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Unmanned Aerial Vehicles: Background and Issues for Congress

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November 21, 2005

Abstract. In the past, tension has existed between the services' efforts to acquire UAVs and congressional initiatives to encourage a consolidated DOD approach. Some observers argue that the result has been a less than stellar track record for the UAV. However, reflecting the growing awareness and support in Congress and the Department of Defense for UAVs, investments in unmanned aerial vehicles have been increasing every year. DoD spending on UAVs has increased from $284 million in Fiscal Year 2000 to $2.1 billion in FY2005. Congressional considerations include the proper pace, scope, and management of DoD UAV procurement; appropriate investment priorities for UAVs versus manned aircraft; UAV future roles and applications; personnel issues; industrial base issues; and technology proliferation.

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Summary

The war on terrorism has put a high premium on a primary mission of UAVs, intelligence gathering. Furthermore, the military effectiveness of UAVs in recent conflicts such as Iraq (1990) and Kosovo (1999) opened the eyes of many to both the advantages and disadvantages provided by unmanned aircraft. Long relegated to the sidelines in military operations, UAVs are now making national headlines as they are used in ways normally reserved for manned aircraft. Conventional wisdom states that UAVs offer two main advantages over manned aircraft: they are considered more cost-effective, and they minimize the risk to a pilot's life. However, the current UAV accident rate (the rate at which the aircraft are lost or damaged) is 100 times that of manned aircraft.

UAVs range from the size of an insect to that of a commercial airliner. DOD currently possesses five major UAVs: the Air Force's Predator and Global Hawk, the Navy and Marine Corps's Pioneer, and the Army's Hunter and Shadow. Other key UAV developmental efforts include the Air Force and Navy's unmanned combat air vehicle (UCAV), Navy's vertical takeoff and landing UAV (VTUAV), and the Broad Area Maritime Surveillance UAV(BAMS), and the Marine Corps's Dragon Eye and Dragon Warrior. The services continue to be innovative in their use of UAVs. Recent examples include arming UAVs (Predator, Hunter), using UAVs to extend the eyes of submarines, and teaming UAVs with strike aircraft and armed helicopters to improve targeting.

In the past, tension has existed between the services' efforts to acquire UAVs and congressional initiatives to encourage a consolidated DOD approach. Some observers argue that the result has been a less than stellar track record for the UAV. However, reflecting the growing awareness and support in Congress and the Department of Defense for UAVs, investments in unmanned aerial vehicles have been increasing every year. DoD spending on UAVs has increased from $284 million in Fiscal Year 2000 to $2.1 billion in FY2005.

Congressional considerations include the proper pace, scope, and management of DoD UAV procurement; appropriate investment priorities for UAVs versus manned aircraft; UAV future roles and applications; personnel issues; industrial base issues; and technology proliferation. This report will be updated as necessary.

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Unmanned Aerial Vehicles: Background and Issues for Congress

Background

Unmanned Aerial Vehicles (UAVs) have been referred to in many ways: RPVs (remotely piloted vehicle), drones, robot planes, and pilotless aircraft are a few of the terms that have been used. Most often called UAVs, they are defined by the Department of Defense (DOD) as powered, aerial vehicles that do not carry a human operator, use aerodynamic forces to provide vehicle lift, can fly autonomously or be piloted remotely, can be expendable or recoverable, and can carry a lethal or nonlethal payload. Ballistic or semiballistic vehicles, cruise missiles, and artillery projectiles are not considered UAVs by the DOD definition.[1] Drones differ from RPVs in that they are designed to fly autonomously. UAVs are either described as a single air vehicle (with associated surveillance sensors), or a UAV system (UAS), which usually consists of three to six air vehicles, a ground control station, and support equipment.

The military use of UAVs in recent conflicts such as Iraq (2003), Afghanistan (2001), and Kosovo (1999) has opened the eyes of many to the advantages and disadvantages provided by unmanned aircraft. UAVs regularly make national headlines as they are used to perform tasks historically performed by manned aircraft. UAVs are thought to offer two main advantages over manned aircraft: they eliminate the risk to a pilot's life, and their aeronautical capabilities, such as endurance, are not bound by human limitations. UAVs may also be cheaper to procure and operate than manned aircraft. UAVs protect the lives of pilots by performing the "3-D" missions - those dull, dirty, or dangerous missions that do not require a pilot in the cockpit. However, the lower procurement cost of UAVs must be weighed against their greater proclivity to crash, while the minimized risk should be weighed against the dangers inherent in having an unmanned vehicle flying in airspace shared with manned assets.

There are a number of reasons why the employment of UAVs has recently grown. Navigation and communication technology is now available that wasn't available just a few short years ago. Some say that the services' so-called "silk scarf syndrome" of preferring manned aviation over unmanned, has diminished as UAVs entered the mainstream.

Although only recently procured in significant numbers by the United States, UAVs have had a century-old history in aviation. First included in *Jane's All the World's Aircraft* in 1920, UAVs were tested during World War I, but not used in combat by the United States during that war. However, it was not until the Vietnam

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[1] Joint Publication 1-02, "DoD Dictionary of Military and Associated Terms."

War that UAVs such as the AQM-34 Firebee were used in a surveillance role. The Firebee exemplifies the versatility of UAVs — initially flown in the 1970s, it was modified to deliver payloads and flew its first flight test as an armed UAV on December 20, 2002.[2]

The Israeli Air Force pioneered several UAVs in the late 1970s and 1980s that were eventually integrated into the United States's UAV inventory. U.S. observers noticed Israel's successful use of UAVs during operations in Lebanon in 1982, encouraging then-Navy Secretary John Lehman to acquire a UAV capability for the Navy. Interest also grew in other parts of the Pentagon, and the Reagan Administration's FY1987 budget requested notably higher levels of UAV funding.[3] This marked the transition of UAVs in the United States from experimental projects to acquisition programs.

One of the UAVs acquired from Israel, Pioneer, emerged as a useful source of intelligence at the tactical level during Operation Desert Storm. Pioneer was used by Navy battleships to locate Iraqi targets for its 16-inch guns. Following the Gulf War, military officials recognized the potential value of UAVs, and the Air Force's Predator became a UAV on a fast track, quickly adding new capabilities.[4] Debuting in the Balkans conflict, the Predator performed surveillance missions such as monitoring area roads for weapons movements and conducting battle damage assessment. Operations in Afghanistan have featured the Air Force's Global Hawk, as well as adding a new mission for Predator that allows the UAV to live up to its name — armed reconnaissance. There are currently five major UAVs in the U.S. inventory: the Navy and Marine Corps's Pioneer, the Air Force's Global Hawk and Predator, and the Army's Hunter and Shadow UAVs.

Reflecting a growing awareness and support in Congress for UAVs, investment in unmanned aerial vehicles has increased annually. The FY2001 investment in UAVs was approximately $667 million, while the FY2003 funding totaled over $1.1 billion dollars. The Pentagon has asked for $1.6 billion in procurement and development funding for FY2006, with much more planned for the out years.

Congress's role in UAV development has been one of strong encouragement tempered with concern. Taking a proactive stance in UAV program management, Congress has in the past directed the formation of joint program offices to ensure commonality between the services' UAV programs. Congress has also expressed concern that DOD's "growing enthusiasm may well lead to a situation in which there is no clear path toward the future of UAVs", and so has required DOD to submit a

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[2] Jefferson Morris. "Northrop Grumman Modifies BQM-34 Firebee To Drop Payloads." *Aerospace Daily*, January 22, 2003.

[3] For more on the early history of UAV use, CRS Report 93-686 F, *Intelligence Technology in the Post-Cold War Era: The Role of Unmanned Aerial Vehicles (UAVs)*, by Richard A. Best, Jr., 1993, p. 7-10, is available from author on request.

[4] Jim Garamone. "From U.S. Civil War To Afghanistan: A Short History Of UAVs." *American Forces Information Service*, *Defenselink.mil*, April 16, 2002.

UAV roadmap.[5] In some instances, Congress has advocated a more aggressive approach to fielding UAVs. For example, in 1996, the House Armed Services Committee (HASC) supported legislation directing DOD to weaponize both the Predator and Hunter, but DOD opposed the initiative.[6] The scope of Congress's support and confidence in UAV technology can be gleaned from a prediction in the report accompanying the National Defense Authorization Act for Fiscal Year 2001, which stated that, "Within ten years, one-third of U.S. military operational deep strike aircraft will be unmanned."[7]

Congressional Considerations

In recent years, the pace of UAV development has accelerated, and the scope of UAV missions and applications has expanded. How should these efforts be managed so that they are cost-efficient, effective, and interoperable? In its eagerness to deploy UAVs, does DoD risk duplication of effort between various programs? Are DOD UAV acquisition plans responsive to congressional direction?

Investment priorities could change as the introduction of UAVs into the U.S. inventory shifts the balance between manned and unmanned capabilities. Congress, as part of its defense oversight responsibilities, may assess DOD's current UAV efforts to verify that they match up with new investment goals and strategies. Conventional wisdom states that UAVs are cheap, or cost-effective. Is this true today? How do UAV costs compare to manned aircraft costs?

UAVs have traditionally been used for reconnaissance and surveillance, but today they are being employed in roles and applications that their designers never envisioned. The unanticipated flexibility and capability of UAVs has led some analysts to suggest that more, if not most, of the missions currently undertaken by manned aircraft could be turned over to unmanned aerial platforms, and that manned and unmanned aircraft could operate together. Congress may have to contemplate the replacement of a significant portion of the manned aircraft fleet with unmanned aircraft that have yet to be designed.

The defining characteristic of UAVs is that they are "unmanned." If UAVs are introduced into the force in large numbers, might personnel issues arise? Recruitment and retention is a perennial congressional issue, that may be receiving increased attention due to the operational stresses associated with the Global War on Terrorism. What impact might wide spread deployment of UAVs have on military personnel?

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[5] U.S. Congress, 2d Session, House of Representatives, Committee on Appropriations, Department of Defense Appropriations Bill for Fiscal Year 2003, H.Rept. 107-532, p.207.

[6] Hearing of the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee. "Fiscal Year 2004 Budget Request for Unmanned Combat Aerial Vehicles and Unmanned Aerial Vehicle Programs." March 26, 2003.

[7] U.S. Congress, 106th Congress, 2d Session, Senate, Committee on Armed Services, National Defense Authorization Act for Fiscal Year 2001, S.Rept 106-292, p.141.

Industrial base issues also need to be considered. If defense companies devote more of their time and expenses to develop unmanned aircraft, will the skills and technologies needed for manned aircraft design erode? Those who argue that UAVs will replace manned aircraft in the future are not as concerned with the industrial base issue as those who feel manned aircraft will still be needed to combat future threats.

As U.S. companies compete for business in a growing international UAV marketplace, concerns about the proliferation of these systems may grow. Are steps required — and if so, what might they be — to control the spread of UAVs? As part of its defense and foreign policy oversight, Congress may examine whether a balance must be struck between supporting legitimate U.S. exports and curbing the spread of UAV technologies to dangerous groups or countries.

Pace of UAV Acquisition and Scope of Missions or Applications

Undeniably, UAVs are being developed, procured and fielded in growing numbers. The diversity of designs and applications is also accelerating. Considering this growth, many in Congress may wish to evaluate the management of UAVs: Are UAVs being developed fast enough? Are they being developed too fast? Has DoD developed an appropriate plan and structure for incorporating UAVs into future military capabilities?

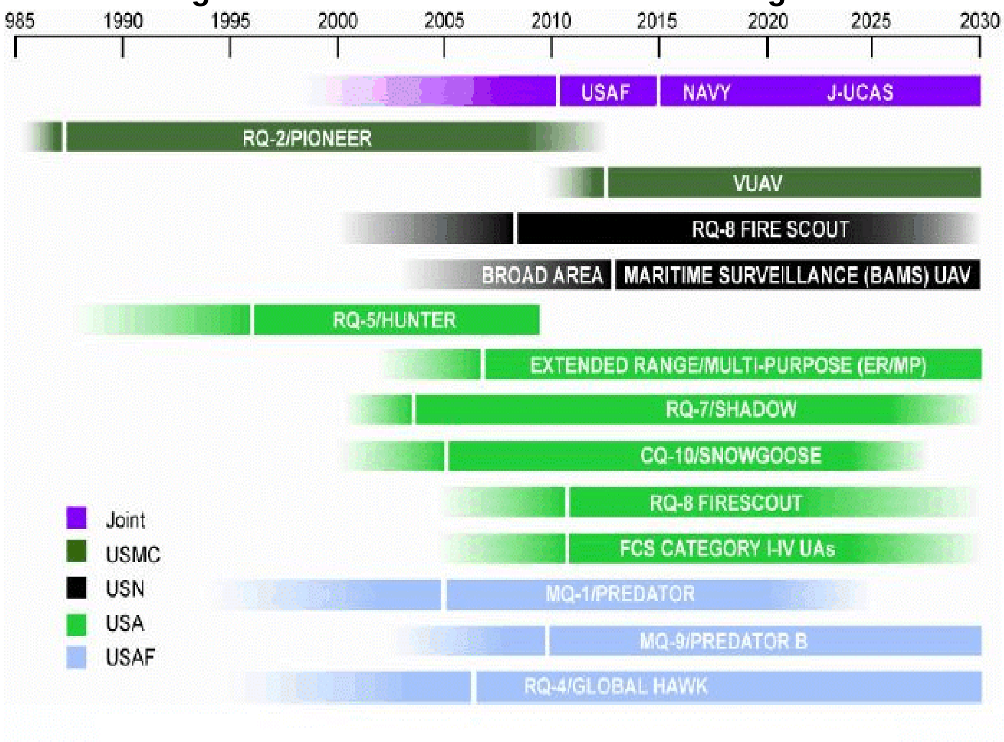
UAV programs range from the combat tested — Pioneer, Hunter, Predator and Global Hawk — to the not yet tested — the Air Force and Navy's Unmanned Combat Air Vehicles. Sizes and ranges of UAVs also vary greatly: the Wasp Micro UAV at 8 inches long has a combat radius of 5 nautical miles, while the Global Hawk at 44 feet long (the size of a medium sized corporate jet) has a combat radius of 5,400 nm. **Figure 1** shows the evolution of UAVs and demonstrates the recent initiation of several UAV programs.[8]

Similarly, **Table 1** outlines the total UAV inventory.[9] When compared to the inventory of February 2003,which only included five major platforms yeilding an inventory of 163 unmanned aircraft, the acceleration and expansion becomes clear. The 604 UAVs includes many 2nd generation derivatives, such as Predator B and I-Gnat-ER, and several non-traditional vehicles, such as Snow Goose, Onyx and Neptune.

[8] For a more comprehensive treatment of these UAV programs, see the "Current DoD UAV Programs" section below.

[9] Note that to avoid accounting issues, these inventories do not include small UAVs, micro UAVs or lighter-than-air platforms.

Figure 1. Current and Planned UAV Programs



Source: OSD, UAS Roadmap 2005-2030, August 2005, Section 2, p. 3.

Table 1. UAV Platforms

UAV	User or Sponsor	Estimated Inventory[a] (Feb 05)
Predator A	Air Force	120
Predator B	Air Force	6
Global Hawk	Air Force/Navy	12
Hunter	Army	62
Shadow	Army	100
Pioneer	Navy/Marine Corps	175
Fire Scout	Navy/Marine Corps	5
I-Gnat-ER	Army	3
J-UCAS	Air	3
Hummingbird	Army/Navy/DARPA	4
Neptune	SOCOM-Navy	15
Maverick	SOCOM-Army/Navy	4
XPV-1 Tern	SOCOM	65
XPV-2 Mako	SOCOM	30
CQ-10 Snow Goose	SOCOM-Army	15
Onyx	SOCOM-Army	5
Total		**624**

Source: OSD, UAS Roadmap 2005-2030, August 2005; Safety and accident reports from each service's website.
Note: For comparison purposes, table does not include Mini/Small, Micro, or Lighter-than-Air UAVs.

a. Estimate Inventories calculated by subtracting number of UAVs lost to attrition from the total number of UAVs delivered. Attrition numbers were taken from Class A accidents reported by each service; Total UAVs delivered for each platform were drawn from the OSD's *UAS Roadmap 2005-2030*, August 2005.

The increase in DoD's UAV inventory appears largely due to the rising demand for UAVs to conduct a wide variety of missions and to branch out from the typical intelligence, surveillance and reconnaissance (ISR) applications. Predator B is equipped with a strike capability, and many Predator As have been modified to carry weapons. The Joint-Unmanned Combat Air Systems (J-UCAS) final product will target air defenses (missiles, artillery, air bases, and command-and-control facilities). Additionally, mine detection, border patrol, medical resupply, and force perimeter protection are increasingly considered as roles for UAVs.[10]

DOD's UAV research and development (R&D) funding has also grown, for a variety of reasons: UAVs are considered a growth industry, many UAVs are relatively inexpensive to produce and new technology in miniaturization has helped accelerate the development of many UAV types. R&D funding in FY2006 for UAVs is more than double the total procurement funding for UAVs. This suggests that accelerated acquisition of UAVs is likely to continue in the future.

In order to understand fully the pace and scope of UAV acquisition, a comparison between manned aircraft inventories and unmanned inventories may prove to be a useful tool. **Figure 2** shows the ratio of manned to unmanned aircraft. Despite the recent acceleration in UAV production, manned aircraft still represent 95% of all DoD aircraft, which suggests that UAVs replacing manned aircraft in the foreseeable future is not likely. Rather UAV programs have quite frequently been described as complements to, or augmentation of manned aircraft.

As it appears from statements and internal recommendations, the pace of UAV production will either continue or accelerate in the coming years. When asked to study DoD's UAV programs, the Defense Science Board (DSB) found that "the single most important recommendation is to accelerate the introduction of UAVs into the force structure."[11]

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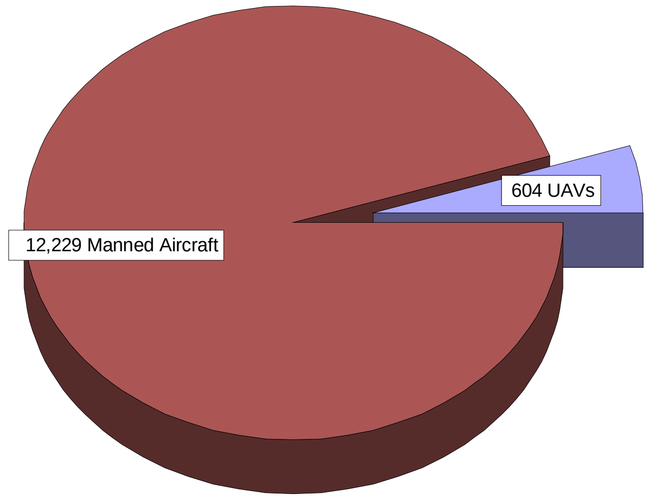
[10] For an more in-depth analysis of UAV capabilities, see *Role and Applications* in the later end of this section.

[11] *Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles*. Office of the Under Secretary of Defense for Acquisition, Technology, and Logistics. February 2004. p.V.

