Exploring Transportation Applications of Small Unmanned Aircraft

SMALL UNMANNED AERIAL VEHICLES (UAVS) ARE INCREASINGLY AFFORDABLE, EASY TO TRANSPORT AND LAUNCH, AND CAN BE EQUIPPED WITH CAMERAS THAT PROVIDE INFORMATION USABLE FOR TRANSPORTATION AGENCIES.

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INTRODUCTION

Unmanned aerial vehicles (UAVs) have become smaller, more capable and less expensive because of military investment in the UAV industry and improved technology. Current-generation UAVs can be transported in small vehicles and launched from a road or a small truck but are still large enough to be equipped with cameras that can provide high-quality aerial information. These aircraft are capable of flying autonomously and completing preset flight plans.

This technology holds considerable promise for traffic and transportation organizations because a UAV could be a useful tool for a range of maintenance, planning and operations functions. Potential use of UAVs includes crash scene photography, surveying, security inspections, construction data collection and monitoring the condition and congestion of roadways.

Despite the promise of this technology, actual applications in the transportation world are limited. A major reason for this is institutional issues, particularly approval to fly by the Federal Aviation Administration (FAA). The FAA is responsible for the national air space over the United States and has expressed concerns about a UAV's ability to "see and avoid" manned aircraft. The FAA requires each UAV user to apply for a project-specific certificate of authorization (COA). While there is a considerable desire to use UAVs commercially, the FAA is still formulating policies concerning their use.

The University of Washington and the Washington State Department of Transportation (WSDOT) conducted a test of two types of UAVs to evaluate their technical capabilities while also exploring institutional concerns. The test was devised to help guide WSDOT's policies toward longer-term use of UAVs.

OVERVIEW OF THE UAV INDUSTRY

An *unmanned aerial vehicle* is a blanket term for an aircraft that flies without a pilot. The UAV industry has been cyclic, but over the past five years, the use and capabilities of UAVs have grown rapidly. This is due to increased military usage, as well as the availability of better sensors, lighter aircraft structures, more powerful computers, better communications and global positioning systems (GPS).

UAVs can range from full-sized aircrafts to vehicles that can be held in one hand. However, the unmanned aircraft of interest to WSDOT needed to be large enough to fly for at least an hour while carrying cameras and other sensors that could be used for roadway monitoring but also portable enough to be carried in WSDOT vehicles and launched on or alongside a road. The aircraft that generally fit this category are known as "man-portable" or "tactical" UAVs and weigh between 10 and 50 kilograms. Another category of small rotary-wing (helicopters) UAVs that have vertical takeoff and landing capabilities were also potentially valuable to WSDOT. Both types of UAV have advantages and disadvantages. Fixed-wing UAVs are simpler to fly, are a more proven technology and have better endurance, but they are less mobile than rotary-wing UAVs and therefore are less capable camera platforms.

PREVIOUS TRANSPORTATION APPLICATIONS OF UAVs

A recent survey of UAV use in transportation concluded, "It has been generally accepted UAVs can be very useful and successful for traffic surveillance."[1] In spite of the promise of UAVs, there have been few actual transportation applications. This is not only because the technology has just recently matured to a level of feasibility attractive to transportation agencies but also because of institutional barriers.

In 2003, in one of the more comprehensive transportation-related studies involving UAVs, Ohio State University tested traffic surveillance by using a small, (11-kilogram) fixed-wing aircraft. The researchers found after a series of flights that the aircraft could effectively collect useful transportation data, including traffic counts, intersection performance and parking lot utilization information.[2, 3]

In 2005, the Florida Department of Transportation funded a research project to investigate the use of UAVs for traffic and emergency management and conducted several test flights. It determined that the use of UAVs was a "cost-effective methodology to collect, analyze and provide selected data for a variety of tasks and missions." However, it also concluded that the FAA COA restrictions were too severe to make UAVs an effective tool, and the project was terminated.[4]

