THE QUALITY OF QUANTITY: Mini-UAVS AS AN ALTERNATIVE UAV ACQUISITION STRATEGY AT THE ARMY BRIGADE LEVEL

A Monograph
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Abstract

THE QUALITY OF QUANTITY: Mini-UAVS AS AN ALTERNATIVE UAV ACQUISITION STRATEGY AT THE ARMY BRIGADE LEVEL by MAJOR Shawn C. Weed, USA, 60 pages.

The U.S. Army, after years of false starts and unfilled promises, is about to make good on its commitment to field an unmanned aerial vehicle system at the maneuver brigade level. Called the Shadow 200 tactical UAV (TUAV), it promises to dramatically enhance the reconnaissance, surveillance, target acquisition (RSTA) capabilities of those at the tip of the proverbial spear by providing them the ability to gather information on enemy formations with a limited risk to men and materiel. For approximately $3million, this program will put three aircraft, and associated support systems, in the hands of each brigade to fulfill those dull, dirty, and dangerous reconnaissance tasks currently challenging the brigade's reconnaissance and surveillance architecture. As compelling as this capability promises to be, the question remains as to whether the Shadow TUAV is the right tool for the wrong job.

This monograph asks should the U.S. Army alter its current UAV acquisition strategy for maneuver brigades from one in which limited numbers of high capability systems are acquired, in favor of another that fields a large quantity of less capable mini-UAVs? A UAV system built around mini-UAVs, essentially smaller, less capable, but much cheaper versions of the more conventional aircraft, has inherent strengths that support its adoption at the brigade level. As a system, the sheer quantity of deployed collection assets, inherent design austerity, and flexible organization give them a significant advantage in fulfilling the requirements of a brigade level UAV system than their more conventional UAV cousins. They will allow a future prospective brigade commander to see more, with more, at less overall cost. To support this conclusion, this monograph will analyze the strengths and weaknesses of both the current UAV acquisition plan and a proposed mini-UAV strategy, compare the two systems in relation to the design parameters established for a brigade level UAV, then marry the results of this assessment to action in the form of a recommended alternative UAV acquisition strategy.

This monograph recommends the Army adopt a mini-UAV system at the maneuver brigade that leverages the intrinsic advantages mini- UAVs provide in terms of employability, functionality and costs over the current Shadow TUAV strategy. While far from a panacea, this suggested course offers a feasible, acceptable, and suitable alternative to the Army's current UAV acquisition strategy. This is critically important now as weaknesses in begin to appear in the plan to acquire the Shadow 200 TUAV. An alternative plan, based on the quality of quantity associated with mini- UAVs, may provide just the right solution to the problem of providing UAV support to the maneuver forces at the lowest tactical echelons. As this monograph will show, in terms of meeting the specific requirements of the maneuver brigade, this alternative strategy has a measure of effectiveness beyond which the current plan is capable of attaining.

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CHAPTER I - THE QUALITY OF QUANTITY

> The ability to move information rapidly, and to process it, will likely change the way we command military operations.[1]
>
> Training and Doctrine Command PAM 525-5
> *Force XXI Operations*

For a generation, the promise of an unmanned aerial vehicle (UAV) in the hands of those war fighters at the point of the proverbial spear has been akin to a desert mirage – a refuge tantalizingly out of reach, which seems to vanish as you approach it. During this timeframe, the intelligence community promised its combat arms brethren a cohesive UAV system was just over the horizon, only to have to renege on that pledge time, and, time again. Shifting priorities, force reorganizations, and shrinking budgets all contributed to sporadic progress and frustrating delays. Despite the rounds of disappointment, the potential of the UAV remained compelling. It promised the tactical commander a simple to use, low risk asset that would allow him to identify, track, and target prospective enemy formations beyond the line of sight of his deployed forces. Despite the consensus on the UAV's functional value, as the time drew closer for actual deployment, the reality of the UAV seemed to slip further and further into the future.

Slowly, the intelligence community is making good on their promise. As of 1999, the Army has officially committed to fielding the tactical unmanned aerial vehicle (TUAV), known as the Shadow 200, at the maneuver brigade level. At a typical unit, this will include three Shadow aircraft, a ground control station (GCS), a remote ground data terminal (GDT), an aerial vehicle transport vehicle (AVTV), and a launcher/recovery system (LRS). Additionally, approximately 6-8 soldiers will deploy to manage the specific functions of the system to include launching, flying, tasking, and recovering the aircraft. The

[1] U.S. Training and Doctrine Command (TRADOC) Pamphlet 525-5, *FORCE XXI Operations* (Fort Monroe, VA: U.S. Army TRADOC, 10 April 1994), 2.

Shadow's purpose is to provide brigade commanders a flexible and responsive collection asset in order to satisfy organic intelligence requirements.

The fundamental question this monograph will examine is whether this is the wrong tool for the right job. The Shadow 200 UAV is a tremendous asset with a price tag to match. At approximately $3 million dollars a system, it has the ability to fly at 200kph, image targets both day and night with integrated global positioning system (GPS) data, relay those images to a ground control station up to 150km away for immediate action or further analysis, and remain aloft for up to 6 hours at a time.[2] Alternatively, a mini-UAV system can replicate most of the Shadow 200's functionality at a fraction of the cost. A typical platform, such as the EXDRONE which saw use during Operation Desert Storm, costs less than $10,000 per unit, can fly at 160kph, remain aloft for four hours, integrate GPS data, image targets in low-light conditions, and transmit that data back to a GCS up to 75km away.[3] Additionally, its sustainment footprint is dramatically less than the Shadow's. It requires only two operators, can be controlled via a ubiquitous laptop computer and a proprietary antenna, and can land even in the absence of an improved runway. Therefore, while the Shadow's per unit capabilities are superior, the synergistic effect of fielding numerous less effective mini-UAVs eclipses the efficacy of the current Shadow acquisition plan. This is especially pertinent in today's tactical army where we have a greater reliance on intelligence in order to effectively conduct full spectrum operations, operate in a fiscally constrained budgetary environment, and finally, face a divergent threat continuum that evades conventional modeling.

This monograph demonstrates that the U.S. Army should alter its current unmanned aerial vehicle (UAV) acquisition strategy for maneuver brigades, from one in which limited numbers of high capability systems are acquired, to one that fields a large quantity of less capable mini-UAVs for three key reasons:

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[2] Adroit Systems Inc. "The Shadow 200 UAV," Internet, http://www.uavforum.net/vehicles/production/shadow200.htm. accessed 03 OCT 01.
[3] BAI Aerosystems, Inc. "The EXDRONE – BQM147A," Internet, http://www.baiaerosystems.com/exdrone.html. accessed 03 OCT 01.

employability, functionality, and cost. This monograph explores these issues in detail and makes recommendations based on the analysis of the three factors listed above.

A SPECTRUM OF SYSTEMS AND CAPABILITIES

The development of unmanned aerial vehicles as a reconnaissance tool actually predates the Wright Brothers' landmark 1903 airplane flight at Kitty Hawk, NC by a generation, and has expanded steadily to encapsulate a wide variety of platforms and capabilities today. In 1887, Englishman Douglas Archibald experimented with attaching a camera to a Kite in order to take pictures over obstructions as a military solution to the timeless problem of trying to see what the enemy is doing.[4] The expansion of this concept accelerated in parallel with the development of the airplane in the early portion of the 20^{th} Century. During World War I, UAVs, as the pilotless aircraft we associate them with today, first saw battlefield employment. The English, French, Americans, and Germans all experimented with, and fielded, an array of unmanned aerial systems during the war aimed at accomplishing such difficult and risky battlefield tasks as reconnaissance, ground attack, and precision bombing with varying degrees of success.[5]

UAV development expanded exponentially over the next three-quarters of a century. Currently, there are over 100 recognized manufacturers of UAVs internationally, fielding over 500 different specific models, fulfilling a plethora of both civil and defense functions.[6] Those models vary widely in cost, physical size, and performance capabilities. At the high end is Global Hawk, the state of the art, long-range endurance UAV from Teledyne, Inc., currently fielded by the Department of Defense (DoD). It has a wingspan of 116 feet, carries a payload of over a ton, can remain aloft for up to 40 hours, and

[4] Park Jan-Wan. "The History of UAVs," Internet, http://www.uavcenter.com/english/e02general/e1history/ehistory.htm. accessed 03 NOV 01
[5] Armitage, Sir Michael. *Unmanned Aircraft (Brassey's Air Power: Aircraft, Weapon Systems and Technology Series, Volume 3).* London: Brassey's Defence Publishers, 1988. 1-3

[6] AW&ST and AUVI. *1999-2000 International Guide to Unmanned Vehicles*. Washington: The McGraw Hill Companies, 2000. 3-5.

cruises at 350 knots.[7] At a cost of approximately $14 million apiece the Global Hawk is a strategic tool that satisfies intelligence requirements associated with the formation and implementation of national policy.

At the opposite end of the scale are micro aerial vehicles (MAVs) defined as those UAVs fewer than 15 centimeters (six inches) in diameter.[8] These systems are tiny in all regards, to include price. With a payload defined in terms of grams, the lifting capabilities of MAVs are microscopic when compared to the tons used to describe the surveillance packages of larger, manned aircraft. Typical of this genre is AeroVironment, Inc.'s Black Widow, under contract from the Defense Advanced Research Projects Agency (DARPA). It measures a scant six inches across, is powered by a tiny electric motor fueled by two small AA batteries, is made of balsa wood and can dash about at a nimble 35 knots for 16 minutes. Its small size belies its capabilities. It has an integrated global positioning satellite (GPS) navigational system, color video camera with tilt, pan, and zoom, and can be controlled from a laptop computer. Where the Global Hawk functions in support of strategic requirements, the Black Widow's function is to fulfill the intelligence requirements of the lowest of Army tactical echelons, the fire team.

In an effort to marry the wide disparity of UAV types to military functions, the Department of Defense (DoD) delineates UAVs into five distinct categories based on range and military uses. Endurance UAVs (E-UAVs), such as the Global Hawk, are those designed for extremely long range (beyond 3,000km), and are capable of sustained operations in excess of 24 hours. Medium range UAVs (MR-UAVs) are those designed to fly at both high speed and altitude to provide near real time imagery of specific targets for a limited time. A recent addition to the UAV lexicon is the vertical take off and landing UAV (VTOL-UAV). Similar to their manned brethren, these systems take off vertically, then transition to level flight and perform UAV functions similar to conventional winged UAVs. This category is generally associated with maritime-based airframes; however, recent developments in hovering UAVs for operations in close and urban terrain also fall into this category. Close range UAVs

[7] Ibid, 56.

(CR-UAVs) are those small systems whose purpose is to fulfill the UAV requirements of the lowest tactical levels. Like the Black Widow, systems typical of this category are designed to be inexpensive, simple to use and easy to recover.[9]

Lastly, the short range UAV (SR-UAV) encompasses those platforms designed to support Army divisions and separate BDEs. Systems in this category are generally more robust and have more extensive capabilities than the lower echelon CR-UAVs, but much less performance than the E-UAVs.[10] The Shadow 200 UAV, selected for deployment at the Army maneuver brigade level, is typical of the SR-UAV category. Mini-UAVs, also known commercially as man-portable UAVs, are not part of DoD's taxonomy, but are characterized as those UAVs larger than MAVs, but smaller than six foot in diameter. It is these types of systems, with their associated smaller size, price, and function set, which will be compared to the Shadow 200 UAV to illustrate the fundamental difference quality versus quantity plays in regards to UAV functionality, acceptability and suitability at the Army maneuver brigade level.

BRIGADE UAV FUNCTIONS – AN OVERVIEW

To understand the seemingly simple argument of whether more is better in regards to UAVs at the maneuver brigade level, it is first necessary to identify what functions they are required to fulfill. From a broad perspective, UAVs are designed to accomplish those reconnaissance and surveillance tasks labeled as, "the dull, the dirty, and the dangerous."[11] In simpler terms, they are to satisfy those battlefield requirements that might dull the foot soldier due to their repetitive and monotonous nature. Monitoring a zone of separation, for example, might require dozens of sentries observing from fixed and roving positions day after day resulting in possible complacency. A UAV, however, with its larger observation

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[8] COL Michael S. Francis. "Micro Air Vehicles – Towards a New Dimension in Flight," Internet, http://www.darpa.mil/tto/MAV/mav_auvsi.html. accessed 04 NOV 01

[9] U.S. Department of Defense. *JP 3-55.1, Joint Tactics, Techniques, and Procedures for Unmanned Aerial Vehicles, 27 Aug 97*. Washington, D.C.: Government Printing Office, 1997. I-2.

[10] Ibid, 3.

footprint, greater speed, and array of sensors, can cover an order of magnitude more space in a given time with arguably more reliable results. Additionally, UAVs, and their inherent lack of human physical limitations, have the ability to perform reconnaissance missions in "dirty" areas suspected of contamination by nuclear, biological or chemical agents. Exposure to a potentially damaging substance does not degrade the platform's capabilities. Operations would continue in the contaminated area without the requisite wear of restrictive protective garments that typically limit soldier performance. The same is true of performing dangerous missions. The lack of an actual human on the asset itself allows the UAV to move into enemy territory and observe targets without putting soldiers at risk.

