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Lessons Learned: Application of Small UAV for Urban Highway Traffic Monitoring

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Traffic and emergency monitoring systems are essential constituents of Intelligent Transportation System (ITS) technologies, but the lack of traffic monitoring has become a primary weakness in providing prompt emergency services. Demonstrated in numerous military applications, unmanned aerial vehicles (UAVs) have great potentials as a part of ITS infrastructure for providing quick and real-time aerial video images of large surface area to the ground. Despite of obvious advantages of UAVs for traffic monitoring and many other civil applications, it is rare to encounter success stories of UAVs in civil application including transportation. The objective of this paper is to report the outcomes of research supported by the state agency to investigate the feasibility of integrating UAVs into urban highway traffic monitoring as a part of ITS infrastructure. These include current technical and regulatory issues, and possible suggestions for a future UAV system in civil applications.

I. Introduction

Rapid advancement in electronics and miniaturization technologies, and their application to aerospace industries, unmanned aerial vehicles (UAVs) have attracted by far the greatest attentions since its introduction dates back to the 1800s.[1] It is no longer a high-tech news item to attract the public interests; rather, it is an essential part of modern military operations. Despite the values being recognized through military applications, their civil usage is lagging far behind, mainly due to non-technical issues associated with regulatory, security concerns, safety and liability, privacy and civil rights, etc. While numerous 'barriers' are standing to be resolved, many government agencies, either as a single or as a team, address various applications and potential benefits by introducing UAVs for civilian interests.[2,3]

One of promising application of UAVs for civilian missions is to enhance the traffic monitoring systems which have been widely deployed and serving as a backbone of Intelligent Transportation System (ITS) infrastructure. Despite its importance, the traffic monitoring systems are rare to find in many rural areas or, if exist, they are to observe simple traffic counts at specific locations rather than to use for comprehensive traffic operations, mainly because of cost effectiveness issues. For this aspect, UAVs provide a cost effective mean to meet the need for rural traffic surveillance system. Deploying UAVs for transportation studies has been considered by a few researchers[3], and very limited trials are reported. To this date, two attempts are accessible in public domain. Coifman, et. al.[4] conducted a field experiment using a small UAV, called BAT III, provided by the MLB Company.[5] They presented methodological developments to exploit video data obtained from UAVs for multiple applications such as measuring level of service, estimating average annual daily travel, examining intersection operation, parking lot utilization, etc. All these efforts are based upon a single, experimental deployment, and issues associated with long-term integration into traffic monitoring system were not addressed. The other effort to use UAVs for traffic surveillance was made by the University of Florida and Florida Department of Transportation (FDOT), aiming at the integration of Airborne Traffic Surveillance System (ATSS) into existing network of FDOT's microwave tower system, traffic management centers, and the State Emergency Operations Center. They considered Aerosonde UAV in Australia, but the actual field test results were not reported and remain unknown to this date.

Recently, Western Michigan University (WMU) and the Michigan Department of Transportation (MDOT) is conducting a feasibility study to integrate UAVs into urban highway traffic monitoring and emergency management infrastructures in the southwestern region of the state of Michigan. The objective of this paper is to report the research findings and lessons learned from this project.

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II. Project Goal & Concept Overview

The main goal of this project is to develop a cost-effective traffic monitoring system for suburban/rural area using UAVs. Specific objectives at the initial stage include; investigation of applicability of UAVs to traffic monitoring and emergency identification by examining regulatory barriers and safety concerns, and development of a communication system that transmits live video images from an UAV to the traffic management agencies. Details of sub tasks were set as follows:

- Analysis and synthesis of mission objectives and operation requirements
- Assessment and procurement of an existing platform that best suits the objectives and requirements
- Familiarization of an AMA (Academy of Model Aeronautics) licensed RC (remotely controlled) aircraft pilot to operate a UAV system
- Familiarization of ground crew to operate and monitor the ground mission equipment
- Collaboration infrastructure among state government agencies for regulatory requirements
- Mission planning for field experiment at local interstate (I-94)
- Field experiment, performance evaluation and assessment for the development of comprehensive airborne traffic surveillance system

The project concept is depicted in Fig.1 that shows an UAV equipped with video camera transmitting real-time video images to the ground station. While recording the images are also to be transmitted through wireless internet to a fixed server which broadcasts to multiple traffic authorities to make quick decisions upon identifying incidences.

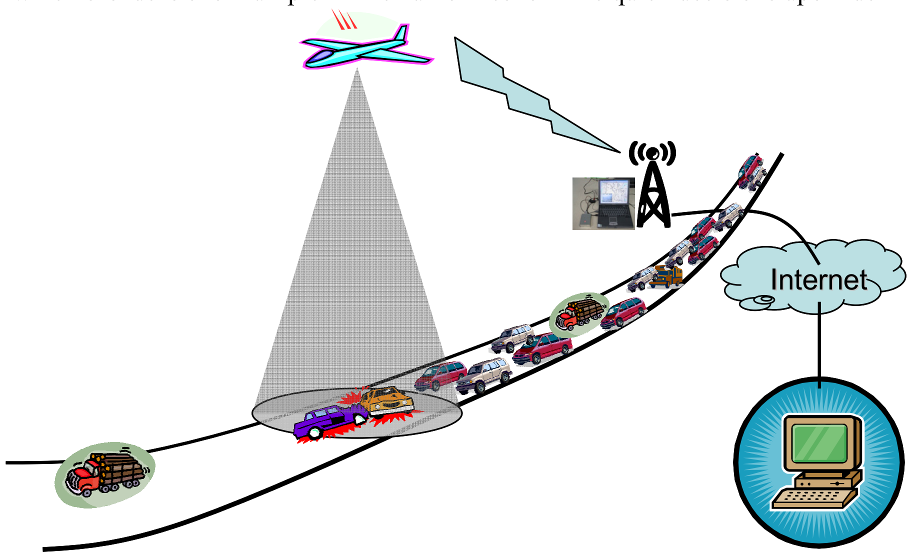


Figure 1 Concept Overview

III. UAV Platform for Traffic Monitoring

Highway traffic flow is very dynamic and uncertain environment that requires instantaneous and accurate information on both assessable and remote areas. Satellites based monitoring is transitory, and thus difficult to track continuous traffic flow. Deploying fixed, wired camera systems over the wide range demands massive investment. Alternatively, UAVs are very agile and responsive mobile sensing system suitable for such a dynamic environment. There are many types of UAVs being used for military applications since the 1950's, and their capabilities vary based upon mission requirements, so as to the size and cost. While the majority of current UAVs in operation is meant for military applications with expensive cost and sufficient logistic support, many potential problems for civil application including traffic monitoring requires an inexpensive, low maintenance UAV system. For this reason, a small UAV system could be the most effective choice for urban highway traffic monitoring. Historically, the classification of UAVs has been made along mission lines rather than platform size; long range/endurance, short range, close range as for fighters, bombers, reconnaissance, etc in manned aircraft. The question of size as a class arose only recently with the advances in technology that allowed small aircraft to accomplish relevant missions. It is widely accepted that a small UAV system usually refers to man-portable and low cost system in terms of manufacturing, operation and maintenance, while providing a quick, non-permanent mobile surveillance capability. Unlike the large UAV system which demands high operational cost – for example, Department of Homeland

Security (DHS) reported $1,351 per flight hours with a crew of up to 20 support personnel to operate their UAV for border patrol, the overall cost of small UAV system is far less than that of a large UAV system yet achieving essential mission objectives. These systems have significant growth potentials owing to abundant commercial-off-the-shelve (COTS) technologies components which are relatively low cost but high fidelity, and possibility the best candidate UAV platform for the majority of civilian applications.

