Wide Area Motion Imagery

Ross McNutt PHd.
Persistent Surveillance Systems
Sept 2013

Persistent Surveillance Systems

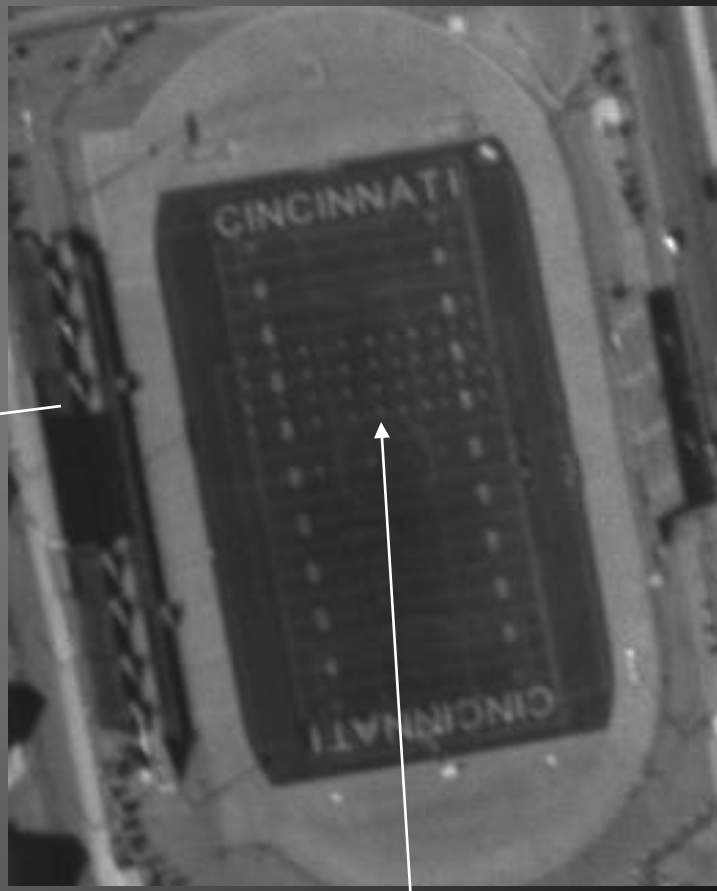
- Wide Area Airborne Surveillance Introduction
- Sample Coverage Areas
- Example Murder Investigation
- Analysis and Law Enforcement Use
- Sample City Unmet Needs
- Systems and Costs
- Invitation to come see systems in use

Persistent Surveillance Systems

Wide Area Surveillance

88 megapixels 1Hz downlinked

Cincinnati 12 Sept 07



Football players practicing

Persistent Surveillance Systems

Samples of Pixels

Typical Security Camera

Standard TV	640 x 480	0.31 MP
HD TV 720P	1280 x 720	0.92 MP
HD 1080	1920 x 1080	2.07 MP
Digital Cinema 2K	2048 x 1080	2.21 MP
Imax Digital Cinema 4k	4096 x 2160	8.84 MP

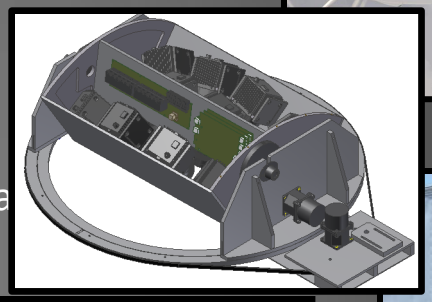
Wide Area Surveillance Systems

PSS Hawkeye	99 MP
PSS Hawkeye II Color	192 MP
NightHawk	88 MP E/O -- 64 MP MWIR
Vision RL Ground Based System	128 MP

HawkEye
Wide Area Surveillance System

- Aircraft: Cirrus SR-22 or AirVan with Pod
  - 8 hours time on station
  - Modern Comfortable aircraft
  - Glass Cockpit with integrated autopilot
- Hawkeye II 192 Megapixel Color WAAS Camera system
- Airborne Image Processing Unit
- Spot Beam (high resolution characterization EO and IR camera
  - PSS High res Spot beam or TASE 400
- Secure Broad Band Data Links 300 Mbps
- 200 TB Image Server and Storage
- Deployable Command Center
- 10 Analyst Workstations
- Mobile Command Vehicle

