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U.S. Unmanned Aerial Systems

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Summary

Unmanned aerial systems comprise a rapidly growing portion of the military budget, and have been a long-term interest of Congress. At times, Congress has encouraged the development of such systems; in other instances, it has attempted to rein in or better organize the Department of Defense's efforts.

Unmanned aircraft are commonly called unmanned aerial vehicles (UAVs), and when combined with ground control stations and data links, form UAS, or unmanned aerial systems.

The use of UAS in conflicts such as Kosovo, Iraq, and Afghanistan, and humanitarian relief operations such as Haiti, revealed the advantages and disadvantages provided by unmanned aircraft. Long considered experimental in military operations, UAS are now making national headlines as they are used in ways normally reserved for manned aircraft. Conventional wisdom states that UAS offer two main advantages over manned aircraft: they are considered more cost-effective, and they minimize the risk to a pilot's life. For these reasons and others, DOD's unmanned aircraft inventory increased more than 40-fold from 2002 to 2010.

UAVs range from the size of an insect to that of a commercial airliner. DOD currently possesses five UAVs in large numbers: the Air Force's Predator, Reaper, and Global Hawk; and the Army's Hunter and Shadow. Other key UAV developmental efforts include the Air Force's RQ-170 Sentinel; the Navy's Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS), MQ-8 Fire Scout, and Broad Area Maritime Surveillance (BAMS) UAV; and the Marine Corps's Small Tactical Unmanned Aerial System.

In the past, tension existed between the services' efforts to acquire UAS and congressional initiatives to encourage a consolidated DOD approach. Some observers argue that the result has been a less than stellar track record for UAS programs. However, reflecting the growing awareness and support in Congress and the Department of Defense for UAS, investments in unmanned aerial vehicles have been increasing every year. DOD spending on UAS has increased from $284 million in FY2000 to $3.3 billion in FY2010.

Congressional considerations include the proper pace, scope, and management of DOD UAS procurement; appropriate investment priorities for UAS versus manned aircraft; UAS future roles and applications; legal issues arising from the use of UAS; issues of operational control and data management; personnel issues; industrial base issues; and technology proliferation.

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Background

Since 1917, United States military services have researched and employed unmanned aerial vehicles (UAVs).[1] Over that time, they have been called drones, robot planes, pilotless aircraft, RPVs (remotely piloted vehicles), RPAs (remotely piloted aircraft) and other terms describing aircraft that fly under control with no person aboard.[2] They are most often called UAVs, and when combined with ground control stations and data links, form UAS, or unmanned aerial systems.

The Department of Defense (DOD) defines UAVs 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 semi-ballistic vehicles, cruise missiles, and artillery projectiles are not considered UAVs by the DOD definition.[3] 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.

Although only recently procured in significant numbers by the United States, UAS were first tested during World War I, although not used in combat by the United States during that war. Indeed, it was not until the Vietnam War that the United States employed UAS such as the AQM-34 Firebee in a combat role. The Firebee exemplifies the versatility of UAS—initially flown in the 1950s as an aerial gunnery target and then in the 1960s as an intelligence-collection drone, it was modified to deliver payloads and flew its first flight test as an armed UAV in 2002.[4]

The military use of UAS in conflicts such as Kosovo (1999), Iraq (since 2003), and Afghanistan (since 2001) has illustrated the advantages and disadvantages of unmanned aircraft. UAS regularly make national headlines as they perform tasks historically performed by manned aircraft. UAS 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. UAS also protect the lives of pilots by performing those dull, dirty, or dangerous missions that do not require a pilot in the cockpit. UAS may also be cheaper to procure and operate than manned aircraft. However, the lower procurement cost of UAS can be weighed against their greater proclivity to crash, while the minimized risk to onboard crew can be weighed against the complications and hazards inherent in flying unmanned vehicles in airspace shared with manned assets.

UAS use has increased for a number of reasons. Advanced navigation and communications technologies were not available just a few years ago, and increases in military communications satellite bandwidth have made remote operation of UAS more practical. The nature of the Iraq and Afghanistan wars has also increased the demand for UAS, as identification of and strikes against targets hiding among civilian populations required persistent surveillance and prompt strike capability, to minimize collateral damage. Further, UAS provide an asymmetrical—and comparatively invulnerable—technical advantage in these conflicts.

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[1] National Museum of the U.S. Air Force, *Kettering Aerial Torpedo "Bug,"* http://www.nationalmuseum.af.mil/factsheets/factsheet.asp?id=320.

[2] Drones differ from RPVs in that they are designed to fly autonomously.

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

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

For many years, the Israeli Air Force led the world in developing UAS and tactics. U.S. observers noticed Israel's successful use of UAS during operations in Lebanon in 1982, encouraging then-Navy Secretary John Lehman to acquire a UAS 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 UAS funding.[5] This marked the transition of UAS in the United States from experimental projects to acquisition programs.

Initial U.S. capabilities came from platforms acquired from Israel. One such UAS, Pioneer, emerged as a useful source of intelligence at the tactical level during Operation Desert Storm, when Pioneer was used by Navy battleships to locate Iraqi targets for its 16-inch guns. Gulf War experience demonstrated the potential value of UAS, and the Air Force's Predator was placed on a fast track, quickly adding new capabilities.[6] 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 Iraq and Afghanistan have featured the Air Force's Global Hawk, as well as adding a new mission that allows the Predator to live up to its name—armed reconnaissance.

Reflecting a growing awareness and support for UAS, Congress has increased investment in unmanned aerial vehicles annually. The FY2001 investment in UAS was approximately $667 million. For FY2012, DOD has asked for $3.9 billion in procurement and development funding with much more planned for the outyears.[7] DOD's inventory of unmanned aircraft increased from 167 to nearly 7,500 from 2002 to 2010.[8]

DOD's UAS research and development (R&D) funding has also grown, for a variety of reasons: UAS are considered a growth industry, many UAS are relatively inexpensive to produce, and new technology in miniaturization has helped accelerate the development of many UAS types.

Congress has approached UAS development with strong encouragement tempered with concern. Notably, in 2000, Congress set the goal of making "one-third of the aircraft in the operational deep strike force aircraft fleet" unmanned.[9] Congress has also directed the formation of joint program offices to ensure commonality among the services' UAS programs. Following expressed concern that DOD's "growing enthusiasm may well lead to a situation in which there is no clear path toward the future of UAS," Congress also required DOD to submit a UAS roadmap.[10] In some instances, Congress has chastened DOD for what it saw as a leisurely rate of UAS acquisition and encouraged it to speed up this pace, or speed up the incorporation of certain capabilities. For example, in 1996, the House Armed Services Committee (HASC) supported

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[5] For more on the early history of UAV use, CRS Report 93-686F, *Intelligence Technology in the Post-Cold War Era: The Role of Unmanned Aerial Vehicles (UAVs)*, by Richard A. Best, Jr., 1993, available to congressional clients from author on request. Other useful sources include two papers by Thomas P. Ehrhard: "Unmanned Aerial Vehicles in the United States Armed Services: A Comparative Study of Weapon System Innovation" (Ph.D. dissertation, The Johns Hopkins University, 2000); and *Air Force UAVs: The Secret History*, Mitchell Institute, July 2010.

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

[7] Office of the Under Secretary of Defense (Comptroller)/CFO, *Program Acquisition Costs by Weapon System*, February 2011, p. 1-1.

[8] Ed Wolski, *Unmanned Aircraft Systems*, OUSD (AT&L) Unmanned Warfare, briefing, January 9, 2009, p. 6. Dyke Weatherington, *Current and Future Potential for Unmanned Aircraft Systems*, OUSD (AT&L) Unmanned Warfare, briefing, December 15, 2010. (Hereinafter "Weatherington brief.")

[9] P.L. 106-398, "Floyd D. Spence National Defense Authorization Act for Fiscal Year 2001," section 220.

[10] 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.

legislation directing DOD to weaponize both the Predator and Hunter, but DOD opposed the initiative.[11]

Although this report focuses on the military uses of UAS, Congress's interest in UAS extends beyond the defense committees, as UAS capabilities have also led to their use in missions outside the military. The Department of Homeland Security operates UAS to help patrol U.S. borders, and Congress has questioned the efficacy of such operations.[12] Further, the use of UAS in a variety of roles, but particularly as platforms for delivering lethal force, raises a number of legal issues of interest to Congress.

Why Does the Military Want UAS?

> In today's military, unmanned systems are highly desired by combatant commanders for their versatility and persistence. By performing tasks such as surveillance; signals intelligence (SIGINT); precision target designation; mine detection; and chemical, biological, radiological, nuclear (CBRN) reconnaissance, unmanned systems have made key contributions to the Global War on Terror.[13]

To be sure, manned systems could accomplish many if not all of the same goals. But "unmanned systems reduce the risk to our warfighters by providing a sophisticated stand-off capability that supports intelligence, command and control, targeting, and weapons delivery. These systems also improve situational awareness and reduce many of the emotional hazards inherent in air and ground combat, thus decreasing the likelihood of causing civilian noncombatant casualties."[14] "UAVs have gained favor as ways to reduce risk to combat troops, the cost of hardware and the reaction time in a surgical strike"[15] and "to conduct missions in areas that are difficult to access or otherwise considered too high-risk for manned aircraft or personnel on the ground."[16]

As a result, "The number of platforms in this category—R/MQ-4 Global Hawk-class, MQ-9 Reaper, and MQ-1 Predator-class unmanned aircraft systems (UAS)—will grow from approximately 340 in FY 2012 to approximately 650 in FY 2021."[17]

Some in the military also tout UAS's reduced cost of acquisition and operation when compared to manned platforms. However, the Congressional Budget Office cautions that savings cannot be taken for granted:

> Unmanned aircraft systems are usually less expensive than manned aircraft. Initial concepts envisioned very low-cost, essentially expendable aircraft. As of 2011, however,

[11] 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.

[12] For more information on DHS UAV operations, see CRS Report RS21698, *Homeland Security: Unmanned Aerial Vehicles and Border Surveillance*, by Chad C. Haddal and Jeremiah Gertler.

[13] Department of Defense, *FY2009–2034 Unmanned Systems Integrated Roadmap* (2009), p. xiii.

[14] Stockdale Center on Ethical Leadership, U.S. Naval Academy, "New Warriors and New Weapons: The Ethical Ramifications of Emerging Military Technologies," Report of the 2010 McCain Conference, Annapolis, MD, April 23, 2010, http://www.usna.edu/Ethics/mccain.htm.

[15] Scott Hamilton, "Here's a Thought: The Pentagon Wants 'Thinking' Drones," *National Defense*, February 2011.

[16] U.S. Customs and Border Protection, "UAS Overview," August 31, 2010, http://www.cbp.gov/xp/cgov/border_security/air_marine/uas_program/uasoverview.xml.

[17] Department of Defense, *Aircraft Procurement Plan, Fiscal Years (FY) 2012-2041*, Washington, DC, March 2011, http://www.airforce-magazine.com/SiteCollectionDocuments/Reports/2011/May%202011/Day25/AircraftProctPlan2012-2041_052511.pdf.

> whether substantially lower costs will be realized is unclear. Although a pilot may not be on board, the advanced sensors carried by unmanned aircraft systems are very expensive and cannot be viewed as expendable.... Moreover, excessively high losses of aircraft can negate cost advantages by requiring the services to purchase large numbers of replacement aircraft.[18]

What Missions Do UAS Currently Perform?

Intelligence, Surveillance and Reconnaissance

Intelligence gathering is UAS' traditional mission. In the 1960s, autonomous drones were used for reconnaissance in the Vietnam War and on strategic reconnaissance missions over denied areas. Early modern controllable UAS were used to loft cameras to allow units in the field to observe opposing forces beyond direct line of sight. Subsequently, longer-endurance systems introduced the ability to maintain surveillance on distant and moving targets.

Strike

The first UAS were essentially unpiloted bombs, designed to fly in a particular direction until the fuel ran out, at which point the entire aircraft would plunge to the ground. Today, some UAS carry precision-guided weapons to attack ground targets, and more are being weaponized, although this is still adding strike capability to systems originally designed for reconnaissance.

A separate class of UAS is being designed from the ground up to carry out combat missions. Called unmanned combat air vehicles, or UCAVs, these systems feature greater payload, speed, and stealth than current UAS.

What Other Missions Might UAS Undertake in the Future?

Resupply

The Navy is investigating how UAS could deliver cargo to ships at sea,[19] and the Marine Corps has awarded contracts to two firms to demonstrate how UAS might resupply units in Afghanistan.[20]

Combat Search and Rescue

Early research is underway to develop the capability for an unmanned system to locate and possibly evacuate personnel behind enemy lines.

Refueling

Large UAS could eventually take on the aerial refueling task now performed by KC-10 and KC-135 tanker aircraft. Tanker flight profiles are relatively benign compared to many others, and they tend to operate far from enemy air defenses. Except for operating the refueling boom (to refuel

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[18] Congressional Budget Office, *Policy Options for Unmanned Aircraft Systems*, Publication 4083, Washington, DC, June 2011, p. 31.

[19] Dan Taylor, "ONR Meets With Industry For Long-Term Cargo UAS Program In Mid-2010s," *Inside the Navy*, July 26, 2010.

[20] Gayle Putrich, "USMC splits unmanned cargo resupply contract," *FlightGlobal.com*, December 2, 2010.

Air Force aircraft), the refueling crew's primary job is to keep the aircraft flying straight, level, and at a steady speed. In July 2010, the Defense Advanced Research Projects Agency awarded a contract to demonstrate refueling by Global Hawk UAVs,[21] and a March 2011 test demonstrated the Global Hawk's ability to receive refueling autonomously.[22] 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. This same technology could allow UAVs to refuel manned aircraft. The second X-47B will be equipped to demonstrate refueling.[23]

Air Combat

A more difficult future task could be air-to-air combat. Although UAS offensive operations to date have focused on ground targets, UCAVs are being designed to carry air-to-air weapons and other systems that may allow them to undertake air superiority missions. 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.[24] While this operational encounter may be a "baby step" on the way toward an aerial combat capability, newer UAS such as the X-47B, Avenger, and Phantom Ray are not being designed with acknowledged air-to-air capability.

