Final Report on

AIRBORNE TRAFFIC SURVEILLANCE SYSTEMS

Proof of Concept Study
for the
Florida Department of Transportation
FDOT Project No. BC354-86

Presented by
Haniph A. Latchman, Tan Wong, John Shea,
Janise McNair and Michael Fang
Department of Electrical and Computer Engineering

and

Ken Courage, David Bloomquist and Irene Li
Department of Civil and Coastal Engineering

University of Florida
Gainesville, Florida 32611

Presented to the
Florida Department of Transportation
ITS Office

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS

ATIS:	Advanced Traveler Information Systems
ATMS:	Advanced Traffic Management Systems
ATSS:	Airborne Traffic Surveillance Systems
DOD:	Department of Defense
DSL:	Digital Subscriber Line
EMC:	Emergency Management Centers
FAA:	Federal Aviation Administration
FCC:	Federal Communications Commission
FDLE:	Florida Department of Law Enforcement
FDOT:	Florida Department of Transportation
FHP:	Florida Highway Patrol
FHWA:	Federal Highway Administration
I-10:	Interstate 10
I-4:	Interstate 4
I-75:	Interstate 75
I-95:	Interstate 95
ITS:	Intelligent Transportation Systems
MAN:	Municipal Area Network
NTCIP:	National Transportation Communications for ITS Protocol
NTIA:	National Telecommunications and Information Administration
NTP:	Notice to Proceed
NTSC:	National Television Standards Committee
PoC:	Proof of Concept (Research Plan)
PI:	Principal Investigator
RCA:	Remote Control Aircraft
RF:	Radio Frequency
RWIS:	Road Weather Information Systems
SEOC:	State Emergency Operations Center
TAT:	Technical Advisory Team
TCA:	Tallahassee Commercial Airport
TGC:	Telecommunications General Consultant
TMC:	Traffic Management Center
TRC:	Transportation Research Center, University of Florida
TV:	Television
UAV:	Unmanned Aerial Vehicle
UNF:	University of North Florida
UF:	University of Florida

1. EXECUTIVE SUMMARY

In February 2001, The Florida Department of Transportation (FDOT) initiated the "Proof of Concept for Using Unmanned Air Vehicles in Florida DOT ITS Applications." research project. The University of Florida Research Team submitted a proposal addressing FDOT's requirements. The scope of services was revised numerous times after on-going discussions with FDOT and the University of Florida, and a formal revised proposal entitled "Airborne Traffic Surveillance System (ATSS) – a Proof of Concept Study for the Florida Department of Transportation" was finally submitted in March 2002. Following several delays due to further revisions of the Scope of Services, as well as waiting for budgetary approvals and appropriations, a Notice to Proceed was received on November 16, 2002.

In summary, the proposal called for a nominal 10-day, 10 hour per day Proof-of-Concept (PoC) ATSS flight test along a 100 mile stretch of Florida highways, with live video being handed off to several communications/control stations along the route of the flight. The proposal was to have at least one daytime flight each day and one nighttime flight every other day. Each flight could include up to two round trips from the Tallahassee Commercial Airport (TCA) to the interchange of I-75 and I-10. The video signal would then be integrated into an existing FDOT microwave system for display at a remote traffic management location. (A copy of the final proposal is located at http://www.list.ufl.edu/uav).

A tentative date was set for Summer 2003 for the PoC flight-testing in the March 2002 submission. In a December 2002 Kick-off meeting with the FDOT and other stakeholders it was further decided to hold to the original schedule with a tentative flight test window occurring over a 10-day period from July 21 to August 1, 2003.

The tentative dates that were agreed upon represented an aggressive schedule and work began immediately to cover the three core areas: 1) researching and contacting UAV vendors, 2) working with FDOT to understand existing microwave communications infrastructure, and 3) functional mission requirements.

