MEDUSA'S MIRROR: STEPPING FORWARD TO LOOK BACK "FUTURE UAV DESIGN IMPLICATIONS FROM THE 21ST CENTURY BATTLEFIELD"

A MONOGRAPH
BY
Major David A. Brown
Field Artillery

School of Advanced Military Studies
United States Army Command and General Staff College
Fort Leavenworth, Kansas

First Term AY 97-98

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
18 December 1997

3. REPORT TYPE AND DATES COVERED
MONOGRAPH

4. TITLE AND SUBTITLE
MEDUSA'S MIRROR: STEPPING FORWARD TO LOOK BACK
"FUTURE UAV DESIGN IMPLICATIONS FROM THE 21st CENTURY BATTLEFIELD"

5. FUNDING NUMBERS

6. AUTHOR(S)
MAJOR DAVID A. BROWN

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
SCHOOL OF ADVANCED MILITARY STUDIES
COMMAND AND GENERAL STAFF COLLEGE
FORT LEAVENWORTH, KANSAS 66027

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
COMMAND AND GENERAL STAFF COLLEGE
FORT LEAVENWORTH, KANSAS 66027

10. SPONSORING / MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION / AVAILABILITY STATEMENT
DISTRIBUTION UNLIMITED

12b. DISTRIBUTION CODE

13. ABSTRACT *(Maximum 200 words)*
SEE ATTACHED

14. SUBJECT TERMS

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
UNCLASSIFIED	UNCLASSFIED	UNCLASSIFIED	UNLIMITED

ABSTRACT

Medusa's Mirror: Stepping Forward to Look Back: "Future UAV Design Implications from the 21st Century Battlefield" by Major David A. Brown, United States Army, 48 pages.

Will general purpose unmanned aerial vehicles, (UAVs), best meet the requirements of the twenty-first century battlefield? Although much of the information is speculative of future progress in this emerging field, this paper attempts to link available data to anticipated trends in both the international security environment and doctrinal directions embodied in Joint Vision 2010, as well as other Army initiatives.

The argument for future UAV design is captured in the conceptual framework of JV2010, a growing scarcity of UAV resources at the tactical level, and an increase in the proliferation of UAV technology both internationally and commercially. This leads into a discussion of the likely link to increased functional uses of UAV technology for military application. Validity for future speculation concerning UAV technology and its use is also based on , adaptability and projections of feasibility in terms of likelihood, cost, training, logistical support, and the near future availability of discussed technology.

"Mission specific functionality" in future UAV design is inevitable. International and commercial proliferation and the vast expansion of unmanned flight will ultimately result in an array of UAV usage much to large to place on any one platform. As UAVs proliferate, acceptance will go up, technological gains will be made, cost and size will go down, and functionality will almost assuredly increase. How this technology is developed today will have a direct impact on our ability to effectively leverage the promises of its possible capabilities tomorrow. A recommendation is that the U.S. shift developmental efforts soon enough to meet future needs before confronted with them.

Specific recommendations include continued funding UAV development efforts for the promises it holds. Secondly, continue to make current initiatives as modular as possible by diversifying capabilities through payload sensor flexibility. Thirdly, continue to fund UAV acquisition of initiatives such as Outrider UAV so as to give additional UAV capability to the tactical level. Finally, carefully research the possibility of distinct functional UAV designs, particularly in the areas of battlefield supply, and lethal UAV platforms for a variety of uses.

SCHOOL OF ADVANCED MILITARY STUDIES

MONOGRAPH APPROVAL

Major David A. Brown

Title of Monograph: *Medusa's Mirror: Stepping Forward to Look Back "Future UAV Design Implications from the 21st Century Battlefield"*

Approved by:

_________________________ Monograph Director
COL Gary E. Phillips, MA, MMAS

_________________________ Director, School of Advanced Military Studies
COL Danny M. Davis, MA, MMAS

_________________________ Director, Graduate Degree Program
Philip J. Brookes, Ph.D.

Accepted this 18th Day of December 1997

DTIC QUALITY INSPECTED 3

ABSTRACT

Medusa's Mirror: Stepping Forward to Look Back: "Future UAV Design Implications from the 21st Century Battlefield" by Major David A. Brown, United States Army, 48 pages.

Will general purpose unmanned aerial vehicles, (UAVs), best meet the requirements of the twenty-first century battlefield? Although much of the information is speculative of future progress in this emerging field, this paper attempts to link available data to anticipated trends in both the international security environment and doctrinal directions embodied in Joint Vision 2010, as well as other Army initiatives.

The argument for future UAV design is captured in the conceptual framework of JV2010, a growing scarcity of UAV resources at the tactical level, and an increase in the proliferation of UAV technology both internationally and commercially. This leads into a discussion of the likely link to increased functional uses of UAV technology for military application. Validity for future speculation concerning UAV technology and its use is also based on , adaptability and projections of feasibility in terms of likelihood, cost, training, logistical support, and the near future availability of discussed technology.

"Mission specific functionality" in future UAV design is inevitable. International and commercial proliferation and the vast expansion of unmanned flight will ultimately result in an array of UAV usage much to large to place on any one platform. As UAVs proliferate, acceptance will go up, technological gains will be made, cost and size will go down, and functionality will almost assuredly increase. How this technology is developed today will have a direct impact on our ability to effectively leverage the promises of its possible capabilities tomorrow. A recommendation is that the U.S. shift developmental efforts soon enough to meet future needs before confronted with them.

Specific recommendations include continued funding UAV development efforts for the promises it holds. Secondly, continue to make current initiatives as modular as possible by diversifying capabilities through payload sensor flexibility. Thirdly, continue to fund UAV acquisition of initiatives such as Outrider UAV so as to give additional UAV capability to the tactical level. Finally, carefully research the possibility of distinct functional UAV designs, particularly in the areas of battlefield supply, and lethal UAV platforms for a variety of uses.

TABLE OF CONTENTS

I. Introduction

What was that snaky-headed Gorgon-shield
That wise Minerva wore, unconquered virgin,
Wherewith she freezed her foes to congealed stone Milton [1]

Such execution, so stern, so sudden, wrought the grisly aspect of terrible Medusa,
When wandering through the woods she turned to stone their savage tenants,
Like rage in marble Armstrong [2]

For now we see through a glass, darkly I Corinthians 13:12 [3]

In ancient Greek myth, the tale is told of Perseus who slew the Gorgon Medusa. Her appearance with a writhing mass of serpents upon her head was so terrifying that anyone who gazed upon her face was instantly paralyzed and turned to stone. In order for Perseus to kill her, he could not look at her directly. Instead, he looked at a dim reflection of her image on a highly polished shield, and walking backwards towards her, cut off her head.[4]

With headlines in defense trade journals over the last year reading, "unmanned aerial vehicles poised to become an indispensable US military asset,"[5] "UAVs vie for the sky in a billion dollar market,"[6] and "real-time surveillance sans pilot danger provides cost-effective monitoring and electronic warfare,"[7] it is abundantly clear that Unmanned Aerial Vehicles, (UAVs), are finally coming of age. Although these assets are currently not in the inventory in large quantities, we may not be planning for the best use of these assets as they become more prevalent.

Even as the Greek hero Perseus had his own hairy issue of hissing serpents, waiting for his own misstep of uncertainty, which would have resulted in stony paralysis, we must also not allow a misstep in development of future UAV technology. Now is the time to achieve the proper mix and design of what will certainly become a major combat multiplier on future battlefields. A misstep in assessing the tangled choices of future UAV design could greatly hinder this technology's ability to meet our needs on the battlefields of the twenty-first century.

Perseus solved the problem by looking back at the problem indirectly, although the reflection was difficult to perceive. We have UAVs on the battlefield - the question is - what are they designed to do? We cannot adequately answer that question solely from today's perspective. We must attempt to "step forward" by examining the trends we are most likely to encounter on the battlefield of 2010 or beyond. We must then use those educated assumptions and speculations to look backwards, at the Medusa, through a dim mirror, helping us design today the UAVs we believe to best suited for tomorrow's use.

This paper intends to explore the differences between a general purpose and a functional design approach, and will attempt to answer the question of which of these approaches will best serve the needs of the services on the twenty-first century battlefield. Currently, UAVs are seen in the Army as generic intelligence gathering devices which can be tailored to the mission at hand. Fielding a general purpose UAV retains a certain amount of flexibility in the way that we have initially integrated the UAV concept. Another possible alternative is to build functionally specific UAV designs, each for a different purpose.

After an examination of the emerging future security environment, and a brief overview of historical and current U.S. UAV initiatives, major areas of comparison will center around the following areas: 1) stated doctrinal endstates as embodied in *Joint Vision 2010, (JV2010)*, and other service specific initiatives such as Army 2010, Force XXI, and Army After Next, (AAN); 2) scarcity of current UAV assets, 3) proliferation of UAV technology; 4) examination of a possible expansion of "mission specific" UAV military tasks; and 5) the comparable amount of adaptability between a general versus a functional future UAV design approach.

Before going further it is necessary to define the term UAV as used in this monograph. As will be later expounded on, the possible roles for UAVs are continuing to expand rapidly. For the purposes of this monograph, the term UAV, (unless otherwise specified), refers to a "powered aerial vehicle that does not carry a human operator, uses aerodynamic forces to provide lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload."[8]

II. **Defining the Emerging Security Environment**

Changing threat environments, new emerging capabilities, shrinking resources, and many other variables both known and unknown are central to this issue. In addition to the Quadrennial Defense Review, (QDR), released earlier this year by the Department of Defense, Congress is releasing their own findings concerning implications for military programs in the National Defense Panel (NDP) report to be released in December 1997.

Military and civilian planners and strategists are attempting to design a future integrated military force structure that is capable of conducting a broad range of activities stretching across the possible spectrum of the employment of military forces. This spectrum ranges from large scale, high tech combat operations against a peer competitor,[9] through security operations to deter regional powers, to serving as a protection force for humanitarian assistance efforts being conducted by the UN, local governments, or non-governmental organizations, (NGOs). The first step forward is a speculative examination or forecast of the international security environment. What are the conditions such a force will contend against and amongst? What threats will a future U.S. military force possibly face? Given that prophecy is always a tenuous prospect at best, those who attempt to part the mists of time can probably at best describe trends which might reflect the path of several possible futures.

Dr. Steven Metz is the Stimson Professor of Military Studies at the U.S. Army War College, analyst at the Strategic Studies Institute, and author of more than fifty articles on world politics and national security affairs. In wrestling with possible future security trends, Dr. Metz makes the argument that the larger security environment is in a state of transition that could eventually settle into one of several different alternative future security environments. These alternative futures range from traditional state based warfare, to one framed by states dealing primarily with internal collapse and violence. Other possibilities include a tiered environment largely along the have and have not lines, or continued conflict from primarily ideological or economic conflicts. It suffices here to point out that Dr. Metz makes a compelling case that one of the greatest implications of this thought process is that it is possible that these environments differ significantly enough that they would argue for radically different U.S. military structures or designs.[10]

In addition to possibly radically different conflict constructs that might lead to a yet unknown post Cold War security environment, other emerging trends present themselves as part of the near future matrix of the next ten to fifteen years. These trends include:

- increased levels of information processing which impacts decision cycles
- an increase in the sheer volume of information available to individuals or groups
- Russia's and China's movement toward free market economies
- direction and growth of the European Union
- direction and expansion of a continued NATO
- continued regional conflicts in Bosnia, Korea, South West Asia, and the Middle East
- vast population growth in many under developed countries and regions
- continued technological advancement in communications and weaponry
- continued growth of international organized crime
- expanding proliferation of Weapons of Mass Destruction, (WMD), particularly by non-state actors
- increases in terrorism especially in ability to use and probability in using WMD.