Tactically, DoD has designed maneuver brigade level SR-UAVs to accomplish a specific set of battlefield tasks. Chief among them is to provide imagery intelligence, day or night, within the brigade's area of operations and area of interest. The primary tool for this is the use of a color video camera with an integrated Global Positioning System (GPS) which records the image and relays it back to ground station for analysis and action. Additionally, the performance parameters for the brigade level UAV also require an ability to relay communications. This function has two purposes: first, to extend the range of UAVs operating in multiple airframe configuration; and secondly, to provide a radio retransmission capability for the ground force in close terrain where ground based radio communications are restricted. Directly related to its use as a communications platform is its potential employment as a signals intelligence collector. Designers have harnessed its ability to fly above most obstructions, loiter for hours on end, and relay that information to a ground station, to create an ideal tool for listening in on the enemy. Lastly, it can integrate the above capabilities to provide, in concert with other intelligence collectors, time critical targeting (TCT). Essentially, the UAV, either self-cued or cued by another sensor, acquires a target visually and relays that information to a fire support mechanism for lethal or non-lethal engagement.[12]

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[11] U.S. Department of Defense. *Unmanned Aerial Vehicles Roadmap, 2000-2025. Apr 2001*. Washington, D.C.: Office of the Secretary of Defense (Acquisition, Technology, and Logistics), 2001. ii.
[12] *Unmanned Aerial Vehicles Roadmap, 15-17.*

To accomplish these functions a UAV system is more than a single airplane boring a hole through the sky. It is a suite of interconnected components that work together to accomplish the system's overall purpose. At the maneuver brigade level, there are six key components associated with a typical UAV system.[13] The first and foremost is the airplane itself. The airplane includes the airborne part of the system and its associated avionics to include propulsion, power and flight controls. Its primary function is to move the payload to where it can accomplish its assigned task. The second component, the GCS, controls the vehicle in flight and is the primary tool for planning the UAV's associated mission. This component allows the user to plan the details of an operation, control the airplane's flight, and down link intelligence. The airplane's payload is the third key UAV system component and defines what tasks the UAV can or cannot accomplish. Physically located on the aircraft, payloads vary in size and capability based on the requirements stated above. The fourth component is the launch and recovery system, or how the airplane gets into, and out of, the air. The fifth component is the data link. This electronic tether controls the airborne platform from the ground and translates commands into action. It also moves information from the payload back to the ground control station. Lastly, the ground support equipment represents those assets required to fuel, fix and arm the complete package, and ensure its mission readiness.[14]

Both the Shadow 200 UAV systems slated for fielding at the maneuver brigade level, and the proposed alternative mini-UAV based system, incorporate the same types of components listed above. Their implementation, however, is radically different, and their capabilities are accordingly dissimilar. This monograph details maneuver brigade level employability,

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[13] Paul Fahlstrom and Dr.Thomas Gleason. *Introduction to UAV Systems. 2nd ed*. Columbia, MD: UAV Systems, Inc., 1998. 21-29.
[14] Park Jan-Wan. "Overview of a UAV System," Internet, http://www.uavcenter.com/english/e02general/e2concept/econcept.htm. accessed 04 NOV 01

functionality, and cost considerations for the Shadow 200 and three mini-UAVs in order to develop a baseline of factors to determine the suitability of each system to fulfill the brigade level UAV mission. Disparities in how these two strategies accomplish the same maneuver brigade level functions lead to this monograph's conclusion that the US Army should alter its current UAV acquisition strategy for maneuver brigades from one in which limited numbers of high capability systems are acquired, in favor of another that fields a large quantity of less capable mini-UAVs.

CHAPTER II - THE SHADOW KNOWS: THE U.S. ARMY'S NEWEST UAV

> UAVs are likely to be crucial in achieving information superiority, particularly because they can collect information that in the past would have been difficult to collect without the risk of the lives of personnel.[15]
>
> *Options for Enhancing DoD's UAV Programs*
> Congressional Budget Office

With the approval of the appropriations bill funding the fielding of the Shadow 200 TUAV in late 1999, Congress, through the DoD, has given the Army its first accepted strategy for implementing UAVs at the maneuver brigade level in its history. The program, costing almost a half a billion dollars, directs the acquisition of 44 Shadow 200 aircraft by the year 2004, and will finally make good on the promise to give brigade commanders their own UAVs.[16] This program's future, however, is not set in stone. As with other UAV programs before it, the Shadow TUAV acquisition plan is subject to meeting stringent performance gates along the way. Failure to succeed during these operational trials could result in the modification of the existing plan or its dissolution altogether.[17] Currently, despite some initial technical problems during Summer 2001 testing which caused a delay in the production schedule, the plan is back on track with a decision to implement full rate production due in early 2003.[18]

The purpose of the Shadow 200 acquisition plan is essentially to provide brigade commanders a day and night reconnaissance, surveillance and target acquisition capability across a broad spectrum of battlefield conditions and environments. To fulfill this requirement, each brigade will receive three airplanes, two ground control stations, four remote video terminals, one portable ground station with

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[15]Congressional Budget Office. *Options for Enhancing the DoD's UAV Programs.* Washington: Congressional Budget Office, 1998. I-4.

[16]U.S. Government Accounting Office (GAO). *Questionable Basis for Revisions to Shadow 200 Acquisition Strategy*. *GAO/NSIAD-00-204.* Washington, D.C.: GAO, SEP 2000. 3.

[17]U.S. Government Accounting Office (GAO). *UAV-More Testing Needed Before Production of Short Range System. GAO/NSIAD-95-311*. Washington, D.C.: GAO, SEP 2000. 6.

associated data terminal, one personnel and equipment transport, and lastly, a launch and recovery vehicle. In addition, the system includes eight personnel to facilitate operations.[19] The cost of the total system at each brigade is approximately $3 million excluding manpower costs. Key to assessing actual costs, however, is identifying the total number of systems associated with the acquisition, the associated payload packages, and the design changes and alterations made from the originally approved design specifications. In the past, specifically with both the Pioneer and Hunter systems, design alterations and "feature creep" significantly altered the cost of the proposed system, dooming the program's long-term efficacy.[20]

SHADOW UAV – A SYSTEM OF SYSTEMS

The Shadow 200 UAV is the latest expression of a SR-UAV concept that traces its lineage back three decades, and gave birth to such novel, but eventually doomed, aircraft as Aquila, Pioneer, Hunter-UAV and Outrider. Produced by AAI Corporation, a subsidiary of United Industrial Corporation, the Shadow 200 is similar in appearance and design philosophy to the Pioneer UAV. It has a single fuselage with twin tail booms similar to the P-38 of World War II, and receives power from a 38 horsepower rotary gasoline engine. This is enough thrust to power the fully loaded 315 pound vehicle to a cruising speed of 75 knots at 15,000 feet for about 5 hours. Payload is estimated to be about 60 pounds, which would allow it when fully loaded to take off in up to 20 knot cross winds. Additionally, it is made of composite material which significantly lowers the radar cross section of the 13 foot wide, 11 foot long airplane.[21]

The aircraft launches and recovers through both conventional takeoff and landing techniques, or by using the included launch and recovery components. In conventional takeoff mode, the Shadow requires a moderately smooth runway approximately 100 meters in length to become airborne. It can

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[18] Adroit Systems Inc. "The Army suspends IOT&E for Shadow TUAV," Internet, http://www.uavforum.net/vehicles/production/shadow200.htm. accessed 03 OCT 01.
[19] Ibid. 6.
[20] U.S. Government Accounting Office (GAO). *UAVs – No More Hunter Systems Should Be Bought Until Problems are Fixed. GAO/NSIAD-95-52*. Washington, D.C.: GAO, MAR 1995. 4-6.

then land on the same field. In areas where the terrain, or time, does not permit a standard takeoff, there is one hydraulic launcher fielded per brigade. About the size of an M198 Howitzer, the launcher catapults the aircraft at an incline into the wind. Landing, however, is still dependent on the use of a smooth, albeit shorter runway, aided by an arresting hook to stop the aircraft. It also has as an optional automatic landing system that will use the data link to automatically land the aircraft.[22]

The heart of the Shadow 200 overall package is the Ground Control System (GCS), which fulfills three functions: mission planning, vehicle control, and payload utilization. Located in a converted communications shelter atop an M998 High Mobility Multi-purpose Wheeled Vehicle (HMMWV), the GCS incorporates three separate Unix based workstations to complete each of the three separate tasks. Two soldiers, a mission planner and aircraft operator, work in the shelter to supervise the execution of a mission. The hardware and software used in the GCS is the same proven effective with the Predator UAV. This helped to speed development time by using a control system with operational experience, as well as to ensure functionality and commonality for operators as they deploy to units across the UAV spectrum (i.e. brigade through corps level.)[23] A subcomponent of the GCS, is the Ground Data Terminal (GDT) that sends and receives digital information from the GCS to the aircraft. When the aircraft is at maximum altitude, approximately 15,000 feet, the GDT can command and control the aircraft and receive battlefield information from a distance of up to 124 miles.[24]

The battlefield information collected from the aircraft is relayed for analysis to one of four remote video terminals (RVTs). These systems provide forward deployed commanders, within the brigade combat team, near real time visualization of what the sensor is collecting. Utilization and placement of these terminals is up to the discretion of the brigade commander and how he feels they can best support his brigade's operations. Because the RVT have their own associated antennae, they can locate up to 40km away, dependent on terrain, from the GCS. The remote terminal itself is essentially a hardened

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[21] AW&ST and AUVSI, 24.

[22] AAI Corporation. "The Shadow 200 UAV," Internet, http://www.shadow200.com/ recovery.html . accessed 07 NOV 01.

PC with flat panel display, a proprietary receive-only antenna, and an analog to digital signal converter. While separate from the GCS, they cannot replace the functions of the GCS. They cannot, for example, receive data directly from the aircraft or give the aircraft instruction of any kind. The ground data terminal, essentially the signal component that relays information to, from the aircraft, and to the remote terminals, is part of the GCS. To facilitate seamless operations, the Shadow UAV system does incorporate a Portable Ground Control Station (PGCS) on a separate HMMWV that allows for temporary command and control of aircraft while the GCS is in transit. The PGCS allows for control of the aircraft and its payload, but does not include the mission planning features inherent with the full GCS.[25]

The whole purpose of having a UAV resides in what information it can collect for the deployed brigade commander. The Shadow 200 system leverages both proprietary and off the shelf technologies in order to provide an array of organic capabilities heretofore unavailable at brigade level. While actual payloads continue to emerge off the drawing board, the current strategy aims to include as the primary collection tool an advanced electro-optical, infrared enhanced, GPS integrated tilt, pan and, zoom camera. Similar to those found on traffic helicopters, the belly-mounted camera can identify and track enemy formations, both day and night. In foul weather, the Shadow has the capability to use hyper-spectral imagery to maintain surveillance on a key target. Additionally, when a target is difficult to identify because of topographic anomalies, target camouflage, or too large an area to cover, one prototype package includes a Synthetic Aperture Radar (SAR) and Moving Target Indicator (MTI) with similar, albeit with a reduced coverage area, functionality as the Joint Surveillance and Target Acquisition Radar System (JSTARS). If fielded, it would allow a single UAV to identify a moving column of suspected vehicles, then cue itself to further refine the nature of the threat.[26]

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[23] AAI Corporation. "The Shadow 200 UAV," Internet, http://www.shadow200.com/ groundcontrol.html . accessed 07 NOV 01.

[24] AW&ST and AUVSI, 24.

[25] AAI Corporation. "The Shadow 200 UAV," Internet, http://www.shadow200.com/ groundcontrol.html . accessed 07 NOV 01.

[26] AAI Corporation. "The Shadow 200 UAV," Internet, http://www.shadow200.com/ payload.html . accessed 07 NOV 01.

The Shadow also has two additional key components to help it fulfill its role as a reconnaissance, surveillance, and target acquisition (RSTA) platform. The first is the ability to mark targets for engagement by fire support systems. The Shadow incorporates both a laser range finder and a laser designation capability to either accurately report the location of a prospective threat on the ground, or paint the target for engagement by precision guided munitions (PGM). To facilitate this process, the Shadow 200 also incorporate an advanced communications package that allows for both long range communications to the GCS and relay of ground communications both voice and digital. The benefit is twofold; first, it allows multiple UAVs to relay for each other thus extending their operational range; and secondly, it allows the UAV to relay ground-based communications to ensure uninterrupted communications in rugged terrain.[27]

SHADOW UAV – SYSTEMS STRENGTHS

If implemented as designed, the Shadow UAV acquisition plan will bring with it a host of capabilities that will significantly improve not just intelligence functions at the brigade, but also the functionality of the maneuver brigade as a whole. The key strengths of the current strategy that predicate this enhancement are its extensive payload versatility, overall system range, robust component construction, and operationally tested command and control system.

The multitude of payload configurations is the cornerstone of the potential of the Shadow UAV system. The payload capacity of 60 pounds in standard configuration and up to 100 pounds with some slight modifications to the airframe, allow the Shadow 200 to field a suite of sensors that both compliment and supplement each other. Particularly valuable is the ability to self-cue. Current UAV doctrine describes cuing a UAV to move to a threat location based on information collected from another external sensor.[28] Typically, this could be either a MTI from a JSTARS platform or a signals intercept from a ground, or air, based signals intercept (SIGINT) collector. The problem with this

[27] Ibid.
[28] JP 3-55.1, II-3.

arrangement is the coordination it takes to effect the cross cueing. JSTARS, for example is a national level asset that, because of its limited numbers, may or may not be deployed where the brigade is. Additionally, even if it is within the same theater as the deployed brigade, it may not be flying at the time required. The Shadow, however, alleviates these issues by incorporating both capabilities within one platform.

In addition to the payloads described above, the relatively generous payload capacity lends itself to modularity with other existing UAV payloads, both foreign and domestic. For example, Shadow could use previously developed components from cancelled UAV programs such as Pioneer, Hunter, and Outrider with minimal reconfiguration. One key existing capability that is promising is the use of the SIGINT package formally used on the Hunter.[29] This would give the brigade commander an added capability to supplement his ground based SIGINT assets with an aerial platform, unfettered by terrain obstructions, to intercept enemy communications and then cue the same aircraft to bring the target under visual observation and even designate the target for engagement if so desired. Additionally, payload packages developed by foreign militaries for specific types of missions can temporarily fulfill a unique requirement. For example, a radiological detection system developed by the Canadian military or a French digital mapping payload used by a private firm, could potentially be incorporated into the Shadow's mission bay without having to develop the technology in house. The payload capacity and system modularity allows for this capability.

Another key strength of the Shadow system is the range at which the GCS can command and control the aircraft. With a digital link capability of 124 miles (approximately 200km), a Shadow UAV can range within the area of operations of any brigade, and probably most divisions. Using one of the brigade's three aircraft to relay for another can further enhance this capability. This would temporarily extend the range to almost 250 miles, but with a significant reduction of time on target (TOT), and the lost utilization of the relay aircraft for other concurrent missions. When a requirement exists, however, for reconnaissance and surveillance of a prospective threat outside the area of operations, but within the area of interest, it is an invaluable capability. It allows the brigade commander, after proper airspace coordination, to develop a situation without having to depend solely on his superior command for the requisite information.