A mailing was sent out to more than 50 UAV manufacturers and service providers and weekly teleconference meetings were established between the University of Florida Research Team and the FDOT ITS Office (now State Traffic Engineering and Operations Office) with Liang Hsia and Lorin Krueger coordinating contact with the ITS office. In addition, an extended meeting was held with Dr. David Lambert, a University of North Florida (UNF) Principal Investigator (PI) with an ongoing FDOT research project that makes use of the FDOT microwave infrastructure for digital communications - similar to that which is envisaged for the ATSS project. A web site at http://www.list.ufl.edu/uav was established to collect ATSS and civilian UAV information. A site was also established at http://list2.list.ufl.edu/uav for sharing resources among the UF Research Team.

The final UAV vendor was decided to be Aerosonde and a sub-contract was negotiated with them. The needs-assessment for the project was completed, and communication and video related equipment was ordered for two microwave tower sites, one tower to be provisioned by SRA/Aerosonde and the other tower by the UF team... Software for handling communications between the UAV, the microwave towers, and the SEOC was developed. In deference of the FAA approval and a decision on the final UAV vendor, the flight date got pushed further and further back. In the meanwhile, a comprehensive ground test was carried out to test the installed communications components of the system. In this test, the video was simulated to be transmitted from a flying UAV and then routed through the communications chain to the screens at SEOC. The final comprehensive test of the terrestrial communication system was completed on April 8, 2004 and confirmed that the complete system with handoff was ready – all that was missing was the flight segment video and tower mounted interface between the terrestrial and the airborne video source. A comprehensive interim report detailing these findings was submitted to FDOT on April 25, 2004.

Since April 2004, The ATSS team (SRA/Aerosonde, FDOT, and the UF Team) held roughly bi-weekly teleconferences at 8:30 am on alternate Tuesdays to discuss the status of the FAA approval of the COA. Several tentative flight windows were set and moved as no word was forth coming from FAA the approval or official denial of the COA.

Finally in December 2004, FDOT communicated to the ATSS team that FAA had denied the COA. The ATSS team then decided on preparing an alternative COA that it was thought might have a better chance of being approved by the FAA in addressing the see and avoid problem.

In February 2005, the Research Team received word from FDOT that the ATSS project was cancelled because there is no solution to FAA's concerns associated with 'see and avoid' and emergency safe landing issues .

This final report documents the progress of this research effort. During the course of the project, reports, descriptions and white papers were submitted as documentation of the proceedings. A summary of each of the submitted documents is presented, in chronological in this report and the full documents are included by reference (and in appendices) as part of this final report.

2. INTRODUCTION

This is the Final Report on the *FDOT Research Contract No. BC-354-86* entitled "AIBORNE TRAFFIC SURVEILLANCE SYSTEM *(ATSS)* - Proof of Concept Study for the Florida Department of Transportation". The reports consists of three major components, arranged in chronological order:

(i) A *Needs Assessment* phase involving a compilation of information critical to the performance of the ATSS mission within the constraints of available resources. A white paper was prepared in this phase to serve as a guideline for the tasks to be implemented in this project.

(ii) Development and deployment of major communication infrastructure for the ground segment of the ATSS.

(iii) Software Documentation for video and signal processing to provide smooth video handoff.

The documentation and appendices include information on the following items:

- Existing data communication capabilities of FDOT's microwave network
- Terrestrial and Aerial communications requirements for control and data signals
- Price quotations from UAV vendors
- Selection of the UAV vendor
- Functional requirements
- Documentation of signal routing software

3. White Paper

A white paper was generated to serve as a complete needs-assessment of the ATSS project. This white paper was submitted to the FDOT on March 27, 2005. It included the findings of the exhaustive search for viable and potential UAV vendors and their offerings and price quotes, the inventory of the existing FDOT telecommunications equipment at hand, a preliminary communication systems design, and tentative test plans and flight schedules.

For the inventory of the existing setup of the microwave tower system network, the UF Research Team worked with Dr. David Lambert of the University of North Florida, who provided a networking infrastructure that is based on the needs of his environmental research team. Figure 1 shows the layout of the system that has been established to retrieve weather-related data at 17 of the FDOT towers.