Figure 2. Manned Aircraft Inventory vs. UAV Inventory



Source: *The Military Balance 2004-2005; 2005-2030 UAS Roadmap*

Further, some describe Air Force plans to grow UAV operations in the Air National Guard and Air Force Reserve as a "massive introduction" of the technology.[12] Former Air Force Chief of Staff, General John Jumper indicated a significantly faster pace of production of UAVs, specifically of the Predator, when he told the Senate Armed Services Committee, "we're going to tell General Atomics to build every Predator they can possibly build."[13]

These statements raise the question of whether the current and anticipated pace of UAV development is appropriate. Historically, Congress has chastened DoD for what it saw as a leisurely rate of UAV acquisition and encouraged it to speed up this pace, or speed up the incorporation of certain capabilities. For example, the National Defense Authorization Act for Fiscal Year 2001 expressed the Senate's desire that "Within ten years, one-third of U.S. military operational deep strike aircraft will be unmanned."[14] This goal was seen at the time as very challenging, because DoD had no unmanned deep strike aircraft. In 1996, the House Armed Services Committee (HASC) supported legislation directing DoD to weaponize both the Predator and

[12] David Fulghum. "Rapid Expansion of UAV Units Planned." *Aviation Week & Space Technology*. September 26, 2005.

[13] Hearing of the Senate Armed Services Committee. "The Defense Fiscal Year 2006 Budget." February 10, 2005. *Federal News Service*.

[14] U.S. Congress, 106th Congress, 2d Session, Senate, Committee on Armed Services, National Defense Authorization Act for Fiscal Year 2001, S.Rept 106-292, p.141.

Hunter, but DoD opposed the initiative.[15] Some in the 109th Congress have advocated increased procurement and application of UAVs for non-military roles. For example, House Homeland Security Committee Chairman, Representative Peter King was reported to have said that UAVs are "'underutilized' by the Department of Homeland Security, and should play a larger role in border security."[16]

On the other hand, Congress has also expressed concern that DoD's "growing enthusiasm may well lead to a situation in which there is no clear path toward the future of UAVs."[17] Some critics have expressed concern that an overly ambitious pace could affect the quality of the end product and the efficiency of the acquisition process. A fast pace could make congressional oversight much more difficult, which could allow UAV programs to exceed cost or to stray from the design objective. As Representative Curt Weldon cautioned,

> Aggressively fielding new types of vehicles and even building more of the same type of vehicle may be premature. We must feel confident that we have adequately addressed some of the fundamentals to ensure that unmanned air systems are designed and fielded consistent with the common communications architecture and that common standards are established for operations. ... Some services are buying million dollar UAVs using operations and maintenance funding that has never been specifically authorized for UAVs and for which appropriations have never been made. ... Other services are leasing UAV services for combat operations using operations and maintenance accounts. And some services have effectively reduced congressional oversight by establishing UAV projects within multi-billion dollar, multi-project aggregated program requests. [18]

The Global Hawk's ambitious pace may be an example of the dilemma Representative Weldon described. A 2004 Government Accountability Office (GAO) report cites a crowded production schedule and aggressive funding strategy as one reason for the "immaturity" of several critical technologies for the Global Hawk program.[19] The report indicates that a deceleration of pace — possibly even a temporary halt in production — must be coupled with management changes in order to preserve the quality and efficiency of the Global Hawk development process. Many, in DoD and in Congress, may argue that the pace is appropriate and the Global

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[15] Hearing of the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee. "Fiscal Year 2004 Budget Request for Unmanned Combat Aerial Vehicles and Unmanned Aerial Vehicle Programs." March 26, 2003.

[16] George Cahlink. "New Homeland Security Chairman Sees Larger Role for UAVs in Border Security." *Defense Daily*. October 14, 2005.

[17] U.S. Congress, 2d Session, House of Representatives, Committee on Appropriations, Department of Defense Appropriations Bill for Fiscal Year 2003, H.Rept. 107-532, p.207.

[18] Rep. Curt Weldon. "House Armed Services Subcommittee on Tactical Air and Land Forces Holds Hearing on FY2006 Defense Budget." House of Representatives. March 9, 2005.

[19] Government Accountability Office. "Unmanned Aerial Vehicles: Changes in Global Hawk's Acquisition Strategy Are Needed to Reduce Program Risks." *GAO -05-6.* November 2004.

Hawk's problems are exceptional. They could argue that the rapid rate of production of the Hunter in the past and the Predator currently are evidence that a fast pace can be extremely efficient and produce high quality aircraft.

While supporting UAV programs in general, and even challenging DoD to pursue UAVs more aggressively, many in Congress appear to want assurances that tax-payer dollars are being well spent. For example, Section 142 of the FY2006 Defense Authorization Act (H.R. 1815, H. Rept. 109-89, p.123) "would preclude procurement of new unmanned aerial vehicle systems by the military services without the written approval of the Under Secretary of Defense for Acquisition, Technology, and Logistics."

UAV Management Issues

In addition to establishing acquisition pace, and scope of application, one crucial Congressional task may be to determine whether DoD's administrative processes and lines of authority within the acquisition process are effective for UAV development and acquisition. The management of DoD's development and acquisition programs has received heightened attention in the 108th and 109th Congresses. The Air Force's attempt to lease 100 KC-767 tanker aircraft, and many aspects of the Army's Future Combat System (FCS) have focused congressional scrutiny on the mechanics of DoD's acquisition process.[20] Because UAVs are acquired by all four of the military services, and the U.S. Special Operations Command, and because UAVs appear to be acquired at an accelerated rate, and for a growing list of applications, it appears that great potential exists for duplication of effort. This leads many to call for centralization of UAV acquisition authority, to ensure unity of effort, and reduce chances for wasteful duplication of effort. On the other hand, if UAV efforts are too centralized, some fear that competition and innovation may be repressed.

Another management issue pertains to cost. UAVs are developed and procured through the same acquisition system as manned aircraft, and they appear to suffer from similar cost growth. Once viewed as a cheap alternative to manned aircraft, or even a "poor man's airforce," some UAVs are beginning to rival manned aircraft in cost. According to DoD's most recent estimate, the Global Hawk program will cost $6.5 billion to purchase 51 aircraft; a program unit acquisition cost of $128 million per UAV. The program has seen $194 million in development cost overruns, triggering a Nunn-McCurdy breach due to an average unit cost growth of 18 percent per airframe and has prompted appropriators to voice their concern (H.R. 2863, 109-119, p.174).[21]

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[20] See, for example, CRS Report RL32056, *The Air Force KC-767 Tanker Lease Proposal: Key Issues For Congress*, by Christopher Bolkcom (coordinator) and CRS Report RL32888, *The Army's Future Combat System (FCS): Background and Issues for Congress*, by Andrew Feickert.

[21] The Nunn-McCurdy provision requires DoD to notify Congress when cost growth on a major acquisition program reaches 15%. If the cost growth hits 25%, Nunn-McCurdy requires DoD to justify continuing the program based on three main criteria: its importance to U.S. national security; the lack of a viable alternative; and evidence that the problems that (continued...)

Much of UAV cost growth appears to be attributable to factors that have plagued manned aircraft programs, such as "mission creep," and inconsistent management practices. Global Hawk costs, for example, have been driven up by adding multiple sensors, which themselves increase cost, but also require larger wings and more powerful engines to carry the increased weight, which also increases cost. Originally, Global Hawk was intended to carry one primary kind of sensor at a time, a fleet of these UAVs would provide a mix of sensors. To make Global Hawk more analogous to the U-2 aircraft, DoD changed the requirement so that Global Hawk is to carry two or more primary sensors, which has increased the UAV's price.[22]

Originally considered a relatively modest UAV, the Joint Unmanned Combat Air System (JUCAS) has evolved into a large, long range aircraft with a heavy payload, which has increased cost. Further, DoD has cut over $1 billion from the JUCAS budget, and has moved management of the program from the Defense Advanced Research Projects Agency (DARPA) to the Air Force. Cutting the JUCAS budget topline may reduce the total number or aircraft to be procured, but can also increase the cost per aircraft. Changing management responsibility can also contribute to cost growth via a lack of coherent direction, and changes in requirements and priority.

The frequent change and realignment of DoD's organizations with a role in UAV development illustrates the difficulties of establishing a comprehensive UAV management system. Over the years, management of UAV programs has gone full circle from the military services, to a Navy-run Joint Program Office (JPO), to the Defense Airborne Reconnaissance Office (DARO) and then back to the services, under the auspices of OSD. The JPO was established in 1988, but met criticism in Congress. In 1992, Congress expressed its...

> serious reservations over the management of these [UAV] programs by the joint program office. Remarkably little progress has been registered during the past five years in this area. The conferees believe the Secretary of Defense should undertake a comprehensive review of the joint [project] office.[23]

The JPO was replaced by the Defense Airborne Reconnaissance Office (DARO), created in 1993 to more effectively manage DoD's disparate airborne reconnaissance programs, including UAVs. DARO was disbanded in 1998, amid further criticism of problems, redesigns, and accidents with the family of systems that

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[21] (...continued)
led to the cost growth are under control. H.R. 1815 (P.L. 109-89 sec. 802) would amend Nunn-McCurdy to lower the cost-growth threshold for providing detailed information on problem programs from 25 to 15 percent.

[22] For more information, see CRS Report RL30727: *Airborne Intelligence, Surveillance, and Reconnaissance (ISR): The U-2 Aircraft and Global Hawk UAV Programs*, by Richard A. Best, Jr. and Christopher Bolkcom.

[23] U.S. Congress, 102d Congress, 2d Session, Committee of Conference, National Defense Authorization Act for Fiscal Year 1993, H.Rept. 102-966, p.635.

it was formed to develop.[24] It is unclear whether this criticism was completely legitimate, or whether it was generated by advocates of manned aviation, who sought to protect these established programs.

Since DARO's demise, there has been no single procurement focal point to manage DOD UAV efforts. General oversight authority resides within the Office of the Assistant Secretary of Defense for Command, Control, Communications and Intelligence (OASD(C3I)), while the military services manage program development and acquisition.

In an effort to increase joint coordination of UAV programs operated by the services, the OSD established the Joint UAV Planning Task Force in 2001. The task force, which falls under the authority of the Pentagon's acquisition chief (Under Secretary of Defense for Acquisition, Technology and Logistics), works to help standardize payload development, establish uniform interfaces, and promote a common vision for future UAV-related efforts. Subsequently, the Joint UAV Planning Task Force has been viewed by many in the defense community as the top rung on the UAV management ladder. Dr. Glenn Lamartin, Director of Defense Systems in the OSD, argued that the Joint UAV Task Force was empowered through the Joint Staff to institute requirements, satisfy joint needs and to provide discipline and structure to individual programs.[25] In order to help a common UAV vision become a reality, the task force has, through the OSD, published three UAV Roadmaps: April 2001, December 2002, and August 2005.

In spite of the creation of the UAV Task Force, Congressional concerns with UAV acquisition management, program duplication, interoperability, and other issues continued. For example, in 2002, the House Committee on Armed Services noted: "The committee expresses its concern about proper program management elsewhere in this report, and is specifically concerned that UAV programs adhere to the same standards as other acquisition programs."[26]

Several other management mechanisms have recently been initiated in addition to the UAV Task Force. In 2003 the U.S. Joint Forces Command announced that it would take the lead in conducting experimentation in UAV interoperability and flexibility for the Joint UAV Task Force.[27] Also in 2003, DoD created the UAV Interoperability Working Group to pursue joint-service and international cooperation in UAV programs to support systems development. The Joint Requirement

[24] Bill Sweetman. "DARO Leaves A Solid Legacy," *Journal of Electronic Defense,* June 1998, p.43.

[25] Glenn LaMartin, testimony before the House Armed Services Subcommittee on Tactical Air and Land Forces. "House Armed Services Subcommittee on Tactical Air and Land Forces Holds Hearing on FY2006 Defense Budget." U.S. House of Representatives, March 9, 2005.

[26] U.S. Congress, 107th Congress, 2nd Session, House of Representatives, Committee on Armed Services, Bob Stump National Defense Authorization Act For Fiscal Year 2003, H.Rept. 107-436, p.243.

[27] Jefferson Morris. "JFCOM Taking Lead Role in Joint UAV Experimentation." *Aerospace Daily*. July 18, 2003.

Oversight Council (JROC), which "reviews operational requirements representing the interests of the operational or warfighting community" and its combatant commanders,[28] established a UAV Special Studies Group, which serves as the staff-level advisory and action organization concerning all UAV issues under JROC's purview. [29]

In what appeared to be a move toward further management restructuring, reports in the spring of 2005 indicated that OSD was considering appointing one of the services as the executive agent and coordinator for UAV programs, a position for which Air Force actively petitioned.[30] However, in late June 2005, the JROC announced that DoD had abandoned the notion of an executive agent in favor of two smaller organizations focusing on interoperability.[31] The first, entitled the Joint UAV Overarching Integrated Product Team (OIPT), provides a forum for identification and problem solving of major interoperability and standardization issues between the services.[32] In compliment, the Joint UAV Center of Excellence coordinates with the OIPT to improve interoperability and enhance UAV applications through the examination of sensor technologies, UAV intelligence collection assets, system technologies, training and tactics.[33]

Over the past three years, management initiatives to increase system uniformity and interoperability have been equally as numerous as the overall management structure initiatives. Most recently, JROC established two organizations to promote joint coordination of production.

The constant organizational changes has led to mounting concern over UAV management. These fluctuations suggest that DoD has not yet landed on a final UAV development and oversight structure to meet the needs of the military. Instead, the recent establishment of the Joint UAV OIPT and Joint UAV COE have lead many to believe that these bodies are not a final solution, but a step in the right direction. The March 2005 testimony by the GAO to the House Armed Services Subcommittee on Tactical Air and Land Forces most likely played a role in facilitating the OSD's creation of these management groups. The testimony criticized DoD for the lack of an "...oversight body to guide UAV development efforts and related investment decisions," which ultimately does not allow DoD "...to make sound program

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[28] Office of the Under Secretary of Defense (Acquistion & Technology) (OUSD(A&T)) Defense Airborne Reconnaissance Office (DARO). "UAV Management and Oversight." UAV Annual Report FY1997, [http://www.fas.org].

[29] Ibid.

[30] John A. Tirpak. "The UAV Skirmishes." *Air Force Magazine*. June 2005, pg. 11.

[31] "JROC Cans UAV Executive Agent Idea, Back Joint Excellence Center." *Inside the Pentagon*. June 30, 2005.

[32] Office of Assistant Secretary of Defense for Public Affairs, "Joint Unmanned Aerial Vehicle Team, Center of Excellence Announced." July 8, 2005.

[33] Ibid.

decisions or establish funding priorities."[34] From the testimony, it would appear that the GAO envisioned a central authority or body to satisfy this role. However, DoD's intended purpose for this oversight body may differ from the GAO's concept. Air Force Major General Stephen M. Goldfein, commander of the Air Warfare Center at Nellis Air Force Base, NV, described the UAV Center of Excellence as a "...one-stop shop that takes a look at all the possibilities for common operating systems and the best ways to use UAVs".[35] If the intent of these bodies are simply to serve as 'one-stop' checkpoints in the UAV development process instead of the centralized monitoring and oversight authority envisioned by the GAO, then questions may arise over where the final management authority resides — within these bodies or with each of the services? The task of finding adequate answers to these problems may fall on the shoulders of Congress in the coming years.

Outside of the current management structure, does our defense establishment have an adequate plan or framework for how UAVs will fit into the future of U.S. warfighting? The Joint UAV Task Force released in 2001 and 2002 the *UAV Roadmap* and a follow up in 2005, entitled the *2005-2030 UAS Roadmap* for the purpose of providing guidance on the future roles for UAVs, the technological progress and opportunities for UAVs, and the potential UAV investment needs. In March of 2005, prior to the release of the updated *UAS Roadmap*, the GAO called upon the Department of Defense to establish a binding and authoritative strategic plan, citing the 2002 Roadmap failure to outline the inter-service strategic goals for UAVs and its lack of clearly defined investment priorities.[36]

The 2005 UAS Roadmap reiterates its predecessor's mandate and scope. It states that its purpose is part of an oversight service in which the intent is to give strong guidance "...in such cross-program areas as standards development and other interoperability solutions."[37] Furthermore, the Roadmap neither, "....authorizes specific UAS nor prioritizes the requirements.... It does, however, identify future windows when technology should become available to enable new capabilities, linked to warfighters' needs, to be incorporated into current or planned UAS."[38] Like its predecessor, the Roadmap only provides guidance and refrains from establishing a authoritative blueprint for the future of UAV development paths and approaches. Most likely, the discrepancy between the DoD's approach to the Roadmap's authority and the GAO's vision of strategic UAV plan will generate significant debate in the

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[34] Sharon Pickup and Michael J. Sullivan, written testimony before the House Armed Services subcommittee on Tactical Air and Land Forces. "Unmanned Aerial Vehicles Improved Strategic and Acquisition Planning Can Help Address Emerging Challenges." Government Accountability Office. *GAO-05-395T*. March 9, 2005, p. 1.

[35] David A. Fulghum. "UAVs, Views From Nellis."*Aviation Week* & Space *Technology*. September 26, 2005, p. 56.

[36] Sharon Pickup and Michael J. Sullivan, written testimony before the House Armed Services subcommittee on Tactical Air and Land Forces. "Unmanned Aerial Vehicles Improved Strategic and Acquisition Planning Can Help Address Emerging Challenges." Government Accountability Office. *GAO-05-395T*. March 9, 2005, p. 1.

[37] OSD. 2005-2030 UAS Roadmap. August, 2005, p. 1.

[38] Ibid.

discussion of future UAV management. Consequently, in the wake of the establishment of the Joint UAV OIPT and COE, Congress may decide to revisit the recommendations of the GAO and to evaluate the adequacy of the Roadmap mandate in order to determine the best way to integrate UAVs into our future warfighting capabilities.

UAVs and Investment Priorities

All four military services, the U.S. Special Operations command (SOCOM), and the U.S. Coast Guard are developing and fielding UAVs. Developing a coordinated, DOD-wide UAV investment strategy appears key to ensuring duplication is avoided, and scarce resources are maximized. As part of its defense oversight role, Congress is positioned to arbitrate between competing UAV investments, or impact DOD's overarching investment plan. Several relevant questions seem apparent: How is UAV cost quantified? What is the most effective balance in spending between UAVs and manned aircraft? How should DoD, Congress and the UAV manufacturers balance cost with capability? Finally, what areas of investment are the most important to maximize UAV capabilities?

Quantifying and characterizing cost has proven to be a complicated task for the members of the UAV community, yet would need to be assessed in an exploration of UAV cost efficiency.[39] As with most aircraft, UAV costs can be depicted by different measurements. Two of the most frequently cited cost descriptions are flyaway cost, and program acquisition unit cost (PAUC). According to the Air Force's System Command (AFSC) Cost Estimating Handbook, an air vehicle's flyaway cost includes "prime mission equipment (sensor payload, propulsion mechanics, and body design), systems engineering, program management, and allowances for engineering changes and warranties."[40] In contrast, the PAUC, as described by the Government Accountability Office, is the "total of all acquisition-related appropriations divided by the total quantity of fully configured end items", which takes into account acquisition cost from previous years that tend to be more than the current year acquisition cost.[41] The difference between Global Hawk's PAUC and flyaway cost demonstrates the wide discrepancy between these

[39] UAV cost can either be defined by unit cost of an individual air vehicle, or by system cost. System cost could include one to six air vehicles, the sensor package, the ground control station, and various support equipment. Acquisition cost is one measure, to include research and development and procurement costs, but operation and maintenance (O&M) cost is another factor. Costs stated are acquisition costs unless otherwise noted.

