Current State of UAV R&D and Deployment in the USA

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1. Overview

The last 10 years have seen an explosive growth of UAV research and development as well as operational deployments by the United States. The primary driver of all UAV systems has been military funding. With the exception of some demonstration programs, use by commercial operators or local governments, have been postponed due to costs. NASA operates a small number of research vehicles derived from the currently used military systems. No significant system development exclusively for commercial or scientific users is underway.

2. Micro UAVs

These are primarily being developed as reconnaissance systems for military use against individuals or small groups, either indoors or inside buildings. DARPA leads this effort and is funding both university research as well as evolution into practical systems. DARPA's driving philosophy is that systems should invoke "biomimicry" and imitate natural creatures, flapping like birds and bees, so the vehicles will be less noticeable when operating at close range to their targets. The key technology would be the ability to navigate an unfamiliar indoor environment without GPS. This requires a high level of machine intelligence which has not yet been fully demonstrated. This is the primary focus of the university-level micro UAV research funding. Although many groups are working on these devices, AeroVironment continues to hold the industry leadership in this area with its recently demonstrated Hummingbird. These types of systems are still more than 10 years from operational field use. For DARPA, this is a relatively low-level expenditure that will likely continue to be funded for a long time.

▲ Nano Air Vehicle /Credit: AeroVironment, Inc.

3. Small UAVs and Man-Portable Systems

These are military reconnaissance systems used by either an individual or a small group of people in support of daily search and patrol missions. Many different companies have tried to enter this market, and many different systems have been tried. Unfortunately, due to the size of these systems, there is a lot of confusion with the model airplane business, both from the customers and from the developers. This has resulted in a rapid evolution of many unsuccessful types, some of which were in active military service for only a few years before being withdrawn. Also, the size of the vehicles puts them in an area that was until recently dominated by unreliable propulsion systems derived from model airplanes or ultralight sport aircraft. At the larger end of the scale, existing systems are being withdrawn from service or allowed to reduce down through attrition without direct replacement. An exception has been Boeing's Insitu Group with a series of vehicles based on their ScanEagle UAV. These vehicles can carry more and fly faster than their smaller battery-

powered cousins, but they also require specialized landing systems or capture nets. Despite twenty years of efforts, no one has succeeded in putting a 1kW heavy fuel internal combustion engine into active service, despite periodic announcements of a breakthrough in this area.

▲ Raven /Credit: AeroVironment, Inc.

This market is dominated at the smaller end by AeroVironment's Wasp, Raven and Puma (formerly Pointer) systems, which are powered by electric motors with batteries that can easily be charged in the field. A key technology for these vehicles is the use of full-featured autopilots that allows any soldier to operate them with minimal training. These systems remain out of reach for use by scientific researchers and local fire and rescue due to their relatively high costs. These small electric platforms have reached maturity and research funding is now being focused on making smaller reconnaissance payloads that can fit on the battery-powered vehicles. This will force hydrocarbon fueled small UAVs into a niche market either for very long range/endurance (up 48 hours) or for only the heaviest, most electric power-intensive payloads.

▲ Puma AE /Credit: AeroVironment, Inc

Table 1. Small and Man-Portable UAV Systems.

Name	Manufacturer	Customer	Unit Cost	First Flight	Span	Payload	Performance	Number Built
Wasp-III	AeroVironment	US Army	$49k	2007	0.7m		1hr, 5km range, 3km altitude	hundreds
RQ-11 Raven	AeroVironment	US Army, Marines	$35k	2001	1.4m	0.25kg	1.5hrs, 10km range, 3km altitude	~10,000
Puma (formerly Pointer)	AeroVironment	US Army		2001	2.6m	0.5kg	2-4hrs, 15km range, 3km altitude	hundreds
ScanEagle	Boeing / Insitu	US Navy		2002	3.1m	0.9kg	24hrs, 3500km range, 6km altitude	~1000

4. Medium Altitude Reconnaissance/Strike Platform

This is the category that was pioneered by the famous Predator series of aircraft made by General Atomics. The initial success of this series has much to do with the simple constraints on the project: this was a relatively conventional airplane with a commercial engine that was remotely operated by an experienced pilot. Only later were complexities like long endurance, higher altitudes, de-icing equipment and remote weapon deployment developed.

Flying between 6-12km altitude puts this category directly into icing conditions, and the endurance

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: ED07–0038–008 Date: March 5, 2007 Photo By: Tony Landis

Silhouetted by the morning sun, NASA's Ikhana, a civil version of the Predator B unmanned aircraft, is readied for flight By NASA Dryden crew chief Joe Kinn.

▲ Ikhana /Credit: NASA

requirements tend to dictate relatively low-power propulsion systems. Together this means these types are susceptible to icing conditions, so research continues to seek improvements in de-icing capabilities for low-speed, non-jet powered aircraft.

In the past, NASA Dryden has operated several Predator derivatives for its Earth Science missions and for use in UAV see-and-avoid experiments. The only one they are currently operating is a version of Predator-B called Ikhana. It has the same performance and uses the same standard ground station as the Air Force MQ-9 systems.