Cirrus SR-22

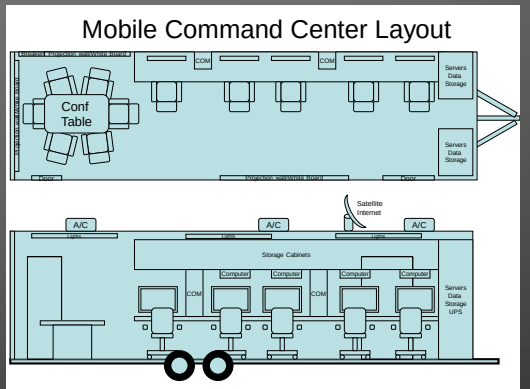


Cirrus Surveillance Pod

Add 300 mbs Ground Links

Cirrus SR-22 with Surveillance Pod

Up-level Command Center



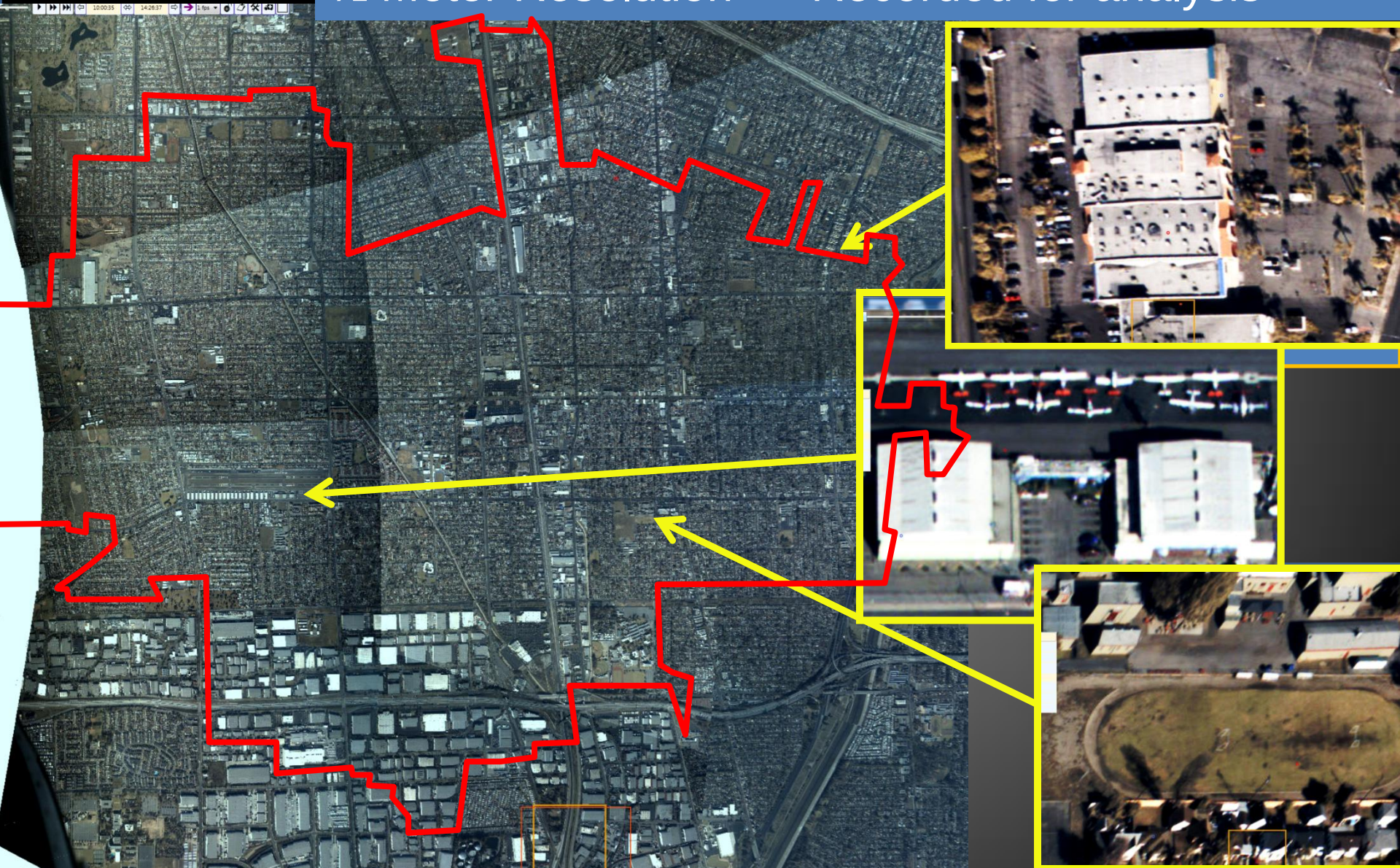
Up-level Highly Mobile Command Vehicle

Persistent Surveillance Systems

Wide Area Surveillance

64 Square Kilometers 192 Megapixel Color Image

½ Meter Resolution Recorded for analysis



Analysts at Work

Persistent Surveillance Systems
Levels of Analysis

- Real -Time Operational Support
  - Event response and information forwarding
  - Multiple simultaneous location surveillance
  - Cued or tasked support - Dispatch or 911, locations of interest, BOLO
- Level 1 Analysis - Overnight
  - Who is directly involved with the crime
  - Where did they come from
  - Where did they go
- Level 2 Analysis – 1-3 days
  - Who did the criminals meet with
  - Where did they come from
  - Where did they go
- Level 3 Network Analysis - 1 week
  - Over the last week or two who did all of the above meet with
  - Where did they come from and where did they go

Persistent Surveillance Systems

Surveillance Systems Integration

- Wide Area Surveillance
- Police and 911 Dispatch
- Ground Based Cameras
- Shot Spotter
- Automatic License Plate Readers
- Electronic Surveillance
  - Direction Finding and intercept

Integrated Surveillance Center - Dayton Ohio

Wide Area Surveillance Other Applications

- Officer Support