After carefully reviewing several small UAV platforms available including an option to develop a custom system, the research team decided to procure an existing small UAV system (BAT III from MLB Company, shown in Fig. 2) considering the underlying factors such as budget and time constraints, previous records and experiences, etc. It is a complete small UAV system that operates autonomously and delivers high quality video imagery and sensor data in real-time. The 10 lbs aircraft has a wing span of 6 ft, but can be disassembled to be fit into an 18″ x 18″ x 36″ box. The compact ground station is transported in a small case so the entire system is man-portable. The aircraft can be prepared for flight within minutes and the mission course is specified by keying a series of waypoints into the ground station. The flight operations are autonomous from catapult launch to wheels-down recovery. It has flight duration up to 6 hours, telemetry range of 7 miles and a payload capacity of 4 lbs. As shown in Fig. 3, it has five communication components as described below:

Figure 2 MLB BAT III Small UAV

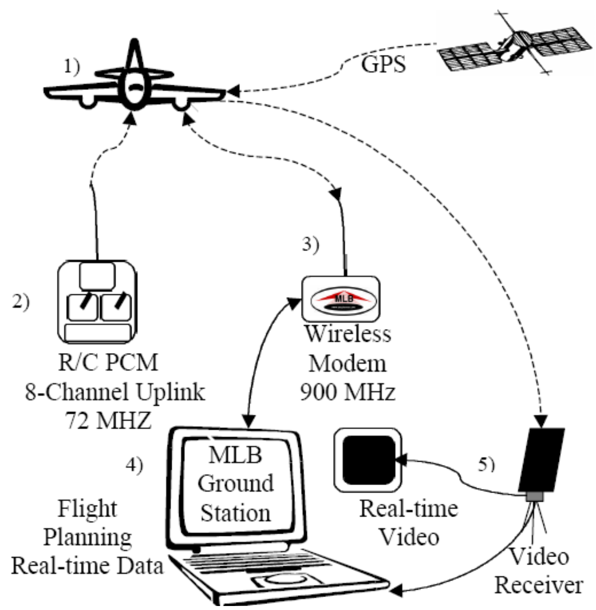


Figure 3 BAT III Communication System

- GPS signal receiver to operate autonomous flight computer
- 72 MHz radio control transmitter for manual mode of piloting, which can be disengaged by 900MHz upload command signal
- 900 MHz 2-way modem for flight data and in-flight re-tasking; 10km range with omni-directional antenna
- A notebook PC with flight data, moving map display of UAV, and graphical user interface for mission planning and updating
- 2.4 GHz real-time video downlink; 10 km range with 12 dB directional antenna

IV. Integration of UAV in to National Airspace System (NAS)

A. Up-to-date Regulatory Standards

To this date there are no FAR (Federal Aviation Regulations) issued by the government that establish standards to conduct UAVs operations in the NAS (National Airspace System). Despite having no clear policy for UAVs the FAA (Federal Aviation Administration) still requires the aircraft comply with current regulations that apply to manned civilian aircraft to allow integration in the current NAS. The FAA's first step toward developing such regulations comes in the form of a memorandum which will be discussed later in this section. As a result a clear understanding of the current regulations was required to try and obtain FAA approval for flight in the airspace around Kalamazoo/Battle Creek area.

Considering unmanned aircraft systems (UAS) regardless of types and sizes, it can be said that there are currently two separate regulations for aircraft operating in the United States. One is the Title 14 CFR (Code of Federal Regulations also known as Federal Aviation Regulation, FAR) and the other is the AMA's (Academy of Model Aeronautics) National Model Aircraft Safety Code in accordance with FAA Advisory Circular (AC) 91-57, Model Aircraft Operating Standards. The CFR relates to all manned aircraft that operate in civil airspace, while the latter relates to remotely operated aircraft (ROA) that are unmanned having a maximum gross takeoff weight of 55 pounds or less. The AMA regulations and FAR AC 91-57 clearly state that a model aircraft cannot operate higher then 400 ft or within 3 miles of an airport without informing an airport operator. With respect to collision avoidance the model aircraft must yield to the path of a manned aircraft, thus requiring the model aircraft pilot to have visual contact with the vehicle at all time.

The FAA's regulations, in general, are far more complex, controlling who, in the form of pilot ratings, what, such as maintenance and manufacturing requirements, and where aircraft can fly, with respect to different classes of airspace. In the 14 CFR, the FAA has divided the airspace in the United States into different classes based upon the size of the airport, level of radar coverage and the amount of air traffic that utilizes it. These classes include, A, B, C, D, E, and G. Each class of airspace requires different equipment and pilot ratings to allow legal entry. To be fully integrated into the civil airspace system, all aircraft, including UAS must comply with these standards for safety, especially with respect to collision avoidance. Each class of airspace is summarized in Table 1 and graphically illustrated in Fig. 4.

Class	Coverage	Entry Requirements
A	All airspace that it at or above 18,000 ft MSL and below 60,000 ft MSL (measured from sea level)	IFR clearance and two way communication with ATC.
B	Usually has a radius of 15 miles and a height of 10,000 ft MSL	A Mode C transponder within 30 NM of the airport. Two-way communication with ATC and at least a Private Pilot Certificate.
C	Usually a 5 mile radius from the surface to 4,000 ft AGL, and an additional 10 mile radius from 1,000 ft AGL to 4,000 ft AGL	Mode C transponder to fly in or above the airspace and two-way communication with ATC.
D	5 mile radius from the airport, including the surface to 2,500 ft AGL	Two-way communication with ATC
E	From the surface, sometimes 700 ft AGL and most often 1200 ft AGL (Altitude above Ground Level) or 14,500 MSL and below class A at 18,000 MSL	Controlled airspace, IFR flights must have two-way communication while VFR must follow weather minimums
G	Ranges from the surface but below 14,500 MSL	Uncontrolled Airspace does not require communication or special equipment.

Table 1 Classification of Air Space and Entry Requirement

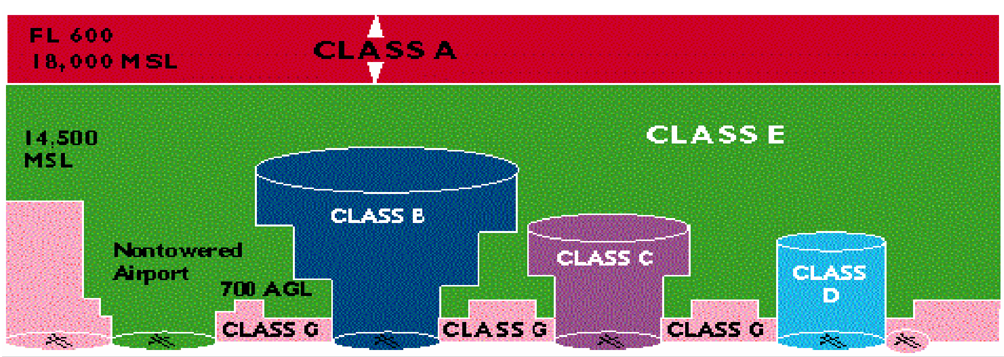


Figure 4 Classification of Air Space

For example, in the case of a UAV flying in Class C airspace the aircraft would have to be equipped with an altitude encoded transponder and the operator would have communication with ATC at all time. Similarly, in the case of the current project the UAV would enter the Class D airspace around Kalamazoo/Battle Creek International airport requiring two-way communication with ATC. In addition, the FAA requires all aircraft must comply with “see and avoid” standards stated in parts 91.111 (Operating near other aircraft) and 91.113 (Right-of-way rules: Except water operations) under 14 CFR.

More current requirements unique to UAV operations have been presented in the form of a memorandum AFS-400 Policy 05-01 (Unmanned Aircraft Systems Operations in the U.S. National Airspace System – Interim Operational Approval Guidance). This memorandum issued by the FAA outlines the basic safety issues that need to be addressed and forms to be completed in order to apply for flight in the NAS (National Airspace System). Key things to be noted are:

- The FAA will issue only special airworthiness certificates to UAS’s in the experimental category for the purposes of research and development, crew training, or conducting market surveys if one plans to fly an UAV as civil aircraft.
- The special airworthiness certificates allow a UAV to be operated only within the line of sight of an observer, during daylight hours and when other aircraft are not in the vicinity.
- In case one is to operate UAS as a public aircraft for the purposes of governmental functions, the experimental certificate is not required but the FAA’s Air Traffic System Operations and Safety Office may issue a Certificate of Waiver of Authorization (COA).

Since the scope of this project is considered as governmental functions, a COA was sought. As a part of COA applications, the candidate UAS must demonstrate that it meets the FAA criteria. One of the major requirements of the memorandum for UAV operations is the completion of the COA (Certification of Authorization or Waiver, FAA form 7711-2). Details for completion of a the COA are found in FAA Order 7610.4, Special Military Operations, and FAA Order 7210.3, Facility Operations and Administration. The document must be submitted 60 days prior to the intended flight. This document outlines the safety requirements partially seen in Table 2 and the specifications of the UAV to be used. The second column of Table 2 shows some of the safety requirements and compliances with those in the capability of the Bat III UAV used for this project.

