles using relay operations (GAO, 1997; Papadales, 1999). The Hunter UAV has electro-optical (EO) and infrared (IR) sensors, and a line-of-sight data link. The Army's original plan to purchase 52 systems was scrapped in 1996 due to the system's poor initial performance. Since the Army's plans to take operational control of Air Force Predator UAVs in order to cover the division and corps level IMINT needs have been rebuffed by the Air Force, their only current asset to cover this mission is the Hunter system, which would have to be brought out of storage. New personnel would also have to be trained to man them.

The Army's current UAV focus is on TUAVs to support the reconnaissance needs of maneuver brigades. They have purchased four Shadow 200 systems with four air vehicles in each system. If the Shadow 200 proves to be successful, they plan to purchase a total of 44 systems. The Shadow 200 has a 108 nautical miles mission radius, 6-hour endurance, EO and IR sensors, and a line-of-sight data link (AAI Corporation, 1999). Shadow 200 air vehicles will cost roughly $300 thousand each (CBO, 2000, p.12).

b. Navy

The Navy originally purchased nine Pioneer TUAV systems with ten aircraft each (CBO, 2000). Pioneer systems currently consist of five aircraft, but the Navy is currently only using them for contingency missions. The Pioneers were originally purchased to serve as spotters for naval gunfire from battleships. They have EO and IR sensors, a mission radius of 100 nautical miles, endurance of 5 hours, and line-of-sight data link. Pioneer air vehicles cost roughly $800 thousand each (Adroit Systems Incorporated, 2000).

In February 2000, the Navy announced its plans to purchase 12 Fire Scout vertical takeoff and landing tactical UAVs or VTUAVs. They will replace all of the Pioneer systems and their mission, in addition to spotting for naval gunfire, will be to provide naval battle groups with near-real-time reconnaissance and surveillance, battle damage assessment, target identification, communications relay, and nuclear biological and chemical monitoring. Because the VTUAVs are a derivative of Schweizer's model 333 light turbine helicopter, they will be able to operate off of the many helicopter capable ships in the fleet. Fire Scout will have a mission radius of 110 nautical miles, endurance of 3 hours, and its normal payloads will include EO, and IR sensors, a laser designator, and line of sight data relay link (U.S. Navy, 2000b). VTUAV air vehicles will cost under $1 million each.

c. Air Force

The Air Force has purchased 18 Predator medium altitude endurance (MAE) UAV systems consisting of four vehicles each. The Predator was designed to support the in-theater CINC, National Command Authority (NCA), and JTF commander with long-range, long-time-over-target, near-real-time IMINT to satisfy reconnaissance, surveillance, and target acquisition (RSTA) requirements (CBO, 2000). It has a mission radius of 3,000 nautical miles, and endurance of 30 hours. Its normal payloads include EO, IR, and synthetic aperture radar/moving target indicator (SAR/MTI) sensors, and it is equipped with one line-of-sight and two satellite data relay links. The Predator air vehicles cost roughly $4 million each (Adroit Systems Incorporated, 2000).

The Air Force is currently developing the Department of Defense's first high altitude endurance (HAE) UAV, the Global Hawk. If the development program is successful, they plan to procure three ground segments and eight air vehicles (GAO, 1997b). Although its mission will be similar to that of the Predator, its mission radius of 7,000 nautical miles and endurance of 41 hours (Papadales, 1999) will allow it to compete for missions currently flown by manned U-2 reconnaissance aircraft. Global Hawk air vehicles cost roughly $14 million (Adroit Systems Incorporated, 2000).

d. Marine Corps

The Marine Corps currently has two Pioneer TUAV systems consisting of five air vehicles each. Their mission is to provide Marine Expeditionary Unit (MEU) commanders with near real-time intelligence to direct air and artillery strikes and to conduct battle damage assessment.

The Marine Corps plans to purchase eleven of the Fire Scout VTUAV systems (Dahl, 2000). Their mission will be to support the Marine Corps' six MEU commanders with RSTA, battle damage assessment (BDA), communications relay, nuclear biological and chemical (NBC) detection, mine detection, electronic warfare (EW), and information warfare (IW) (Waugh, 1999). The Marines are also planning to purchase two Dragon Warrior systems for close-in (possibly urban) RSTA, BDA, NBC detection and land mine detection (Dahl, 2000).

3. What UAV Capabilities Should SOF Request/Purchase?

a. UAV Capabilities SOF Should Request from the Services

SOF should receive their wide area IMINT and SIGINT products from Air Force HAE and MAE UAVs or other theater assets for three principle reasons. First, these MAE and HAE UAVs tend to be the most expensive systems. Second, theater and strategic assets are best able to keep imagery properly safeguarded for classified operations. Third, the more likely customers for customized products from this class of UAVs are those conducting *coup de main* type missions. These are the same SOF that are most likely to get dedicated and habitual (i.e., during both training and operational missions) UAV support.

USSOCOM, in concert with the warfighting CINCs, should solicit the Services to develop, purchase, and provide dedicated surrogate communications satellite UAVs to facilitate theater-wide C4I connectivity and to provide GPS pseudolite services for three reasons. These systems will be fairly large and expensive. The services they provide lend themselves well to area coverage and easy access for all. And finally, the signals passed over them can be secured before transmission and decrypted upon receipt.

b. Organic UAV Capabilities SOF Should Establish

U.S. Special Operations Command should develop an organic TUAV capability to conduct tactical RSTA, NBC detection, land mine detection, non-lethal weapon dispensing, and electronic warfare in support of JSOTF commanders. This conclusion is supported by the fact that the TUAVs can be relatively low-cost systems. The second reason for organic TUAVs is that the mission and area of interest for JSOTF commanders are normally not the same the Service component commanders. Because of this fact, they will not be able to get TUAV support from those conventional forces. The final justification for organic TUAVs for JSOTF commanders is that conventional force UAV operators will not need or have security clearances above secret for their normal operations. For that reason, they are not well suited to support many SOF missions.

U.S. Special Operations Command should develop an organic micro-UAV capability and support research and development into future concepts using micro electro-mechanical systems (MEMS) technology. Production micro-UAVs will cost an order of magnitude less than the TUAVs of today, be man portable, expendable, difficult to detect, have a small logistical requirement, and be easy to fly (Defense Advanced Research Projects Agency, 1997; Devine, 1999). A realistic estimate of how far away this type of technology is to being ready is about ten years depending on how vigorous the research effort is (S. Morris [president of MLB, and builder/designer of small UAVs], personal conversation, August 11, 2000). The successful development and fielding of micro-UAVs for SOF has the potential of increasing a small SOF element's situational awareness because of the new view of the battlefield it will give them. It will increase their force protection because of the increased standoff capability it will give them for reconnaissance (including NBC detection), surveillance, target acquisition and designation. Because the physics of micro-UAVs will keep them relatively short-range systems, getting them near a target of interest and retrieving them covertly will best be done by special operations forces.

SOF should develop an organic, unmanned cargo transport vehicle for conducting resupply of SOF operators across a wide spectrum of missions in non-permissive areas. Although this would probably be a more expensive system than a TUAV, none of the services are planning to procure such a system in the foreseeable future[*]. SOF are more likely to be deep in denied areas, where the danger to manned aircraft is high, and in need of resupply than any other group of military personnel. This project would meet head-on Senate Armed Services Committee Chairman John W. Warner's challenge for DOD to have one-third of their deep penetration aircraft unmanned by 2010 (Wilson, 2000). Table 6 illustrates how certain classes of UAVs are more obvious choices to become SOF-organic systems than others.

Current or Planned **Service Capability**	**Cost:** High	**Cost:** Low
Yes		TUAV VTUAV
No	Cargo Assault	Micro-UAV

Table 6: Sorting UAV Missions or Types by Relative Cost and Whether or not the Services Have, or Plan to Purchase, their Capability.

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[*] The Marine Corps has given a research grant to Kaman Helicopters to study unmanned vertical replenishment.

D. WHO SHOULD CONTROL UAVs?

1. Levels of Control

UAV control is generally defined according to five levels (Peterson, 1999). The levels are defined as follows.

a. Level 1

An organization with level 1 UAV control is one that is able to receive a processed, or secondary, product from the UAV. An example of this is when a battalion intelligence officer downloads UAV imagery posted on the joint deployable intelligence support system (JDISS).

b. Level 2

An organization with level 2 UAV control is one that is able to receive unprocessed data directly from the UAV. An example of this is when near-real-time imagery from a UAV is retransmitted to a second organization.

c. Level 3

An organization with level 3 UAV control is one that is able to receive unprocessed data directly from the UAV and control the payload. An example of this type of control is when a UAV is conducting a support mission and the supported organization has a direct down-link and is allowed to temporarily take control of the payload (e.g., EO/IR camera) or tell the UAV operator what to do with the payload (e.g., tell him where to aim a sensor).

d. Level 4

An organization with level 4 UAV control is one that is able to receive unprocessed data directly from the UAV and control both the payload and the flight of the air vehicle. One example of this level of control would be if an organization assumed operational control (OPCON) or tactical control (TACON) of a UAV unit. A second example would be if an organization possessed its own ground control stations and personnel to man them and simply took over control of air vehicles and payloads for mission execution and then turned it back over to the owning unit prior to landing.

e. Level 5

An organization with level 5 UAV control is one that has all of the characteristics of level 4 control and also takes over control of the launch and recovery of the air vehicle and payload. This normally implies that the UAV systems are organic assets.

2. Considerations

In this discussion, I assume that a SOF unit has either received OPCON/TACON of non-SOF UAV assets or has organic UAVs. I want to explore who within the SOF organization should have what level of control. For this discussion, I will group the elements of SOF organizations into four levels: individual operator level, small unit leader level (e.g., ODA or ODB commanders, SEAL platoon leaders, etc.), subordinate staff level (e.g., staffs that are at least one echelon below the JTF level), and higher staff level (e.g., JTF, USSOCOM, USASOC, AFSOC, NAVSPECWARCOM, etc.). There are four main considerations that should be evaluated in this discussion.

a. How Easy is the UAV to Control?