In short, UAS are expected to take on every type of mission currently flown by manned aircraft.

Why Are There So Many Different UAS?

Although UAS have a long history, only in the last 10-15 years have advances in navigation, communications, materials, and other technologies made a variety of current UAS missions possible. UAS are therefore still in a period of innovation, both in their design and how they are operated. This can be seen as analogous to military aircraft in the 1930s and 1940s, when technologies and doctrines evolved at a rapid rate to exploit the new technology, and also to the early Jet Age, when the military acquired many different models of aircraft with varying capabilities before settling on a force made up of large numbers of relatively few models based on lessons learned.

Also, the period of UAS innovation has coincided with ongoing U.S. combat operations in Iraq, Afghanistan, and elsewhere. Demand for UAS capabilities in the field is essentially unconstrained.[25] As new systems and capabilities have emerged, the availability of urgent-needs funding has allowed commanders to bring the latest technology into theater without lengthy procurement processes. Thus, instead of traditional competitions in which systems may be tested

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[21] W.J. Hennigan, "Northrop Grumman Wins Contract To Turn Unmanned Spy Plane Into Refueling Tanker," *Los Angeles Times*, July 2, 2010. W. J. Hennigan, "Northrop Grumman Wins Contract To Turn Unmanned Spy Plane Into Refueling Tanker," *Los Angeles Times*, July 2, 2010; Graham Warwick, "Global Hawk To Demonstrate Autonomous Air Refueling," *Aerospace Daily*, July 2, 2010.

[22] Graham Warwick, "Flight Paves Way For Global Hawk Autonomous Aerial Refueling," *Aerospace Daily*, March 10, 2011.

[23] Carlo Munoz, "After Successful First Flight, Navy Plans For Next Stage of UCAS-D Development," *Defense Daily*, February 8, 2011.

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

[25] CRS interview with LtGen. David Deptula, Air Force Deputy Chief of Staff for Intelligence, Surveillance, and Reconnaissance, February 3, 2010.

against each other in advance of operations, new UAS have been deployed directly to the field, where U.S. forces are able to experiment with and exploit their capabilities. The combination of funding, demand, and technological innovation has resulted in DOD acquiring a multiplicity of systems without significant effort to reduce the number of systems or consolidate functions across services.

> For example, the Office of the Secretary of Defense (OSD) is concerned that the Army and Air Force are unnecessarily developing two different electro-optical and infrared sensor payloads for Sky Warrior and Predator when a common payload could be achieved—currently the basic sensors are 80 percent common and manufactured by the same contractor. However, according to Army officials, the Air Force sensor is more expensive and has capabilities, such as high-definition video, for which the Army has no requirements. Therefore, the Army does not believe a fully common solution is warranted.[26]

It should be noted that the number of systems acquired does not correspond to the number of unique platforms. By installing different sensors, a mostly common airframe can be made to serve the requirements of multiple services. The General Atomics I-GNAT developed into the Air Force Predator and Reaper, which served as the basis for the Army Gray Eagle and DHS's Predator optimized for marine environments; Northrop Grumman's Air Force Global Hawk became, with different equipment, the Navy's Broad Area Maritime Surveillance (BAMS) system.

This is not to say that the resulting systems are the same. Due to different requirements and payloads, a BAMS, for example, costs almost twice as much as a Global Hawk. This commonality may, however, provide an argument for those who advocate greater jointness in UAS development.

Does the Department of Defense Have an Integrated UAS Development Policy?

In September 2007, the Secretary of Defense ordered creation of a UAS Task Force within the office of the Under Secretary of Defense for Acquisition, Technology and Logistics.[27] The Task Force's charter gives it the responsibility to coordinate UAS requirements among the services, "promot[e] the development and fielding of interoperable systems and networks," and to "[s]hape DoD UAS acquisition programs to prioritize joint solutions." The charter does not give the Task Force the authority to terminate redundant programs nor compel their consolidation. Thus, development of UAS in DOD can be said to be federated, but not integrated.

DOD also issues a biannual roadmap indicating what technologies and capabilities it expects to see in future systems, and attempting to project the requirements for broad UAS capabilities 25 years into the future.[28] Development of UAS is still carried out by individual military services.

UAS 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

[26] U.S. Government Accountability Office, *Defense Acquisitions: Opportunities Exist to Achieve Greater Commonality and Efficiencies among Unmanned Aircraft Systems*, 09-520, July 2009, page 4.

[27] Under Secretary of Defense (Acquisition, Technology and Logistics), *Department of Defense Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, September 2010. Creation of the UAS Task Force was a compromise outcome. DOD had sought to designate a single executive agent to oversee UAS development across the Department. The Air Force actively sought the role, but other services did not support their bid.

[28] See, for example, Department of Defense, *FY2009–2034 Unmanned Systems Integrated Roadmap* (2009).

of UAVs also vary greatly: the 8-inch-long Wasp Micro UAV has a combat radius of 5 nautical miles, while the 44-foot-long Global Hawk (the size of a medium sized corporate jet) has a combat radius of 5,400 nm.[29]

Table 1 outlines the total UAV inventory.[30] When compared to the inventory of February 2003, which only included five major platforms and an inventory of 163 unmanned aircraft, the acceleration and expansion becomes clear. The 7454 UAVs include many second-generation derivatives, such as Predator B and BAMS, and some non-traditional vehicles, such as gMAV and T-Hawk.

Table 1. DOD UAS Platforms

Name	Vehicles	Ground Control Stations	Employing Service(s)	Capability/Mission
RQ-4A Global Hawk/BAMS-D Block 10	9	3	USAF/Navy	ISR/Maritime Domain Awareness (Navy)
RQ-4B Global Hawk Block 20/30	15	3	USAF	ISR
RQ-4B Global Hawk Block 40	1	1	USAF	ISR/Battle Management Command & Control
MQ-9 Reaper	54	61[a]	USAF	ISR/Reconnaissance, Surveillance, and Target Acquisition/EW/Precision Strike/Force Protection
MQ-1A/B Predator	161	61[a]	USAF	ISR/Reconnaissance, Surveillance, and Target Acquisition/Precision Strike/ Force Protection (MQ-1C Only-C3/LG)
MQ-1 Warrior/MQ-1C Gray Eagle	26	24	Army	ISR/Reconnaissance, Surveillance, and Target Acquisition/Precision Strike/ Force Protection (MQ-1C Only-C3/LG)
UCAS-D	2	0	Navy	Demonstration Only
MQ-8B Fire Scout VTUAV	9	7	Navy	ISR/Reconnaissance, Surveillance, and Target Acquisition/Anti-Submarine Warfare/ASUW/MIW/OMCM
MQ-5 Hunter	25	16	Army	ISR/Reconnaissance, Surveillance, and Target Acquisition/Battle Damage Assessment
RQ-7 Shadow	364	262	Army/USMC/SOCOM	ISR/Reconnaissance, Surveillance, and Target Acquisition/Battle Damage Assessment
A160T Hummingbird	8	3	SOCOM/DARPA/Army	Demonstration

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

[30] Note that these inventories do not include small UAVs, micro UAVs or lighter-than-air platforms.

Name	Vehicles	Ground Control Stations	Employing Service(s)	Capability/Mission
STUAS	0	0	Navy/USMC	ISR/Explosive Ordnance Disposal/Force Protection
ScanEagle	122	39	Navy /SOCOM	ISR/Reconnaissance, Surveillance, and Target Acquisition/Force Protection
RQ-11 Raven	5,346	3291	Army/Navy/SOCOM	ISR/Reconnaissance, Surveillance, and Target Acquisition
Wasp	916	323	USMC/ SOCOM	ISR/Reconnaissance, Surveillance, and Target Acquisition
SUAS AECV Puma	39	26	SOCOM	ISR/Reconnaissance, Surveillance, and Target Acquisition
gMAV / T-Hawk	377	194	Army (gMAV) Navy (T-Hawk)	ISR/Reconnaissance, Surveillance, and Target Acquisition/Explosive Ordnance Disposal

Source: Weatherington brief.

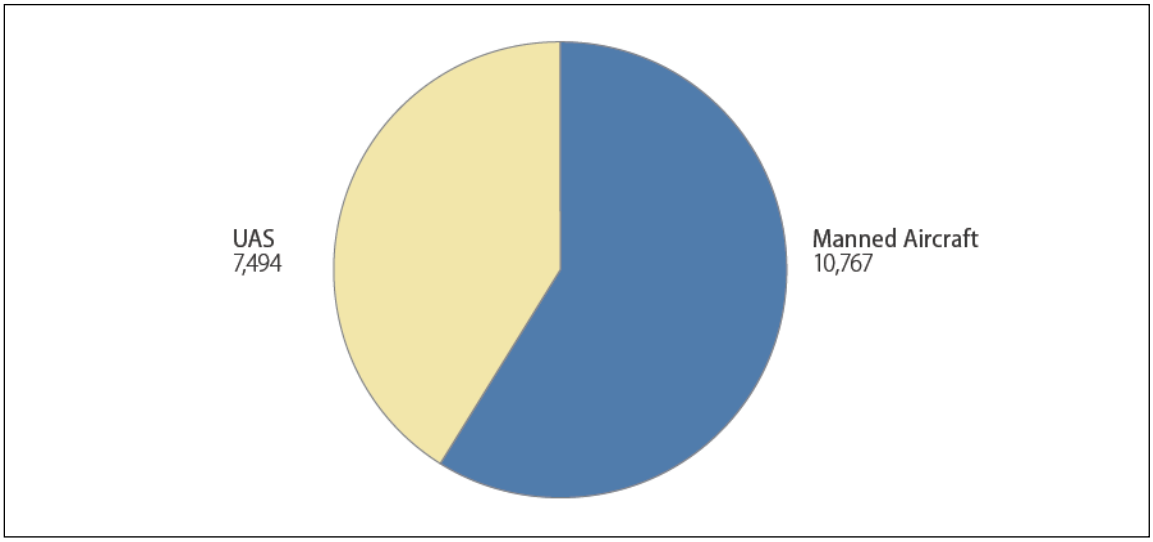
Note: For comparison purposes, table does not include mini/small, micro, or lighter-than-air UAS.

a. MQ-1 and MQ-9 use the same GCS.

The increase in DOD's UAV inventory appears largely due to the rising demand for UAVs to branch out from the typical intelligence, surveillance and reconnaissance (ISR) applications and conduct a wider variety of missions. Predator B and Reaper are equipped with a strike capability, and many Predator As have been modified to carry weapons. Additionally, mine detection, border patrol, medical resupply, and force perimeter protection are increasingly considered as roles for UAS.

In order to understand fully the pace and scope of UAS acquisition, a comparison between manned aircraft inventories and unmanned inventories may prove to be a useful tool. **Figure 1** shows the ratio of manned to unmanned aircraft. Due to the recent acceleration in UAS production and drawdowns in manned aircraft, manned aircraft have gone from 95% of all DOD aircraft in 2005 to 59% today. Previously described as complements to, or augmentation of, manned aircraft, user demand and budgetary push have increasingly promoted UAS into a principal role.

Figure 1. Manned Aircraft Inventory vs. UAS Inventory



Source: The Military Balance 2010; Weatherington brief.

A significant congressional boost to UAS acquisition came in the conference report for the National Defense Authorization Act for Fiscal Year 2001, which expressed Congress's desire that "within ten years, one-third of U.S. military operational deep strike aircraft will be unmanned."[31] This goal was seen at the time as very challenging, because DOD had no unmanned deep strike aircraft.

Subsequently, the Fiscal 2007 Defense Authorization Act required the Secretary of Defense to "develop a policy, to be applicable throughout the Department of Defense, on research, development, test and evaluation, procurement, and operation of unmanned systems." The policy was required to include, among other elements, "A preference for unmanned systems in acquisition programs for new systems, including a requirement under any such program for the development of a manned system for a certification that an unmanned system is incapable of meeting program requirements."[32] Thus, Congress changed the default assumption of new systems; instead of seeking unmanned systems to accomplish the same tasks as manned equivalents, unmanned systems would be developed to accomplish military tasks unless there was some need that the systems be manned.

UAS Management Issues

In addition to establishing acquisition pace, and scope of application, one significant congressional task may be to determine whether DOD's administrative processes and lines of authority within the acquisition process are effective for UAS development and acquisition. The management of DOD's development and acquisition programs received heightened attention in recent Congresses. Given that UAS are acquired by all four of the military services and the U.S. Special Operations Command, and that UAS acquisition is accelerating (for a growing list of

[31] H.Rept. 106-945, U.S. Congress, Enactment of Provisions of H.R. 5408, the Floyd D. Spence National Defense Authorization Act For Fiscal Year 2001, Conference report to accompany H.R. 4205, 106th Cong., 2nd sess., October 6, 2000, section 220.

[32] P.L. 109-364, *John Warner National Defense Authorization Act for Fiscal Year 2007*, section 941.

applications), it appears that great potential exists for duplication of effort. This leads many to call for centralization of UAS acquisition authority, to ensure unity of effort and inhibit wasteful duplication. On the other hand, if UAS efforts are too centralized, some fear that competition and innovation may be repressed.

Cost Management Issues

Once viewed as a cheap alternative to manned aircraft, or even a "poor man's air force," some UAS are beginning to rival manned aircraft in cost. According to DOD's most recent estimate, the Global Hawk program will cost $13.9 billion to purchase 66 aircraft; a program acquisition unit cost of $211 million per UAV.[33] The program has twice triggered Nunn-McCurdy breaches, which require DOD to notify Congress when cost growth on a major acquisition program reaches 15%.[34] In 2005, development cost overruns led to an average unit cost growth of 18% per airframe and prompted appropriators to voice their concern (H.R. 2863, H.Rept. 109-119, p. 174). In April 2011, a reduction in the number of Global Hawk Block 40 aircraft requested in the FY2012 budget from 22 to 11 caused overall Global Hawk unit prices to increase by 11%, again triggering Nunn-McCurdy.