  - Support for local law enforcement in crime investigations
  - Philadelphia, Baltimore, Dayton, Compton, Nogales, Juarez, Mexicali, Torreon, Indianapolis, Columbus, Cleveland
- Major Event Security
  - Security and traffic management support of large events
  - Brickyard 400, Coca Cola 600, Sarah Palin VP announcement, 4th July Fort Leonard Wood, Ohio State Football
- Emergency Response
  - Quick response to natural disasters and other events
  - Iowa Floods, Gulf Oil Spill, Hurricane Sandy
- Border Surveillance
  - Coverage of large swaths of remote borders
  - Yuma Proving Grounds, Nogales Sector, El Paso Sector
- Environmental Management
  - Pipeline surveillance, environmental impact, wild life studies, traffic Studies

Persistent Surveillance Systems

- **Conducting Live Operations since 2008**
  - NASCAR BrickYard 400 Indianapolis Motor Speedway
  - North Philadelphia Philadelphia Police Department
  - Baltimore Police Department
  - NASCAR Race Cola Cola 600 Charlotte Motor Speedway
  - Iowa Floods
  - Dayton Police Department
  - Sarah Palin VP Candidate Announcement
  - Ft Leonard Wood
  - Juarez Mexico
  - Private Kidnapping
  - El Paso Border Surveillance DEA
  - Gulf Oil Spill
  - Mexicali Mexico
  - Torreon Mexico
  - Compton California – LA Sheriffs Office
  - Nogales Arizona Border Security Operations
  - Dayton Police Department
  - Hurricane Sandy Response NJ/NY Emergency Response