The answer to this question depends on which UAV we are talking about. For example, the Air Force's Predator system requires two highly skilled and fully rated pilots to fly it from the ground control station (GCS). On the other hand, the Army's new Shadow 200 system utilizes a much more autonomous control system called the Vehicle Control Station (VCS). The VCS is so much easier to use, that SOF personnel of many military occupational specialties (MOS) and no more than two weeks training should be able to pilot it. When considering transferring level 2 through 4 control of the UAV to an operator in the field, we have to consider the size of the control station. One representative of CDL Systems, the maker of the VCS, told me that the VCS could be displayed on a laptop computer and the whole system transported in a suitcase sized container. Before an individual operator would consider carrying such a terminal around, however, it would have to be no larger than a pair of binoculars and quite rugged. Furthermore, it would have to be self-contained (e.g., battery powered and solar recharged) since SOF operators are often far from electrical power sources. In many ways, control of the UAV is limited to those who can afford to take over responsibility for the GCS. For small units then, it is largely a transportability issue. If they are going to have a vehicle and a ready source of electrical power, they can use a suitcase sized GCS, but if they have to be foot-mobile and will be away from sources of electricity, they cannot.

b. Who Needs Real-time Information?

Because of the UAVs ability to provide near-real-time imagery via downlink, determining who needs that kind of product should be a consideration when deciding who will control the UAV. Real-time information is often necessary in order to obtain information about moving objects or non-routine events. For example, if a person wants to know what goes on at a prison camp on a daily basis, he can have a remote camera film the camp. He can then view the images later (real-time information is not required). However, if he wants to know where the camp commandant goes in his staff car every day, he needs to be able to watch for the commandant to come out of his headquarters and enter the vehicle, then he must be able to direct the camera to follow that vehicle. This is an example of a moving object. In this case, real-time images would be required by the UAV operator in order to track the target, but not necessarily required by the consumers of the information. If, on the other hand, there was a SOF demolition team with the mission of killing the commandant by blowing up a bridge while the commandant was crossing it, they would need near-real-time information about the staff car's location. That information could be relayed by voice from a person controlling a UAV or level 2 UAV control could be given directly to the demolition team.

c. Who Controls Mission Execution, Operators or C2 Elements?

All other things being equal, level 3 and 4 control should be delegated to the lowest level where full authority for mission execution has been delegated. Some examples follow to illustrate this principle. If a SOF direct action team is conducting pre-raid reconnaissance of a target, they should be able to control where the supporting UAV flies and what it looks at because they are driving the mission (i.e., they have the authority to execute the mission as they see best). If, on the other hand, there is a small unit conducting an operation where rules of engagement (ROE) are very restrictive and where detailed information must be sent to a higher HQ for permission to engage, it may make sense to leave level 3/4 control at the approving HQ in order to facilitate more rapid decision-making. In this case, the mission is being controlled (or regulated) by the higher headquarters. In another example, if target selection is being made at a unit headquarters, it would be best for that headquarters to retain level 3/4 UAV control while they are selecting targets, and pass control down to the executing unit level once they issue a task order (TASKORD) to that lower echelon for mission execution. In this case, the higher headquarters controls the mission until they issue the TASKORD, then the lower echelon unit has authority for controlling mission execution.

When UAVs are part of a complex mission including manned aircraft, it may be best if the UAV is controlled from an airborne platform. As discussed above, all other things being equal, the UAV is best controlled at the lowest level where authority for mission execution rests; that would be the air mission commander (AMC) if the UAV was directly supporting his mission. For example, if a UAV is acting as a scout/decoy for a helicopter insertion, it might be best controlled by someone with the AMC aboard the command and control (C2) aircraft. If unexpected enemy activity or new information about the landing zone were discovered, the AMC could direct the UAV to gather the pertinent information he would need in order to decide whether a change of mission were warranted. If the UAV's mission were suppression of enemy air defense (SEAD) instead of scout/decoy, it is probably best controlled from some other location besides the C2 aircraft. In this case, the SEAD is a supporting mission that is not normally controlled by the AMC. All the AMC needs to know is if it worked or not and where he might expect to encounter enemy air defense.

d. Who Can Best Utilize the UAV's Full Potential?

Commanders with dedicated UAVs must consider where the UAVs and their services can be best utilized. In general, the smaller the unit, the more susceptible it is to information overload. Accordingly, there are times, especially at the small unit and individual levels, when SOF operators have all the information they need to properly execute the mission or they are so involved with other aspects of the mission that they do not have the time to operate or monitor a UAV. At times like these, they should consider transferring UAV control to a unit that is able to control and benefit from the UAV. In these cases, higher headquarters personnel can send information updates from the UAV by exception.

3. Conclusions

The preceding discussion suggests that UAV control should be pushed as far down the hierarchy as possible provided one of the four considerations above do not indicate to the contrary. In the following discussion, I will address my conclusions according to the four levels of analysis that I defined above:

a. Individual

Because the individual SOF operator can not normally be encumbered with large pieces of equipment which require external power sources, he will not be able to receive level 2 or higher control of a UAV unless the equipment required to do so is about the size and weight of a pair of binoculars and fully self contained. Furthermore, he should be able to operate the equipment with little or no formal training—probably two weeks or less. Missions or mission phases that require SOF operators to be highly mobile and fully aware of their surroundings would be unsuitable for them to be monitoring UAV operations. However, if the equipment is not cumbersome, the operator is able to devote his attention to UAV operations, and it will provide him with useful information and/or support, the individual operator should be given the appropriate level of control. Once a network-centric architecture is established and cargo-pocket-sized displays are available—ones that allow operators to view operations when they can or need to and put the display away when they do not—the UAV will greatly enhance the potential effectiveness of the individual SOF operator.

b. Small Unit

The small unit level has more transport capability than the individual level. Furthermore, the small unit level is better able to devote man-hours to monitoring or operating UAV than the individual level. This would be a good level to own and operate organic micro-UAVs, and assume level 2 through 4 UAV control of semi-autonomous TUAVs for select missions or mission phases. The small unit level is not currently suitable for level 3 or higher control of complex GCS equipment such as that currently used for the Army's Hunter UAV system or the Air Force's Predator UAV system. This fact could change however, once a suitably small display and standard control protocols are in place.

c. Subordinate Headquarters

This is the level of the SOF hierarchy where I would recommend organic, semi-autonomous TUAVs and, eventually, cargo transport UAVs. I recommend that a SOF UAV company assigned to the joint special operations air component command (JSOACC) be responsible for maintenance and control of UAVs for all missions except as delegated to other organizations within the JSOTF and its subordinate units. As required, JSOTF staff sections could assume partial control of the asset during certain phases of their operation. For example, the intelligence section could assume level 2 or 3 control of TUAVs for conduct of RSTA, and BDA. The UAV company and its personnel would be responsible for all command functions not delegated elsewhere.

d. Higher Headquarters

Higher SOF headquarters should have level 1 and 2 control available on demand, when possible, for SOF UAV operations. This will allow senior commanders and their staffs to monitor operations and avoid burdening subordinate staffs with numerous requests for information beyond that already supplied in standard, periodic reports. Identifying and forwarding pertinent non-SOF UAV products to subordinate staffs should be one function of the higher headquarters staffs with respect to UAVs.

e. Connectivity and Viable Control Levels for UAVs

The following four figures illustrate viable options for SOF control of UAVs. Figure 15 illustrates that the SOF micro-UAV will be best controlled at the small unit level due to its short range and endurance. A retransmitter platform, if brought close enough, could retransmit signals from the micro-UAV to a satellite or surrogate satellite for dissemination to all interested SOF. Figure 16 illustrates viable options for control of organic SOF TUAVs. Level 5 UAV control would be retained at the SOF UAV company, while level 3 or 4 control could be delegated down as far as the small unit level. Meanwhile, the SOF company would uplink the imagery from the TUAV to a satellite or surrogate satellite for distribution to all interested SOF. Figure 17 illustrates viable options for controlling a SOF cargo UAV. This architecture is similar to that for the TUAV except that a provision is added for level 3/4 control by an individual SOF operator—to include downed aviators. This provision would allow a SOF operator who became separated and needed an emergency resupply or downed SOF aviators to assume final guidance of a cargo UAV which would either air drop or airland its cargo. It would be prudent for individual SOF operators to have personal identification numbers (PIN) that they would use in order to authenticate before assuming control of a cargo UAV. Figure 18 illustrates viable control options for a non-organic UAV under OPCON or TACON to SOF (e.g., Predator or Global Hawk). The SOF UAV company would be the only SOF unit who could be capable of assuming control over one of these systems. Due to the complexity of their operation, it would take dedicated UAV operators with extensive training and relatively bulky GCS equipment to assume level 3 or 4 control of an Air Force UAV and most of the other Services' current or projected systems as well. The SOF UAV company could retransmit images from the UAV via satellite or surrogate satellite to all interested SOF. Level 1 products from Service UAVs can be collected by SOF representatives at the JTF level and disseminated to all interested SOF.

Connectivity and Control Levels for SOF Micro-UAVs

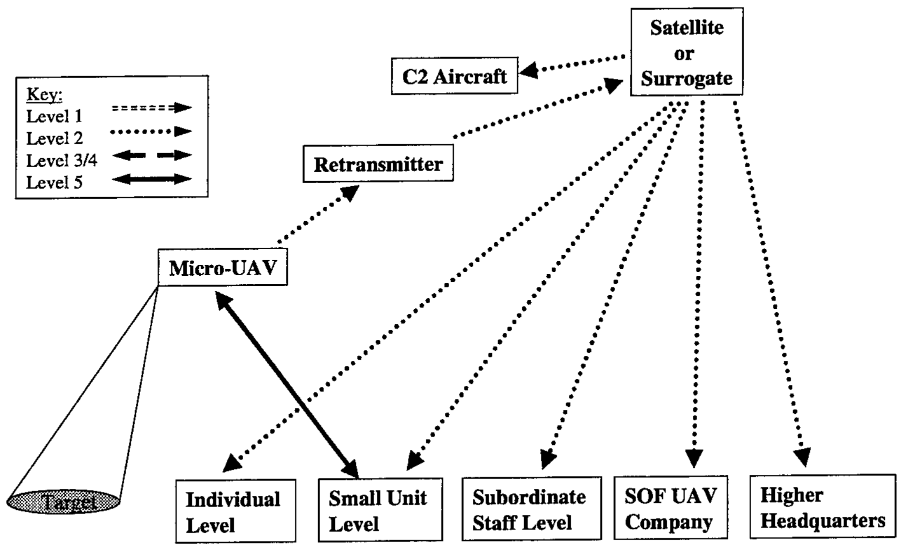

Figure 15: Connectivity and Viable Control Levels for SOF Micro-UAVs.