> [T]he RQ-4 Global Hawk surveillance drone, by Northrop Grumman [NOC] has been criticized by the Air Force for higher than expected cost growth. [Under Secretary of Defense Ashton] Carter said that program is "on a path to being unaffordable" and will be studied in detail to determine what is causing the suspected inefficiencies.[35]

Much UAS cost growth appears to spring from factors that have also affected manned aircraft programs, such as "requirements 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. Although originally intended to carry one primary sensor at a time, DOD changed the requirement so that Global Hawk is to carry two or more primary sensors—which has increased the UAS's price.[36]

Global Hawk is not the only example of requirements creep. Originally considered a relatively modest UAS, the Joint Unmanned Combat Air System (J-UCAS) evolved into a large, long range aircraft with a heavy payload, which increased cost. J-UCAS was canceled in 2006.

Organizational Management Issues

The frequent change and realignment of DOD's organizations with a role in UAS development illustrates the difficulties of establishing a comprehensive UAS management system. Over the years, management of UAS 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

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[33] OSD (AT&L), *Selected Acquisition Report (SAR): RQ-4A/B UAS Global Hawk*, December 31, 2010. Costs are expressed in constant 2002 dollars.

[34] 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 led to the cost growth are under control. For more information, see CRS Report R41293, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, by Moshe Schwartz.

[35] Marina Malenic, "Pentagon Unveils Belt-Tightening Plan For Acquisition Programs," *Defense Daily*, June 29, 2010.

[36] 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.

then back to the services, under the auspices of OSD. The JPO was established in 1988, but met criticism in Congress.

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 UAS. DARO was disbanded in 1998, amid criticism of problems, redesigns, and accidents with the family of systems that it was formed to develop.[37] 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, no single organization has managed DOD UAS 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 UAS programs operated by the services, 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 UAS-related efforts. Subsequently, the Joint UAV Planning Task Force has been promoted to the top rung on the UAS management ladder.

> In lieu of creating an executive agent for UAS, the Deputy Secretary of Defense (DepSecDef) directed the formation of a UAS Task Force (TF). The TF was directed to identify to the Deputy Advisory Working Group (DAWG) and, where appropriate, assign lead organizations for issues related to the acquisition and management of UAS including interoperability, civil airspace integration, frequency spectrum and bandwidth utilization, ground stations, and airframe payload and sensor management.[38]

In order to help a common UAS vision become a reality, the task force, through the OSD, published three UAS Roadmaps in April 2001, December 2002, and August 2005. A more recent UAS roadmap was published in April 2009 as part of a DOD integrated roadmap that also included unmanned systems for ground and sea warfare.

In March 2005 testimony to the House Armed Services Subcommittee on Tactical Air and Land Forces, the GAO 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 decisions or establish funding priorities."[39] From the testimony, it would appear that the GAO envisioned a central authority or body to satisfy this role.

In what appeared to be a move toward further management restructuring, reports in 2005 indicated that OSD was considering appointing one of the services as the executive agent and coordinator for UAS programs, a role the Air Force actively pursued.[40] However, later that year the JROC announced that DOD had abandoned the notion of an executive agent in favor of two

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

[38] Under Secretary of Defense (Acquisition, Technology and Logistics), *Department of Defense Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, September 2010.

[39] 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.

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

smaller organizations focusing on interoperability.[41] 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.[42] A complementary Joint UAV Center of Excellence coordinates with the OIPT to improve interoperability and enhance UAS applications through the examination of sensor technologies, UAS intelligence collection assets, system technologies, training, and tactics.[43]

That command arrangement was revised in 2007, when the Deputy Secretary of Defense directed the formation of a UAS Task Force.[44] The task force was directed to, "where appropriate, assign lead organizations for issues related to the acquisition and management of UAS including interoperability, civil airspace integration, frequency spectrum and bandwidth utilization, ground stations, and airframe payload and sensor management."[45] That arrangement remains in place today.

UAS and Investment Priorities

All four military services, the U.S. Special Operations Command (SOCOM), and the U.S. Coast Guard are developing and fielding UAS. Developing a coordinated, DOD-wide UAS 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 UAS investments, or impact DOD's overarching investment plan. Several relevant questions seem apparent: How is UAS cost quantified? What is the most effective balance in spending between UAS and manned aircraft? How should DOD, Congress, and the UAS manufacturers balance cost with capability? Finally, what areas of investment are the most important to maximize UAS capabilities?

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 consists of a ground control station, a ground crew including remote pilots and sensor operators, communication links, and often multiple air vehicles. Unlike a manned aircraft such as an F-16, these supporting elements are a requisite for the vehicle's flight.[46] 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 UAS 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 UAS funding requests in "Other Procurement, Army." This account contains a broad range of dissimilar items. Also, because most UAS conduct

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

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

[43] Ibid.

[44] Office of the Secretary of Defense, *Deputy Secretary of Defense Memorandum, "Unmanned Aircraft Systems (UAS),"* September 13, 2007.

[45] Under Secretary of Defense (Acquisition, Technology and Logistics) , *Department of Defense Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, September 2010.

[46] Manned aircraft like the F-16 do require radar operators and air traffic controllers in order to maximize their performance, yet these are not required for flight. 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 low probability of sustained flight.

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.

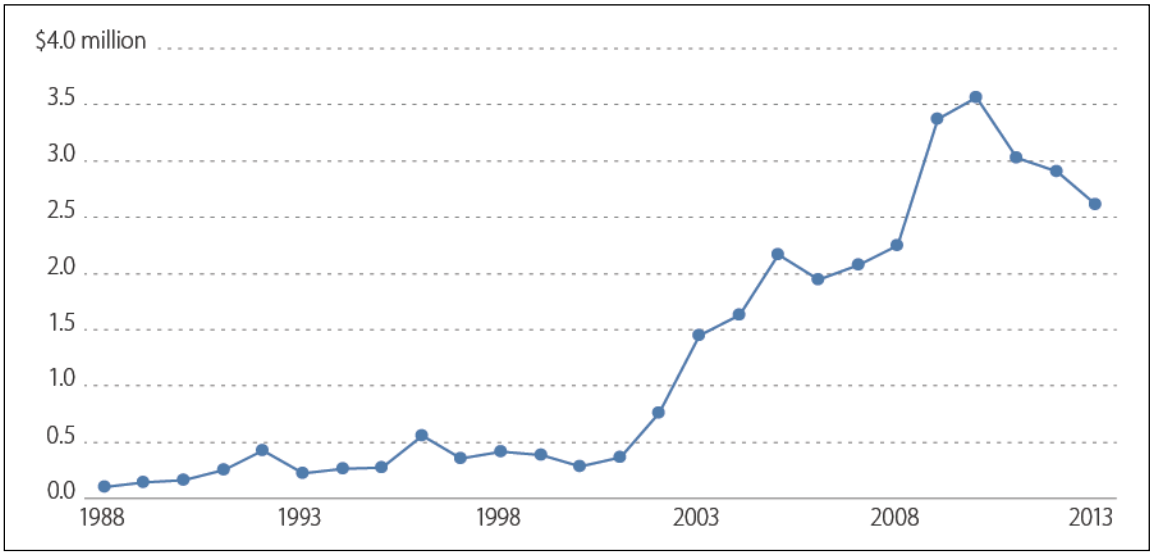
Once an adequate and uniform cost comparison mechanism or definition has been established, the next step for Congress may be to identify an appropriate balance in spending between UAS and manned aircraft. If the upward trend in UAS funding continues through 2013, as shown in **Figure 3**, DOD is projected to have spent upwards of $26 billion on procurement, RDT&E, operations, and maintenance for UAS from 2001-2013. This number far exceeds the $3.9 billion spent on UAS from 1988-2000.

Table 2. FY2011-FY2013 President's Budget for UAS

	FY11	FY12	FY13
RDT&E	$1076.4	$894.0	$719.5
PROC	$1704.7	$1734.3	$1576.2
O&M	$249.0	$274.9	$320.2
TOTAL	$3,030.1	$2,903.2	$2,615.9

Source: DOD FY2009–2034 Unmanned Systems Integrated Roadmap, April 2009, page 4.

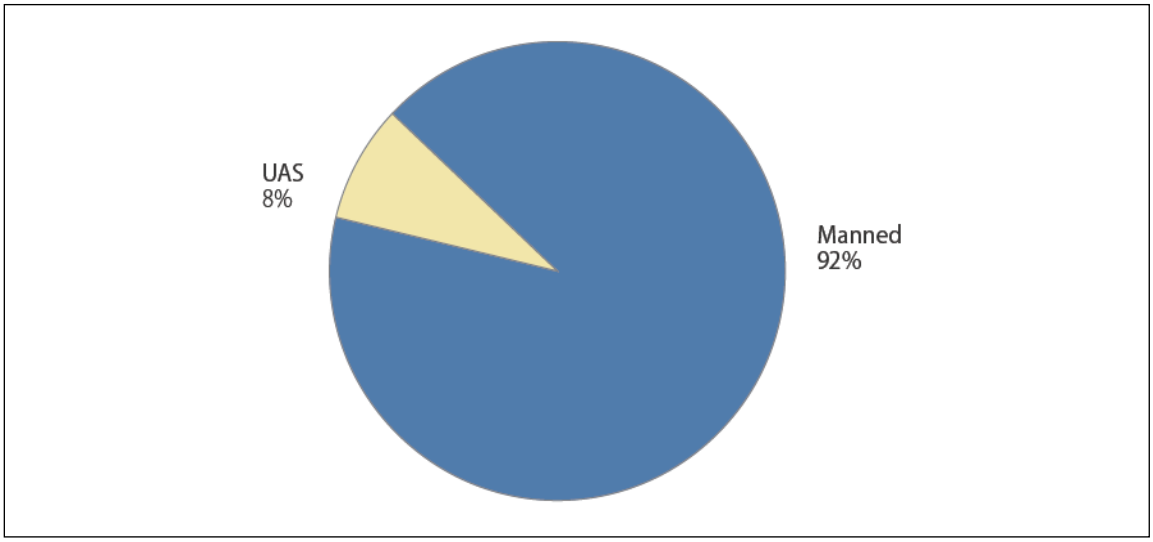
Figure 2. UAS budgets, 1988-2013



Source: OSD, UAS Roadmap 2005-2030, August 2005, p.37 and DOD FY2009–2034 Unmanned Systems Integrated Roadmap, April 2009, Page 4.

Figure 3 demonstrates the total funding for UAS as a percentage of the total military aviation funding. As the pie chart shows, despite the recent acquisition of many UAS, such systems represent only 8% of all military aviation procurement funding.

Figure 3. Manned vs. Unmanned Aircraft Procurement Budget (FY2011)



Source: DOD UAS Roadmap 2009-2030; FY2011 DOD justification books for procurement of manned aircraft. Does not include small UAVs, micro-UAVs, or lighter-than-air platforms.

Cost savings have long been touted by UAS 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 UAS aircrew operating the UAV from the ground control station. Another cost question concerns personnel. Do UAS "pilots" cost less to train and keep proficient than pilots of manned aircraft?[47] So although the air vehicle might be cheaper than a manned aircraft, the UAV system as a whole is not always less expensive.[48] Additionally, UAS 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, UAS ground control stations are capable of simultaneously flying multiple UAVs, somewhat restoring the advantage in cost to the unmanned system. 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."[49]

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.[50] The inexpensive designs 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-4B second generation Global Hawk's sensor payload represents approximately 54% of the vehicle's flyaway cost, which does not include the cost of

[47] For more on personnel issues, see "Recruitment and Retention" section below.

[48] As an example, a Predator air vehicle costs $4.5 million, while the Predator system, including four air vehicles and control equipment, costs over $20 million.

[49] 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.

[50] 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.

the increased wingspan that shoulders the extra 1000 pounds of sensor suites.[51] 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 UAS sensor producers face little competition, which would help keep costs down.

Growing sensor costs have prompted some observers to recommend equipping UAVs with self-protection devices, suggesting those UAVs are no longer considered expendable. Consequently, two schools of thought exist for employing UAVs in ways 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.[52] One example of this investment approach was included in the Army's developmental Future Combat System, which intended to link several relatively inexpensive UAVs like the Raven, the Shadow, and the Fire Scout with 18 other weapons platforms. None of these UAVs could individually shoulder all of the air duties required by the system, yet the robust communications network was expected to distribute the mission duties to allow each platform to provide its specialized task.[53]

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 has risen in cost and been the target of funding cuts.[54]

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

Interoperability

UAS development has been marked by the slow advancement of interoperability. The future plans for UAS use within the framework of larger battlefield operations and more interconnected and potentially joint-service combat systems require UAS to communicate seamlessly between each other and numerous different ground components, and to also be compatible with diverse ground control systems. The lack of interconnectivity at these levels has often complicated missions to the point of reducing their effectiveness, as Dyke Weatherington, head of DOD's UAS planning taskforce, noted: "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."[55]

[51] More information on the second generation RQ-4B and its difference from the RQ-4A is included in "Current DOD UAV Programs," below. Also, please see OSD, *UAS Roadmap 2005-2030*. August 2005, Appendix B, p. B-1.

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

[53] See CRS Report RL32888, *Army Future Combat System (FCS) "Spin-Outs" and Ground Combat Vehicle (GCV): Background and Issues for Congress*, by Andrew Feickert and Nathan J. Lucas.

[54] See the "Current DOD UAV Programs" section for more information about the Global Hawk and J-UCAS programs.

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

Advancing the interoperability of UAS has been a critical part of the OSD's investment plans. The Department of Defense has pushed forward with the establishment of communication between similar UAS to help facilitate interoperability among four system elements:[56]

- 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.
- Third, the weapons interface will constitute a separate transfer medium by which operators can coordinate these platforms' 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, H.Rept. 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 for real-time situational awareness, as well as real time sensor and targeting data to tactical commanders."[57] If UAS are to achieve the level of interoperability envisioned by the OSD, the services and industry 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 UAS applications infeasible and leave many platforms grounded. Ultimately, the requirement for bandwidth grows with every war the United States fights.[58] The increased use of UAS in Iraq and Afghanistan indicates that remotely piloted platforms' mass consumption of bandwidth will require a more robust information transfer system in the coming years.