FAA Regulations	Bat III UAV + Support System
[6.5] Direct communication between Visual observer and Pilot	Hand Radios
[6.7] Transponder requirements	System modified to accommodate a transponder
[6.7.1] Radio Relay through UAV	Just use direct communication between Pilot and ATC (not through UAV) with an air band transceiver
Risk and hazard analysis study	Develop Risk assessment for operating over congested areas; Slow turn slow decent mode
Lost Link recovery system	Continues flight along uploaded flight plan, Loss of GPS will result in a magnetic heading back to the ground station.
Optical Systems not sufficient for collision avoidance	IFR Rating for pilots as long term option
Develop observer requirements	Ground school certified
Develop pilot requirements	Ground school certified, 40 hours flight time with similar class aircraft
Pilot proficiency events (3) in 90 days prior to operation	3 flights with aircraft in 90 days in contained airspace
Pilot responsible for aircraft	Responsible for both autonomous mode and manual.
Pilot responsible for airworthiness	Follow the Bat III preflight checklist
One pilot in command at all times	Pilot in command is in control at all times
One UAV at a time for Pilot and Observers	
Observer Guidelines	No more than 1 mile from plane, No more than 3000 feet altitude, Always in sight

Table 2 Classification of Air Space and Entry Requirement

Completion of the COA also requires an Airworthiness Certification. The Airworthiness Certification is issued to all aircraft that are registered and deemed safe in compliance with the FAA. The application for an Airworthiness Certificate (FAA Form 8130-6) provides the option for labeling the aircraft as experimental, allowing a UAV that would not normally be given a certificate, to fly with restrictions. These restrictions could include limits on times and locations where the UAV may fly, but allows research and even demonstration of compliance with the CFR.

The 14 CFR Part 21.193 requires that a dimensioned picture, statements for purpose, estimated time for experiment, and location be submitted with the application.

This outlines the up-to-date regulations for civilian aircraft that operate in the NAS including UAVs. The Bat III used for this project is below 55 pounds in weight and therefore can be classified as an RC aircraft however this severely limits its range and operating altitude. Therefore, an attempt to meet the regulatory standards for the FAA was made. The results are addressed in the next section.

B. Efforts of obtaining certification using BAT III

To meet the requirements of the current rules and regulations of unmanned aircraft systems (UAS) within the NAS, the project started with a breakdown of the Federal Aviation Administration's Memorandum AFS-400 UAS Policy 05-01. This was to identify critical factors that must be reviewed in order to meet approval standards for any UAS operation. Critical factors to be addressed from the breakdown of AFS-400 IAS Policy 05-01 included:

- Section 6.1 Certificate of Waiver or Authorization
- Section 6.3 Airworthiness Certification
- Section 6.5 Communication Requirements
- Section 6.7.2 Operations on other than an instrument flight plan
- Section 6.11 Flight over congested or Populated Areas
- Section 6.12 Lost Link
- Section 6.14 Observer Qualifications
- Section 6.16 Pilot/Observer Medical Standards
- Section 6.17 Pilot Qualifications and Responsibilities
- Section 6.20 Visual Observer Responsibilities

Section 6.1 Certificate of Waiver or Authorization

This section states that in order to conduct operations in the NAS, the operator must apply with the FAA Air Traffic Organization (ATO) for a Certificate of Waiver or Authorization (COA). This should be done with the FAA Form 7711-24, Application for Certificate of Waiver or Authorization, through the local Air Traffic Service Area Office. ATO also has a guidance checklist covering the application and approval process. This form requires such information as: Point of Contact; Type of aircraft system; Performance characteristics; detailed description of the flight plan, radio communication, lost link situations and how situations will be dealt with, ways for avoiding manned aircraft, and pilot name and qualifications.

Section 6.3 Airworthiness Certification

In order for the FAA to issue a COA for any operation, the applicant must show in some manner that compliance with the Airworthiness requirements of the 14 CFR Part 21 is met. For this operation with the MLB BAT III to meet these requirements the UAS needed to be certificated as an experimental aircraft under the research and development category. Due to the unavailable guidelines for airworthiness for unmanned air systems, the project team followed the regulations of the 14 CFR Part 23, Airworthiness Standards: Normal, Utility, Acrobatic, and Commuter Category Airplanes, and applied these to UAS applications to develop usable guidelines for airworthiness of an unmanned aircraft system. The application for an experimental Airworthiness Certificate, FAA Form 8130-6, must be filled with the local FAA representative or nearest Flight Standards District Office (FSDO).

At the same time, the FAA also requires that the aircraft in question also be registered with them for identification purposes and future updates on the airworthiness of the type of aircraft. In order to meet this with the MLB BAT III the registration form (AC Form 8050-1) for the FAA under the N number of N131WM was filled out. With this, the evidence of ownership must accompany the registration form either as a copy of the AC Form 8050-2 Aircraft Bill of Sale Information or a Contract of Conditional Sale must be sent in along with the applied registration fee. These documents must be sent to the Federal Aviation Administration Aircraft in Oklahoma City, Oklahoma. With registration of an aircraft, written copies must be sent in, to receive a blank copy, and to contact the local Flight Standards Districts Office (FSDO).

Section 6.5 Communication Requirements

This section calls for the direct communication between the UAS pilot and all visual observers and radar monitors. In order to meet this requirement, it was determined that a visual observer stationed with the UAS pilot would be in direct communication with the radar monitor or the Kalamazoo/Battle Creek Air Traffic Control Tower over a VHF frequency those currently used in aviation. The observer would also be in direct contact with the other ground observers over a system of hand held radios. With these observers, radar monitor and communication between them and the pilot, the UAS could safely be observed during the whole duration of flight and kept clear of all manned aircraft.

Section 6.7.2 Operations on other than an instrument flight plan

This section sets some guidelines for operation of UAS under visual flight rules. This calls for the pre-coordination with Air Traffic Control (ATC), the UAV be equipped with a mode C transponder unless other guidelines are met. This also states the need for direct communication between the UAS pilot and ATC, if specified by air traffic and visual observers are used in accordance with this policy memo. To meet these guidelines the project team met with a representative from the Kalamazoo/Battle Creek Air Traffic Control Tower. During this meeting, a few concerns raised were the planned altitudes that might bring a conflict with manned aircraft with in the airport area and the need for a transponder aboard the aircraft were suggested in order for the UAS to be visible on the radar monitor.

Section 6.11 Flight over congested or Populated Areas

The primary concern shared not only by the FAA but to all is the concern of safety to manned aircraft, people and property not in connection with this project. This being the focus of this section, the memo calls for the clear establishment that the risk of injury to persons in the gourd in highly unlikely. To clearly address this, a period of flight testing was developed to be conducted before the planned field experiment to be discussed. The goals would be to show that in different conditions which might possibly happen during a flight, the UAS could be safely conducted as to not create a hazard to persons in the air or on the ground.

Section 6.12 Lost Link

In this section, the issue of means for automatic recovery in the event of lost link between the controlling station and UAS is provided. This issue was already dealt with by the MLB Company when developing the software program that would control the BAT III. They have already programmed in a “return to home” mode that will automatically engage in if connection between the ground station and UAS is lost. This feature would also be one point of testing during the flight test period with the UAS. In this mode the UAS would track towards the last known location of the ground station, where the pilot could take control manually with the R/C Transmitter and safely land the UAS.

Section 6.14 Observer Qualifications

Guidelines for the qualification for the visual observers are dealt with in this section. This is to insure that the observers are trained to meet the demands of the flight operations and how to properly communicate with the pilot any information necessary for the safely of flight. The memo states a few regulations the observers must be trained on and have a working knowledge to be able to apply this in the line of work. To met the training requirements of this section, the observers will met with the Certified Flight Instructor on the project team to receive this training and have a record of the date the training took place, what information trained on and the instructors signature and certificate number. The observers will also carry this record with them while acting under their responsibility as observers for UAS operations. The regulations that training is to be over are 14 CFR 91.111, Operating near Other Aircraft,14 CFR 91.113, Right of Way Rule, and 14 CFR 91.17 Alcohol and drugs. These regulations can be seen on the footnotes of pages 6 and 7 of the memorandum AFS UAS Policy 05-01.

Section 6.16 Pilot/Observer Medical Standards

This section calls for all pilots and observers carry with them a current third class or higher airman medical certificate that has been issued under 14 CFR Part 67, Medical Standards and Certification. This can be done through any local Airman Medical Examiner. A listing of which can be found on the FAA website (*www.faa.gov*).

Section 6.17 Pilot Qualifications and Responsibilities

This section is to ensure that UAS pilots be trained properly to interact with ATC and have sufficient expertise to perform the tasks readily. This calls for the pilot to have an understanding of Federal Aviation Regulations applicable to the airspace that the UAS will operate and other knowledge needed to operate safely in NAS. This also includes having passed the required knowledge test for a private pilot certificate as stated in 14 CFR 61.105, if operating under visual flight rules or be a certificated pilot with an instrument rating to operate under instrument flight rules. This section also states the need to be proficiently qualified in the operation of the UAS in the preceding 90 days by doing three proficiency events. Proficiency events to include any event requiring the pilot to exercise the training and skills unique to the UAS in which proficiency is maintained, such as launching, landing and controlling the UAS in flight manually and autonomously.

To meet this section, a certified flight instructor who meets all the knowledge is needed to pilot the UAS safely in NAS. The secondary pilots will be also needed to receive the training on knowledge to meet the requirements of this section in order to safely operate the UAS to the extent of their responsibilities such as to safely land the UAS in the case of emergency. All pilots have received training from the MLB Company on the operation of MLB BAT III, and must continue to meet the proficiency requirements of this section to stay current with the system.