Connectivity and Control Levels for SOF TUAVs

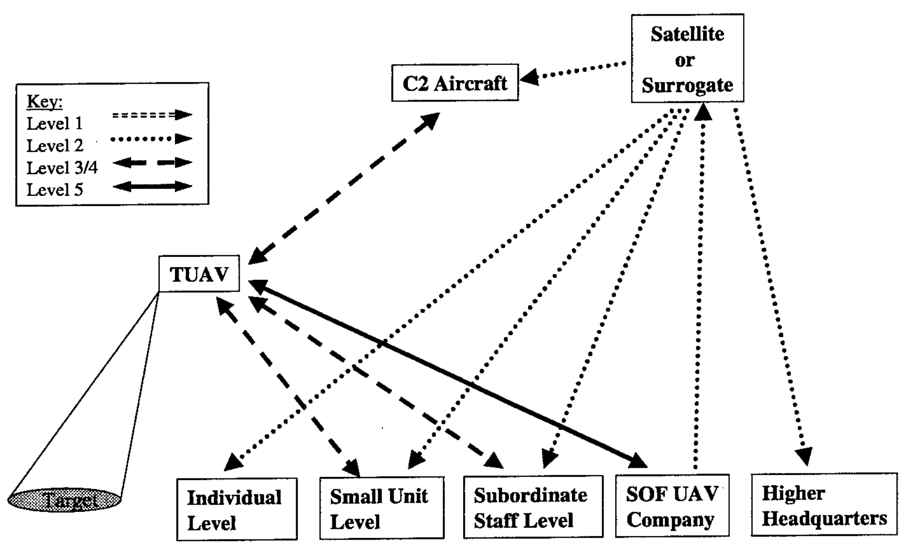

Figure 16: Connectivity and Viable Control Levels for SOF TUAVs.

Connectivity and Control Levels for SOF Cargo UAVs

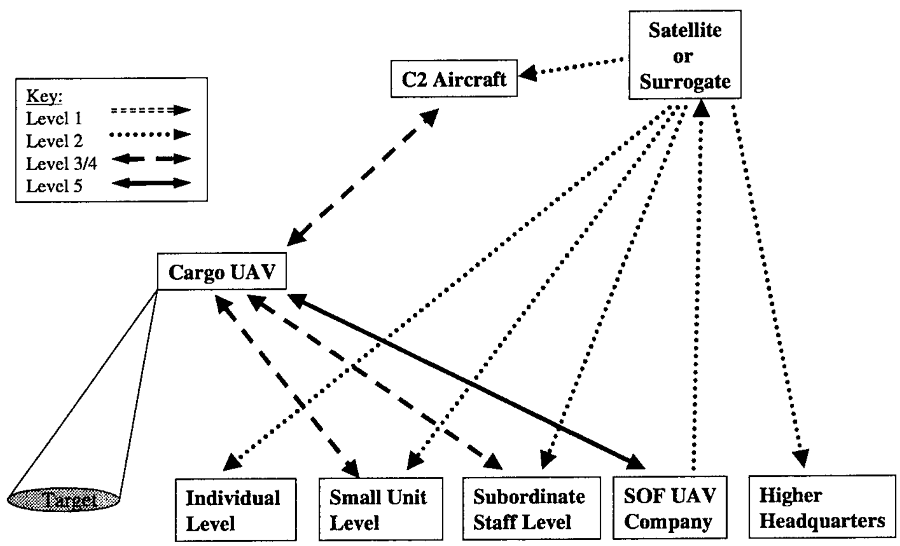

Figure 17: Connectivity and Viable Control Levels for SOF Cargo UAVs.

Connectivity and Control Levels for Non-Organic UAVs

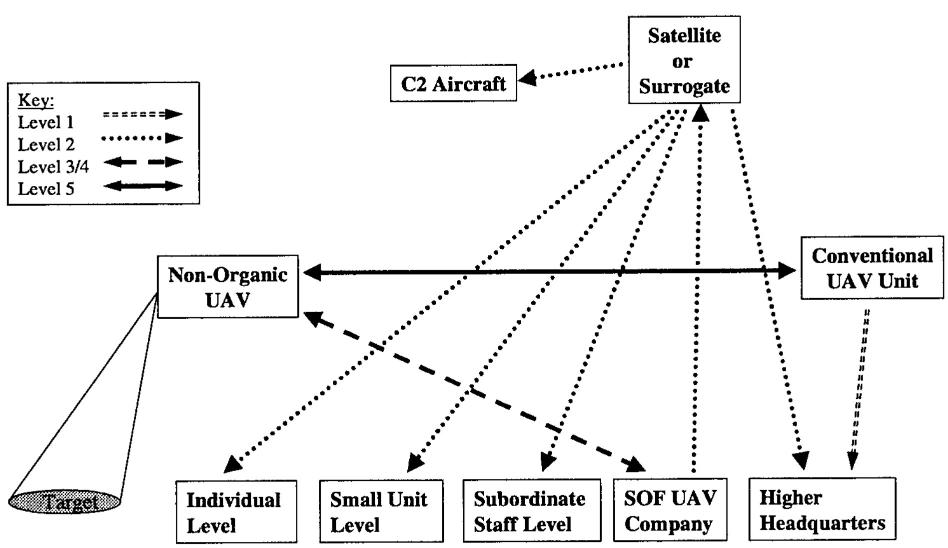

Figure 18: Connectivity and Viable Control Levels for Non-Organic UAVs.

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IV. FUTURE IMPLICATIONS OF UAVs

A. ISSUES

1. Need to Counter Adversary UAVs

To the extent that UAVs can compete with manned systems, prevent casualties, provide new capabilities, and produce economic efficiencies, militaries throughout the world will increasingly seek to purchase them. Because, in the future, the U.S. is likely to face adversaries that have their own UAVs, we must think about and develop the ability to counter UAVs at the same time as we move forward with developing UAVs ourselves. The problem of UAV proliferation could potentially affect SOF more significantly than conventional forces. Because special operations missions are frequently linked to high level policy directed against high payoff targets, adversary reconnaissance UAVs could be more likely to try to ascertain the location, size, and activities of U.S. SOF than of comparably sized general purpose forces. To the degree that these adversary reconnaissance UAVs are successful, SOF may lose the element of surprise that is so vital to the success of SOF missions (McRaven, 1995). Furthermore, because SOF personnel take more time to produce than general-purpose force personnel, and because of the unique capabilities that SOF provide to the NCA and CINCs, SOF bases will arguably-be higher priority targets than most similar sized general-purpose force bases. Following a successful enemy reconnaissance mission, adversaries may target SOF bases of operation. Therefore, SOF are arguably even more vulnerable to UAVs than similar sized general-purpose forces. Accordingly, SOF should be particularly interested in developing capabilities to defend against hostile UAVs. Those capabilities could be active, aimed at destroying adversary UAVs; passive, aimed at reducing the likelihood of SOF detection by UAVs and the vulnerability of SOF to UAVs if detected; or both. In any case, the subject of SOF defense against hostile UAVs will become increasingly important as the proliferation of UAVs continues.

2. Increased Autonomy of UAVs

Because intelligent machines capable of outperforming human pilots will probably not be developed before 2020, and intelligent machines will probably never be able to fully replicate complex, learned human traits such as judgment and intuition, there will always be a place for humans in the loop for the most complex UAV operations. That fact notwithstanding, as artificial intelligence becomes a reality, the major disadvantage to being autonomous—that autopilots are less capable than human pilots to access relevant information and make sound decisions in complex environments—will become less true. As this happens, UAV control and guidance will shift away from remote control towards autonomous operations for certain types of UAVs. The main advantages of intelligent autopilots over remote human pilots are that autopilots can negate UAVs' needs for digital RF links, thereby lowering their detectability and making them more resistant to meaconing[1], jamming, and interference. This particular advantage does not apply to those UAVs that must transmit real-time broadband data, including many UAVs conducting reconnaissance, surveillance, target acquisition/designation, and retransmission missions. However, the assault, attack, transport, and decoy missions could all benefit from the lower RF signature provided by intelligent autopilots because they do not have the same need to transmit broadband data in order to successfully complete their missions.

A second advantage that intelligent autopilots would have over remote human pilots is that intelligent autopilots could become more economical than human pilots because they would not need food, clothing, dental or medical care, or monetary compensation for their work. Furthermore, intelligent autopilots would not need to continually practice in order to keep their skills honed the way human pilots must, thus lowering training costs. This particular advantage would apply to all types of UAVs including those that must transmit real-time data.

3. Fewer Manned Aircraft

As UAVs become more capable, they will naturally replace manned aircraft for many missions. We can see a foreshadowing of that in Senate Armed Services Committee Chairman John W. Warner's recent challenge for the Department of Defense to have one-third of its deep penetration aircraft unmanned by 2010 (Wilson, 2000). Senator Warner stated that the reason he specified deep penetration aircraft is that these are the missions most likely to result in downed pilots. However, since UAVs are currently most capable of replacing manned aircraft in the area of high altitude reconnaissance, surveillance, and target acquisition, this is where I believe the trend will begin, not in the area of deep penetration. That fact notwithstanding, the desire to prevent the death or capture of pilots, expressed by influential men like Senator Warner, will press the development of uninhabited combat aerial vehicles (UCAVs) for deep penetration attacks.

