APPLYING INSTRUMENTATION & TELEMETERING TECHNOLOGIES FROM THE DOD TEST & EVALUATION ARENA TO COMMERCIAL LAW ENFORCEMENT APPLICATIONS

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ABSTRACT

The Law Enforcement Aerial Platform System (LEAPS), designed and integrated by Spiral Technology, Inc., was architected to marry airborne sensors and ground-based instrumentation in support of and to augment the Law Enforcement and/or Disaster Response and Recovery agencies of counties and municipalities. The mission of LEAPS is to provide an affordable reliable manned or unmanned aerial surveillance system that readily integrates with existing Law Enforcement's and Local Government's infrastructures.

The initial sensors being integrated into the LEAPS concept include both Visible Spectrum and Infrared Imager. Salient requirements for LEAPS include: Ground Control of Airborne Sensors; Sensor Data captured and archived on the ground with time-tag and geographic location data; and Controlled Custody and Preservation of Sensor Data as Evidentiary Material

This paper describes the LEAPS System Development Effort.

KEY WORDS

Telemetry, Instrumentation, Test and Evaluation, Law Enforcement, DoD, Video Surveillance, Disaster Response and Recovery

INTRODUCTION

The Law Enforcement Aerial Platform System (LEAPS) has been architected to marry airborne sensors and ground-based instrumentation to augment Law Enforcement (LE) and/or Disaster Response and Recovery agencies of counties and municipalities. The mission of LEAPS is to provide an affordable, reliable, manned or unmanned, aerial surveillance system that integrates with existing Law Enforcement and/or Local Government's infrastructures.

The LEAPS design goals were centered on:

- Providing an affordable reliable manned or unmanned aerial surveillance system that readily integrates with existing Law Enforcement's and Local Government's infrastructures.
- Combining airborne sensors and ground-based instrumentation in support of and to augment Law Enforcement.
- Providing Support to Disaster Response and Recovery agencies of counties and municipalities.
- Cost Effectively Operating LEAPS

The high level requirements for the LEAPS are defined as follows:

- Provide Airborne Imaging 10 Hrs./Day, 7 Days/Week
    - On-Station Time in Visual Flight Rules (VFR) flight conditions
- Ground Control of Airborne Sensor by Law Enforcement Dispatch Staff
    - No sensor imagery accessible in the air vehicle
- Imagery resolution sufficient to see persons and actions from 3,000 feet above ground level (AGL)
- Imagery captured and archived with time-tag and geographic location data to allow search and retrieval by date/time and latitude/longitude
- All Radio Frequency Communications are Encrypted
- Access to all Command and Control (C/C) functions as well as imagery requires user authentication
- Write Once, Read Many Imagery Archive
    - Preservation of Evidentiary Material

The LEAPS architecture was designed, integrated, and put into operation by Spiral Technology, Inc. The LEAPS Aircraft Operations is managed by Aero-View, LLC. Aero-View is responsible for the day-to-day operations of LEAPS and providing Law Enforcement with the data required.

LAW ENFORCEMENT AERIAL PLATFORM SYSTEM (LEAPS) DEVELOPMENT

Selecting the LEAPS Aircraft

The Cessna 172 "Skyhawk" platform was chosen, for many reasons. It is a well proven design, first produced in 1956 and is one of the most popular high-wing aircraft that many have flown and are familiar with. Its low operating costs, high-wing design and speed profile (65-115 Knots) make it the ideal candidate for use as a camera platform such as LEAPS. Many 172's have been deployed in similar "airborne camera" operations. The equipment installed in the LEAPS is already Supplemental Type Certificate (STC) approved.

Figure 1 - 1979 Cessna Model 172N

A close-up view of the LEAPS camera system is shown in the photograph on the right. The video images from this camera along with positioning information are transmitted to the ground and presented to LE operations personnel in the Dispatcher Station

Figure 2 - Airborne Camera (Visible & IR)

LEAPS was developed using four (4) Segments of design.