This list is not inclusive and has been drawn from numerous sources. Its importance lies in seeing the breadth of the spectrum and backdrop against what a future military force must be able to contend with.

As we find ourselves gazing into this dark glass and pondering future environments, the next question that rises out of the mist is - what roles will the military be used for in one or more of the above scenarios? This is particularly hard to refine, as it is generally difficult in a democratic pluralistic society to agree on operational or strategic ends. Our elected officials are rotated on a frequent basis (in most cases) making it difficult to maintain any long term continuity. In addition, in our western mind-set, and instant gratification society, we tend to want solutions to complex problems yesterday, or at least by tomorrow. This is seen in our voracious appetite for quick solutions: microwaves, email, faxes, drive throughs, sit-com solutions, sound bites, headlines, fast food, and exit strategies. Sometimes this leads to advocacy of unsound simple "solutions" to complex problems. Furthermore, the very diverse nature of American society makes it extremely difficult to define common ideas of what properly constitutes national interests both here and abroad.

Dr. Metz, although speaking about holistic strategies commonly found in ideologically based security systems, makes a statement that is useful for describing the problems with constructing any overall national strategy for the American government. He states, "for a variety of reasons, some dealing with the distribution of power within the government and some dealing with an attitude toward the use of force that sees it as an aberration rather than an integral part of strategy, crafting and sustaining a coherent, holistic strategy is somewhat difficult for Americans."[11] He goes on to state that to more fully integrate the use of military force into an overall strategy "would probably require fundamental reform of the strategy-making mechanisms used in the United States and fundamental reform of the policymaking system."[12]

The last National Security Strategy, (NSS), of "Engagement and Enlargement" as well as the current one of "A National Security Strategy for a New Century" both operate on the premise that the enlargement of the body of democratic nations will ultimately serve U.S. national interests given the fact that democratically elected governments make war less frequently on other democracies, have fewer human rights violations and generally help promote regional stability.[13] Since U.S. interests are truly global in scope, the more stable regions that exist in the world, the greater mutual profit may be gained in a free market global economic environment. The National Military Strategy, (NMS), is built on supporting the NSS. The last NMS touted the two objectives of promoting stability and thwarting aggression, and assigned the military an overall strategy that promoted peacetime engagement, deterred conflict when possible, and applied decisive military force as a final option.[14] In addition, it reflected a core requirement of maintaining sufficient force to "fight and win two major regional conflicts nearly simultaneously."[15]

The question here is whether or not the force size, composition, and capabilities of a future force, (including advanced technologies such as UAVs), will be built on the basis of meeting national strategy or on non-strategy related issues such as service desires, a need to maintain national defense industry infrastructure or budgetary concerns. Shortly before the QDR was released, Secretary of Defense, William Cohen, was reported to be considering three possible future shapes of U.S. military forces based on a strategy assessment. The draft strategy document used by the QDR stated, "the demand for smaller scale contingency operations is expected to remain high over the next 10-15 years."[16] The strategy called for the need to increase spending on new military technological hardware in order to continue to improve existing military capabilities for a continuing high demand for intervention from military forces.[17] However, less than two weeks later, leaks from the soon to be released QDR stated, "we still have dollars driving the work instead of strategy as [agencies] rush to complete their reports."[18]

The issue between strategy and resourcing is a real one with no easy answers, but of vital concern for all emerging technologies. An excerpt from a Congressional Budget Office memorandum clearly illustrates.

> DOD is facing a serious dilemma in the next decade. It wants to maintain a large number of ready and well-equipped forces so it can fight two wars similar in size to Operation Desert Storm nearly simultaneously without relying heavily on allies or civilian support. However, the funds to pay for and equip the forces that the Army would like to keep are becoming increasingly hard to come by. [19]

However, the need is to design a force that will cover the entire gambit of possible situations ranging from large scale, high tech combat operations against a peer competitor, to augmenting humanitarian assistance efforts being conducted by NGOs. It is no longer a question of a major Force on Force or some lesser Operation Other Than War - the future force must operate across the entire spectrum of possible military application. The United States' people and government demand that any future force be one which can do anything and literally everything.

Still, although the threat environment and the proposed purposes of a future force stand in close attendance, the remaining practical question of what the force must be able to do demands an answer. This is a particularly important question since it is primarily determined by what we purchase today in the way of hardware and research. Much of the debate surrounding this aspect of the future force design revolves around the question of whether or not we are in what is termed a Revolution in Military Affairs, (RMA), which is changing or evolving the very nature of warfare and its conduct. Many recent writers have argued that we are in fact in a RMA that revolves around information processing and availability, along with added range and lethality to precision delivered munitions. While some have argued that this is nothing more than the evolution of military capability, others have indicated that the nature of what the U.S. military is doing is more revolutionary in nature and will change the conduct of war.

Particularly germane to these two emerging concepts of information processing linked to extended range precision munitions are the emergence of technologies that specifically turn these conceptions into realistic capabilities. In the "how to get there from here" category, UAV technologies touch directly on both of these areas and are the brightest stars in the dark sky of tomorrow's possibilities.

Recent experiments at the National Training Center, (NTC), to incorporate such emerging capabilities using UAVs have met with limited success. The buzz phrase coming from NTC describing part of this capability is that by using emerging technologies, (particularly UAVs), now, as never before, commanders and soldiers have the ability to know exactly where they are, where other friendly units are, and exactly where the enemy is and what he is doing.[20] It is claimed that this knowledge gives a large fundamental advantage over an adversary who does not have such technology.[21] This argument is at the forefront of *JV2010* with its four sub-elements of dominate maneuver, precision strike, full dimensional protection, and focused logistics, undergirded in all areas by a "leveraging" of information technologies. The major trends that we see in technology for enhanced warfighting capabilities are increased weapons ranges, increased lethality, digital processing and miniaturization of components. UAV technology is the prime example of these trends for future warfare.

All of that being said, there is a caveat. UAVs, along with long range precision missiles, information technologies, or *any* technological enhancement, whether a new plane or submarine, is not by itself, a master key unlocking the solution to victory in future war. "Focusing primarily on technology also entails great risks. The never ending search for elusive silver bullet weaponry ignores the fact that once any military technology is known to exist and its characteristics are understood, it is possible to devise countermeasures that will reduce or completely negate its effectiveness."[22] There are even dangers of being susceptible to our own technology.[23] In addition to a lack of historical perspective that countermeasures closely follow technological advancement, over reliance on technology may convince decision makers to move away from sufficient conventional forces necessary to project strategic landpower in a global environment where U.S. interests are broad and far ranging. There are other useful questions that inquire about technology as a military means. Will our opponent continue to be a high technology competitor, and if not, will a high technology approach work across the spectrum of military operations? If not, then what implication does it have, if any, to the design of military forces and in particular here, for the design of military technology in the years ahead?

Be that as it may, western democracies, particularly the United States, will likely continue to pursue military superiority from a decidedly technological bent, for a variety of reasons. For one, we have the monetary resources to do so, and technology tends to be one of our nation's perceived international advantages. In addition, our nation's history tells of a lengthy romance with technological means, even to the extent that some writers have referred to America having an "abiding love affair with the machine,"[24] and an "attachment of much of their national and personal identity to technology."[25]

As an exceptional example then, UAVs present an emerging technology that will link our likely means of technological military engagement to the most likely trends of a emerging future international security environment. The possibility of this technology's capabilities, although covered more adequately later in the monograph, have the potential to make great contributions to the NSS and NMS. Specifically, of the trends mentioned earlier, UAVs have unique abilities to enhance information processing and information sharing by providing exceptional non-satellite communication retransmission capability linking commanders and units from the strategic to the tactical level. Extended ranges built into UAVs today may also give strategic planners an increased range of options in monitoring regional conflicts without deployability problems. In addition, UAVs may help provide our continued technological edge in communications and weaponry, and offer additional strategic surveillance options over a variety of uses ranging from international organized crime, to terrorism, to proliferation of WMD.

The central key here is to understand that how this technology is designed today will have a direct impact on our ability to effectively leverage the promises of its possible capabilities on future battlefields. The next step is to look specifically at the historical design, development and acquisition of this type of technology in the United States.

III. Overview of UAV Historical Background & Current US Programs

A few years ago although there were several ongoing UAV/RPV initiatives, actual working UAVs which solved tactical problems while overcoming technical limitations were few and far between. In fact, U.S. DOD historical acquisition efforts have been fraught with problems and generally disappointing.[26] "Since 1979, of eight UAV programs, three have been terminated (Aquila, Hunter, Medium Range), three remain in development (Outrider, Global Hawk, DarkStar), and one is now transitioning to low rate production (Predator). Only one of the eight, Pioneer, has been fielded as an operational system."[27] The General Accounting Office (GAO), estimates that in this same time period, DOD has spent more than two billion dollars for development and procurement of these eight programs.[28]

In the early years of these programs, there was little unity of effort as each service managed their own programs. This included the programs for Aquila, Pioneer, and the Medium Range UAV. As a result, Congress consolidated funding and DOD formed a UAV Joint Project Office in 1988, which now falls under the Office of the Secretary of Defense's, Defense Airborne Reconnaissance Office (DARO).[29] This seems to have streamlined research, development, design, and overall consideration of UAV mission needs within DOD, and helps prevent unnecessary duplication by each service.[30]

Aquila was the first major U.S. UAV program. It was run by the Army and although initial estimates of cost were $123 million, the program cost over $1 billion, plus, (if the program had continued), an anticipated future addition of over a billion dollars for procurement of 376 airframes. The design mission included a small frame (portable by four soldiers), that sent beyond line-of-sight battlefield imagery back to ground commanders. Ultimately the small size of the airframe was unable to accommodate the desired avionics and other payload related items. In addition there were difficulties in meeting the many desired mission requirements. These requirements were only met on seven of 105 operational testing flights before the Army abandoned the program in 1987 due to "cost, schedule, and technical difficulties."[31]

Akin to Aquila was the Navy's small propeller driven Pioneer that was to be used for naval gunfire spotting and Marine Corps use. This was a joint venture with an Israeli firm, and eight vehicles were purchased in 1986. Similarly, unanticipated problems arose, in this case particularly regarding shipboard recovery and electromagnetic interference which led to numerous crashes. The Navy spent an additional $50 million to upgrade Pioneer to minimum design criteria which were considered essential for useful capability. Pioneer never met design requirements but was used with great success in Desert Storm, Somalia and Bosnia. It is currently scheduled to be phased out upon procurement of the Outrider UAV system.[32]

The third historical service effort was a joint Navy/Air Force program called the Medium Range UAV. This UAV was built as a jet designed to precede manned aircraft on a strike mission or return to the target location after the mission to collect Battle Damage Assessment, (BDA). It was supposed to be capable of a 350 nautical mile range into enemy territory and of relaying video imagery back to waiting control cells. The Navy built the airframe and the Air Force built the sensor payloads. Besides airframe crashes, the payload prototype was too large to fit into the space allotted on the frame by the Navy. The program was scrapped in 1993 due to technical difficulties and cost over runs.[33]

The first UAV to come under the Joint Project Office's auspices was the Short Range UAV later named Hunter. Begun in 1988, it also eventually doubled in cost estimates from initial assessments to an anticipated $2 billion dollars for 52 systems which would have included over 400 vehicles and associated equipment. Hunter was designed for Army Division's and Corps' (and Naval Task Force's), use as a reconnaissance, intelligence, surveillance, and target acquisition platform. Because of certain limitations, the system was forced to rely on a second Hunter in the air as a data relay platform. The dependability of this data transfer became one problem along with general system reliability. In addition, the huge support system for this vehicle led to a judgment of Hunter's unsupportability in a field environment, as well as a determination that it exceeded limited air-lift space requirements. Regardless, because of the need for some UAV capability in the force, seven Hunter systems were purchased in 1993. New problems were found in these delivered systems' software, data transfer link, and engines. Several crashes caused the system to be grounded and the program was eventually terminated from further production in 1996.[34]

Currently there are four U.S. UAV programs being pursued by DOD and DARO generally designed around a range related concept. These systems include Outrider (short range), Predator (medium range), Global Hawk and DarkStar (both long range, high altitude - now known as High Altitude Endurance or HAE UAVs).

