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A Review of Unmanned Aerial Vehicle Designs and Operational Characteristics

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It is a fact, though a very simplistic fact, that unmanned aerial vehicles (UAVs)[1] are little aircraft, more or less. This means that the UAVs follow the laws of aerodynamics, and in a larger sense, the laws of physics. In other words, the category of vehicles called "aircraft" (heavier-than-air aerial vehicles) can be divided into two sub-categories, manned and unmanned. It is fairly common that, under certain conditions, manned aircraft can appear strange and unusual to observers, even pilots. It is certainly reasonable that UAVs could appear even more strange and unusual than manned aircraft. UAVs are a relatively new development. Even more important, they do not have the major design constraints associated with having a pilot onboard. This paper explores the characteristics of UAVs that could result in their being misidentified as anomalous phenomena, instead of as aircraft.

It is worth noting that the Federal Aviation Administration (FAA), which regulates aircraft design and operations in the United States, has stated emphatically that UAVs must meet the "rules of the road," essentially as do manned aircraft. The FAA standards are still being developed, but the FAA has made it clear that they will not let aviation safety be degraded by

[1] The term "unmanned aerial vehicle" (UAV) is interchangeable with the terms "remotely piloted vehicle" (RPV) and 'remotely operated aircraft" (ROA). Today the term is also commonly used interchangeably with "drone," though some droned UAV/RPV aircraft were once manned aircraft such as the F-100, F-102, and F-4. The FAA and DOD also use the term "unmanned aerial system" (UAS) interchangeably with the other terms. The Government prefers this term in order to emphasize that the system includes the vehicle PLUS the remote operator and communications links. The broader term "unmanned aircraft" includes airships, which are not a part of this discussion.

UAVs.[2] There will be volumes of airspace that are at low altitude and uncontrolled where there will be reduced regulation, much like the rules environment that applies to the operation of scale model aircraft (which may be considered as personal UAVs). Government UAV operations can also be separated from all other air traffic, using airspace exclusively assigned to the Government, such as restricted areas. Government UAVs often cannot meet FAA requirements, so this concept of separation is frequently used to prevent collisions.

For virtually all operations where the air traffic is mixed, the concept of see-and-avoid applies to UAVs as it does to manned aircraft. Manned aircraft have the pilot's senses for avoiding other aircraft and the ground. With UAVs, there are usually sensors and cameras on the vehicle that relay environmental/traffic information to the remote operator. There also may be a chase pilot (flying nearby) operating as a safety observer, or there may be a suitable radar environment that supports safety. The use of chase aircraft could explain why UAVs are frequently seen in the company of a more-conventional aircraft. The UAVs that are flown in the USA, where there may be mixed air traffic, also have the same exterior lighting requirements as manned aircraft, the same transponder requirements, and the same compliance requirements for flight rules.

UAVs are even more varied in their physical characteristics than are manned aircraft. They are as small as 4 inches, and some have wingspans of well over 200 feet. Their weights range from less than a pound to more than 40,000 pounds. Some can hover, and some can travel faster than Mach 2 (research and development projects intended to develop hypersonic UAVs are underway). Figure 1 is a NASA photo of two paint schemes of the venerable Northrop Grumman / Air Force / NASA UAV, "Global Hawk," that can fly above 60,000 feet and stay aloft in excess of 40 hours on its scientific missions. Figure 2 is a NASA photo of the X-45A boomerang-shaped UAV delivering an air-to-ground weapon, with an F-18 chase aircraft nearby.

Many UAVs will appear to pilots as manned aircraft, except that they have no cockpit. It would be unlikely that a pilot would consider a UAV to be an unidentified aerial phenomenon (UAP) if the vehicle had the general shape and operating characteristics of an aircraft. However, there are currently some UAVs, and have been in the recent past some experimental UAVs, that could appear too bizarre to be readily identified. In addition, it is also likely that there are several classified "exotic" UAV development projects underway now and will be many more in the future. Some may have ducted propulsion and could appear essentially saucer- or cylindrical-shaped, without wings. These could hover and fly vertically, perhaps with unprecedented accelerations. The elimination of the pilot and associated hardware and systems may allow for unimagined performance. UAVs will surely attain many-Mach speed and fly to or past the edges of space. Without the limitations of a pilot onboard, UAVs could attain missile-like performance. In fact, missiles are UAVs of sorts, and are capable of accelerations of twenty Gs or more. There seems little doubt that such a vehicle could appear phenomenal to a pilot seeing it with no warning, for the first time.