During development of the complete Shadow UAV system as the Army's SR-UAV choice, program managers purposely chose to use components that were either battle tested or otherwise had been proven reliable through extensive training in realistic environments. The benefit of this method is in minimizing the traditional growing pains associated with fielding a new battlefield system. The GCS for example is essentially the same rugged system that has seen service in Bosnia, Kosovo, and Saudi Arabia. It utilizes an existing architecture that, while not perfect, has proven itself functionally sound and reliable in both training and real world operations. The associated advantage is that the development teams can focus on aircraft or payload specific shortfalls during fielding as opposed to investing scores of man-hours trying to create something that already exists.

The aircraft itself has also shown itself to be a sturdy, sustainable vehicle. Its composite exterior overlaid on a tubular frame has shown through its trials to be resistant to both damage and down time. Its exterior requires little maintenance and its Kevlar skin is difficult to rupture or tear. Its drive train, the AR741 rotary engine made by UAV Engines, Ltd., of Lichfield, England, has also proven to be both reliable and fuel-efficient.[30] It capitalizes on its unique rotary design to limit internal moving parts, and therefore, the potential engine failures more prevalent in conventional piston engine models. During its operational testing at Fort Huachuca in March 2001, the Shadow 200 exceeded requirements by maintaining at least one aircraft in the air perpetually for the 96-hour duration of the exercise. They were able to achieve this by launching an aircraft before the other had left station.[31] Additionally, the Shadow's mission capable rate is enhanced by the inclusion of an automatic landing component. This

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[29] Unmanned Aerial Vehicle Roadmap: 2000-2025, 16.
[30] AW&ST and AUVSI, 24.
[31] Susan Flowers. "United Industrials AAI Shadow TUAV Passes Operational Test," Internet, http://www.shadow200.com/newsreleases.html . accessed 07 NOV 01.

device takes over control of the aircraft and brings it in for landing, mitigating the potential for human error, which typically is the leading cause of aircraft damage.[32]

SHADOW UAV – SYSTEM LIMITATIONS

While the Shadow UAV acquisition plan will undoubtedly enhance the capabilities of the deployed maneuver brigade, there are significant shortfalls in its configuration, organization, and equipment that adopting an alternative mini-UAV strategy would help to overcome.

As with any system designed to perform a battlefield function, getting it where needed at the right time is a top priority. This is even more pertinent today as the Army transforms itself towards a more rapidly deployable, flexible force. The Shadow 200 TUAV system's multi-functionality comes at the cost of size, weight, and the associated resources required moving its bulk. During operational testing, the Shadow 200 TUAV system required two complete C-130s to move all of its components, totaling approximately 40 tons, into a theater.[33] The costs to the brigade commander in time, manpower, and lift to employ the Shadow TUAV are significant. This is especially true in a rapid deployment situation where both time and lift assets are scarce commodities. Two C-130s filled with fragile, cumbersome equipment takes time and trained manpower to properly offload, reassemble, and subsequently prepare for tactical deployment. Additionally, there is an opportunity cost associated with moving two C-130s filled with a large, albeit advanced, intelligence collection system. Specifically, every extra pound of TUAV equipment occupying space in an airplane is a pound of men, weapons, and materiel that is not entering the theater. To further compound the significance of the problem, an analysis by Government Accounting Office intimated that the SR-UAV's transportation requirements will be far more greater than those detailed by the manufacturer. They found that more than 14 C-130 plane loads would be

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[32] Ibid.
[33] Susan Flowers. "Shadow 200 TUAV finishing Successful Initial Tests," Internet, http://www.shadow200.com/newsreleases.html . accessed 07 NOV 01.

required to transport one complete short range system, which the test agency concluded was unsatisfactory.[34]

Another critical issue related to system size is its large tactical footprint, and constraints on where it can locate in order to conduct UAV operations based on system performance parameters. Similar to a manned fixed wing aircraft, the Shadow 200 requires a significant obstruction free area within which to conduct launch and recovery operations. In desert environs, this may not be a significant concern. Open spaces facilitate both launching and recovery of the aircraft as well as the line of site (LOS) communications required for command and control. Additionally, even if an acceptable runway is not initially available a unit can quickly construct one, or, as an alternative, use the optional launching and recovery system. In close terrain, however, this is a much more critical issue. In mountainous, heavily forested or even jungle environments, flat and open real estate is often at a premium. The launcher system, while eliminating the requirement for a 100-meter runway, still requires 50 meters of obstruction free area down range of the catapult. The same is true when the aircraft comes in for a landing. While a runway is not required when employing the arrestor hook, the plane still requires an obstruction free approach of approximately 50 meters.[35]

In practice, this employment constraint has shown to create significant dilemmas for the brigade commander. If, for example, terrain limitations require positioning the LRS away from other units or command and control elements it becomes vulnerable to attack. The large and unique signature of the LRS, coupled with the overall value of the system to the brigade, make it a natural high payoff target (HPT) for an enemy commander to attack with either direct or indirect means. With only two LRS crewman, they simply do not have the manpower to secure themselves when isolated. "Without combat arms or other defensive augmentation, the LRS is a lamb ready for slaughter," CPT Raymond

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[34]U.S. Government Accounting Office (GAO). *UAVs – Performance of SR-UAV Still in Quaestion. GAO/NSIAD-95-65.* Washington, D.C.: GAO, DEC 1995. 6-7.

[35] JP 3-55.1, II-16

Pickering, a SR-UAV company commander, observed[36]. CPT Pickering's observation on the employment constraints of the Shadow TUAV requires the brigade commander to provide some form of security if TUAV operations are to continue unimpeded. Conversely, if terrain facilitates employment of the LRS close to a supported headquarters, in order to maximize efficient support, it then becomes a magnet for enemy indirect fires and can lead to the destruction of not just the UAV system, but also the brigade's command and control node with which it is collocated.[37]

The base organization of the Shadow 200 TUAV system also has inherent limitations that curb its potential functionality at the brigade level. Chief among these are the quantity of aircraft in relation to the number of intelligence tasks required of a typical maneuver brigade. With just three aircraft, the Shadow equipped brigade can essentially cover three named areas of interest (NAIs) at any given time, representing just a fraction of the brigade's total area of operations (AO). For example, a brigade with a 25km by 25km AO (625 square kilometers) can have three Shadow TUAVs flying simultaneously. Their observation footprint is approximately a square kilometer per aircraft at a detail where they can identify stationary vehicles (greater if the vehicles are moving and there are associated dust plumes).[38] Therefore, by having only three systems, the coverage rate within the brigade's area of operations at any given time is a maximum of about one half of one percent of the brigade's total area. This figure is decidedly less if the calculation includes the area of interest. In actuality, it would likely be even lower, as one aircraft would typically be on the ground preparing to replace an aircraft as it comes off station for refueling and maintenance. In addition, by having only two, at maximum three, aircraft available at any given time, a fourth priority intelligence requirement (PIR), requiring the unique function of the UAV to satisfy it, may potentially go unfulfilled.

[36] Pickering, Raymond D. "Tactical UAVs: A Supported Unit's Primer." *Military Intelligence Professional Bulletin*, (APR-JUN 1997): 22.
[37] Ibid, 23.
[38] Ibid, 21.

The reason for this is that an SR-UAV, in its primary mode as an imagery platform, is a point sensor.[39] In other words, it observes a relatively small area at any given time. For maximum effectiveness, it relies on cuing from another sensor to hone its search. LTC Edward Gibbons, former Executive Officer of 2nd BCT, 3d Infantry Division (M) at Fort Stewart, Georgia experienced first hand the difficulties of integrating SR-UAVs with maneuver brigade operations during the All Services Combat Identification and Evaluation Trials (ASCIET) joint training exercise at Fort Stewart in 1999. "There is a misconception that the UAV is like a big vacuum cleaner which sucks up all enemy activity on the battlefield…Without being cued, it's like looking at the battlefield through a soda straw. It is very difficult to identify an enemy…especially in close terrain."[40] Searching for enemy formations in the forested training areas typical of coastal Georgia with only two aircraft proved to be a taxing process without first having some tip-off from another asset. "It's like looking for a needle in a haystack," LTC Gibbons observed. "Once, however, you have a cue from another sensor, such as JSTARs, or even Quickfix, we were able to redirect the UAV and track targets very accurately," he added.[41]

Survivability of aircraft has also shown to be a limitation of UAVs in general, and even more so for those systems which operate in the close fight where the Shadow TUAV is designed to conduct operations. When compared to their manned peers, SR-UAVs would appear to have an advantage in avoiding detection and engagement by a hostile force. They are smaller, quieter, provide a reduced infrared signature, and reflect a minuscule radar cross-section. They are not invisible, however. In fact, unlike manned aircraft that can vary their speed, utilize terrain masking, and leverage ordnance release lines to thwart enemy engagement, SR-UAVs are vulnerable to attack as they methodically fly through the sky.[42] They have also shown a tendency to fail for mechanical reasons that contribute greatly to their historically high attrition rates. The result is that during combat deployments their operational rate is traditionally low through a combination of enemy action and system failure.

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[39] Congressional Budget Office. *Options for Enhancing the DoD's UAV Programs.* I-6
[40] LTC Edward Gibbons, USA, Interview by Author, USA, 09 NOV 01.
[41] Ibid.
[42] CPT Brian P. Tice. "UAVs – The Force Multiplier of the 1990s." *Air Chronicles,* (Spring 1996): 13.

In 1991 during Operation Desert Storm, for example, the first major American operational use of UAVs since Vietnam, the 40 Pioneer UAVs deployed suffered a 60 percent overall damage rate through both crashes and enemy fire, primarily the former.[43] Among the causes for this high attrition figure were weather, operator error, equipment failure, enemy fire, and loss of radio connection. This is not an isolated example. In 1995, five Predator UAVs deployed to both Albania and Croatia in support of UN Peacekeeping efforts in the Former Republic of Yugoslavia. Within 30 days of deployment, enemy fire reputedly brought down one aircraft, and another crashed, sparking a DoD reassessment of the viability of the entire Predator UAV program. A similar fate befell American UAV usage in Kosovo in 1999. Of the 31 systems deployed by the United States (five Pioneers, 18 Hunters and eight Predators), approximately a third received damage from either crashes or enemy fire.[44] The implications for the brigade commander are simple. With only a limited number of systems at his disposal and a historically high attrition rate through either mechanical failure or enemy actions, the loss of a single system has a greater impact on his operations than if he had a large quantity of systems.

In short, the Shadow TUAV best fulfills the needs of a brigade commander who primarily requires a highly functional UAV system to counter high technology threats in an environment with a limited target set so that he can achieve success through the employment of a low-density of collection assets. In this employment condition, the Shadow performs exceptionally well. The Shadow's ability to carry a plethora of modern payloads allows it to collect against a wide range of modern threats in a myriad of climactic and terrain conditions. Whether scanning the frequency spectrum for an enemy commander's voice, or searching through the night sky for the heat of an enemy reconnaissance vehicle, the Shadow can draw from a wide variety of capabilities to accomplish its specified intelligence mission. Additionally, the aircraft's robust construction, and generous performance capability, allows the aircraft to move effectively within the brigade's area of operations, and place the collection asset where it is needed at the critical time. It also incorporates an effective command and control suite, that allows for

[43] Park Jan-Wan. "Overview of a UAV System," Internet, http://www.uavcenter.com/english/e02general/e2concept/econcept.htm. accessed 04 NOV 01

detailed mission planning and the subsequent distribution of collected intelligence to key nodes within the brigade. Where the Shadow's luster begins to diminish, however, is under battlefield conditions where the brigade commander faces a high density of low technology threats. These conditions limit the effectiveness of the Shadow TUAV to fulfill the brigade commander's intelligence requirements because of limited number of aircraft in relation to the quantity of places required to look for enemy activity. Under conditions where the enemy lacks high technology signatures, the quantity of simple, observation platforms ascends in importance. The Shadow TUAV lacks such a quality. Additionally, the Shadow TUAV has employment limitations that degrade its ability to answer the brigade commander's intelligence requirements. Key questions concerning enemy activity in urban, or other close terrain, may go unanswered because of the inability of the Shadow TUAV to deploy and physically collect information in such areas. While very capable, the Shadow TUAV fails to satisfy significant potential requirements a future brigade commander may need to successfully conduct full spectrum operations.

[44] Ibid.

CHAPTER III - Mini-UAVs – AN ALTERNATIVE SOLUTION PATH

Mini-UAVs will save lives…this is an expendable asset.[45]

MAJ John Cane, USMC
Marine Corps Warfighting Lab, Quantico, VA

If the Shadow 200 TUAV is the Cadillac of tactical unmanned aerial reconnaissance systems, given its ability to execute a multitude of missions across a wide spectrum of situations and matching price tag, then mini-UAVs are akin to the ubiquitous pickup truck, working without notice day in and day out. Classified as those systems between six inches and six foot in diameter, they are characterized as cheap, simple, portable, and with limited, but valuable functionality. In comparison to the Shadow 200, they seem almost toy like. The Pointer UAV, for example, used in Desert Storm, Somalia, and Bosnia weighs a mere 30 pounds and can be assembled in minutes by simply snapping its precisely fabricated plastic parts together like a child's box of Legos. With a flick of a switch and a simple toss, however, the aircraft, powered by an efficient electric motor, is silently airborne and enroute to its target area. No LRS, refueling, or elaborate payload synchronization required. It is this design austerity that provides mini-UAVs their major advantage over other more capable, and extravagant UAV systems, designed for fielding at the maneuver brigade level.