Outrider's program began in 1996 to meet the continuing UAV capability need at the tactical level since the termination of Hunter. Outrider was designed to be fielded down to Army Brigades (or Battalions), Marine Regiments and Naval Task Forces for primarily reconnaissance and surveillance tasks out to 200 km. Based on the success of its testing, DOD is prepared to spend over three quarters of a billion dollars by the year 2003 for development and procurement of 60 Outrider systems which will include 240 airframes and associated equipment.[35]

In order to cut through some of the lengthy acquisition process, some UAV development has been accomplished under "advanced concept technology demonstrations"(ACTDs). The Predator UAV was initially purchased under this process but has been successful enough to merit low production contracts estimated at over half a million dollars for thirteen systems which include 80 airframes. Predator will support theater and JTF levels out to 500 km with a dwell time of over twenty hours. The primary purpose of this system is also to provide reconnaissance, surveillance and target acquisition capabilities. A much larger system than those already discussed, Predator will provide more of an adverse weather capability and include satellite relay data links. Two lost Predators over Bosnia demonstrated problems in engine reliability and vulnerabilities to hostile fire.[36]

Global Hawk is also an ACTD and a HAE UAV. It was designed to maintain altitudes of 65,000 feet with a radius of over 3,000 nautical miles (read - 6,000 miles round trip), and a dwell time (over a target area) of 24 hours at that 3,000 mile range. It is designed to remain aloft for over 40 hours. Since it has no special protection from enemy radar systems it will be used primarily in low to medium risk environments.[37] The DarkStar HAE program (also an ACTD) was created to augment Global Hawk's abilities with stealth technology that would allow operation in higher risk environments. Projected to fly at 45,000 feet or higher, DarkStar is capable of a 500 nautical mile radius with a dwell time of eight hours. These two systems are designed to utilize the same ground component for launch, recovery, command, control and communications. Several test flights of DarkStar occurred in 1996 and 1997 resulting in the crash of one system.[38]

The historical antecedents of U.S. UAV design, development, and acquisition provide a base argument for a continuing trend towards more functional, (i.e. mission task specific), UAV designs in five areas: 1) functional design's closer support of the Army's desired doctrinal related endstates, 2) current scarcity of UAV resources and its impact on tactical UAV availability, 3) international and commercial UAV proliferation's impact on a trend towards a functional design approach, 4) likely areas for expansion of military "mission specific" UAV applications, and 5) functional design approach's greater adaptability to the needs of tomorrow's battlefields.

IV. Future UAV Design - Functional vs General Purpose (Criteria)

A. Doctrinal Directions and Related End States

1. National Security Strategy

As stated earlier our National Security Strategy is built on the premise that the enlargement of democratic nations tied to us with free market mutual trade concerns will generally help to support regional and by extension world stability. With the latest NSS, our national interests are more clearly delineated, along with areas of vital interest, or those we as a nation are prepared to direct military force to protect or maintain as an instrument of power of last resort. The major threats to our interests are broadly categorized as regional or State-centered threats, transnational threats, (such as terrorism, drug trade, organized crime and environmental damage), and threats from weapons of mass destruction.[39] In the event that military force is opted for as a strategic solution, the NSS points out that a military response encompasses a "full range" of operations up to and including major theater warfare and "accordingly, U.S. forces will remain multi-mission capable."[40] In describing a military role in our national strategy, the NSS goes on to point out that we must maintain the capability to "rapidly defeat initial enemy advances short of enemy objectives in tow theaters, in close succession," in an environment that may well be characterized by asymmetric means such as "WMD, information operations or terrorism."[41] Finally, in directing future endstates, the NSS maintains that we must prepare now for an uncertain future by development of various capabilities in modernizing U.S. military forces.[42]

2. National Military Strategy

Derived from this is the National Military Strategy which closely mirrors the directives inherent in the current NSS, including the nature of future threats such as the combination of asymmetric challenges and transnational dangers, and the necessity of maintaining a credible force to deal with these threats.[43] As the NMS addresses preparation for such future conflict it specifically highlights the need for robust technological modernization to "leverage emerging technologies," specifically the "development and acquisition of new systems and equipment [that] will improve our ability to conduct decisive operations and achieve full spectrum dominance."[44] Later in the document it speaks to specific areas of capabilities and specific roles such technological advancement should be ready to support including Special Ops, Forcible Entry, Force Protection, Countering WMD, Focused Logistics, and Information Operations.[45]

3. Joint Vision 2010

In attempting to more clearly define the direction that current preparation efforts should work towards, the NMS emphasizes a joint vision document put out by the Joint Chiefs of Staff, (JCS), called *Joint Vision 2010,* and describes it as a "conceptual template for joint operations and warfighting in the future."[46] This document along with its subcomponent Army Vision 2010 provide what can be referred to as stated doctrinal endstates. These are desired endstates in scope and capabilities that the services, (in this case the Army), are striving to make into reality by early in the twenty-first century. In essence, capability experiments and structural redesign considerations like Advanced Warfighting Experiments, and specifically Force XXI and the Army After Next project derive their target endstates from the template broadly provided by *JV2010*. Army Vision 2010 states that it "provides the directional azimuth for developing the doctrine for land force operations in support of *JV2010*."[47]

Secretary of Defense William Cohen's report on the recently released Quadrennial Defense Review (QDR), stated that the transformation of the force is an ongoing process and that *JV2010* provides a conceptual direction for long-range vision and plans. He goes on to state that "by undertaking efforts ranging from studies and wargames to advanced concept technology demonstrations (ACTDs), and experiments, the Armed Forces are developing and testing concepts and capabilities that will ensure their ability to transform for the future."[48] He further goes on to specifically highlight a central role in modernization to command, control, communications, computers, intelligence, surveillance, and reconnaissance (C4ISR) systems.[49]

In particular to a discussion of future UAV design are the four areas of emphasis expounded upon in *JV2010* in its overall goal of being able to "leverage technological opportunities to achieve new levels of effectiveness in joint warfighting"[50] and thereby ultimately achieve what it terms "full spectrum dominance. These four areas under the umbrella of Information Superiority are Precision Engagement, Dominate Maneuver, Full

Dimensional Protection, and Focused Logistics."[51] These concepts paint a particular future mission picture. According to the Institute for National Strategic Studies' most current strategic assessment, in broad outline there will be a greater need for forces that can accomplish a very wide range of missions, particularly all of the following: [52]

- provide detailed monitoring of the battlespace in near real time
- provide precise targeting information to strike systems
- strike targets promptly with high precision
- attack while standing off from the bulk of enemy firepower
- operate in dispersed units while maintaining mission coordination
- monitor and enforce cease fire agreements between hostile parties
- monitor and enforce economic embargo or exclusion zones
- conduct effective counterterrorist operations

UAV technology is specifically designed to augment and enhance our capability to support exactly such operations as these, as well as two of the five specific "Strategic Enablers" listed by the NMS; robust all-source intelligence, and global command and control.[53] The question remains as to whether generic or general purpose UAVs will more adequately support the range of these operations and needed capabilities on tomorrow's battlefield more than functional task oriented UAVs could. As alluded to earlier, one of the issues involved concerns the building of new technologies towards these stated strategies and doctrinal directives, or suboptimizing all possibilities by revolving new technology designs primarily around budgetary "realities."

It may be that general purpose platform UAVs are inherently flexible to accomplish a wider variety of UAV missions, or it might be argued that building such generic platforms is primarily driven by fiscal considerations as opposed to strategic and doctrinally desired endstates. Consider that by expanding the design platforms of UAVs, such as with additions of lethal UAV designs, the ability to support precision engagement and truly offer the force full dimensional protection would be greatly enhanced. In like manner, if UAVs were functionally designed, for say, logistical battlefield supply, this might greatly enhance our doctrinal stated objective of focused logistics by leveraging the emerging UAV technology of today for the battlefield needs of the next century.

Even though a close examination of desired doctrinal endstates may support future functional type UAV, historic evidence demonstrates that the development and acquisition trend has been and continues to be a general purpose UAV design approach. General purpose platform machines are inherently more flexible, but as a result of being able to accomplish a wider range of missions, fewer of such systems may be purchased on the basis of enhanced cost effectiveness. The resulting problem is that there are simply not enough systems to adequately meet future, (or even current), demand, and users habitually argue over their payload packages and mission allocations. This next segment will discuss the resulting central effect - suboptimization, and end with a discussion of the impact of UAV scarcity on tactical availability.

B. Scarcity of UAV Resources & Its Impact on Tactical Availability

There is a current scarcity of UAV resources. UAVs today are needed to perform a wide variety of uses and also needed by a wide variety of users and as a result there are simply not enough systems to go around. Secondly, as in any situation with scarce but valuable resources, there is heated debate as to who should control the asset and what the asset should be doing. Although someone eventually brokers the argument through a mission needs assessment that supports the commander's intent for the situation at hand, the question is whether or not the availability of only general purpose UAVs enhances this problem.

If the UAV does a generic task (such as produce video imagery) and its product can be utilized equally by a wide variety of users, there is likely to be a struggle over control of the asset. This will be true even if the information is made available (through for example wide dissemination of downloaded material) to a wide range of users. The argument will center over where these few available assets are being deployed. In similar manner, if the system is designed to carry a variety of sensor payloads but cannot carry them all at the same time, then an argument will ensue over which sensor packages will be employed at any given time during a given mission. The same issue will arise, (and is heatedly debated today), over which targets the platform will service during any given mission.

Through the process of prioritization, the issue will be resolved. Today, with UAVs being valuable but scarce resources there is no choice but to continue such a prioritization of assets or buy more assets. The effect however is suboptimization of the asset itself. The UAV must perform a little bit of capability over a wide range of possible tasks. Everyone gets some of their needed capability from a flexible albeit overworked system. This is not enough to satisfy needed requirements, and therefore only the highest priority needs are met overall. Arguing that prioritization is a good thing does not alter the conclusion that some needs are not being met that could enhance our capabilities on an ever more lethal battlefield environment. Those missions that get priority are enhanced. Those missions lower on the priority list, (but still vitally important), make do with less capability. Everyone gets some capability, no one gets enough.

However, if UAV systems were specifically designed or tailored to perform particular functions, the result might be; more UAVs in the system since their use would be more specialized, sufficient capabilities for each specific mission need, less cost per UAV system. Prioritization would still be necessary but prioritization in each functionally related mission area so that each area would then have at least some of their higher priorities needs met. Also, particular UAVs asset might more easily be assigned to the appropriate agency which handles a particular function within the military structure. If for example the UAV is functionally designed to map geographic features it could be assigned to a terrain team responsible for support to that mission. If the UAV is designed to collect signal intelligence, it could be assigned duty to an Electronic Warfare, (EW) team, if designed to find and/or destroy air defense radars, to the Air Force, if to provide precision targeting locations to the targeting cell, and so on. Although this approach could result in serious questions regarding manning, structure, and supportability issues, future technological enhancements such as miniaturization could significantly lessen their seriousness.