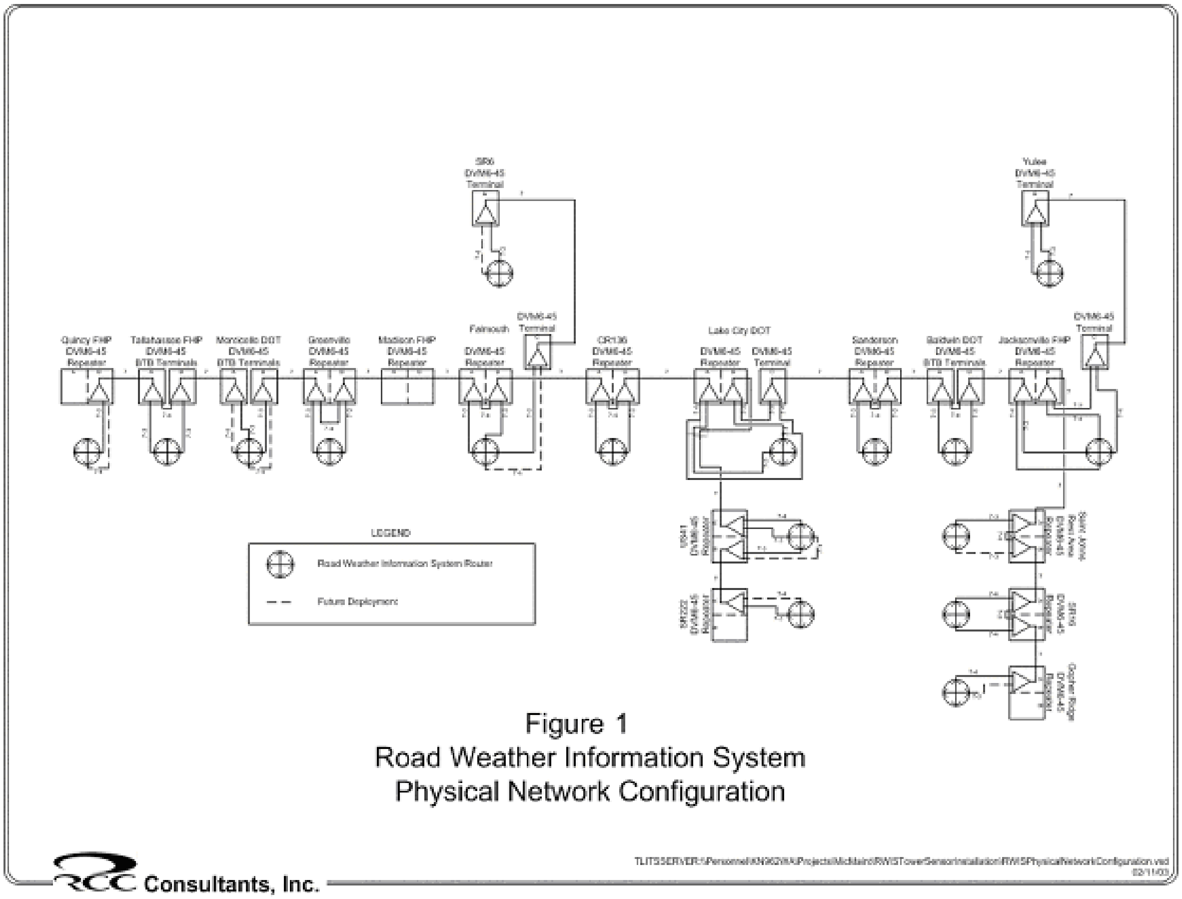

Figure 1: Physical network configuration of FDOT's microwave system

Figure 2 shows the equipment that was housed at each tower at the time the inventory was done.