One approach to alleviating the bandwidth concern was the Transformational Satellite Communications (TSAT) project. DOD intended to use that laser and satellite communications system to 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.[59] However, the TSAT project was canceled in 2009. 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.[60] However, it is unclear that autonomy will actually decrease bandwidth

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

[57] 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.Rept. 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.

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

[59] Sandra Erwin. "Multibillion-Dollar 'Internet in the Sky' Could Help Ease Bandwidth Crunch." National Defense. June 2005, p. 24.

[60] Hearing of the Tactical Air and Land Forces Subcommittee of the House Armed Services Committee. "Fiscal Year

requirements since the transmission of data from the UAV's sensors drives the demand for bandwidth. As an example, a single Global Hawk, already an autonomous UAV, "requires 500Mbps bandwidth—which equates to 500 percent of the total bandwidth of the entire U.S. military used during the 1991 Gulf War."[61]

Another approach to alleviating the bandwidth problem is allowing UAVs to be operated from a manned stand-off aircraft such as a command and control aircraft with line of sight to the UAV. 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. Experimentation is currently ongoing in this area, with the first step being controlling the UAV's sensor payload from an airborne platform.

Reliability/Safety

A 2010 media study reported that "Thirty-eight Predator and Reaper drones have crashed during combat missions in Afghanistan and Iraq, and nine more during training on bases in the U.S.—with each crash costing between $3.7 million and $5 million. Altogether, the Air Force says there have been 79 drone accidents costing at least $1 million each."[62]

In 2004 the Defense Science Board indicated that relatively high UAV mishap rates might impede the widespread fielding of UAVs.[63] Although most UAV accidents have been attributed to human error,[64] investment in reliability upgrades appears to be another high priority for UAS. The 2005 UAS Roadmap indicated that UAV mishap rates appeared to be much higher than the mishap rates of many manned aircraft. **Table 3** shows the number of Class A Mishaps per 100,000 hours of major UAVs and comparable manned aircraft as of 2005.[65]

Table 3. Selected Mishap Rates, 2005
(per 100,000 hrs)

Vehicle Type	Class A Mishaps
UAV	
Predator	20

2004 Budget Request for Unmanned Combat Aerial Vehicles and Unmanned Aerial Vehicle Programs." March 26, 2003.

[61] Department of the Navy Chief Information Officer Spectrum/Telecommunications Team, "Transformational Communications," *CHIPS*, January-March 2005.

[62] David Zucchino, "War zone drone crashes add up," *Los Angeles Times*, July 6, 2010.

[63] 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.

[64] A 2005 study cited human operational or maintenance mistakes as causing 68% of UAV accidents. William T. Thompson, Major Anthony P. Tvaryanas, and Stefan H. Constable, *U.S. Military Unmanned Aerial Vehicle Mishaps: Assessment of the Role of Human Factors Using Human Factors Analysis and Classification System (HFACS)*, U.S. Air Force, 311th Human Systems Wing, HSW-PE-BR-TR-2005-0001, Brooks City-Base, TX, March 2005.

[65] 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 Corps 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. Finally, note that the definition of a Class A mishap is not indexed for inflation, so the actual damage need to reach $1 million in cost effectively declines each year.

Vehicle Type	Class A Mishaps
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.

However, "(a)ccident rates per 100,000 hours dropped to 7.5 for the Predator and 16.4 for the Reaper last year (2009), according to the Air Force. The Predator rate is comparable to that of the F-16 fighter at the same stage, Air Force officers say, and just under the 8.2 rate for small, single-engine private airplanes flown in the U.S."[66]

In its 2004 study, the Defense Science Board (DSB) notes that manned aircraft over the past five decades have moved from a relatively high mishap rate to relatively low rates through advancements in system design, weather durability improvements, and reliability upgrades.[67] It should be pointed out, however, that the UAS, 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 UAS in **Table 3** have flown numerous missions while still under development. Predator and Global Hawk, for instance, entered combat well prior to their planned initial operational capability (2005 for Predator, and 2011 for Global Hawk). It may be unfair to compare the mishap rates of developmental UAS with manned aircraft that have completed development and been modernized and refined over decades of use.

The DSB report also suggests that nominal upgrades and investment—arguing even that many UAS 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.[68] Also, the incorporation of advanced materials—such as high temperature components, light-weight structures, shape memory alloys, and cold weather tolerance designs that include significant de-icing properties—will be expected to improve the survivability of UAS in adverse environments.[69]

Force Multiplication/Autonomy

One of the most attractive and innovative technological priorities for UAS is to enable one ground operator to pilot several UAVs at once. Currently most UAS require at least two ground operators; one to pilot the vehicle and another to control the sensors. The end goal for UAS manufactures and users is to reduce the 2:1 operator-vehicle ratio and eventually elevate the

[66] David Zucchino, "War zone drone crashes add up," *Los Angeles Times*, July 6, 2010.

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

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

[69] Ibid.

autonomy and interoperability of UAS to the point where two or more vehicles can be controlled by one operator. If this technological feat is achieved, the advantage of UAS as a force-multiplier on the battlefield could provide a dramatic change in combat capability.

The process of achieving this goal may 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.[70] Considering the two operator system currently in place for most UAS, 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 the complete UAS. The Global Hawk and the Scan Eagle possess significant automated 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 on a scale of 1 to 10; **Table 4** shows the OSD's Autonomous Capability Levels for UAVs.

Table 4. 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.

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 8. Currently, the Global Hawk, which is considered by many the most autonomous UAV currently in service, maintains an ACL of approximately 2.5. FAA and the UAS 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 UAS to 4. Additionally, inter-UAS communication and the coordination associated with interoperability 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. In 2005, the Air Force evaluated a Predator upgrade that allowed one operator to control the flight

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

plan of four Predator UAVs during an exercise in which one UAV engaged a target and the other three hovered nearby on standby status.[71] The next step is to consolidate the tasks of the four mission payload operators, each manning the sensors or weapons system on the four Predators, into one or fewer operators.

Engine Systems

Another technology under development is fuel cell-generated electric power. Supporters of fuel cells note that these devices could double the efficiency of mid-sized UAS and could reduce the aircrafts' acoustic and thermal signatures, effectively making them more difficult to detect and target.[72] Air Combat Command is sponsoring the project with the goal to use the fuel cells in many of its smaller UAS, and the Air Force Research Laboratory flight tested a fuel cell-powered Puma UAV in 2007. "With a power system using a chemical hydride fuel, the UAV demonstrated flight endurance of more than 7 hr., versus 2.5 hr. for the standard Puma."[73]

Figure 4. UAS Technology Futures

	2009 Evolutionary Adaptation	2015 Revolutionary Adaptation	2034
Dependency	Man Dependent SA/ Off Board SA	Sense and Avoid	Fully Autonomous/ On Board SA
Speed	Subsonic	Transonic	Super/Hypersonic
Stealth	Signature High		Signature Low
Maneuverability	1 "G"	9 "G"	40 "G"
Self Protection	Threat Detection	Threat Jamming and Expendables	
Sensor Ranges	Current	25% Extended	50% Extended
Icing	Visual Meteorological Conditions - Light	Moderate	Severe
Turbulence	Light	Moderate	Severe
Precipitation	Light	Moderate	Severe

Source: DOD FY2009–2034 Unmanned Systems Integrated Roadmap, April, 2009, Page 30.

Note: SA is "situational awareness," although in this context "Sense and Avoid" capability is also an appropriate fit for the acronym.

Some key technologies that will enable future UAS include:

> lightweight, long endurance battery and/or alternative power technology, effective bandwidth management/data compression tools, stealth capability and collaborative or teaming technologies that will allow UAS to operate in concert with each other and with manned aircraft. A critical enabler allowing UAS access to U.S. National and ICAO

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

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

[73] David Eshel, "Mini-UAVs rack up big gains," *Defense Technology International*, May 15, 2008. Fuel cell technology has already been tested on other types of aircraft:."German Aerospace Centre has converted an Antares 20E, the DLR-H2, to fly with a fuel cell. Boeing has also flown a Dimona motor glider with an electric motor powered by a fuel cell. And United Technologies, which makes Sikorsky helicopters, has flown a large model electric-helicopter powered by a hydrogen fuel cell." "Electric planes: High voltage," *The Economist*, June 10, 2010.

> airspace will be a robust on-board sense and avoid technology. The ability of UAS to operate in airspace shared with civil manned aircraft will be critical for future peacetime training and operations. There is also a need for open architecture systems that will allow competition among many different commercial UAS and ground control systems allowing DoD to "mix and match" the best of all possible systems on the market. Technology enablers in propulsion systems coupled with greater energy efficiency of payloads are required to extend loiter time and expand the missions of UAS to include Electronic Attack and directed energy.[74]

Duplication of Capability

Congress may ask if the production of different UAS with relatively similar performance capabilities constitutes unnecessary duplication. Critics of expanded UAS roles often argue that the production of 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-7 Shadow—could perform and fulfill the same duties as the expanded inventory.

According to GAO, for example,

> Although several unmanned aircraft programs have achieved airframe commonality, service-driven acquisition processes and ineffective collaboration are key factors that have inhibited commonality among subsystems, payloads, and ground control stations. For example, the Army chose to develop a new sensor payload for its Sky Warrior,[75] despite the fact that the sensor currently used on the Air Force's Predator is comparable and manufactured by the same contractor. To support their respective requirements, the services also make resource allocation decisions independently. DOD officials have not quantified the potential costs or benefits of pursuing various alternatives, including common systems. To maximize acquisition resources and meet increased demand, Congress and DOD have increasingly pushed for more commonality among unmanned aircraft systems.[76]

Table 5 shows a comparison of the performance specifications of UAS with electro-optical and infra-red sensors. The chart indicates that a majority of such UAS feature an endurance of 5 to 24 hours, an altitude of 10,000-25,000 ft, max speeds between 105 and 125 knots and radiuses of 100 to 150 nm.

Table 5. ISR UAS 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
Grey Eagle	26	25000	120	150	None	Army
Maverick	7	10300	118	175	None	SOCOM
MQ-1	24	25000	118	500	SAR	AF

[74] DOD FY2009–2034 Unmanned Systems Integrated Roadmap, April, 2009, pp. 48-49.

[75] Sky Warrior is now Grey Eagle.

[76] U.S. Government Accountability Office, *Defense Acquisitions: Opportunities Exist to Achieve Greater Commonality and Efficiencies among Unmanned Aircraft Systems*, GAO-09-520, July 2009.

	Vehicle Endurance (hrs) Max	Altitude (ft) Max	Speed (kt)	Range (nm)	Additional Sensor	User
MQ-5B	18	18000	106	144	None	Army
RQ-4A	32	65000	350	5400	SAR/MTI	AF
RQ-4B	28	60000	340	5400	SAR/MTI, SIGINT	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

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

The 2011 program acquisition unit cost for the MQ-9 Reaper is $28.4 million, just over half the $55 million estimate for the F-16 Falcon.[77] A simple payload comparison shows that the F-16 can carry approximately four times the payload of the Reaper (10,750 lbs vs. 2,500 lbs).[78] Further, the F-16 is a versatile combat aircraft that can be used to perform many missions that the Reaper cannot. This may suggest that using manned aircraft for air-to-ground combat may generally prove more cost effective than using UAS, and that the UAS's unique combat capabilities may be most valued in niche circumstances, such as when manned aircraft would be in extreme danger.

Other Potential Missions

Other missions for which UAS 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 as dropping leaflets. UAS such as the Army's Shadow have been evaluated for their capability to deliver critical medical supplies needed on the battlefield.

While UAS use in foreign theaters is well established, one of the most commonly discussed new mission areas for UAS is homeland defense and homeland security. The Coast Guard and U.S. Border Patrol already employ UAS such as the Eagle Eye and Predator to watch coastal waters, patrol the nation's borders, and protect major oil and gas pipelines.

It appears that interest is growing in using UAS 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, DC, is one example. The U.S. Department of Transportation has studied possible security roles for UAS, such as following trucks with hazardous cargo, while the Energy Department has been developing high-altitude instruments to measure radiation in the atmosphere.[79] UAS might also be used in sparsely populated areas of the

[77] Reaper cost from Office of the Secretary of Defense (Acquisition, Technology & Logistics), *Selected Acquisition Report: MQ-9 UAS Reaper*, RCS: DD-A&T(Q&A)823-424, Washington, DC, December 30, 2010., p. 69. F-16 cost from Air Force reporting referenced in U.S. Government Accountability Office, *Tactical Aircraft: Air Force Fighter Reports Generally Addressed Congressional Mandates, but Reflected Dated Plans and Guidance, and Limited Analyses*, GAO-11-323R, February 24, 2011, p. 9.

[78] 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 2005-2030*. August, 2005, Section 2, p.10.

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

western United States to search for forest fires. Following the widespread destruction of Hurricane Katrina, some suggest that a UAS like Global Hawk could play roles in "consequence management" and relief efforts.[80] Also, UAS advocates note that countries like South Korea and Japan have used UAS for decades for crop dusting and other agricultural purposes.[81]

> Historically, UAS were predominately operated by DoD in support of combat operations in military controlled airspace; however, UAS support to civil authorities (JTF Katrina in 2005, U.S. Border surveillance, and fire suppression) continues to expand. This expansion, coupled with the requirement to train and operate DoD and [other government agency] assets, highlights the need for routine access to the [national airspace system] outside of restricted and warning areas, over land and water.[82]

Heavier-than-air UAS may not always be the preferred platforms for these new roles and applications. Other options could include manned aircraft, blimps, and space satellites.[83] 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 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, spotting incoming enemy missiles and border monitoring. Furthermore, these platforms could provide services equivalent to many border surveillance UAS, but their decreased dependency on fuel could reduce operations costs. One drawback to these lighter-than-air platforms is their lack of maneuverability and speed relative to UAVs like the Global Hawk; their long persistence once on station may be somewhat offset by the time required for them to relocate in response to new taskings. Nonetheless, many major UAS manufacturers are preparing—and, in some cases, testing—lighter-than-air systems that could carry out a variety of missions for homeland security.[84]

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 UAS, 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.[85]

The Issue of Airspace

Not all of these new UAS applications are uncontroversial or easily implemented. UAS advocates state that in order for UAS to take an active role in homeland security, law enforcement, aerial

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

[81] 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

[82] Department of Defense, *FY2009–2034 Unmanned Systems Integrated Roadmap* (2009), p. 91.

