THE UBIQUITOUS UAV

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"Man must sit in chair with mouth open for very long time before roast duck fly in."
--- Chinese Proverb

For many years unmanned aerial vehicles (UAVs) have been on the verge of being produced for significant civil and commercial applications. But the UAV industry cannot just "sit with its mouth open" and expect to reap its just rewards. Much needs to be done to determine which of the many potential applications are technically and economically feasible. Many UAV civil and commercial applications seem reasonable. But if only a handful of UAVs are needed to satisfy the market for a given application, no UAV developer is likely to undertake the risk and expense of entering that market. The risk is reduced if many applications, each requiring only a few systems, can be satisfied with a single basic UAV design plus a few minor modifications.

Also, the Federal Aviation Administration (FAA) must formulate *reasonable* rules for civil and commercial applications within the U.S. For example, rules concerning collision-avoidance systems for large-sized UAVs are not necessarily relevant for hand-launched UAVs.

(Note: In our usage, c*ivil* applications are those involving non-defense government agencies, including federal, state and local governments, while *commercial* applications involve the private sector).

STARTING FROM SCRATCH

The UAV was developed primarily for military applications from its inception during World War I. Its entry into the civil/commercial market will be almost from scratch, with almost no history of civil government or commercial industry operations, no supporting infrastructure or expertise, and no existing customer base. There is a large potential market, as there was for the airplane when it was invented. But like the early manned airplane, the UAV will have to overcome technical, economic, political, legal, and psychological barriers before achieving full commercial success and societal acceptance. It took more than two decades for the airplane to become commercially viable, and that was after a period of accelerated technological progress prodded by military requirements during World War I. Likewise, military applications have spurred the development of today's UAVs, with advanced sensors, processors, and software. They are far more capable than their predecessors which flew during World War II and the war in Vietnam.

In 1981, the General Accounting Office (GAO), in a report to the Congress (*DOD's Use Of Remotely Piloted Vehicle Technology Offers Opportunities For Saving Lives And Dollars*) noted that "the predominate factor against widespread civil use is the lack of development funds and the market potential to attract industry developers. Widespread use of unmanned vehicles in civil aviation is, therefore, not likely in the near future. Unless they are developed by the military, which could bring costs down, they will not be affordable." Thus the recommendation that civil should follow military development.

The GAO's concerns are still valid after nearly thirty years. Significant investment is still needed for many civil applications, and the market remains too uncertain for industry to invest by itself in the technology. But dual-use government funding for the fledgling UAV industry can be justified because numerous civil government agencies are potential users of UAVs for a wide variety of missions. The government, especially the FAA, must also formulate rules for UAV operations and address legal/liability issues.

APPLICATIONS

The remarkable success of UAVs during *Desert Storm* gave the world a brief glimpse of their potential. This was followed by extensive experience and success with many different kinds of UAVs from the U.S. and allies in Iraq and Afghanistan. Within the military, UAVs are no longer a technological solution looking for a problem. Now production cannot keep up with demand.

It is now time to transition UAVs to the civil/commercial sector as recommended long ago by the GAO; they are ideal for a defense conversion pilot program. UAV civil/commercial applications could begin to dominate the UAV market, worth billions of dollars, in the next ten years. The civilian market for UAVs could grow at a rate of four to five times faster than the military market in the next ten to twenty years.

UAVs can take many forms: fixed wing, rotary wing, glider, gyroplane, or ducted fan; heavier than air or lighter than air; single engine or multi-engine; propeller or jet; battery-powered electric, solar-powered electric, microwave-powered electric, gasoline, or diesel. UAVs can be any size, and they are capable of a wide range of performance: from small, hand-launched, low-altitude UAVs with a range of 10 km or less, to large wing-span, high-altitude, long-endurance UAVs able to traverse the globe. Civil and commercial applications can be performed by any or all of the many UAV forms, although certain applications tend to favor some vehicle and system configurations over others.

Civil/commercial UAVs, regardless of form, perform one or more of the following functions:

- Carry Sensors (for example: video, infrared, radar, and bio-chemical)
- Carry Communications Relays
- Carry Cargo

Civil Government Agencies

Many federal, state, and local government agencies are potential users of UAVs.

Prospective users include:

- **Homeland Security**
  - **Customs & Border Protection** (border patrols, surveys and control, counter narcotics and illegal alien surveillance; counter-terrorist nuclear, biological, and chemical (NBC) detection of weapons of mass destruction (WMD));
  - **Federal Emergency Management Agency** (disaster area surveys and assessment, facilitate relief operations, communications relay);
  - **Coast Guard** (surveillance for counter narcotics, illegal aliens, illegal fishing, national security threats; search and rescue operations);
- **Department of Agriculture** (pesticide & fertilizer spraying, insect sampling (bug catching), farm management);
- **National Aeronautics and Space Administration** (high altitude atmospheric sampling, such as for ozone and pollution; astronomical sensing);
- **Postal Service** (package delivery);
- **Forest Service** (area surveillance of forest to determine plant growth and provide fire control, counter narcotics surveillance, mapping, firefighting with water or chemicals);
- **Weather Service** (storm observation, tornado chaser);
- **Fish and Wildlife** (river and estuary surveys for illegal hazardous waste dumps, wildlife tracking and accounting in remote areas, mapping, counter poaching, fishing law enforcement);
- **Department of Energy** (monitoring nuclear facilities, reconnaissance for hazardous waste cleanup, atmospheric and climatic research);
- **Bureau of Land Management** (archeological surveys and monitoring, hazardous waste dump surveys and monitoring);
- **Federal Bureau of Investigation** (S.W.A.T support, counter narcotics surveillance, surveillance of suspects, search and rescue, detection of NBC & WMD);
- **State and Local Law Enforcement** (S.W.A.T support, riot control, area surveillance, highway patrol, counter narcotics surveillance, search and rescue; detection of NBC & WMD);
- **State Department** (area security surveillance);
- **Drug Enforcement Agency** (counter narcotics surveillance);
- **National Guard** (counter narcotics surveillance, riot control, law enforcement support, emergency relief surveys);
- **Environmental Protection Agency** (air sampling, hazardous waste dump surveys and monitoring);
- **Department of Transportation** (traffic and highway surveys and monitoring, crash mitigation, mapping);