Pilot responsibilities of this section include a thorough preflight of the UAS to ensure safe operation during flight and the UAS is airworthy to meet the standards of the airworthiness certificate issued to the UAS and the airworthiness provisions of 14 CFR 91.7, Civil Aircraft Airworthiness. This section also states that one pilot will be pilot-in-command (PIC) at all times and will be responsible for the safety of the UAS and person and property along the UAS flight path. The PIC will be held accountable for controlling the aircraft to the same responsible standards as the pilot of a manned aircraft. This includes the provisions of 14 CFR 91.13, Careless and Reckless operation.

The guidelines of this section have been met by assigning a certified flight instructor accepting the responsibility for the safety of flight, and will hold the provisions of this section to the highest degree to ensure that injuries or damage to person or property is highly unlikely.

Section 6.20 Visual Observer Responsibilities

This section gives some guidelines to the use of visual observers during operations. The observers will remain within a one mile laterally or 3000 feet vertically, distance from the UAS when conducting their responsibilities. Also stated is that observers will remain in continuous visual contact with the UAS and give instructions for steering the UAS clear of any potential collision with other manned traffic to the pilot while being the primary observer responsible when the UAS is in their area. The UAS is to give way to all manned aircraft.

C. Field Experiment (Operational Specifications) Plan

As a part of application for COA, a detail of flight plan or operational specifications must be submitted as a part of checklists. A flight plan that is coordinated with our field experiment plan is established and attached as a checklist. The proposed location is highlighted in Fig. 5, which is the segment between US 131 and the Kalamazoo/Battle Creek International Airport. The ground observers would be used to comply with COA and their locations placed along position to make sure that there is constant visual contact with the UAV. The operation of the UAV for this test would be conducted by a team of four members. One individual would be responsible for setup and control of the catapult launching system. Another person would be responsible for setup and monitoring of the ground station. The third person would handle communication with ATC and the ground observers. And the fourth person would be the RC pilot responsible for doing a preflight of the UAV and control during takeoff and landing. Three other properly trained and radio equipped individuals would serve as the ground observers along the proposed flight plan.

The launch point and ground based location was Portage Northern High School, which is just south of the construction zone of interest on I-94. A survey of the area was conducted with a GPS and a device to measure angles. The information was used to determine the height of local obstacles such as power lines and tress and to see whether the athletic fields would be large enough for descend and rollout during landing. The accurate GPS coordinates were used to properly calibrate the map that the BAT III software uses in determining its flight path. The test flight over I-94 was broken down into four different segments; Preflight Setup, Launch/Takeoff, Flight/Traffic Monitoring, Landing / Recovery.

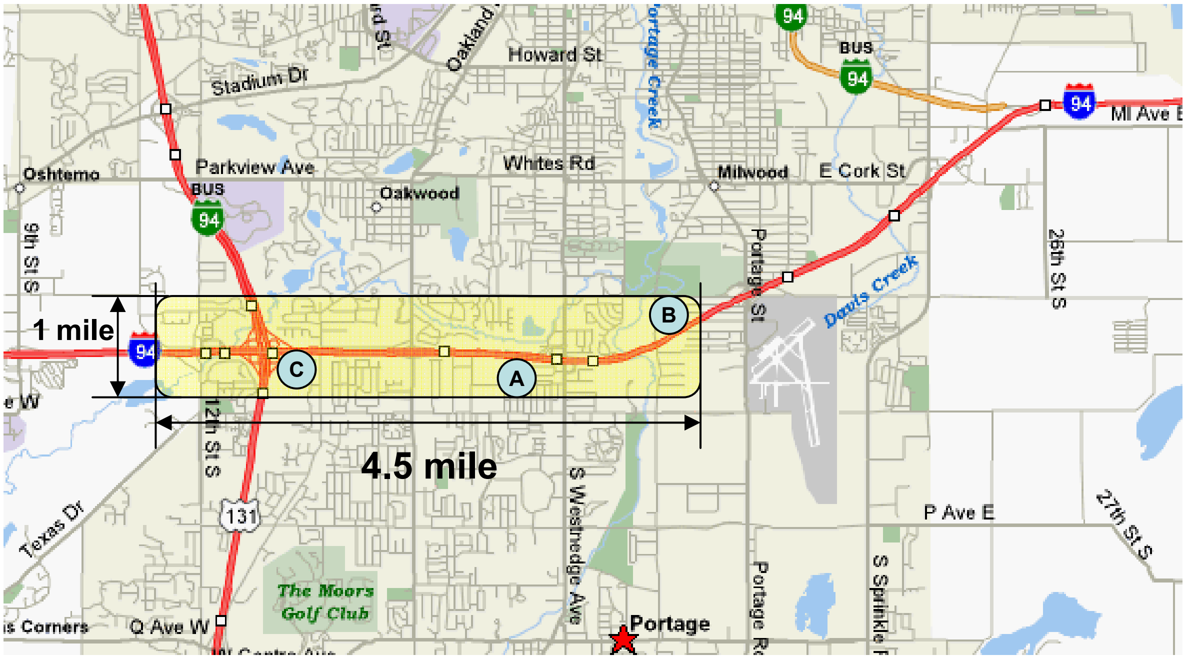


Figure 5 Field Experiment Plan

A: Pilot location (Launching/Landing: Portage Northern High School, 1000 Idaho Ave., Portage, MI)

B - C: Observers

B: Emergency landing area (Loy Norrix High School, 606 E Kilgore Rd, Kalamazoo, MI)

C: Emergency landing area (open area)

The first segment, the preflight setup should involve three people for a minimum setup time. A properly trained field team should have the Bat III preflight checked and ready for launch in less then 20 minutes. One person would be responsible for the set up of the UAV, which would ideally be the RC pilot. This would involve attaching the wings, making sure the batteries and servos are connected, fueling the aircraft, and later starting the motor. Another person would be responsible for the setup of the ground station. This would include setting up the antennas, video recorder, laptop computer and checking the programmed flight plan. The third person would be responsible for the setup of the catapult launching system. This requires removal from the travel case, checking that it is secure to the car rack, and arming it for launch. The ground observers would be taking their positions during this time and giving a radio check.

Takeoff would require four people. First the Bat III would go through the preflight checklist, which would be run by the pilot. The Bat III would have been launch autonomously, but the pilot would be ready in case of an emergency. A second person would be responsible for communicating with ATC (Air Traffic Control). Another person would be responsible for the ground station, making sure that aircraft was functioning normally and communicating with the modem. The fourth person would be responsible for activating the catapult, by pulling the safety pin.

During the third segment, traffic monitoring, the primary responsibility would be on the person running the ground station. During the flight the aircraft would be flying autonomously, using the latest uploaded flight plan given by that person. The pilot would be ready to take control with the transmitter if required. The person in charge of the radio would be responsible for giving position reports and relaying information between the pilot, ground station operator, and ATC. In addition this person would be in communication with the ground observers to make sure that there is visual contact at all times. The UAV would be flying back and forth over the construction zone for about one hour to get a proper test of the equipment and enough data to provide proof of concept.

After flying for an hour the recovery process would begin. For the landing segment the responsibility of the UAV would fall to the pilot. The ground station operator would make sure that the UAV was positioned within one mile so that the RC transmitter could take control. Once that was done the pilot would land the aircraft manually and then shut the engine off. A third person with the radio would inform ATC that it had landed. After it had landed the ground station operator could download the flight data from the computer to the laptop for later analysis along with storing the video images. Those responsible for setup of the Bat III, ground station, and catapult would also properly breakdown and store the equipment.

D. Problems, Suggestions and Potential Solutions regarding FAA Regulations on UAVs

There were numerous issues encountered while trying to comply with the current FAA regulations for aircraft, and the standards set by the memorandum. Most of these standards required compliance with the similar regulations that apply to manned aircraft. For example, to receive an Airworthiness Certification that is not experimental, giving unrestricted flight, would require meeting all the standards stated in 14 CFR Part 23, which hold little applicability to UAV aircraft. For instance UAV aircraft do not require safety belts or an oxygen supply. A simple adaptation of Part 23 for UAVs with minimal rewriting resulted in standards that the Bat III could not meet and would be difficult for most of other UAVs of similar kinds. In addition there seems to be no FAA branch or department that is specialized to issue the documentation for UAVs making it difficult to contact the appropriate FAA representatives. Another major issue was meeting the requirement for "see and avoid". According to the memorandum a forwarding looking camera is not sufficient, it needs to be met with either ground observers or a chase plane. These requirements severely restrict the range of use and long term and full potential of UAV technology. Another problem was the pilot requirements for the UAV such as a private certification. The process to receive such a qualification is expensive and would result in training that would yield little knowledge of flying UAVs or R/C aircraft.