[83] For more information on blimps (airships) and aerostats, see CRS Report RS21886, *Potential Military Use of Airships and Aerostats*, by Christopher Bolkcom.

[84] Bob Cox, "The blimp is back," *Sky Talk blog/Dallas Star-Telegram*, July 27, 2011.

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

surveying, crop dusting, and other proposed civilian uses, Federal Aviation Administration (FAA) regulations and UAS flight requirements must approach a common ground. According to FAA spokesman William Shumann, the primary challenge in finding this common ground is "to develop vehicles that meet FAA safety requirements if they want to fly in crowded airspace."[86] The August 2003 announcement that the FAA had granted the Air Force a certificate of authorization for national airspace operation signified the first steps in the reconciliation of these discrepancies.[87] Upgrading UAS collision avoidance capabilities, often referred to as "sense and avoid" technology, appears to be a critical part in the next step of reaching the UAS-airspace common ground. The FAA's Unmanned Aircraft Systems Working Group is working with the Department of Defense to facilitate safe UAS operations and the adequacy of flight requirements.[88]

The schedule for integrating UAS into the national airspace remains contentious. Industry has expressed frustration at not being able to test new UAS from their own test facilities due to airspace restrictions. Also:

> DOD has pioneered UAS applications for wartime use and, in 2007, was the major user of UAS, primarily for ongoing conflicts in Iraq and Afghanistan. While many of DOD's UAS operations currently take place outside the United States, DOD needs access to the national airspace system for UAS to, among other things, transit from their home bases for training in restricted military airspace or for transit to overseas deployment locations.[89]

In November 2009, Secretary of the Air Force Michael Donley and FAA Administrator Randy Babbitt co-moderated an industry forum on UAS in the national airspace system. At that event, Administrator Babbitt said:

> In order for us to get to the place where the UAS can become a viable, accepted part of the national airspace system, we have to make sure that sense-and-avoid is more than a given—it must be a guarantee.
>
> Without a pilot who can look and scan to the left and the right—just the way you and I do when we're backing out of a parking space—there's a perceived level of risk that the American public isn't ready for.[90]

The issue of when and how UAS will be allowed to operate in U.S. airspace continues to evolve, and continues to be of interest to Congress. The House passed a proposed FAA reauthorization bill in 2011 which "includes a provision requiring FAA to develop a comprehensive plan within nine months of enactment to safely integrate commercial unmanned aircraft systems (UASs) in the national airspace system. The bill further specifies that this integration is to be completed as soon as possible, but not later than September 30, 2012, and authorizes such sums as may be necessary to carry out the implementation plan."[91] A companion Senate bill "includes a provision requiring FAA to develop a plan for accelerating the integration of UASs into the National Airspace System within one year of enactment." More detailed information on this issue can be

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

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

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

[89] U.S. Government Accountability Office, *Unmanned Aircraft Systems: Federal Actions Needed to Ensure Safety and Expand Their Potential Uses within the National Airspace System*, GAO-80-511, May 2008, p. 9.

[90] "FAA: Drones Not Ready for Prime Time," *Aviation Today*, December 7, 2009.

[91] CRS Report R41798, *Federal Aviation Administration (FAA) Reauthorization: An Overview of Legislative Action in the 112th Congress*, coordinated by Bart Elias.

found in CRS Report R41798, *Federal Aviation Administration (FAA) Reauthorization: An Overview of Legislative Action in the 112th Congress*.

Recruitment and Retention

The defining characteristic of UAS is that they are "unmanned" or "unpiloted." However, this may be a misnomer.

> "There's nothing unmanned about them," [former Air Force Lt Gen David] Deptula said. It can take as many as 170 persons to launch, fly, and maintain such an aircraft as well as to process and disseminate its ISR products.[92]

Recruitment and retention is a perennial congressional issue that may be receiving increased attention due to the operational stresses associated with the ongoing efforts to counter terrorism. What impact might widespread deployment of UAS have on military personnel? If UAS are introduced into the force in large numbers, might personnel issues arise?

It has not always been easy for the aviation culture to adapt to flying aircraft from the ground. The Air Force has realized the retention implications of requiring rated pilots to fly their UAS,[93] and has offered enticements such as plum assignments after flying the UAS, and allowing pilots to keep up their manned flying hours during their UAS tour of duty.

Historically, many believed that as more UAS 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 UAS 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. The Air Force and Navy are actively trying to reduce their number of uniformed personnel. Thus, possible reduced enlistments due to increased UAS use might not have the anticipated negative impact.[94]

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

Many people 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 UAS 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 UAS as was believed in the past. Flying armed UAS may be more appealing to these personnel than is flying non-armed UAS. Also, flying UAS may be an attractive compromise for certain 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 UAS from control stations in the United States will be attractive to some in the reserve component who may be disinclined to experience an active duty lifestyle consistent with flying

[92] John A. Tirpak, "The RPA Boom," *Air Force*, August 2010.

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

[94] For more information on recruitment issues see CRS Report RL32965, *Recruiting and Retention: An Overview of FY2009 and FY2010 Results for Active and Reserve Component Enlisted Personnel*, by Lawrence Kapp.

manned aircraft. Also, not all UAS compete with manned aircraft for pilots. Those UAS that are pre-programmed and operate autonomously (like Global Hawk) do not require a pilot, unlike the Predator and other remotely piloted aircraft.

The Air Force maintains that their UAS are more technologically and operationally sophisticated than other UAS, and a trained pilot is required to employ these UAS most effectively. As UAS 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 UAS.[95]

Increased employment of UAS 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 UAS 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

Defense industrial base issues perennially confront Congress. 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?[96] It appears that DOD's pursuit of UAS presents several interrelated issues relevant to the defense industrial base.

Some commentators argue that increasing acquisition of UAS may take funds from manned aircraft programs, and the technical expertise required to design and perhaps build manned combat aircraft could erode. Many observers 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 UAS could harm the industrial base. They argue that the F-35 Joint Strike Fighter (JSF) 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 UAS.

Those who fear manned industrial base atrophy argue that the future of UAS is overrated, and that demand will continue 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 in tactical aircraft design to wane. These proponents point out that UAS 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.[97]

Others disagree, and believe that critical manned aircraft design skills are not jeopardized by increased pursuit of UAS because there is considerable commonality between manned and unmanned combat aircraft. Except for the obvious lack of a cockpit, unmanned combat aircraft

[95] LtGen Dave Deptula, *The Way Ahead: Remotely Piloted Aircraft in the United States Air Force*, U.S. Air Force, undated briefing, http://www.daytonregion.com/pdf/UAV_Rountable_5.pdf.

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

[97] 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 H. Else.

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 UAS are beginning to play a prominent role in warfare, as seen in Operations Enduring Freedom and Iraqi Freedom. 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 JSF in 2001, are looking towards unmanned bombers and fighters as prospects for growth. Were Boeing to design manned aircraft in the future, the critical skills needed would still be present, according to this argument. Boeing acquired UAS maker Insitu in 2008.[98] Northrop Grumman Corp., as another example, has created a new business unit to aggressively pursue UAS contracts, and acquired Scaled Composites in 2007 in part for UAS design expertise.[99]

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 UAS market. One survey finds that in 2011, there are 680 different UAS programs worldwide, up from 195 in 2005.[100] Another estimates that global UAS expenditures will double from $1.7 billion in 2011 to $3.5 billion in 2020.[101] The global market for combat aircraft alone, at approximately $15.8 billion in 2011, dwarfs the UAS market. But the rate of growth is projected to be much slower, peaking at approximately $21 billion in 2017, and dropping to approximately $19 billion in 2020.[102] Thus, some would argue that much new business is likely to be generated in the UAS market, and if U.S. companies fail to 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 UAS 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.

As U.S. companies compete for business in a growing international UAS 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 UAS? 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 UAS technologies to dangerous groups or countries.

Congressional Considerations

Advances in UAS technology and their expanding role in national security lead to a number of possible questions for congressional consideration. They may include:

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

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

[100] J.R. Wilson, "2011 Worldwide UAV Roundup," *Aerospace America*, March 2011. "Unmanned Aerial Vehicles Directory," *Flight International*, June 21-27, 2005.

[101] "Unmanned Aerial Vehicles Market Overview," World Missiles Briefing, Teal Group Inc., Fairfax, VA, January 2011.

[102] "Fighter/Attack Aircraft Market Overview," World Military & Civil Aircraft Briefing, Teal Group Inc., Fairfax, VA, February 2011.

Funding

Should Congress increase, reduce, or approve DOD's proposed overall funding level for UAS?

Budget impact: How might an increased reliance on UAS affect future DOD funding needs? Would it permit a net reduction in DOD funding requirements for performing a given set of missions, and if so, by how much?

Trade-Offs

If funding constraints require choices to be made among DOD UAS programs, what are some of the key potential choices? Choices may include whether to reduce the number of UAS programs, buy fewer UAS overall, defer purchase of more sophisticated UAS, or other choices.

Measures of Effectiveness

How should the effectiveness of UAS be evaluated? Number of aircraft procured? Number of UAS tracks supported? Area under surveillance by UAS? Suppression or elimination of a particular threat or category of threats?

Pace of Effort

In terms of developing, procuring, and integrating UAS into their operations, are DOD and the services moving too slowly, too quickly, or at about the right speed? Are the services adequately implementing their UAS road maps? Should the current requirement for issuing road maps every two years be changed, and if so, how? Can a standard metric be established to determine the optimal pace?

Management

Who should manage the development and procurement of DOD UAS? Should management of at least some of these programs be centralized? If so, where in DOD should the central authority reside?

Air Force Chief of Staff General Norton Schwartz made the case that "Ideally, what you want to do is have the U.S. government together in a way that allows us to get the best capability…. An example is BAMS and Global Hawk. Why should the Navy and Air Force have two separate depots, ground stations and training pipelines for what is essentially the same airplane with a different sensor? I think there is lots of opportunity for both of us to make better uses of resources."[103]

Operators

Are current service policies regarding who can operate a UAS satisfactory? If not, how should they be changed? Should there be a uniform, DOD-wide policy? Should DOD consider using a mix of uniformed and civilian personnel for operating UAS, particularly those that are not used for firing weapons (somewhat similar to how Military Sealift Command ships are operated by a mix of uniformed and civilian personnel)? What would be the potential advantages and

[103] David A. Fulghum, "USAF Chief Considers F-35 And F-22 Replacement," *Aerospace Daily*, November 25, 2010.

disadvantages of such an arrangement for operating UAS? What is an appropriate role for contractors in operating military UAS?

R&D Priorities

What new UAS capabilities are most needed? Should priority be given to incremental increases in capability versus ambitious technological leaps? What is the importance of maintaining the U.S. technological lead in UAS?

Development Facilities

Are current FAA limits on DOD access to domestic U.S. flight facilities for developing UAS hindering the development of DOD UAS? What are the relevant factors and capabilities involved, and do they make a persuasive case for the change or retention of current limits?

Other Issues

In recent years, the pace of UAS development has accelerated, and the scope of UAS 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 UAS, does DOD risk duplication of effort between various programs? Are DOD UAS acquisition plans responsive to congressional direction? Are UAS being developed fast enough? Are they being developed too fast? Has DOD developed an appropriate plan and structure for incorporating UAS into future military capabilities?

Investment priorities could change as the introduction of UAS 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 UAS efforts to verify that they match up with new investment goals and strategies. Conventional wisdom states that UAS are cheap, or cost-effective. Is this true today? How do UAS costs compare to manned aircraft costs?

In Summation

UAS 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 UAS have 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. Future Congresses may have to contemplate the replacement of a significant portion of the manned aircraft fleet with unmanned aircraft.