- **Civil Air Patrol** (training cadet UAV pilots);
- **Merchant Marines** (training pilots for commercial maritime UAV operations);
- **Army Corps of Engineers** [civil missions] (monitoring recreational areas, surveying for dams, levees, and other construction projects, disaster control).

Commercial Applications

Private sector potential UAV commercial applications include:

- **Communication Relay** (equivalent to low-altitude satellites or cell towers);
- **Delivery Services** (overnight package and mail delivery, especially to small towns);
- **Security** (surveillance, counter-terrorism, detection of NBC & WMD);
- **Media** (overhead cameras for news and special events);
- **Real Estate** (pictures for selling property, surveying);
- **Surveying** (city and suburban planning);
- **Farming and Ranching** (check on cattle, fence lines, and work crews, spraying crops with pesticide and fertilizer, monitoring crops, soil, moisture, and pest conditions, and insect sampling);
- **Maritime** (monitoring and reconnaissance of fishing areas, shipping hazards and disasters, and search and rescue);
- **Lumber Industry** (tree spotter and removal);
- **Film Industry** (aerial photography and special effects);
- **Archaeology** (aerial observation of sites and digs);
- **Oil and Mineral Industry** (gas and oil pipeline monitoring in desolate areas, search for mineral and fossil fuel deposits);
- **Railroads** (aerial monitoring of rail lines and trains for operations and accidents).

As an example of civil/commercial applications, UAVs can be used in counter-drug law enforcement operations to: locate and maintain surveillance of illicit crops and processing laboratories; follow suspects in moving vehicles; patrol the border; serve as a communications relay platform; and view crime scenes from an overhead, all-encompassing perspective.

There is a potential role for UAVs at every stage of the drug cycle. Agents on foot or in automobiles can have their own organic air force to locate illicit crops hidden in clearings in the wilderness. They can survey suspicious areas from safe positions, yet remain within striking distance if the situation requires immediate action. Suspected drug processing facilities and distribution centers can be watched surreptitiously with small, naturally stealthy UAVs. For example, Israelis have tailed suspected terrorists in automobiles through towns and countryside, over hill and dale, for hours, without losing them or alerting them that they were under continuous observation.

For meteorological missions, UAVs offer advantages over satellites, balloons, and manned aircraft. Satellites cannot take direct measurements, and their measurements

can be imprecise. Balloons cannot be maneuvered to areas of interest, and they and their payloads are eventually lost. Manned aircraft have altitude and duration limitations, and the missions can be hazardous.

Satellites are used for agricultural applications, but the data on crop moisture, insect infestations, etc. are too aggregated and the response time too slow for the individual farmer to get any immediate benefit. A network of long-endurance UAVs, serving as low altitude satellites, could be used to micromanage farms and other agricultural enterprises. Data from the sensors could be beamed to the individual farmers in near real-time. He could water his crops, or spread fertilizer or pesticide when the conditions so indicate. Small UAVs can collect insect samples at tree-top height above a fruit orchard. The results of the sampling could be used to determine when to apply pesticide, and the optimum amount required.

UAVs can be used for real-time disaster (nuclear or chemical) control. The UAV can perform plume sampling and tracking, reactor and other site monitoring, and damage assessment. The UAV can also be used to monitor toxic leaks from oil and gas pipelines. UAVs are ideal for damage assessment in natural disasters, such as earthquakes, floods, hurricanes, volcanic eruptions, and forest fires. UAVs are also ideal for environmental surveys, including: video photo-geologic inspection of the ground; oil/gas fields control; fishery fields control; radiometric airborne surveys for geologic mapping and mineral prospecting; airborne magnetic and electromagnetic surveys, such as geological and geophysical mapping for mineral prospecting; airborne monitoring over geothermal areas; analysis of gases over gas fields; local monitoring of atmospheric conditions, such as temperature and humidity. The time required for geophysical surveys can be shortened by more than 80% compared with conventional methods.

UAVs have been flown to sample air over power stations; photograph water movements for a water authority; to provide forest surveillance, flood detection, wildlife observation, shoreline pollution detection and mapping, fishing law enforcement, and fishery spotting. Over the years, UAVs have been examined or developed for sundry other civil applications, including: autonomous package delivery; bridge inspection; collecting smoke for analysis; investigate environmental emergencies; and measure noise.

It remains to be determined whether all of this portentous possibility adds up to a marketplace in which UAV developers can make a living.