[2] AFS-400 UAS Policy 05-01, Unmanned Aircraft Systems Operations in the U.S. National Airspace System – Interim Operational Approval Guidance, September 16, 2005.

Table 1 is a brief listing of some of the UAV characteristics that may puzzle a pilot or other observer. The researcher has narrowed this list to thirteen key features. This could certainly be expanded to include much more detail.

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: ED07-0244-074 Date: December 3, 2007 Photo By: Tony Landis

NASA's two Global Hawks, one sporting a NASA paint scheme, the other in its prior Air Force livery, are shown on the ramp at the Dryden Flight Research Center.

Figure 1. Global Hawk, Courtesy of NASA Dryden Flight Research Center (DFRC)

NASA Dryden Flight Research Center Photo Collection
http://www.dfrc.nasa.gov/Gallery/Photo/index.html
NASA Photo: EC04-0100-10 Date: April 18, 2004 Photo By: Jim Ross

X-45A in flight with F-18 #846 chase aircraft, during first GPS-guided weapon demonstration flight

Figure 2. X-45A UAV with F-18 Chase Aircraft, Courtesy of NASA DFRC

FEATURE	OPTIONS or RANGE of SPECIFIC FEATURE
Size	Length, range of inches to 60+ ft; Span, range of inches to 240+ ft
Weight	Ranging from ounces to 40,000 lb (or more)
Speed	Ranging from hover to Mach 2+ (perhaps much more)
Propulsion System	Glider, recip, turbojet, turbofan, rocket, ram-jet, solar, fuel cell, exotic
Lift	Wings, rotor, lifting body, ducted fan, combinations
Aspect	Conventional aircraft, missile, spheroid, cylindrical, saucer, other
Flight Characteristics	Ranging from conventional aircraft performance to seemingly incredible performance with very unconventional control mechanisms
Lighting	Conventional, though classified systems may stretch this
Surface Appearance	Painted, metallic, other
Launch	Hard surface, water, "mother" aircraft, pedestal, sling shot, person (hand launch), truck, rocket assist, rocket launch vehicle, underwater (submarine), orbital vehicle (such as space station)
Recovery	Hard surface, water (aircraft carrier or splashdown), in-flight net, exotic
Control Method	Ranging from complete person-in-loop to virtually autonomous
Mission	Military and law enforcement, recon., crop spraying, other unlimited commercial missions that are not human-rated

Table 1, Selected UAV Features and Options

There is no doubt that aviators, air traffic controllers and other members of the aviation community will be experiencing more and more visual and sensor contact with UAVs in the future. The performance of some UAVs will continue to be more and more phenomenal, as budgets for UAVs grow rapidly. (One forecast estimates the emerging annual UAV market to reach nearly $7.2 billion by 2009.[3]) There is the inescapable fact that being able to eliminate the pilot, the entire cockpit environment, the redundancy and multiple systems required for the safety of aircrews, and the limits associated with manned flight will allow for rapid improvements in performance of UAVs. People are going to be seeing objects of strange shape doing things that don't seem possible. It is even known that research is underway to develop materials and technologies that will allow a UAV to "morph" in flight in order to optimize performance throughout its flight envelope. Research is also underway to develop UAVs that do not require conventional control surfaces and distinctive horizontal and vertical stabilizers for stability and control. It is an understatement to say that such vehicles could be considered to be "unexplained." Members of the aviation community should be aware of these new developments. Further, those persons investigating reports of UAPs must consider UAVs (especially exotic UAVs) increasingly to be possible explanations of these sightings.

Figure 3 is an artist's concept of the Cormorant submarine-launched, rocket-assisted UAV. Such a UAV would unlikely be seen over the U.S. land mass. However, it could be seen near the coast, and it could certainly be considered to be a UAP. Seen in a side view it could

[3] www.asdreports.com, "The UAV Market Report: Forecasts and Analysis 2008-2018, Visiongain, 6/12/2008

even be considered nearly saucer-like.