In addition to suboptimization, current UAV scarcity also greatly impacts on tactical availability. As stated earlier, current UAV supply cannot meet current UAV demand from a wide variety of users. This pertains equally as well to the level at which the UAV is currently (or will be) available for use. As with any scarce but valuable asset, the scarcer the system is in the inventory the higher the level of command that will control its use. This is as true with satellites, U2, and ATACMS as it is with UAVs. It may be that growing numbers of UAVs will only come about as functional mission tasks need specific UAV capability. It is possible that by designing only general purpose platforms, due to their inherent flexibility, DOD will purchase fewer systems believing that the available assets can cover a wider variety of situations. Without increased numbers of UAV systems in the inventory, (which a functional approach might yield based on the fact that specialization would limit their broad use), there will always be a problem with UAV availability at the tactical level. Scarce valuable resources tend to remain at higher levels to give the entire force the benefits of their capabilities. Due to scarcity of assets, there will never be enough general purpose UAVs to perform needed requirements, but because of the inherent hierarchical structure of the military, the dearth of needed systems and their unique capabilities will remain even more acute at the tactical level than at those organizations operating at the theater or operational level.

Scarcity of UAV assets may partly stem from a historic generic "do-everything" design approach created to meet a very wide needs assessment. Is the resulting suboptimization worth the general flexibility this approach generates? In addition, there is the issue of availability of unique capabilities both in mission areas and at the tactical level. Functional UAVs might provide the answer to these issues by optimizing a UAV's capability for particular missions, and by providing increased availability at the tactical level of these valuable combat multipliers. The key to being able to proceed towards such a functional design approach might well be found in the growing developmental markets of UAV programs that are expanding internationally for both military and commercial use. These markets show strong indications that as more and more UAVs are researched, developed and built, the uses of this technology will increase, cost will decrease, and functionality is a likely byproduct.

C. UAV Proliferation in International Programs and Commercial Initiatives

1. Impact of International UAV Proliferation

For much of the historical development of UAV technology, the promises of unmanned vehicles remained just that. As discussed earlier, problems centered around range, payload, and dwell time. However, with the miniaturization that has fueled other new technologies, the alluring promises of unmanned vehicles has almost come within modern technology's reach, Although these assets are not currently in the U.S. military inventory in large quantities and there are only a few programs in development, there is a great amount of international UAV development going on in a race to exploit UAV technology and add the capabilities of unmanned intelligence/reconnaissance to the next battlefield. There is in fact a growing proliferation of such technology on the open market.

Currently there are over 120 current UAV and programs under development world wide for various purposes.[54] These countries include Canada, China, France, Germany, Israel, Italy, Russia, South Africa, Sweden, the UK, the US, and several international cooperative programs. For poorer nations the cost benefit alone may be sufficient to fund these efforts. UAVs are certainly less costly than satellites (although each have different capabilities), and when weighed against human or "manned" reconnaissance and the possible loss of machine - over the possible loss of life, their advantage for some operations becomes clear. From a command perspective, there are also enormous benefits in the ability to see the ground in near real time rather than waiting hours or even critical minutes, in some cases, to see what the command wants to see. This affords real reaction or planning advantages even if incapable of immediately response. If the data is within targetable range, the advantage is obvious.

Many recent writings talk about the continued robotization of the battlefield and remotely controlled vehicles and sensors. And as stated earlier, one of the growing trends in military technological equipment is increasing miniaturization. One recent article addressing this possibility in UAV technology discussed the future feasibility of hand or pocket sized UAVs. According to the Pentagon's Advanced Research Project Agency, these tiny UAVs, (possibly as small as a dollar bill), "could scout inside buildings, collect biological-chemical samples, or attach themselves to structures and equipment to act as listening or video posts."[55]

Growing use of UAVs is likely to increase significantly as more countries and more industries compete in this growing market. As one example of the encroachment of such technology onto the modern battlefield, Jane's Defense Weekly published photographs of two Bosnian Serb soldiers holding parts of what they claimed was a Croatian UAV shot down near the western Bosnian town of Grahovo.[56] For many countries then, UAVs certainly help even the playing field for those who don't possess the technological space capabilities of an United States.

2. Impact of Proliferation into Non-military Roles

This growing proliferation is not however, limited to the military community. A former president of the Association of Unmanned Vehicle Systems stated two years ago at an international conference that "UAVs are being used for more functions every day."[57] It has been calculated that the UAV market is set to grow to around 1 billion dollars per year by the year 2000 and the commercial sector is likely to grow well beyond that.

There is growing interest in the commercial application of UAV technology although up until now most research and development has been mostly geared to solve tactical military problems. It is thought that the work already accomplished by military developers can be extended and transitioned into the civilian marketplace.

Outside of the obvious regulatory requirements needed to be worked out with such agencies as the Federal Aviation Agency, (FAA) and the Federal Communications Commission, (FCC), there are already many civilian applications that could benefit from UAV resources and many civilian agencies that currently desire to go forward with UAV programs. These UAV platforms could take many design forms: fixed, rotary wing, glider, gyroplane; heavier or lighter than air; single or multi-engine; propeller or jet; gasoline, diesel, battery, microwave or solar powered. Capabilities could also include wide ranges of performance from "small, hand launched, low-altitude UAVs with a range of 10 km or less to large wing-span, high-altitude, long-endurance UAVs able to traverse the globe."[58]

There are a number of potential uses of UAVs outside of the military. Possible civil government applications that have been suggested include the Department of Agriculture for spraying pesticides or fertilizers, and insect sampling; NASA for high altitude atmospheric testing or sampling (such as ozone); the Postal Service for package delivery; FEMA for assessing disaster areas, relaying communications and facilitating/controlling relief operations; the Forest Service for fire control or other surveillance needs and fire fighting; the National Weather Service for storm observation; Department of Energy for monitoring nuclear sites and reconnaissance of hazardous waste sites; Department of Transportation for traffic monitoring and highway mapping; Customs for counternarcotics surveillance; Border Patrol for patrolling borders and illegal alien surveillance; DEA & FBI for suspect or counternarcotics surveillance and special weapons team support; State and Local Law Enforcement Agencies for riot control, area surveillance and search & rescue. This is only a sample of possibilities, other agencies include Merchant Marines, Fish and Wildlife, Bureau of Land Management, State Department, the National Guard, the EPA and the Army Corps of Engineers.[59] In addition, private sector applications would yield benefits for monitoring, inspections, communications relaying or quick response in areas such as real estate, maritime shipping, farming/ranching, surveying, media, security, archaeology, railroads, as well as lumber, film, oil and mineral industries and even delivery services.[60]

In facilitating a transition of current military development to the civilian sector the military stands to increase industry interest, civilian UAV research & development, and of course spur private commercial funding for increased UAV development that might in and of itself be adaptable to future military applications as many of these stated civilian initiatives could. This type of proliferation could result in more third party suppliers for new systems, refinement of current systems, and potentially cut development and acquisition life cycle costs for future military UAV initiatives.

Growth in the civil sector of such technological enhancements will in and of itself drive further acceptance of UAV use and add to the growing presence of UAV technology both in the civilian sector and the military community. One conclusion then is that although current UAV assets are limited and must therefore be closely prioritized, their continuing technological gains, possible cost benefit savings in money and human life, and their continuing proliferation internationally both in military and in commercial sectors may ultimately result in a vastly increased range of applications for UAV technology in the years ahead.

The ensuing question then is, as the use of UAVs expand, can general purpose or generic UAV design platforms accomplish such a wide range of possible applications either in the civilian sector, or as capability and miniaturization increases in the range of a broader arena of possible military applications either? One point is clearly illustrated;

civilian agencies will build functional and not general purpose UAVs in order to tailor their use to narrowly needed specific needs. This is turn may both directly and indirectly reduce cost in developing functional UAVs for military use. The overall impact of increased UAV proliferation both internationally and commercially appears to be the likely expansion of military applications for functional UAV technology as well.

D. Potential Functional Area Applications of Tactical UAV Usage

This growing proliferation of systems and potential technological applications opens the possibility in future UAV development of a growing need to create functional UAV platforms since UAVs are unlikely to be able to carry equipment for too many technology specific missions on one vehicle. Over time, it may become more and more difficult to design one UAV platform that can perform the probable wider range of needed technological applications. Specifically for military applications, this could entail moving away from a range/dwell time management approach, to one specifically tailored to the mission a UAV is tasked to perform. UAVs could be fitted with sensors or weapons or other payloads that match a particular mission need - Jamming UAVs, radar killing UAVs, reconnaissance UAVs, IEW UAVs, or targeting UAVs. Or UAVs may be built from the ground up to meet a specific military functional need such as a battlefield delivery platform, or an expendable lethal weapon system.

1. Wide Variety of Needs in C4ISR for UAV Usage

One possible future mission specific functional UAV application is clearly command, control, communications, computers, intelligence, surveillance, and reconnaissance systems, (C4ISR). As U.S. military forces move closer towards embracing information warfare, the role of these functions rises in direct proportion. As stated earlier, Secretary Cohen specifically highlighted expanded emphasis to the modernization efforts of C4ISR systems. UAVs provide unique abilities to enhance these specific functions through common picture imagery, but also by linking commanders on the battlefield through enhanced communications capabilities.

While image intelligence currently provides the bulk of immediate UAV mission tasks, Electronic Surveillance Missions, (ESM), EW, communication relay, and control functions are also being accepted as viable missions for UAV technologies.[61] France and Germany, for example, have been cooperating on a joint project to produce an EW specific battlefield UAV.[62] In another example, although Global Hawk's sensors were originally geared for primarily imagery intelligence (IMINT) payloads, there was an early desire (albeit not the funding) to also "integrate other capabilities such as signals intelligence (SIGINT), sensors for passive collection of communications and electronic emissions, as well as laser designator and battlefield communications relay units."[63] It is possible that in the future, UAVs could be specifically fielded to place communications and control related functions over various parts of the battlefield.

2. Targeting (D3A) Integration

Another potential future functional UAV military application is target processing. Three factors contribute to this area as an early choice for functional UAV expansion. First of all there may not be enough systems in today's force that can provide data specific enough to be considered useful to the targeting support structure, especially considering a growth of precision strike platforms that can utilize such capability. With only a handful of UAVs available in a regional contingency, (such as Bosnia), the ratio of actual target providers to deliver systems is increasing rapidly. This is exasperated by the limited targeting specific capabilities on current UAV systems largely due to payload limitations. Secondly, enhanced weapons ranges and proliferation of precision munitions will continue to drive up demand for systems that can provide timely target collection, monitoring, and post strike assessment. Thirdly, an increased integration of targeting processing and UAV usage clearly supports current and future doctrinal concepts.

a) <u>Scarcity of Capability & Lack of Alternate Targetable Data Providers</u>

Because of the lack of adequate alternative targetable data providers in the current inventory, UAVs offer a particularly appealing solution to targeting needs because they can be arrayed or designed to provide targeting specific data in ways that are useful to targeting teams. Satellites and U2 data typically give an accuracy of up to 400 m, while many delivery systems require data as close as 100 m. This is equally true of the Joint Surveillance Targeting Attack Radar System, (JSTARS) which provides indications of movement or blocks of potential targets, but is, (at least currently), unable to provide data specific enough to engage specific targets.