If it were not for the importance of avoiding collateral damage to civilian targets, the development of UCAVs might allow the replacement of deep penetration aircraft for the conduct of such dangerous missions as preliminary air to ground attacks to neutralize enemy air defenses. However, because the desire to avoid collateral damage is often just as important as avoiding friendly casualties to maintaining public support for military operations, there will be humans in the loop for deep strikes for the foreseeable future. This fact suggests that there will be a trend towards manned-unmanned (MUM) teaming of manned attack aircraft with UCAVs in the future. Based on the current rate of development, MUM is likely to be used by rotary-wing attack aircraft first, then by fixed-wing attack aircraft. This is because there are already TUAVs fielded which are suitable for MUM with attack helicopters, and experimental testing is being conducted in both the U.S. and U.K. in this area (Watson, 1999 and Waddington, 2000). On the fixed-wing side, however, MUM is awaiting the construction of suitable UAVs, namely the UCAV and Canard/Rotor, which are projected for Air Force and Navy procurement in the 2010 time frame.

To summarize, there will be a place for some manned aircraft and humans in the loop for the foreseeable future; however, the trend will be for UAVs to replace an increasing percentage of manned aircraft depending on the particular mission. This trend will begin with reconnaissance and surveillance platforms, then move to MUM with attack helicopters, and finally MUM with attack fixed-wing aircraft.

B. COULD UAVs TURN AGAINST THEIR MAKERS?

Is there a danger of UAVs being turned against their makers? The question is certainly worth considering. I can think of a few scenarios where this could theoretically happen, therefore it is a subject worthy of further study.

1. Could Captured UAVs be Used Against Us?

There is some possibility that a UAV could be captured and then used against its original owner; however, this could also happen with a manned aircraft whose pilot could be replaced by an enemy pilot and the aircraft used against its original owners. Furthermore, since human pilots on both sides of a conflict are more easily replaced with adversary pilots than GCSs for different types of UAVs, it is actually easier to "turn" a manned aircraft than to capture a UAV and use it against its original owner. These facts, coupled with the fact that the capture and use of manned aircraft has not been a significant problem through history, imply that this will not be a significant problem for UAVs.

2. Could Captured UAVs be Reverse Engineered?

This is a real danger with many historical cases. Captured aircraft can and do allow the transfer of sensitive technology to belligerents and competitors. As long as technology has been important to warfare, both sides have captured each other's equipment with the hope of determining how it worked, assimilating previously unknown technology, and developing new countermeasures against the captured weapon type. During the Cold War, A Russian defector flew a MIG-25 into an Air Force Base in Japan, the U.S. subsequently learned, among other things, that the aircraft took much longer to climb to high altitudes than previously estimated. That knowledge allowed us to make more realistic battle plans when facing adversaries equipped with MIG-25s. More recently, an F-117 stealth fighter crashed and was captured by Serbian forces. It is widely believed that Serbia allowed our competitors to view and perhaps take pieces of the aircraft for study, which may lead to countermeasures that are more effective against our stealth technology. Because these types of technology transfers can and do happen, leaders must consider how to prevent UAVs with sensitive technology onboard, from being exploited in the event of a shootdown. They may install a self-destruct mechanism, have a recovery/destruction team standing by, and/or be more judicious as to the types of missions where they allow sensitive technology payloads to be used.

3. Could a UAV's Guidance Signals be Intercepted and Altered?

For remote control UAVs, there is a possibility that the enemy may use meaconing[1], jamming, and interference with the guidance signal in such a way that UAVs would do harm to their owners. This is not a trick that could be played as easily on manned aircraft, because human pilots are, and will remain, less easily fooled than autopilots for the foreseeable future. Based on the incompatibility of different GCSs mentioned earlier, this would not be an easy thing to do; however, it could be a high pay-off operation. For example, this type of action could be the key ingredient to a PSYOP campaign aimed at making the target military look incompetent. It could also be used to make the target military loose confidence in their UAVs and stop using them. Given that turning UAVs against their owners is something that could be done either to us or by us against an adversary, this subject merits further study from both aspects.

4. Could UAVs with Artificial Intelligence Change Loyalties?

From the time that robots first entered the human imagination, there has been a corresponding fear that they could turn against their masters. A well-known example of this scenario is illustrated in the book "2001 - A Space Odyssey" (Clark, 1968) where a team of astronauts is pitted against a self-aware computer that controls every system in their ship and believes that its own survival depends on killing the crew. The kind of intelligence portrayed in "2001 – A Space Odyssey" is not likely to be available by 2020, so that type of scenario is beyond the 20-year scope of this thesis. However, a programmable, autonomous UAV could be captured and reprogrammed to attack its former owner, or it could be confused into believing that it is somewhere where it is not and accidentally attack its owner. These are both realistic scenarios that merit further study and the development of countermeasures against them.

C. WILL MANNED AIRCRAFT BECOME OBSOLETE?

Although computers are able to conduct routine calculations at a much faster rate than humans, they have a long way to go before they will be able to think and make decisions like humans. Those two facts make computers more suitable for conducting routine tasks under human supervision then as totally autonomous agents potentially making life and death decisions. Furthermore, because important human attributes such as loyalty, duty, respect, self-less service, honor, integrity, courage, ethics, judgment, intuition, and emotion are particularly difficult for computers to replicate, as are the abilities to discern friend from foe and maintain situational awareness, computers will not be able to replace humans in tasks where these characteristics are required for many years if ever. To the extent that many aircraft missions require those attributes, and other human-unique attributes, there will continue to be humans in the loop in aircraft operations for the foreseeable future. That said, the human supervisor does not necessarily have to be inside the aircraft in order to supervise its operation; he could be flying in formation with it, in a command and control aircraft circling nearby, in an over-watching hide site—as in the example which opens Chapter 1—or in a ground control station a great distance away. The further away he is from the UAV he is controlling, the more vulnerable the UAV is to interruption of the guidance signal. These facts seem to suggest that MUM teams will be the way of the future for missions where signal interference is possible and humans must be in the loop (e.g., attack aircraft).

In the case of aircraft whose mission is to transport personnel, such as assault platforms carrying SOF personnel, a human must be in the loop, but does the human in the loop need to be aboard the aircraft? Until computers with the ability to think like humans are developed, I would argue yes for the following reasons.

1. Reduced Casualty Avoidance Advantage

Because the assault UAV's mission would be to transport SOF personnel, it would no longer have the advantage of being unmanned. If an assault UAV were shot down with SOF personnel on board, there is a high probability that there would be a friendly death or capture. One might refer to the Battle of Mogadishu as an example and consider the negative effect caused by the shootdown of manned MH-60s on the battle (Bowden, 1999). Would the outcome have been different if the MH-60s were unmanned? I think the short answer is probably not. After all, in this scenario a Ranger had been already been seriously injured while fast-roping and Task Force Ranger's ground vehicles had been split up before the first Blackhawk was shot down. Many of the casualties on both sides resulted as the vehicles carrying the main element got lost trying to find their way back to safety. Of the two MH-60s shot down, the first was conducting helicopter close air support for the embattled forces on the ground (a mission for which no UAV will be suitable before 2020). The second MH-60 shot down was carrying a combat search and rescue team in addition to its crew, meaning that if there were no pilots on board, there would still have been soldiers down in need of rescue. We must also wonder what would an unmanned helicopter do if the pre-planned landing zone (LZ) were not suitable? Would it automatically go around and risk the subsequent loss of surprise, could it ask the ground force commander whether he wanted to be put down in an alternate location, if so could the autopilot choose an alternate LZ? It is just this kind of uncertainty and dynamic mission environment that will make autonomous UAVs unsuitable assault platforms for the foreseeable future and mean that manned aircraft are here to stay, though in fewer numbers.

The above discussion does not necessarily apply to a UAV designed to conduct a CSAR extraction. It is possible, in some circumstances, that CSAR recovery of one person would be considered too risky to put numerous people at risk to conduct. This is a case where an autonomous UAV could be sent to an LZ to recover the person. Once the aircraft is in the LZ and the precious cargo is aboard, the complexity of the mission diminishes and there are fewer decisions to make. All the vehicle needs to do is get home. To enhance its chances, it could receive human in the loop guidance as long as the communication link were sound, but proceed autonomously if the link were interrupted.

2. Vulnerability of UAV Guidance Links

To the extent that the guidance links for remotely controlled UAVs are vulnerable, they are unsuitable platforms for carrying personnel. They must have both an autonomous capability and a (reliable) man in the loop in order to be suitable for carrying personnel.

3. Need to Transfer Assault UAV's Guidance

As mentioned before, MUM teaming could put a human controller close enough to ensure the reliability of his guidance signal. However, by getting close enough to ensure signal coverage, the controller is potentially just as vulnerable to shootdown as the UAV. What if the human controller's aircraft is shot down or forced to abort? Can he safely and reliably transfer control of the assault UAV he is controlling to a second controller? If not, the chances of survival for the personnel in the unmanned assault UAV are even lower. Let us look at an example. Assume that the unmanned assault UAV has a 90 percent chance of delivering its personnel without being shot down. Also, assume that the controller's manned helicopter has a 95 percent chance of not being shot down before the personnel are delivered (assuming that he is staying somewhat out of harms way and therefore has a better chance of survival). Since the unmanned assault helicopter needs both helicopters to survive in order to be successful, it has an 85.5 percent chance of success (90 percent × 95 percent = 85.5 percent).

This analysis should not preclude the use of MUM teaming of decoy and/or reconnaissance UAVs with manned assault helicopters. As noted in Chapter II, for a scenario where there are more targets than shooters, adding another equally susceptible target does not change the overall probability of kill, but it does reduce the probability of kill for each individual target. In other words, if you double the number of targets, you reduce the probability of kill for each target by one-half. A second way that MUM teaming can be used is as currently being tested with attack helicopters (Harvey, 2000). In this technique, a TUAV flies high and in front of a flight of helicopters, transmitting real-time overhead images of the route to the air mission commander and giving him time to alter his course or tactics based on the advance warning.