[40] "AFSC Cost Estimating Handbook Series." Reading, MA. Prepared for the U.S. Air Forces Systems Command. p. 1986: 217.

[41] U.S. Government Accountability Office. "Defense Acquisitions: Information for Congress on Performance of Major Programs Can Be More Complete, Timely, and Accessible." Report to the Subcommittee on Defense, Committee on Appropriations, U.S. Senate. March 2005, GAO-05-182.

cost descriptions: Global Hawk's flyaway cost for FY2005 was $64.1 million, while its PAUC is $128.7 million.[42]

When compared to other aircraft, the cost of an individual remotely piloted vehicle can be misleading. UAVs operate as part of a system, which generally consist of a ground control station, a ground crew including remote pilots and sensor operators, communication links and often other air vehicles. Unlike a manned aircraft such as an F-16, these supporting elements are a requisite for the vehicle's flight.[43] Consequently, analysts comparing UAV costs to manned aircraft may need to consider the cost of the supporting elements and operational infrastructure that make up the complete unmanned aviation system.

Monitoring or evaluating UAV costs can also be complicated by budgeting conventions. While UAVs can be found in the "Aircraft Procurement, Air Force" account in that service's budget request documentation, the Army includes its UAV funding requests in "Other Procurement, Army." This account contains a broad range of dissimilar items to be procured. Also, because most UAVs conduct Intelligence, Surveillance and Reconnaissance missions, some portion of their costs are covered in the Intelligence budget rather than the DOD budget, which complicates building a complete picture of cost.

Once an adequate and uniform cost comparison mechanism or definition has been established, the next step for Congress may be to identify an appropriate balance in spending between UAVs and manned aircraft. As a result of the apparent ascension of UAVs to a permanent position in the US's military aircraft inventory, one logical question should be, "How much should be spent on UAVs in relation to manned aircraft?." If the upward trend in UAV funding continues through 2010, as shown in **Figure 3**, DoD is projected to have spent upwards of $18 billion on procurement, RDT&E, operations and maintenance for UAVs from 2001-2010. This number far exceeds the $3.5 billion spent on UAVs in the preceding decade.

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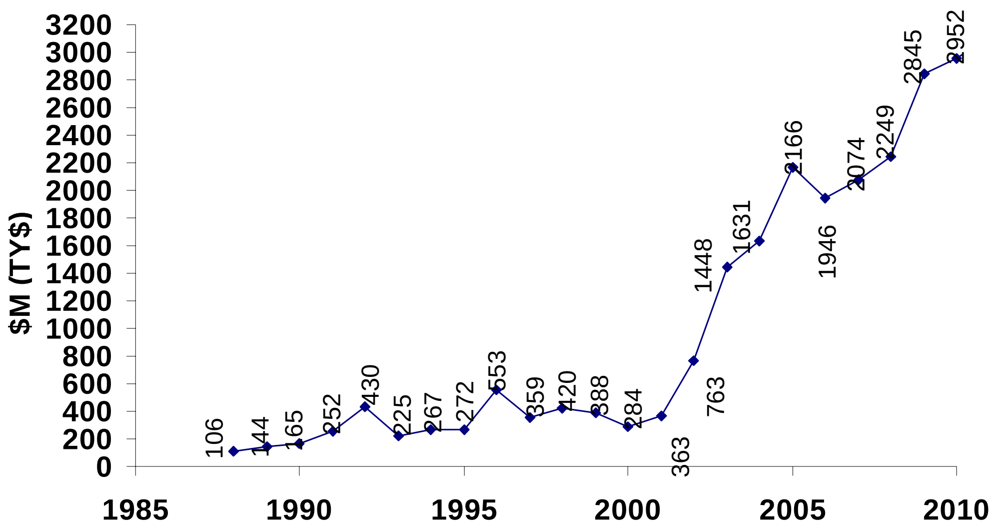
[42] Flyaway cost: OSD. Aircraft Procurement, Air Force, BA 04: Other Aircraft FY2005, February 2004, High Altitude Endurance - UAV, Item No. 17, p. 4 of 39. PAUC: OSD. Selected Acquisition Report. December 31, 2004, p. 11.

[43] Manned aircraft like the F-16 do require a ground crew for takeoff/landing, radar operators and air traffic controllers in order to maximize their performance, yet none of these are requisite for flight. Feasibly, an F-16 needs a pilot in the cockpit and little-else. UAVs, with the exception of the few autonomous flight models, require constant intervention and control from a ground crew. The probability that an F-16 could sustain flight without communication from its ground crew is relatively high, whereas the lack of communication between the ground operators and the UAV yields a significantly low probability of sustained flight.

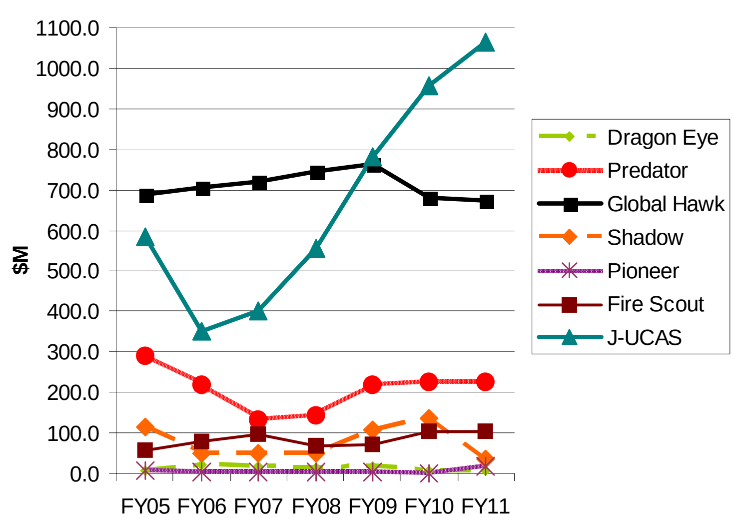
Figure 3. UAV Annual Funding Profile



Source: OSD, UAS Roadmap 2005-2030, August 2005, p.37.

Figure 4 illustrates the funding by platform requested and expected to be requested by the executive branch from FY2005 to FY2011. While funding for many of these programs will remain steady through the decade, the Presidential Budget Requests for the Joint Unmanned Combat Air System is expected to break $1 billion by FY2011, which could be an indicator of where the Department of Defense plans to go with UAV funding.

Figure 4. President's Budget Request For UAV (By Platform)



Source: OSD, UAS Roadmap 2005-2030, August 2005, p.38.

Figure 5 compares manned to unmanned funding from FY2006 through FY2011. The chart reveals that UAV will remain somewhere under 10% of the total spending on all military aviation.[44] **Figure 6** demonstrates the total funding for UAVs as a percentage of the total military aviation funding. As the pie chart shows, UAV funding only represents three percent of all military aviation funding.

Figure 5. Manned versus Unmanned Aircraft Funding

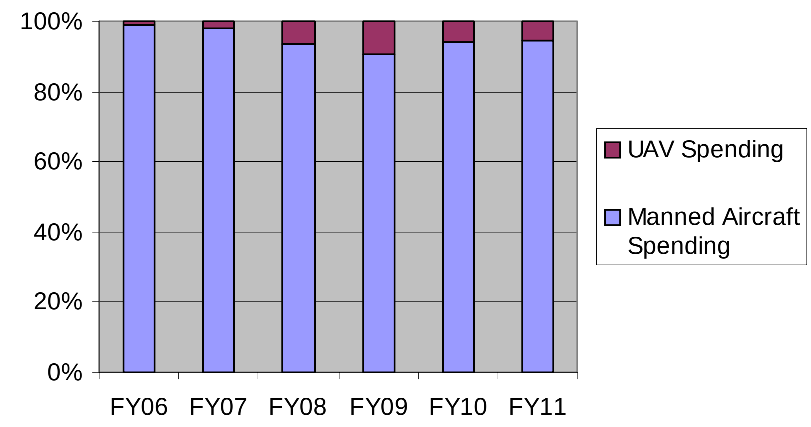
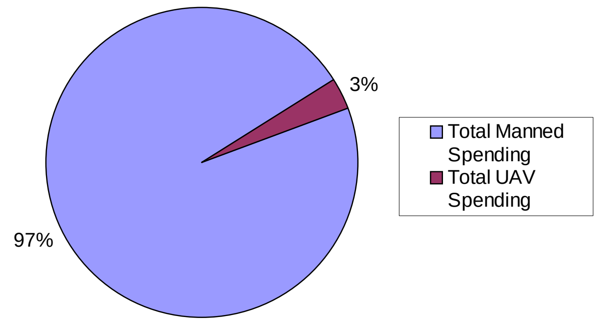


Figure 6. Manned vs. Unmanned Aircraft Spending (FY06-FY11)



Source for Figs 5 & 6: DoD UAS Roadmap 2005-2030; FY2006 DoD Justification Books for procurement and RDT&E of manned aircraft. Does not include small UAVs, micro-UAVs or lighter-than-air platforms.

[44] Note that the funding ratios do not include funding for small UAVs, Micro-UAVs and lighter-than-air vehicles.

Cost savings have long been touted by UAV advocates as one of the advantages offered by unmanned aircraft over manned aircraft. However, critics point out that the acquisition cost savings are often negligible if one considers that money saved by not having a pilot in the cockpit must be applied to the "ground cockpit" of the UAV aircrew operating the UAV from the ground control station. Another cost question concerns personnel. Do UAV "pilots" cost less to train and keep proficient than pilots of manned aircraft?[45] So although the air vehicle might be cheaper than a manned aircraft, the UAV system as a whole is not always less expensive.[46] Additionally, UAVs have a higher attrition rate and lower reliability rate than manned aircraft, which means that the operation and maintenance costs can be higher. On the other hand, UAV ground control stations are capable of simultaneously flying multiple UAVs, somewhat restoring the advantage in cost to the unmanned system.[47] Congress has noted that, "while the acquisition per unit cost may be relatively small, in the aggregate, the acquisition cost rivals the investment in other larger weapon systems."[48]

Two studies have addressed the head-to head manned vs. unmanned cost issue. The first, a CBO study, showed that replacing Army manned attack helicopters with UCAVs would produce no significant savings in steady-state procurement costs relative to current plans.[49] DoD also studied the comparative costs of manned vs. unmanned aircraft in their UAV Roadmap 2000. It found that development costs were essentially the same while there was a cost savings in procurement costs when an F-16 was compared to an unmanned combat aerial vehicle (UCAV).[50]

Assuming that a funding balance is struck between manned and unmanned vehicles, how then will DoD juggle cost with capability? The OSD has cited this question as one of its most pressing challenges. A significant concern with some UAVs is their rising price tag. In a March 9, 2005 hearing, for example, members of the House Armed Services Committee Tactical Air and Land Forces Subcommittee expressed their concern over cost growth of not just "high-tech" UAVs like Global Hawk and JUCAS, but also relatively less technologically ambitious UAVs. [51]

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[45] For more on personnel issues, see *Recruitment and Retention* section below.

[46] As an example, the Predator air vehicle costs $4.5 million while the Predator system, including four air vehicles, cost $30 million.

[47] OSD. UAV Roadmap 2000, p.53.

[48] U.S. Congress, 107th Congress, 2nd Session, House of Representatives, Bob Stump National Defense Authorization Act for Fiscal Year 2003, H.Rept. 107-436, p.243.

[49] A CBO Study. "The Long-Term Implications of Current Defense Plans." January 2003, p.94.

[50] OSD. UAV Roadmap 2000, p. 51-54.

[51] House Armed Services Committee: Subcommittee on Tactical Air and Land Forces. Hearing on the Fiscal Year 2006 Budget Request for Defense Department Unmanned Aerial Vehicle Systems. March 9, 2005. See especially, Rep. Weldon's opening statement.

At what threshold does an "expendable" UAV cost too much to lose? Sensors have consistently increased the cost of the air vehicle, according to Former Air Force Secretary James Roche.[52] The inexpensive design of small UAV air vehicles like the Desert Hawk and Dragon Eye are dwarfed by the cost of the lightweight electro-optical/infrared cameras that make up their payloads. On the other end of the size spectrum, the RQ-4 B second generation Global Hawk's sensor payload represents approximately 54 percent of the vehicles flyaway cost, which does not include the cost of the increased wingspan that shoulders the extra 1000 pounds of sensor suites.[53] These costs are increasing due to the basic law of supply and demand. Growing demand, matched with a lack of commercial sensor equivalents, means that UAV sensor producers face little competition, which would help keep costs down.

Growing sensor costs have prompted some to recommend equipping UAVs with self-protection devices, suggesting those UAVs are no longer considered expendable. Consequently, there are two schools of thought for UAV employment that could help balance cost with capability. One is to field many smaller, less expensive and less capable UAVs controlled through a highly interconnected communications network.[54] One example of this investment approach is the developmental Army's Future Combat System, which networks several relatively inexpensive UAVs like the Raven, the Shadow and the Fire Scout with 18 other weapons platforms. None of these UAVs can individually shoulder all of the air duties required by the system, yet the robust communications network is expected to distribute the mission duties to allow each platform to provide its specialized task.[55]

A second approach advocates fielding fewer, more expensive and more capable UAVs that are less networked with other systems, such as the autonomous Global Hawk. The Global Hawk serves as a high altitude, "all-in-one" surveillance platform capable of staying aloft for days at a time, yet does not operate in concert with any of its fellow UAV peers. Since 2003, programs at both ends of this spectrum have experienced delays and a reduction in funding. The Army's Future Combat System has experienced delays due to significant management and technology issues. Similarly, the highly capable Global Hawk and the J-UCAS program have risen in cost and been consumed by apparent management struggles, which have prompted funding cuts for both.[56]

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[52] U.S. Congress, 107th Congress, 2nd Session, Senate, Committee on Armed Services, "Department of Defense Policies and Programs to Transform the Armed Forces to Meet the Challenges of the 21st Century," Senate Hearing 107-771, April 9, 2002, p.124.

[53] For more information on the second generation RQ-4 B and its difference from the RQ-4 A, please seen section 3; OSD. UAS Roadmap 2005-2030. August 2005, Appendix B, p. B-1.

[54] Some have referred to this option as the "swarming UAV" concept.

[55] See CRS Report RL32888. *The Army's Future Combat System: Background and Issues for Congress*, by Andrew Feickert.

[56] See the "Current DOD UAV Programs" section starting on p. 37 for more information about the Global Hawk and J-UCAS programs.

Finally, what areas of investment will yield the maximum effectiveness out of these UAVs? Four specific issues stand out as the most pressing: interoperability, reliability, force multiplication/autonomy, and engine systems.

Over the past three years of the UAV evolution, one the most worrisome issues for UAVs has been the slow pace of the advancement of interoperability. Recently, acting chief of acquisitions for the Department of Defense Michael Wynne declared that the lack of interoperability could be one of the pitfalls that causes DoD to "fall out of love with UAVs" unless the matter was resolved soon.[57] The future plans for UAV usage within the framework of larger battlefield operations and more interconnected and potentially joint-service combat systems require UAVs to seamlessly communicate between each other and numerous different ground components, and to also be compatible with as equally numerous ground control systems. The lack of interconnectivity at these levels have often complicated missions to the point of reducing their effectiveness, as Dyke Weatherington, head of DoD's UAV planning taskforce, noted in 2004; "There have been cases where a service's UAV, if it could have gotten data to another service, another component, it may have provided better situational awareness on a specific threat in a specific area that might have resulted in different measures being taken."[58]

Advancing the interoperability of UAVs has been a critical part of the OSD's investment plans. The Department of Defense has pushed forward with the establishment of inter-communication between similar UAVs as a vehicle to help facilitate interoperability among four categories.[59] First, DoD hopes to integrate an adequate interface for situational awareness, which will relay the objective, position, payload composition, service operator and mission tasking procedure to other unmanned aircraft and potentially to ground elements. Second, a payload interface will allow the coherent transfer of surveillance data while the third category, the weapons interface, will constitute a separate transfer medium by which operators can coordinate these platform's offensive capabilities. Finally, the air vehicle control interface will enable navigation and positioning from the ground with respect to other aircraft.

Although the framework for these categories of interoperability has been established, the technology has been slow to catch up. The House of Representatives version of the FY2006 Defense Authorization Act (H.R. 1815, House Report 109-89) took a major step to encourage inter-platform communication. The members of the House Armed Services Committee included a clause that called for the requirement of all tactical unmanned aerial vehicles throughout the services to be equipped with the Tactical Common Data Link, which has become the services' standardized communication tool for providing "critical wideband data link required

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[57] Marc Selinger. "Wynne Warns UAV Industry About Cost, Networking." *Aerospace Daily*. December 16, 2004, p. 3.

[58] Michael Peck. "Pentagon Setting Guidelines For Aircraft Interoperability". *National Defense*. July 2004, p. 47.

[59] Four categories as outlined by Dyke Weatherington and reported by Michael Peck. " Pentagon Setting Guidelines For Aircraft Interoperability". *National Defense*. July 2004, p. 47.

for real-time situational awareness, as well as real time sensor and targeting data to tactical commanders."[60] The 2005 Unmanned Aircraft Systems (UAS) Roadmap[61] endeavors to take a step further; it intends to field the Common Data Link communications systems for not only tactical UAVs, but for all large UAVs as well.[62] If UAVs are to achieve the level of interoperability envisioned by the OSD, the services and industry must will likely need to keep focused on achieving the Common Data Link communications system goal and invest appropriately to facilitate an expedited and efficient development process.

The finite bandwidth that currently exists for all military aircraft, and the resulting competition for existing bandwidth, may render the expansion of UAV applications infeasible and leave many platforms grounded. Ultimately, the requirement for bandwidth grows with every war the U.S. fights.[63] The increased use of UAVs in the Iraq war indicates that remotely pilotted platform and their mass consumption of bandwitdth will require a more robust information transfer system in the coming years. Some sources say that the military currently does not have enough bandwidth to download video and radar images via satellite communications from more than one UAV at a time. In a hearing of the House Armed Services Committee's subcommittee on Tactical Air and Land Forces, Representative Curt Weldon noted that while the United States possesses an extensive fleet of UAVs, "many sit on many sit on the ground because there is inadequate bandwidth for them to be used effectively."[64] As confirmed by an OSD official in the same hearing, an unspecified number of UAVs in Iraq and Afghanistan are incapable of operations because the information transfer capacity connecting UAVs to the ground operators are simply not large enough to manage multiple UAVs.