The Israeli Defense Forces (IDF) first developed Mini-UAVs for military use as an inexpensive alternative to manned aircraft reconnaissance in response to high aircraft attrition during the 1973 Yom Kippur War. During the first 48 hours of that conflict, the Israelis lost a staggering 40 aircraft as they conducted reconnaissance and ground attack missions against both the Syrians and Egyptians.[46] In order to preclude such severe losses in the future, the Israelis' integrated contemporary off the shelf

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[45] Andrea Stone. "Mini Devices May Soon Replace Combat Scouts," *USA Today*, 25 JUN 01. 4.
[46] Franklin D. Margiotta, *Brassey's Encyclopedia of Military History and Biography*, London: Brassey's Defence Publishers, 1994. 32-34.

technologies and concepts borrowed from other militaries internationally to design and implement a mini-UAV strategy. The result was the "Owl", essentially a hobbyist's remote control airplane with a cheap black and white television camera mounted on the airframe. About the size of a trash can lid, the aircraft would be hand launched, then controlled via an FM radio link. The navigation system relied on dead reckoning using the black and white video images received by the pilot to determine the location and direction of travel of the aircraft. Following a demonstration to the Israeli Government and the Tadiran Electronics Conglomerate, both of whom quickly grasped the compelling nature of a tool that could conduct effective battlefield surveillance with a minimum of cost and risk to human life, a contract was issued to develop and field an operational mini-UAV system.[47]

Their efforts culminated with the mini-UAV known as "Mastiff," entering service with the Israeli Defense Forces (IDF) for testing in 1975.[48] Powered by a twin stroke 22 horsepower gasoline engine, the "Mastiff" demonstrated its tactical utility during numerous trials and real world border monitoring missions. The lessons learned from these operations helped to improve not just mini-UAV system design, but also operational doctrine as well. Particularly compelling was its ability to mount a variety of payloads ranging in function from video imaging to electronic counter measures (ECM). This flexibility gained it favor among the different IDF services, as it could satisfy several requirements that normally would require the risk of both men and materiel. By 1980, the "Mastiff" and the "Scout", its competitor from the Israeli Aircraft Industries (IAI), had successfully entered into the IDF's tactical reconnaissance system.[49]

The efficacy of this mini-UAV integration as battlefield surveillance platform found validation just two years later during Israel's 1982 war in Lebanon. Both the "Mastiff" and "Scout" mini-UAVs saw extensive use by both the Israeli Army and Air Force with dramatic results. The Air Force in particular found the mini-UAV an invaluable tool for observing Syrian airfields and providing real time early

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[47] George V. Goebel. "Israeli Battlefield UAVs," Internet, http://www.vectorsite.net/avuav8.html. accessed 17 NOV 01.
[48] Sir Michael Armitage. *Unmanned Aircraft (Brassey's Air Power: Aircraft, Weapon Systems and Technology Series, Volume 3).* 84-86.

warning data as to when aircraft were about to take off, thus allowing the Israeli Air Force to intercept them in the air, or destroy them on the ground before they could take off.[50] Additionally, the use of both "Mastiff" and "Scout" aircraft was exceptionally effective in the infamous Bekaa Valley to identify Syrian surface to air missile (SAM) locations for targeting. Through the innovative technique of using mini-UAVs as bait to highlight a SAM radar, subsequently intercepting and pinpointing its location, then observing it for engagement, the Israeli Air Force was able to attack and destroy 28 of 28 SAM sites. During this operation, enemy fire destroyed eight mini-UAV aircraft. In relation to the pilots and aircraft likely lost replicating their mission, however, the cost was miniscule, further confirming the viability of using mini-UAVs in a tactical role.[51]

The effective use of mini-UAVs by the IDF was closely watched by the United States, who looked to the mini-UAV as a specialized tool to fill a reconnaissance void at the lowest tactical echelons as they prepared to deploy forces to Lebanon in 1983. This interest amplified following the October 1983 bombing of the Marine Corps barracks in Beirut, Lebanon that killed 241 American servicemen. General P.X. Kelley, Commandant of the Marine Corps at the time, during a trip to the region to investigate the tragedy, observed with admiration the IDF's routine use of mini-UAVs to conduct reconnaissance in high threat areas. His conveyed his interest to then Chairman of the Joint Chiefs of Staff (CJCS), GEN John W. Vessey, Jr., who also saw the utility of such an asset and began to investigate its potential use by American military forces.[52]

While the interest of the US military's top leadership was piqued, the requirement for the UAV's unique capabilities became self evident in the wake of another military tragedy in Lebanon later in 1983. In December, the U.S. Navy lost two ground attack aircraft during an attack against Syrian SAM sites. During the subsequent investigation, Secretary of the Navy John Lehman found that they could have attacked those same targets using the U.S.S. New Jersey's 16 inch guns had their been an

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[49] Ibid, 85.
[50] Richard A. Gabriel. *Operation Peace for Galilee: The Israeli-PLO War in Lebanon*, New York: Hill and Wang, 1984. 97-98.
[51] LTC David A. Longino. *Role of Unmanned Aircraft – Future Armed Conflict Scenarios*. Maxwell AFB, AL: Air University Press, 1996. 6.

effective means to identify and track the targets.[53] Shortly following this revelation, the U.S. Navy received a compliment of “Mastiff” mini-UAVs from the IDF for use in Lebanon. While the “Mastiff” effectively fulfilled the Navy’s short term requirements, the Navy’s long term needs led them beyond the mini-UAV concept towards a more robust UAV system that was fulfilled by the acquisition of the Pioneer UAV, made by the same manufacturer as the Shadow 200 TUAV, AAI.

The U.S. Navy’s departure from the use of mini-UAVs, towards a concept incorporating larger systems, did not nullify the viability of mini-UAVs as an inexpensive, yet effective, reconnaissance option for tactical forces. In 1991, during Operation Desert Storm, for example, both the Army and Marines made use of over 100 mini-UAVs to conduct battlefield reconnaissance and accomplish other routine functions. In fact, the most numerous UAV in theater was BAI’s BQM 147A Exdrone (Expendable Drone) that was used by the U.S. Marines to fulfill tactical reconnaissance, signals intercept and radio relay functions. Its small size, ease of launch and recovery, and sheer quantity (60), allowed them to accomplish tasks beyond the scope of the less plentiful, but more individually capable, conventional UAV systems.[54]

The FQM 151A Pointer UAV, designed by AeroVironment, Inc., is another mini-UAV that saw use by American forces during Operation Desert Storm, and due to its unique capabilities, remains deployed today. Lighter and more austere than even the diminutive Exdrone, the Pointer’s ability to be man packed, hand launched, and manually recovered without the need for special arresting equipment gives the Pointer a high degree of flexibility of employment.[55] During Desert Storm it performed such diverse roles as direct support to special operations forces, as well as with the U.S. Navy conducting counter-mine operations.[56] Pointer’s unique functionality marks it as a compelling asset today, over a decade later. Essentially unchanged in its original configuration except for a more efficient power

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[52] George V. Goebel. “U.S. Battlefield UAVs,” Internet, http://www.vectorsite.net/avuav8.html. accessed 17 NOV 01.
[53] Ibid.
[54] Program Executive Office – Strike Weapons and Unmanned Aviation, “Experimental Interim Small UAVs,” Internet, http://www.strikenet.js.mil/PAO/tuav/tuav2000/eisuav.htm., accessed 17 NOV 01.
[55] Stephen P. Howard. *Special Operations Forces and UAVs: Sooner or Later*. Maxwell AFB, AL: Air University Press, 1996. 9.

source and an expanded payload capacity, the Pointer is currently in use at the brigade and lower level in such diverse places as the Iraqi-Kuwaiti-Saudi Arabian frontier, Kosovo, and Bosnia.[57] Its continued demand is attributable to those qualities inherent in mini-UAVs as a whole: flexibility, functionality, and cost effectiveness.

Mini-UAVs – A SURVEY OF SYSTEMS

The quantity of mini-UAV manufacturers, associated functional types, and specific models has risen exponentially over the past decade driven by both technological improvements and demand. Specifically, advancements in computer processor design, optical miniaturization, GPS proliferation, and digital communications have allowed manufacturers to put more capabilities in smaller and smaller packages at less cost. A simple black and white imaging payload integrated on the “Mastiff”, for example, took up most of the 60lb payload. Today, an even greater imaging capability is resident on some Micro-UAVs - with a total weight penalty of about a gram.[58] Correspondingly, this downward trend in size and cost has spawned an up tick in demand and availability for small, cheap unmanned aerial vehicles to accomplish a variety of functions in both the government and civilian communities. Mini-UAVs in a variety of forms now monitor cattle ranches, freeway traffic, and international borders throughout the world

Of the wide variety of mini-UAVs available, this monograph details three systems whose performance characteristics merit potential use at the Army maneuver brigade level: the Exdrone, Pointer, and Sikorsky Cypher vertical take off and landing (VTOL) aircraft. The purpose is to highlight their performance parameters in relation to the stated requirements for a TUAV at the brigade level, and then analyze these systems in terms of their systemic strengths and weaknesses.

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56 AeroVironment. “Pointer UAV,” Internet, http://www.aerovironment.com/area-aircraft/prod-serv/pointer.html . accessed 17 NOV 01.

57 Park Jan-Wan. “The History of UAVs,” Internet, http://www.uavcenter.com/english/e02general/e1history/ehistory.htm. accessed 03 NOV 01

58 COL Michael S. Francis. “Micro Air Vehicles – Towards a New Dimension in Flight,” Internet, http://www.darpa.mil/tto/MAV/mav_auvsi.html. accessed 04 NOV 01

The BQM-147A Exdrone, manufactured by BAI, is by far the most prolific of the three systems to be examined. With over 600 aircraft delivered since its inception in 1984, the basic design of the delta-winged aircraft has changed little over the life of its production run. The reason for this is that the triangle shaped 6-foot long airframe has proven to be a reliably stable platform.[59] Fully loaded, the aircraft weighs in at about 80 pounds, of which 17 is for payload transport. Its power source is an eight horsepower two-stroke gasoline engine that propels the low silhouette aircraft to a maximum speed of 100kts for up to 5.5 hours (although 2.5 hours is generally the norm). The cruising speed is about 75kts and can maintain stability as low as 40kts to loiter over an area for an extended period.

Like the Shadow UAV, the Exdrone aircraft is just one component of an overall UAV system that includes 10 aircraft, two LRSs, various payloads, two GCSs, and assorted spare parts and maintenance tools. To get into the air, the Exdrone can launch from a proprietary pneumatic rail launcher, dolly catapult, or rocket assisted takeoff from an unimproved runway. There are three ways to land: on board parachute system, skid landing, or by an arresting net. The area required to launch is about 50 unobstructed meters. Additionally, the Exdrone's 17-pound payload capacity, though relatively small, takes advantage of technological developments in both electronics and miniaturization to expand the system's overall capability. It can carry a wide variety of packages to include full tilt and pan television, FLIR, frequency jammers, radio relay and other customized packages as desired. To control the aircraft in flight and communicate with the payload, the Exdrone incorporates a state of the art UHF uplink and L-band video with data sideband downlink.[60]

The GCS is essentially a laptop computer with a software program that allows the user to preplan a mission, control the aircraft while in flight, and manipulate the payload. Depending on the customer's desires, can also mount in a truck for tactical use, or load on a standard laptop computer. The associated auto-tracking antenna is the communication mode for moving information back and forth between the GCS and the aircraft.

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[59] Jay Willmot, Executive Vice President, BAI Aerosystems, interview with author, 21 NOV 01.
[60] AW&ST and AUVSI, 29.

The cost of the Exdrone fielded in Desert Storm was $10,000 per aircraft. A complete system today as listed above with all the subcomponents costs about $1 million. Limiting payload options, simplifying the GCS configuration, and limiting LRS options, however, can significantly reduce the total price. Additionally, economies of scale inherent in an acquisition strategy that would field this system to maneuver brigades throughout the army would further diminish the cost to a level commensurate with the 1991 cost.[61]

In contrast to the Exdrone is the more conventional, and more Spartan, Pointer UAV. Designed by Paul McCready, PhD., the engineer who designed the "Gossamer Albatross", the first human powered aircraft to cross the English Channel, the Pointer UAV's design reflects an engineering philosophy predicated on maximizing efficiency.[62] To make the aircraft as efficient an airframe as possible, the Pointer's design team shaved off every extra ounce. The result is a wispy aircraft weight of just three pounds when empty, and the capability to carry a four-pound payload (133% of the aircraft's mass). The tremendous lift to weight ratio results from the aircraft's large wingspan and associated surface area. The Pointer measures, when fully assembled, nine foot wide and six foot long with a total lifting surface of six square feet (note: the Pointer still qualifies as a mini-UAV, despite its over six foot status, because of its ability to collapse into a one meter tube for carrying.) This expansive wingspan, when operating in conjunction with its eight horsepower electric motor, provides the aircraft a power to weight ratio in excess of a Formula One racecar.[63]

While less than those performance figures achieved by the Exdrone, the Pointer UAV's capabilities are still impressive given it diminutive bulk. It has a maximum speed of 50mph, can achieve an altitude of 5,000 feet, and remain in the air for about two hours. Additionally, its huge wing size provides it the ability to slow down to just 19mph and loiter over a target. An advanced operator can extend its endurance by taking advantage of weather conditions and soaring the aerodynamically efficient aircraft,

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[61] Jay Willmot, Executive Vice President, BAI Aerosystems, interview with author, 21 NOV 01.
[62] Martyn Cowley, Pointer UAV Project Manager, AeroVironment, Inc., interview with author, 17 NOV 01.
[63] Ferrari World – F1 Cars Specification. Internet, http://www.ferrari.com/cgi-bin/fworld.dll/ferrariworld/scripts/gt/car_data.jsp?car_type=F1, accessed 24 NOV 01.

thus conserving battery power. Its range, however, is its Achilles heel. The Pointer UAV, in its current configuration, has a maximum range of approximately 8-10kms.[64] This range, however, is can very due to the Pointer's susceptibility to even moderate crosswinds or updrafts found around tall hills or buildings.

Similar to both the Exdrone and Shadow TUAV, the Pointer aircraft is just one component of an overall UAV system. The difference with the Pointer, however, is in its asceticism of design. A Pointer UAV system consists of just three elements: the aircraft, its payload and the ground control unit (GCU). The total package (with only one aircraft) weighs less than 60 pounds and can be shipped anywhere in the world overnight by commercial carrier.[65] The aircraft's design allows for quick disassembly and can fit into two hardened tubes for transport. Additionally, the GCU consists of a laptop computer and specialized antenna for controlling the aircraft in flight, and can also fit into a man portable container.