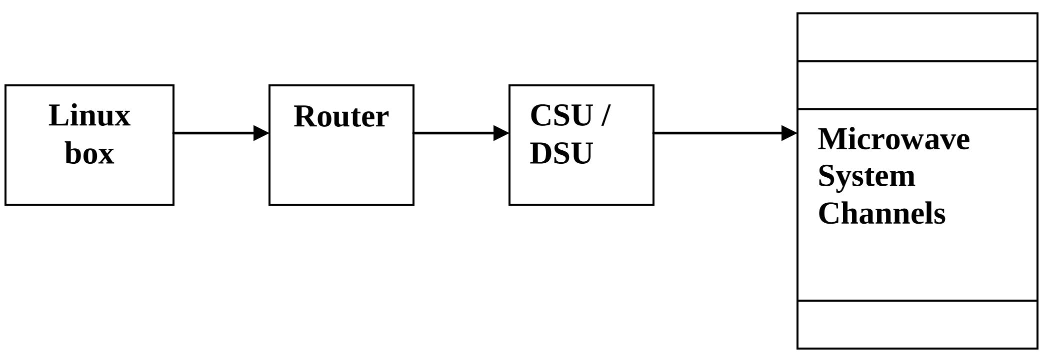

Figure 2: Weather information network tower equipment.

It was established that the towers were capable of providing an equivalent T3 line for data transmission. The hardware and software additions in the existing set up were worked out on the basis of the requirement of video and control signals to be exchanged between the

towers and the UAV, and the back end digitization and transmission of the video on the wired network to the emergency centers.
The proof of concept study came up with the scheme depicted in figure 3.

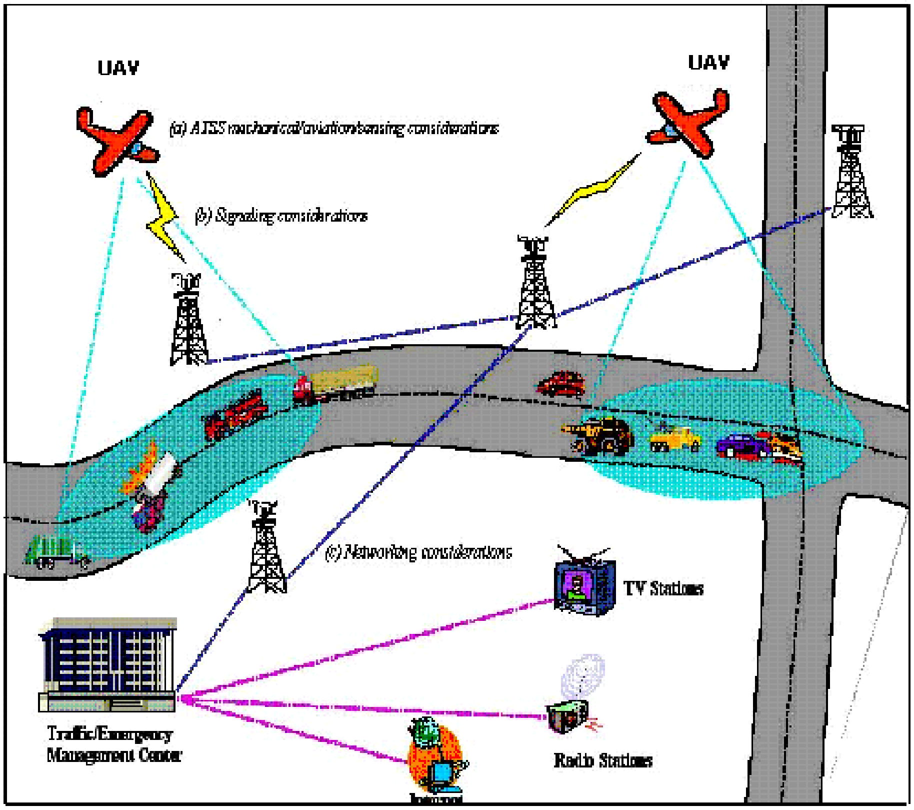

Figure 3: Overview of the ATSS System

The summary of negotiations with the UAV vendors is shown in table 1. Many vendors that were contacted were not interested in civilian applications but the vendors listed below were very positive about the ATSS project and expressed a strong desire to work with the UF Research Team and FDOT for this study. The aerial platform product and price quotes from each vendor are included in the summary below.