Current Major DOD UAS Programs

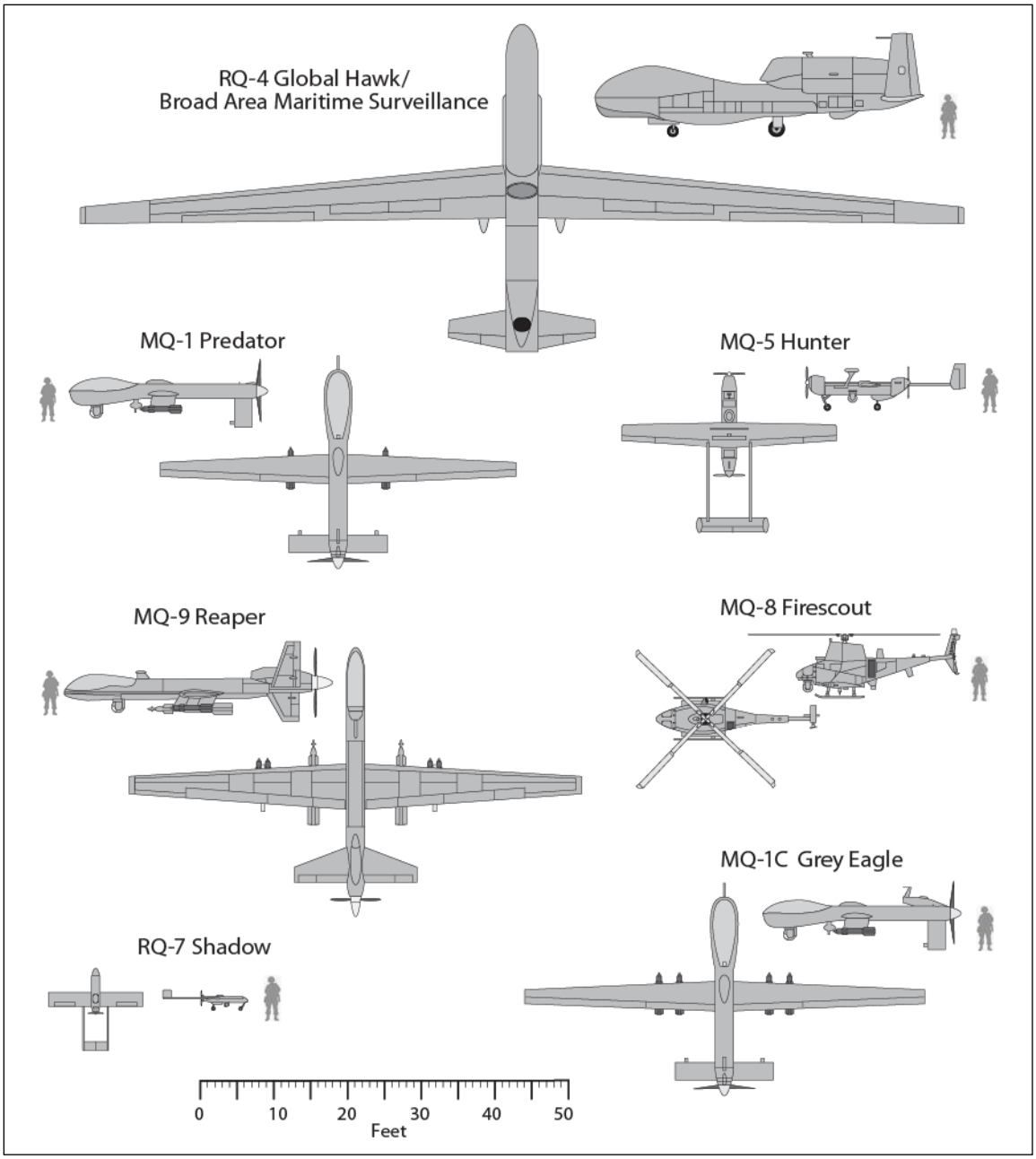
This section addresses the program status and funding of some of the most prominent UAS programs being pursued by DOD, and most likely to compete for congressional attention. This section does not attempt to provide a comprehensive survey of all UAS programs, nor to develop a classification system for different types of UAS (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 UAS programs. Individually, these UAVs appear very popular with ground forces, yet do not necessarily demand as much congressional attention as larger UAS programs like Predator or Global Hawk. As a whole, however, these small, man-portable UAVs appear likely to increasingly compete with major UAS programs for congressional attention and funding.

Table 6. Characteristics of Selected Tactical and Theater-Level Unmanned Aircraft

System	Length (ft)	Wingspan (ft)	Gross weight (lbs)	Payload capacity (lbs)	Endurance (hours)	Maximum altitude (ft)
Predator	27	55	2,250	450	24+	25,000
Grey Eagle	28	56	3,200	800	40	25,000
Reaper	36	66	10,500	3,750	24	50,000
Shadow	11	14	375	60	6	15,000
Fire Scout	23	28	3,150	600	6+	20,000
Global Hawk	48	131	32,250	3,000	28	60,000
BAMS	48	131	32,250	3,200	34+	60,000

Figure 5. U.S. Medium-Sized and Large Unmanned Aircraft Systems



Source: Congressional Budget Office, *Policy Options for Unmanned Aircraft Systems*, Publication 4083, Washington, DC, June 2011.

Notes: All aircraft are drawn to the same scale. The silhouette figure is a 6-foot-tall soldier, also drawn to scale.

Table 7. Acquisition Cost of Medium-Sized and Large Unmanned Aircraft Systems Under the Department of Defense's 2012 Plan

(Millions of 2011 dollars)

	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total, 2011-2020
Air Force											
RQ-4 Global Hawk	1,200	1,060	890	790	810	710	1,160	530	80	60	7,290
MQ-1 Predator	30	10	10	10	a	a	a	a	a	a	60
MQ-9 Reaper	1,700	1,550	1,740	1,440	1,350	1,150	1,060[b]	1,040[b]	1,030[b]	1,010[b]	13,070
Army											
MQ-1C Grey Eagle	870	1,060	1,040	740	220	90	a	a	a	a	4,020
RQ-7 Shadow	610	250	270	200	300	280	a	a	a	a	1,910
Navy and Marine Corps											
RQ-4 Broad Area Maritime Surveillance	530	560	760	880	900	1,010	1,230	1,260	1,130	1,130	9,390
MQ-8 Fire Scout	60	70	60	80	80	90	130	160	150	150	1,030
RQ-7 Shadow	90	10	10	10	a	a	a	a	a	a	120
All services											
	5,090	4,570	4,780	4,150	3,660	3,330	3,580	2,990	2,390	2,350	36,890

Source: Congressional Budget Office based on data from the Department of Defense's budget request for 2012, Selected Acquisition Reports for December 2010, and Aircraft Procurement Plan: Fiscal Years 2012-2041 (submitted with the 2012 budget, March 2011).

Notes: Acquisition cost includes the cost of procuring air vehicles, sensors, and grounds stations, plus the cost for research. development, test, and evaluation. The services' cost data have been adjusted using CBO's projection of inflation and rounded to the nearest $10 million.

a. The Department of Defense has no plans to acquire or modify the specified system in these years.

b. The cost is for the follow-on aircraft the Air Force plans to acquire instead of the Reaper.

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 UAS. Developed by General Atomics Aeronautical Systems in San Diego, CA, the Predator has helped to define the modern role of UAS 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 other closely related UAS (described below) designed for a variety of missions.

System Characteristics. Predator is a medium-altitude, long-endurance UAS. 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 15th and 17th Reconnaissance Squadrons out of Creech Air Force Base, NV; the 11th Reconnaissance Squadron provides training. A second control station has been established at Whiteman AFB, MO.[104] Further, "[t]here are plans to set up Predator operations at bases in Arizona, California, New York, North Dakota, and Texas."[105] The Air Force has about 175 Predators;[106] the CIA reportedly owns 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 UAS 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 ordnance enables the UAS 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).[107] The air vehicle launches and lands like a regular aircraft, but is controlled by a pilot on the ground using a joystick.

MQ-1C Grey Eagle

A slightly larger, longer-endurance version of the Predator, the Army's MQ-1C Grey Eagle entered low-rate initial production on March 29, 2010.[108] The Grey Eagle can remain aloft for 36 hours, 12 hours longer than its Air Force sibling.

An Army platoon operates four aircraft with electro-optical/infrared and/or laser rangefinder/designator payloads, communications relay equipment, and up to four Hellfire missiles. Each platoon includes two ground control stations, two ground data terminals, one satellite communication ground data terminal, one portable ground control station, one portable ground data terminal, an automated takeoff and landing system, two tactical automatic landing

[104] Phillip O'Connor, "Drones seeking terrorists guided from Missouri air base," *St. Louis Post-Dispatch*, May 10, 2011.

[105] P.W. Singer, *Wired for War* (New York: The Penguin Press, 2009), p. 33.

[106] Congressional Budget Office, *Policy Options for Unmanned Aircraft Systems*, Pub. No. 4083, June 2011, p. 5.

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

[108] Department of Defense, *Selected Acquisition Report (SAR), MQ-1C UAS Gray (sic) Eagle*, DD-A&T(Q&A)823-420, Washington, DC, December 31, 2010.

systems, and ground support equipment. In total, the program will be 124 aircraft, plus 21 attrition aircraft and 7 schoolhouse aircraft, for a total of 152 aircraft. The average procurement unit cost of a Grey Eagle system is $114.1 million.[109]

MQ-9 Reaper

The MQ-9 Reaper, formerly the "Predator B," is General Atomics' follow-on to the MQ-1. The Reaper is a medium- to high-altitude, long-endurance Predator optimized for surveillance, target acquisition, and armed engagement. While the Reaper borrows from the overall design of the Predator, the Reaper is 13 feet longer and carries a 16-foot-longer wingspan. It also features a 900 hp turboprop engine, which is significantly more powerful than the Predator's 115 hp engine. These upgrades allow the Reaper 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 of 2,000 nautical miles.[110] However, the feature that most differentiates Reaper from its predecessor is its ordnance capacity. While the Predator is outfitted to carry 2 100-pound Hellfire missiles, the Reaper 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.

As of February 4, 2011, General Atomics Aeronautical Systems had delivered 65 of 399 planned Reapers, 43 of which are operationally active.[111]

The MQ-9 is operated by the 17th Reconnaissance Squadron and the 42nd Attack Squadron, both at Creech Air Force Base, NV, and the 29th Attack Squadron at Holloman AFB, NM.[112]

Program Status. Predator–family UAS are operated as part of a system, which consists of four air vehicles, a ground control station, and a primary satellite link. The unit cost in FY2009 for one Predator system was approximately $20 million,[113] while the average procurement unit cost for a Reaper system was $26.8 million.[114]

Table 8. Predator and Reaper Combined Funding
($ in Millions)

		Procurement	RDT&E
FY11			
Request	62 air vehicles	1600.0	
	Mods	31.8	
Appropriations Conference	12 air vehicles	176.6	83.2
	Mods	31.8	

[109] Ibid.

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

[111] Department of Defense, *Selected Acquisition Report (SAR), MQ-9 UAS Reaper*, DD-A&T(Q&A)823-424, Washington, DC, December 31, 2010.

[112] U.S. Air Force, *Fact Sheet: MQ-9 Reaper*, August 18, 2010.

[113] U.S. Air Force, *Fact Sheet: MQ-1 Predator*, July 20, 2010.

[114] Department of Defense, *Selected Acquisition Report (SAR), MQ-9 UAS Reaper*, DD-A&T(Q&A)823-424, Washington, DC, December 31, 2010.

		Procurement	RDT&E
FY12			
Request	9 air vehicles	125.5	61
	Mods	30.2	

RQ-4 Global Hawk

Northrop Grumman's RQ-4 Global Hawk has gained distinction as the largest and most expensive UAS currently in operation for the Department of Defense. Global Hawk incorporates a diverse surveillance payload with performance capabilities that rival or exceed most manned spy planes. However, Pentagon officials and Members of Congress have become increasingly concerned with the program's burgeoning cost, which resulted in Nunn-McCurdy breaches in April 2005 and April 2011.[115] Also, the RQ-4B Block 30 was deemed "not operationally suitable" due to "low air vehicle reliability" by the office of Operational Test and Evaluation in May 2011.[116]

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 the 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 UAS requires frequent intervention by remote operators.[117] 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 pounds of surveillance payload.

Mission and Payload. The Global Hawk UAS has been called "the theater commander's around-the-clock, low-hanging (surveillance) satellite."[118] The UAS 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

[115] Amy Butler, "USAF Declares Second Major Global Hawk Cost Breach," Aerospace Daily, April 13, 2011. The 2005 breach stemmed from costs in transitioning from the Block 10 Global Hawk to the larger Block 30; the 2011 breach was attributed primarily to reduced procurement quantities rather than issues with the program.

[116] J. Michael Gilmore, *RQ-4B Global Hawk Block 30* , OSD Director, Operational Test and Evaluation, Operational Test and Evaluation Report, May 2011. John T. Bennett, "Pentagon testers slam aerial spy drone as unfit for operations," *The Hill*, June 7, 2011.

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

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

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.[119] The end goal is to field a UAS that will work with space-based sensors to create a "staring net" that will prevent enemies from establishing a tactical surprise.[120] In August 2003, the Federal Aviation Administration granted the Global Hawk authorization to fly in U.S. civilian airspace, which further expanded the system's mission potential.[121] This distinction, in combination with the diverse surveillance capabilities, has led many officials outside the Pentagon to consider the Global Hawk an attractive candidate for anti-drug smuggling and Coast Guard operations.[122]

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. As of November 2009, the Air Force possessed 7 RQ-4As and 3 RQ-4Bs.[123] Another 32 Global Hawks had been authorized and appropriated through FY2011.[124] According to the most recent Selected Acquisition Report, the current average procurement unit cost for the Global Hawk has reached $140.9 million in current dollars.[125]

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."[126] 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.[127] 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.[128]

Following a 2010 Defense Acquisition Board review of the Global Hawk program,

> Air Force acquisition executive David Van Buren told reporters that he is "not happy" with the pace of the program, both on the government and the contractor side. Chief Pentagon

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

[120] Ibid.

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

[122] Ron Laurenzo, "Global Hawk Scouts Ahead for Other UAVs," *Defense Week*, September 2, 2003.

[123] U.S. Air Force, *Fact Sheet: RQ-4 Global Hawk*, November 19, 2009.

[124] Department of Defense, *Department of Defense Fiscal Year 2012 Budget Estimates, Aircraft Procurement, Air Force*, February 2011.

[125] OSD, *Selected Acquisition Report*, December 31, 2010, p. 29.

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

[127] 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.

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

arms buyer Ashton Carter also criticized the program, saying that it was "on a path to being unaffordable."[129]

In April 2011, a reduction in the number of Global Hawk Block 40 aircraft requested in the FY2012 budget from 22 to 11 caused overall Global Hawk unit prices to increase by 11%, again triggering Nunn-McCurdy.[130]

In its markup of the FY2011 defense authorization bill, the House Armed Services Committee expressed concern "that differing, evolving service unique requirements, coupled with Global Hawk UAS vanishing vendor issues, are resulting in a divergence in each service's basic goal of maximum system commonality and interoperability, particularly with regard to the communications systems." The bill report directs the Under Secretary of Defense for Acquisition, Technology, and Logistics to certify and provide written notification to the congressional defense committees by March 31, 2011, that he has reviewed the communications requirements and acquisition strategies for both Global Hawk and BAMS. The subcommittee wants assurance that the requirements for each service's communications systems have been validated and that the acquisition strategy for each system "achieves the greatest possible commonality and represents the most cost effective option" for each program.[131]

A May 20, 2011, report from the Air Force Operational Test and Evaluation Center found the Global Hawk Block 20/30 to be "effective with significant limitations ... not suitable and partially mission capable." The report cited "lackluster performance of the EISS imagery collector and ASIP sigint collectors at range" rather than issues with the Global Hawk airframe itself.[132]

Table 9. Global Hawk Funding
($ in Millions)

	Quantity	Procurement	RDT&E	Advance Procurement
FY11				
Request	4	649.6	251.3	90.2
Authorization Conference[a]	N/A	N/A	N/A	N/A
Appropriations Conference	4	503.0	220.3	72.3
FY12				
Request	3	323.9		71.5

a. As passed, H.R. 6523, the Ike Skelton National Defense Authorization Act For Fiscal Year 2011, did not include program-level detail, so no amounts were specified for these program elements.