Segment 1: THE AIR VEHICLE - This segment provides an aerial platform to contain and support the Segment Two Airborne System.

Segment 2: AIRBORNE SYSTEM – This segment will reside in the Air Vehicle and provides the imager and associated mechanical and electronic elements to position these assets for optimal support to the Segment Three, Ground System including a primary and backup downlink of position information.

Segment 3: GROUND SYSTEM – This segment is rack mounted and located in the local LE dispatch facility and operated by local LE dispatch staff.

Segment 4: DATA ARCHIVAL/RETRIEVAL SYSTEM – This segment is rack mounted and located in the local LE dispatch facility and operated by local LE staff. It consists of a Real Time Video Storage Array to accommodate recording with write once, read many (WORM) access to the stored data. Its design maintains uncorrupted evidentiary data in controlled custody.

Figure 3 below represents the operational concept of the LEAPS program as it applies to the surveillance tasks assigned by the Sheriff's Dispatcher.

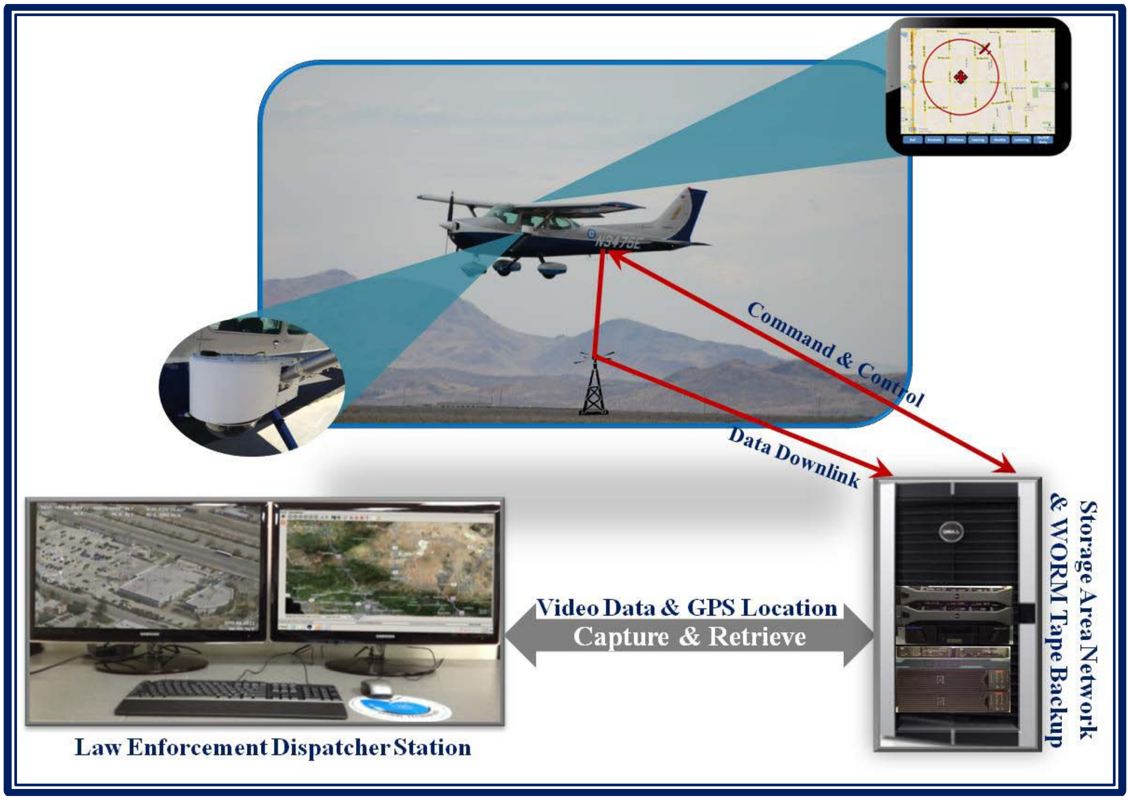

Figure 3 - LEAPS Operational Concept

The Law Enforcement Ground System Operator (Dispatcher) will create video sensor tasking by entering a street address, point and click on a selected area of the displayed map, or move the cursor to the center of the image to be viewed. This sends commands to the aircraft and immediately points the camera toward the selected GPS Coordinates. From this station the Dispatcher may: 1) Point the Camera; 2) See the current location of the LEAPS Aircraft; 3) Zoom the Camera In/Out; 4)Track an item in view, i.e. vehicle, person, etc.; 5) Direct the LEAPS Aircraft to the scene; or 6) Return the Aircraft to normal surveillance mode.

Figure 4 - Tasking the LEAPS Pilot

In the LEAPS Aircraft, the pilot will follow a generated air vehicle desired surveillance ground track to be delivered via the Pilot Tasking Software. This flight path will be based on air vehicle altitude and will be a calculated ground track needed to optimize the Law Enforcement Ground System Operator's selected view and generate a desired ground track that is published to the Pilot Tasking Display. If the aircraft is to be dispatched to provide a more optimized view of the selected scene, the pilot will be provided a ground track to optimize time and access to the selected information.