Vendor	Aerial Platform Product	Price Quote
Adroit Systems	Aerosonde	$99,885
Aurora Flight Sciences	Goldeneye Vertical Take-Off & Landing (VTOL) UAV	$150,000
DRS Technologies	Sentry HP UAV	$160,000
Geo Data Systems (GDS)	Airborne Data Acquisition System (ADAS)	$15,790

Rumpf Associates	AeroStar UAV	Within $50,000

Table 1: UAV Vendors, Aerial Platform and Price Estimate

The UF Research Team and the FDOT unanimously selected Adroit/SRA as the vendor of choice for the ATSS project. This was after lengthy and detailed teleconferences with the development teams of the five major UAV vendors who were short listed in the ATSS project. Adroit / SRA was selected as the vendor of choice with their Aerosonde Mark 3 Robotic Aircraft for reasons that included cost and transmission capability in civilian communication bands.

Figure 4: The Aerosonde UAV

The Aerosonde UAV (see Figure 4) is made in Australia and operated by Aerosonde Pty Ltd (AePL). It was first introduced to the marketplace in 1995 for weather surveillance applications. Approximately 50 of these planes have been built to date. The plane has a 9.5-foot wingspan, 6.2 ft. length, and weighs 30 lbs fully loaded with 1 1/2 gallons of fuel (gasoline). It has flown continuously for over 32 hours. FDOT anticipates that the Aerosonde UAV will fly at an altitude of between 1,000 and 2,000 feet above the ground for the test, where it will be largely invisible during daylight hours. Its on-board strobe lights will make it visible at nighttime. The Aerosonde employs a Sony XC555 color video camera and a pair of Vaisala RSS901 weather sondes to gather freeway surveillance and RWIS data for transmission to the FDOT microwave towers.

The white paper also addressed issues of video quality, equipment procurement, operating conditions for the UAV in terms of altitude, sky conditions, aircraft stability etc., and tentative flight schedules.

4. Interim Report

An Interim Report was filed on April 25, 2004 to describe the proceedings of a series of visits of UF's research teams made to the SEOC at Tallahassee and to the microwave towers at Lake City and White Springs. The communications equipment and software packages were installed at all the locations during these visits and a final simulation of ground operation was carried out to show the effectiveness of the arrangement in capturing the received signal strength of video that was simulated to be coming from an airborne UAV. This simulation test was successful in demonstrating the satisfactory operation of all the components in the video signal chain including video handoff, and the final projection of video on the SEOC monitors.

For completing the ground communications aspect of the signal chain, the signal would be transmitted over the FDOT's microwave network and the switching of the video signals would be based on the strengths of the signals at the two tower sites of Lake City and White Springs. Software specialized for the purpose of transmitting signals and switching video based on signal strength was unavailable in the market, and so the UF team developed a preliminary version of it. The video equipment used the Microsoft Media tools for transmitting the digital video.

In addition, the UF Team was responsible for equipping one tower to receive the video signal (SRA/Aerosonde was responsible for equipping the other tower as part of their subcontract work). All the required equipment (Antenna, mounting gear, cables, and electronic components, etc.) were procured. A GSM receiver was bought to receive the video from the UAV. The other power equipment for controlling voltage surges was bought from Atlantic Scientific. All this equipment was taken to the Lake City FDOT office in January 2004.

The first ground simulation of networking, video encoding and video switching using software developed by the UF Team was performed on August 30, 2003, and proved successfully the fidelity of FDOT's network infrastructure and the video capturing, encoding, and streaming capability of the software. The broadcast session was recorded at SEOC and the video was considered to be of excellent quality.

In the meanwhile, the UF team had developed a more advanced version of the hand-off software that could read in the signal strength from the video receiver and transmit it over the network to the video-processing software residing at SEOC. This signal strength reader software was placed at the two towers, and the video processing software, that could read the encoded signal strength in the two video streams coming from the two towers, would choose the stronger signal and display on the screen.