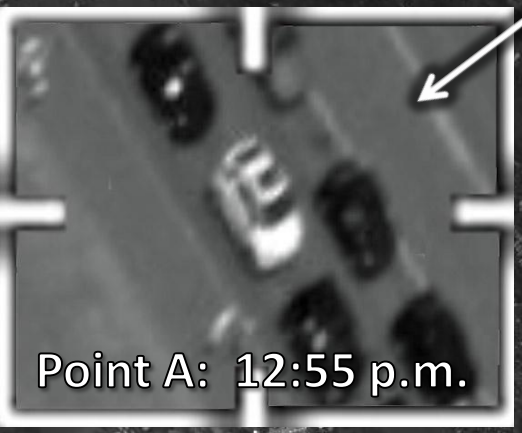
Persistent Surveillance Systems

Major Event Security

- Pre-Race Planning
- Minor Incident Response
- Major Incident Response
- Traffic Management
- Business Case

Brickyard 400 Indianapolis Motor Speedway

Charlotte Motor Speedway Coca-Cola 600
VEHICLE TRACKED FROM POINT A TO POINT B



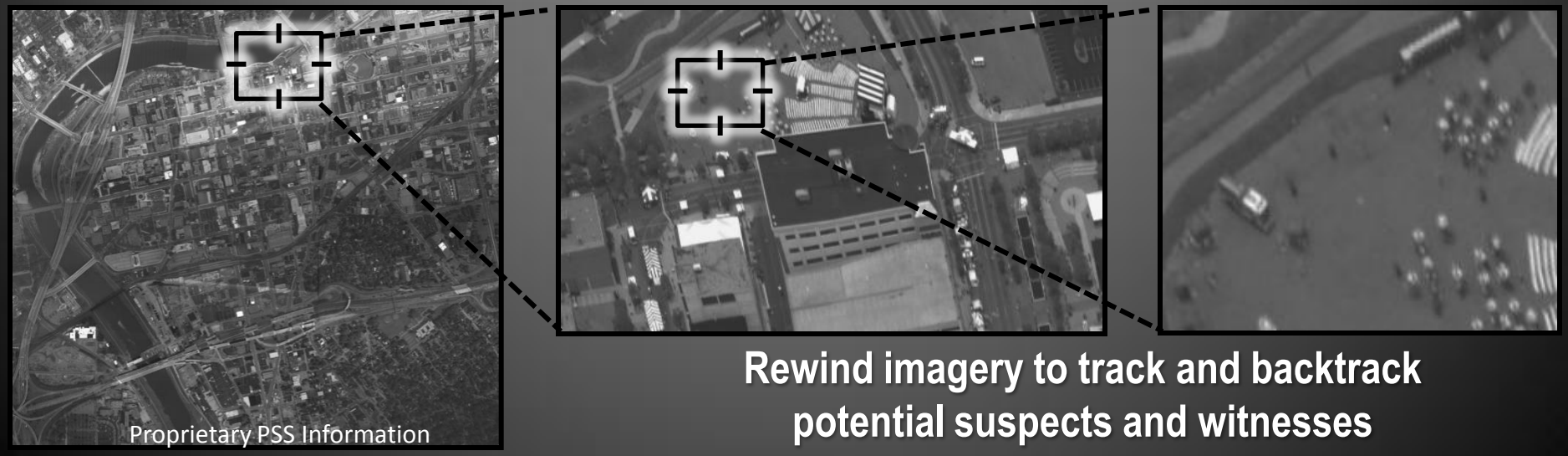
- Total Distance Traveled: 1.4 Miles
- Total Travel Time: 1 Hour, 45 Minutes
  - Does not include travel time on interstate or roadways approaching track

Persistent Surveillance Systems

Emergency Support and Disaster Response

Real-Time Major Incident Response:

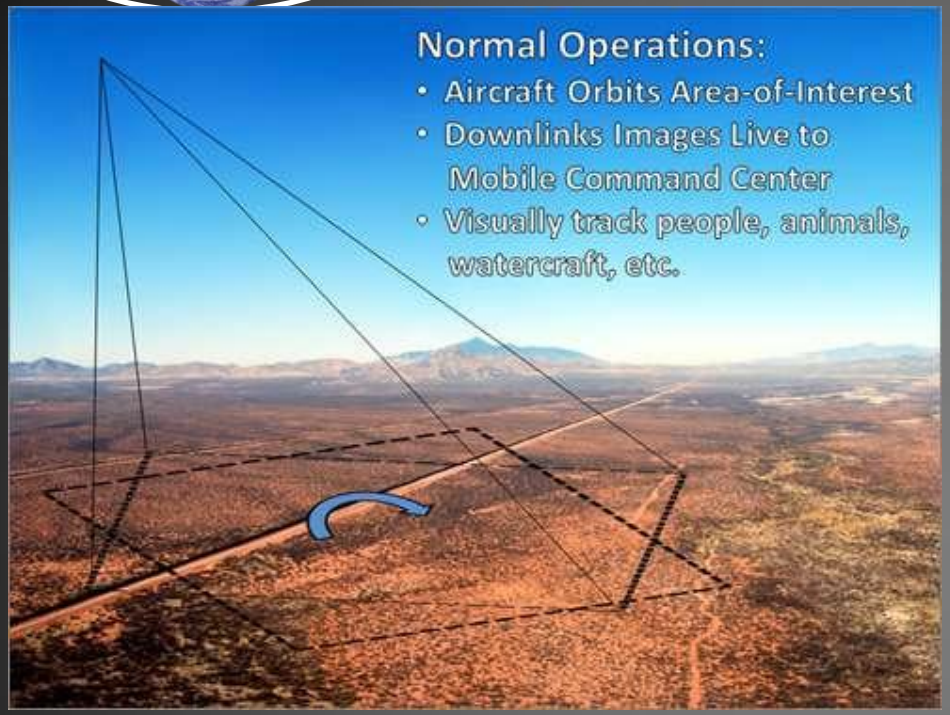
- Fast wide-area damage assessment
- Coordinate mass-evacuation, perimeter cordon
- Common Operating Picture for Police, FBI, emergency responders, and other event personnel
- Detect movement over broad areas for potential survivors



Rewind imagery to track and backtrack potential suspects and witnesses

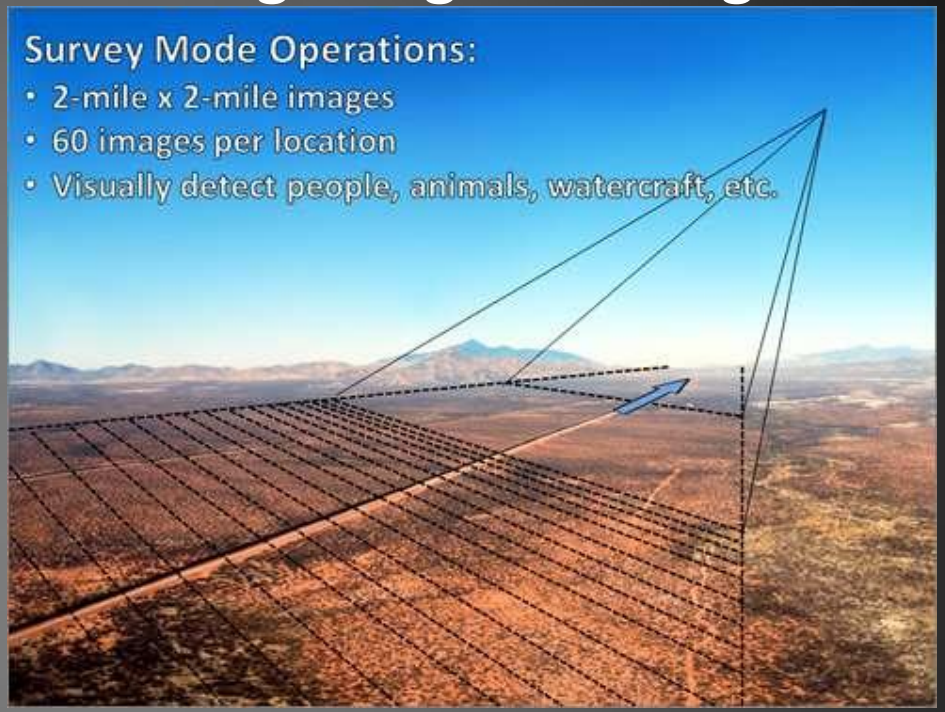
Staring and Survey Modes

Persistent Stare and Long Range Coverage



Persistent Coverage over and Area

-- Used for high activity areas
-- Constant Coverage over large area
-- Detect and Track Movement Within Area
-- Real Time Constant Download