LEAPS Dispatcher Station

Figure 5 – The LEAPS Dispatcher's Workstation

At the Dispatcher Station, LEAPS presents the following Information:

- Real-Time View from the Camera
- Map Presenting the Location of the Aircraft and the Camera view angle and field of view.
- Camera Pointing and Control Information (Pan, Zoom, and Spectrum)
- Optical Tracker Option Command and Control
- Downlink Transmitter / Receiver Status and Tracking Antenna Performance Parameters
- Aircraft Status

Data Archival and Retrieval System

- Real Time storage device has 12 Terabyte capacity which can be expandable to 192 Terabyte capacity.
- Video Storage Array (Tape Based) for archival of recorded video with WORM media.
- Ability for Law Enforcement to "prune" archived video to catalog and maintain only that which is deemed necessary to support legal actions and playback functions.
- Equipment includes:
  - ➢ 2 Cisco Switches
  - ➢ Cisco Firewall
  - ➢ 2 Uninterruptable Power Supplies
  - ➢ Storage Area Network Server
  - ➢ Storage Area Network
  - ➢ Write Once Read Many Tape Backup System

Figure 6 - LEAPS Servers

LEAPS – The Implementation

Satisfying Acoustic Concerns:

Gather acoustic signature data for LEAPS planned operating modes and altitudes in a realistic setting.

Flight Scenarios:

Scenario #1: 3,000' AGL, 80 Knots. Flight path will be out and back along Avenue K in Lancaster, CA to simulate non-tasked loiter mode – repetition over monitor site approx 5 minutes. Aircraft will fly over monitoring station; 5 passes or more if needed for adequate sound measuring.

Scenario #2: 3,000' AGL, 80 Knots. Flight path will be a counter-clockwise circular orbit around a point offset so as to pass over monitor station, with a 2 minute turn. This will simulate the aircraft being tasked to look at an area, from its initial higher altitude.

Scenario #3: 1,200' AGL, 80 Knots. Flight path will be a counter-clockwise circular orbit around a point offset so as to pass over monitor station, with a 2 minute turn. This will simulate the aircraft being tasked to look at an area, from the lowest altitude we expect to operate at.

Scenario #4: 1,200' AGL climbing to 3,000' AGL 75 Knots
Full power climb, circular flight path counter-clockwise returning to higher altitude. This should represent the maximum noise condition.