Once a battle begins, significant portions of intelligence gathering assets are tied directly to targeting efforts to kill the enemy. This means that during tactical engagements many UAV assets will likely be taken up by targeting processes. However, this does not mean that there are not any other significant intelligence gathering tasks that may need to be performed by UAV assets simultaneously. Lack of available targeting assets may then become critical for servicing targets by waiting weapons delivery platforms.

In the Gulf War, General Scales writes that UAVs became the only reliable system that was capable of finding passive, static targets with the precision necessary for launch of long range delivery systems such as ATACMS.[64] Besides the consternation experienced by the Air Force in clearing a path for such a long range missile, Scales reports, "the chief short-coming of ATACMS in the Gulf was the dearth of deep 'eyes' capable of spotting a lucrative target with sufficient precision and timeliness to justify expending a missile."[65]

As recently as February of this year, the Chief of Field Artillery, lamented the need of targeting UAVs for some of the reasons highlighted above. He maintains that in the future, the ability to leverage "Predator," specifically for targeting purposes will be understandably limited, and that currently "Hunter" will not be fielded for Force XXI.[66] MG Rigby goes on to argue that the UAVs we are fielding now are primarily intelligence systems and that to optimize targeting, the fire support structure needs a dedicated targeting UAV that "furnishes timely, targeting-level accuracy for high-payoff targets."[67] From warfighting exercises he also provides evidence of increased effectiveness when a UAV platform is directly linked with a delivery platform that can respond rapidly to relayed targetable data. This could be an manned air asset or a rocket/missile system like MLRS/ATACMS. In addition, the entire process becomes especially effective when queued to other collection assets. The specific example MG Rigby provides is the link to Q-37 Firefinder radar feeds for enemy artillery target locations. From the specific location that the radar provides, the UAV can then be directed to that near vicinity to search for and provide data on additional targets.

Lack of targetable data providers is also exasperated by limited targeting specific capabilities on current UAV systems largely due to payload limitations which can prevent having useful targeting specific sensors on UAV platforms today. On larger air frames this is not as big a problem because the larger frames can accommodate various payloads of various sizes and weights, or can carry additional payloads, (like laser designators), and secure communication modules without undue impact on the UAV's aerodynamic stability. For larger manned systems such as the U2, this results in a reconfiguration ability that can accommodate various missions. However, for smaller UAVs with limited payload capabilities, the result has historically evolved into a generic platform that revolves around digital image transfer only. This means that as a generic collection asset primarily used for general intelligence data gathering, the UAV is only dedicated to the targeting process when absolutely necessary or when not performing other missions. Functional targeting UAVs could solve these problems.

b) Growing Need to Service Advanced Delivery Platforms

A second reason that targeting process might be an early choice for functional UAV expansion is the increase in enhanced weapons ranges and proliferation of precision munitions which will drive up demand for systems that can provide timely target collection, monitoring, and post strike assessment. With the advent of more and more precision strike capabilities and long range shooters of ranges out to 300 and 500 km, the ability to have dedicated UAV technology tied to these systems will only grow more acute. One writer in discussing targeting UAVs, states, "inexpensive unmanned aerial vehicles equipped with thermal imaging technology for night targeting liked to terminally guided missile systems [will only continue] to proliferate."[68]

This concept of having the capability to actual link useable or targetable data and real time target surveillance directly to a capable weapons delivery system is where the concept of a functional UAV targeting platform becomes most apparent. As our abilities to make this reality on the battlefield increase, so will the demand for its use. As an example from one of several Army service branches wedded to targeting issues, one writer describes increased future needs for targeting capabilities as paramount to the progress towards the "Army After Next." She writes, "several warfighting capabilities will be integral to [this] evolution. The ranges of our [indirect] weapons and target acquisition systems will need to be extended out to 500 km with automatic target acquisition, target-type recognition and battle damage assessment (BDA) capabilities. We will [also] need real-time information collection and fusion capabilities to link sensor-to -shooters."[69] Dedicated targeting UAVs could be part of this future vision for targeting capabilities.

c) <u>UAV linkage to D3A Process and JV2010</u>

As mentioned above, a third reason that targeting might be a likely expansion of functional UAV missions is that an increased integration of targeting processing and UAV usage clearly supports current and future doctrinal concepts. UAVs dedicated to specific targeting functions would clearly enhance all phases of our current doctrinal targeting process - D3A, (which consists of Decide, Detect, Deliver, and Assess phases).

Tactical targeting tasks are generally comprised in four areas, those of supporting the close fight, fighting the counterfire fight, interdiction of enemy forces at deep ranges, and suppressing enemy air defense assets as a support to aviation systems. In terms of the targeting process, during the Decide phase of D3A, the collection plan is built, and in the Detect and Assess phases the decisions are made as to where collection assets will look, what they are looking for, when they will look at particular locations, and finally with what resource the looking will be done with.

With availability of dedicated UAV assets the targeting process can be enhanced in each phase. In the Decide phase, targeting UAVs would contribute to other collection assets in adding to the overall collection plan. With additional eyes over the battlefield, the ability to locate higher priority targets that have already been identified as crucial Priority Information Requirements, (PIR) will be enhanced. This in turn will enhance the accuracy and efficiency of continual reassessment in advising the command on priority of targets and target categories. The Detect phase would also be enhanced because with more "eyes" available, detection efforts could be conducted earlier with assets dedicated, (within the overall collection plan), to tracking targets prior to engagement. This in turn could speed the amount of acquisitions the targeting team could service without waiting for UAV assets to become available or re-available in the Delivery phase.

As opposed to having information that a target was at a given location some period of time ago but nothing is currently available to confirm that information due to the lack of a targeting asset, dedicated targeting specific UAVs could lessen the likelihood of having to divert a UAV from a non-targeting mission to another location where it is needed for targeting purposes. This could enhance the rate of detection to delivery and (under the right conditions) provide the means to have "continuous real time" and immediate fires deployability upon detection of those targets that met criteria formulated in the Decide phase of D3A. In addition, for the Assessment phase, much more accurate and more continuous assessments of BDA could be made that would aid in immediate re-strike considerations and decisions.

Even as targeting criteria tied to dedicated collection assets in the form of functional specific targeting UAVs would clearly enhance all phases of D3A, it could be argued that a targeting functional UAV approach also supports the doctrinal concepts of *Joint Vision 2010*. Of its four emerging operational concepts two of its major provisions are closely linked with the targeting process, "Precision Engagement," and "Full Dimensional Protection." In order to better accommodate the needs for increased precision engagement, the fire support and intelligence communities are having to directly link shooters and sensors much more than they have in the past. This process allows for more timely delivery against all targets but especially against those which may not remain in one location very long, or have the ability to inflict extreme damage to the force (such as WMDs). In addition, as one of the overarching concepts of *JV2010*, functionality also supports information warfare. Ultimately one of the main goals of information warfare is to provide commanders at all levels with an enhanced view or awareness of the battlefield so that they can more swiftly prosecute the tactical fight. The only real way to do this is to dedicate assets to the functions that can benefit by them. The targeting process is clearly one of those functions.

It is exactly this possibility of dedicating UAV assets to particular functions (as in this case, targeting), that brings to the fore, the issue of general purpose versus functional specific UAV platforms. Currently U.S. UAVs platforms are designed as general purpose platforms that have short range, medium range and long range capabilities. This is linked to which service will control the asset. For example, the Army controls UAVs which fly out to a certain range and the Air Force controls UAVs that fly to ranges beyond that. This categorization is thought to be in line with who can impact operations at the range limits that the UAV is capable of operating at. However, longer range UAVs can still provide needed capabilities at shorter ranges and the issue of resource allocation again raises its ugly head. A better categorization would be the designed function of a UAV platform, rather than length of flight time or range capability.

Although the intelligence community, has currently made provision for the broadest use of UAV utilization by placing UAV organizations down to the DS MI Company, and tied its gathered data to an all source intelligence collection process that provides the most users with the most available data, a further refinement might be to create functional targeting UAV platforms which would enhance targeting specific processes and not tie up

UAVs needed for other missions. Results could include increased availability for targeting functions, payloads or entire vehicles built to optimize specific targeting data needs, ability to service likely increases in long range delivery systems in a more timely manner, and better alignment with future doctrinal initiatives.

3. Delivery Assets vs Data Collector UAVs

Even as military imagery and data collection has been a primary function of UAV technology, there is more and more talk of UAV use for transport purposes. Commercial post carriers and cargo companies have already expressed interest in the idea of the "unmanned cargo aircraft, which would cut crew costs for them."[70] For the expansion of military applications along this line the possibilities are endless but immediate implication can be drawn to the UAV as a battlefield logistical supplier. Examples could include: munitions packages flown to forward units, emergency resupply of all supply classes, decreased use of Main Supply Routes, (MSRs), force protection for fewer combat service support personnel, and so forth.

One of the clear implications here is that current UAV designs could not accomplish such missions, therefore if this area is explored for future UAV missions, the resulting platform would by default be designed under at least a broad functional category (in this case a delivery transportation function). Additional refinements could result in further delineation of functional designs with some UAVs flying large cargo over longer distances, while other UAVs could be developed to make shorter range or smaller package deliveries.

4. <u>Lethal vs Non-lethal UAVs</u>

In like manner, there has been discussion of lethal UAVs specifically designed to carry deliverable weapon systems or even expendable UAV that would destroy selected targets. There has been discussion of future requirements for a "hard kill UAV for anti-radar missions,"[71] and even some suggestions that one variant of the new Joint Strike Fighter Aircraft might be an unmanned vehicle.[72] One writer in fact maintains that it is hard to imagine that advanced programs today could not "produce tactical aircraft of similar performance and superior capability to manned vehicles."[73] Another writer states that unmanned fighter aircraft have benefits in cost, and range, could take on dangerous missions like tactical reconnaissance and suppression of enemy air defenses, and "could maneuver even more violently than manned fighters (which are limited to the pilot's tolerance of 9 g's)."[74] Similarly, if UAV design expands in this direction, a functional approach is mandated automatically in order to create the desired capability.

In looking at the possible growing expansion of "mission specific" UAV tasks, for military application, in such areas as C4ISR, targeting, delivery/transportation assets, and lethal weapons platforms, one conclusion is that there will be a continued cry for increased numbers of systems to perform an ever wider variety of UAV mission tasks on the horizon. Certainly reconnaissance, stealth strike, long-range electronic warfare, and logistical delivery platforms are all candidates for the expansion of applications in UAV technology use in areas that have traditionally been fulfilled by manned vehicles.[75] This motif of not only growing proliferation of the amount of projected use of UAVs but the expansion of roles that can be included in their repertoire of capability leads to a possible conclusion that while general purpose platforms can do many things well, they cannot hope to accomplish the wider litany of purposes future UAVs are likely to be asked to perform. All of this argues that a functional design approach may achieve a greater degree of adaptability to the needs of tomorrow's battlefields.

E. Adaptability

1. Flexibility through Standardization (General Purpose)

In discussing future UAV design based on likely future needs, one approach is to build general purpose platforms designed to operate at various ranges that could download visual and locational data of the enemy to a wide variety of field users across the spectrum of conflict. Certainly an advantage in this type of approach is flexibility in terms of the vehicle's use. For example, an imaging platform could serve uses in reconnaissance, surveillance, or target acquisition (at high enough resolutions). As a practical result the vehicle could be made available to a wide variety of uses and users without the limitations imposed from making the platform so specialized that only certain users could benefit from its utility. Another advantage would be in supportability across units or services. Common chassis based vehicles simplify the ordering, stockpiling and general sustainability of any platform, not to mention an easier training process from documentation to instructional support for using personnel. Our current U.S. systems are designed around fairly generic functions to operate at various range depths and differing dwell times.