The Predator series is a success, but the Air Force is looking for the next generation of systems with a program called MQ-X. It would carry a 2300kg payload, fly twice as fast, have improved weather capability and a modular, multi-mission payload. This will probably be the largest UAV contract of the next 5 years and likely is worth billions of dollars in the long term.

An odd player in this business is the Orion by Aurora Flight Sciences. Aurora started by trying to build small, high-altitude UAVs, something that it never really succeeded in, but later teamed with Boeing to design a hydrogen-powered HALE airplane to compete with AVs Global Observer. Boeing went its own separate way, and Aurora revised Orion to be a medium altitude endurance airplane –capable of flying five days at 6km with a 430kg payload while running on heavy fuel. The intended payload differs from the Predator. The Orion will carry one of the Air Force / DARPA developed Wide-Area Airborne Sensors (WAAS), for example: Gorgon Stare. Gorgon Stare is an attempt to view an entire city simultaneously with IR sensors and to automate the intel-

ligence collection. As this sensor is currently designed, it requires the modest 6km altitude of the Orion. If Gorgon Stare fails, there are several other programs with different strategies for the same goal that will replace it. The UAV part of the program, which uses off-the-shelf engines, is funded by the US Air Force at approximately $100M and is expected to make its first flight this year.

The only major lighter-than-air systems in active development also fit into the Medium Altitude category. The Long-Endurance Multi-Intelligence Vehicle (LEMV) is a direct competitor to the Orion concept. The US Army is providing $517M to Northrop Grumman for this hybrid vehicle that is an airship that gets some of its lift dynamically from the shape of its hull. A very similar program that is a pure airship is the Blue Devil made by TCOM. The Air Force is providing $211M in funding. It is not clear in public materials what kind of propulsion system either vehicle uses, but neither seems to be primarily solar powered, if at all. Statements about the Blue Devil indicate it has enough fuel for a 7-day endurance mission and the LEMV for a 21-day mission. The Blue Devil is expected to fly before the end of this year and the LEMV in early 2012.

Table 2. Medium Altitude Reconnaissance / Strike Systems.

Name	Manufacturer	Customer or Funding Agency	Funding Level or Unit Cost	First Flight (projected)	Span	Payload	Performance	Number Built
MQ-1 Predator (Predator-A)	General Atomics	US Air Force, Army	$5M each	1994	15m	~500kg	24hrs, 3700km range, 7.6km altitude	~360
MQ-9 Reaper (Predator-B)	General Atomics	US Air Force	$11M each	2001	20m	1700kg	14hrs, 3700km range, 14km altitude	~60
Orion	Aurora Flight Sciences	US Army	$100M	(2011)	40m	450kg	120hrs, 24000km range, 6km altitude	1 in production
MQ-X		US Air Force		(2015)		2300kg	in definition phase	future

5. UCAV (Unmanned Combat Air Vehicle)

Unmanned Combat Air Vehicle (UCAV) is a long-term program to make fighter and long-range strike aircraft operate unmanned. Key characteristics of this program are the requirements for radar-evading stealth technology as well as a modular airframe that allows a single vehicle to be reconfigured for different types of missions. These requirements dictate small, tailless configurations and have involved a lot of flight controls development work which continues to this day. Approximately $2B has been spent over the last ten years primarily on the two main flying test vehicles, the Boeing X-45 and the Northrop Grumman X-47 Pegasus.

The next area of development will be in robust, secure datalinks and tactical control strategies that will allow swarms of these vehicles to be operated from a single manned aircraft or "mothership." A goal of these experiments is to automate as much as possible the tactical operation of this type of vehicle. Therefore, the operator need only "guide" the UCAV strike force and make a limited number of top-level decisions regarding its operation. This is a long-term project. All vehicles in this category are highly experimental, and it is unlikely that the US will field an operational vehicle in less than 10 years.

6. High Altitude Endurance Surveillance/Comm Relay Platforms

This category has long been seen as a driving case for unmanned vehicles. Although a few high-altitude airship concepts continue to be discussed and studied, only aircraft programs have major development funding.

The Global Hawk was developed as an unmanned replacement for the U2 spy plane. However, demand for intelligence is so high that the 30 aircraft U2 program has been repeatedly extended even

▲ Global Hawk /Credit: NASA

as more Global Hawks are entering service. The original design requirement of 48 hours at 20km for the Global Hawk has never been met. The best it can currently achieve is 32 hours at 18km. Global Hawks have also been troubled by system reliability problems which limit their responsiveness and availability for reconnaissance missions. Despite these significant shortfalls and a number of crashes early in the program, the Global Hawk is considered a modest success, perhaps because it is the only system to have made it to operational status after 25 years of continuous effort in HALE aircraft. Only now that the RQ-4B model is available it will enter full production, almost 16 years after the original start of the program. It will also likely be the first HALE UAV to be exported to foreign services, with the EuroHawk version for Germany leading way, followed by South Korea. Last year, NASA Dryden started operating three of the original production aircraft for scientific research missions. No proposals have publically appeared for commercial use of the Global Hawk.