The UF research team and FDOT project team carried out a comprehensive ground test on April 8th, 2004 to demonstrate the video encoding, streaming and switching capabilities of the ground network. UF researchers transported the required equipment to the sites and set up the equipment to simulate a full ground simulation. The experiment was completely successful in the demonstration of how the video encoder, signal reader and video processor could act in tandem for transmission and projection of video signals at the SEOC. It was shown that the software and hardware purchased and set up by the UFL research team was fully ready for the actual ATSS project and the UAV flight.

5. Software Documentation

The program documentation outlines the details of the software packages that were developed at the LIST lab at the University of Florida to assist in signal capture. Essentially, the software is designed in such a way as to read the strength of video signals that will be caught by two microwave towers between which the UAV is flying. Both these video streams are sent to the SEOC where the video processor program constantly monitors the two streams and intelligently decides which stream to display on the TV monitors on the basis of received signal strength.

The software comprises two distinct components – the Video Processor that is stationed at the SEOC, and the Signal Strength Readers that are installed at the microwave towers at Lake City and White Springs.

The Video Processor provides switching capability between video signals coming in from the two towers (currently Lake City and White Springs) based on the strength of the video signals. The videos, as well as the signal strengths, are sent over the network from the two towers as a composite data stream. The interface of this software is shown in Figure 5.