D. HOW SHOULD SPECIAL OPERATIONS LOOK AT UAVs?

This question calls for a summary of the issues considered previously. Accordingly, Table 7 combines the information of Tables 2, 4, and 5 to show the types of missions that UAVs can do, the types of UAVs that are suited to do those missions, the UAV missions that support the SOF primary missions and collateral activities, and the UAVs and mission capabilities that the Services are planning to purchase.

			UAV Types						SOF Primary			
			HAE	MAE	UCAV	Mini/Tactical	Micro	Meso	Counterproliferation [1]	Combating Terrorism [2]	Foreign Internal Defense [3]	Special Reconnaissance [4]
UAV MISSIONS	Assault	Deliberate Insertion of Combat Troops			20						X	
		Deliberate Extraction of Combat Troops			20						X	
		Emergency Extraction/CSAR			20							
	Attack, Air -to-Air	Anti-Airplane or Anti-helicopter			20				X	X		
	Attack, Air-to-Ground	Close Air Support (CAS)			20				X	X	X	
		Mine Destruction			10	3					X	
		Mine Emplacement			10	3					X	
		Precision Strike			10							
		Suppression of Enemy Air Defense (SEAD)			10							
		Manned-Unmanned Teaming			10				X	X		
		Strategic Bombing			20							
	Cargo Transport	Surface-Deliver Payloads				0					X	X
		Air-Drop Payloads				3					X	X
		Air-Drop Non-lethal Weapon				3					X	
	Decoy	Decoy		0	10	0						
	Electronic Warfare	Electronic Attack (EA), Jamming or Deception	0	0		0						
		Electronic Support Measures (ES), ELINT	0	0		3						
	Reconnaissance	Air Sample, Meteorological	0	0		0						
		Air Sample, NBC Detection	0	0		0	10	20				
		Combat Search and Rescue (CSAR) Support	0	0	10	0	10	20				
		Mine Detection	3	3		3					X	
		Manned-Unmanned Teaming	3	3	10	0						
		Manned-Unmanned Teaming, Forward Air Controller				0			X	X	X	
	Reconnaissance/Surveillance	Enclosed Space (e.g. inside building)						20				
		Linear, Border	0	0		0					X	
		Strategic, IMINT	0	0								
		Theater, IMINT	0	0								
		Tactical, Area, IMINT		0		0	10					
		Tactical, Point, IMINT		0		0	10					
		Strategic, SIGINT	0	0								
		Theater, SIGINT	0	0								
		Tactical, Area, SIGINT		0		0						
		Tactical, Point, SIGINT		0		0						
	Retransmission	Ground or Airborne Sensor	0	0		0						
		Data/Communications	0	0		0						
		GPS Pseudolite	0	0		0						
	Target Acquisition	Enclosed Space (e.g. inside building)						20				
		Target Acquisition, Specific Target	0	0	10	0	10					
		Target Acquisition, Target of Opportunity	0	0	10	0	10					
	Target Designation	Enclosed Space (e.g. inside building)						20				
		Moving Target	0	0	10	0	20					
		Stationary Target	0	0	10	0	20					

Notes:

1 Includes SOF raids to capture or destroy WMD as well as SOF activities to find, track and determine intentions.
2 Includes raids to free hostages or retaliate against terrorist organizations (e.g. Iran Hostage Rescue).
3 Assumes U.S. in advisory/support role (e.g. El Salvador and Philippines), not active role (e.g. Greece or Viet Nam).
4 SR team needs insertion/extraction, possible emergency extraction and possible UAV to get a closer look of items of interest (e.g. SR in Desert Storm).
5 Includes pre-attack intelligence support and assets for possible contingencies.
6 Leaflet drop, commercial broadcast, loudspeaker, deception.
7 Humanitarian assistance, command and control assistance, reestablishing basic governmental functions.
8 Similar to FID in that U.S. is in advisory/support role but it occurs in a country whose government is hostile to the U.S. (e.g. WWII Jedbergs and Partisans).

Table 7: Master Correlation Matrix of UAV Capabilities, SOF Missions, and Planned Service UAV Capabilities

Missions					SOF Collateral Activities							Current and Planned Future Service Missions [17]											
Direct Action [5]	Psychological Operations [6]	Civil Affairs [7]	Unconventional Warfare [8]	Information Operations [9]	Coalition Support [10]	CSAR [11]	Counter Drug Activities [12]	Humanitarian Demining [13]	Humanitarian Assistance [14]	Security Assistance [15]	Special Activities [16]	Army-Hunter TUAV	Army-Shadow 200 TUAV	Navy-Pioneer TUAV	Navy-Fire Scout VTUAV	Navy-Canard/Rotor	Air Force-Predator MAE UAV	Air Force-Global Hawk HAE UAV	Air Force-UCAV	Marines-Pioneer TUAV	Marines-Fire Scout VTUAV	Marines-Dragon Warrior-VTUAV	Marines-SURSS Micro-UAV
X			X	X																			
X			X	X																			
X			X	X		X																	
X			X	X		X																	
X			X	X		X																	
			X					X							3	10			10		3		
			X												3	10			10		3		
X				X												10			10				
X			X	X		X										10			10				
X			X	X												10			10				
X	X	X	X	X	X			X	X														
X	X	X	X	X	X	X		X	X		X												
X				X		X			X														
X	X		X																				
X			X	X		X						0	3	0	3	10	0	3	10	0	3		
X			X	X		X											0	3	10				
X				X					X		X				3						3		
X												0	3	0	3	10	0	3	10	0	3	3	10
X			X	X		X						0	3	0	3	10	0	3	10	0	3	3	10
X			X	X		X		X				3	3	3	3		3			3	3	3	
X				X		X						0	3	3	3	10	3		10	3	3	3	
X			X	X		X						0	3	0	3					0	3	3	
X	X		X	X							X												
	X											0	3	0	3		0	3		0	3		
X	X		X	X		X					X						0	3					
X	X		X	X		X											0	3					
X	X		X	X		X						0	3	0	3		0			0	3	3	10
X	X		X	X		X						0	3	0	3		0			0	3	3	10
X	X		X	X		X					X						0	3					
X	X		X	X		X											0	3					
X	X		X	X		X						0	3		3		0	3			3		
X	X		X	X		X						0	3		3		0	3			3		
X	X		X	X	X	X					X	0	3	0	3		0	3		0	3	3	
X	X	X	X	X	X	X			X		X	0	3	0	3		0	3		0	3	3	
X	X		X	X		X						0	3	0	3		0	3		0	3	3	
X				X							X												
X				X								0	3	0	3	10	0	3	10	0	3	3	10
												0	3	0	3	10	0	3	10	0	3	3	10
X				X							X												
X				X								0	3	0	3	10	0	3	10	0	3	3	20
X				X								0	3	0	3	10	0	3	10	0	3	3	20

Key:
0 = Current Capability
3 = Possible by 2003
10 = Possible by 2010
20 = Possible by 2020+
X = UAV missions and the SOF missions which they can contribute to

Conducted By:
Persistent SOF
Coup de Main SOF

9 C4I attack and defend.
10 Liaison between U.S. and coalition forces, facilitate C3I connectivity, linguists.
11 In support of SOF as well as theater CINC's CSAR plan.
12 Assumes permissive environment where SOF train host nation forces to conduct counter drug activities.
13 Permissive environment where SOF both conduct demining and train host nation forces to conduct demining.
14 Emergency relief assistance: distribute supplies and assist host nation, interagency, and non-governmental organizations.
15 Similar to counter-drug activities; assume SOF conduct training of host nation personnel in a permissive environment.
16 Most salient difference from other special operations is the need to conceal the identity of the sponsor, thereby limiting the use of overtly U.S. systems.
17 Lists the current and planned programs for each Service along with the missions for which they are being developed.

1. Short Term View

In the short term, SOF should develop its own organic tactical UAV assets, fund micro UAV research and development, and seek to shape Service procurements so as to best support special operations. Right now, there are UAVs capable of providing JSOTF commanders with dedicated, real-time, tactical reconnaissance and surveillance, voice and data retransmission, target acquisition/designation, electronic warfare, decoy, and airland payload delivery. Working in concert with SOF teams in the field, these UAVs could contribute to all nine of the SOF primary missions and 5 out of 7 SOF collateral activities (see Table 6). By 2010, micro-UAVs suitable for small-unit SOF could be available (Figure 19) and should be integrated into SOF organizations and operations. Over the next 20 years, UAV producers could add the ability to air drop payloads, and both detect and destroy land mines. In order to ensure that industry develops the right capabilities, USSOCOM must articulate its requirements to industry. At the same time, USSOCOM must articulate what future UAV support it wants from the military Services. This will allow them to take USSOCOM's needs for strategic UAV support (see Chapter III, paragraph 3.a) into account when they are procuring the applicable UAVs.

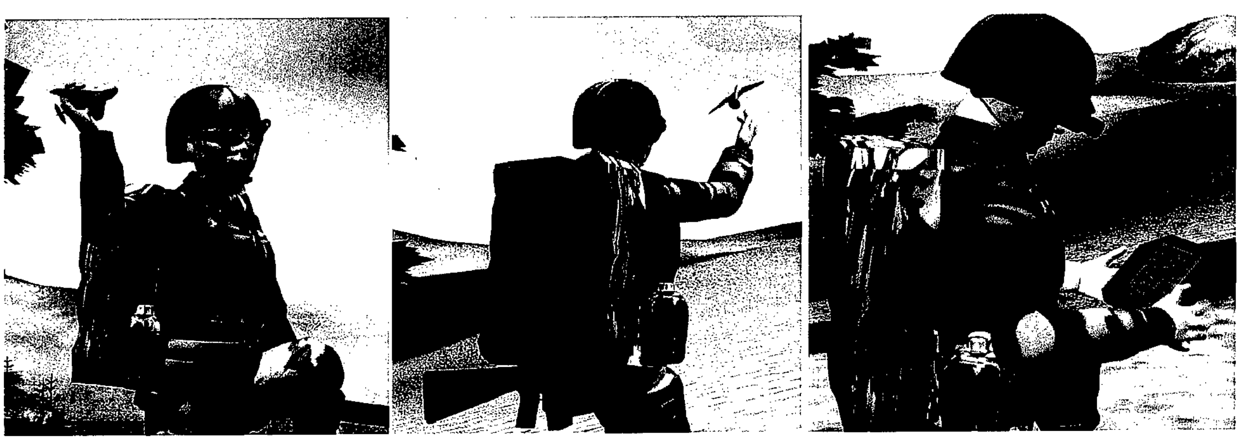

Figure 19: The MicroSTAR, a Man-packable Micro-UAV (from Devine, 1999).