One of the major problems with a general purpose approach is the ever increasing need for the platform to provide one more functional capability. In other words, can a general purpose platform do everything we want it to be able to do? Can any one system do everything. This problem was specifically addressed in the most recent GAO UAV review.

One of the major conclusions of the report on UAV acquisition was that "the more you ask a UAV to do, the harder it becomes to build."[76] The finding goes on to state, that system programs like this must be protected from "requirements creep." In other words, just because new capabilities can be added to a UAV system does not mean that they should be. As highlighted earlier in the historical review of U.S. programs, UAV systems designed with an initial mission function have been at least partly undermined by additional requirements.[77] The GAO conclusion is that proposed new requirements must be judged on the overall effect on the system in terms of "cost, schedule and performance."[78]

2. Flexibility through Design (Function Specific)

If, as this paper has explored, there is increasing proliferation of UAV technology and expanding roles for its use, then general purpose UAVs, (although offering the major advantage of standardization) are the ones most likely to be continually bombarded with requests for the platform to ever increase its repertoire of capability. This seems at least in part intuitively obvious if the demand for functional capability does expand. The alternative is to build UAVs that are designed specifically to meet certain mission requirements creating an alternative form of adaptability in terms of increased use of UAV technology but adaptable from the standpoint of functional design. It could be argued that the very reason that current systems are designed with different range depths, and generally thought to be directed at different levels of the spectrum of conflict (tactical, operational/theater, and strategic), is to support the contention that there is a need for different functions, for different missions, at different levels.

One short term solution that combines some of the advantages of both general purpose UAVs with designed functionality is to move towards general purpose airframe platforms and gain needed functional diversity through payload design. This in fact seems to be the current direction that U.S. UAV systems are moving.[79] The distinctions for UAV design could grow less distinct as new UAV technologies enter the marketplace. It may become just as easy to provide longer flights and communication/control at longer distances with the miniaturization of components. This would mean that common flight platforms could remain airborne for as long as needed over any part of the world desired in support of both tactical commanders or strategic decision makers. The key to adding mission functional distinctiveness would be in tailored payloads. In this particular regard the problem with "requirements creep" could be side-stepped as long as the new capability resided in a modular payload that fit the dimensional and weight restrictions of the airframe. Again, with increased miniaturization, this becomes increasingly possible. Already we do a limited similar process on tailoring payloads on fighter aircraft (for weapons packages) and on such aircraft as the U2. What is most gained in this approach is mission adaptability which allows the commander to utilize the right tool for the right job at the right time. This however also requires substantial technological enhancements in several areas, without again arriving at the point of suboptimization. What is not solved by this approach is resource scarcity and resulting prioritization issues. It is also clear that functional design is absolutely necessary to pursue capabilities such as battlefield resupply, expendable weapon platform, or unmanned fighter aircraft.

A discussion of the possible utility of functional payload leads us to another important question, of whether or not UAV type technology can in fact be "purchased off the shelf" and adapted for military mission requirements. This is particularly evident if the new requirement is "available" on the open market. Another conclusion resulting from the latest GAO UAV review was that such availability should not necessarily be construed as being automatically mature in capability when combined into a military requirements package. Although the resulting cost savings of a "nondevelopmental item" is attractive, off the shelf technology "cannot be assumed to meet DOD or service requirements when subjected to the rigors of realistic operating environments or wartime operation tempos."[80] Civilian technological applications not built to military specifications often neglect both logistical and MANPRINT issues necessary to military operations. The GAO went on to say that making such technology useful to the military user can be extremely costly.

F. Additional Considerations

Related problems to the question of general versus functional UAVs needing to be addressed are concerns over UAV logistical support, organizational structure and training issues. One of the best ways to understand the nature of the these issues is to understand that when you are buying a UAV, you are buying much more than the airframe itself. The air vehicle is only the most visible portion of the system. A UAV system also includes "computer processors, software, sensor payloads, data links, data dissemination equipment, ground control stations, launch and recovery equipment, and a logistics support network."[81] Time and time again, DOD has been confronted with the need to test how all of these things interact successfully together as a complete system, and evaluate how affordable the entire system will be to operate and maintain over its entire lifecycle prior to considerations of production or procurement.[82] MG Israel, Director of DARO, is quoted as saying, "many people oversimplify UAV technology. Developing UAVs is not simply taking composite materials and slapping an engine on an airframe."[83]

Thinking of UAVs as systems contributes to a host of related topics which this paper is unable to adequately address. One of the greatest implications and historical lessons learned from the Hunter program was the need to consider the logistical support package necessary to sustain the UAV in a field environment. If the support package is too large, this greatly impacts on the ability to project the equipment where ever the system is needed (at least in a timely fashion, if at all) due to inadequate air lift capability that could be dedicated to the movement of UAVs vice other needed equipment. Structural and organizational questions also arise as to which units have the ability to maintain, operate and sustain the system with personnel and logistical support. If the supporting structure is too large or its operation is overly technical, training issues are also raised that must be addressed.

V. Recommendations and Conclusions

Dr. Edward Teller, who helped to develop the atomic and hydrogen bombs, predicted in the late 1970s that man would control unmanned aerial vehicles over intercontinental distances.[84] Today that vision is coming about, as modern UAVs are coming of age. But looking through the mist of a hazy future security environment and its implications for new military technologies, will the preparation we accomplish today serve us well on tomorrow's battlefields? Two emerging technological concepts stand out as future key combat multipliers: information dominance, and extended range precision munitions. Almost as a linchpin between them, UAVs provide the means to exploit these concepts to their fullest degree.

Today, U.S. UAV design is making great headway for the short term. Our design approach is built on cost effective, general purpose platforms that offer some inherent flexibility and offer some savings in cost, training and sustainability. In addition, with an renewed emphasis on modular payload sensors, flexibility and mission application are being expanded.

It is however a short sighted approach and one that may in fact not meet the growing UAV needs of the coming century. Today, partly because of cost benefit, UAVs are scarce but valuable resources resulting in contention over their use between military functions and services, and greatly reducing the tactical availability of these extraordinary capabilities. As a result, the demand, if not the minimum essential requirements go largely unmet.

The decision to build UAVs designed around a particular mission, or "mission specific functionality" is not really a choice at all. International and commercial proliferation and the vast expansion of unmanned flight will ultimately result in an array of UAV usage much to large to place on any one platform. Its like watching the very first car come out of development and making an assumption that all motorized vehicle needs could be served by a few common vehicle configurations. As UAVs proliferate, acceptance will go up, technological gains will be made, cost and size will go down, and functionality will almost assuredly increase. The only real choice is whether or not we will shift our developmental efforts soon enough to meet future needs before we are confronted with them. How this technology is developed today will have a direct impact on our ability to effectively leverage the promises of its possible capabilities tomorrow.

Specifically I recommend that we continue to fund UAV development efforts for the promises it holds. Secondly, we should continue to make our current initiatives as modular as possible by diversifying capabilities through payload sensor flexibility, (particularly enhancing C4ISR and targeting capabilities). Thirdly, we should continue to fund UAV acquisition of initiatives such as Outrider UAV so as to give additional UAV capability to the tactical level. Finally, we should carefully research the possibility of distinct functional UAV designs, particularly in the areas of battlefield supply, and lethal UAV platforms for a variety of uses.

UAVs present an emerging technology that will link our likely means of technological military engagement to the most likely trends of an emerging twenty-first century battlefield. GEN Joseph Ralston, Commander of Air Combat Command, stated in Defense News, Aug 95, that "UAVs have enormous potential, but they are going to present enormous challenges to fit into our overall construct."

We must look backwards from the needs of the years ahead. And whereas we are bound to get some answers wrong, neither will we be caught in Medusa's gaze, frozen in the past without the weapons that will enhance not only our survival but our dominance in future wars. The mirror is dim, and although we do see through a glass darkly, if we peer hard enough, there are enough faint images of what we need to know to step forward in the right direction.

ENDNOTES

[1] Thomas Bulfinch, *Bulfinch's Mythology,* (New York, NY: Harper & Row, 1970), 117.

[2] Ibid.

[3] *The Holy Bible, "The First Epistle to the Corinthians,"* King James Translation, (New York, NY: Oxford University Press, 1967), 1245.

[4] Robert Graves, *The Greek Myths, Volume One,* (New York, NY: George Braziller, Inc, 1959), 239. See also Arthur Cotterell, *The Macmillan Illustrated Encyclopedia of Myths & Legends,* (New York, NY: Macmillan Publishing Co., 1989), 149, 220.

[5] Title subheading on Glen Goodman, "New Eyes in the Sky," *Armed Forces Journal International*, July 1996, 32.

[6] Title cover on *Jane's Defense Weekly,* Vol 24, No 6, 12 August 1995.

[7] Title subheading on CAR, "Europe's Unmanned Aerial Vehicles Enable Fast Action," *Signal,* Vol 51, No 1, September 1996, 31.

[8] In addition, ballistic or semiballistic vehicles and artillery projectiles are generally not considered UAVs. This definition is consistent with all of DOD's UAV Master Plan documents. The sited quotation and the following definitions are taken specificially from the Unmanned Aerial Vehicles Joint Project Office, Department of Defense, *Unmanned Aerial Vehicles 1994 Master Plan,* (Washington, D.C.: U.S. O.S.D., May. 31, 1994), F-1. Other useful definitions include the following:

Remotely Piloted Vehicle (RPV): An unmanned vehicle capable of being controlled from a distant location through a communications link. It is normally designed to be recoverable.

Nonlethal UAV: An UAV that does not carry a payload for physical damage and/or destruction of enemy targets. It carries payloads for missiona such as RSTA; target spotting; C2; meterological data collection; NBC detection; special operations support; communications relay; and electronic disruption and deception. Most of the time the term UAV is synonymous with "nonlethal UAV."

Lethal UAV: An UAV, normally autonomous and expendable, that carries a payload used to attack, damage, and/or destroy enemy targets. Lethal UAVs are more specifically addressed in the classefied Department of Defense Standoff Weapons Master Plan.

[9] *Strategic Assessment, Flash Points and Force Structure, 1997,* Washington, DC: National Defense University Press, 1997, 233. This assessement points out that the most obvious candidates for peer competitors "are China or Russia, but possibly one of the larger regional powers, such as India, could transform itself into a major military power in the next decade." This source also more clearly delineates this type of threat by providing the following caveat. "It is not necessary to specify which one of these powers could be the source of problems, because all of the major powers that the US might confront in the foreseeable future share sufficient characteristics that it is possible to describe a composite, which we refer to as a *potential theater peer.* That term captures the essence of the military challenge from such countries: they are not peers with the US, able to challenge it world-wide, but they may have sufficient power to be a peer with the US in a theater of operations near them." These are generally construed to be continental, nuclear, and space capable nations of "enormous size and resources which for practical reasons cannot be overrun or occupied."

[10] Steven Metz , "*STRATEGIC HORIZONS: The Military Implications of Alternative Futures,*" (Carlisle Barracks, PA: Strategic Studies Institute, 1997), vi - viii, 1-52.

[11] Ibid. p. 41.

[12] Ibid.

[13] For additional support for this idea - see for example Think-Tank work such as *Foreign Policy into the 21st Century: The U.S. Leadership Challenge,* (Washington, DC: The Center for Strategic & International Studies, 1996), xii, which states that "not only has history shown that industrialized democracies are among the countries least likely to go to war with one another, but they also have significant trade-related incentives for resolving lesser conflicts in a cooperative manner."