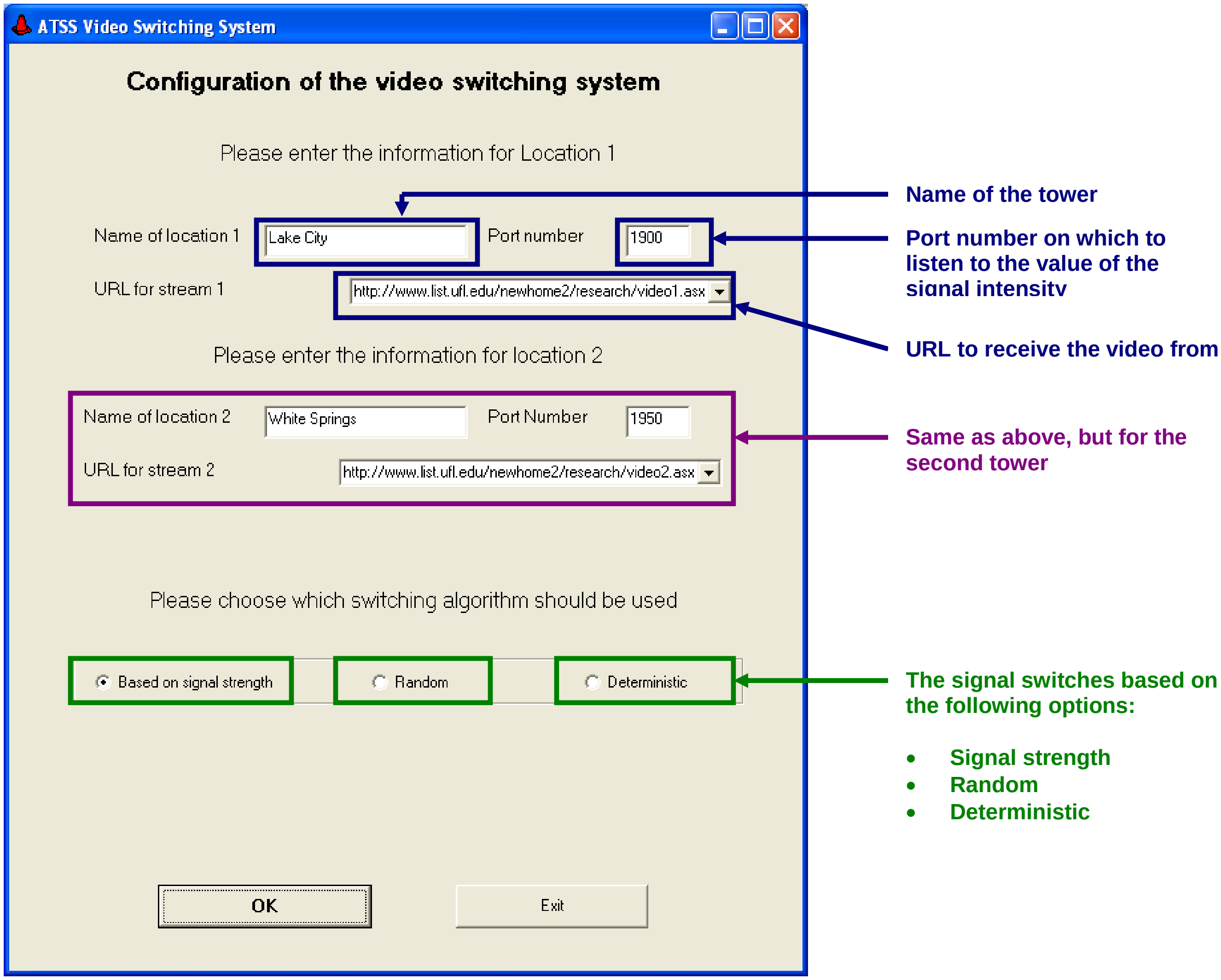

Figure 5: Interface for the Video Processor software, with descriptions of each component

The Signal Strength Reader reads the strength (as voltage) of the video signal received by GMS receiver from the UAV. It then encodes this strength information in the data stream that is to be transmitted to the SEOC. The working interface of this software is shown in Figure 6.