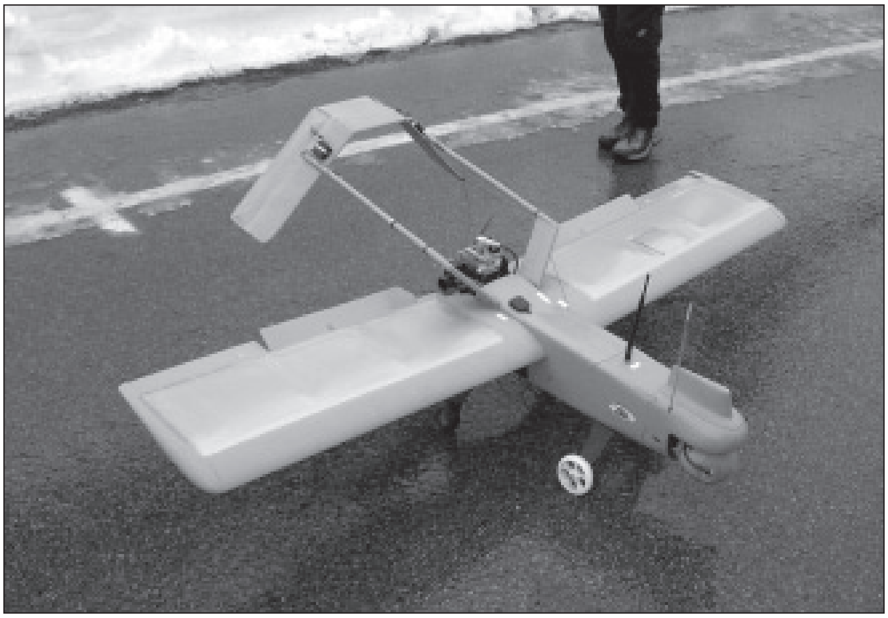

Figure 1.

TEST FLIGHT SETUP

The project described in this paper was an effort to "get a foot in the door" so WSDOT could become familiar with UAV technology and institutional issues. The effort was completed in conjunction with avalanche control operations because there was an obvious and immediate need for UAV capabilities in that area. Current WSDOT control efforts involve the use of military equipment to shoot explosives and the dispatching of snowmobilers with handheld charges, plus the occasional use of helicopters to drop explosive into inaccessible areas. This project's test flights explored whether, in the longer term, UAVs could fit within WSDOT's operations structure and provide more options for both avalanche control and other tasks.

Because the FAA application process is aircraft specific, the first step required finding a suitable UAV. A review of other studies, as well as discussion with WSDOT staff, suggested the following parameters:

- The tests should use smaller UAVs that could be operated on or next to a state highway.
- The actual flights would be completed under contract with the aircraft owners.
- The test would use a UAV system (the aircraft as well as a ground control station) that would potentially be affordable to a state department of transportation (DOT) and researchers decided the system should cost no more than $500,000. In addition, the UAV should be operable and maintainable by WSDOT personnel with appropriate training.
- Both a fixed-wing and rotary-wing system would be considered.

Given that FAA certification could be a major roadblock, this test also focused on reducing these concerns. The researchers decided to complete the test in a rural area. This reduced complications related to flying UAVs in an urban environment with potential conflicts due to tall buildings, more air traffic and a higher density of people on the ground. The application process and test were coordinated with WSDOT's aviation division.

THE FIRST TEST

The regional FAA office was contacted to initiate the COA process. Because the UAVs would be used in conjunction with avalanche control operations, a 14-by-14 kilometer test area was selected above State Route 20 in rugged terrain in north-central Washington State, USA.

The aircraft selected for the first test was the same aircraft used for the tests in Ohio mentioned above. This 11-kilogram UAV had a 1.8-meter wingspan and carried both a pan-tilt video camera and a digital camera (Figure 1). The aircraft could be disassembled and placed in a car trunk and could be launched from a vehicle and landed on the roadway. The ground station consisted of a portable computer and video screens that were placed in the back compartment of a van, plus an antenna on a tripod (Figure 2).

Approximately six months after submission, the FAA awarded a one-year COA to WSDOT to fly this UAV. The COA stipulated a number of communications protocols and required that observers remain in visual contact with the aircraft at all times.