[129] Marina Malenic, "Air Force, Navy Pledge Greater Global Hawk-BAMS Cooperation," *Defense Daily*, July 2, 2010.

[130] 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 led to the cost growth are under control. For more information, see CRS Report R41293, *The Nunn-McCurdy Act: Background, Analysis, and Issues for Congress*, by Moshe Schwartz.

[131] U.S. Congress, House Committee on Armed Services, *National Defense Authorization Act for Fiscal Year 2011*, Report to accompany H.R. 5136, 111th Cong., May 21, 2010, H.Rept. 111-491, p. 178.

[132] Amy Butler, "Poor Testing Results Latest Hurdle for Global Hawk," *Aviation Week/Ares blog*, June 3, 2011.

BAMS

The Navy's Broad Area Maritime Surveillance system is based on the Global Hawk Block 20 airframe but with significantly different sensors from its Air Force kin. This, coupled with a smaller fleet size, results in a higher unit cost. "The air service's drone costs $27.6 million per copy, compared to an expected $55 million per BAMS UAV, including its sensors and communications suite…. At 68 aircraft, the BAMS fleet will be the world's largest purchase of long-endurance marinized UAVs."[133]

System Characteristics and Mission. "BAMS ... provides persistent maritime intelligence, surveillance, and reconnaissance data collection and dissemination capability to the Maritime Patrol and Reconnaissance Force. The MQ-4C BAMS UAS is a multi-mission system to support strike, signals intelligence, and communications relay as an adjunct to the MMA/P-3 community to enhance manpower, training and maintenance efficiencies worldwide."[134]

"The RQ-4 ... features sensors designed to provide near worldwide coverage through a network of five orbits inside and outside continental United States, with sufficient air vehicles to remain airborne for 24 hours a day, 7 days a week, out to ranges of 2000 nautical miles. Onboard sensors will provide detection, classification, tracking and identification of maritime targets and include maritime radar, electro-optical/infra-red and Electronic Support Measures systems. Additionally, the RQ-4 will have a communications relay capability designed to link dispersed forces in the theater of operations and serve as a node in the Navy's FORCEnet strategy."[135]

"The drones ... will collect information on enemies, do battle-damage assessments, conduct port surveillance and provide support to Navy forces at sea. Each aircraft is expected to serve for 20 years."[136]

Program Status. The Administration's FY2012 budget request documents place Milestone C for BAMS in the third quarter of FY2013, with initial operational capability in the first quarter of 2016. "Since Milestone B for the Navy BAMS UAS program, identifying opportunities for the RQ-4-based BAMS and Global-Hawk programs has been a significant interest item for the UAS TF and has been well documented within the Department."[137] In one effort to integrate development, on June 12, 2010, the Navy and Air Force concluded a Memorandum of Agreement (MOA) regarding their Global Hawk and BAMS programs, which use a common airframe. "Shared basing, maintenance, command and control, training, logistics and data exploitation are areas that could be ripe for efficiencies, says Lt. Gen David Deptula, Air Force deputy chief of staff for intelligence, surveillance and reconnaissance…. Also, a single pilot and maintenance training program is being established at Beale AFB, Calif., for both fleets."[138] However, issues still exist over common control stations and whether one service's pilots should be able to operate the other service's aircraft.

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[133] Gayle S. Putrich, "Northrop selected to build BAMS drone," *Navy Times*, April 22, 2008.

[134] Northrop Grumman, "MQ-4C BAMS UAS," press release, http://www.as.northropgrumman.com/products/bams/index.html.

[135] Department of Defense, *Department of Defense Fiscal Year 2012 Budget Estimates, Research, Development, Test & Evaluation, Navy*, Budget Activity 7, February 2011.

[136] Gayle S. Putrich, "Northrop selected to build BAMS drone," *Navy Times*, April 22, 2008.

[137] Under Secretary of Defense (Acquisition, Technology and Logistics), *Department of Defense Report to Congress on Addressing Challenges for Unmanned Aircraft Systems*, September 2010.

[138] Amy Butler, "U.S. Navy/Air Force UAV Agreement Raises Questions," *Aerospace Daily*, July 6, 2010.

MQ-8B Fire Scout

Now in deployment, the Fire Scout was initially designed as the Navy's choice for an unmanned helicopter capable of reconnaissance, situational awareness, and precise targeting.[139] Although 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 MQ-8, making the Fire Scout DOD's first joint UAS helicopter.

System Characteristics and Mission. Northrop Grumman based the design of the Fire Scout on a commercial helicopter. The RQ-8B model added a four-blade rotor to reduce the aircraft's acoustic signature.[140] With a basic 127-pound payload, the Fire Scout can stay aloft for up to 9.5 hours; with the full-capacity sensor payload, endurance diminishes to roughly 6 hours. Fire Scout 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.[141] Fire Scout also currently possesses line-of-sight communication data links. Initial tests of an armed Fire Scout were conducted in 2005, and the Navy expects to add "either Raytheon's Griffin or BAE's Advanced Precision Kill Weapon System" small missiles to currently deployed Fire Scouts soon.[142] Discussions of future missions have also covered border patrol, search and rescue operations, medical resupply, and submarine spotting operations.

Program Status. Six production MQ-8 air vehicles have been delivered to date.[143] The Pentagon's 2009 UAS Roadmap estimates a future inventory of 131 RQ-8Bs for the Navy to support the Littoral Combat Ship class of surface vessels.[144] The Army had intended to use the Fire Scout as the interim brigade-level UAV for its Future Combat System program,[145] but canceled its participation in January, 2010.[146]

A Fire Scout attracted media attention in August 2010, when it flew through Washington, DC, airspace after losing its control link. "A half-hour later, Navy spokesmen said, operators re-established control and the drone landed safely."[147]

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[139] "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.

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

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

[142] Joshua Stewart, "Navy plans to arm Fire Scout UAV with missiles," *Navy Times*, August 18, 2011.

[143] Department of the Navy, *Fiscal Year (FY) 2012 Budget Estimates, MQ-8 UAV*, February 2011.

[144] Northrop Grumman Corp. Press Release, "Northrop Grumman's Next-Generation Fire Scout UAV on Track," June 23rd, 2005. *FY2009–2034 Unmanned Systems Integrated Roadmap*, p. 66.

[145] The Army intended to field four different classes of UAVs as part of its Future Combat System (FCS): Class I for platoons, Class II for companies, Class III for battalions, and Class IV for brigades. See CRS Report RL32888, *Army Future Combat System (FCS) "Spin-Outs" and Ground Combat Vehicle (GCV): Background and Issues for Congress*, by Andrew Feickert and Nathan J. Lucas, for more information.

[146] April M. Havens, "U.S. Army wants to cancel Fire Scouts (sic) program," *The Mississippi Press*, January 15, 2010, As presented on http://www.gulflive.com.

[147] Elisabeth Bumiller, "Navy Drone Violated Washington Airspace," *The New York Times*, August 26, 2010.

FIRE-X/MQ-8C

The FIRE-X project, recently designated MQ-8C but continuing the Fire Scout name, is a developmental effort to adapt the Fire Scout software and navigation systems to a full-size standard helicopter. The Navy "is to award Northrop Grumman a contract to supply 28 MQ-8C Fire Scout ... to be fielded by the first quarter of 2014 to meet an urgent operational requirement."[148]

> Fire Scout can fly for 8 hours with a maximum range of 618 nautical miles? Well, Fire-X will fly for 15, with a max range of 1227. Fire Scout tops out at 100 knots? Fire-X can speed by at 140. Fire-X will carry a load of 3200 lbs. to Fire Scout's 1242. All this talk from a drone helicopter that just took its first flight in December.... Fire-X isn't going to be a big departure from Fire Scout, though. The BRITE STAR II and other radars will remain on board, as will its software for relaying information to a ship.[149]

RQ-170 Sentinel

Although publicly acknowledged to exist, most information about the Lockheed Martin RQ-170 Sentinel is classified. First photographed in the skies over Afghanistan, but also reportedly in operation from South Korea,[150] the RQ-170 is a tailless "flying wing" stealthier than other current U.S. UAS. An RQ-170 was reported to have performed surveillance and data relay related to the operation against Osama bin Laden's compound on May 1, 2011. The government of Iran claimed on December 2, 2011, to be in possession of an intact RQ-170 following its incursion into Iranian airspace.

System Characteristics. Built by Lockheed Martin, the RQ-170 has a wingspan of about 65 feet and is powered by a single jet engine. It appears to have two sensor bays (or satellite dish enclosures) on the upper wing surface. Although an inherently low-observable blended wing/fuselage design like the B-2, the RQ-170's conventional inlet, exhaust, and landing gear doors suggest a design not fully optimized for stealth.[151]

Potential Mission and Payload. "The RQ-170 will directly support combatant commander needs for intelligence, surveillance and reconnaissance to locate targets."[152]

Program Status. "The RQ-170 is a low observable unmanned aircraft system (UAS) being developed, tested and fielded by the Air Force."[153] No further official status is available.

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[148] Graham Warwick, "U.S. Navy Goes Ahead With Bell 407-Based Fire Scout UAV," *Aerospace Daily*, September 8, 2011.

[149] Spencer Ackerman, "Navy Upgrades Its Spying, Drug-Sniffing Robot Copter," *Wired.com/Danger Room blog*, April 11, 2011.

[150] Bill Sweetman, "Beast Sighted In Korea," *Aviation Week/Ares blog*, February 16, 2010.

[151] U.S. Air Force, *Fact Sheet: RQ-170 Sentinel*, December 2, 2010. and CRS analysis of available RQ-170 photography.

[152] U.S. Air Force, *Fact Sheet: RQ-170 Sentinel*, December 2, 2010.

[153] Ibid.

Other Current UAS Programs

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 UAS, the Hunter system found a home as one of the Army's principal 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 apiece, but the Hunter program 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 Stewart, GA; by the 15th Military Intelligence Battalion out of Ft. Hood, TX; and by 1st Military Intelligence Battalion out of Hohenfels, 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 pounds, 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 engine, which allows the Hunter II to stay airborne for three extra hours and to reach altitudes of 18,000 feet.[154] 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.

Mission and Payload. The Army has mostly used the Hunter system for short- and medium-range surveillance and reconnaissance. More recently, however, the Army expanded the Hunter's missions, including weaponization for tactical reconnaissance/strike operations with the GBU-44/B Viper Strike precision guided munition, which can designate targets either from the munition's laser, from another aerial platform, or from a ground system. This weapon makes the Hunter the Army's first armed UAS. "Also, in 2004, the Department of Homeland Security, Customs and Border Protection Bureau, and Office of Air and Marine utilized Hunter under a trial program for border patrol duties. During this program, the Hunter flew 329 flight hours, resulting in 556 detections."[155]

Program Status. The Army halted Hunter production in 2005. As of May 2011, 45 Hunter UAVs were still in operation and periodically receiving upgrades and modifications. In August 2005, the Army awarded General Atomics' Warrior UAS (which later became Grey Eagle) the contract for the Extended Range-Multi Purpose UAS program over the Hunter II.[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

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

[155] Kari Hawkins, "Pioneer platform soars to battlefield success," *www.army.mil*, May 19, 2011.

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

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.

The Administration's FY2011 budget request did not include funding for Shadow aircraft, although it did include continued RDT&E funding for Shadow.[157]

System Characteristics. Built by AAI Corporation (now owned by Textron), 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 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 UAS also possesses automatic takeoff and landing capabilities. The upgraded version, the RQ-7B Shadow, features a 16-inch greater wingspan and larger fuel capacity, allowing 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 UAS'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.[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 with the Tactical Common Data Link currently in development to network the UAS with battalion commanders, ground units, and other air vehicles.[159] The Marine Corps is considering how to arm Shadow.[160]

Program Status. The Army and Marine Corps currently maintain an inventory of 364 Shadow UAVs.[161] 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 $11.1 million in current year dollars for FY2008.[162] The Army procured 102 systems through 2009.[163] In FY2012, the Army requested $25 million for 20 Shadow aircraft to replace combat losses, and approximately $200 million for payload upgrades.

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[157] Todd Harrison, *Analysis of the FY 2011 Defense Budget* (Washington, DC: Center for Strategic & Budgetary Assessments, 2010), p. 38.

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

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

[160] Paul McCleary, "Marines Want a Big Bang From a Small Package," *Aviation Week/Ares blog*, October 26, 2010.

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

[162] Department of the Army, Army Procurement OPA 02: Communications and Electronics FY2009, February 2008, TUAS (B00301), Item No. 61, p. 18 of 23.

[163] Department of the Army, *Committee Staff Procurement Backup Book, Fiscal Year 2012 Budget Estimate, Aircraft Procurement, Army, RQ-7 UAV MODS*, Washington, DC, February 2011, p. 1 of 10.