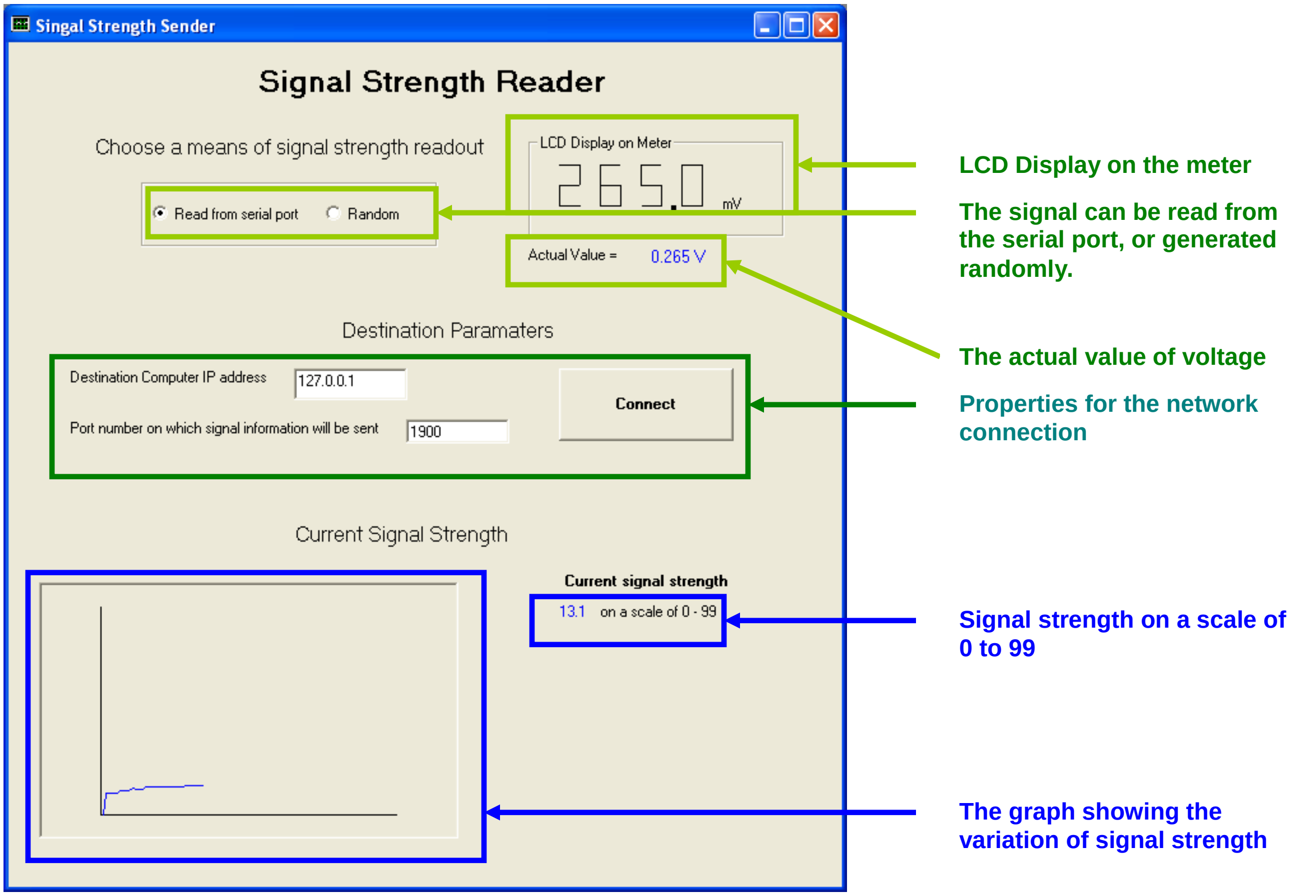

Figure 6: Interface for the Signal Strength Reader software, with descriptions of each component

A UAV that flies in a corridor between the two microwave towers sends signals that are received by both towers. The encoding hardware and software at the towers forward the data streams to the SEOC, where the signal to be projected on the screen in chosen from the two signals coming in on the basis of their strengths. The software at SEOC constantly monitors the signal level and transitions between the two signals in real time, always projecting the stronger signal.

6. Technical Paper

A technical paper describing the salient features of the ATSS project was written and submitted to the 2^{nd} International Workshop on Video Surveillance Networks, which was a part of the ACM multimedia conference. This paper was accepted and was presented at Columbia University, New York, in October 2004.

The Abstract of the paper reads:

Timely information about highway traffic conditions is very important for the Department of Transportation (DOT) and other relevant agencies. Such live information would be very important when traffic incidents or accidents occur. An aerial view is the best for traffic situations, particularly over highways. Unmanned aircraft equipped with monitoring video cameras and/or other sensors may be able to deliver the necessary information through video images with relatively low operational costs and risks to human life. ATSS (Airborne Traffic Surveillance System), a project funded by the Florida Department of Transportation, attempts to make this vision a reality. This paper describes how the University of Florida research team implemented a system for ATSS from ground up, using unmanned aerial vehicles, digital video encoding, and transmission of data and multimedia video streams over FDOT's microwave IP networks.

7. State of Completion of Project

At the time we submitted our Interim Report (Appendix III), the project was at 70% completion, with the major tasks remaining being the actual proof of concept flight test and subsequent data analysis and preparation of the final report.

At this time we report a 74% completion with an unspent balance of $79, 885 which was encumbered for payment to the subcontractor SRA. All other work has been completed.

8. Conclusions

It is our view that the ATSS project has successfully demonstrated the feasibility of using the existing FDOT microwave communication systems, augmented with TCP/IP networking equipment, to transport seamlessly video signals from various tower locations in the network.

The Interim report clearly confirms that a fully functional video distribution network with video originating from at least two towers, with seamless handoff based on received signal strength was designed, and implemented. The only missing components was the airborne segment with video from the Aerosonde.

It is unfortunate that we were unable despite much effort to secure FAA permission to fly as per our original COA.

There is no doubt that the FDOT's vision in the ATSS project has a great deal of potential and this project has advanced these ideas significantly. It is our hope that in the near future strategic vision embedded in the FDO/UF ATSS project will be fully realized and the University of Florida Team is eager to participate in such future endeavors.