Figure 3, Cormorant UAV (Artist's Concept), Courtesy U. S. Air Force (USAF)

Figure 4 is a prototype of a small UAV. It is the BAE version of the Organic Air Vehicle II, a surface-launched, ducted propulsion vehicle. It is small, but highly maneuverable. Seen from close range, flying vertically, but with no rotary wing and no flight control surfaces, it could possibly be considered to be a UAP.

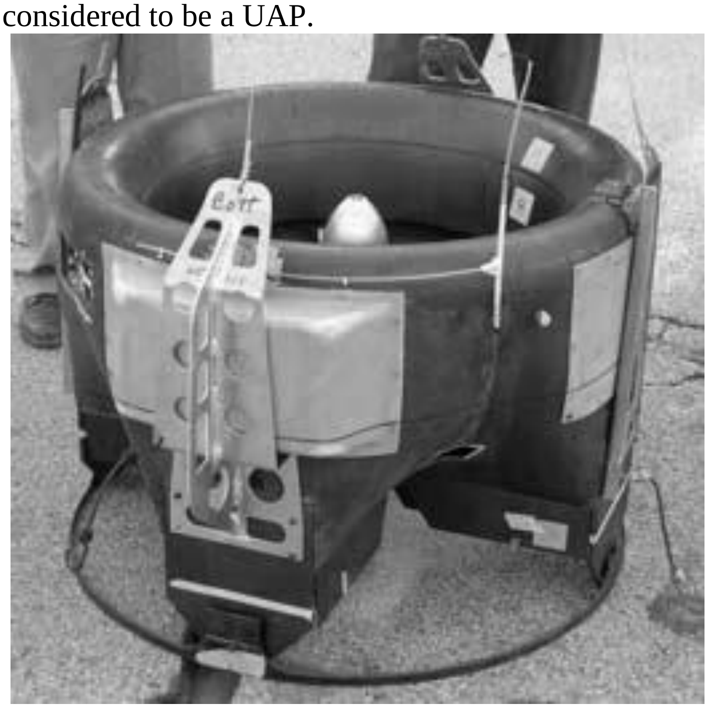

Figure 4, BAE Concept Organic Air Vehicle II, Courtesy USAF

Their pilotless nature is what drives three important characteristics of UAVs, size, performance, and electro-magnetic (EM) influence. At a minimum, having a cockpit, manual controls and pilot onboard requires at least 40 ft^3 of space. If there is an ejection seat, this volume is even greater. This volume of space dedicated to the occupant is a significant driver of the size of the aircraft and prevents an aircraft from being as small as functional UAVs can be. Having the pilot onboard drives not only the fuselage size, but also the amount of wing surface required. The pilot must also be counter-balanced to make the center of gravity of a manned-aircraft manageable. The UAV greatly minimizes these complications, allowing these vehicles to have much more variability of design.

The pilot in a manned aircraft also limits performance in at least two ways. Most obviously, piloted aircraft are designed to be limited to around 8G, or less. This is a serious limit on performance. In general, UAVs have no such limitation. If the mission benefits from a vehicle that can pull 20G or accelerate like a rocket, the UAV can be assigned that mission. A more subtle aspect of this performance issue is the safety of the system. A manned vehicle must tolerate multiple failures and allow the pilot to survive. This requires redundancy of many systems and likely mitigates against propulsion systems having serious single-failure modes. The weight of the safety features adversely impact performance, and being able to omit them is a distinct advantage of UAVs.

UAVs must make up for not having a pilot. This is done by having a remote pilot, linked to the vehicle with radio frequency signals. Each UAV is bandwidth intensive, and carries with it an EM environment that may greatly exceed that of a manned aircraft. The airspace system will be challenged by the band and bandwidth requirements of an airspace system populated by a large number of UAVs.

These factors, size, performance, and EM environment together, mean that pilots and air traffic controllers will be exposed to vehicles that seem much more amazing than current aircraft. Pilots and controllers may also experience unusual influences from the unique and changing EM environment associated with UAVs. Observers and investigators of UAPs must certainly consider these factors carefully.

The author encourages others to further this research as UAVs continue to be developed and to update the information on UAVs that may be useful to aviators and investigators of UAPs. The author also suggests that this subject be expanded to cover remotely piloted lighter-than-air vehicles. There is very likely to be coming a time in the near future when there will be very interesting airships doing some very surprising and phenomenal activities, while appearing to observers to be quite strange.