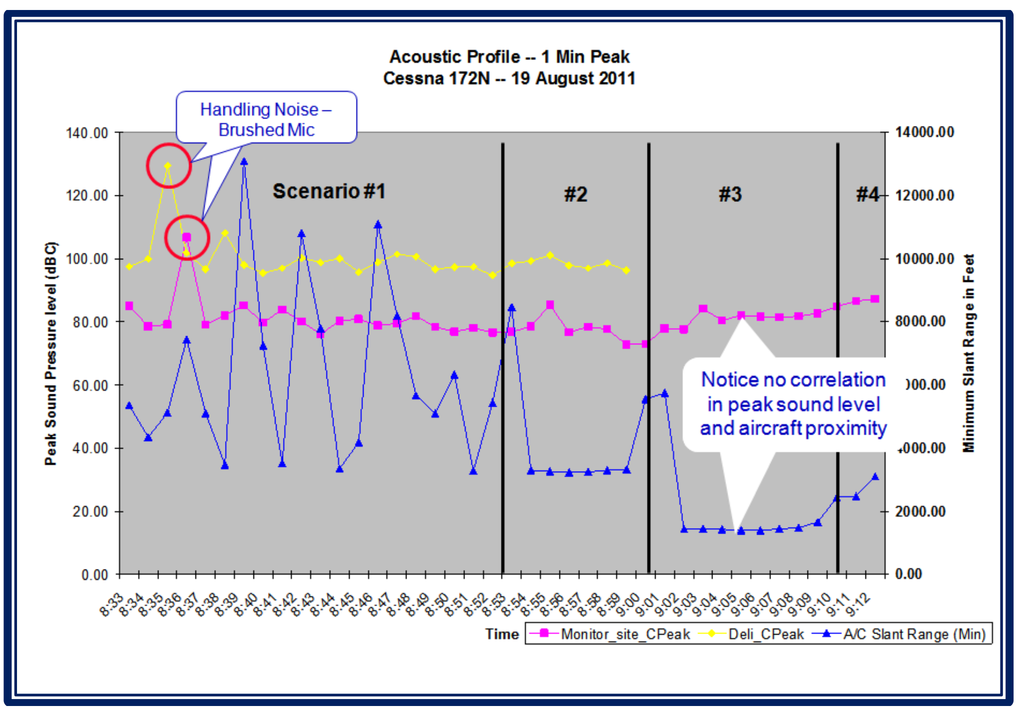

Figure 7 - Flight Scenarios Acoustic Profile Results

Radio Frequency (RF) Communincations

Our first flights looked as though they were matching the predictions. On the ground we were seeing -85 dBm levels in the intended spectrum. However, shortly after take-off with elevations of 1,000 feet we began seeing the noise floor increase to as much as -55 dBm with a dominate floor value of -70 dBm. A spectrum analysis from the radio's internal analyzer is shown in Figure 9.

The data from our link analysis showed that the noise impact to 2.4 GHz in our area of operation (noise floor as much as -55 dBm with a dominate floor value of -70 dBm) was significant. With these results, we selected the airborne and ground antenna systems described below for use on LEAPS.

Figure 8 - Aircraft Antenna

The increased noise floor led to our deployment of the current antenna configuration. The aircraft is configured with a Broadcast Microwave Services (BMS) GCA-11 11 dBi gain antenna in which the azimuth is electronically steered to point at our ground tracking antenna. A photo of the antenna is shown in Figure 8.

The ground segment is using a 24 dBi grid parabolic mounted to a pan-tilt positioner as shown in the drawing at Figures 9, 10, and 11. The azimuth and elevation is controlled via software to track the GPS location of the aircraft as reported via the downlink data stream and the secondary downlink position stream. The combination of directional gain antenna on both aircraft and ground has overcome our link margin issue caused by the higher than estimated noise floor. We have sufficient margin to meet the customers range with margin to allow for an increasing noise floor as additional users flock to this spectrum. We are also researching licensed spectrum for future implementations as may be required.