[14] *National Military Strategy of the United States of America, 1995,* (Washington, DC: US Government Printing Office, 1995), i.

[15] Ibid., ii.

[16] Colin Clark, "Major Force Structure Cuts Loom, Says Top Army Official," *Defense Week*, 14 April 1997, 1.

[17] Bradley Graham, "Cohen Weighing Three Possible Courses for Shape of Future US Military," *Washington Post*, 04 April 1997, 4.

[18] Clark.

[19] Ibid.

[20] Scott R. Gourley, "US Glimpses a 'Digitized' Future," *Jane's International Defense Review*, Vol 30, September 1997, 54.

[21] "In all operations, technological advances and the use of information will provide major qualitative advantages to war fighters at the individual crew and small unit levels." Cited from CAR., (Staffwriter-no name supplied), "Aerial Reconnaissance Boosts Battlefield Awareness Scheme," *Signal,* Vol 51, No 9, May 1997, 36.

[22] Hirsh Goodman and W. Seth Carus, *The Future Battlefield and the Arab-Israeli Conflict*, (London: Transaction Publishers, 1990), 167; quoted in Douglas Macgregor, *Breaking the Phalanx*, (Westport, CT: Praeger, 1997), 3, n. 6.

[23] See for example Charles Dunlap's article "How We Lost the High-Tech War of 2007 - A Warning From the Future," *The Weekly Standard*, 29 January 1996, 22-28.

[24] See specifically, Michael L. Smith's article, "Recourse of Empire: Landscapes of Progess in Technological America," in Merritt R. Smith, & Leo Marx, eds. *Does Technology Drive History?* (Cambridge, MA: The MIT Press, 1994), (37)-52. For a look at current American writing on possible future technologies' cultural impacts and interactions, see Kevin Kelly, *Out of Control,* (New York, NY: Addison-Wesley Publishing Co., 1994).

[25] Ibid.

[26] Director, Defense Acquisitions Issues, National Security and International Affairs Division, *Unmanned Aerial Vehicles, DOD's Acquisition Efforts,* United States General Accounting Office Report, GAO/T-NSIAD-97-138, (Washington, D.C.: U.S. General Accounting Office, 1997), 1. Testimony before Subcommittees on Military Research, Development and Procurement, Committee on National Security, House of Representatives.

[27] Ibid.

[28] Ibid.

[29] Ibid.

[30] DARO as an example did a technology study and made a list of 70 technologies considered important to extended reconnaissance. The four broad functional categories

these technologies fell in were, platforms, sensors, information processing and communications. Challenges in current reconnaissance capabilities listed as continuous broad area coverage, higher resolution data for targeting, improved sensors for BDA, improved over the horizon commo and connectivity, increased commo bandwidth, better data retrieval and distro, comprehensive source correlation, and better synchronization with users. DARO is investing in technologies ranging from propulsion, to avionics, to processing. Cited in CAR., (Staffwriter-no name supplied), "Aerial Reconnaissance Boosts Battlefield Awareness Scheme," *Signal,* Vol 51, No 9, May 1997, 36-38.

[31] GAO UAV Overview Report, GAO/T-NSIAD-97-138, 2. Aquila was meant to have autopilot, sensors to locate/identify point tgts day or night, and a laser for artillery delivered Copperhead projectiles. It was supposed to be able to support normal artillery support and survive Soviet style ADA defenses. This required a "jam-resistant, secure communications link," the use of which degraded the video which in turn degraded targeting ability. See also, *Aquila Remotely Piloted Vehicle: Its Potential Battlefield Contribution Still in Doubt,* (GAO/NSIAD-88-19, Oct. 26, 1987), and *Unmanned Vehicles: Assessment of DOD's Unmanned Aerial Vehicle Mater Plan,* (GAO/NSIAD-89-41BR, Dec. 9, 1988).

[32] Ibid, 3. See also *Unmanned Vehicles: Assessment of DOD's Unmanned Aerial Vehicle Mater Plan,* (GAO/NSIAD-89-41BR, Dec. 9, 1988).

[33] Ibid. See also *Unmanned Aerial Vehicles: Medium-Range System Components Do Not Fit,* (GAO/NSIAD-91-2, Mar. 25, 1991).

[34] Ibid, 4. See also *Unmanned Aerial Vehicles: No More Hunter Systems Should Be Bought Until Problems are Fixed,* (GAO/NSIAD-95-52, Mar. 1, 1995), and *Unmanned Aerial Vehicles: Maneuver System Schedule Includes Unnecessary Risk,* (GAO/NSIAD-95-161, Sep. 15, 1995), and *Unmanned Aerial Vehicles: Hunter System Is Not Appropriate for Navy Fleet Use,* (GAO/NSIAD-96-2, Dec. 1, 1995).

[35] Ibid.

[36] Ibid, 5. Note: Predator still requires a large support group and deployments in support of operations in Bosnia have highlighted limitations under certain weather conditions. The Air Force has assumed operational command of the remaining ACTD assets.

[37] Ibid, 5-6.

[38] Ibid.

[39] *A National Security Strategy for a New Century*, May 1997, (Washington, DC: US Government Printing Office, 1997), 5-6.

[40] Ibid., 12.

[41] Ibid.

[42] Ibid., 13.

[43] *National Military Strategy of the United States of America, Shape, Respond, Prepare Now: A Military Strategy for a New Era*, 1997, (Washington, DC: US Government Printing Office, 1997), 9-16.

[44] Ibid., 18.

[45] Ibid., 27.

[46] Ibid., 17.

[47] *Army Vision 2010,* (Washington, DC: Department of Defense, Department of the Army, 1996), 9.

[48] William S. Cohen, "Report of the Quadrennial Defense Review," *Joint Force Quarterly*, Summer 1997, 12.

[49] Ibid.

[50] *Joint Vision 2010,* (Washington, DC: Department of Defense, Chariman of the Joint Chiefs of Staff, 1996), 1.

[51] Ibid., 19-25.

[52] *Strategic Assessment, Flash Points and Force Structure, 1997,* (Washington, DC: National Defense University Press, 1997), 258.

[53] *NMS*, 1997, 28.

[54] See Chart in Steven J. Zaloga, "UAV Military Future Deemed 'Promising'," *Aviation Week & Space Technology*, 13 January 1997, 92-97. See also charts in, Charles Bickers, "Systems Worldwide," *Jane's Defense Weekly* , Vol 24, No 6, 12 August 1995, 38; and Doug Richardson, "Unmanned Aerial Vehicles Stretch Their Wings," *Armada International* , Vol 20, No 5, Oct - Nov 1996, 10-11.

[55] Stacey, Evers, "ARPA Pursues Pocket Sized Pilotless Vehicles," *Jane's Defense Weekly*, Vol 25, No 12, 20 March 1996, 3.

[56] Photograph and heading in Charles Bickers, "Tier II - Plus: Taking the UAV to New Heights," *Jane's Defense Weekly*, Vol 24, No 6, 12 August 1995, 37.

[57] Charles Bickers, "UAVs Take Off Into a Multifunction Future," *Jane's Defense Weekly*, Vol 24, No 6, 12 August 1995, 33.

[58] Unmanned Aerial Vehicles Joint Project Office, Department of Defense, *Unmanned Aerial Vehicles 1994 Master Plan,* (Washington, D.C.: U.S. O.S.D., May. 31, 1994), C-4.

[59] Ibid., C-4 - C-5.

[60] Ibid.

[61] Bickers, "UAVs .... Multifunction Future," 33.

[62] Ibid., 34.

[63] Bickers, "Tier II-Plus: Taking the UAV to New Heights," 34.

[64] Robert Scales, Jr., *Firepower in Limited War,* (Novato, CA: Presidio Press, 1995). 261.

[65] Ibid., 260.

[66] Randall Rigby, "Targeting UAVs," *Field Artillery Journal*, Jan-Feb 1997, 2.

[67] Ibid.

[68] Douglas Macgregor, *Breaking the Phalanx*, (Westport, CT: Praeger, 1997), 127.

[69] Susan Walker, "Fires 2020 - The Field Artillery Roadmap," *Field Artillery Journal*, March-April 1997, 33.

[70] Bickers, "UAVs .... Multifunction Future," 33.

[71] Ibid., 34.

[72] Ibid.

[73] Ibid.

[74] David A. Fulghum, "Defense Dilemma: Force Structure or Modernization," *Aviation Week & Space Technology*, 17 March 1997, 80.

[75] Bickers, "UAVs .... Multifunction Future," 34. For additional mission expansion roles see also, William B. Scott, "USAF Set to Fly 'Mini-Spaceplane'," *Aviation Week & Space Technology*, 4 August 1997, 20-21. This article maintains that small unmanned spacecraft could eventually perform reconnaissance and weapon delivery missions.

[76] GAO UAV Overview Report, GAO/T-NSIAD-97-138, 6. (cited in note 26 above).

[77] See earlier discussion under section III - Overview of UAV Historical Background & Current US Programs, for examples of additional requirements that contributed to technical over-reach such as the add on to initial Aquila design requirements for precision targeting capability.

[78] GAO UAV Overview Report, GAO/T-NSIAD-97-138, 6.

[79] U.S. systems are generally moving towards payload functionability if not full functionality. The director of DARO is looking for a flexible approach through pods which he believes "reduces reconfiguration time, and allows a single hardware configuration to support multiple missions." He states in the same article, "we want to consolidate platforms." Cited in CAR., (Staffwriter-no name supplied), "Aerial Reconnaissance Boosts Battlefield Awareness Scheme," *Signal,* Vol 51, No 9, May 1997, 38.

[80] GAO UAV Overview Report, GAO/T-NSIAD-97-138, 7.

[81] Ibid.

[82] Ibid.

[83] CAR., "Aerial Reconnaissance Boosts Battlefield Awareness Scheme," 38.

[84] Staffwriter-no name supplied, "Vigorous Visions." *Signal,* Vol 51, No 9, May 1997, 3.

BIBLIOGRAPHY

BOOKS

Bulfinch, Thomas. *Bulfinch's Mythology.* New York, NY: Harper & Row, 1970.

Cotterell, Arthur. *The Macmillan Illustrated Encyclopedia of Myths & Legends.* New York, NY: Macmillan Publishing Co., 1989.

Foreign Policy into the 21st Century: The U.S. Leadership Challenge. Washington, DC: The Center for Strategic & International Studies, 1996.

Graves, Robert. *The Greek Myths, Volume One.* New York, NY: George Braziller, Inc, 1959.

Gudmundsson, Bruce. *On Artillery.* Westport, CT: Praeger, 1993.

Heinl, Robert D. Jr. *Dictionary of Military and Naval Quotations.* Annapolis, MD: United States Naval Institute, 1966.

Huntington, Samuel P. *The Clash of Civilizations and the Remaking of World Order.* New York, NY: Simon & Schuster, 1996.

Kelly, Kevin. *Out of Control.* New York, NY: Addison-Wesley Publishing Co., 1994.

Macgregor, Douglas. *Breaking the Phalanx.* Westport, CT: Praeger, 1997.

Scales, Robert Jr. *Firepower in Limited War.* Novato, CA: Presidio Press, 1995.

Smith, Merritt R., and Marx, Leo, eds. *Does Technology Drive History?* Cambridge, MA: The MIT Press, 1994.

Strategic Assessment, Flash Points and Force Structure, 1997. Washington, DC: National Defense University Press, 1997.