Two HALE programs are currently developing hydrogen-fuelled aircraft with multi-day endurance. The Phantom Eye by Boeing has a 46m wingspan and is designed for 4-day endurance at 20km with 200kg payload. It is expected to make its first flight later this year.

The Global Observer by AeroVironment has already been in low-altitude flight-testing since summer of last year. Its 54m wingspan is designed to carry 180kg at 20km for five days or 17km for seven days.

▲ Global Observer /Credit: USAF via AeroVironment, Inc.

Both Phantom Eye and Global Observer development will likely continue evolving toward operational demonstrations in the next one or two years even before full-scale production is started. It seems unlikely that both vehicles would be funded to production since their performance points are so similar.

Boeing and AeroVironment both have concepts for larger designs which would extend the endurance to 10-14 days. It is unclear if military customers will be satisfied with 5-7 day endurance or push to obtain funding for the larger vehicles. A key problem of these designs is getting

▲ Zephyr /Credit: QinetiQ

Table 3. HALE Surveillance / Comm Relay aircraft development programs.

Name	Manufacturer	Customer or Funding Agency	Funding Level or Unit Cost	First Flight (projected)	Span	Payload	Performance	Number Built
RQ-4B Global Hawk	Northrop Grumman	US Air Force	$70M each	1998	40m	1360kg	32hrs, 16000km range, 18.3km altitude	~20
Phantom Eye	Boeing	company funded	?	(2011)	46m	200kg	4 days at 19.8km altitude	1 in production
Global Observer	AeroVironment	multi-agency funding	$120M	2010	53m	180kg	5 days at 19.8km, 7 days at 16.7km altitude	2
SolarEagle demonstrator	Boeing	DARPA Vulture	$89M	(2013)	132m	-	90days at 18.3km altitude	1 in production
Zephyr	Qinetiq	DARPA / British MOD	?	2006	22.5m	2.5kg	14days at 21.3km altitude	1

Table 4. Airship HALE Surveillance / Comm Relay development programs.

Name	Manufacturer	Funding Agency	Funding Level	First Flight (projected)	Length	Payload	Performance	Number Built
LEMV	Northrop Grumman	US Army	$517M	(2012)	110m	1100kg	21 days at 6.7km altitude	1 in production
Blue Devil	TCOM LP	US Air Force	$211M	(2011)	110m	1100kg	7 days at 6.4km altitude	1 in production

large quantities of liquid hydrogen to operating bases and establishing an economical supply chain for its continual delivery. There is no doubt operators will look critically at the cost and complexities of using hydrogen. This will mark the first time that any operational system except for expendable space rockets, has used liquid hydrogen as a fuel. One should assume that there will be a competition at some point between the Orion and a heavy-fuel derivative of Global Observer or Phantom Eye.

Table 5. Vertical Takeoff and Landing Systems.

Name	Manufacturer	Funding Agency	First Flight (projected)
A-160 Hummingbird	Boeing	DARPA	1998
Eagle Eye	Bell Helicopter	company funded	1993
MQ-8 Fire Scout	Northrop Grumman	US Navy	2000
Fire-X	Northrop Grumman	company funded	2010
K-Max	Lockheed / Kaman	company funded	2010
unmanned Blackhawk	Sikorsky	company funded	(2015)

Despite a recent realignment toward hydrogen, research and development continues for solar-electric endurance aircraft. DARPA is providing $89M to Boeing for the Vulture program. The goal is a vehicle capable of staying aloft for 5 years of continuous flight. The second phase of the project involves building a technology demonstrator of approximately 131m wingspan which will be capable of flying for a minimum of three months during the winter season. This demonstration is scheduled for the fall of 2013 although the aircraft is still in construction and a date for the first flight has not been announced. Boeing had teamed up with U.K. defense company Qinetic to fly their Zephyr at Yuma Proving Grounds in Arizona. Last year, the Zephyr flew for 14 days at altitudes of 18-21km. It is not clear if this effort will continue as a technology support for Vulture.

7. Vertical Takeoff and Landing Systems

Most vertical takeoff systems are intended either for shipboard use, as a kind of vertical flying equivalent of the Predator, or for automated delivery of light cargo to troops in the field. Typically these are converted from existing manned light helicopter systems. One exception is Bell's mini tilt-rotor Eagle Eye that has been in development for over 20 years. Another is the A-160 Hummingbird, which is an experiment to make a very long-range (3700km) helicopter. None of these efforts is funded to significant levels, but like the Micro UAV systems, is likely to remain funded at a low level for the long term.

8. Conclusions

2011 and 2012 will be a very exciting time for the HALE category, with several high endurance aircraft and airships starting their flight testing in this period.

Ten years ago, almost any organization with an idea could get a project funded and many ideas were tried. Several systems were put into service before their problems were fully resolved. This was accepted as a means of learning what how to write the requirements and how to best use such systems. In most cases those systems have been completely withdrawn from service or scrapped. The rush of Defense Department money that has come into the unmanned vehicle business over the last 10 years is starting to diminish. For the successful companies, funding levels will change very little. The industry and the customer have matured and over the next several years and many smaller, less successful companies will be forced to merge or leave the business.■