Conspicuously absent from the Pointer UAV system, in relation to other UAV systems, is an LRS, a vehicle mounted GCS, and a large crew of operators. The Pointer UAV LRS, for example, consists of a soldier who simply turns the engine on, establishes radio contact via his laptop, and then gently tosses the aircraft into the air. Landing is also simple. The aircraft flies back to the area where the operator wants it to land; the aircraft's then reduces speed, and then the operator induces a stable deep stall causing the aircraft to gently fall to the ground. No runway improvement or preparation is required.[66] To control the aircraft in flight, the crew, consisting of only two soldiers, uses a standard laptop computer to preplan the mission, control the aircraft while in flight, and manipulate the payload. The system is simple enough, that for limited periods, even a single soldier can run the complete operation.[67]

Despite its limited carrying capacity, the Pointer fields a surprisingly varied payload capability. Originally designed to carry a black and white video camera when fielded in 1986, the current iteration has improved on that capability considerably. It now has the ability to provide color daylight video

[64] AW&ST and AUVSI, 26.
[65] Martyn Cowley, Pointer UAV Project Manager, AeroVironment, Inc., interview with author, 17 NOV 01.
[66] Program Executive Office – Strike Weapons and Unmanned Aviation, "Experimental Interim Small UAVs," Internet, http://www.strikenet.js.mil/PAO/tuav/tuav2000/eisuav.htm., accessed 17 NOV 01.
[67] Martyn Cowley, Interview with author, 17 NOV 01.

with integrated GPS, microbolometer thermal imaging for nighttime operations, and atmospheric sampling for chemical detection. It cannot do all of these simultaneously, however. Therefore, the mission planner must convert the supported commander's requirements into payload priorities in order to accomplish his intent. The overall price to field this capability is approximately $5,000-$10,000 per aircraft depending on the quantity of the order.[68]

On the cutting edge of mini-UAV design is Sikorsky's Cypher VTOL-UAV. Designed and manufactured by the company whose name is synonymous with helicopter innovation, the Cypher is fundamentally different from the Exdrone and Pointer due to its ability to take off vertically, hover, and fly in 360 degrees. First designed and built in 1992 as a competitor for the U.S. Army Maneuver UAV program, the Cypher has made over 550 flights as a research platform and is currently being used as a test bed by the Infantry School at Fort Benning, GA for research into reconnaissance in urban areas.[69]

The most distinctive aspect of the Cypher is its shape. From the side, its disc profile and side mounted camera aperture give it the look of a 1950's era prototypical flying saucer. This disc form however, has a purpose. In the center of the six-foot wide aircraft is a laterally mounted propeller that spins at several thousand revolutions per minute (RPM) from power it receives from a 55hp AR801 gasoline engine. This is enough motive force to lift the 300-pound Cypher to an altitude of 10,000 feet for up to three hours. Laterally, it can also fly at speeds up to 90kmh. Additionally, it has sufficient power to carry a relatively generous 50-pound payload.[70]

The other elements of the Cypher system include the GCS and functional payloads. No LRS hardware is required, as the Cypher takes off and lands like a conventional helicopter. The GCS itself uses a Microsoft Windows based personal computer (PC) and can be mounted in a vehicle or removed and set up independently inside a tent. It consists of a single workstation that accomplishes the functions of mission planning, flight control and manipulation of the payload. Additionally, the Cypher

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[68] Ibid.
[69] Lawrence Newcome, "Sikorsky's Cypher VTOL-UAV," Internet, http://www.uavforum.com/vehicles/developmental/cypher.htm. Accessed 12 NOV 01

incorporates GPS into its mission-planning component, which allows the aircraft to fly an exceptionally accurate path given to it by an operator. This is particularly valuable when operating on close or urban environments. During testing, the Cypher was able to routinely fly between obstructions 12 feet apart. The means by which the GCS transmits and receives data to the aircraft is a proprietary antenna using the UHF frequency band, giving the Cypher a 30km combat radius.[71]

As mentioned, the payload capacity on the Cypher is significantly greater than either Exdrone or Pointer UAVs. This allows it to mount several different payload types simultaneously. Among those packages tested are FLIR, color video camera, Cesium Magnetometer (used for mine detection), and an active magnetic sensor (also used for mines). Additional payloads currently under development and testing could allow the Cypher to conduct BDA, geophysical mapping, unexploded ordnance detection, and chemical agent detection missions simultaneously.[72]

Because the Cypher is still in development, actual system costs are difficult to accurately assess. Currently, Sikorsky is under contract to deliver two aircraft and four GCS systems for a total sum of $5.46 million, with an option for the US Navy to purchase 10 additional aircraft for $3.76 million. Its intended purpose is to help in naval countermine operations.[73] While the U.S. Army has not committed itself to purchasing the Cypher in quantity, the per unit cost of the system would likely decrease in relation to the quantity of systems acquired.

Mini-UAVs – SYSTEM STRENGTHS

As a battlefield tool, mini-UAV systems have intrinsic qualities that could greatly enhance the combat effectiveness of a future maneuver brigade. Chief among them are the factors of employability,

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[70] Bill Tuttle, "Cypher UAV Program," Internet, http://www.sikorsky.com/programs/cypher/index.html. accessed 22 NOV 01

[71] Ibid.

[72] AW&ST and AUVSI, 72.

[73] Mike W. McKee, PhD., "VTOL UAVs Come of Age: US Navy Begins Development of VTOL UAV," Internet, http://www.vtol.org/uavpaper/NavyUAV.htm. accessed 24 NOV 01.

flexibility and cost-effectiveness as they apply to the lowest tactical echelons of the Army. These three aspects are particularly pertinent today as maneuver brigades strive to conduct operations across a continuum of battlefield environments and against a spectrum of potential threats. Mini-UAVs, and their inherent flexibility, have the potential to help improve not just a single battlefield functional area, but also the combat effectiveness of the brigade as a whole. The key to this is the austerity and simplicity of design, which allows mini-UAVs to get to the fight quickly and with a minimum of support.

Mini-UAVs offer an exceptional level of employability due to their small system size, austere launch and recovery requirements, and enhanced survivability. Mini-UAV systems, as typified by the three detailed earlier in this chapter, are exceptionally easy to move strategically. The Pointer UAV for example can be moved anywhere in the world by commercial shipping due to its low weight and limited physical dimensions. Even the largest of the three, the Exdrone, can be moved into a theater by a commercial aircraft, then moved intra-theater by a single five-ton truck. Additionally, the small number of support personnel required for these systems to function also enhances the employability of the system by limiting transportation requirements, as well as helping to keep the deploying element within force cap limitations.

Tactically, this small size provides significant advantages for employment. The footprint for a mini-UAV system is minuscule. The Exdrone, for example, in its most extravagant battlefield configuration takes up the space of a single HMMWV with a trailer. The Pointer and Cypher both occupy considerably less space. The impacts are two fold: first, the time to set up, move, and employ the system is very short, allowing them to keep pace with the maneuvering brigade; and secondly, the systems can operate in close environments where space is at a premium. This is particularly important in mountain, jungle or urban areas where terrain management is a key issue. An additional benefit is that the small footprint presents a much smaller battlefield signature for attack by an enemy force. Unlike other larger systems, the mini-UAV profile on the battlefield is virtually transparent. There is no large runway or grandiose antennae array to compromise the position of the UAV asset.

The ability to launch and recover aircraft without need for an improved runway contributes significantly to the employability of mini-UAVs. Their requirements for takeoff are very flexible. The most restricted, the Exdrone, launched from a trailer mounted pneumatic catapult, requires a clear field of fire for about 25 meters down range of the launcher. The limitations on the Pointer and the Cypher, however, are virtually nonexistent. The Exdrone, for example, can launch almost vertically using its organic rocket assisted dolly launcher. The Cypher is by far the most versatile in terms of launching and recovery. It can take off at a zero degree climb and maneuver straight through a jungle canopy or urban sprawl. Recovery of these systems is equally versatile. The benefits for the commander are readily apparent. The brigade commander can position the mini-UAVs for optimal utilization without the constraints of terrain dictating their placement.

Additionally, mini-UAVs have shown to be remarkably survivable due to their small physical and aural signatures, aircraft performance, and limited electronic and thermal profiles. Quite simply, mini-UAVs are hard to see and even harder to hit. The Pointer UAV, for example, driven by its eight horsepower electric motor is virtually silent at a distance of 1,000 foot.[74] Additionally, its diminutive cross section, less than a square foot when flying directly at a target, makes it difficult to visually identify during daytime, and virtually impossible at night. They also have design considerations that help them avoid enemy engagement. The Exdrone's unique delta winged shape and front mounted motor, for example, provide it great aerobatic capabilities. If spotted, it can rotate its body position towards the incoming fire and present just a fraction of its overall size as a target.[75] The Cypher also has a unique ability to avoid engagement. It can simply move behind an object and hover, or exfiltrate using available cover and concealment. Another consequence of their small size and correspondingly small engine is that they do not put out much heat, nor do they present much of a radar cross-section. The Pointer for example, with its electric engine and low mass, composite construction, presents little in

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[74] Martyn Cowley, Pointer UAV Project Manager, AeroVironment, Inc., interview with author, 17 NOV 01.
[75] George V. Goebel. "U.S. Battlefield UAVs," Internet, http://www.vectorsite.net/avuav8.html. accessed 17 NOV 01.

the way of a target to a radar or thermal imaging system. The result is that a commander can employ these systems in dangerous situations with a high confidence in their ability to survive.

One of the critical strengths of Mini-UAVs is the wide spectrum of functionality they have based on their payload capabilities, aircraft performance, and the quality of quantity. Mini-UAVs, like their larger more sophisticated cousins, can now perform a variety of battlefield tasks. Once the purview of only the largest and most expensive UAVs, capabilities such as color video, FLIR, chemical detection, radio relay and laser designation, are now commonplace on mini-UAVs. The performance parameters of the aircraft themselves enhance these basic capabilities. This is particularly true of the Cypher with its VTOL performance. A commander can now use his traditional sensor suite to conduct reconnaissance operations in areas that were previously beyond his intelligence gathering capability. In urban areas for example, a Cypher can actually go into buildings, fly under obstructions, and leverage covered and concealed positions to conduct reconnaissance using the full range of his sensors' capabilities to identify and track threat forces. This is beyond the capability of traditional UAVs, which are limited by their conventional airframe's requirement for forward movement to maintain lift.

A third component of mini-UAV functionality is their unique ability to employ a large number of aircraft simultaneously in order to gain a high degree of situational awareness within a given area. By flooding a zone with an armada of relatively inexpensive mini-UAVs, there is a synergistic effect of simultaneously painting the whole picture for the commander throughout the breadth of a brigade's area of operations. "One of the main shortcomings of large UAV systems is the so far insurmountable challenge of disseminating their intelligence to interested users in real time. The small inexpensive widely deployed organic UAV system answers this challenge,"[76] Jay Willmont said, referring to the capability of the Exdrone in a tactical environment. Simply put, Mini-UAVs will allow the commander to see more of the battlefield, more of the time.

[76] Jay Willmot, Executive Vice President, BAI Aerosystems, interview with author, 21 NOV 01.

Finally, a pragmatic strength of the mini-UAVs is that they are relatively inexpensive to field, replace, and sustain. In short, money matters. The initial cost of a mini-UAV system is substantially less than a larger conventional UAV system because of mini-UAV' smaller size and lesser individual capability. For the same amount of money, an organization can acquire many more aircraft, thus providing a system level capability that is greater than the performance of an individual aircraft. Additionally, the economies of scale associated with larger production runs make replacement aircraft readily available and much less expensive. The first Pointer, for example, cost $75,000 in order to cover research and development costs and hand crafting many of the initial components. Once production was under way, however, this cost dropped by an order of magnitude.[77]

The cost of sustaining a mini-UAV system is also much less expensive than conventional UAV systems, as they require fewer personnel, have fewer and less expensive components, and cost less per unit to replace. The biggest expenditure associated with UAVs is not the hardware, but the cost to man the system and train the soldiers. "The cost of the hardware is only the tip of the iceberg. The real associated cost that is not being met is that of operator training, development of operational tactics, and funding of command structure exercises."[78] The benefit of mini-UAVs is that they are simpler to train and require only a fraction of the soldiers to make a system operational. Additionally, a mini-UAV system typically requires fewer hardware components to make it function, and those which it does have are generally cheaper to replace. The Pointer, Exdrone and Cypher, for example, use a ubiquitous laptop as the basis for their GCS. The brigade can generate a replacement from within. Larger, more robust systems, that use proprietary systems, will have to look external to the brigade for replacement with an associated cost of both money and lost asset utilization. Lastly, because of the low cost of an individual aircraft, the cost connected with losing one is insignificant. This is especially so when a mini-UAV system may have 20 aircraft. In a traditional UAV system, with three or four aircraft, the loss of a

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[77] Martyn Cowley, Pointer UAV Project Manager, commenting on the larger cost picture associated with UAVs, AeroVironment, Inc., interview with author, 17 NOV 01.
[78] Ibid.

single plane has a much more demonstrative impact on the mission. Additionally, the dollar cost to replace it is also significant because the relatively low production runs result in a higher per unit price.

Mini-UAVs – SYSTEM LIMITATIONS

While mini-UAV systems have the potential to greatly improve the effectiveness of a maneuver brigade, they are not a panacea in and of themselves. These systems, with their diminutive size and moderate performance, have specific inherent limitations that require analysis in order to show what these systems can and cannot do for the maneuver brigade commander. Among the most critical of these shortfalls are those related to all weather operations, the quantity of deployed systems, and the individual aircraft's limited performance capabilities.