2. Long Term View

In the long run, SOF should see UAVs, and the types of operations and organizations that they will help facilitate, as a completely new way of doing business. Over the next 10 to 20 years, a host of factors related to the explosion in technology could work together to make new methods of information-use possible. The realization of this new potential is causing visionaries inside and outside the military to espouse new methods of doing business with names like "net-centric warfare," (Cebrowski, 1999) and "swarming" (Arquilla and Ronfeldt, 1997, pp. 465-477).

Multiple constellations of communications satellites currently orbit the Earth, facilitating the near-instantaneous transmission and linkage of data streams from disparate sources. This global communications network could be augmented at theater and lower levels with virtual satellites—either HAE UAVs or unmanned blimps—to increase the potential communications bandwidth and/or robustness in certain areas. This vast communications network could support swarms of unmanned vehicles, digitized soldiers, sailors, marines and airmen; all sharing information, and reacting to unfolding events according to a real-time, continuously updated commander's intent. The idea of swarming suggests a need for many dispersed and relatively inexpensive nodes capable of gathering and transmitting information as well as numerous entities, human or otherwise, capable of executing military missions. Given the current trends towards information proliferation and casualty aversion, as well as the need for economy, both of these jobs seem to call for low-cost unmanned systems.

Within this vast military command and control network will be a subset of nodes that perform special operations. Their operators do not generally join in large swarming operations because they are intended to conduct a more specialized subset of missions: those with high pay-off, and linkages to high policy, requiring specialized military forces with skills and capabilities not found in the conventional forces. In order to thrive in this multi-level, network-centric environment of the future, all nodes must be monitoring the net, standing by, and ready for employment as opportunities present themselves.

E. QUESTIONS FOR FURTHER STUDY

The following issues are worthy of further study.

1. Counter UAV TTPs

Given the probability of UAVs proliferating adversary military forces, it would be worthwhile to investigate possible tactics techniques and procedures to be used to counter adversary UAV operations. This should probably be a subject of interest to the Service UAV battlelabs.

2. Best UAV Systems for Organic SOF Use

Although it is beyond the scope of this thesis to suggest specific UAV models for organic SOF use, it seems to be a relevant question for both the Special Operations Acquisition and Logistics (SOAL) and the Special Operations Requirements and Resources (SORR) Centers of USSOCOM.

3. Preventing Our UAVs from Being Used Against Us

Keeping an adversary from using our UAVs against us is another problem worth investigation; however, answering this question seems to be one of universal responsibility. Industry, Service UAV battlelabs, and planners at all levels with responsibility for planning UAV operations and integration should study or at least consider this issue during the completion of their plans and programs.

4. Using Adversary UAVs Against Them

As discussed earlier in this chapter, the ability to turn an adversary's UAVs against him in a few well-chosen instances could cause him to stop trusting them altogether. You could take over guidance and cause them to attack themselves, view their data streams and know what they are looking at, or insert phony data that would deceive the enemy. This is probably a program that would require its own mission need statement and some interagency pooling of resources. In other words, this is probably a mission that the Central Intelligence Agency should share responsibility for.

F. CONCLUSIONS AND RECOMMENDATIONS

After over 80 years of development, the technology required to make unmanned aerial vehicles among the most important systems on the battlefield is just now becoming available. In order to best take advantage of this fact, there are three measures of effectiveness that can guide decisions regarding future uses of UAVs. They are the probability of mission failure, the probability of friendly death or casualty, and the cost of the operation. There are two trends in warfare that will most effect the future demands for UAVs, the trend towards information dominance and the trend towards network-centric organizational designs.

With regard to special operations, UAVs could support all nine primary missions and five of the seven collateral activities of USSOCOM. USSOCOM should buy an organic UAV capability, beginning with tactical UAVs, and then go on to add micros, cargo carriers, and perhaps CSAR platforms as technology matures. It should articulate its UAV support requirements to the Services, including their need for strategic reconnaissance and C4I connectivity. Control of SOF UAVs should go to those best able to utilize them with the general goal to push them as far down in the chain of command as possible without unnecessarily burdening small units.

As far as the future of UAVs is concerned, appropriate agencies must consider how to counter adversary UAVs, when and how humans should be in the loop in UAV operations, and the implications of UAVs replacing manned systems. Manned aircraft will not become obsolete. This is because of the vulnerability of UAV guidance links, the shortcomings of artificial intelligence, and the loss of a casualty-avoidance advantage when passengers are carried in UAVs. For most applications, UAVs should be seen as complimenting a manned presence.

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[1] Meaconing refers to the transmitting of actual or simulated radio navigation signals to confuse navigation systems (Defense Mapping Agency, 1993, p. 2-27).

REFERENCES

AAI Corporation. (1999, December 30). Shadow 200, the little airplane that did. Retrieved August 23, 2000 from the world wide web: http://shadow200.com/)

AAI Corporation. (2000). Shadow 200. Retrieved August 3, 2000 from the world wide web: http//www.aaicorp.com/defense/uav/index

Adroit Systems Incorporated. (2000). UAV forum: librarian's desk (frequently asked questions). Retreived August 28, 2000 from the world wide web: http://www.adroitnet.com/uavforum/faq.htm

Aerospace Industries Association of America. (1990). Aerospace facts and figures 1989-1990. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1991). Aerospace facts and figures 1990-1991. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1997). Aerospace facts and figures 1996-1997. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1998). Aerospace facts and figures 1997-1998. Washington, D.C.: Aerospace Industries Association of America.

Alfke, P. (2000). Integrated circuits. Technology review and update 2000, session #5. Monterey, California: Naval Postgraduate School.

Armitage, M. (1988). Brassey's unmanned aircraft. McLean, Virginia: Brassey's Defense Publishers.

Arquilla, J. (1996). From Troy to Entebbe: special operations in ancient and modern times. Lanham, Maryland: University Press of America.

Arquilla, J. and Ronfeldt, D. (1997). In Athena's camp: preparing for conflict in the information age. Santa Monica, California: RAND.

Assistant Secretary of Defense for Special Operations and Low Intensity Conflict. (2000). United States special operations forces posture statement 2000. Retrieved August 30, 2000 from the world wide web: http://defenselink.mil/pubs/sof/index.html

Ball, R. (1985). The fundamentals of aircraft combat survivability analysis and design. New York: American Institute of Aeronautics and Astronautics.

Ball, R. (2000). Aircraft combat survivability analysis and design. Retrieved August 27, 2000 from the world wide web: http://www.aircraft-survivability.com/Survivability_course.html

Boeing Corporation. (2000). Boeing AH-64 Apache home page. Retrieved July 3, 2000 from the world wide web: http://www.voodoo.cz/ah64lgal12.html

Bowden, M. (1999). Blackhawk down. New York: Atlantic Monthly Print.

Bowman, T. (2000, March 22). Cost of war: A new accounting strategy. Baltimore Sun.

Boyd, A. (2000). Military satellite communications technology. Technology review and update 2000, session #6. Monterey, California: Naval Postgraduate School.

Cebrowski, A. (1999, August 10). Network-centric warfare. Lecture presented to the student body, Naval Postgraduate School, Monterey, California.

Clark, A.C. (1968). 2001 - a space odyssey. New York: New American Library.

Congressional Budget Office. (1998, September). Options for enhancing the Department of Defense's unmanned aerial vehicle programs. Retrieved August 14 from the world wide web: http://www.fas.org/man/congress/1998/cbo-uav3.htm

Congressional Budget Office. (2000, March). Budget options for national defense. Retrieved August 23, 2000 from the world wide web: http://www.cbo.gov/showdoc.cfm?index=1873&sequence=3&from=5

Cook, S. (2000). Task Force Hunter for NATO Operation Allied Force over Kosovo. Presented at Shephard's Unmanned Vehicles 2000 conference and exhibition, London, United Kingdom.

Dahl, M. (2000, July). U.S. Marine Corps tactical unmanned vehicle concept of employment. Presentation at Shephard's Unmanned Vehicles 2000 conference, London, United Kingdom.

Defense Advanced Research Projects Agency. (1997, August 7). Micro air vehicles: toward a new dimension in flight. Retrieved August 28, 2000 from the world wide web: http://www.darpa.mil/tto/programs/mav_auvsi.html

Defense Mapping Agency. (1993, January 7). Flight information publication: General planning. Washington. D.C.: Defense Mapping Agency.

Devine, W. O. (1999, 29-30 November). MicroSTAR micro air vehicle: A revolution in soldier sensing. Presented at Strategic Management Information (SMi) UAV and UCAV payloads conference, London, United Kingdom.

Fahey, J. (1946). U.S. Army aircraft (heavier than air) 1908-1946. New York: Murray-Hill.

Fardink, P. (2000, February 29). Amazing men. Army aviation, 49, 26.

Federation of American Scientists. (2000). BGM-109 Tomahawk. Retrieved August 3, 2000 from the world wide web: http://www.fas.org/man/dod-101/sys/smart/bgm-109.htm

Friedman, S. (2000). Inflation calculator. Retrieved August 21, 2000 from the world wide web: http://www.westegg.com/inflation/infl.cgi

Government Accounting Office. (1997a, June 12). Operation Desert Storm: Evaluation of the air campaign. Retrieved August 14, 2000 from the world wide web: http://www.fas.org/man/gao/nsiad97134/app_03.htm

Government Accounting Office. (1997b, April 9). Unmanned aerial vehicles: DOD's acquisition efforts. Washington D.C.: U.S. Government Printing Office.

Harkin, J. (2000). Military aircraft archive. Retrieved August 3, 2000 from the world wide web: http://www.militaryaviation.com

Harvey, D. S. (2000, August – September). Eye on the Americas. Defense helicopter, 19, 4.