The manufacturer of the UAV was contracted for the flights, and the test occurred in April 2006 along an avalanche-prone section of roadway that had been closed for the winter because of snow. WSDOT was in the midst of a month-long effort to reopen the road and was conducting avalanche control operations using a surplus military howitzer. The test flight was designed to evaluate the ability of the UAV to use an onboard video camera to view the roadway and survey the surround avalanche terrain as well as operate off a highway.

The flying conditions during the test were difficult, complicated by gusty winds and at times poor visibility. The UAV was launched by a catapult system mounted on top of a van (Figure 3) and was set to circle a preset GPS waypoint 750 meters above

Figure 2.

Figure 3.

Figure 4.

the roadway. The plane was then commanded to travel to selected avalanche-prone snow chutes, where it successfully captured video images. The next task was to fly the plane at 450 meters above the highway. The resulting videos provided a clear view of the roadway, and individual vehicles could easily be identified.

The test also highlighted some issues that may affect a transportation agency's use of a fixed-wing aircraft. Landing this UAV required a 30-meter long flat stretch of roadway, and this requirement could limit the use of these aircraft in crowded urban areas. In addition, the aircraft also had operational limitations related to difficult terrain and weather, and the aircraft's owner was understandably reluctant to push the aircraft to some areas in which WSDOT was interested.

THE SECOND TEST

Given the difficulties with terrain and weather encountered in the first test, researchers selected a more mobile, vertical-takeoff-and-landing UAV for the second test. The rotary-wing aircraft selected was originally developed in Japan for crop spraying. This UAV weighed 68 kilograms and had a rotor span of 3 meters (Figure 4).

The FAA's COA process had changed since the first test and now required an online application. The process required some detailed information about the aircraft as well as an airworthiness certification. As a public agency, WSDOT had an advantage in that it could certify the airworthiness of each UAV in the test. This certification was based mainly on the fact that the aircraft would be operated over an unpopulated area.

The second test occurred over two days in September 2007. The aircraft contracted for this project was operated by the Georgia Institute of Technology and was equipped with pan-tilt cameras (Figure 5). The ground station for this aircraft was set up in the back of a specially equipped truck that doubled as a transporter for the aircraft. The truck was equipped with generators, computers with aircraft control screens and external antennae on tripods (Figure 6).

The weather was warm, with light winds and good visibility. Initially the aircraft demonstrated the ability to autonomously follow a road using predetermined waypoints. This exercise was designed to simulate a survey before the start of snow-clearing operations on the road, but it was also a successful test of the UAV's ability to fly along a road centerline to record traffic conditions. The ability of the aircraft to hover provided a stable platform on which camera use was effective.

This test also demonstrated the aircraft's ability to survey terrain alongside a roadway. This capability could easily be used for construction site surveys, security checks and other tasks that benefit from an aerial view.

Several issues arose that affected the flight. The day was warm, and the resulting thinner air combined with the altitude degraded the capabilities of the UAV. In addition, as a safety precaution, the flight crew restricted the flight range of the aircraft to no more than one kilometer from the ground control station, limiting the potential effectiveness of the aircraft.

Figure 5.

Figure 6.

TRANSPORTATION APPLICATIONS

Both aircraft systems showed considerable potential for aerial roadway surveillance and traffic monitoring as well as avalanche control. They were able to obtain clear videos of the roadway at a height that allowed for efficient viewing of roadway conditions and traffic. At times, however, the mountainous terrain and weather provided operational challenges.

If transportation organizations are to routinely use UAVs, a number of specific issues will have to be addressed. In 2003 the United States Department of Transportation's (U.S. DOT) Volpe Center sponsored a study to develop a roadmap for deploying UAVs in transportation.[5] The resulting document noted that UAVs have demonstrated technological success but also raised questions about institutional barriers.

As the Volpe study notes, UAV adoption probably requires that UAV be an economical alternative to manned flight. However, as UAVs have become more effective and less costly, they have become candidates for applications that do not necessarily replace manned flight. For example, a UAV might provide occasional roadside information where a fixed camera is not cost effective.