Mini-UAV systems, as shown earlier, can operate in a wide variety of environments ranging from the dense, cluttered urban sprawl of a major metropolitan area, to the triple canopy jungle typically found in Central and South America. Where they do not excel, however, is in foul weather conditions. Their small size and relatively low mass make them particularly vulnerable to less than ideal climatic conditions. The Pointer, for example, with its large wingspan and waif like seven-pound weight, buffets easily in winds above 10kts. As winds increase, the ability of the aircraft to function is even more dramatically decreased to the point where in 20kts, the Pointer is at the upper limit of its performance envelope.[79] Another consequence of foul weather is the degradation on aircraft endurance. In high winds and rain, the aircraft simply uses more energy to get to, and return from, its destination. For an aircraft like the Exdrone, for example, which can remain airborne for three hours under ideal conditions, foul weather reduces by up to half the time the aircraft can remain on station.[80] Operations in below freezing conditions are particularly difficult. None of the currently available mini-UAV systems incorporate a de-icing capability. This becomes problematic for mini-UAVs, as the extra burden of lifting frozen water on their surfaces overwhelms their already limited payload capacity.

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[79] Lawrence newcome, "Pointer UAV Specifications," Internet, http://www.uavforum.net/vehicles/production/pointer.htm. Accessed 18 NOV 01.

[80] Jay Willmot, Executive Vice President, BAI Aerosystems, interview with author, 21 NOV 01.

Additionally, foul weather has a significant impact on the payload performance carried by mini-UAVs. Low-level fog, rain and cloud cover can degrade or prevent mini-UAVs from conducting their reconnaissance missions by impeding visibility. Some payloads, such as FLIR and IR systems, have a limited ability to penetrate fog, generally forcing the aircraft to fly lower, limiting their field of view and making them more vulnerable to ground threats. CPT Raymond Pickering, former UAV company commander, summed up the weather and tactical effects on UAV use thusly: "combat theaters with low ceilings make UAV operations extremely difficult. In order to collect needed exploitable imagery, tactical UAVs must fly lower, increasing their potential for detection and exposure to enemy air defense systems. Fog also makes landing more difficult."[81] Low observation conditions also make the aircraft difficult to navigate in close terrain. The Cypher, for example, which relies on its optics to help the operator navigate in urban areas, becomes vulnerable to crashing if the operator has a degraded situational view due to weather. Icing also remains a significant problem. Moisture can also obstruct the optics on the payload, or even freeze the internal mechanical components, rendering them incapable of moving. In addition, precipitation can negatively affect the ability to command and control the aircraft. The typical mode of transmitting and receiving information between the ground station and the aircraft is FM communications. Moisture, especially rain, generally degrades this type of communication means.

Another critical dilemma associated with mini-UAV systems is the management of large numbers of systems simultaneously. Frequency management, the method of apportioning the use of the electromagnetic spectrum, is a particularly vexing problem. There is simply a finite amount of frequencies for use by a brigade, and increasing the number of consumers makes managing this system even more difficult. "Without proper management, one brigade's GCS could send commands to an adjacent unit's UAV that could receive and execute that order. Video downlinks from different UAVs can become tangled, sending imagery from the first brigade's aerial sensor to an RVT in the second

[81] Pickering, Raymond D. "Tactical UAVs: A Supported Unit's Primer." *Military Intelligence Professional Bulletin*, (APR-JUN 1997): 24.

brigade's sector causing serious confusion," CPT Pickering observed.[82] The result could be chaos. The problem appears to be solvable, however. Stavrous Toumpis, an electrical engineer doctoral candidate at Stanford University in Palo Alto, CA, is currently conducting research on how to solve this very problem. "A fleet of UAVs can certainly be organized and controlled. There is no question about the feasibility of this. There are two caveats, however: sufficient bandwidth needs to be available, and a protocol suite is required. The Office of Naval Research (ONR) has initiated a project with this aim," he said.[83]

In addition to the complexity of managing the dispersal of electrons across the battlefield, the physical management of the airspace filled with a prospective squadron of small UAVs is equally daunting. The crux of the problem is how to keep manned aircraft and unmanned aircraft from running into each other. The IDF's method for solving this problem gives UAVs specific operations zones based on identifiable terrain features, and also separates manned and unmanned aircraft by altitude. If an aircraft must enter a UAV zone, it notifies the airspace control authority (ACA) to ensure no UAV is in close proximity.[84] For an American maneuver brigade to adopt this tactic will take considerable training. Another management challenge is how to conduct mini-UAV operations with dozens of aircraft flying simultaneously, all with relatively limited endurance. To maintain this large observation footprint over an area of operations will require the mini-UAV operators to continually be recovering and launching aircraft. This will be particularly difficult in a fluid battle situation that calls for the brigade to continually move.

Lastly, the performance of the aircraft themselves, specifically range, speed and endurance, limits the overall effectiveness of mini-UAVs at the maneuver brigade level. Mini-UAVs cannot observe everywhere all the time. Their ability to get into position and conduct their assigned mission is directly related the characteristics of the aircraft and its associated payload. Mini-UAVs are slower, have a

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[82] Ibid.
[83] Stavrous Toumpis, Stanford University EE Doctoral Candidate, Interview with the author, 07 NOV 01.
[84] Pickering, Raymond D. "Tactical UAVs: A Supported Unit's Primer." *Military Intelligence Professional Bulletin*, (APR-JUN 1997): 25.

shorter range, and reduced endurance when compared to larger systems. These limitations compound as the size of the brigade's area of operations and interest increases. In a small sector, however, mini-UAVs have the ability to observe targets within the upper limits of their performance parameters. Little time wastes moving into position, they operate within their combat radius negating the need for relay, and they can spend a majority of their finite endurance conducting the mission. As the area of operations expands, however, the mini-UAV's limited performance in terms of speed, range, and overall endurance negatively impacts the time an aircraft can spend observing a target. The primary reason for this is their slow speed. This requires them to spend an inordinate amount of their endurance time just getting to the requisite NAI. Limited combat radius is also an issue. If the target is beyond the aircraft's range envelope, a relay is required, which takes another aircraft away from conducting its own mission, and increases the complexity of the mission.

In short, mini-UAVs readily fulfill the needs of a brigade commander who requires a moderately functional, flexible UAV system to counter low technology threats in variable battlefield environments so that he can achieve success through the employment of a high density of collection assets. In this employment condition, mini-UAVs excel. A key component of their suitability is that the large quantity of individual aircraft, typical of mini-UAV systems, allows them to observe numerous NAIs simultaneously, albeit with simplistic, but accurate intelligence gathering tools. While lacking the expanded capability of more robust UAV systems, mini-UAV's employ a simple visual observation means that allows them to provide the commander an accurate picture of what is happening from several points on the battlefield at the same time. Additionally, the variety of mini-UAV systems, and their associated performance characteristics, allow for mini-UAV employment in a multitude of battlefield conditions. Their design disparity allows the mini-UAV's ability to collect against enemy activity in all types of terrain, from open desert, to jungle, to urban areas. The result is that a brigade commander using mini-UAVs can visualize what the enemy is doing in more places, and in more types of terrain, than one using low density UAV systems. Conversely, mini-UAV systems, with their inherent austerity, lack complex and expansive payload capabilities. The result is that mini-UAV systems sacrifice the ability to collect against certain spectrums of enemy activity typical of high technology threats. Additionally, the performance characteristics of mini-UAV aircraft are less capable than more expensive SR-UAVs in terms of range, speed, and endurance; however, they provide brigade commanders a flexible and effective solution for finding a low technology adversary distributed within a large and diverse area of operations.

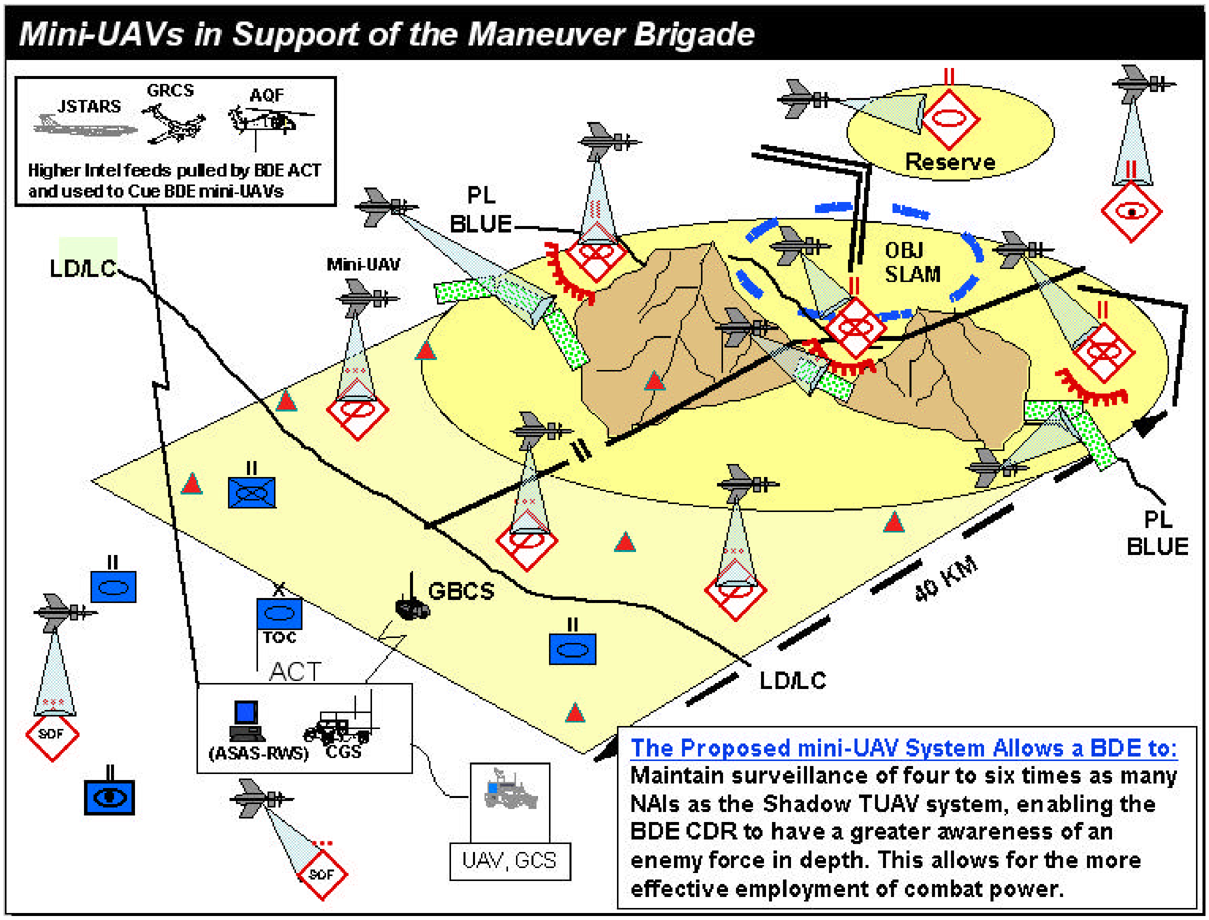

Figure 1. A prospective armor brigade attack supported with the proposed mini-UAV system

CHAPTER IV – CONCLUSION: THE QUALITY OF QUANTITY

I Think it is absolutely sinful that we don't have these things (UAVs) proliferated down to the Brigade level.[85]

GEN Edward Burba, US Army (Ret.)
Battle Command Training Program Senior Mentor

The benefits of having UAVs at the maneuver brigade level, regardless of the configuration, are compelling to be sure. As discussed earlier, they provide the commander an extraordinary capability to observe enemy activity, across a spectrum of environments, with a minimum of risk to his own soldiers. Not all choices are equal, however. While the current Shadow 200 system and a prospective mini-UAV system have their own inherent strengths and weaknesses, the latter system, in direct comparison, has significant advantages in terms of employability, functionality, and cost effectiveness that make it the more efficacious choice for inclusion at the maneuver brigade level. Quite simply, mini-UAVs allow the commander to do more with more at less cost.

Mini-UAVs are more employable as a system than the Shadow TUAV because of their smaller size, enhanced survivability, and ability to operate in more restrictive terrain, which together allows them to be used in more places, more of the time. The Shadow TUAV, as envisioned for inclusion at the maneuver brigade, is still a robust package that occupies a large quantity of physical space. This bulk translates into substantial requirements to move it, both strategically and tactically, in comparison to the more diminutive mini-UAV systems. Additionally, once deployed, its tactical footprint is substantially larger than a mini-UAV system which limits where it can locate within a given area of operations. This is especially pertinent in rugged or close environs where suitable terrain conducive to Shadow TUAV launch and recovery operations is at a premium. Additionally, the larger Shadow TUAV system requires substantially more personnel to physically move, deploy, and operate the system in a tactical environment. This is critically important in rapid deployment situations or when an operation is constrained strategically to a limited number of soldiers who can deploy.

One of the consequences of the mini-UAV's smaller size is that it is more survivable when operating in hostile areas than the relatively large Shadow 200 TUAV. The Shadow 200 TUAV has a physical size of approximately 12 foot by 12 foot, with an approximately 23 square foot wing area. This is approximately four times the Exdrone's, and eight times the Pointer's, overall physical dimensions.[86] The result is the Shadow TUAV is easier to acquire visually, acoustically and electronically, and therefore more vulnerable to attack. The primary threat to UAVs operating at the brigade level are antiaircraft artillery (AAA), thermal based short range surface to air missile (SAM) systems, and small arms surface to air fire from deployed maneuver units. Larger, surface and air based RADAR systems and their associated missile systems also pose a threat, but generally to a lesser degree. In all cases, however, the smaller size inherent in the design of mini-UAVs makes them more difficult to see, whether physically or electronically, and subsequently attack.

All three mini-UAV systems have organic aircraft performance capabilities that enhance their survivability in relation to the Shadow TUAV. The Pointer UAV, for example, capitalizes on its electric propulsion system and narrow, aerodynamically efficient fuselage to cruise through the sky almost silently. This, coupled with its ability to fly its reconnaissance mission from an altitude of over 2,500 feet makes the Pointer virtually invisible on the battlefield. Alternatively, The Exdrone relies on its small physical size and high degree of aerobatic mobility afforded by its delta-winged body to avoid detection and engagement. Its engine, a two-stroke gasoline model, is substantially noisier than the Pointer's. To overcome this, the Exdrone can fly at altitudes up to 10,000 feet, at which point it is virtually invisible to the naked eye. Additionally, if acquired, the Exdrone's exceptional in-flight agility allows it to effectively avoid engagement from ground threats by minimizing its visible cross section to

[85] GEN Edward Burba, oral presentation to BCTP observer controllers at Camp Casey, ROK, 8 DEC 01, in preparation for 2nd Infantry Division's Warfighter Exercise.

those aiming at it. Slower than either of its fixed wing brethren, the Cypher's ability to hover and move in any direction allows it to use available ground cover and concealment to enhance its survivability. In comparison, the Shadow TUAV's greater size, mass, and conventional aircraft design make it less able to avoid both detection and engagement than the smaller systems.