One program designed to alleviate the bandwidth concern is the Transformation Satellite Communications (TSAT) project. DoD intends to use the laser and satellite communications system to the provide U.S. armed forces with an unlimited and uninhibited ability to send and receive messages and critical information around the world without data traffic jams.[65] However, the multibillion dollar project,

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[60] For text of congressional clause see National Defense Authorization Act for Fiscal Year 2006, Report of the House of Representatives' Committee on Armed Services, H. Report 109-89, Section 141 of Legislative Provisions, May 20, 2005. For citation of TCDL purpose, see "Tactical Common Data Link (TCDL) Overview." BAE Systems, [http://www.cnir.na.baesystems.com/cnir_tcdl_overview.htm]. 2005.

[61] In 2005, DoD changed the name of the UAV road map to Unmanned Aircraft Systems (UAS) road map, to reflect the importance of, and increase awareness of the the overall UAV system, which includes command, control, communications, sensors, and often weapons.

[62] OSD. UAS Roadmap 2005-2030, August 2005, p. 75.

[63] Bandwidth is defined as the amount of data that can be transmitted over a communications link in a fixed amount of time.

[64] VHearing of the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee. "Fiscal Year 2006 Budget Request." March 9, 2005.

[65] Sandra Erwin. "Multibillion-Dollar 'Internet in the Sky' Could Help Ease Bandwidth

(continued...)

nicknamed "the internet in the sky", is expected to be the subject of funding cutbacks and, at earliest, will be deployed between 2015 and 2016. [66] As another interim option, DOD has testified that a more autonomous UAV would require less bandwidth, since more data are processed on board and less data are being moved.[67] However, it is unclear that autonomy will actually decrease bandwidth requirements since Global Hawk, an autonomous UAV, is currently the most aggressive bandwidth user.

One solution to alleviating the bandwidth problem is allowing UAVs to be operated from a manned stand-off aircraft such as a command and control aircraft. Stationing the mission control element of the UAV system in another aircraft instead of on the ground would reduce the reliance on satellites for beyond line of sight communication, simplifying command and control. Not only would this help overcome the bandwidth issue, but it would also address another potential problem area, which is pilot manpower and retention. Pilots in this case would still get to "fly" while operating the UAV. Experimentation is currently ongoing in this area, with the first step being controlling the UAV's sensor payload from the air.

Investment in reliability upgrades appear to be another high priority for UAVs in recent years. In 2004 the Defense Science Board indicated that relatively high UAV mishap rates might impede the widespread fielding of UAVs.[68] The 2005 UAS Roadmap indicates that UAV mishap rates appear to be much higher than the mishap rates of many manned aircraft. **Table 2** shows the number of Class A Mishap per 100,000 hours of major UAVs and comparable manned aircraft.[69]

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[65] (...continued)
Crunch." *National Defense*. June 2005, p. 24.

[66] Ibid.

[67] Hearing of the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee. "Fiscal Year 2004 Budget Request for Unmanned Combat Aerial Vehicles and Unmanned Aerial Vehicle Programs." March 26, 2003.

[68] Defense Science Board. "Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles." Office of the Undersecretary of Defense for Acquisitions, Technology, and Logistics. February 2004, p.vii-viii.

[69] Note that Class A Mishaps, according to the Army Safety Center are considered to be damage costs of $1,000,000 or more and/or destruction of aircraft, missile or spacecraft and/or fatality or permanent total disability. Similar definitions for the Air Force, Navy and Marine Corp can be found at their respective safety center websites. Also note the performance capabilities of the manned versus unmanned vary greatly and may have an impact on the mishap rate. Additionally, the underlying assumption is that the UAVs and the manned aircraft will perform the same missions and operate under the same circumstance as the manned aircraft, which may not hold for all missions and all platforms. For more on military aviation safety, see CRS Report RL31571, *Military Aviation Safety*, by Christopher Bolkcom.

Table 2. Select Mishap Rates

Vehicle Type	Class A Mishaps (per 100,000 hrs)
UAV	
Predator	20
Hunter	47
Global Hawk	88
Pioneer	281
Shadow	191
Manned	
U-2	6.8
F-16	4.1

Source: DoD's UAS Roadmap 2005-2030, p. 75.

In its recent UAV study, the Defense Science Board (DSB) notes that manned aircraft over the past five decades have moved from the relatively high mishap rate to relatively low rates through the advancement of system design, weather durability improvements and reliability upgrades.[70] It should be pointed out, however, that the UAVs, with the exception of Predator, have total flight times that are significantly less the than the 100,000 hours used to calculate the mishap rate. Most aircraft tend to have a much higher mishap rate in their first 50,000 hours of flight than their second 50,000 hours of flight. Further, some of the UAVs in Table 2, have flown numerous missions *while still under development*. Predator and Global Hawk, for instance, were rushed into combat well prior to the aircrafts' initial operational capability: 2005 for Predator, and a projected FY2006 for Global Hawk. It is unfair, some might argue, to compare the mishap rates of developmental UAVs with manned aircraft that have completed development and been modernized and refined over decades of use.

The DSB's report also suggests that nominal upgrades and investment — arguing even that many UAVs will need little change — could produce substantial reductions in the UAV mishap rates. The 2005 UAS Roadmap proposes investments into emerging technologies, such as self-repairing "smart" flight control systems, auto take-off and recovery instruments, and heavy fuel engines, to enhance reliability.[71] Also the incorporation of advanced materials — such as high temperature components, light-weight structures, shape memory alloys and cold

[70] Defense Science Board. "Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles." Office of the Undersecretary of Defense for Acquisitions, Technology, and Logistics. February 2004, p.viii.

[71] OSD. UAS Roadmap 2005-2030, August 2005, p. H-8 and H-9.

weather tolerance designs that include significant de-icing agent — will also be expected to improve the survivability of UAVs in adverse environments.[72]

One of the most attractive and innovative technological priorities in the industry is to enable one ground operator to pilot several UAVs at once. At the 2003 Paris Airshow, Vice President of Boeing's Integrated Defense Advanced Systems, Mike Heinz said, "We have to reduce operator workload. That's been a real thorn in our side. Typically, we have had multiple operators per vehicle, ...but where we want to go is multiple vehicles per operator."[73] Currently most UAVs require at least two ground operators; one to pilot the vehicle and another control the sensors. The end goal for UAV manufactures and users is to reduce the to 2:1 operator-vehicle ratio and eventually to elevate the autonomy and interoperability of UAV to the point where two or more vehicles can be controlled by one operator. If this technological feat is established, the advantage of UAVs as a force-multiplier on the battle field could provide a dramatic change in combat capability.

Many believe that the process of achieving this goal would most likely require significant time and investments. As the 2005 UAS Roadmap notes, "Getting groups of UA to team (or swarm) in order to accomplish an objective will require significant investment in control technologies" with specific reference to distributed control technologies. [74] Considering the two operator system currently in place for most UAVs, the logical approach to reaching this technological advancement is to first invest in the autonomous flight capabilities of the UAVs, so as to reduce the workload for UAVs. The Global Hawk and the Scan Eagle possess significant automate flight capabilities, but their degree of actual flight autonomy can be debated due to the UAV's need for continuous operator intervention in poor weather conditions. The OSD quantifies the degree of UAV autonomy in on a scale of one to ten. **Table 3** shows the OSD's Autonomous Capability Levels for UAVs.

[72] Ibid.

[73] Bill Sweetman. "Boeing's IDeAS Group Moving Ahead Wth UAVs." *Aviation Now*. May 26, 2003.

[74] OSD. UAS Roadmap 2005-2030, August 2005, p. D-7.

Table 3. Autonomous Capability Levels (ACL)

Level	Capability
10	Fully Autonomous Swarms
9	Group Strategic Goals
8	Distributed Controls
7	Group Tactical Goal
6	Group Tactical Replan
5	Group Coordination
4	Onboard Route Replan
3	Adapt to Failures & Flight Conditions
2	Real Time Health/Diagnosis
1	Remotely Guided

Source: Data taken from DoD's UAS Roadmap 2005-2030, p. D-10.
Note: OSD. UAS Roadmap 2005-2030, August 2005, p. D-7.

In order for UAVs to achieve maximum use when being controlled by a single pilot, the UAV ACL must achieve a level of at least eight. Currently, the Global Hawk, which is considered by many as the most autonomous UAV presently in service, maintains an ACL of approximately 2.5. J-UCAS plans hope to make the combat UAV capable of autonomous flight levels of six, yet the timetable for this level is fairly far off. FAA and the UAV industry are working with the Department of Defense in order to facilitate the universal development of "see and avoid" technology that would allow a UAV to operate autonomously and avoid approaching aircraft, potentially increasing the standard ACL for UAVs to four. Additionally, inter-UAV communication and the coordination associated with interoperability (see interoperability above) must match the autonomous flight abilities. Full automation of sensor capabilities would enable the lone operator to control a network of intelligence collecting drones.

The first steps towards the "one-operator-per-several-UAVs" advancement are already underway. Recently, the Air Force evaluated a Predator upgrade that allowed one operator to pilot up two four UAVs.[75] The Multi-Aircraft Control (MAC) system allowed one ground pilot to control the flight plan of four Predator UAVs during an exercise in which one UAV engages a target and the other three hover nearby on standby status. The next step is to consolidate the tasks of the four mission payload operator, each manning the sensors or weapons system on the four Predators, into one or fewer operators.

One key area of investment interest may be heavy fuel burning engines. The OSD's 2005-2030 Unmanned Aviation System Roadmap outlined the development of heavy fuel engine (HEF) in order to replace gasoline-powered internal combustion

[75] "Predators Fly First Four-Ship Sortie." *Air Force Print News*. September 26, 2005.

engines as a top priority for UAV investment. [76] (Heavy fuel refers to diesel or JP-8 fuel, used by the Army and Air Force.[77]) The Defense Science Board urged DoD to take the lead in investing in the rapid development and acquisition of heavy fuel engines for Predator, Shadow, Hunter and Fire Scout primarily because of the lack of commercial demand for these engines. Enrique J. Enriguez, President of the Locust USA, Inc. testified that the

> ...military has clearly established their need for heavy fuel burning engines for UAVs, but industry has been slow to respond to this need. In the small size range that we are working in, the military requirements are in place requiring heavy fuel burning engines; however, these requirements are being placed on the aircraft developer.[78]

The incorporation of heavy fuel engines onto UAVs could help the vehicle to climb faster, operate at more lofty altitudes and to reduce the amount of time spent servicing the engine on the ground. Proponent of heavy fuel engines argue that the integration of heavy fuel engines would not only increase performance capabilities and reduce servicing time, but would make the UAVs flight system more reliable and significantly reduce operations and maintenance costs. Furthermore, heavy fuel is cheaper and more abundant than the gasoline used in standard internal combustion engines.

However, some drawbacks may exist when applying HFE to UAVs. The targeted unmanned platforms for this engine are the medium-sized and less complex UAVs such as Shadow, Pioneer and Predator. Although the operations and maintenance costs may lessened by the heavy fuel engine, the initial acquisition cost is much greater than traditional engines and could burden these relatively cheap UAVs with increased production costs. Furthermore, developers are experiencing difficulties in designing an engine light enough and small enough to accommodate the flight requirements of this lighter UAV.

Another alternative being considered is a modified fuel cell under development by Pacific Northwest National Laboratory. Supporters of fuel cells note that these devices could double the efficiency of mid-sized UAVs and could reduce the acoustic and thermal signatures of the UAVs, effectively making them more difficult to detect and target. [79] Air Combat Command is sponsoring the project with the idea in mind to use the fuel cells in many of its smaller UAVs and expects a flight test in 2010.

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[76] OSD. 2005-2030 UAS Roadmap. August 2005, p. 76.

[77] [http://www.darpa.mil/tto/programs/a160_eng_dev.html]

[78] Enrique J. Enriquez. Statement to the House Armed Service's Committee's Subcommittee on Tactical Air and Land Forces. U.S. House of Representatives, July 21, 2004.

[79] Libby John. "Fuel Cell Project Could Help Make UAVs Less Detectable, More Efficient." *Inside the Air Force*. September 23, 2005.

UAV Roles and Applications

Considering the growing abundance of remotely-piloted platforms and the rapid growth of the UAV industry, some may question whether DoD has a coherent plan for determining UAV roles and applications. Specifically, are UAVs being applied to new roles aggressively enough? Conversely, is DoD too eager to use UAVs? Are there alternatives that should be considered for their missions? Under what circumstances does it make more sense to add missions to a single-mission UAV, rather than develop a new UAV for the new mission?

Traditionally, and contemporaneously, most UAVs are designed and used primarily for intelligence, surveillance and reconnaissance (ISR) missions.[80] Some project that ISR UAVs will be the dominant UAV role until at least 2014.[81] ISR applications range from multi-intelligence, high altitude and long endurance missions conducted by the Global Hawk over Iraq and Afghanistan, or "over-the-hill" reconnaissance and sniper spotting performed by the Army's Raven UAV. In 2003 100 percent of DoD's major UAV programs (five of five programs) conducted ISR missions.[82] In 2005, 87 percent (12 of 16 major programs) are designed for ISR missions. This two year comparison indicates some diversification of UAV missions, and a rapid growth in overall programs.

With this rapid growth in ISR UAVs may come the concern that production of numerous aircraft with the same basic mission could yield unnecessary duplication. Some contend that DoD has had a difficult time building joint manned aircraft in the past.[83] The Services' desire to optimally satisfy their unique operational requirements have often made them unwilling to compromise and accept an aircraft developed by another service. Might UAV development be equally vulnerable to this dynamic? Why, some in Congress have asked, for example, does the Navy require a new maritime surveillance UAV? Why can't they purchase the Global Hawk?[84] The

[80] Specialized UAVs have been developed and used extensively as decoys. Decoys are autonomously guided. They have been used in numerous conflicts to attract the attention of enemy air defenses while manned aircraft either avoid these defenses, or attack them. It is anticipated that DoD will continue to develop and produce decoys. Operational goals would include decreasing price, and improving abilities to mimic friendly aircraft and thus reduce the ability of enemy air defenses to different between the decoy, and the real aircraft.

[81] Steven Zaloga. "Unmanned Aerial Vehicles Market Overview." *World Missiles Briefing.* Teal Group Inc. Fairfax, VA. January 2005.

[82] Of the 12 platforms, five vehicles (Predator A, Hunter, Fire Scout, I-Gnat-ER and Neptune) are considered multi-mission UAVs because of their ability to carry-out significant non-ISR missions. Also statistic does not include small UAV inventory, lighter-than-air/Aerostat vehicles, or micro-UAVs.

[83] See CRS Report RL30563 *F-35 Joint Strike Fighter (JSF) Program: Background, Status, and Issues*, by Christopher Bolkcom, for more information on this subject.

[84] See for example Q&A between Rep. Neil Abercrombie and Mr. Dyke Weatherington, UAV Planning Task Force DoD during House Armed Services Committee, Tactical Air and Land Forces Subcommittee Hearing on the FY'04 Defense Authorization: Unmanned Aerial Vehicles. *FDCH Political Transcripts.* March 26, 2003 Wednesday.

majority of ISR UAVs possess apparently similar electro-optical and infrared sensors. They are differentiated, however, by the altitude reached, their communications range, their flight endurance and their landing/takeoff procedure. In the future, Congress may act to decide when a new UAV program is justified, and when it is duplicative.

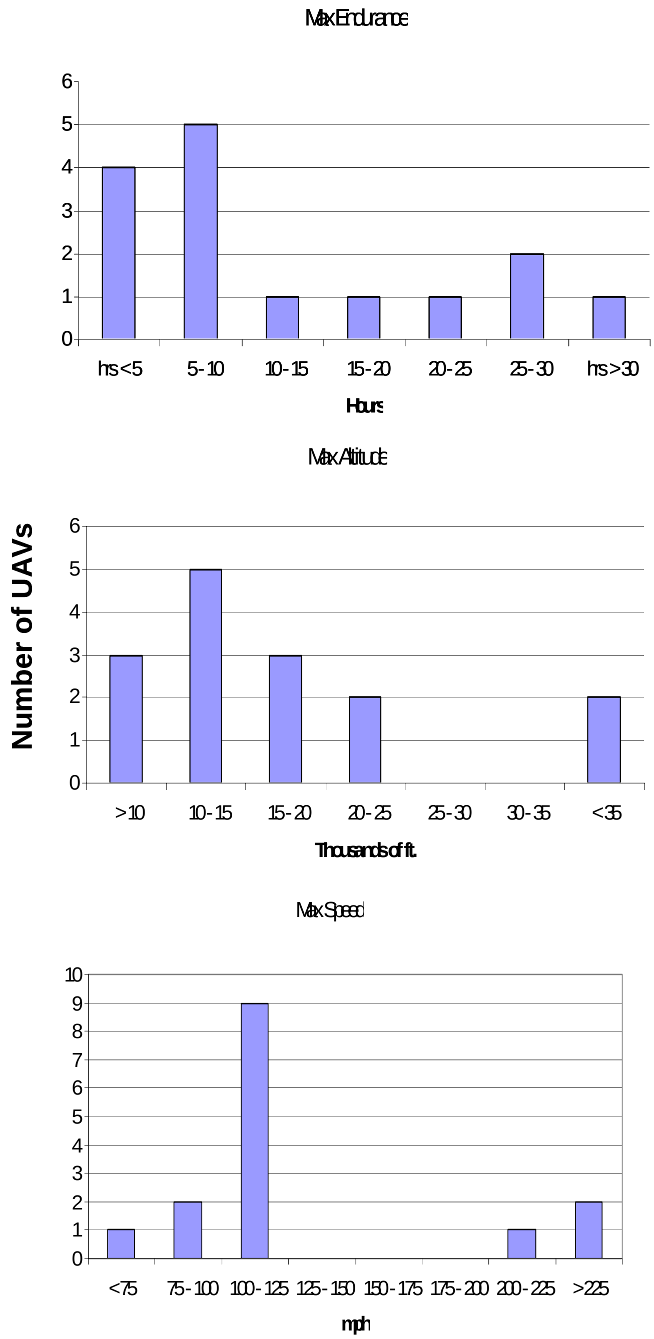
Table 4. ISR UAVs with E-O/IR Sensors

Vehicle	Endurance (hrs)	Max Altitude (ft)	Max Speed (kt)	Range (nm)	Additional Sensor	User
Eagle Eye	5.5	20000	210	110	MMR	Coast Guard
I-Gnat-ER	30	25000	120	150	None	Army
Maverick	7	10300	118	175	None	SOCOM
MQ-1	24	25000	118	500	SAR	AF
MQ-5B	18	18000	106	144	None	Army
Neptune	4	8000	84	40	None	SOCOM
RQ-2	5	15000	110	100	None	Navy/MC
RQ-4A	32	65000	350	5400	SAR/MTI	AF
RQ-4B	28	60000	340	5400	SAR/MTI, SIGNIT	AF
RQ-5A	12	15000	106	144	None	Army
RQ-7A	5	14000	110	68	None	Army
RQ-7B	7	15000	105	68	None	Army
RQ-8	6	20000	125	150	LDFR	Army/Navy
XPN-1	2	10000	87	40	None	SOCOM
XPN-2	8.5	10000	75	40	None	SOCOM

Source: OSD. 2005-2030 UAS Roadmap. August 2005, p.4-25.