The operating cost of a UAV is an area in which there is limited information, as many of the UAVs in use today are research platforms or in development. However, the costs associated with the UAVs used for this test do give some idea. If a DOT used the fixed-wing UAV flown in this project operationally, the agency would need to purchase an aircraft, a ground station, a launching catapult and supporting equipment. The aircraft is one of the less expensive UAVs in production, and this system would be around $50,000. If the use of the aircraft were part of critical operations, the DOT would need to consider a backup aircraft that would cost approximately $30,000. Other costs would include training personnel as aircraft operators. According to the manufacturer, training an operator requires 20 hours of flight time, and this costs around $15,000. There are also maintenance costs, which the manufacturer estimates to be $500 every 200 hours.[6]

According to the Georgia Tech team, the cost of the rotary-wing aircraft is around $270,000, but importing such aircraft from Japan into the United States is currently difficult. This cost includes a full ground control system. The operating cost of this aircraft is higher than that of the fixed-wing UAV, since the rotary aircraft must be operated by a minimum of two people.[7] Other costs, such as training, maintenance and aircraft transport, would also be higher than those for a fixed-wing UAV. For a cost comparison, renting a manned helicopter costs the WSDOT $800 an hour. A small fixed-wing aircraft and pilot can be hired for $160 an hour.

A critical and uncertain cost factor is the potential of destroying a UAV; therefore, the cost of flying a UAV may also need to anticipate a loss. While UAV technology is maturing, UAVs are not as reliable as manned aircraft. The military's UAV accident rates are still an order of magnitude greater than the accident rate for Air Force manned aircraft.[8]

Liability is also linked to reliability because aircraft failure could damage property or injure people on the ground.[9] However, WSDOT frequently operates dangerous equipment and has mechanisms to deal with liability. In addition, the UAVs have some fail-safes; for example, in case of a communications failure, the fixed-wing UAV could autonomously return to a landing site. The smaller UAVs are also lightweight, thus reducing their potential to cause damage in a crash. UAVs may also have lower liability than manned aircraft because no pilot and passengers would be hurt in the case of a crash.

Also mentioned in the Volpe report is the possibility that a UAV using a camera to monitor traffic could arouse concern about privacy violations. However, many transportation agencies already operate cameras and have mechanisms to deal with privacy concerns.

The major barrier for transportation agencies flying UAVs is related to the ability of a UAV to "see and avoid" other aircraft. This concern is the main reason that the FAA requires UAV flights to obtain a certificate of authorization.

The FAA recognizes the increasing interest in nonmilitary UAV use. The number of civilian UAV applications has been steadily increasing. In the spring of 2007, the FAA hired a consultant to help develop a roadmap for integrating UAVs into the national air space. Transportation professionals can follow the progress of this program through the FAA's Web site (www.faa.gov). Concurrently, improved technology—such as detect, see and avoid systems—may enhance a UAV's ability to safely fly in the NAS.

CONCLUSIONS

Unmanned aircraft systems have become more affordable so that a state-level transportation agency could operate them without major organizational additions. These aircraft systems are technically able to complete a range of surveillance and monitoring tasks that are potentially useful to transportation organizations. Work by others, as well for this project, indicates that they can perform effective aerial surveillance of roads and are able to do so while operating autonomously.

Because of institutional considerations, there are some notable limitations to flying a UAV. These are principally linked to the need to obtain FAA authorization to fly in order to comply with strict "see and avoid" rules. Fortunately, both technical and organizational solutions are being considered. Other concerns include liability and privacy, but DOTs have dealt with these issues in numerous other situations.

Another potential limitation for transportation agencies is uncertainty about the reliability of UAVs related to the costs for equipment replacement and the consequences of a crash. These problems may be reduced in the future, as UAVs become less expensive and more reliable. However, this project highlighted the reluctance of the aircraft owners to risk their UAVs. The reliability of the aircraft was a concern and may make their use less feasible in difficult terrain or weather.

As a result of reliability concerns and because of FAA authorization rules, routine operation of a UAV will continue to be a challenge for state DOTs. These issues may change with new technology and FAA rules. ■

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