It is strongly believed that there must be separate regulations and dedicated FAA authorities that are unique to UAVs. The regulation for UAV airworthiness should be appropriate in providing safety to individuals on the ground and traveling in other aircraft in the area. An FAA UAV department, if exists or planned to exist, would be responsible in handling the airworthiness inspection and other documentation for integration into the NAS.

The "see and avoid" problem could be addressed by requiring UAVs to have Mode C or S transponders (as shown in Fig. 6) that would make it easier for radar to track them. Also a lighting beacon system such as strobes (as shown in Fig. 7) would also have to be added to increase visibility to other aircraft. Ultimately the UAV should have an automated collision avoidance system. The UAV would have the ability to detect other aircraft and make adjustments in heading and altitude to remain at a safe distance without the need of a ground pilot. Such technology is already in development, and could be applied to UAV in the near future.

The pilot or operator of the UAV should not be required to have a current pilot and medical certificate. Rather, qualification should be based off the private pilot written exam. Passing the written exam would demonstrate the operator's knowledge of important matters such as airspace, FAA rules and regulations, and ATC communication, which is required to fly in the NAS. The pilot's skills should be tested in their ability to fly and control RC and UAV aircraft. Implementation of these suggested policies should provide a safe integration of UAVs into the NAS.

V. Design of Ground Communication Scheme

A prompt or real-time distribution of the aerial video images from the UAV to appropriate authorities to make appropriate decisions is another important aspect of this project. The MLB BAT III system includes the radio frequency transmission device that connects the UAV with the ground control station. The video images captured by

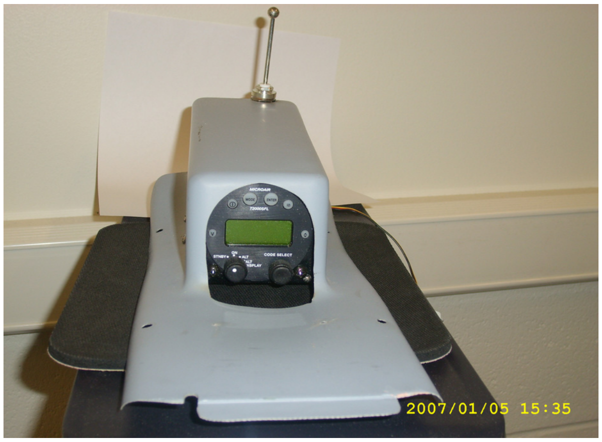


Figure 6 Transponder

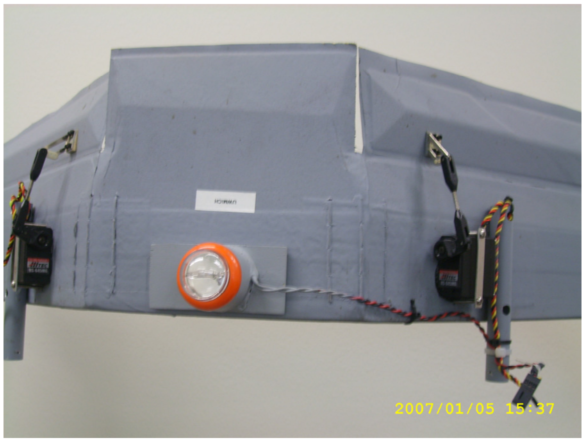


Figure 7 Lighting Beacon

the onboard camera is transmitted to the mobile ground station computer, and needs to be further relayed to end user computers at the MDOT local offices.

Our task focused on how to deliver the video images from the UAV ground station in the field to the end user computers in the office. Most of the end user computers have access to the Internet and to simplify the requirement of the end user computers, the Internet is chosen as the communication backbone for video data delivery. The UAV ground station, i.e. the notebook computer, is positioned in the field such that the UAV has an effective flying radius that covers the area of a segment of I-94. The optimal location of the ground station may not have any wired Internet plug-in. On the other hand, the ground station is most likely setup close to the highway, where the base station towers for cellular telecommunications are readily available along the highway. Therefore, the nationwide Sprint mobile broadband network is exploited for the UAV ground station to transfer the video data, and then pass on to the Internet. A coverage map of Sprint mobile broadband service around Kalamazoo Michigan is shown in Fig. 8.

As depicted in Fig. 9, when the UAV captures the video images, it transmits the data towards the ground station. The ground station receives the radio signal and converts it into baseband digital video. The ground station laptop applies with a nationwide wireless PC Card system connected to Sprint Network and a program which encodes the video stream in real-time image developed by Microsoft. The Sprint cellular network is connected with the backbone Internet. Finally, the end user computers obtain the video images from the Internet. The Sprint cellular network provides mobility; however, the mobile broadband connection becomes the bottle neck of the data pipe. Therefore, when this data transmission scheme is applied through the Sprint Cellular network, it has limited bandwidth for data communication. Table 3 shows communication components for the UAV video data communication, and their specification.

UAV data downlink carrier frequency	2.4 GHz
Sprint PCS wireless mobile card data rate	Max 500 – 700 kbps
Average data rate of Sprint PCS wireless mobile card measured in Kalamazoo area	130 Kbps
End user maximum data rate	130 Kbps