Strategic Assessment, Instruments of U.S. Power, 1996. Washington, DC: National Defense University Press, 1996.

Strategic Assessment, U.S. Security Challenges in Transition, 1995. Washington, DC: National Defense University Press, 1995.

Sullivan, Gordon, & J. Dubik. *Envisioning Future Warfare.* Fort Leavenworth, KS: US Army Command and General Staff College Press, 1995.

Toffler, Alvin & Heidi. *War and Anti-War.* Boston, MA: Little Brown, 1993.

Turabian, Kate L. *A Manual for Writers, Sixth Ed.* Chicago, IL: The University of Chicago Press, 1996.

The Holy Bible, "The First Epistle to the Corinthians," King James Translation. New York, NY: Oxford University Press, 1967.

Van Creveld, Martin L. *The Transformation of War*. New York, NY: The Free Press, 1991.

GOVERNMENT PUBLICATIONS

A National Security Strategy for a New Century, May 1997. Washington, DC: US Government Printing Office, 1997.

A National Security Strategy of Engagement and Enlargement, February 1996. Washington, DC: US Government Printing Office, 1996.

Army Vision 2010. Department of Defense, Department of the Army. Washington, DC: US Government Printing Office, 1996.

Joint Vision 2010. Department of Defense, Chariman of the Joint Chiefs of Staff. Washington, DC: US Government Printing Office, 1996.

National Military Strategy of the United States of America, Shape, Respond, Prepare Now: A Military Strategy for a New Era, 1997. Washington, DC: US Government Printing Office, 1997.

National Military Strategy of the United States of America, 1995. Washington, DC: US Government Printing Office, 1995.

Metz, Steven. "*STRATEGIC HORIZONS: The Military Implications of Alternative Futures.*" Carlisle Barracks, PA: Strategic Studies Institute, 1997.

Tilford, Earl H. "*WORLD VIEW: The 1997 Strategic Assessment from the Strategic Studies Institute.*" Carlisle Barracks, PA: Strategic Studies Institute, 1997.

UAV Annual Report, FY 1996. 6 November 1996. Department of Defense, Defense Airborne Reconnaissance Office. Washington, DC: US Government Printing Office, 1996. [DTIC ADA321302].

United States General Accounting Office. Testimony of Director, Defense Acquisitions Issues, National Security and International Affairs Division, before Subcommittees on Military

Research, Development and Procurement, Committee on National Security, House of Representatives. *Unmanned Aerial Vehicles, DOD's Acquisition Efforts.* GAO/T-NSIAD-97-138. Washington, D.C.: U.S. General Accounting Office, Apr. 9, 1997.

United States General Accounting Office. *Unmanned Aerial Vehicles: Hunter System Is Not Appropriate for Navy Fleet Use.* GAO/NSIAD-96-2. Washington, D.C.: U.S. General Accounting Office, Dec. 1, 1995.

United States General Accounting Office. *Unmanned Aerial Vehicles: Maneuver System Schedule Includes Unnecessary Risk.* GAO/NSIAD-95-161. Washington, D.C.: U.S. General Accounting Office, Sep. 15, 1995.

United States General Accounting Office. *Unmanned Aerial Vehicles: No More Hunter Systems Should Be Bought Until Problems are Fixed.* GAO/NSIAD-95-52. Washington, D.C.: U.S. General Accounting Office, Mar. 1, 1995.

United States General Accounting Office. *Unmanned Aerial Vehicles: Medium-Range System Components Do Not Fit.* GAO/NSIAD-91-2. Washington, D.C.: U.S. General Accounting Office, Mar. 25, 1991.

United States General Accounting Office. *Unmanned Vehicles: Assessment of DOD's Unmanned Aerial Vehicle Mater Plan.* GAO/NSIAD-89-41BR. Washington, D.C.: U.S. General Accounting Office, Dec. 9, 1988.

United States General Accounting Office. *Aquila Remotely Piloted Vehicle: Its Potential Battlefield Contribution Still in Doubt.* GAO/NSIAD-88-19. Washington, D.C.: U.S. General Accounting Office, Oct. 26, 1987.

Unmanned Aerial Vehicles Joint Project Office, Department of Defense. *Unmanned Aerial Vehicles 1994 Master Plan.* Washington, D.C.: U.S. O.S.D., May. 31, 1994.

Unmanned Aerial Vehicles Joint Project Office, Department of Defense. *Unmanned Aerial Vehicles 1994 Master Plan.* Washington, D.C.: U.S. O.S.D., Apr. 15, 1992.

INFORMATION SERVICE/INTERNET

Collins, Kipp A. *A Concept of Unmanned Aerial Vehicles in Amphibios Operations.* Monterey, CA: Naval Postgraduate School, 1993. DTIC ADA272764.

Davis, C. R. *Airborne Reconnaissance: The Leveraging Tool for Our Future Strategy.* Washington, D.C.: Industrial College of the Armed Forces, 1995. DTIC ADA294120.

Defense Airborne Reconnaissance Office. Home Page. http://www.acq.osd.mil/daro/homepage/daro_org.html

Fallon, Michael P. *Tracking Cellular Phones with UAV's.* Monterey, CA: Naval Postgraduate School, 1995. DTIC ADA301710.

Howard, Stephen P. *Special Operations Forces and Unmanned Aerial Vehicles, Sooner or Later?* Maxwell, AL: School of Advanced Airpower Studies, 1996. DTIC ADA305682.

Israeli UAV Technologies. Home Page. http://shani.co.il/NewsGuide/news/avi/uav.html

Lukaszewicz, Thomas B. *Joint Doctrine and UAV Employment.* Newport, RI: Naval War College, 1996. DTIC ADA307450.

Predator UAV. Home Page. http://www.peocu.js.mil/Predator/INDEX.HTML

Tactical UAV information. Home Page. http://wwwjtuav.redstone.army.mil/tactical.htm

United States Air Force UAV Program. Home Page. http://www.wg53.eglin.af.mil/battlelab/

United States General Accounting Office. Home Page. http://www.gao.gov

MANUSCRIPTS

Howard, Michael. "*Military Science in an Age of Peace.*" excerpt reprinted in US Army Command and General Staff College, C610 Book of Readings - The Evolution of Modern Warfare, 25-31, Fort Leavenworth: USACGSC, July 1992, 29.

Longino, Dana A., LTC. "*Role of Unmanned Aerial Vehicles in Future Armed Conflict Scenarios*" Research Report No AU-ARI-92-12. Maxwell Air Force Base, AL: Air University Press, December 1994.

Massinon, Anton E., MAJ. "*Collection Tasking of the Corps Unmanned Aerial Vehicale - Short Range (UAV-SR)*" Monograph. Fort Leavenworth, KS: Command and General Staff College, School of Advanced Military Studies, 1993.

McGonigle, Ronald L., MAJ. "*Unmanned Aerial Vehicles (UAVs) on the Future Tactical Battlefield - Are UAVs an Essential Joint Force Multiplier?*" Monograph. Fort Leavenworth, KS: Command and General Staff College, School of Advanced Military Studies, 1992.

PERIODICALS

Bickers, Charles. "UAVs Take Off Into a Multifunction Future." *Jane's Defense Weekly*, Vol 24, No 6, (12 August 1995): 33-34.

Bickers, Charles. "Tier II - Plus: Taking the UAV to New Heights." *Jane's Defense Weekly*, Vol 24, No 6, (12 August 1995): 34-37.

Bickers, Charles. "Systems Worldwide." *Jane's Defense Weekly*, Vol 24, No 6, (12 August 1995): 38.

CAR., (Staffwriter-no name supplied). "Aerial Reconnaissance Boosts Battlefield Awareness Scheme." *Signal,* Vol 51, No 9, (May 1997): 34-39.

CAR., (Staffwriter-no name supplied). "Reconnaissance Demands Swell For Precision-Guided Munitions." *Signal,* Vol 51, No 9, (May 1997): 39-40.

CAR., (Staffwriter-no name supplied). "Europe's Unmanned Aerial Vehicles Enable Fast Action." *Signal,* Vol 51, No 1, (September 1996): 31-34.

Clark, Colin. "Major Force Structure Cuts Loom, Says Top Army Official." *Defense Week*, (14 April 1997): 1.

Cohen, William S. "Report of the Quadrennial Defense Review." *Joint Force Quarterly,* (Summer 1997): 8-14.

Dunlap, Charles J., Jr. "How We Lost the High-Tech War of 2007 - A Warning From the Future." *The Weekly Standard*, (29 January 1996): 22-28.

Evers, Stacey. "ARPA Pursues Pocket Sized Pilotless Vehicles." *Jane's Defense Weekly*, Vol 25, No 12, (20 March 1996): 3.

Evers, Stacey. "USAF; Developing a 30 Year Vision." *Jane's Defense Weekly*, Vol 25, No 15, (10 April 1996): 27-29.

Evers, Stacey. "Rise of the Robots." *Jane's Defense Weekly*, Vol 26, No 5, (31 July 1996): 19-21.

Fulghum, David A. "UAVs, Precision Missiles Pace Australia's Future." *Aviation Week & Space Technology,* (25 August 1997): 62-63.

Fulghum, David A. "First Flight a Success For Outrider UAV." *Aviation Week & Space Technology,* (17 March 1997): 37.

Fulghum, David A. "Defense Dilemma: Force Structure or Modernization." *Aviation Week & Space Technology*, (17 March 1997): 78-80.

Goodman, Glen. "New Eyes in the Sky." *Armed Forces Journal International*, (July 1996): 32-33.

Goodman, Glen. "New Family of US Military UAVs Takes Shape." *Sea Power*, Vol 39, No 12, (December 1996): 33-36.

Gourley, Scott R. "US Glimpses a 'Digitized' Future." *Jane's International Defense Review*, Vol 30, (September 1997): 49-55.

Grier, Peter. "Darkstar and its Friends." *Air Force Magazine*, Vol 79, No 7, (July 1996): 40-45.

Grimes, Vincent. "Drone Aircraft Builders." *National Defensive*, Vol LXXX1, No 522, (November 1996): 38-39.

Graham, Bradley. "Cohen Weighing Three Possible Courses for Shape of Future US Military." *Washington Post*, (04 April 1997): p.4.

Lok, Joris J. & Sweetman, Bill. "Breaking the Bounds of High-Speed Warfare." *Jane's International Defense Review*, Vol 30, (September 1997): 57-64.

Lok, Joris J. "Sky-High Surveillance Realigns the Battlefield." *Jane's International Defense Review*, Vol 30, (September 1997): 65-71.

Morrocco, John D. "Companies Team to Study UCAVs." *Aviation Week & Space Technology*, (4 August 1997): 22.

Richardson, Doug. "Unmanned Aerial Vehicles Stretch Their Wings." *Armada International*, Vol 20, No 5, (Oct - Nov 1996): 6-16.

Rigby, Randall. "Targeting UAVs." *Field Artillery Journal*, (Jan-Feb 1997): 2.

RKA., (Staffwriter-no name supplied). "Technologies Benefit Israel Air Defense, Assaults, Surveillance." *Signal*, Vol 50, No 9, (May 1996): 99-101.

Scott, William B. "USAF Set to Fly 'Mini-Spaceplane'." *Aviation Week & Space Technology*, (4 August 1997): 20-21.

Walker, Susan. "Fires 2020 - The Field Artillery Roadmap." *Field Artillery Journal*, (March-April 1997): 30-33.

Zaloga, Steven J. "UAV Military Future Deemed 'Promising'." *Aviation Week & Space Technology*, (13 January 1997): 89-97.