"Small UAVs"

RQ-14 Dragon Eye

AeroVironment's Dragon Eye is a backpack-carried, battery-operated UAV employed by the Marines at the company level and below for reconnaissance, surveillance, and target acquisition. Dragon Eye features a 3.8-foot rectangular wing, twin propellers, and two camera ports each capable of supporting day-light electro-optical cameras, low-light TV cameras, and infrared cameras. The compact and lightweight design of the UAV allows an operational endurance of 45 minutes and can travel as far as 2.5 nautical miles from the operator. Low-rate-initial-production of 40 aircraft began in 2001. After a 2003 operational assessment, the Marine Corps awarded AeroVironment a contract to deliver approximately 300 systems of full-rate-production Dragon Eyes.[164] However, that contract was later revised to acquire Raven UAS instead. One Dragon Eye system consists of three air vehicles and one ground station. The final Marine Corps procurement budget request in FY2006 anticipated the current unit cost per Dragon Eye system as $154,000.[165]

FQM-151 Pointer

Although procurement of this early UAS began in 1990, the electric-powered Pointer has seen service in Operation Enduring Freedom (OEF) and Operation Iraqi Freedom (OIF). Pointer is a short-range reconnaissance and battlefield surveillance UAV developed by AeroVironment. Its flight endurance (two hours) is greater than most similar small UAVs, in part due to its relatively large, 9-foot wingspan. That wingspan decreases portability of the 8.5-pound Pointer, and as a result, transportation of a Pointer system (two air vehicles and a ground control unit) requires two personnel. Although superseded by the Raven (below), Pointer remains a valued short-range ISR asset for the Air Force and Special Operations Command.

RQ-11 Raven

Engineered from the basic design of the Pointer, the Raven is two-thirds the size and weight of its predecessor, with a much smaller control station, making the system man-portable.[166] "The RQ-11A is essentially a down-sized FQM-151 *Pointer*, but thanks to improved technology can carry the same navigation system, control equipment, and payload."[167] The Raven provides Army and SOCOM personnel with "over-the-hill" reconnaissance, sniper spotting, and surveillance scouting of intended convoy routes. The 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

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

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

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

[167] Andreas Parsch, "AeroVironment RQ-11 Raven," *Directory of U.S. Military Rockets and Missiles*, September 12, 2006.

two-aircraft configurations. "Raven was adopted as the US Army's standardised short range UAV system in 2004 with a total of 2469 air vehicles (including older RQ-11A series models) in operational service by mid 2007."[168] "The US Army has an ongoing acquisition objective for about 2,200 Raven systems and has taken delivery of more than 1,300 to date."[169] A three-aircraft system costs approximately $167,000.[170]

ScanEagle

Developed by the Insitu Group (owned by Boeing) as a "launch-and-forget" UAV, the ScanEagle autonomously flies to points of interest selected by a ground operator.[171] The ScanEagle has gained notice for its long endurance capabilities and relative low cost. The gasoline-powered UAV features narrow 10 foot wings that allow the 40-pound 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. Using an inertially stabilized camera turret carrying both electro-optical and infrared sensors, ScanEagle currently provides Marine Corps units in Iraq with force-protection ISR and is also used by Special Operations Command. ScanEagle operations began in 2004,[172] and continue today. Although ScanEagle was expected to cost about $100,000 per copy, the Navy and SOCOM have contracted for operations instead of procurement, with Boeing providing ISR services utilizing ScanEagle under a fee-for-service arrangement.[173]

ScanEagle is also in use by non-military organizations for surveillance purposes, including tracking whale migrations.[174]

Small Tactical Unmanned Aerial System (STUAS)

In July 2010, the Department of the Navy awarded Insitu a two-year, $43.7 million contract for the design, development, integration, and test of the Small Tactical Unmanned Aircraft System (STUAS) for use by the Navy and Marine Corps to provide persistent maritime and land-based tactical reconnaissance, surveillance, and target acquisition (RSTA) data collection and dissemination. "For the USMC, STUAS will provide the Marine Expeditionary Force and subordinate commands (divisions and regiments) a dedicated ISR system capable of delivering intelligence products directly to the tactical commander in real time. For the Navy, STUAS will provide persistent RSTA support for tactical maneuver decisions and unit-level force defense/force protection for Navy ships, Marine Corps land forces, and Navy Special Warfare Units."[175]

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[168] "UAV Directory - Aircraft Specification AeroVironment - RQ-11A Raven," *FlightGlobal.com*, (2011).

[169] "UAV Directory - Aircraft Specification AeroVironment - RQ-11B Raven," *FlightGlobal.com*, (2011).

[170] The FY2012 budget request includes $70.8 million for 424 systems and supporting equipment. Department of Defense, *Department of Defense Fiscal Year 2012 Budget Estimates, Aircraft Procurement, Army*, February 2011.

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

[172] Insitu, "Backgrounder: ScanEagle® Unmanned Aircraft System," press release, September 22, 2011, http://www.boeing.com/bds/mediakit/2011/ausa/pdf/bkgd_scaneagle.pdf.

[173] See, inter alia, Boeing, "Boeing Awarded Navy Contract for ScanEagle Services," press release, June 6, 2008, http://www.boeing.com/news/releases/2008/q2/080606a_nr.html and Insitu, "Boeing Wins $250M Special Ops Contract for ScanEagle ISR Services," press release, May 22, 2009, http://www.insitu.com/print.cfm?cid=3774.

[174] Boeing, " From saving soldiers to saving whales," undated press release, http://www.boeing.com.au/ViewContent.do?id=61784&aContent=ScanEagle.

[175] Naval Air Systems Command, *Aircraft and Weapons: Small Tactical Unmanned Aircraft System*, http://www.navair.navy.mil/index.cfm?fuseaction=home.display&key=4043B5FA-7056-4A3A-B038-C60B21641288.

Payloads include day/night video cameras, an infrared marker, and a laser range finder, among others. STUAS can be launched and recovered from an unimproved expeditionary/urban environment, as well as from the deck of Navy ships.[176]

STUAS uses Insitu's Integrator airframe, which uses common launch, control, and recovery equipment with ScanEagle. STUAS has a takeoff weight of up to 125 pounds with a range of 50 nautical miles. However, STUAS will be procured and operated by the services rather than operated on a fee-for-service basis because "the Scan Eagle's current fee-for-service contract limits the way the UAS is deployed ... with Boeing/Insitu employees usually operating the aircraft in the field due to liability issues." Procuring the system will allow the services to train their own operators. Initial operating capability is expected in the fourth quarter of FY2013.[177]

Future UAS

Unmanned Carrier-Launched Airborne Surveillance and Strike (UCLASS)

In the mid-1990s, the Pentagon began developing a UAS 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 programs in order to establish the Joint Unmanned Combat Air System (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 missions.[178] 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.[179] J-UCAS was cancelled in 2006. The total money spent on the J-UCAS/UCAV program, which reached more than $1.45 billion in RDT&E funding, made it one of the most expensive UAS ventures undertaken by DOD.

Subsequently, in May 2010, the Navy issued a Request for Information for a carrier-borne UCAV called UCLASS,

> seeking ideas on a stealthy strike/surveillance platform that could operate alongside manned aircraft as part of a carrier air wing by the end of 2018. The notional system would comprise four to six aircraft capable of autonomous operation from Nimitz- and Ford-class carriers, with an unrefueled endurance of 11-14 hours and the capability for both hose-and-drogue and boom-and-probe aerial refueling.[180]

Another significant attribute of UCLASS is that—unlike most current UAS that are designed to operate only in permissive or lightly defended environments—UCLASS "must be capable of operating in hostile airspace, which means the aircraft design must feature low-observable

[176] Ibid.

[177] Gayle Putrich, "Insitu wins long-awaited US Navy STUAS deal," *FlightGlobal.com*, July 30, 2010.

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

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

[180] Graham Warwick, "Predator C Flexes its Sea Legs," *Aviation Week/Ares blog*, May 3, 2010.

traits."[181] Navy Secretary Ray Mabus said that "The notion here is that—just like the F-35 carrier version—it is going to be stealthy. It is going to be low observable," he says. "And, if you are going to integrate an airplane into the carrier air wing, it should be able to go into contested airspace."[182]

The Navy has awarded UCLASS concept study contracts to Boeing, General Atomics Aeronautical Systems, Lockheed Martin, and Northrop Grumman.[183] The UCLASS request for proposal is expected in fall 2011.[184]

Likely UCLASS contenders include the following:

X-47B

Northrop Grumman's X-47B, an advanced version of the X-47A UCAV-N contender, is nearly 36 feet long, with a wingspan of 62 feet. The increased wingspan in combination with the Pratt & Whitney F100-220U turbojet engine may allow X-47B an endurance of nine hours and range of 1,600 nautical miles. The X-47B features folding wing-tips that cut down on size, making it more suitable for storage aboard an aircraft carrier.[185]

Phantom Ray

System Characteristics. 36 feet long with a wingspan of 50 feet; single GE F404-102D engine. The X-45C was expected to achieve speeds of 450 knots and altitudes of 40,000 feet, with a flight duration of up to seven hours and a range of 1,200 nautical miles.

Program Status. First flown on May 27, 2011, Phantom Ray is a development of Boeing's X-45C J-UCAS contender. Although it is a company-funded one-off demonstrator, it is expected to contend for the Navy's UCLASS program.

Avenger/Sea Avenger

General Atomics is currently developing a third generation Predator that uses a turbojet engine to fly long-endurance, high-altitude surveillance missions. The Avenger (formerly "Predator C") will reportedly use the fuselage of the Reaper, but will be similar to Northrop Grumman's Global Hawk in payload capacity and flight performance. General Atomics confirmed its offer of the "Sea Avenger" variant for the UCLASS competition in 2010.[186]

> With a 41-foot long fuselage and 66-foot wingspan, the Avenger is capable of staying in the air for up to 20 hours, and operating at up to 50,000 feet. Powered by a 4,800-lb. thrust Pratt & Whitney PW545B jet engine, it can fly at over 400 knots—50 percent faster than the turboprop-powered Reaper unmanned plane, and more than three times as quick as the Predator.
>
> General Atomics says the first Avenger is now flying two to three times a week.... A second and third Avenger are now in production. It'll be a little longer than the first—44 feet—

[181] Amy Butler, "Mabus: Uclass Must Operate In Contested Airspace," *Aerospace Daily*, April 6, 2011.

[182] Ibid.

[183] Carlo Munoz, "Navy Awards Multiple Contracts For UCLASS Development," *Defense Daily*, June 27, 2011.

[184] Amy Butler, "Mabus: Uclass Must Operate In Contested Airspace," *Aerospace Daily*, April 6, 2011.

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

[186] Graham Warwick, "Predator C Flexes its Sea Legs," *Aviation Week/Ares blog*, May 3, 2010.

> and able to haul a 6,000 pound payload. That's a 50 percent improvement over what the Reaper can carry.[187]

Lockheed is also reported to be interested in entering an RQ-170 variant in the UCLASS competition.[188]

High Altitude Long Endurance Systems

Tactical UAS, ranging from Raven to Reaper, have become familiar, and the prototypes of combat UAS like UCLASS are already in the air. But a new class of UAS is under development that would move beyond the endurance and range of Global Hawk to provide much more persistent platforms for ISR, data relay, and other purposes. Among these HALE, for high altitude long endurance systems, are:

Phantom Eye

Proposed by the Boeing Phantom Works, Phantom Eye would use hydrogen-fueled automobile engines to carry a 3,000-pound payload for 10 days.[189] A 150-foot wingspan demonstrator version hopes to achieve "up to four days of endurance at 65,000 ft." with a first flight in autumn 2011.[190]

Orion

In 2009, Aurora Flight Sciences unveiled the Orion, which would use hydrogen-fueled diesel engines to carry a 2,600-pound payload at 30,000 feet, or a 1,000-pound payload for 10 days at 15,000-20,000 feet.[191] Its demonstrator version is designed to reach 5-day endurance with the same payload.[192] Orion is part of a system called MAGIC, an acronym for Medium-Altitude Global ISR and Communications, being developed by under a $4.7-million contract from the Air Force Research Laboratory.[193]

Global Observer

A third hydrogen-powered HALE contender, AeroVironment's Global Observer "can fly as high as 65,000 feet for five to seven days while carrying a 400-pound payload."[194] It is optimized for "persistent communications and remote sensing."[195] Global Observer flew for the first time in 2010, but the first test aircraft crashed in April 2011.

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[187] Noah Shachtman, "Killer Drones Get Stealthy," *Wired.com/Danger Room blog*, July 19, 2010.

[188] Amy Butler, "Mabus: Uclass Must Operate In Contested Airspace," *Aerospace Daily*, April 6, 2011.

[189] "U-2 Option," *Defense Daily*, April 25, 2011.

[190] Graham Warwick, "Phantom Eye UAV Readied For Hydrogen Flights," *Aerospace Daily*, September 26, 2011.

[191] Marcus Weisgerber, "USAF Seeks Endurance-Payload Sweet Spot," August 29, 2011. Graham Warwick, "Orion UAS To Demo 120-hr. Endurance," *AviationWeek.com*, September 20, 2010.

[192] Graham Warwick, "Aurora Unveils Orion Persistent UAV," *Aerospace Daily*, September 16, 2009.

[193] Richard Whittle, "Gorgon Stare Broadens UAV Surveillance," *Defense Technology International*, November 3, 2010.

[194] Marcus Weisgerber, "USAF Seeks Endurance-Payload Sweet Spot," August 29, 2011.

[195] AeroVironment, "Stratospheric Persistent UAS: Global Observer," undated press release, http://www.avinc.com/uas/stratospheric/global_observer/.

Airships

Several firms (Lockheed Martin, MAV6, Northrop Grumman, and others) are developing unmanned airships for long- to extremely long-endurance missions. "In comparison with unmanned fixed-wing aircraft, such as the Global Hawk or Reaper, an airship ... would have a similar payload and substantially longer endurance but considerably slower cruise speed."[196] The Army's High Altitude Airship program "has the long-term objective of building an airship capable of carrying a 2,000-pound payload and generating 15 kilowatts of power (to run the payload and aircraft systems) at 65,000 feet for more than 30 days."[197]

Author Information

Jeremiah Gertler
Specialist in Military Aviation

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[196] Congressional Budget Office, *Recent Development Efforts for Military Airships*, Pub. No. 4239, Washington, DC, November 2011.

[197] Ibid. For more information on lighter-than-air platforms, see CRS Report RS21886, *Potential Military Use of Airships and Aerostats*, by Christopher Bolkcom.