Table 3 Communication Specifications

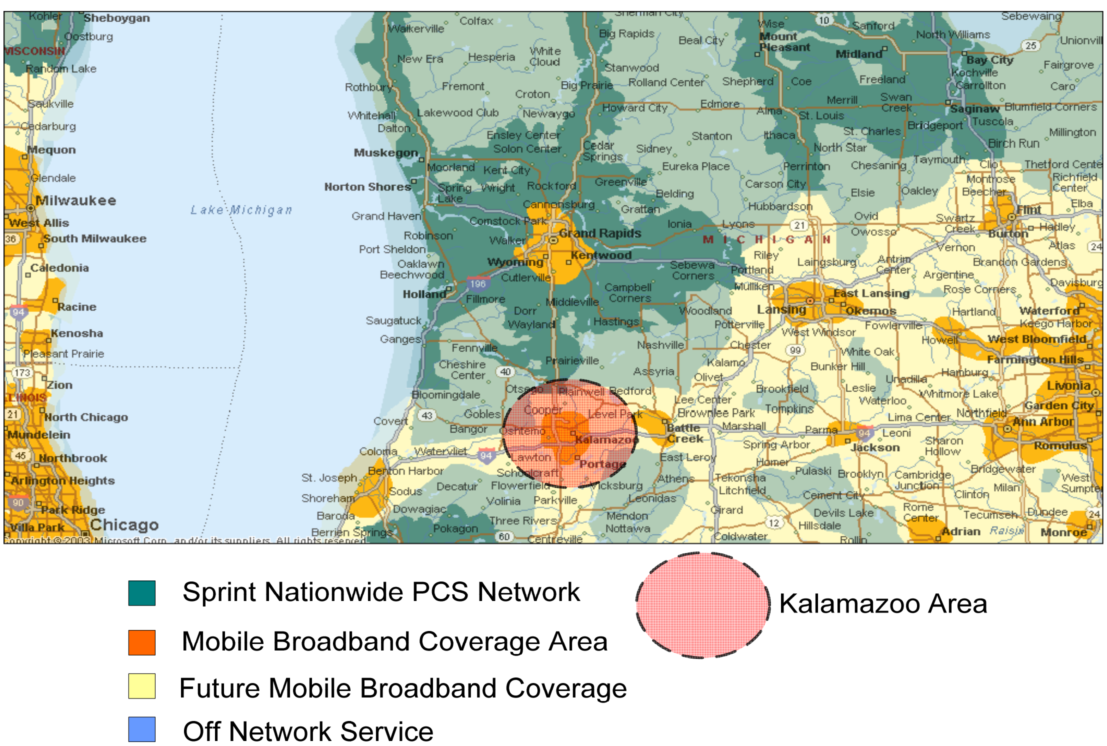


Figure 8 Coverage of Sprint Mobile Broadband Services

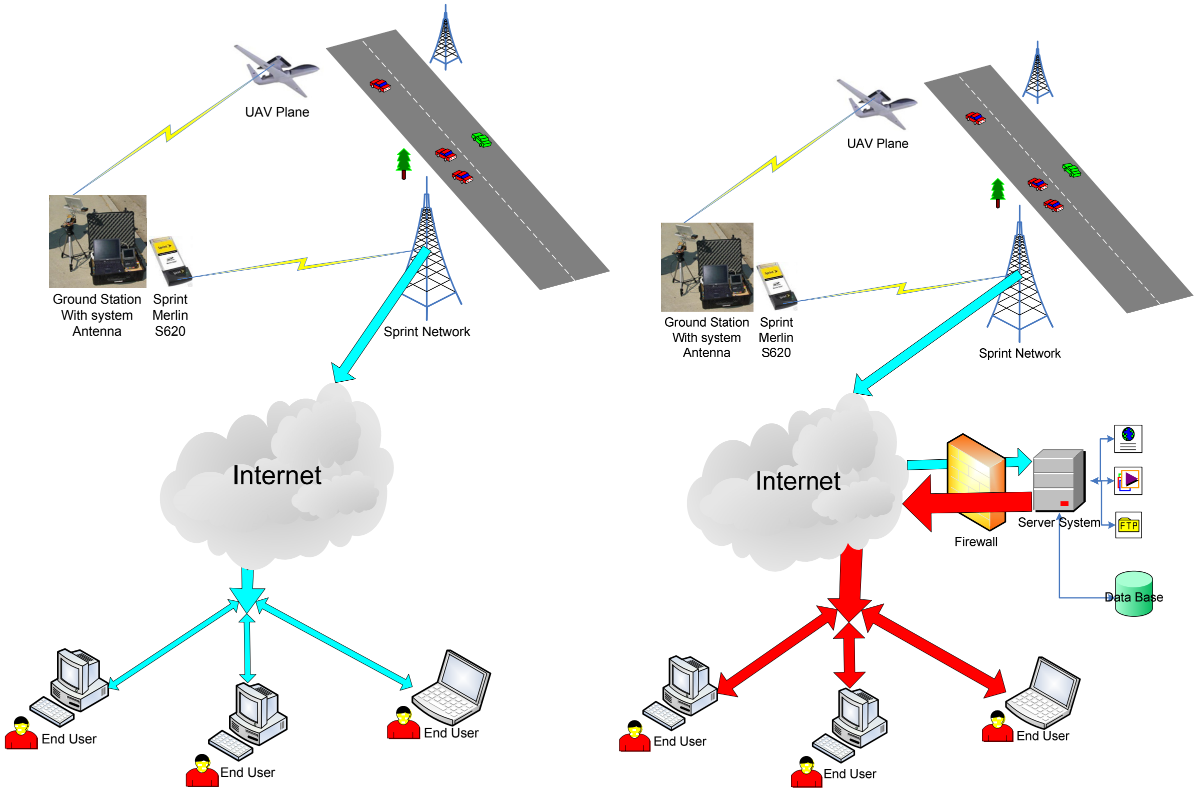


Figure 8 UAV Data Communication Link

A. Data Communication Schemes

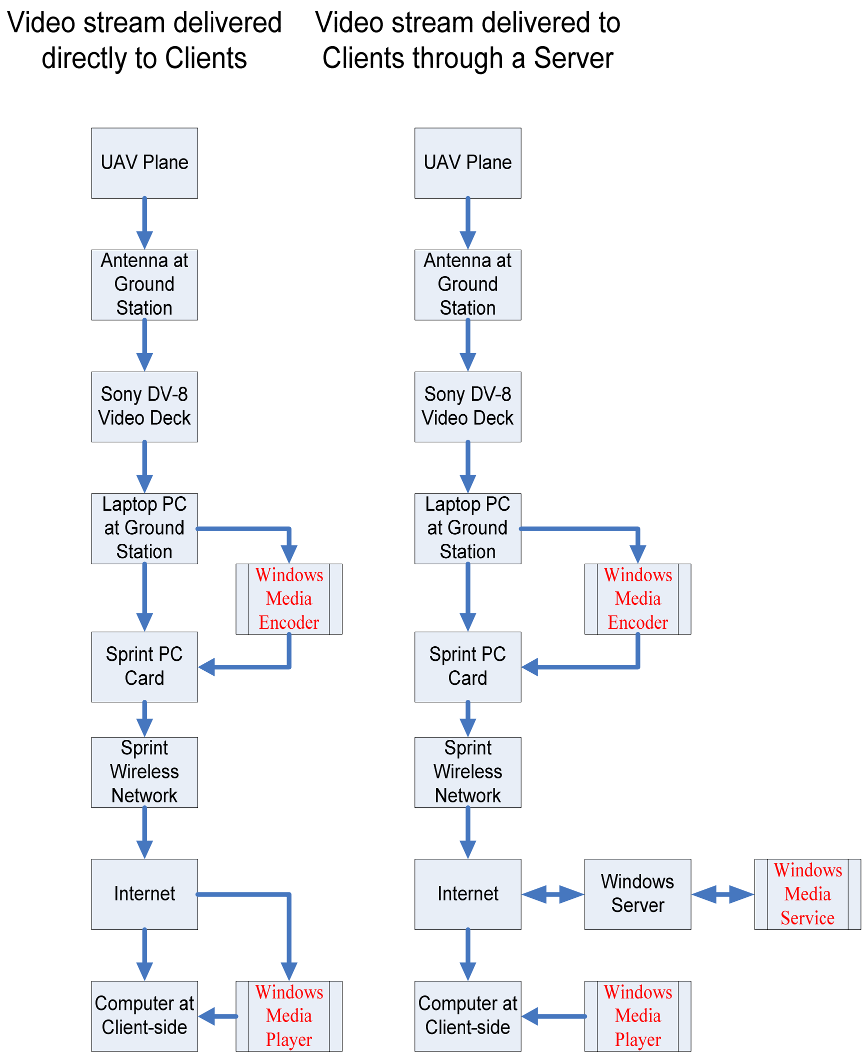
1. Two Data Relay Schemes

In order for the end user computers to retrieve the digital video captured by the UAV camera, in this project, we implemented two schemes to relay the digital video to the end users via the Internet. In the first scheme in Fig. 9, the UAV ground control laptop informs the end user of its IP address, and the end user computers can open a media player to retrieve the video stream from this IP address. It should be mentioned that the Sprint mobile broadband service assigns a dynamic IP address upon every new request for connection. This means that the IP address is changed every time the ground control laptop connects with Sprint cellular Network. Therefore, the ground crew needs to inform the end users of its recently acquired IP address of every connection.

In the second scheme in Fig. 9, an additional server is used and served as a host of the data communication link. The server is operated with a fixed IP address which can be known a prior to the ground control laptop and the end user computers. The UAV ground control laptop streams the video to the server with this particular IP address, and the end user retrieves the video from the server via this particular IP address. In addition to real-time video streaming, the server can store the received video onto its hard drive for future off-line analysis.

The server also hosts the project website. This website has a link to a page that displays the real-time video captured by the UAV onboard camera. In order to host the website and at the same time be ready for the incoming signals from the UAV ground control computer, multiple network ports are opened for the server. The server may add additional processing delay and has certain concerns with the firewall. These issues will be discussed in detail in the following subsections.

Comparing the scheme 1 and 2, in the first scheme multiple end users share the data pipe that has the data rate of the mobile broadband connection. Since the wireless link is the bottle neck for video signal transmission, the scheme can only support a limited number of end users with acceptable data rate. The sum of the maximum data rates that the end users can have is smaller than the data rate with which the UAV ground control computer transmits to the server via mobile broadband connection. In the second scheme, UAV ground control laptop sends data to the server via the mobile broadband network. The server relays the data to the end user computers via the wired Internet



(a) Scheme 1 (b) Scheme 2

Figure 10 Block Diagrams of UAV Data Communication Links

connection. The maximum number of end users can watch the video simultaneously depends on the data rate of the wired Internet connection of the server, which is much higher than that of the wireless connection. Therefore, more end user computers can receive the video stream simultaneously with acceptable data rate. Here, the maximum data rate that each end user can have is smaller than the data rate with which the UAV ground control laptop transmits to the server via mobile broadband connection. Fig. 10 shows block diagrams of UAV data communication links of Scheme 1 and Scheme 2, respectively.

2. Streaming Media Protocols

Basically, a protocol means that a set of rules and procedures on how data is transferred between devices or computer programs. Protocols contain important information to make sure data is delivered properly. Depending on the protocol, this kind of information can include the IP addresses of the sending and receiving computers, ports numbers, error-checking methods, end-of-files indicators, and so forth.

There is no one particular protocol that is sufficient for all purposes. Instead, every protocol has different tasks depending on their position in the OSI (Open System Interconnection) model. Based on this model, protocols are implemented in multiple layers. The lower layers define how to connect devices to one another. The upper layers specify rules for conducting communications or interpreting application.

- Standard Internet Protocols

There are some protocols which are standards of networking and the Internet used by Windows Media 9 Series for video streaming. Those protocols are listed and introduced as following.

User Datagram Protocol (UDP): UDP is one of the most common Internet protocols used for sending data in a continuous stream because it provides for one-to-one or one-to-many communications on a connectionless basis. It uses less error correction than other common Internet protocols and no delivery receipts are required. Due to these features, UDP Protocol has to rely upon other applications or upper layer protocols to make sure data packages arrived intact.

Real-Time Protocol (RTP): Real-Time Protocol has some properties of a transport-layer protocol. It is used for transmitting audio and video contents in real-time. RTP can also govern how the server constructs these audio and video content packages. RTP lays out rules for identifying the type of packet, how packets are numbered in sequence, and how they are stamped with the data and time. The architecture is similar to UDP and TCP, through RTP packets are meant to work specifically with the RTSP and RTCP protocols.