Figure 7 shows a comparison of the performance specifications of ISR-capable UAVs. The chart indicates that a majority of UAVs feature an endurance of 4 to 8 hours, an altitude of 10,000 - 20,000 ft, max speeds between 105 and 125 knots and radiuses of 100 to 150 nm.

Figure 7. ISR UAV Characteristics



Congress may ask if the production of different UAVs with relatively similar performance capabilities constitutes unnecessary duplication. Critics of these expanded UAV roles often argue that the production of these similar platforms is unnecessary, considering that a consolidated inventory — hypothetically consisting of only the RQ-4B Global Hawk, the RQ/MQ-1 Predator and the RQ-2 Pioneer — could perform and fulfill the same duties as the expanded inventory. However, proponents of the more varied platform inventory often argue that these basic performance capabilities cannot alone qualify the necessity of these UAVs, and that the variety of UAVs reflects the specific need of the mission or user-services and not unnecessary duplication. Furthermore, they argue that landing/takeoff capabilities, durability, storage requirements and overall cost all play additional roles in determining the necessity of the vehicle.

In recent years, the UAV's role in combat missions has significantly increased. The first public acknowledgment that UAVs were being used for combat operations was in 2002 when a Predator UAV outfitted with a Hellfire missile attacked and killed several Al-Qaeda operatives in Yemen.[85] Now the UAV combat landscape has changed: the majority of the Predator A UAVs have been equipped with Hellfire missiles; Predator B comes off the assembly line with a large array of munitions; the Maverick, I-Gnat-ER, Fire Scout and Hunter UAVs are undergoing armament evaluations; and the J-UCAS program endeavors to create the first UAV primarily designed for offensive applications.

Using UAVs to deliver air-to-ground munitions appears inherently useful. UAVs can loiter over the battlefield to attack emerging targets, at no risk to flight crew. Yet, UAVs are not without limitations. While cost and effectiveness comparisons between manned and unmanned aircraft must be made cautiously, doing so can help determine when using UAVs for combat operations is more attractive than using manned aircraft.

The 2006 actual current year cost for the MQ-9 Predator B is $11.7 million, about one-third the $35.5 million estimate for the F-16 Falcon. A simple payload comparison shows that the F-16 can carry approximately four times the payload of the Predator B (10,750 lbs vs 2,500 lbs).[86] This means that the cost per one pound of munitions delivered is $4,680 for the Predator and $3,302 for the F-16.[87] Further, the F-16 is a versatile combat aircraft that can be used to perform many missions that the Predator B cannot. This may suggest that using manned aircraft for air-to-ground combat may generally prove more cost effective than using UAVs, and that he UAV's unique combat capabilities may be most valued in niche circumstances, such as when manned aircraft would be in extreme danger.

Other missions for which UAVs appear useful, or are being considered in the near-term, include electronic attack (also called stand-off jamming, or escort jamming), and psychological operations, such dropping leaflets. On the medical side, UAVs such as the Army's Shadow have been studied and evaluated for its capability to deliver critical medical supplies needed on the battlefield.

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[85] Walter Pincus. "U.S. Strike Kills Six in Al Qaeda." *The Washington Post*, November 1, 2002.

[86] Payload based on the maneuvering capability of an F-16 flying at 9 *g* with a center fuel tank , see *Jane's All the World Aircraft 2005-2006*. 96th edition, edited by Paul Jackson, p. 728. OSD. UAS Roadmap 2005-2003. August, 2005, Section 2, p.10

[87] It is important to point out that the operating costs, RDT&E costs, logistics cost and personnel cost are not factored into this comparison. Furthermore, flight performance and specific combat missions, which are critical to the distinction of between these two vehicles, are also not factored into this comparison.

While UAV use in foreign theaters is well established, one of the most commonly discussed new mission areas for UAVs is homeland defense and homeland security. The Coast Guard and U.S. Border Patrol already have plans to deploy UAVs such as the Eagle Eye to watch coastal waters, patrol the nation's borders, and protect major oil and gas pipelines. Congressional support exists for using UAVs like the Predator for border security. During a Senate Armed Services Committee hearing on homeland defense, several members agreed that although it would not be appropriate or constitutional for the military to patrol the border, domestic agencies using UAVs could carry out this mission.[88]

It appears that interest is growing in using UAVs for a variety of domestic, and often non-defense roles. Long-duration law enforcement surveillance, a task performed by manned aircraft during the October 2002 sniper incident near Washington, D.C. is one example. The U.S. Department of Transportation has studied possible security roles for UAVs, such as following trucks with hazardous cargo, while the Energy Department has been developing high-altitude instruments to measure radiation in the atmosphere.[89] The inexpensive vertical take-off and landing GoldenEye 100 UAV is expected to serve as a medium-range, small-package transport and may be affordable enough for local law enforcement use during events of large-scale civil unrest.[90] UAVs might also be used in sparsely populated areas of the western United States to search for forest fires. Following the wide-spread destruction of Hurricane Katrina, some suggest that a UAV like Global Hawk could play roles in "consequence management" and relief efforts.[91] Also, UAV advocates note that countries like South Korea and Japan have used UAVs for decades for crop dusting and other agricultural purposes.[92]

Not all of these new applications have are uncontroversial — UAV advocates state that in order for UAVs to take an active role in homeland security, Federal Aviation Administration (FAA) regulations and UAV flight requirements must approach a common ground. According to FAA spokeman William Shumann, the primary challenge in meeting this common ground is "to develop vehicles that meet FAA safety requirements if they want to fly in crowded airspace".[93] The August 2003 announcement that the FAA had granted the Air Force a certificate of authorization for national airspace operation signifies the first steps in the reconciliation of these

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[88] Marc Selinger. "Sen. McCain Says Predator May Be Useful For Border Security," *Aerospace Daily*, April 9, 2003.

[89] *National Journal's Congress Daily*. "Pilotless Aircraft Makers Seek Role For Domestic Uses," December 17, 2002.

[90] "GoldenEye in the Sky." *The Economist*. July 5th, 2003.

[91] Martin Matishak. "Global Hawk Could Perform Multiple Tasks in Relief Efforts, Study Finds." *Inside the Air Force*. September 23, 2005.

[92] See, for example Statement of Christopher Bolkcom. Analyst in National Defense Congressional Research Service. Before the Senate Governmental Affairs Committee, Subcommittee on International Security, Proliferation, and Federal Services. Hearing On Cruise Missile Proliferation. June 11, 2002. [http://hsgac.senate.gov/061102bolkcom.pdf]

[93] Greta Wodele, "Firms to showcase unmanned planes for Border Patrol," National Journal's Technology Daily, Aug. 11, 2003.

discrepancies. [94] Upgrading UAVs collision avoidance capabilities appears to be a critical part in the next step of reaching the UAV-airspace common ground. The FAA's Unmanned Aircraft Systems Working Group indicates it will work with the Department of Defense, specifically through the new UAV OIPT and Center of Excellence to facilitate safe UAV operations and the adequacy of flight requirements.[95]

The schedule for integrating UAVs into the national airspace may become contentious. A February 2004 study by the Defense Science Board found that "DoD has an urgent need to allow UAVs unencumbered access to the National Airspace System...here in the United States and around the world."[96] In September 2005 it was reported, however, that NASA planned to cancel funding for *Access 5*, a government/industry partnership created to facilitate the incorporation of UAVs into the national airspace system. UAV advocates bemoaned this development, arguing that disbanding *Access 5* would severely hamper the forecasted development of UAVs and their numerous global applications.[97]

Further in the future, large UAVs could take on the aerial refueling task now performed by KC-10 and KC-135 tanker aircraft. Although DOD has not expressed plans for exploring the aerial refueling role, it appears to some to be a mission well suited for unmanned aircraft. The flight profiles flown by KC-10 and KC-135 aircraft are relatively benign compared to many other aircraft, and they tend to operate far from enemy air defenses. Except for operating the refueling boom (to refuel Air Force aircraft), the refueling crew's primary job is to keep the aircraft flying straight, level, and at a steady speed. The Global Hawk's 2001 trans-oceanic flights (from the United States to Australia and from the United States to Portugal) demonstrate the ability of current UAVs to fly missions analogous to aerial refueling missions.

Another, far more difficult future task, could be air-to-air combat. DOD is experimenting with outfitting today's UAVs with the sensors and weapons required to conduct such a mission. In fact, a Predator has reportedly already engaged in air to-air combat with an Iraqi fighter aircraft. In March, 2003 it was reported that a Predator launched a Stinger air-to-air missile at an Iraqi MiG before the Iraqi aircraft shot it down.[98] While this operational encounter may be a "baby step" on the way toward an aerial combat capability, it appears significant. Aerial combat is often described as the most challenging mission for manned aircraft to perform, and, some

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[94] Sue Baker. "FAA Authorizes Global Hawk Flights." Aeronautical Systems Center Public Affairs. August 21, 2003.

[95] "UAV Sense-And-Avoid Technologies Not Just A Military Concern." *Defense Daily*. August 2, 2005.

[96] *Defense Science Board Study on Unmanned Aerial Vehicles and Uninhabited Combat Aerial Vehicles.* Office of the Undersecretary of Defense for Acquisitino, Technology, and Logistics. February 2004. P.XII

[97] B.C. Kessner. "International UAS Organization Protests To NASA Over Potential Cut." *Helicopter News.* September 20, 2005.

[98] David Fulghum. "Predator's Progress." Aviation Week & Space Technology. March 3, 2003.

say, one that UAVs will never be able to accomplish. Though embryonic, the recent Predator launch of an air-to-air missile will likely hearten UAV advocates who wish to see more aggressive missions for unmanned aircraft.

Are UAVs always the preferred platforms for these new roles and applications? Other options could include manned aircraft, blimps, and space satellites.[99] Each platform offers both advantages and disadvantages. Manned aircraft provide a flexible platform, but risk a pilot's life. Some of the country's largest defense contractors are competing to develop unmanned blimps that may be capable of floating months at a time at an altitude of 70,000 feet and carrying 4,000 pounds of payload. OSD's 2005 UAS Roadmap includes a section on lighter-than-air blimps and tethered "aerostat" platforms, which OSD indicates to be important for a variety of roles, including psychological operations, spot incoming enemy missiles and border monitoring. Furthermore, these platforms could provide services equivalent to many border surveillance UAVs, but their decreased dependency on fuel could minimize operations costs. One drawback to these lighter-than-air platforms is their lack of maneuverability and speed relative to UAVs like the Global Hawk. None-the-less, the goal of many major UAV manufacturers is to develop an operational system by 2010 that could carry out a variety of missions for homeland security.[100]

Space satellites offer many benefits — they are thought to be relatively invulnerable to attack, and field many advanced capabilities. However, tasking the satellites can be cumbersome, especially with competing national priorities. The limited number of systems can only serve so many customers at one time. Additionally, some satellites lack the loitering capability of UAVs, only passing over the same spot on Earth about once every three days. Due to the high costs of space launches, UAVs like Global Hawk are being considered for communication relays as substitutes for low-orbiting satellite constellations.[101]

Recruitment and Retention

One commonly voiced concern with the pace of UAV production is that these remotely piloted planes will replace manned aircraft in large numbers.[102] Critics of mass UAV production warn that a reliance on unmanned vehicles degrades pilot skills and takes away the tactical flexibility and adaptability that manned aircraft bring to combat operations.

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[99] For more information on blimps (airships) and aerostats, see CRS Report RS21886: *Potential Military Use of Airships and Aerostats*

[100] Peter Pae. "A Rebirth For Blimps; Military Has Plan For Cousin of Hindenburg," *Los Angeles Times*, November 4, 2002.

[101] David Fulghum. "Air Force Chief Predicts Growth of UAV Use By Military," *Aviation Week and Space Technology*. March 17, 2003.

[102] See, for example. David Bond. "As RPVs Deliver Sigint, Pentagon Officials Question Manned Platforms." *Aviation Week & Space Technology*. October 17, 2005.

It has not always been easy for the aviation culture to adapt to flying aircraft from the ground. Deputy Secretary of Defense Wolfowitz, during a hearing on transformation, stated that:

> Not long ago, an Air Force F-15 pilot had to be persuaded to forego a rated pilot's job to fly Predator. Now Air Force leadership is working hard to encourage this pilot and others to think of piloting UAVs as a major mission and to become trail blazers in defining new concepts of operations.[103]

The Air Force has realized the retention implications of requiring rated pilots to fly their UAVs[104], and has offered enticements such as plum assignments after flying the UAV, and allowing pilots to keep up their manned flying hours during their UAV tour of duty.

Historically, many believed that as more UAVs were fielded, recruitment and retention would suffer because those inclined to join the military would prefer to fly manned aircraft instead of unmanned aircraft. This may be the case in some instances. The future impact of DoD's UAV programs on recruitment, however is more complicated than this argument suggests.

The recruitment and retention situation varies among the services and for different types of personnel. While the Army appears to be having some difficulty with recent recruitment, the Air Force and Navy are actively trying to reduce their number of uniformed personnel. Thus, reduced enlistments due to increased UAV use, if that turns out to be the case, might not have the anticipated impact.[105]

A central question related to the potential impact of increased UAV employment on personnel, is "what qualifications are required to operate UAVs?" Currently, the Air Force require Predator and Global Hawk operators to be pilot-rated officers. Other services do not require UAV operators to be pilot-rated officers. This means that, in the other services, there is no competition between manned and un-manned aircraft for potentially scarce pilots.

Many enlist in military service with no desire, or intention to fly manned aircraft. Some wish to fly, but lack physical qualifications, such as good eyesight. The increased fielding of UAVs may encourage some to enlist because it offers them an opportunity to "fly" that they may not have had otherwise. Further, those inclined to fly manned aircraft may not be as disinclined to fly UAVs as was believed in the past. Flying armed UAVs may be more appealing to these personnel than is flying non-armed UAVs. Also, flying UAVs may be an attractive compromise for certain

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[103] U.S. Congress, 107th Congress, 2d Session, Hearing Before the Committee On Armed Services United States Senate.*"Department of Defense Policies And Programs To Transform The Armed Forces To Meet The Challenges Of The 21st Century."* April 9, 2002, p.10.

[104] Currently the Air Force is the only service to require rated pilots to fly their UAVs.

[105] For more information on recruitment issues see CRS Report RL32965 *Recruiting and Retention: An Overview of FY2004 and FY2005 Results for Active and Reserve Component Enlisted Personnel*, by Lawrence Kapp.

personnel. While it may not confer all the excitement of flying a manned aircraft, it also avoids many of the hardships (e.g. arduous deployments and potential harm). The Air Force believes that flying UAVs from control stations in the United States will be attractive to some Reservists and Guardsmen who may already be disinclined to experience an active duty lifestyle consistent with flying manned aircraft. Also, not all UAVs compete with manned aircraft for pilots. Those UAVs that are pre-programmed and operate autonomously (like Global Hawk) do not require a pilot, like the Predator and other remotely piloted vehicles.

The Air Force maintains that their UAVs are more technologically and operationally sophisticated than other UAVs, and a trained pilot is required to employ these UAVs most effectively. As UAV autonomy, or command and control matures, or if personnel issues for the Air Force become more troublesome, it, or Congress, may decide to review the policy of requiring pilot-rated officers to operate UAVs.

Increased employment of UAVs could potentially boost enlistment in other specialties, if they are perceived as being effective in their missions. If, for example, those inclined to enlist in infantry positions perceive UAVs to offer improved force protection and CAS capabilities over today's manned aircraft, these potential recruits may have fewer qualms about the potential hazards of combat.

Industrial Base Considerations

Congress is perennially confronted with a spate of defense industrial base issues. Is U.S. industry becoming too dependent on foreign suppliers? Do foreign competitors get government subsidies that put U.S. firms at a competitive disadvantage? Should Congress take steps to encourage or discourage defense industry consolidation? Should Congress take steps to promote competition in the defense industrial base? Should Congress takes steps to protect U.S. defense industries in order to safeguard technologies or processes critical to national defense?[106] It appears that DoD's pursuit of UAVs presents several inter-related issues relevant to the defense industrial base.

Some are concerned, that if UAVs are increasingly designed and built, funding for manned aircraft programs is likely to wane, and the technical expertise required to design, and perhaps build manned combat aircraft could erode. Many point out that the ability to produce world class combat aircraft is a distinct U.S. comparative advantage, and should be guarded closely. Others disagree that the pursuit of UAVs could harm the industrial base. They argue that the Joint Strike Fighter is likely to be the last manned tactical fighter, and that the industrial base is naturally evolving toward the skills and processes required to make increasingly advanced UAVs.

Those who fear manned industrial base atrophy argue that the future of UAVs is overrated, and that there will be a demand for tactical manned aircraft in the post-JSF timeframe. In their eyes, crucial skills and technologies could thus be lost by concentrating only on unmanned aircraft design, possibly causing U.S. dominance

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[106] See, for example, CRS Report RL31236 *The Berry Amendment: Requiring Defense Procurement to Come from Domestic Sources*, by Valerie Bailey Grasso.

in tactical aircraft design to wane. These proponents point out that UAVs have been around for almost a century, yet only recently became operationally effective, and are not likely to replace manned aircraft in the near future.[107]

Some disagree, and believe that critical manned aircraft design skills are not jeopardized by increased pursuit of UAVs because there is considerable commonality between manned and unmanned combat aircraft. Except for the obvious lack of a cockpit, unmanned combat aircraft may require stealthy airframes, advanced avionics, and high performance engines just like manned combat aircraft. Also, major defense contractors have already begun to shift to unmanned aircraft design in order to stay competitive. This is because UAVs are beginning to play a prominent role in warfare, as seen in Operation Enduring Freedom in 2001 and Operation Iraqi Freedom in 2003. The same skills and technologies required for building manned aircraft will likely lend themselves to unmanned aviation design as well. Companies that have lost out in recent aviation contracts, such as Boeing and the Joint Strike Fighter (JSF) in 2001, are looking towards unmanned bombers and fighters as prospects for growth.[108] Northrop Grumman Corp., as another example, has created a new business unit to aggressively pursue UAV business.[109] If Boeing were to design manned aircraft in the future, the critical skills needed would still be present, according to this argument.

Others would argue that maintaining a healthy U.S. defense industrial base depends, in part, on how well U.S. firms compete for the global UAV market. One survey finds that in 2005, there are 195 different UAV programs world wide.[110] Some estimate that global UAV expenditures double from $2.1 billion in 2005 to $5 billion in 2014.[111] The global market for combat aircraft alone, at approximately $12.5 billion in 2005, dwarfs the UAV market. But the rate of growth is projected to be much slower, peaking at approximately $16 billion in 2013, and dropping to approximately $14 billion in 2014.[112] Thus, some would argue that much new business is likely to be generated in the UAV market, and if U.S. companies don't capture this market share, European, Russian, Israeli, Chinese, or South African companies will. From this perspective, capturing this new business, and nurturing industrial expertise in UAV challenge areas (e.g. autonomous flight, control of multiple vehicles, command and control, communications bandwidth) would be an effective way to keep U.S. industry competitive and healthy.