Figure 9 - Grid Parabolic Antenna

Figure 11 - Pan & Tilt Positioner

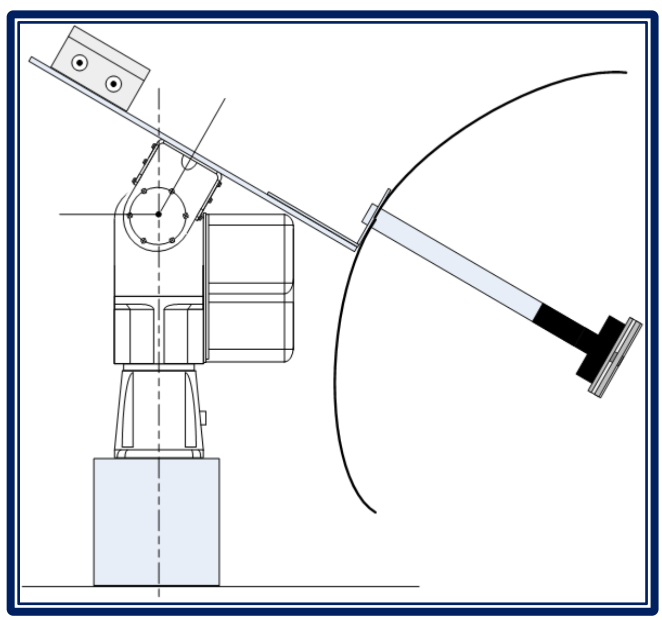

Figure 10 - Integrated Tower Mounted Antenna

Figure 12 – Ground Antenna System Mounted Atop a 180' Tower

This Ground Tracking system is currently mounted on top of a 180ft tower located near the center of the LEAPS system's 90 square mile surviellance area.

This tower is depicted in Figure 12. The downlinked data is captured by the Ground Antenna Systems, transmitted over Ethernet cable down to a Ground Based System (Figure 6) located in the basement of the attached service building where it is recorded onto a 16 TeraByte (expandable to 192 TeraByte) Storage Area Network (SAN) and sent, over Ethernet, to the Dispatcher Station (Figure 5) which resides approximately 1.5 miles away.

This path is used to provide full communications between the Aircraft and the Ground and consists of two data streams. One stream contains camera imagery, and aircraft/camera system status sent from the aircraft to the ground. This stream also issues commands to the camera system from the ground.
A second stream is used for ground/aircraft communications (pilot tasking - see Figure 4). This low-bandwidth "4G" stream is used to direct the pilot, and to provide communications between the pilot and the ground. This stream is independent, so if the primary camera imagery stream is lost, communications with the pilot tracking antenna pointing is still possible.

Commercial Off The Shelf Software and Custom Developed Software:

Software for the LEAPS program is the components provided by the manufacturers of the various equipments in the system. These were integrated together and utilized where it fit our requirements. In other cases custom software was developed to optimize the operation and efficiency of the system. This custom software is composed of two pieces of software: Ground software and pilot software. They are used to receive camera imagery, command the camera system, and communicate commands between aircraft and ground the following components were developed to satisfy the following characteristics.

- Platform Independence preferred
- Windows based ground station
- Windows applications, and Javascript web application in use on the ground
- Javascript application on ground can also be used at multiple desktops, allowing more than one person to monitor the system
- Camera imagery can be displayed on multiple desktops
- Aircraft software is also a Javascript web application.
- Tablet on aircraft, is robust, simple to use, with touch screen
- Both applications communicate with a server (to transfer commands, and to log events)

CONCLUSIONS

The LEAPS aircraft and associated components are currently in use supporting LA County Sheriff's Department Station in the Lancaster, CA Station, providing surveillance in support of the Officers in the community who provide protection for their citizens.

It has proven to be an extremely successful effort even with the challenges we encountered during the development process.

As the program grows and more requirements are determined from the day to day use of LEAPS, the lessons learned in this development effort will assist in making the next system better and more efficient as well as reducing the cost for future generations of LEAPS.