Kaminski, P. (1997, March 19). Fielding equipment second to none. Washington, D.C.: Acquisition and Technology Subcommittee, Senate Arms Services Committee. Retrieved May 9, 2000 from the world wide web: http://www.defenselink.mil/speeches/1997/t19970319-kaminski.html

Koppel, T. (Anchorman). (2000, April 26). ABC News nightline: Pilot down; [rescue of Hammer 3-4, pilot who went down in Yugoslavia a year ago]. New York: American Broadcasting Corporation.

McRaven, W. (1995). Spec ops: case studies in special operations warfare theory and practice. Novato, California: Presidio Press.

Munsan, K. (1998). Jane's unmanned aerial vehicles and targets. Coulsdon, United Kingdom: Jane's Information Group Limited.

Papadales, B. (1999, December). Electronic database of current UAV descriptions. USA: MIRADA Inc.

Peterson, A. (1999, September 23). Airborne manned/unmanned system technology (AMUST) program update. Presented at the second annual American Institute of Engineers and Society for Computer Simulation International's conference on unmanned aerial vehicles, Washington, DC.

Pioneer UAV Incorporated. (2000). Pioneer UAV home page. Retrieved 8 May 2000 from the world wide web: http://www.puav.com/

Powers, J. (2000). Electro-optical and infrared systems. Technology review and update 2000, session #2. Monterey, California: Naval Postgraduate School.

Reed, A. (1979). Brassey's unmanned aircraft, London: Brassey's Publishers Limited.

Robinson, C. (1997, April). Submarine's aerial vehicle verifies tactical intelligence. Signal, 51, 18.

Shaker, S., and Wise, A. (1988). War without men – robots on the future battlefield, McLean, Virginia: Pergamon-Brassey's International Defense Publishers, Inc.

Schoomaker, P. (1998) Special operations: the way ahead. Defense issues, 13, 10. Retrieved September 14, 2000 from the world wide web: http://www.defenselink.mil/speeches/1998/di1310.html

Sullivan, J., Brouillette, G., Joles, J. (1998, July). 1998 Army after next unmanned aerial vehicle studies. Command Sponsored Research Report, United States Military Academy, West Point, New York.

Taylor, J. (1961). Jane's all the world's aircraft 1961-1962, London: Jane's All the World's Aircraft Publishing Company, Limited.

Taylor, J. (1981). Jane's all the world's aircraft 1981-1982. London: Jane's Publishing Company, Limited.

Teledyne Ryan Aeronautical Corporation. (2000). Teledyne Ryan Aeronautical Corporation home page. Retrieved February 28, 2000 from the world wide web: http://www.tdyryan.com/07_History/History.html

United States Air Force. (2000). Global Hawk UAV. Retrieved August 3, 2000 from the world wide web: http://www.af.mil/photos/Feb1999/globalhawk.html

United States Joint Chiefs of Staff. (1996, July 10). JP 3-53: Doctrine for joint psychological operations. Washington, D.C.: United States Joint Chiefs of Staff.

United States Navy. (2000b). Unmanned aerial vehicles PMA 263 home page. Retreived August 3, 2000 from the world wide web. http://uav.navair.navy.mil/vtuav/photogra.htm

United States Special Operations Command. (1999a). United States Special Operations Command history, third edition. McDill AFB, Florida: United States Special Operations Command.

Waddington, S. (1999, August). Camcopter hunts for landmines. Unmanned vehicles, 8-1.

Waddington, S. (2000, May). Integrating the assets: the U.K. Ministry of Defense has chosen the winners of its 12 month assessment phase for sender TUAV programme. Unmanned vehicles, 5-2.

Wagner, W. (1982). Lightening bugs and other reconnaissance drones. Fallbrook, California: Aero Publishers.

Watson, G. (1999, July). Army XXI-air cavalry operations: Examining manned and unmanned team operations, Army Aviation, 15-17.

Waugh, S. (1999). VTUAV concept of employment (CONOPS). Retrieved August 23, 2000 from the world wide web: http://uav.navair.navy.mil/vtuav/files/Conops.html

Wilson, G. (2000, March 8). Senate chairman pushes unmanned warfare. Retrieved August 24, 2000 from the world wide web: http://www.adroitnet.com/uavforum/news.htm

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BIBLIOGRAPHY

AAI Corporation. (1999, December 30). Shadow 200, the little airplane that did. Retrieved August 23, 2000 from the world wide web: http://shadow200.com/)

AAI Corporation. (2000). Shadow 200. Retrieved August 3, 2000 from the world wide web: http//www.aaicorp.com/defense/uav/index

Adroit Systems Incorporated. (2000). UAV forum: librarian's desk (frequently asked questions). Retreived August 28, 2000 from the world wide web: http://www.adroitnet.com/uavforum/faq.htm

Aerospace Industries Association of America. (1990). Aerospace facts and figures 1989-1990. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1991). Aerospace facts and figures 1990-1991. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1992). Aerospace facts and figures 1991-1992. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1993). Aerospace facts and figures 1992-1993. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1994). Aerospace facts and figures 1993-1994. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1995). Aerospace facts and figures 1994-1995. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1996). Aerospace facts and figures 1995-1996. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1997). Aerospace facts and figures 1996-1997. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1998). Aerospace facts and figures 1997-1998. Washington, D.C.: Aerospace Industries Association of America.

Aerospace Industries Association of America. (1999). Aerospace facts and figures 1998-1999. Washington, D.C.: Aerospace Industries Association of America.

Alfke, P. (2000). Integrated circuits. Technology review and update 2000, session #5. Monterey, California: Naval Postgraduate School.

American Institute of Engineers and Society for Computer Simulation International. Proceedings of the second annual conference on unmanned aerial vehicles. (1999, September 23-24). Washington, D.C.: American Institute of Engineers and Society for Computer Simulation International.

Anderson, J. (1985). Introduction to flight. New York: McGraw-Hill.

Armitage, M. (1988). Brassey's unmanned aircraft. McLean, Virginia: Brassey's Defense Publishers.

Arquilla, J. (1996). From Troy to Entebbe: special operations in ancient and modern times. Lanham, Maryland: University Press of America.

Arquilla, J. and Ronfeldt, D. (1997). In Athena's camp: preparing for conflict in the information age. Santa Monica, California, RAND.

Assistant Secretary of Defense for Special Operations and Low Intensity Conflict. (1998). United States special operations forces posture statement 1998. Retrieved August 30, 2000 from the world wide web: http://www.defenselink.mil/pubs/sof/sof1998/index.html.

Assistant Secretary of Defense for Special Operations and Low Intensity Conflict. (2000). United States special operations forces posture statement 2000. Retrieved August 30, 2000 from the world wide web: http://defenselink.mil/pubs/sof/index.html

Aviation Week and Space Technology and Association for Unmanned Vehicle Systems International. 1997-98 international guide to unmanned vehicles: air land sea. (1997). New York: McGraw-Hill Companies.

Ball, R. (1985), The fundamentals of aircraft combat survivability analysis and design. New York: American Institute of Aeronautics and Astronautics.

Ball, R. (2000). Aircraft combat survivability analysis and design. Retrieved August 27, 2000 from the world wide web: http://www.aircraft-survivability.com/Survivability_course.html

Berenji, H. (2000). Computational intellegence. Technology review and update 2000, session #8._Monterey, California: Naval Postgraduate School.

Boeing Corporation. (2000). Boeing AH-64 Apache home page. Retrieved 3 July 2000 from the world wide web: http://www.voodoo.cz/ah64lgal12.html

Bowden, M. (1999). Blackhawk down. New York: Atlantic Monthly Print.

Boyd, A. (2000). Military satellite communications technology. Technology review and update 2000, session #6. Monterey, California: Naval Postgraduate School.

Bowman, T. (2000, March 22). Cost of war: A new accounting strategy. Baltimore Sun.

Cebrowski, A. (1999, August 10). Network-centric warfare. Lecture presented to the student body, Naval Postgraduate School, Monterey, California.

Cheney, R. (1991, July). Conduct of the Persian Gulf conflict: an interim report. Washington, D.C.: U.S. Congress.

Clark, A.C. (1968). 2001 - a space odyssey. New York: New American Library.

Congressional Budget Office. (1998, September). Options for enhancing the Department of Defense's unmanned aerial vehicle programs. Retrieved August 14 from the world wide web: http://www.fas.org/man/congress/1998/cbo-uav3.htm

Congressional Budget Office. (2000, March). Budget options for national defense. Retrieved August 23, 2000 from the world wide web: http://www.cbo.gov/showdoc.cfm?index=1873&sequence=3&from=5

Cook, S. (2000). Task Force Hunter for NATO Operation Allied Force over Kosovo. Presented at Shephard's Unmanned Vehicles 2000 conference and exhibition, London, United Kingdom.

Dahl, M. (2000, July). U.S. Marine Corps tactical unmanned vehicle concept of employment. Presentation at Shephard's Unmanned Vehicles 2000 conference, London, United Kingdom.

Defense Advanced Research Projects Agency. (1997, August 7). Micro air vehicles: Toward a new dimension in flight. Retrieved August 28, 2000 from the world wide web: http://www.darpa.mil/tto/programs/mav_auvsi.html

Defense Airborne Reconnaissance Office. UAV annual report FY 1995. (1995). Washington, D.C.:. Defense Airborne Reconnaissance Office.

Defense Airborne Reconnaissance Office. UAV annual report FY 1996. (1996). Washington, D.C.: Defense Airborne Reconnaissance Office.

Defense Airborne Reconnaissance Office. UAV annual report FY 1997. (1996). Washington, D.C.: Defense Airborne Reconnaissance Office.

Defense Mapping Agency. (1993, January 7). Flight information publication: General planning. Washington. D.C.: Defense Mapping Agency.

Devine, W. O. [MicroSTAR Business Development Manager] (1999, 29-30 November). MicroSTAR micro air vehicle: A revolution in soldier sensing. Presented at Strategic Management Information (SMi) UAV and UCAV payloads conference, London, United Kingdom.