One of the key advantages mini-UAVs have over the Shadow TUAV system in regards to employability is their ability to operate from, and in, virtually any terrain environment. The Shadow TUAV's restrictive launch and recovery requirements, coupled with the large physical footprint for the aircraft, associated runways, and support systems, necessitate the Shadow TUAV operate from moderately open areas. This constraint makes it difficult to use the system in mountainous or jungle areas where such requisite space is difficult to come by. In comparison, mini-UAVs can essentially launch and recover from point locations. The Pointer, for example, requires no more area than that of a clearing through which a soldier tosses it. The Cypher requires less than that, as its VTOL capability lets it fly though any overhead obstructions that would render the Shadow TUAV inoperable. Additionally, the conventional fixed wing flight dynamics inherent in the Shadow TUAV limit its ability to operate effectively in urban and extremely close terrain. Quite simply, it cannot see under things. Conversely, the Cypher's design allows it to fly in and around objects in very tight confines. This ability gives the mini-UAVs a vast advantage in the range of environments within which they can operate.

Mini-UAVs have their limitations too, chief of which is foul weather operations. The Shadow TUAV has a significant employability advantage in periods of foul weather. While neither the Shadow TUAV nor the different mini-UAV systems profiled operate effectively in extreme weather, the Shadow performs better overall in moderately windy and rainy conditions. The principal reason is mass and endurance. The Shadow's 312lb. takeoff weight allows it to handle better in head and cross winds, as well as light rain, than any of the flyweight mini-UAVs. Its heft allows it to stay on track towards the target area, and maintain the camera on its target once it gets there. Mini-UAVs, however, with their

[86] AW&ST and AUVSI, 24

low mass and limited horsepower, consume an inordinate amount of their total endurance during foul weather operations just getting to their station.

Mini-UAVs – AN ADVANTAGE IN FUNCTIONALITY

In addition to their ability to deploy and operate in a greater variety of environments, mini-UAVs have an advantage of functionality over the Shadow TUAV in terms of coverage, mission flexibility, and mission customization. This is not to disparage the Shadow TUAV system. Its capabilities on an aircraft to aircraft comparison, for the most part, far surpass those of the mini-UAVs sampled. It is faster, has greater endurance, and carries a greater payload than any of the other systems. As a tool designed to fulfill the reconnaissance and surveillance target acquisition (RSTA) needs of a maneuver brigade, however, its weakness is its limited numbers. This austerity fundamentally limits how many tasks the Shadow TUAV can successfully accomplish at any given time. Conversely, the greater quantity of aircraft associated with any prospective mini-UAV system allows it to function in different areas, with different sensor packages simultaneously, thus overcoming its individual shortfalls through economies of scale.

A mini-UAV system can conduct reconnaissance and surveillance on a greater portion of a brigade's area of operations and area of interest than the Shadow TUAV system. The Shadow TUAV package contains three aircraft to conduct RSTA operations in support of a maneuver brigade's mission. At any given time, only two of three aircraft would be airborne, as the third would be undergoing maintenance. Therefore, the Shadow TUAVs can maintain surveillance on two NAIs simultaneously for extended times, and three for shorter periods if operations are surged. A mini-UAV system, depending on its configuration, has as many as 10 times the aircraft, each with a similar visual footprint on the ground as a Shadow 200 TUAV. Each aircraft's endurance is about half that of the Shadow's, however two-thirds of the total number of mini-UAVs can remain aloft at any given time, after considering refueling and maintenance requirements. This allows for the theoretical surveillance of up to 20 NAIs within a brigade's area of operations for extended times. This extensive coverage allows the brigade commander to dedicate UAVs to support each of his nine maneuver companies, as well as his brigade's targeting efforts and rear area operations.

Additionally, the quantity of mini-UAVs in relation to Shadow TUAVs within the brigade allows the commander greater flexibility to use a variety of payloads during a single operation. Currently, the Shadow TUAV has the ability to carry several different types of payloads, which give it a wide variety of collection capabilities. It can collect imagery, signals intercept, or track moving target indicators with a high degree of effectiveness. It cannot, however, do this simultaneously from the same aircraft. Therefore, to employ multiple sensors to achieve a reconnaissance objective requires multiple aircraft. Once again, the Shadow TUAV systems' limited numbers directly limits how effective this approach is. With two aircraft available, a typical mission may consist of one aircraft with an MTI collector to identify moving vehicles, and a second aircraft carry an imagery payload to track the target once cued by the MTIs. The large quantity of aircraft associated with a mini-UAV system, however, would allow for not just an MTI collector, but also several signals intercept aircraft to help identify unit types and command and control relationships, as well as several imagery platforms to track multiple maneuver formations and conduct surveillance of critical NAIs. This blanket coverage provides the commander a greater degree of situational awareness within his area of operation.

Lastly, the inclusion of a mini-UAV system that includes different types of aircraft allows the commander to tailor his reconnaissance effort to specific environments. This is particularly important in operations where the brigade is required to operate in both open and close terrain. The Shadow TUAV system, with its limited number of aircraft and conventional flight profile, has limited effectiveness when operating in urban terrain. This is especially so in larger urban areas where tall buildings, highways, and other man made obstructions restrict visibility. The Shadow TUAV will only be able to observe NAIs from an overhead perspective, providing at best a two dimensional view of enemy activity. A customized mini-UAV package, however, could incorporate both conventional winged aircraft and VTOL platforms, to observe activity from both overhead and lateral vantage points, providing the commander a more complete picture of what exactly the enemy was doing. Additionally, the VTOL aircraft and its unique omni-directional flight profile provide the commander the ability to see areas within an urban environment that neither ground troops nor fixed wing aircraft can.

Mini-UAVs – AN ADVANTAGE IN COST

A final, but key, advantage a prospective mini-UAV acquisition strategy has over the current Shadow TUAV program is in costs related to acquisition, training, and tactical sustainment. As described earlier, the Shadow TUAV is a very capable, yet acutely expensive system. This is in part true because its design lineage is from systems dedicated to higher echelon roles. Its current configuration is the result of years of research and development, which has systematically improved upon existing division level UAV systems, primarily the Pioneer, Hunter, and Outrider UAVs. The result is a latticework of high quality components, which, while reliable and functional, have been refined to the point where they are very expensive to produce, and replace, in relation to what tasks they are required to accomplish at the brigade level. In essence, the Shadow TUAV represents engineering overmatch for the mission of supporting the maneuver brigade. The net effect is that the Army pays for features not required at the brigade level.

Mini-UAVs represent a more cost effective alternative, to meet stated brigade UAV requirements, than the Shadow TUAV system. Brigade level UAV operational requirements include: a three-hour endurance, an imaging capability with both EO and IR functions, and a range of 50km.[87] The Shadow TUAV clearly exceeds all these standards by a large margin. It has an endurance of up to eight hours, a data link range of 180km, and a can carry a myriad of payload configurations.[88] This excessive capability is not gratis. By taking the Shadow 200, essentially a division level asset, and applying it to the brigade, the Army fulfills their proposed UAV requirements, but pays a premium for excess

[87] COL William Knarr, "Army Family of UAVs", slide 6 & 13, Powerpoint Briefing; available from http://huachuca-dcd.army.mil/tsmuav/tsm-uav.htm; Internet; accessed 28 NOV 01.
[88] AW&ST and AUVSI, 24

capability, and overlooking a more efficient means of satisfying the requirement. A brigade level UAV acquisition strategy, built around mini-UAVs more closely marries system performance to stated requirements. The EXDRONE, for example, can meet the three-hour endurance requirement, transmit data from 50km and carry a wide variety of payloads.[89] It achieves this at a cost of between one-third to one-sixth that of the Shadow TUAV system, with three times the number of aircraft. Quite simply, you get more for less with mini-UAVs.

Additionally, the training costs associated with a mini-UAV acquisition strategy are less than those with the current Shadow UAV plan. As currently envisioned, each Shadow UAV package at the brigade will require six to eight soldiers trained in the 96U Unmanned Aerial Vehicle Operator Military Occupation Specialty (MOS). The basic course, which takes place at Fort Huachuca, Arizona, takes approximately five and a half months to produce one basic UAV operator capable of operating the different components of the system.[90] Additionally, there is a requirement to develop instructors capable of teaching the system, maintain functional systems upon which to train on, and establish facilities within which to train the students. All of these together represent a substantial cost in terms of personnel, resources, and funds. Conversely, mini-UAV systems are less elaborate systems with fewer components upon which to train and man. Some mini-UAV systems require only two personnel, who do not necessarily require extensive specialized training to perform their tasks. Soldiers at their unit, for example, can use on the job training to learn Pointer UAV, because its austere components list and straightforward launch and recovery method simplify instruction.[91] The Exdrone and Cypher systems, while more elaborate than the Pointer, are still relatively simple to use, require fewer soldiers to conduct operations, and take less time to train the operators to proficiency, than the Shadow TUAV system.

Finally, mini-UAVs are more cost effective to sustain in a tactical environment than the Shadow TUAV because there are fewer system components to fail, the components are easier to replace when

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[89] Ibid, 29
[90] Rod Powers, "Army MOS Qualifications," Internet, http://usmilitary.about.com/library/milinfo/arjobs/bl96.htm. accessed 21 DEC 01.
[91] Martyn Cowley, Pointer UAV Project Manager, AeroVironment, Inc., interview with author, 17 NOV 01.

they do break, and the quantity of aircraft associated with a mini-UAV system limits the impact of the loss of an individual aircraft.

One of the key advantages mini-UAVs have over the Shadow TUAV in a tactical environment is their lack of overall system complexity. The Shadow TUAV package is a relatively complex system of systems. If any single component fails, whether the GCS, the LRS or the data link antennae, the UAV system's functionality as a whole is severely degraded. This is especially important when deployed into an immature theater where the logistical support system has yet to be completely developed. A component failure incurs not just the expense of extended logistical effort required to replace the failed part, but also a cost in terms of lost collection in support of the brigade's operation. On the other hand, mini-UAVs have fewer individual components to fail. The Cypher, for example, requires no LRS and therefore is not dependent on hydraulics that could break and leave it without a means to get airborne. The Pointer is an even simpler system. It does not even require petroleum products to maintain its functionality. Additionally, when mini-UAV elements do fail, there are similar components within the brigade that serve as quick substitutes. The GCS for mini-UAVs, for example, all use ubiquitous Windows based laptop computers. If one fails, any laptop in the TOC could serve as a replacement with a simple installation of software. If the Shadow's Sun Sparc workstation based GCS fails, its replacement must come from sources external to the brigade.

Finally, the quantity of aircraft associated with a mini-UAV system is more cost effective than the Shadow TUAV because it limits the impact of the loss of an individual platform. With only three aircraft per Shadow system, each individual plane represents one-third of the total UAV collection capability for the brigade. If a Shadow 200 aircraft is lost to mechanical failure, crashing, or enemy action the impact on the brigade's ability to perform reconnaissance and surveillance operations is significant. Additionally, a replacement aircraft will take a significant amount of time and money to acquire with the associated cost of lost intelligence gathered in support of a specific operation. A brigade level UAV strategy based on a quantity of mini-UAVs is much less vulnerable to the loss of a single aircraft. With a fleet of mini-UAVs at their disposal, the loss of even several aircraft would have a minimal net impact on the brigade's ability to continue to conduct sustained intelligence and electronic warfare operations, because of their ability to redirect aircraft to cover critical NAIs. With a Shadow TUAV system, the loss of an aircraft represents a gap in the coverage that may never be reconciled.

System	Cost	Performance	Size	LRS	Payload
Shadow 200 by AAI Corporation	$250k-$500k per aircraft	**Max Alt**: 15,000ft **Endurance:** 11 hrs **Max Speed:** 120kmh **Tether**: 200kms	**Width:** 12.8ft **Height:** 2.8ft **Wing Area**: 23 sq. ft. **Weight:** 315lbs	Pneumatic launcher on road, runway takeoff and landing (requires 100')	**51lbs.** **Types:** Color TV/FLIR, relay
Exdrone by BAI Aerosystems, Inc.	$10k-$25k per aircraft depending on order QTY	**Max Alt**: 10,000ft **Endurance:** 5.5 hrs **Max Speed:** 160kmh **Tether**: 50kms, can extend with relay	**Width:** 8.1ft **Height:** 1.7ft **Wing Area**: 12 sq. ft. **Weight:** 95lbs	Pneumatic launcher on road, runway takeoff and landing (requires 50')	**17lbs.** **Types:** Color TV/FLIR, SIGINT
Pointer by Aero-Vironment, Inc.	$5k-$10k per aircraft depending on order QTY	**Max Alt**: 5,000ft(+) **Endurance:** 2.0 hrs **Max Speed:** 70kmh **Tether**: 8-10kms	**Width:** 9ft **Height:** .75ft **Wing Area**: 6 sq. ft. **Weight:** 7lbs	Hand thrown take off technique; lands by stalling	**4lbs.** **Types:** Video, IR, night vision, Chemical
Cypher by Sikorsky Aircraft, Inc.	$25k-$50k per aircraft	**Max Alt**: 10,000ft **Endurance:** 2.5 hrs, **Max Speed:** 120kmh **Tether:** 50kms	**Width:** 6ft **Height:** 2.5ft Wing Area: 16 sq. ft. **Weight:** 300lbs	VTOL	**50lbs.** **Types:** Video, FLIR, mine detection

Figure 2. A comparison of the Shadow 200 and prospective mini-UAV aircraft

CHAPTER V: Mini-UAVs – A RECOMMENDED SOLUTION PATH

He that will not apply new remedies must expect new evils; for time is the greatest innovator.[92]

Francis Bacon
1561-1626 (English Essayist)

This monograph demonstrates why the U.S. Army should alter its current UAV acquisition strategy for maneuver brigades from one in which limited numbers of high capability systems are acquired, in favor of another that fields a large quantity of less capable mini-UAVs. The mini-UAV option proved itself more advantageous in employability, functionality, and cost considerations. This chapter marries the aforementioned analysis to a recommended course of action in terms of a specific alternative UAV acquisition strategy. In other words, this chapter provides a solution path focused on the acquisition of a prospective mini-UAV system which offers the future maneuver brigade commander greater employability, more functionality, with less overall costs than the current Shadow TUAV program.