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[107] For more information on the arguments for and against future demand of tactical aircraft, see CRS Report RL31360, *Joint Strike Fighter (JSF): Potential National Security Questions Pertaining to a Single Production Line*, by Christopher Bolkcom and Daniel Else.

[108] Andy Pasztor. "Boeing Aims For Slice Of Fighter-Jet Contract Awarded to Lockheed, But Blow Still Stings," *Wall Street Journal*, October 29, 2001.

[109] David Fulghum. "New Northrop Grumman Unit Focuses on Unmanned Aircraft." *Aviation Week & Space Technology*. April 30, 2001.

[110] "Unmanned Aerial Vehicles Directory." *Flight International.* June 21-27, 2005.

[111] "Unmanned Aerial Vehicles Market Overview." *World Missiles Briefing.* Teal Group Inc. Fairfax, VA. January 2005.

[112] "Fighter/Attack Aircraft market Overview." *World Military & Civil Aircraft Briefing.* Teal Group Inc. Fairfax, VA. February 2005.

UAV Proliferation and Export Control Considerations

This apparent and projected global growth of UAVs presents the related policy issue of UAV proliferation and export controls. Both the 108th and 109th Congresses have held hearings to express concern and explore the policy dimensions of UAV and cruise missile proliferation.[113]

UAVs and cruise missiles (essentially a UAV with a weapon payload) are concerns for policy makers for two reasons. First, because their proliferation appears difficult to control. The majority of UAV components are indistinguishable from components found in civil manned aviation.[114] Therefore, many believe that it is relatively easy to divert legitimate civilian or military exports of aviation technology into a covert UAV or cruise missile program.[115] UAVs could be accessible to many countries or even non-state actors (Hizbollah militants, for example, have flown UAVs over Israel, and Al Qaeda has used UAVs to monitor Pakistani soldiers [116]), that might not otherwise have access to long range aircraft or ballistic missiles. Second, UAV proliferation is a concern because, if armed, they appear to be cost effective weapons. It cost much more to effectively defend against these threats than it costs to create the threat.[117] Cruise missiles and UAVs, it is feared, could become the "poor man's air force." The George W. Bush Administration has expressed concern over the potential military effectiveness of UAVs in the wrong hands. Prior to the beginning of Operation Iraqi Freedom, for example, both White House and DoD officials focused on Iraq's UAVs and how they could be used to attack neighboring countries with weapons of mass destruction.[118] Foreign companies are increasingly gaining access to key technologies that could make future UAVs even more effective. [119] Policy makers may become particularly mindful of potential

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[113] See "U.S. Representative Christopher Shays Holds a Hearing on Missile Technology and Export Controls." U.S. House of Representatives. Government Reform Committee, National Security, Emerging Threats and International Relations Subcommittee. *FDCH Political Transcripts.* March 9, 2004. And, "U.S. Senator Daniel Akaka Holds Hearing on Cruise Missile Threats." U.S. Senate. Government Affairs Committee, Proliferation and Federal Services Subcommittee. *FDCH Political Transcripts*. June 11, 2002

[114] Ballistic missiles, on the other hand, are composed of many components that are virtually unique.

[115] For more information, see CRS Report RS21252 *Cruise Missile Proliferation,* by Andrew Feickert.

[116] Riad Kahwaji. "Hizbollah's UAV." *Defense News.* November 15, 2004. And Iqbal Khattak. "Troops find 'spy drone' in Al Qaeda hideout." *Daily Times (Pakistan).* September 27, 2005.

[117] For more information, see CRS Report RS21921, *Cruise Missile Defense,* by Ravi R. Hichkad and Christopher Bolkcom,and CRS Report RS21394, *Homeland Security: Defending U.S. Airspace*, by Christopher Bolkcom.

[118] " Wolfowitz Reinforces Threat From Iraqi Chem-Bio-Carrying UAVs." *Defense Daily*. October 17, 2002.

[119] See for example, Robert Hewson. "EADS readies new stealth facility for UAVs." *Jane's Defence Weekly.* October 12, 2005.

exports of stealth technology, efficient turbofan engines, and terrain avoidance/terrain following guidance systems that could be incorporated in foreign UAVs.

As DoD employs UAVs more aggressively, and as U.S. companies pursue a growing body of international business opportunities, some in Congress may wish to address policy issues related to the potential for UAV proliferation, and its consequences: What steps might be taken to ensure the pursuit by U.S. companies of domestic and international UAV export success doesn't lead to the dissemination of critical UAV technologies? What balance should be struck between supporting legitimate military aid to U.S. allies, which may include UAVs, and concerns about the proliferation of these weapon systems?

Another complicating issue is that UAVs, when used for ISR, can be very effective in enabling the discriminating use of military force. UAVs can help positively identify enemy combatants, and reduce the accidental targeting of friendly forces or innocent civilians.[120] How might overseers weigh the potential benefits of reducing collateral damage versus the potential acquisition of UAVs by enemy groups and their use against the United States? What revisions might be considered to existing non-proliferation accords such as the Missile Technology Control Regime (MTCR), to more effectively control the spread of UAVs and their technology? Would tighter controls on UAVs be a detriment to industry?[121]

Current DOD UAV Programs

This section addresses the program status and funding of some of the most prominent UAV programs being pursued by DoD, and most likely to compete for congressional attention. This section does not attempt to provide a comprehensive survey of all UAV programs, nor to develop a classification system for different types of UAVs (e.g. operational vs developmental, single mission vs multi mission, long range vs short range). One exception is a short subsection below titled "Small UAVs." The UAVs described in this section are distinguished from the proceeding UAVs by being man-portable and of short range and loiter time. These smaller UAVs are not currently, and are unlikely to be, weaponized. The Services do not provide as detailed cost and budget documentation for these UAVs as they do for major UAV programs. Individually, these UAVs appear very popular with ground forces, yet do not necessarily demand as much congressional attention as larger UAV programs like Predator or Global Hawk. As a whole, however, these small, man-portable UAVs appear likely to increasingly compete with major UAV programs for congressional attention and funding.

[120] Gail Kaufman. "Evolving UAVs Force MTCR Reconsiderations." *Defense News*. December 10-16, 2001.

[121] For more information on the MTCR see CRS Report RL31559, *Proliferation Control Regimes: Background and Status*, by Sharon A. Squassoni, Steven R. Bowman, and Carl E. Behrens.

MQ-1 Predator

Through its high profile use in Iraq and Afghanistan and its multi-mission capabilities, the MQ-1 Predator has become the Department of Defense's most recognizable UAV. Developed by General Atomics Aeronautical Systems in San Diego, CA, the Predator has helped to define the modern role of UAVs with its integrated surveillance payload and armament capabilities. Consequently, Predator has enjoyed accelerated development schedules as well as increased procurement funding. The wide employment of the MQ-1 has also facilitated the development of several closely related UAVs (described below) designed for a variety of missions.

System Characteristics. Predator is a medium-altitude, long-endurance UAV, roughly half the size of an Air Force F-16 Falcon. At 27 feet long, 7 feet high and with a 48 foot wingspan, it has long, thin wings and a tail like an inverted "V". The Predator typically operates at 10,000 to 15,000 feet to get the best imagery from its video cameras, although it has the ability to reach a maximum altitude of 25,000 feet. Each vehicle can remain on station, over 500 nautical miles away from its base, for 24 hours before returning home. The Air Force's Predator fleet is operated by the 11th Reconnaissance Squadron out of the Indian Spring Auxiliary Field, Nevada and the 15th and 17th Reconnaissance Squadrons out of Nellis Air Force Base, Nevada. Current reorganization efforts will make Indian Springs the home for all three squadrons.[122] The CIA reportedly possesses and operates several Predators as well.

Mission and Payload. The Predator's primary function is reconnaissance and target acquisition of potential ground targets. To accomplish this mission, the Predator is outfitted with a 450-lb surveillance payload, which includes two electro-optical (E-O) cameras and one infrared (IR) camera for use at night. These cameras are housed in a ball-shaped turret that can be easily seen underneath the vehicle's nose. The Predator is also equipped with a Multi-Spectral Targeting System (MTS) sensor ball which adds a laser designator to the E-O/IR payload that allows the Predator to track moving targets. Additionally, the Predator's payload includes a synthetic aperture radar (SAR), which enables the UAV to "see" through inclement weather. The Predator's satellite communications provide for beyond line-of-sight operations. In 2001, as a secondary function, the Predator was outfitted with the ability to carry two Hellfire missiles. Previously, the Predator identified a target and relayed the coordinates to a manned aircraft, which then engaged the target. The addition of this anti-tank ordinance enables the UAV to launch a precision attack on a time sensitive target with a minimized "sensor-to-shoot" time cycle. Consequently, the Air Force changed the Predator's military designation from RQ-1B (reconnaissance unmanned) to the MQ-1 (multi-mission unmanned).[123] The air vehicle launches and lands like a regular aircraft, but is controlled by a pilot on the ground using a joystick.

Variants. *MQ-9 Predator B*. The MQ-9 Predator, or "Predator B", is General Atomic's follow on to MQ-1, or "Predator A". The goal of the Predator B project is

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[122] Elizabeth Rees. "Predator Squadron, Ops Center to Relocate to Indian Springs." *Inside The Air Force*, October 1, 2004.

[123] Glenn W. Goodman, JR. "UAVs Come of Age." *The ISR Journal*, July 2002, p.24.

to build upon the strengths of the parent UAV and to advance its mission capabilities. The result is a medium-to-high altitude, long endurance Predator optimized for surveillance, target acquisition and armed engagement. While the B-model borrows from the overall design of the A-model, the newest incarnation is longer by 13 feet in length and 16 feet in wingspan. It also features a 900hp Honeywell TPE 331-10 turbo propjet engine, which is significantly more powerful than the Predator A's 115hp propjet engine. These upgrades allow the Predator B to reach a maximum altitude of 50,000 feet, a maximum speed of 225 knots, a maximum endurance of 32 hours and a maximum range on 2000 nautical miles.[124] General Atomics also upgraded the 17-inch diameter MTS camera gimbal to a 22-inch MTS-B gimbal for extended range surveillance. However, the feature that most differentiates Predator B from its predecessor is its ordinance capacity. While the Predator A is outfitted to carry two 100-pound Hellfire missiles, Predator B now can carry as many as 16 Hellfires, equivalent to the Army's Apache helicopter, or a mix of 500-pound weapons and Small Diameter Bombs approximately equal to the munitions payload of an F-16. Additionally, Raytheon has experimented with a mini-UAV known as "Silent Eyes" to be launched from the fuselage of the Predator B and to serve as a target identifier in supplement to the laser designator.[125]

Predator B-ER, "Mariner". The Predator B-Extended Range or "Mariner" is less of a next generation Predator and more of hybrid of the Predator B and NASA's Altair UAV, also produced by General Atomics. The Mariner was created as a result of General Atomic's pursuit of the Navy's Broad Area Maritime Surveillance (BAMS) program contract. As an extended range UAV, the Mariner retains the original airframe of the Predator, but adds the 86 ft. wing from the Altair and an increased fuel capacity. The subsequent combination has yielded a surveillance UAV capable of altitudes of 50,000 feet and a flight endurance of 49 hours. General Atomic has partnered with Lockheed Martin System and Sensors to integrate an exterior-mounted maritime radar that will advance the surveillance capabilities of the Mariner beyond the standard Predator B payload. The Mariner is expected to compete with Northrop Grumman's Global Hawk for the BAMS contract, and the vehicle's proponents hope that Mariner could have a flyaway cost as little $19 million per vehicle.[126]

Predator C. In addition to the Mariner, General Atomics is currently developing a third generation Predator that uses a turbo-jet engine to fly long endurance, high altitude surveillance missions. The Predator C will reportedly use the fuselage of the Predator B, but will be similar to Northrop Grumman's Global Hawk in payload capacity and flight performance. A spokesman for General

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[124] OSD, UAS Roadmap 2005-2030, August 2005, p. 10.

[125] Michale Sirak. "Predator B Faces Fielding Slowdown." *Jane's Defense Weekl*y, May 28, 2003.

[126] Ron Laurenzo. "Global Hawk, New Predator to Compete For Navy Contract." *Defense Week*, December 22, 2003.

Atomics stressed that the Predator C will not be a direct competitor with the Global Hawk.[127]

I-Gnat-ER. Currently, the Army uses the I-Gnat as a temporary gap-filler for the RQ-5 Hunter when that UAV is removed from deployment to be overhauled or modified. Servicemen in the field have characterized the I-Gnat as a downsized version of the Predator UAV.[128] This medium altitude, long-endurance surveillance and reconnaissance platform is also manufactured by General Atomic Aeronautical Systems and evolved as an upgraded derivation of the Gnat-750. The I-Gnat-ER features nearly the same system, payload and performance characteristics as the MQ-1 Predator A with a few exceptions. The I-Gnat-ER can remain aloft for 30 hour, six hours longer than its Air Force sibling, yet it lacks the SAR and Beyond-Line-Of-Sight (BLOS) capabilities and is engineered for a significantly shorter flight radius. The Army currently owns three I-Gnat vehicles as the result of an FY2004 Congressional budget increase for ER/MP CONOPS development.[129] Two additional vehicles outfitted with Satellite Communications (SATCOM) data links, MTS sensor/target designators and Hellfire missiles are expected to be delivered to the Army by the end of 2005. [130] According to DoD congressional testimony, the I-Gnat will continue to augment Hunter operations in Iraq.[131]

Program Status. Predator UAVs are operated as part of a system, which consists of four air vehicles, a ground control station, and a Predator Primary Satellite Link. The actual current year cost in FY2005 for one Predator A system was approximately $18.0 million, while the current year cost (CY05) for a Predator B system was $46.8 million.[132] The Air Force currently possesses 57 deployable MQ-1 Predators and fields 12 systems. The current inventory of MQ-9 Predator Bs stands at six vehicles and initial Pentagon plans anticipate the number to grow to 46 by the end of FY2011. Recent developments have led many to believe that both Predators will continue to be some of the Air Force's most valued assets. During a Senate Armed Service hearing, Air Force Chief of Staff General John Jumper said, "We're going to tell General Atomics to build every Predator they can possibly build."[133] However, in order to avoid the logistical complications experienced with the

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[127] Elizabeth Rees. "General Atomics to Roll Out High-Altitude 'Predator C' by Year's End." *Inside The Air Force*, May 13, 2005.

[128] Emily Hsu. "Army Deploys 'Improved Gnat' UAV to Support Troops in Combat." *Inside the Army*, March 29, 2004.

[129] Sgt. 1st Class Marcia Triggs, U.S. Army. "Aviation Unveils Life Without Comanche." *Army News Service*, April 5, 2005.

[130] Greg Grant. "US Army Steps Up UAV Efforts." *Defense News*, June 27, 2005.

[131] Dr. Glenn Martin's Testimony Before the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee. "Unmanned Combat Air Vehicles (UCAV) and Unmanned Aerial Vehicles (UAV)." March 17, 2004.

[132] Major Thomas Macias, U.S. Air Force. "Point Paper on Predator Program Acquisition and Flyaway Cost." Air Force Legislative Liaison Office, August 18, 2005.

[133] U.S. Congress, 109th Congress, 1st Session, Senate, Committee on Armed Services. "Fiscal 2006 Defense Authorization." February 10, 2005.

accelerated development of the Predator A in the mid 1990s, the Air Force announced that the initial operation capability (IOC) of the Predator B has been pushed back from FY2006 to FY2009. The extra time will be used to ensure that trained operators, adequate support infrastructures and appropriate operation strategies are in place.[134] In FY2005 and FY2006, Congressional appropriators increased both Predator R&D and Procurement funding from the President's Budget Request. In FY2006, Senate Authorizers supported research into integrating "Viper Strike" munitions on the Predator. For complete budget activity, see **Table 7** below:

Table 5. Predator A & B Combined Funding

($ in Millions)

	Procurement		**RDT&E**
FY05			
Request	9 air vehicles	146.6	81.3
	Mods	31.8	
Authorization Conference	9 air vehicles	176.6	81.3
	Mods	31.8	
Appropriations Conference	12 air vehicles	176.6	83.2
	Mods	31.8	
FY05 Supplemental			
Appropriations Conference	Spares	8	
FY06			
Request	9 air vehicles	125.5	61
	Mods	30.2	
Authorization, House	15 air vehicles	210 .5	61
	Mods	30.2	
Authorization, Senate	9 air vehicles	125.5	66
	Mods	30.2	
Appropriations, House	13 air vehicles	177.5	63.5
	Mods	30.2	
Appropriations, Senate	9 air vehicles	125.5	63.5
	Mods	30.2	

Source for all funding tables in this section:
FY2005 Auth: H.R. 4200, P.L. 108-375, H.Rept. 108-767
FY2005 Appro: H.R. 4613, P.L. 108-287, H.Rept. 108-622
FY2005 Emergency Supplemental: H.R. 1268
FY2006 Auth: H.R. 1815, H.Rept. 109-89, S. 1042, S.Rept. 109-69
FY2006 Appro: H.R. 2863, H.Rept. 109-119, H.R. 2863, S.Rept. 109-141

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[134] Michale Sirak. "Predator B Faces Fielding Slowdown." *Jane's Defense Weekly*, May 28, 2003.

RQ-2 Pioneer

The Pioneer UAV has gained distinction for its nearly twenty years of service to the Navy, Army and Marine Corps. Originally developed by Israeli Aircraft Industries (IAI), RQ-2 Pioneer was acquired by the U.S. Navy in 1986. Subsequently, Aircraft Armaments Incorporated out of Hunt Valley, MD and IAI jointly manufactured the Pioneer for the Navy, U.S. Marine Corp and the U.S. Army. The UAV was often employed in 1991 during Operation Desert Storm for reconnaissance and Naval gun spotting missions. At the end of FY2002 the Navy ended its use of the air vehicle and passed its assets to the Marine Corps, which intends to field the RQ-2 until either 2010 or until a Vertical Take off and Landing UAV (VTUAV) is ready for operation.[135] Many believe that Pioneer has remained useful during its service life by being durable-the Marine Corp unofficially refers to the vehicle as "Old Reliable"-and by undergoing several progressive performance upgrades.[136]

System Characteristics. At 14 feet long, the Pioneer is roughly half the size of the Air Force's MQ-1 Predator A UAV. It can reach a maximum altitude of 15,000 feet, but flies an optimal altitude of 5,000 feet above its target. The vehicle can achieve flight by rocket-assisted takeoff (RATO), a catapult launcher, or traditional runway takeoff from land or from ships. Pioneer is maintains a flight range of 100 nautical miles. The propeller driven SF-350 piston engine keeps the UAV aloft for up to five hours. The Pioneer can land on a runway or can be recovered using a retrieval net when a runway is unavailable. Since 1986, Pioneer has flown over 36,500 hours in direct support of Navy and Marine Corps operational commanders, including more than 7,500 flight hours during Operation Iraq Freedom.

Mission and Payload. The mission of the Pioneer is to provide real-time intelligence and a reconnaissance capability to field commanders. Pioneer can be used for over-the-horizon targeting, surveillance, Naval gunfire spotting, and battle damage assessment. Its 75 lb payload consists of a combined E-O/IR camera. Other payloads that have been demonstrated include a meteorological sensor, a mine detection sensor and a chemical detection sensor.