Real Time Streaming Protocol (RTSP): the RTSP protocol is an open standard application-level protocol that controls the real-time delivery of data including audio and video contents endorsed by the Internet Engineering Task Force (IETF) which is a body of prominent Internet engineers. RTSP supports two ways communication which allows users to control some features such as Play/ Pause/Stop of on-demand streams. The users will communicate with streaming server based on RTSP. RTSP usually works with RTP to setup a format of packets of multimedia content and negotiate the most efficient transport-layer protocol (either UDP or TCP) to use when delivering the video stream. The protocol of UDP or TCP can be specify by Server administrator for transferring packets. The decision is based on many factors such as firewall configuration and the speed of UDP versus the quality of TCP. RTSP is intended for unicast transmissions between servers and end-users or between source and distribution servers.

Real Time Control Protocol (RTCP): RTCP packets work with RTP packets to check the delivery of other packets. RTCP packers are often used to monitor Quality of Service (QoS).

Hypertext Transfer Protocol (HTTP): Hypertext Transfer Protocol (HTTP) is an application layer protocol that Web pages browsers and Web servers use to exchange information. HTTP relies heavily on the transport capability of TCP for traffic control.

Microsoft Media Server Protocol (MMS): MMS is a proprietary application layer protocol developed by Microsoft Company to deliver unicast stream. It enables two-way communication so users can have fast forward, rewind, and pause the playback of unicast, on-demand stream. Like RTSP, MMS protocol can use either UDP or TCP to carry media packets across network. MMS is intended for unicast streaming between Windows Server System and clients.

3. *Server Firewalls and Communication Ports*

A firewall is a piece of hardware or software that can be controlled by network administrators to decide which data packets can either get into or leave from a protected network. In order to control the flow of data traffic, there are numbered ports in the firewall chosen to either open or close for certain types of data packets. The firewall controls the data flow of traffic based on the destination port, the source IP address, and the target IP address which is related to its data packets. Some firewalls can also control the data flow further based on the protocols. If the firewall is configured to accept the specified protocol through the targeted port, the data packets are allowed to get through and into the network.

For this project, the allocating ports for Windows Media Streams are different and depend on ways of content distribution methods. In the PULL distribution method from Windows Media Encoder, the allocating port usually uses and sets at port 8080 but is also changeable to other free allocating ports. Meanwhile, in the PUSH distribution method, the Windows Media Encode program sends media contents to a Server system which is located at Parkview campus in Western Michigan University. The firewalls and communication ports are controlled and also authorized by Networking Administration from Western Michigan University. In order to receive any media content from outside networks, some certain communication ports from WMU have to open for the media packets through. Table 4 shows the communication ports which have been issued and authorized from WMU for the Server System of the UAV project.

Protocols	Communication Ports	Using Purposes
HTTP	80	Windows Media Service
HTTPS	443	Web Pages

Table 4 Server Communication ports

4. Wireless Data Link

- Sprint Mobile Broadband Networks

Sprint and Novatel Wireless has developed a new technology which operates on CDMA 1xEvDO (Evolution Data Optimized) and 1xRTT networks. Based on the CDMA 1xEvDO and 1xRTT wireless network, the UAV project is able to broadcast a real-time video stream from ground station in field area back to a traffic monitoring center. A Sprint Mobile Broadband Sprint PCS Connection Card (Merlin S620) made by Novatel Wireless is needed to use with a laptop computer in order to connect to one of cellular antenna towers of Sprint Networks around highways. Based on EvDO and 1xRTT protocols, Sprint PCS Connection Card operates at average download speed range from 400 to 700 Kbps (bit per second) and up to 2 Mbps with peak rates in Mobile Broadband coverage areas and at average speeds of 40-70 Kbps and with peak rates up to 144 Kbps on the Sprint Nationwide PCS Network.

With a lightweight design and an advanced, embedded antenna, the Merlin S620 by Novatel Wireless can be used in conjunction with a laptop computer running Windows 2000, XP or Tablet XP and a PCMCIA Type II PC Card slot to remotely and securely access the Internet and data-intensive corporate applications, as well as send and receive email with sizable attachments.

Sprint PCS Connection Manager(SM) Software comes packaged with the card to manage the user's connection to the packet data network and provides a compression client, self-diagnostic tools and automatic software updates from the Web. Customers using the device can benefit from bandwidth optimization for certain applications, providing increased data throughput of two to five times average user speeds on the Sprint Nationwide PCS Network. Novatel Wireless is pleased to continue its long-term partnership with Sprint during its extensive EV-DO network rollout.

EvDO: The newest CDMA data protocol, EvDO, is commonly referred to as DO (Data Only). It allows for maximum forward link capacity ranging from 500 kbps up to 2.4 Mbps, and a maximum reverse link capacity of 153 kbps. EvDO networks are optimized for data transfer on the forward link through the use of packet based TDM (time division multiplexing) and by scheduling packets based on a users channel quality, rather than utilizing traditional round-robin scheduling. In contrast, CDMA is used on the reverse link, but with adaptive rate control, which allows an increase in reverse link throughput that can be higher than 1xRTT networks.

A revision to the EvDO standard, EvDO Revision A, currently available in Korea and Japan, new standard is designed to decrease network latency and increase bandwidth beyond the current EvDO maximum, with theoretical maximum forward link and reverse link capacities of 3.1 Mbps and 1.8 Mbps, respectively. One of the intended purposes of the next EvDO revision is to support low latency applications such as video telephony and VoIP (Voice over IP), a technology which allows voice communications over the internet.

5. Media Processing Programs

- Windows Media Encoder

The most important part of communication is to find out how a real-time video stream can be delivered from the ground station in the field back to a control center at the local MDOT office miles away. Due to the source material of UAV project, i.e. it is a digital video (DV) tape from Sony video deck system, the encoder program may need to convert it from the DV format to another digital format (such as Windows Media Video). After the video stream is converted, it may be distributed over the Sprint network and further onto the Internet. The digital-to-digital conversion process is performed by connecting a DV tape from Sony i.LINK ports to an IEEE 1394 port installed in a computer. According to the specification of the project, the real-time video stream has been recorded as an analog format on a Digital Video (DV) 8 tape in the Sony video deck system. Any media content has transferred as a digital format once exporting out through the USB port. Therefore, a suitable image coding program called an encoder is needed for further processing. The main task of encoder is to compress the media content so that it can be delivered on the Internet. Compression is necessary because video in its original state is too big to deliver within available network bandwidth. After an intensive researching, a program named Windows Media Encoder developed by Microsoft has met the needs of the transmission tasks.

Microsoft has been developing a lot of digital media software in various purposes more than a decade. One of digital media technologies is known as Microsoft Windows Media Encoder. The Windows Encoder is an encoding program that can convert and compress media content into Windows Media Format. Both real-time and prerecorded audio and video format can be encoded for secure streaming instead of download and play, or physical format delivery.

The Encoder Series has applied in UAV project based on following functions:

- Capturing a real-time video stream in simultaneously when Sony DV video deck device is recording the video stream from UAV.
- Compressing the captured video stream into Windows Media Format in a pre-set coding bit rate.
- Encoding and delivering the real-time video stream to a server system operating with Windows Media Services for broadcasting as a live streaming event on the Internet.
- Using other routing to encoding and deliver the real-time video stream directly to end-users without using a server system for broadcasting on the Internet.
- Customizing in a proper coding bit rate to compromise for a highly variation of transmission rate of Sprint Merlin S620 nationwide PC Card.
- Converting files from one format or bit rate into Windows Media Format.

Fig. 11 shows the sizes of images that encoder program can provide.