Eardley, D., and Katz, J. (1997, September). Small scale propulsion – fly on the wall, cockroach in the corner, rat in the basement, bird in the sky. McLean,Virginia: The MITRE Corporation.

Fahey, J. (1946). U.S. Army aircraft (heavier than air) 1908-1946. New York: Murray-Hill.

Fardink, P. (2000, February 29). Amazing men. Army aviation, 49, 26.

Federation of American Scientists. (2000). BGM-109 Tomahawk. Retrieved August 3, 2000 from the world wide web: http://www.fas.org/man/dod-101/sys/smart/bgm-109.htm

Friedman, S. (2000). Inflation calculator. Retrieved August 21, 2000 from the world wide web: http://www.westegg.com/inflation/infl.cgi

Gabriel, R. (1984). Operation peace for Galilee: the Israeli-PLO war in Lebanon. New York, Hill and Wang.

Government Accounting Office. (1997a, June 12). Operation Desert Storm: Evaluation of the air campaign. Retrieved August 14, 2000 from the world wide web: http://www.fas.org/man/gao/nsiad97134/app_03.htm

Government Accounting Office. (1997b, April 9). Unmanned aerial vehicles: DOD's acquisition efforts. Washington D.C.: U.S. Government Printing Office.

Harkin, J. (2000). Military aircraft archive. Retrieved August 3, 2000 from the world wide web: http://www.militaryaviation.com

Harvey, D. S. (2000, August – September). Eye on the Americas. Defense helicopter, 19, 4.

Heath, G. (1999, June). Simulation analysis of unmanned aerial vehicles (UAV). Master's Thesis, Naval Postgraduate School, Monterey, California.

Herrick, K. (1999). World markets for military, civil, and commercial unmanned aerial vehicle systems. Mountain View, California: Frost and Sullivan.

Holeman, D. (1999, July). Black Widow micro air vehicle mission and system requirements analysis. Monrovia, California: Aerovironment, Inc.

Howard, S. (1996, February). Special operations forces and unmanned aerial vehicles: sooner or later. Command Sponsored Research Report, Air University Press, Maxwell AFB, Alabama.

Joint Chiefs of Staff. (1995, May). Doctrine for command control communications computer (C4) systems support to joint operations: Joint pub 6-0. Washington, D.C.: U.S. Government Printing Office.

Joint Chiefs of Staff. (2000, June). Joint Vision 2020. Washington, D.C.: U.S. Government Printing Office.

Jones, R. (1999, June). The design challenge of high altitude long endurance (HALE) unmanned aircraft. The Aeronautical Journal, 103, 1024, 273-280.

Kaminski, P. (1997, March 19). Fielding equipment second to none. Washington, D.C.: Acquisition and Technology Subcommittee, Senate Arms Services Committee. Retrieved May 9, 2000 from the world wide web: http://www.defenselink.mil/speeches/1997/t19970319-kaminski.html

Koppel, T. (Anchorman). (2000, April 26). ABC News nightline: Pilot down; [rescue of Hammer 3-4, pilot who went down in Yugoslavia a year ago]. New York: American Broadcasting Corporation.

Larson, E.V. (1996). Casualties and consensus: The historical role of casualties in domestic support for U.S. military operations. Santa Monica, California: RAND.

Longino, D. (1994, December). Role of unmanned aerial vehicles in future armed conflict scenarios. Command Sponsored Research Report, Air University Press, Maxwell AFB, Alabama.

Majewski, S. (1999, March). Naval command and control for future UAVs. Master's Thesis, Naval Postgraduate School, Monterey, California.

McRaven, W. (1995). Spec ops: case studies in special operations warfare theory and practice. Novato, California: Presidio Press.

Mayne, R. and Margolis, R. (1984). Introduction to engineering. New York: McGraw-Hill.

Munson, K. (1988). World unmanned aircraft. London: Jane's Publishing Company Limited.

Munsan, K. (1998). Jane's unmanned aerial vehicles and targets. Coulsdon, United Kingdom: Jane's Information Group Limited.

National Aeronautics and Space Administration. (2000). Wallops Flight Facility home page. Retrieved February 28, 2000 from the world wide web: http://uav.wff.nasa.gov/

Office of the Assistant Secretary of Defense (Special Operations and Low Intensity Conflict). (1997). United States special operations forces posture statement 1998. Washington D.C.: Office of the Assistant Secretary of Defense (Special Operations and Low Intensity Conflict).

Papadales, B. (1999, December). Electronic database of current UAV descriptions. USA: MIRADA Inc.

Peterson, A. (1999, September 23). Airborne manned/unmanned system technology (AMUST) program update. Presented at the second annual American Institute of Engineers and Society for Computer Simulation International's conference on unmanned aerial vehicles, Washington, DC.

Pioneer UAV Incorporated. (2000). Pioneer UAV home page. Retrieved 8 May 2000 from the world wide web: http://www.puav.com/

Powers, J. (2000). Electro-optical and infrared systems. Technology review and update 2000, session #2. Monterey, California: Naval Postgraduate School.

Reed, A. (1979). Brassey's unmanned aircraft. London: Brassey's Publishers Limited.

Robinson, C. (1997, April). Submarine's aerial vehicle verifies tactical intelligence. Signal, 51, 18.

Shaker, S., and Wise, A. (1988). War without men – robots on the future battlefield. McLean, Virginia: Pergamon-Brassey's International Defense Publishers, Inc.

Sheffield, R. (1992, May/Jun). An analysis tool for UAV effectiveness evaluation. Vertiflite, 38, 31-37.

Shephard Press. (1998). Shephard's unmanned vehicles handbook 1999. Burnham, United Kingdom: The Shephard Press.

Shephard Press. (1999). Shephard's unmanned vehicles handbook 2000. Burnham, United Kingdom: The Shephard Press.

Schoomaker, P. (1998) Special operations: the way ahead. Defense issues, 13, 10. Retrieved September 14, 2000 from the world wide web: http://www.defenselink.mil/speeches/1998/di1310.html

Stuart, J. (2000). Satellite communication technologies and trends. Technology review and update 2000, session #7. Monterey, California: Naval Postgraduate School.

Sullivan, J., Brouillette, G., Joles, J. (1998, July). 1998 army after next unmanned aerial vehicle studies. Command Sponsored Research Report, United States Military Academy, West Point, New York.

Taylor, J. (1961). Jane's all the world's aircraft 1961-1962, London: Jane's All the World's Aircraft Publishing Company, Limited.

Taylor, J. (1981). Jane's all the world's aircraft 1981-1982. London: Jane's Publishing Company, Limited.

Teledyne Ryan Aeronautical Corporation. (2000). Teledyne Ryan Aeronautical Corporation home page. Retrieved February 28, 2000 from the world wide web: http://www.tdyryan.com/

Thom, M. (1997, June 13). UAVs for the operational commander: beyond reconnaissance, surveilance and target acquistion (RSTA). Command Sponsored Research Report, Naval War College, Newport, Rhode Island.

United States Airforce. (2000). Global Hawk UAV. Retrieved August 3, 2000 from the world wide web: http://www.af.mil/photos/Feb1999/globalhawk.html

United States Army Training and Doctrine Command System Manager – Unmanned Aerial Vehicles. (2000). TRADOC System Manager – UAV home page. Retrieved May 8, 2000 from the world wide web: http://huachuca-dcd.army.mil/tsmuav/tsm-uav.htm#UAV Programs:

United States Army Intelligence Center. (2000, March 22). Tactical unmanned aerial vehicle (TUAV) concept of operations (CONOPS): draft version 1.0. Fort Huachuca, Arizona: United States Army Intelligence Center.

United States Department of Defense. (1997, September 3). Memorandum for correspondents number 154-M. Retrieved August 14, 2000 from the world wide web: http://www.defenselink.mil/news/Sep1997.html

United States Department of Defense. (2000). Annual defense review 2000. Washington, D.C.: United States Department of Defense.

United States Joint Chiefs of Staff. (2000, April 7). JP 3-5: Joint doctrine for electronic warfare. Washington, D.C.: United States Joint Chiefs of Staff.

United States Joint Chiefs of Staff. (1996, July 10). JP 3-53: Doctrine for joint psychological operations. Washington, D.C.: United States Joint Chiefs of Staff.

United States Navy. (2000a). The Navy fact file. Retrieved August 24, 2000 from the world wide web: http://www.chinfo.navy.mil/navpalib/factfile/ffiletop.html

United States Navy. (2000b). Unmanned aerial vehicles PMA 263 home page. Retrieved August 3, 2000 from the world wide web: http://uav.navair.navy.mil/vtuav/photogra.htm

United States Special Operations Command. (1996, January). SOF vision 2020. McDill AFB, Florida: United States Special Operations Command.

United States Special Operations Command. (1999a). United States Special Operations Command history, third edition. McDill AFB, Florida: United States Special Operations Command.

United States Special Operations Command. (1999b). USSOCOM PUB 1: Special operations in peace and war. McDill AFB, Florida: United States Special Operations Command.

Waddington, S. (1999, August). Camcopter hunts for landmines. Unmanned vehicles, 8-1.

Waddington, S. (2000, May). Integrating the assets: the U.K. Ministry of Defense has chosen the winners of its 12 month assessment phase for sender TUAV programme. Unmanned vehicles, 5-2.

Wagner, W. (1982). Lightening bugs and other reconnaissance drones. Fallbrook, California: Aero Publishers.

Watson, G. (1999, July). Army XXI-air cavalry operations: Examining manned and unmanned team operations, Army aviation, 15-17.

Waugh, S. (1999). VTUAV concept of employment (CONOPS). Retrieved August 23, 2000 from the world wide web: http://uav.navair.navy.mil/vtuav/files/Conops.html

White, R. (2000). Micro electro-mechanical systems (MEMS). Technology review and update 2000 session #3. Monterey, California: Naval Postgraduate School.

Wilson, G. (2000, March 8). Senate chairman pushes unmanned warfare. Retrieved August 24, 2000 from the world wide web: http://www.adroitnet.com/uavforum/news.htm

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