The structure of a prospective mini-UAV system should reflect key advantages mini-UAVs have, as a generic group, over the larger Shadow TUAV system in order to better provide for the reconnaissance and surveillance functions within the brigade. These factors include: austerity of design, quantity of assets, and quality of support in relationship to cost. When effectively integrated into the blueprint of a prospective mini-UAV system, the result is a tool that allows the maneuver brigade commander to do more, with more, at less overall cost. This quality of quantity is the cornerstone of the recommended mini-UAV system described below. It leverages leverage the benefits of having numerous simple platforms collecting simultaneously, backed by an austere support system, in order to provide the commander an unheralded level of situational awareness within his area of operations.

[92] Lord Francis Bacon and edited by Joseph Devey. *Novum Organum* (New York: P.F. Collier & Son, 1902), 27.

This monograph recommends that the Army adopt a mini-UAV system at the maneuver brigade level that consists of: 10 BQM 147A Exdones, 10 Pointer UAVs, and six Cyphers VTOL UAVs, three laptop GCS with associated portable datalink antennas, and one Exdrone LRS. The complete system can easily deploy by air in a single C-130 airplane, and subsequently move tactically by a single five-ton truck with trailer. Additionally, this package includes five 96U soldiers (one E5 and four E1-E4s) to accommodate 24-hour operations and fulfill the LRS, mission planning, and flight operations tasks. To limit costs, the system would incorporate only two payload types: a color tilt-pan-zoom video camera with integrated GPS for daytime and low-light use, and a FLIR system for nighttime and poor visibility conditions. This minimalist capability is in tune with the original moderate design specifications for a brigade level UAV.[93] A signals relay for both voice and data would be organic on each aircraft thus negating the requirement for a specialized payload. The cost of such a system, accounting for economies of scale, limitations in payload variations, and reduction of support requirements would likely range between $500,000 and $600,000 as opposed to the $2.5- 3.0 million currently envisioned for the Shadow TUAV implementation.

MORE IS BETTER – PROPOSED SYSTEM STRENGTHS

This recommended system design has inherent strengths that make it a better solution to the problem of providing UAV support at the brigade level because of its multi-functional platform mix, high collection asset vice support requirement distribution (tooth to tail ratio), and ease of program implementation. Individually, these factors point specifically to the ability of a prospective commander to execute a more effective R & S plan within his area of operation, at less cost, and with more immediacy than the current Army strategy. Collectively, however, these features lend credence to the overall concept of the quality of quantity in regards to UAV deployment strategy.

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[93] COL William Knarr, "Army Family of UAVs", slide 10, Powerpoint Briefing; available from http://huachuca-dcd.army.mil/tsmuav/tsm-uav.htm; Internet; accessed 28 NOV 01.

This proposed asset mix is not arbitrary. Its design allows the brigade commander to conduct RSTA operations across the width and breadth of his area of operations, in a variety of battlefield conditions, and against multiple threats simultaneously. What provides him this flexibility is the mixture and quantity of aircraft with their unique performance characteristics. The Exdrone component, for example, has the ability to conduct reconnaissance or sustain surveillance of up to six brigade NAIs at the depth of the brigade's area of operations, in both open and moderately close terrain. It is able to maintain this perpetual coverage due to the continual cycling of off station aircraft. Simultaneously, the Cypher can conduct either reconnaissance or surveillance of up to four additional NAIs throughout the depth of the brigade's area of operations in the most restrictive of terrain environments to include urban areas. Lastly, the Pointer is included as a short-range (under eight kilometers) system designed to fly in direct support of the brigade's nine maneuver companies under the command and control of their respective maneuver task force's headquarters. The result is a latticework of coverage capability that by design can support the individual tasks and purposes of the brigade's major subordinate commands as well as enhance the commander's visualization of his area of operations. The current Shadow TUAV system, and its associated limitations of quantity and functionality, does not provide this flexibility.

Adding to the viability of this recommendation is the relatively high tooth to tail ratio of collection assets deployed vice resources dedicated to supporting them. This intentional austerity makes the overall system less complex, simpler to sustain, and much less expensive than the Shadow 200 plan, which in turn allows it to deploy an order of magnitude more collection assets for less cost. This is attributable to a "less is more" design philosophy wherein the value of having fewer components is there are fewer individual nodes to fail that might result in an overall system failure. The proposed mini-UAV scheme, by design, simply does not need as much infrastructure to operate as the Shadow TUAV does. It has fewer command and control nodes, takes fewer resources to launch and recover the aircraft, and needs less manpower to transport, prepare, and operate the system. The result is decision makers can allocate more money to fielding collection assets rather than to the components required to sustain them.

A contributing factor for the low tooth to tail ratio of the Shadow TUAV program is the high cost of the aircraft itself. The cost of the individual aircraft is directly proportional to the cost of the required support. The relatively low cost and high volume of mini-UAVs makes the loss of an individual aircraft a disheartening, but not earth-shattering event. The loss of an individual Shadow 200 TUAV, however, represents a much larger impact to the brigade in terms of both lost capability and sheer dollar value; therefore, more robust support systems are emplaced to ensure those few aircraft on hand remain operational.

There is a cost related to the mini-UAV's design austerity, however, and is measured in functionality. The proposed mini-UAV system design aims to meet the standards listed in the original design proposals for brigade level UAVs. This it does very well. If required to fulfill functions beyond the scope, other systems are much more suitable.

Lastly, the proposed acquisition strategy can be implemented very quickly, which is a particularly critical factor now in an international security environment in which every nightly news broadcast might bring with it a potential deployment. The system components listed above are not theoretical sketches on some drawing board, but assets that have either been combat tested (e.g. the Pointer and Exdrone), or have received extensive simulated combat testing (e.g. the Cypher). Both the Exdrone and Pointer, for example, have flown hundreds of hours of combat missions in such diverse environments as Iraq, Kosovo and Somalia with a substantial record of reliable performance. Additionally, these systems are currently in production and have manufacturers who are experienced in large-scale deliveries. The Shadow 200 TUAV program, however, is in danger of falling victim to the longstanding UAV curse – program postponement. After the seventh Shadow crash, only 600 flight hours into evaluation trials in May 2001, the Army questioned Shadow's reliability and temporarily postponed Initial Operational Test and Evaluation (IOT&E) trials. This could subsequently slip the delivery schedule to maneuver brigades by up to a year, or more.[94] Waiting for the Shadow TUAV acquisition

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[94] Lawrence Newcome, "UAV Newsroom," Internet, http://www.uavforum.com/library/news.htm. Accessed 21 DEC 01.

strategy to run its course essentially means in the near term that soldiers are at risk of deploying without any UAV support at all, despite the current availability of a feasible, acceptable and suitable alternative now.

THE OPPORTUNITY COST – PROPOSED SYSTEM LIMITATIONS

The level of situational awareness at the brigade level theoretically provided by the mini-UAV system, recommended herein, is unparalleled in the annals of military operations. If implemented, it will allow the future brigade commander, his subordinate commanders, and his supporting brigade staff to see critical areas of the battlefield at critical times, thus allowing him to make critical decisions more effectively. This capability, however, comes with a cost. There are tradeoffs associated with the choice to acquire the specific mini-UAV strategy recommended above. Chief among these are the sacrifices in multi-discipline collection capability, an increase in the complexity of reconnaissance and surveillance operations, and sensory overload of the commander and his staff presented with too much information. These challenging issues, while not preclusive to the adoption of the mini-UAV strategy, are significant enough to deserve further analysis as to their impact on brigade operations.

In order to limit overall costs, reduce the system's physical footprint, and focus collection efforts in line with the stated design parameters, the payloads fielded with the recommended system are intentionally limited to day, and night, imaging systems. The Shadow 200 TUAV, and even the mini-UAVs recommended for acquisition, is capable of donning a myriad of payload configurations that will allow them to do everything from mine detection to chemical reconnaissance. The recommended system, however, opted not to integrate these advanced capabilities because of the increase in cost they would have incurred to the overall system. There would also be an additional penalty in the physical size of the system on the ground. The inclusion of a signals intercept package represents an illustration of this point. Each signals intercept payload would cost approximately $5,000 additional per aircraft to field. In addition, 98G, Signals Intercept Linguists, would be required to transcribe the intercepted communications, while 98C, Signals Intercept Analysts, are required to manage targeting and collection of enemy frequencies. The result is an increase in both the dollar cost of the system and the physical size of the brigade's Analytical Control Team (ACT) in response to the additional requirement to manage this function. The opportunity cost, therefore, is to not have a UAV based SIGINT collection means organic to the brigade. The brigade, however, can still receive this type of information, but must rely on a superior echelon to insure its integration.

Reconnaissance and surveillance operations planning, preparation, and execution will become dramatically more complicated upon adoption of the recommended mini-UAV system strategy. Already a staple of after action reviews (AAR) at the army's combat training centers (CTC), R and S operations will only become more complex with the addition of a collection system that brings an additional score of airborne collection assets into the equation. Not all is doomed, however. Shortfalls current brigade level R & S efforts have is their ability to focus efforts on reconnaissance objectives, allocate requisite resources towards supporting NAIs, and subsequently tracking enemy formations across the whole of the brigade's area of operations.[95] The plethora of collection assets associated with the adoption of the mini-UAV package will meet this challenge. The difficulty remains, however, as to how to plan and manage this effort. The problem of airspace command and control, and the distributed command and control of the UAVs themselves, further complicates this task. The Pointer UAV, for example, will likely operate OPCON to a task force during specific operations, but its routes must integrate into the brigade's overall airspace management system in order to avoid mid-air mishaps involving UAVs. An additional level of complexity to be sure, but one whose benefits in terms of intelligence collected is worth the additional effort.

One of the unintended consequences of the successful implementation of a mini-UAV system is to provide the commander too much of a good thing. With his fleet of UAVs providing him information from all corners of his area of operations, coupled with information from his brigade reconnaissance troop (BRT), task force scouts, ACT, units in contact, combat laser designation teams (COLTs), among

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[95] Jenny Solon, "National Training Center Trends Compendium," Internet, http://call.army.mil/products/ctc_bull/01-11/intell.htm. Accessed 23 DEC 01.

others, a brigade commander can quickly become awash in too much information and not enough analyzed intelligence. The result can be described as sensory overload, a condition where an individual receives more information than they have the faculty to process, thus clouding their decision making process. LTC James R. Rice, an infantryman who has seen combat in Cambodia and Korea, and worked on the development of the Force XXI initiative, described this phenomenon. "There is such a thing as providing a commander too much information…too much information can make indecisive people more indecisive. Some people never have enough information or they hold off on making a critical decision until they get the piece of information they expect to come."[96] To alleviate this problem, the staff needs to be an intelligent conduit of information passed to the commander. The commander does not need to know everything, but he does require that his commanders and staff help him answer his commander's critical information requirements (CCIR). Focusing on answering these will facilitate, not hinder, the commander's ability to make decisions.

CONCLUSION – A SYSTEM FOR TOMORROW, TODAY

There is something inherently powerful about a UAV and its ability to transmit video images of enemy activity in near real time. It is mesmerizing, and more importantly, it accomplishes dull, dirty and dangerous reconnaissance and surveillance tasks without having to risk human life in the process. Therein lies the reason for their recent and expected enduring popularity. This is especially so at the brigade and below level where national policy is often entrusted to 19-year-old soldiers operating some of the most advanced weaponry on the planet. The promise of a UAV system at the brigade is to provide a collection asset that will limit the risk to these young soldiers, while simultaneously allowing the commander to visualize his area of operations to the degree required to make effective and lethal decisions. The fundamental question this monograph answers is whether it is a better to support the commander by fielding a few, albeit very capable aircraft, embodied by the Shadow 200 TUAV plan, or

[96] LTC James R. Rice, infantry officer, interview by author, 12 JUL 1998.

alternatively, distribute a large quantity of simple, yet effective, systems associated with the mini-UAV proposal. The answer is demonstratively the latter in terms of employability, functionality and costs.

While the Shadow TUAV program, as currently envisioned for implementation, is a step forward in aiding the brigade commander to see himself, the terrain, and the enemy, the proposed mini-UAV system, with its ability to simultaneously collect across the width and breadth of the brigade's area of operation, exceeds the Shadow TUAV's collection capability at far less cost. The Shadow is a viable tool at the brigade level, but too few aircraft, too large a support base, and feature overkill causes the system to buckle under the weight of its own extravagance. What was originally envisioned as a simple idea to put an austere yet effective collection asset in the hands of those at the Army's lowest tactical echelon, has systematically ballooned into the multi-million dollar leviathan it is today. The prospective mini-UAV system, however, represents a desired step backwards towards the original intent of UAVs for the maneuver brigade. They are simple, cheap, and ubiquitous. This austerity, coupled with the quality of quantity, gives a mini-UAV system a decided advantage over the Shadow TUAV in terms of accomplishing the specific set of tasks required of it at the brigade level,

This specific mini-UAV proposal is not a panacea. Its design can meet a specific set of criteria and fulfill a finite set of tasks. It will not make reconnaissance problems at the brigade level disappear overnight. It does offer, however, a feasible, acceptable, and suitable alternative to the Army's current acquisition strategy for UAVs at the maneuver brigade level. This is critically important now as weaknesses begin to appear in the plan to acquire the Shadow 200 TUAV. An alternative acquisition strategy, based on the quality of quantity provided by the inclusion of mini-UAVs, provides just the right solution to the problem of providing UAV support to the maneuver brigade. As shown, in terms of employability, functionality, and cost this alternative strategy has a measure of effectiveness beyond which the current plan is able to attain.

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