Program Status. The Navy had planned to retire the Pioneer in 2004 and replace it with the VTUAV. However, when it quit that program, the Navy gave all of its Pioneer systems to the Marine Corps. The Marine Corps hopes keep them flying another 10 years through a product improvement program.[137] Current procurement funds are geared towards post-production support. In FY2005 and FY2006, DoD's Pioneer procurement requests contained funding for upgrade kits only and no actual system or vehicle procurement appropriations. According to the Office of the Secretary of Defense, in the final year of production, the Pioneer

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[135] Peter La Franchi. "Directory: Unmanned Air Vehicles." *Flight International*, June 21st, 2005, p. 75.

[136] B.C. Kessner and Lorenzo Cortes., "Reliable, But Unglamorous Pioneer Epitomizes Legacy UAV Predicament." *Defense Daily*, April 27, 2004.

[137] Glenn W. Goodman Jr. "UAVs Come Of Age." *The ISR Journal*, July 2002. p.28.

system, which includes five vehicles, a ground control station with supporting equipment and launch/recovery devices, cost $17.2 million in FY2004 dollars. The Marine Corps currently possesses 35 Pioneer UAVs operated out of MCAS Twenty Nine Palms, CA, MCAS Cherry Point, NC and with the Marine Aviation Detachment in Paxtuxent River, MD.

Table 6. Pioneer Funding
($ in Millions)

	Procurement	RDT&E
FY05		
Request	8.7	0
Authorization Conference	8.7	0
Appropriations Conference	8.7	0
FY06		
Request	1.9	0
Authorization, House	1.9	0
Authorization, Senate	1.9	0
Appropriations, House	1.9	0
Appropriations, Senate	1.9	0

RQ-4 Global Hawk

Recently, Northrop Grumman's RQ-4 Global Hawk has gained distinction as the largest and most expensive UAV currently in operation for the Department of Defense. This large UAV incorporates a diverse surveillance payload with performance capabilities that rival or exceed most manned spy planes. The Global Hawk's surveillance achievements in demonstrations and over the battlefield have led many to believe that the RQ-4A and its successor, the RQ-4B, play an important role in the future of ISR. However, the complex task of adding specific intelligence systems to the payload configuration has helped to keep this high altitude, long endurance UAV from advancing beyond developmental stage despite extensive operational deployment. Many Pentagon officials and Congressional members have become increasingly concerned with the program's burgeoning cost and have subsequently slowed development progress until adequate program controls are implemented.[138]

[138] For the most recent Congressional concerns, see House Report 109-89. House Armed Service Committee "National Defense Authorization Act For Fiscal Year 2006." May 20, 2005, p. 91.

System Characteristics. At 44 feet long and weighing 26, 750 lbs, Global Hawk is about as large as a medium sized corporate jet. Global Hawk flies at nearly twice the altitude of commercial airliners and can stay aloft at 65,000 feet for as long as 35 hours. It can fly to a target area 5,400 nautical miles away, loiter at 60,000 feet while monitoring an area the size of that state of Illinois for 24 hours, and then return. Global Hawk was originally designed to be an autonomous drone capable of taking off, flying, and landing on pre-programmed inputs to the UAV's flight computer. Air Force operators have found, however, that the UAV requires frequent intervention by remote operators.[139] The RQ-4B resembles the RQ-4A, yet features a significantly larger airframe. In designing the B-model, Northrop Grumman increased the Global Hawk's length from 44 feet to 48 feet and its wingspan from 116 feet to 132 feet. The expanded size enables the RQ-4B to carry an extra 1000 lbs. of surveillance payload.

Mission and Payload. The Global Hawk UAV has been called "the theater commander's around-the-clock, low-hanging (surveillance) satellite."[140] The UAV provides a long-dwell presence over the battlespace, giving military commanders a persistent source of high quality imagery that has proven valuable in surveillance and interdiction operations. The RQ-4A's current imagery payload consists of a 2,000-lb integrated suite of sensors much larger than those found on the Predator. These sensors include an all-weather SAR with Moving Target Indicator (MTI) capability, an E-O digital camera and an IR sensor. As the result of a January 2002 Air Force requirements summit, Northrop Grumman expanded its payload to make it a multi-intelligence air vehicle. The subsequent incarnation, the RQ-4B, is outfitted with an open-system architecture that enables the vehicle to carry multiple payloads, such as signals intelligence (SIGINT) and electronic intelligence (ELINT) sensors. Furthermore, the classified Multi-Platform Radar Technology Insertion Program (MP-RTIP) payload will be added in order to increase radar capabilities. These new sensor packages will enable operators to eavesdrop on radio transmissions or to identify enemy radar from extremely high altitudes. Future plans include adding hyper-spectral sensors for increased imagery precision and incorporating laser communications to expand information transfer capabilities.[141] The end goal is to field a UAV that will work with space-based sensors to create a "staring net" that will prevent enemies from establishing a tactical surprise.[142] In August of 2003, the Federal Aviation Administration granted the Global Hawk authorization to fly in U.S. civilian airspace, which further expanded the vehicles' mission potential.[143] This distinction, in combination with the diverse surveillance capabilities, has led many officials outside the Pentagon to consider the Global Hawk an attractive candidate

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[139] Jeff Morrison. "USAF No Longer Viewing Global Hawk As An Autonomous System, Official Says." *Aerospace Daily*, December 3rd, 2005.

[140] Glenn W. Goodman, Jr. "UAVs Come Of Age." *The ISR Journal*, July 2002.

[141] David A. Fulghum. "Global Hawk Shows Off Updated Package of Sensor Aviation Week & Space Technology." *Aviation Week Intelligence Network*. September 08, 2003.

[142] Ibid.

[143] Sue Baker. "FAA Authorizes Global Hawk Flights." Aeronautical Systems Center Public Affairs, August 21, 2003.

for anti-drug smuggling and Coast Guard operations.[144] Documentation from the Office of the Secretary of Defense (OSD) indicates that the RQ-4A is expected to reach initial operational capability (IOC) in 2006.[145]

Program Status. Developed by Northrop Grumman Corporation of Palmdale, CA, Global Hawk entered low-rate-initial-production in February 2002. The Air Force has stated that it intends to acquire 51 Global Hawks, at an expected cost of $6.6 billion for development and procurement costs. Currently, the Air Force possesses 12 RQ-4A vehicles. According to the most recent Select Acquisition Report, the current program-unit cost for the Global Hawk has reached $128.7 million.[146] In April 2005, the Air Force reported to Congress that the program had overrun by 18% as a result of an "increasing aircraft capacity to accommodate requirements for a more sophisticated, integrated imagery and signals intelligence senor suite".[147] A Government Accountability Office Report in December 2004 noted that the program had increased by nearly $900 million since 2001 and recommended delaying the purchase of future Global Hawks until an appropriate development strategy could be implemented.[148] The rising costs of the UAV and accusations of Air Force mismanagement have caused concern among many in Congress and in the Pentagon as well as facilitating an overall debate on the Air Force's development strategy.[149] The Conferees of the FY2005 Defense Authorization Bill [House Report 108-767] admonished the Air Force's management strategy for not using previously authorized funds for a counter-drug surveillance evaluation program. They noted that "the committee suspects the Air Force used the $18.0 million set aside in 2001 for the counter-drug demonstration to meet other requirements of the Global Hawk development program".[150] As a result, the Conferees recommended a cut of $18 million to the President's R&D request for the Global Hawk. The final appropriation bill [Public Law 108-335] cut the R&D request by six million dollars. In June of 2004, the House Appropriations Committee expressed serious concern over Air Force's accelerated development strategy and consequently cut the president's budget request for advanced procurement by $21.3 million and current year procurement by $89.86 million.[151] The current year procurement cut transferred one RQ-4A to the Navy for FY2005. Neither of the cuts

[144] Ron Laurenzo. "Global Hawk Scouts Ahead for Other UAVs." *DEFENSE WEEK*, September 2, 2003.

[145] OSD. UAS Roadmap 2005-2030. August 2005, p. 6.

[146] OSD. Selected Acquisition Report. December 31, 2004, p. 11.

[147] James R. Asker. "Global Hawk 18% Over Budget." *Aviation Week & Space Technology, April 25, 2005.*

[148] United States Government Accountability Office. GAO-05-6 Unmanned Aerial Vehicles, Changes in Global Hawk's Acquisition Strategy Are Needed to Reduce Program Risks. November 2004, p. 3-4.

[149] See House Report 109-89. House Armed Service Committee "National Defense Authorization Act for the Fiscal Year 2006." May 20, 2005, p. 91.

[150] U.S. Congress, 108th Congress, 2nd Session, Committee of Conference, Ronald W. Reagan National Defense Authorization Act for Fiscal Year 2005, House Report 108-767, p.209-210.

[151] See House Report 108-553, accompanying H.R. 4613, 108th Congress, June 18th 2004, p. 193-194.

survived conference and the Air Force's procurement budget request was fully funded for FY2005. In December 2004, Michael Wynne, acting Under Secretary of Defense for Acquisitions, emphasized that DoD would not purchase UAVs that cost as much as manned aircraft of equivalent capabilities. Of the Global Hawk, Wynne noted that the vehicle had gone from being "relatively inexpensive to [where it] now approaches what we have paid for some bombers in the past".[152] As a result of increasing cost criticism, the Air Force devised a plan in early 2005 intended to restructure the Global Hawk program in an effort to facilitate IOC by the end of 2005. The House Appropriations Committee cut the President's FY2006 current year procurement request by $110 million, advance procurement request by $10 million and increased Global Hawk R&D by $21 million. Final appropriations and authorizations await the Senate Defense Appropriations and Senate Defense Authorization (S. 1042, Senate Armed Services Committee Report 109-69) bills. See Table 9 for a complete overview of FY2005 and FY2006 funding.

Table 7. Global Hawk Funding
($ in Millions)

	Procurement		RDT&E
FY05			
Request	4 air vehicles	287.7	336.1
	AP CY	71.8	
Authorization Conference	4 air vehicles	287.7	336.1
	AP CY	71.8	
Appropriations Conference	4 air vehicles	287.7	336.1
	AP CY	71.8	
FY05 Supplemental			
	18.3		39.7
FY06			
Request	5 air vehicles	327.6	308.5
	AP CY	69.9	
Authorization, House	4 air vehicles	297.7	308.5
	AP CY	69.9	
Authorization, Senate	5 air vehicles	327.6	308.5
	AP CY	69.9	
Appropriations, House	3 air vehicles	199.4	329.7
	AP CY	59.9	
Appropriations, Senate	5 air vehicles	327.6	317.5
	AP CY	69.9	

[152] Dave Ahearn. "Northrop Grumman Defends $30 Million Global Hawk Cost." *Defense Today*. December 17, 2004.

RQ-5A Hunter / MQ-5B Hunter II

Originally co-developed by Israel Aircraft Industries and TRW (now owned by Northrop Grumman) for a joint U.S. Army/Navy/Marine Corps short range UAV, the Hunter system has found a home as one of the Army's principle unmanned platforms. The service has deployed the RQ-5A for tactical ISR in support of numerous ground operations around the world. At one time, the Army planned to acquire 52 Hunter integrated systems of eight air vehicles a piece, but the Hunter program has experienced some turbulence. The Army canceled full-rate-production of the RQ-5A in 1996, but continued to use the seven systems already produced. It acquired 18 MQ-5B Hunter IIs through low-rate-initial-production in FY2004 and FY2005. The MQ-5B's design includes longer endurance and the capability to be outfitted with anti-tank munitions. Both variants are currently operated by the 224th Military Intelligence Battalion out of Fort Steward, GA; by the 15th Military Intelligence Battalion out of Ft. Hood, TX; and by 1st Military Intelligence Battalion out of Hoenfel, Germany.

System Characteristics. The RQ-5A can fly at altitudes up to 15,000 feet, reach speeds of 106 knots, and spend up to 12 hours in the air. Weighing 1,600 lbs, it has an operating radius of 144 nautical miles. The MQ-5B includes an elongated wingspan of 34.3 feet up from 29.2 feet of the RQ-5A and a more powerful Mercedes High-Fuel Engine, which allows the Hunter II to stay airborne for three extra hours and to reach altitudes of 18,000 feet.[153]

Mission and Payload.. During its years of service, the Army has used the Hunter system mostly for short and medium range surveillance and reconnaissance. More recently, however, the Army has explored the expansion of the Hunter's missions, including weaponization for tactical reconnaissance/strike operations and border surveillance for the Department of Homeland Security. The Hunter primarily uses a gimbaled E-O/IR sensor payload for its ISR functions, yet a 2003 Northrop Grumman demonstration showcased a new ground operated SAR/MTI (moving target indicator) sensor on the Hunter as part of a potential Tactical Unmanned Aerial Vehicle Radar (TUAVR) package.[154] The Hunter II is also set to receive an advanced software architecture in order to ease the integration of future payloads and to extend the vehicle's service-life. During the later half of 2004, Northrop Grumman tested a variety of munitions as part of the Hunter payload. The Viper Strike precision guided munitions, which can designate targets either from the munition's laser, from another aerial platform or from a ground system, appears to be weapon of choice for the Hunter system. This weapon allows the Hunter to provide accurate strikes at targets that elude the Hellfire missile, and makes the Hunter the Army's first armed UAV.

Program Status. The Army has halted production on the RQ-5 Hunter and now fills service gaps in the Hunter force with the I-Gnat-ER. As of February 2005, all 32 Hunter UAVs are still in operation and periodically receive upgrades and

[153] OSD. UAS Roadmap 2005-2030. August 2005, p. 7

[154] "Army Test NG-Built SAR/MTI Sensors on Hunter UAV" *Aerospace Daily*, June 23, 2003.

modifications. The Hunter system consists of eight aircraft, ground control systems and support devices, and launch/recovery equipment. In FY2004, the final year of Hunter procurement, a Hunter system cost $26.5 million. The FY2005 and FY2006 Defense budgets contained no funds for the procurement or R&D of any RQ-5 system. An August 2005 announcement revealed that the Army awarded General Atomic's Warrior UAV the contract for the Extended Range-Multi Purpose (ER-MP) UAV program over the Hunter II.[155] Despite the loss, Northrop Grumman expects to continue to market the Hunter II to the rest of the services over the next few years.[156]

RQ-7 Shadow

The RQ-7 Shadow found a home when the Army, after a two decade search for a suitable system, selected AAI's close range surveillance platform for its tactical unmanned aerial vehicle (TUAV) program. Originally, the Army, in conjunction with the Navy explored several different UAVs for the TUAV program, including the now-cancelled RQ-6 Outrider system. However, in 1997 after the Navy pursued other alternatives, the Army opted for the low cost, simple design of the RQ-7 Shadow 200. Having reached full production capacity and an IOC in 2002, the Shadow has become the primary airborne ISR tool of numerous Army units around the world and is expected to remain in service through the decade.

System Characteristics. Built by AAI Corporation of Hunt Valley, MD, the Shadow is 11 feet long with a wingspan of 13 feet. It has a range of 68 nautical miles, a distance picked to match typical Army brigade operations, and an average flight duration of five hours. Although the Shadow can reach a maximum altitude of 14,000 feet, its optimum level is 8,000 feet. The Shadow is catapulted from a rail-launcher, and recovered with the aid of arresting gear. The UAV also possesses automatic takeoff and landing capabilities. The upgraded version, the RQ-7B Shadow, features a greater wingspan by 16 inches and larger fuel capacity that allows for an extra two hours of flight endurance.

Mission and Payload. The Shadow provides real-time reconnaissance, surveillance and target acquisition information to the Army at the brigade level. A potential mission for the Shadow is the perilous job of medical resupply. The Army is considering expanding the UAV's traditional missions to include a medical role, where several crucial items such as blood, vaccines and fluid infusion systems could be delivered to troops via parachute.[157] Unlike the RQ-5 Hunter, the Shadow will not be outfitted with weapons capabilities.[158] For surveillance purposes, the Shadow's 60-pound payload consists of an E-O/IR sensor turret which produces day or night video, and can relay data to a ground station in real-time via a line-of-sight data link. As part of the Army's Future Combat System plans, the Shadow will be outfitted

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[155] Jefferson Morris. "Army More Than Doubles Expected Order for ERMP with General Atomics Win." *Aerospace Daily & Defense Report*. August 10th, 2005.

[156] Ibid.

[157] Erin Q. Winograd. "Army Eyes Shadow UAVs Potential For Medical Resupply Missions." *InsideDefense.com*, [http://www.InsideDefense.com]. December 20, 2002, p.14.

[158] Kevin Mauer. "Pilotless Plane guides 82nd." *Fayetteville Observer*, August 13, 2004.

with the Tactical Common Data Link currently in development to network the UAV with battalion commanders, ground units and other air vehicles.[159]

Program Status. The Army currently maintains an inventory of 100 Shadow UAVs at Ft. Bragg, Ft. Hood, Ft. Lewis, Ft. Stewart, Ft. Wainwright, at military bases in Germany and Korea, and with National Guard units in Baltimore, MD and Indian Town Gap, PA.[160] The program cost for a Shadow UAV system — which includes four vehicles, ground control equipment, launch and recovery devices, remote video terminals, and High Mobility Multipurpose Wheeled Vehicles for transportation-reached $16.4 million in current year dollars for FY2005.[161] The Army intends to use the Shadow as the interim Class III TUAV for the future combat systems project, which the Army expects to reach IOC in 2014.[162] In FY2005 the Army procured eight TUAV systems, but only requested $26 million in FY2006 for retrofitting the existing Shadow fleet with previously developed upgrades and modifications. Total RDT&E requests equalled $53.6 million in FY2005 and $139.6 million in FY2006. In FY2005, the Appropriations Conferees increased the request amount by nearly a third, while in FY2006 the House Appropriators matched the request levels.

Table 8. RQ-7 Shadow Funding

($ Millions)

	Procurement	RDT&E
FY05		
Request	100.5	45.6
Authorization Conference	118.2	45.6
Appropriations Conference	118.2	54.4
FY06		
Request	26	139.6
Authorization, House	26	139.6
Authorization, Senate	26	139.6
Appropriations, House	26	142.6**
Appropriations, Senate	26	156.6

**Markup includes funding for RDT&E of an I-Gnat ER system

[159] "Upgraded Shadow UAV Rolls Off Production Line." *Defense Today*, August 5, 2004.

[160] OSD. UAS Roadmap 2005-2030. August 2005, p. 8.

[161] OSD. Army Procurement BA 02: Communications and Electronics FY2006, February 2005, TUAV (B00301), Item No. 62, p. 1 of 16.

[162] Peter La Franchi. "Directory: Unmanned Air Vehicles." *Flight International*, June 21, 2005.