The graphic shown in Figure 13 below represents the view afforded to the Dispatcher using the LEAPS Airborne Surveillance System.

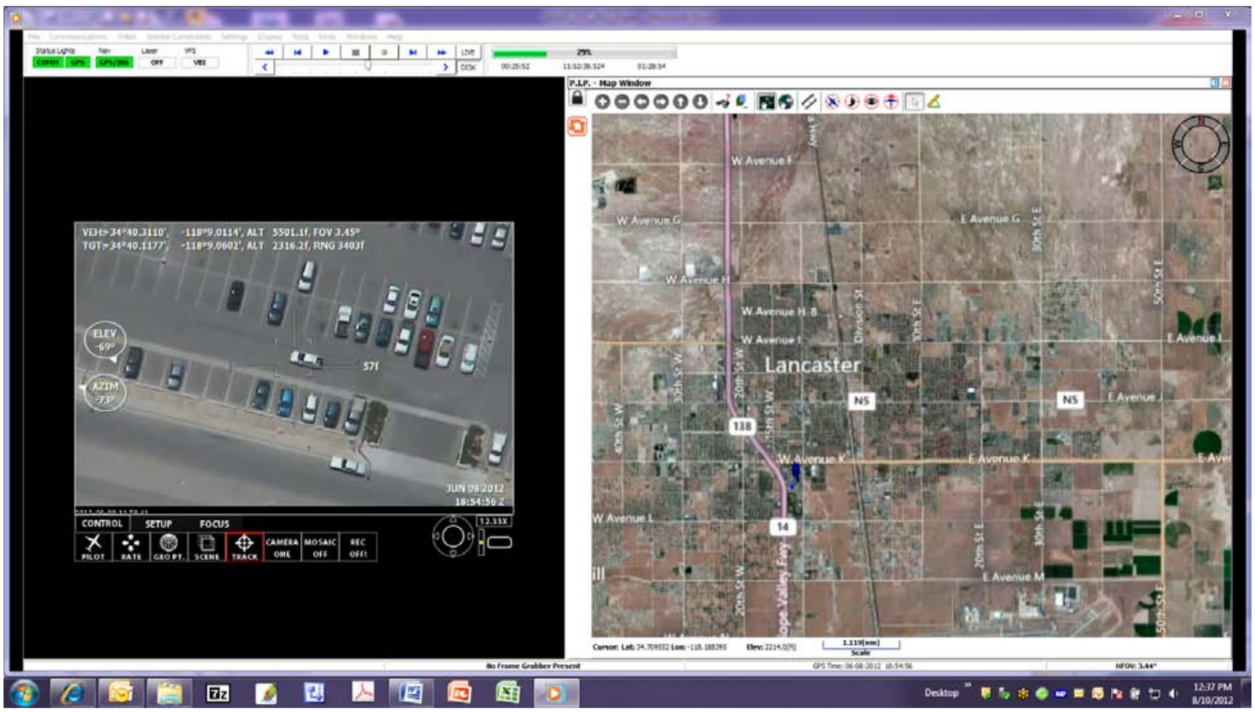

Figure 13 – The LEAPS Dispatcher Station Video Information Display

NOMENCLATURE

4G	The fourth generation of cell phone mobile communications standards
AGL	Above Ground Level
BMS	Broadcast Microwave Services
C/C	Command and Control
COTS	Commercial Off The Shelf
dBi	decibel isotropic
dBm	power ratio in decibels (dB) of the measured power referenced to one milliwatt
DoD	Department of Defense
GHz	Giga Hertz
GPS	Global Positioning System
IR	Infra-Red
ISM	Industrial, Scientific, Medical unlicensed spectrum
LE	Law Enforcement
LEAPS	Law Enforcement Aerial Platform System
RF	Radio Frequency
STC	Supplemental Type Certificate
VFR	Visual Flight Rules
WiFi	Wireless Local Area Network
WORM	Write Once Read Many