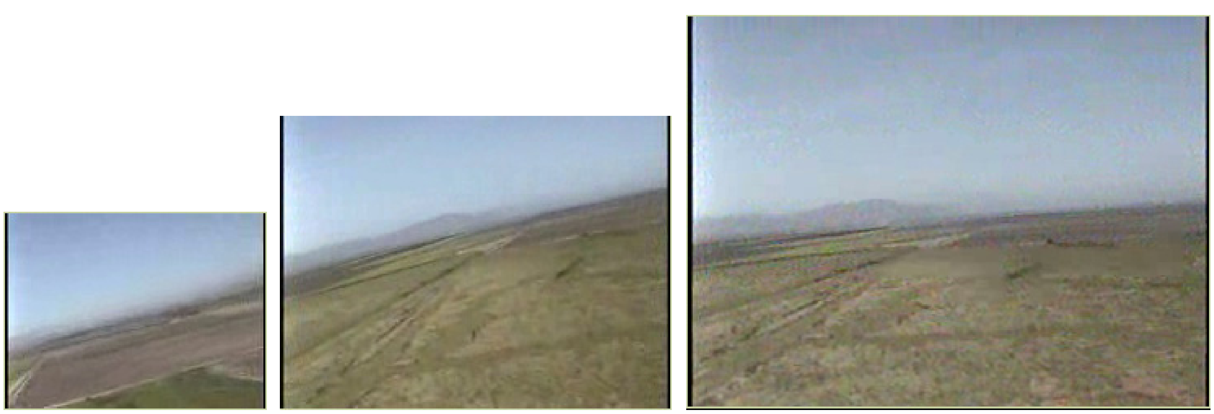
▪ Windows Media Service

Windows media service is one of applications which have built into the Microsoft Windows Server 2003 operating system. Based on functions provided from windows media service, the administrators can enable to organize pre-recoded video and audio files and control the real-time media content to be published to other clients on the Internet. A server system plays as the host to manage and organize any video and audio content which windows media service broadcasts and accesses in real-time. The real-time live broadcast videos will mainly be used during every UAV flying mission. Therefore, the server system can provide a stable environment while windows media service is operating in real-time condition.

The windows Media Service has applied in UAV project based on following functions:

- Setup the bandwidth limits for the publishing during the content distribution.
- Control the number of clients accessing audio and video files simultaneously
- Manage the overall bandwidth demands of the windows media services functions
- Minimize the excessive demands of media service distribution over the network by properly configuration and optimizing media services functions.
- Decide a Real-time live broadcasting to certain clients with authorized IP address
- Provide functions to multiple media files to a single broadcast or in a single directory for selective broadcasting

Windows media service provides two kinds of delivered methods which are unicast and multicast to distribute media content. Basically, the unicast delivery option sets up a one-to-one video stream between the windows media server and each client system, whereas the multicast delivery option sends a single video stream that can be accessed



160x120 240x180 320x240

Figure 11 Encoded Images with Different Sizes

by multiple users simultaneously. This delivery method is simpler to configure and more likely to work without much network infrastructure (router, firewall, system configuration) changes. However, unicast is a significantly more bandwidth-intensive environment. Because each client to server session is a separate video stream, a broadcast with 10 users would have 10 video streams from the server to the clients, and a broadcast with 100 users would feature 100 video streams from the server to the clients. For a relatively small or low-demand windows media service environment, unicast delivery is easier to implement, but be careful when using unicast delivery in large or broadly distributed environments.

On the other hand, the multicast delivery method sends a single video stream out on the network, which can accessed by multiple clients system simultaneously. With a multicast delivery stream, whether 10 users or 100 users need to access the system, there is only s single broadcast either way. However, for a multicast delivery to work, the routers must be configured to support multicast routing. The client systems receiving the multicast broadcasts need to be running in a windows server.

- Windows Media Player

Windows Media player is one of most common media-play applications which usually embed within windows operating systems. For the UAV project, the media player is used to receive any real-time video which has delivered either directly from media encoder or indirectly from server system via the Internet. Any video tobe processed will eventually be represent on the media player. This program is only used on the clients' side in the traffic controlled center.

6. Field Tests

At the beginning of the field experiments, a video stream was delivered from encoder to the end user media player. The playback repeated but the video image was not constant or stable. Instead, the image of video stream had happened either freezing or buffering when the end users were receiving and watching the video. There are some reasons may cause a real time video instability during the streaming. First of all, it is the capacity of bandwidth provided from Sprint cellular network. Even thought the maximum of uploading speed is claimed from 144k to 152k bps by Sprint, the actual speed transmission in field was only between 80k to 135k bps. In order to find out the optimal resolution bit rate, a testing experiment was made and shown in Table 5. It basically shows the results of comparisons of two transmission schemes in different image resolutions. According to the results, the transmission with no server system scheme could only provide a video stream in continuous and smooth image in a bit rate of 43k bps and below. Even though the resolution could increase up 58k bps without any image buffering, the video stream would still freeze up in few minutes. Therefore, an optimal resolution for transmission without a server is setup around 45k bps.

A rate of resolution below 48k bps may not meet the requirement of UAV project. Therefore, a server is needed as a host in order to increase the rate of resolution. According to the experiment results, the transmission with a server system scheme could provide a video stream in continuous and smooth image in a bit rate of 109k bps with a screen size of 160x120 and a rate of 15 frames per second. It proved that a server system can actually improve the drawback of bandwidth limit from Sprint network. Besides, during the late field tests, a server system actually could provide the same rate of resolution to a few end users watching a live media content simultaneously. Therefore, an optimal resolution for transmission with a server system can be setup about 100k bps.

According to the one feature of encoder program, the frame rate can be setup by customer or a specific value such as 15 or 30 frames per second. A higher frame rate can provide a smoother image for end users playback. But somehow, a high frame rate may only occupy the capacity of bandwidth. Therefore, a better frame rate is 15 fps for the UAV project.

Another concern of image quality is the screen size. Usually, a bigger screen size may provide a clearer picture of video stream. However, the bandwidth of network has held up for most possibility of having a high quality image video stream. Therefore, from the testing experiment in field, the image size of 240x160 is a tolerable setup. In the final demonstration to a local MDOT office, the image size was increased into 320x280. Finally, the two transmission schemes are set as listed in Table 6.

	Bit Rate (Kbps)	Frame Rate (fps)	Screen Size	Sprint PCS PC card		
				Buffering	Picture freeze	Picture Smooth
With Server	1128	29.97	320x240	Yes	Yes	NO picture
	764	29.97	320x240	Yes	Yes	NO picture
	548	29.97	320x240	Yes	Yes	NO picture
	340	29.97	320x240	Yes	Yes	NO picture
	282	29.97	320x240	Yes	Yes	NO picture
	148	15	240x180	No	Yes	Yes
	109	15	160x120	No	No	Yes
	58	15	160x120	No	No	Yes
	43	15	160x120	No	No	Yes
	28	15	160x120	No	No	Yes
Without Server	1128	29.97	320x240	Yes	Yes	NO picture
	764	29.97	320x240	Yes	Yes	NO picture
	548	29.97	320x240	Yes	Yes	NO picture
	340	29.97	320x240	Yes	Yes	NO picture
	282	29.97	320x240	Yes	Yes	NO picture
	148	15	240x180	Yes	Yes	NO picture
	109	15	160x120	Yes	Yes	No
	58	15	160x120	No	Yes	No
	43	15	160x120	No	No	Yes
	28	15	160x120	No	No	Yes

Table 5 Communication Data Rates and Feather Results of Field Experiments

Transmission Schemes	Bit Rate (Kbps)	Frame Rate (fps)	Screen Size
With Server	105	15	320x280
Without Server	50	15	160x120

Table 6 Optimal Value for Two Transmission Schemes

VI. Summary

In this study, a small UAV system called MLB's BAT III was chosen for evaluation of the UAV capability in civil applications and documents for approval of flights from the Federal Aviation Administration (FAA) were prepared. Although the FAA recently has set regulations for UAV operations in National Airspace System (NAS), it is extremely difficult for the present UAVs to meet these requirements. Meeting such requirements significantly limits the UAVs capabilities. This study has identified that many requirements can be met by enhancing the present UAV system which may also be served for a future small UAV system design criteria. These may include

- To improve UAV's see-and-avoid capability, a transponder, a lighting beacon, etc. should be included to meet the requirements
- To improve applicability in the suburban/rural area, short landing or special recovery systems should be furthered developed
- To prevent potential failure of communication, redundant communication systems should be considered.

This project was intended to conduct a field experiment but it is still in a pending status due to safety concerns and regulatory issues. The research team has prepared all relevant documents for the FAA certificates including the certificate of airworthiness and the certificate of authorization. There have been numerous issues in the process of obtaining the certificate, and findings are summarized as follows:

- Current regulation requiring either ground observers or chase plane severely hampers UAV applications, so there needs new concept of "see-and-avoid" regulation instead of the present requirements.

- There is a need for defining necessary qualifications of UAV pilots as opposed to requiring airplane pilots for UAV operations.
- There needs to be a FAA authority and separate regulations specifically applicable for UAVs.

This study incorporated video communication systems in the current small UAV system in order to deliver real-time data to a fixed location where traffic authorities can able to make a quick decision. The data communication system was fulfilled by integrating currently available wireless communication technology to Internet space. The web based real-time video streaming system was developed through the server located at the Western Michigan University. The web-server provided reliable video streams to multiple end users without significant communication delays. The web-based information shows its applicability in other monitoring purpose as well.

Although the application of UAV in civil area is still at the early developmental stage, the UAV technology is expected to play a major role for effective infrastructure management and intelligent traffic management by supplying both static data acquisition as well as dynamic data streaming. The UAV applications will become popular in civil and transportation area in near future; however, only more vigorous research efforts will prompt and warrantee safe and effective applications.

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