Joint Unmanned Combat Air Systems (J-UCAS)

In the mid 1990s, the Pentagon began developing a UAV designed primarily for combat missions. The result was two separate Unmanned Aerial Combat Vehicles (UCAV) programs, the Air Force's UCAV and the Navy's UCAV-N demonstrator program. The Air Force favored Boeing's X-45 for its program, while Northrop Grumman's X-47 Pegasus and Boeing's X-46 competed for the Navy's project. However, in June 2003, the Pentagon merged the two separated programs in order to establish the Joint Unmanned Combat Air Systems (J-UCAS) project under the management of the Defense Advanced Research Projects Agency (DARPA). The objective of the J-UCAS merger was to create a flexible offensive network in which the air and ground elements are adapted to meet specific combat mission.[163] As part of Program Budget Decision (PBD) 753 in December 2004, DARPA was ordered to transfer administration of the J-UCAS resources to Air Force, which will form a joint program planning committee with the Navy.[164] While questions surround the direction in which the Air Force will move the program forward, statements from the Pentagon have indicated that the program will maintain a competitive environment between Boeing and Northrop Grumman's vehicles.[165]

System Characteristics. Currently, J-UCAS consists of two variants from the Navy and Air Force's previous programs. Featuring a length of 39 feet and a wingspan of 49 feet, the X-45C evolved as an enhanced cross-breed of the two evaluation X-45A vehicles DARPA inherited from the Air Force and the Boeing's experimental X-46A submission for the Navy program. Powered by General Electric's GE F404-102D turbojet engine, the X-45C is expected to achieve speeds of 450 knots and altitudes of 40,000 feet. Furthermore, the X-45 can stay aloft for up to seven hours and operate at a range of 1,200 nautical miles. When engineering the X-45C, Boeing experimented with airframe designs that maximized the stealth capabilities of the UAV system. They landed on the larger arrowhead design, which resembles fellow stealth aircraft like the B-2 Spirit Bomber and F117A-Nighthawk. As the X-45C's competitor, Northrop Grumman's X-47B, an advanced version of the UCAV-N's X-47A, is nearly as long as the X-45C, yet possess a significantly greater wingspan of 62 feet. The increased wingspan in combination with the more powerful Pratt & Whitney F100-220U turbojet engine will allow X-47B an endurance of nine hours and range of 1,600 nautical miles. The speed and altitude of the Pegasus is expected to match that of the X45-C. The X-47B retains a smooth and sleek design optimized for stealth but features folding wing-tips that cut down on size, making it more suitable for storage aboard an aircraft carrier.[166] Designs are in place for the X-47B's common operating system, which is expected to accommodate both Air Force and Naval technology.[167] Both aircraft possesses automated flight capabilities.

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[163] OSD. UAS Roadmap 2005-2030. August 2005, p. 11.

[164] OSD. Program Budget Decision 753. December 23, 2004, p. 9.

[165] Sharon Weinberger. "J-UCAS May Lead to Multiple Air Vehicles". *Defense Daily,* March 15th, 2004.

[166] "UCAVs and Future Military Aeronautics." *Military Technology*, June 2005, p. 100.

[167] Ibid.

Potential Mission and Payload. Initially, the separate Navy and Air Force programs envisioned UCAV combat missions specific to the needs of the individual services. The Air Force intended the X-45's primary mission to be the suppression of enemy air defenses (SEAD) and secondary mission of electronic attack warfare.[168] The Navy planned to use its UCAV for armed intelligence, surveillance and reconnaissance.[169] The payloads of each vehicle are expected to be tailored to the respective mission. Both Boeing and Northrop Grumman's systems will possess internal weapons bays and will be capable of carrying guided weapons similar to those of conventional strike aircraft. The current weapon choice for the X-45C and the X-47B is the GBU-31 Joint Direct Attack Munitions (JDAM). Both vehicles will feature SARs, Electronic Support Measure sensor suites (ESM), and Ground Moving Target Indicators (GMTI). Additionally, the X-47B's payload will include an E-O/IR camera combination in order to augment its surveillance and reconnaissance missions.

Program Status. Since its inception, the UCAV programs have experienced a constant change in administration and organization, which many believe will affect the pace of development. In 2003, the Air Force and Navy's respective UCAV projects were combined under the DARPA controlled J-UCAS program in order to facilitate interoperability and development synergy. In September of 2004, DARPA hired the Johns Hopkins University Applied Physics Laboratory as a not-for-profit integrator/broker in charge of promoting cooperation for common vehicle architectures.[170] In a move viewed by several observers as an abrupt reversal, the Office of the Secretary of Defense instructed the Air Force to take control over the project. The subsequent fluctuation of J-UCAS management appears to complicate forecasting of the program's future. Development of the combat UAV has been advanced via the spiral development process.[171] Currently, the J-UCAS aircraft inventory includes two X-45A air vehicles and one X-47A air vehicle. OSD plans indicate that three X-45Cs three and the X-47Bs will be delivered by the end of 2006. Operational flight assessments of both vehicles are expected to begin in 2007.[172] The total money spent on the J-UCAS/UCAV program, which prior to FY2006 reached more than $1.45 billion in RDT&E funding, made it one of the most expensive UAV ventures undertaken by DoD. For recent funding developments, see Table 11.

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[168] Steven J. Zaloga. "World Missile Briefing." *The Teal Group Corporation*. February 2004, UCAV section, p.4.

[169] Amy Butler. "OSD Eyes E-10A As Possible Billpayer For Attack Drone Program." *Defense Daily*, December 5th, 2003.

[170] Ibid.

[171] For more information on spiral development, see CRS Report RS21195, *Evolutionary Acquisition and Spiral Development in DOD Programs: Policy Issues for Congress*, by Gary J. Pagliano and Ronald O'Rourke.

[172] Amy Butler. "Contractors Seek Program Stability with USAF J-UCAS Oversight." *Aviation Week & Space Technology*, June 20th, 2005, p. 44.

Table 9. J-UCAS Funding
($ in Millions)

	RDT&E	
	Demonstration & Validation	**Advanced Tech. Development**
FY05		
Request	422.9	284.6
Authorization Conference	222.9	284.6
Appropriations Conference	222.9	363.6
FY06		
Request	272.3	77.8
Authorization, House	272.3	77.8
Authorization, Senate	272.3	77.8
Appropriations, House	272.3	77.8
Appropriations, Senate	72.3	77.8

RQ-8B Fire Scout

Currently in the engineering and manufacturing development phase of production, the Fire Scout was initially designed as the Navy's choice for an unmanned helicopter capable of reconnaissance, situational awareness and precise targeting.[173] While the Navy canceled production of the Fire Scout in 2001, Northrop Grumman's vertical take-off UAV was rejuvenated by the Army in 2003, when the Army designated the Fire Scout as the interim Class IV UAV for the future combat system. The Army's interest spurred renewed Navy funding for the RQ-8, making the Fire Scout DoD's first joint UAV helicopter. Recent experimentation and evaluation efforts have explored the possibility of arming the Fire Scout and adding multiple and non-traditional mission capabilities to the platform.

System Characteristics and Mission. Northrop Grumman based the design of the Fire Scout on a commercial Schweitzer Co. helicopter. As an upgrade from the original RQ-8A, the RQ-8B Fire Scout features an advanced four-blade

[173] "RQ-8A Fire Scout, Vertical Take Off and Landing Tactical Unmanned Aerial Vehicle (VTUAV)" *GlobalSecurity.org*, [http://www.globalsecurity.org/intell/systems/vtuav.htm], April 26th, 2004.

rotor design to reduce the aircraft's acoustic signature.[174] With a basic 127 lbs payload, the Fire Scout can stay aloft for up to 9.5 hours. With the full capacity sensor payload the helicopter UAV endurance diminishes to roughly six hours. The vehicle also possesses autonomous flight capabilities. The surveillance payload consists of a laser designator and range finder, an IR camera and a multi-color EO camera, which when adjusted with specific filters could provide mine-detection capabilities.[175] The Fire Scout currently possesses line-of-sight communication data links. Northrop Grumman officials hope to expand the communications capabilities to include a wideband data relay from another airborne platform and possible satellite communications.[176] Accompanying the renewed interest in the Fire Scout is an expanded vision of mission capabilities, which most notably includes the armament of the helicopter UAV for strike missions. Recent weaponization plans have included the integration of Hydra folding-fin rockets, 2.75 inch Mark 66 unguided rockets, or the Hellfire II anti-tank missiles. Discussions of future missions have also covered border patrol, search and rescue operations, medical resupply and submarine spotting operations.[177]

Program Status. Currently, five RQ-8A air vehicles accompanied by four ground stations have reached the developmental testing phase of the acquisition process. These evaluation Fire Scouts were produced as low-rate-initial-production vehicles. The Pentagon's 2005 UAS Roadmap estimates a future inventory of 192 vehicles between both the Army and Navy.[178] The Army anticipates full-rate-production in 2008 and IOC by 2010.[179] Furthermore, the Army intends to use the Fire Scout as the interim brigade-level UAV for its Future Combat System program[180], while the Navy selected the RQ-8B to support the Littoral Combat Ship class of surface vessels.[181] Fire Scout funding is spread out through a variety of Navy and Army programs.

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174 David A. Fulghum. "Army Adopts Northrop Grumman's Helicopter UAV." *Aviation Week & Space Technology*, October 20th, 2003.

175 Northrop Grumman Corp Press Release. "Northrop Grumman's Next-Generation Fire Scout UAV on Track." June 23rd, 2005.

176 David A. Fulghum. "Army Adopts Northrop Grumman's Helicopter UAV." *Aviation Week & Space Technology*. October 20th, 2003.

177 Ibid.

178 OSD. UAS Roadmap 2005-2030. August 2005, p. 9.

179 Peter La Franchi. "Directory: Unmanned Air Vehicles." *Flight International*, June 21st, 2005, p. 74.

180 The Army intends to field four different classes of UAVs as part of its Future Conbat System (FCS): Class I for platoons, Class II for companies, Class III for battalions, and Class IV for brigades. See CRS Report RL32888: *The Army's Future Combat System (FCS): Background and Issues for Congress*, by Andrew Feickert, for more information.

181 Northrop Grumman Corp Press Release. "Northrop Grumman's Next-Generation Fire Scout UAV on Track." June 23rd, 2005.

Eagle Eye[182]

In February 2003, the Coast Guard selected the Bell Helicopter Textron's TR911D Eagle Eye tilitrotor UAV for its Deepwater Modernization program. A partnership of manufacturers, led by Bell and including Lockheed Martin and AAI, manages the development of the Eagle Eye.[183] The $3 million Eagle Eye takes off vertically like a helicopter, but then tilts down its rotors to fly like a plane. The Coast Guard, anticipates the eventual acquisition of 69 vehicles, which will extend the surveillance capability of their cutters.[184] Able to patrol the U.S. coastline for drug smugglers, refugees and ships in distress, the Eagle Eye will also be able to transmit video and infrared images to the cutter and command centers ashore. Furthermore, the vehicle can fly up to 220 knots and has an operational radius of roughly 300 miles, which surpasses the performance capabilities of comparable VUAVs.[185] Subsequently, Marine Corps officials have expressed interest in the Eagle Eye as a short to medium range replacement for the RQ-2 Pioneer. [186]

"Small UAVs"

Force Protection Aerial Surveillance System (FPASS). Serving as part of the Air Force's airbase defense system, Lockheed Martin's FPASS currently monitors the perimeter of several airbases in Iraq and Afghanistan in an effort to prevent enemy incursions or terrorists attacks. Known to airmen as the Desert Hawk, this battery operated, propeller driven UAV was developed in 1999 at the request of U.S. Central Command (CENTCOM) to improve situational awareness through area surveillance, patrols of base-perimeters and runway/departure paths, and aerial spotting for ground convoys. The Desert Hawk's small size, light weight and Styrofoam body have led many servicemen to draw comparison to remote-controlled model planes. The simple design, however, appears conducive to on-the-job repairs, which operators perform routinely with tape or glue.[187] Launched by a shoulder mounted slingshot device, the aircraft flies preprogrammed paths for up to one hour and lands through a controlled crash. The Desert Hawk carries either a small digital or infrared camera and can operate as far away as six nautical miles. The total inventory of Desert Hawks for

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[182] The Eagle Eye is not currently a DoD UAV program. However, it merits attention in this report because if fielded, it could likely be used in Homeland Defense scenarios. Also, Marine Corps and Navy officials have expressed interest in VTUAVs such as Eagle Eye.

[183] Christopher J. Castelli. "Bell Signs Industry Agreement for Eagle Eye Tiltrotor UAV." *Inside the Navy*, August 2nd, 2004.

[184] OSD. UAS Roadmap 2005-2030. August 2005, p. 19.

[185] Jefferson Morris. "No Plans To Use Fire Scout UAV, Deepwater Team Leader Says." *Aerospace Daily*, August 12th, 2002, p.4.

[186] Lorenzo Cortes. "Marine Corps Looks to Eagle Eye for VUAV Requirements." *Defense Daily*, April 22nd, 2004, p.3.

[187] Staff Sgt. C. Todd Lopez. "Desert Hawk Gives Security Forces an Eye in Sky." 379th Air Expeditionary Wing Public Affairs, U.S. Air Force, July 21st, 2004.

the Air Force stands at 126 vehicles.[188] Each system, including ground control stations, six vehicles and spare parts, costs approximately $300,000.[189]

Dragon Eye. AeroVironment's Dragon Eye provides Marines at the company level and below with reconnaissance, surveillance and target acquisition capabilities. This backpack carried, battery operated UAV features a 3.8 ft. rectangular wing, twin propellers and two cameras ports each capable of supporting day-light electro-optical cameras, low-light TV cameras, and infrared cameras. Using autonomous GPS navigation, Dragon Eye surveys preprogrammed area and relays near real-time images to a control station on the ground. The compact and lightweight design of the UAV allows an operational endurance of 45 minutes and can travel as far as two and a half nautical miles from the operator. Low-rate-initial-production of 40 aircraft began in 2001. However, after a 2003 operational assessment, the Marine Corps awarded AeroVironment a contract to deliver approximately 300 systems of full-rate-production Dragon Eyes.[190] One Dragon Eye system consists of three air vehicles and one ground station. The FY2006 Marine Corps procurement budget request anticipated the current unit cost per Dragon Eye system as $154,000.[191]

FQM-151 Pointer. Currently in service in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF), the Pointer is a short range reconnaissance and battlefield surveillance UAV developed by AeroVironment. The Pointer is capable of greater flight endurance (two hours) than most similar small UAVs, in part due to its relative large wingspan. The Pointer weighs in at nearly 8.5 lbs and features a 9 foot wingspan, which decreases portability when part of a system of two air vehicles and a ground control unit. As a result, transportation of a Pointer system requires two personnel.[192] The battery-operated UAV carries either an IR or a daytime E-O sensor and has remained a valued short range ISR asset for the Air Force and Special Operations Command. Currently, these two organizations own 50 Pointer systems and, according to OSD documentation, plan to purchase an additional 50 systems in the near future for OIF and OEF.[193] AeroVironment is in the process of developing the Pointer's successor, the Puma, which is expected to have an endurance of four hours and be capable of simultaneously carrying E-O and IR cameras.[194]

Raven. AeroVironment's development of the Raven emerged from the company's attempt to maximize the simplicity, portability and short range utility of mini-UAVs for the warfighter. Engineered from the basic design of the Pointer, the

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188 Peter La Franchi. "Directory: Unmanned Air Vehicles." *Flight International,* June 21st, 2005, p. 72.

189 "Desert Hawk Miniature UAV." *International Online Defense Magazine,* January 28th, 2005.

190 Peter La Franchi. "Directory: Unmanned Air Vehicles." *Flight International,* June 21st, 2005, p. 56.

191 Department of the Navy, FY2006-FY2007 Budget Estimate - Marine Corps Procurement, February 2005, BLI No. 474700, Item 44, p. 20 of 22.

192 Bill

193 OSD. UAS Roadmap 2005-2030. August 2005, p. 27.

194 Bill Sweetman. "Mini-UAVs — the Next Small Thing." *Jane's Information Group*, 2005.

Raven is two-thirds the size and weight of its predecessor, making it backpackable.[195] The Raven provides Army and SOCOM personnel with "over-the-hill" reconnaissance, sniper spotting and surveillance scouting of intended convoy routes. The advanced electric motor initiates flight once hand-launched by a running start from the ground operator. The vehicle is powered by an electric battery that needs to be recharged after 90 minutes, but deployed soldiers are equipped with four auxiliary batteries that can be easily charged using the 28 volt DC outlet in a Humvee. The vehicle lands via a controlled crash in which the camera separates from the body, which is composed of Kevlar plating for extra protection. Like the Pointer, the Raven can carry either an IR or an E-O camera and transmits real-time images to its ground operators. The relatively simple system allows soldiers to be trained in-theater in a matter of days. Raven systems can either be deployed in three aircraft or two-aircraft configurations. The Army and SOCOM have purchased 185 and 70 three-aircraft systems respectively, while the Air Force is currently in the process of buying 41 two-aircraft systems.[196] A three-aircraft system costs approximately $250,000.[197]

Silver Fox. Developed by Advanced Ceramic Research in conjunction with the Office of Naval Research (ONR), the Silver Fox is a Diesel-powered, front propeller UAV designed for tactical ISR support of brigade and battalion forces. With a five foot fuselage and an eight foot wingspan, the twenty pound vehicle achieves flight through a compressed air catapult or by hand, depending on wind speed. The fuselage houses both a daylight E-O and a micro-IR camera for surveillance purposes. While ONR and Advanced Ceramic Research Inc. began development of the Silver Fox in early 2003, the vehicle now supports U.S. forces in Iraq through a variety of undisclosed applications. Currently 20-30 systems of three vehicles each are planned for the Navy.[198]

Scan Eagle. While still in development, the Scan Eagle, has gained notice for its long endurance capabilities and relative low cost. The single propeller gasoline powered UAV features a wingspan two and a half times the length of its fuselage. The narrow 10 foot wings allow the 40 lb. vehicle to reach altitudes as high as 19,000 feet, distances of more than 60 nautical miles and a flight endurance of almost 20 hours. Developed by Boeing and the Insitu Group as a "launch-and-forget" UAV, the Scan Eagle autonomously flies to points of interest selected by a ground operator.[199] Using an inertially stabilized camera turret carrying both E-O and IR sensors, the Scan Eagle currently provides Marine Corps units in Iraq with force-protection ISR. The vehicle achieves flight through the use of a pneumatic launcher and lands through the Skyhook recovery system. Scan Eagle can be launched from

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[195] Peter La Franchi. "Directory: Unmanned Air Vehicles." *Flight International,* June 21st, 2005, p. 57.

[196] Ibid.

[197] Staff Sgt. Raymond Piper. "Eye in the Sky: The Raven Unmanned Aerial Vehicle." *Army News Service*, February 21, 2005.

[198] OSD. UAS Roadmap 2005-2030. August 2005, p. 27.

[199] Jim Garamone. "ScanEagle Proves Worth in Fallujah Fight." *American Forces Press Service*, January 11th, 2005.

the deck of a ship. Furthermore, the UAV's sensor data links possess the "Cursor-on-Target" feature, making a Scan Eagle system of eight vehicles interoperable with other legacy UAV systems. The Marine Corps, which is evaluating two systems under lease, expects the price of a single Scan Eagle to be approximately $100,000.