Long Range Periodic Coverage

-- Used for Long areas of interest
-- Multiple real time images allow for image to image change detection to auto detect movement within the area
-- Pass by pass detection can highlight changes that occur between over flights
-- Periodic Downlink when within range

Persistent Surveillance Systems

Iowa Floods

Survey Mode Operations

Imaged entire 160 miles of flooded rivers in slightly over an hour (Route shown)

70 to 100 images per location

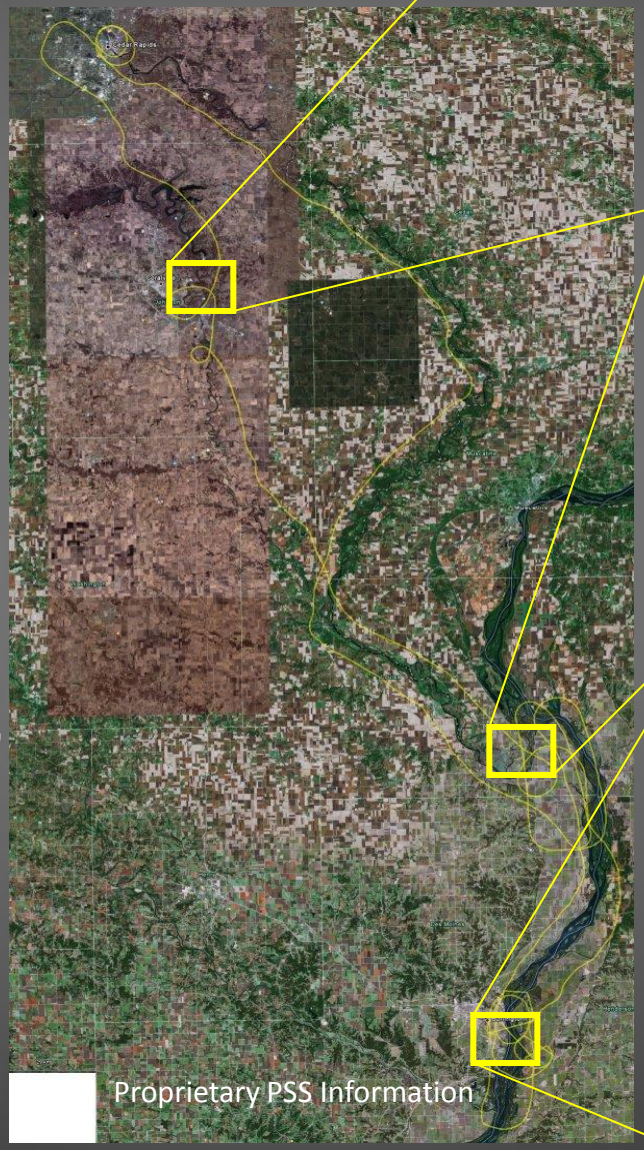
Circles over locations of particular interest

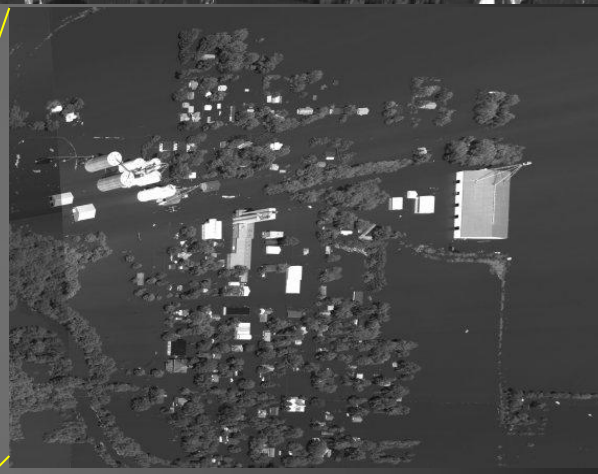
2 to 3 mile wide images

See individuals, vehicles, boats, and animals

Original images are 88 megapixels each

Images to right are highly subsampled.



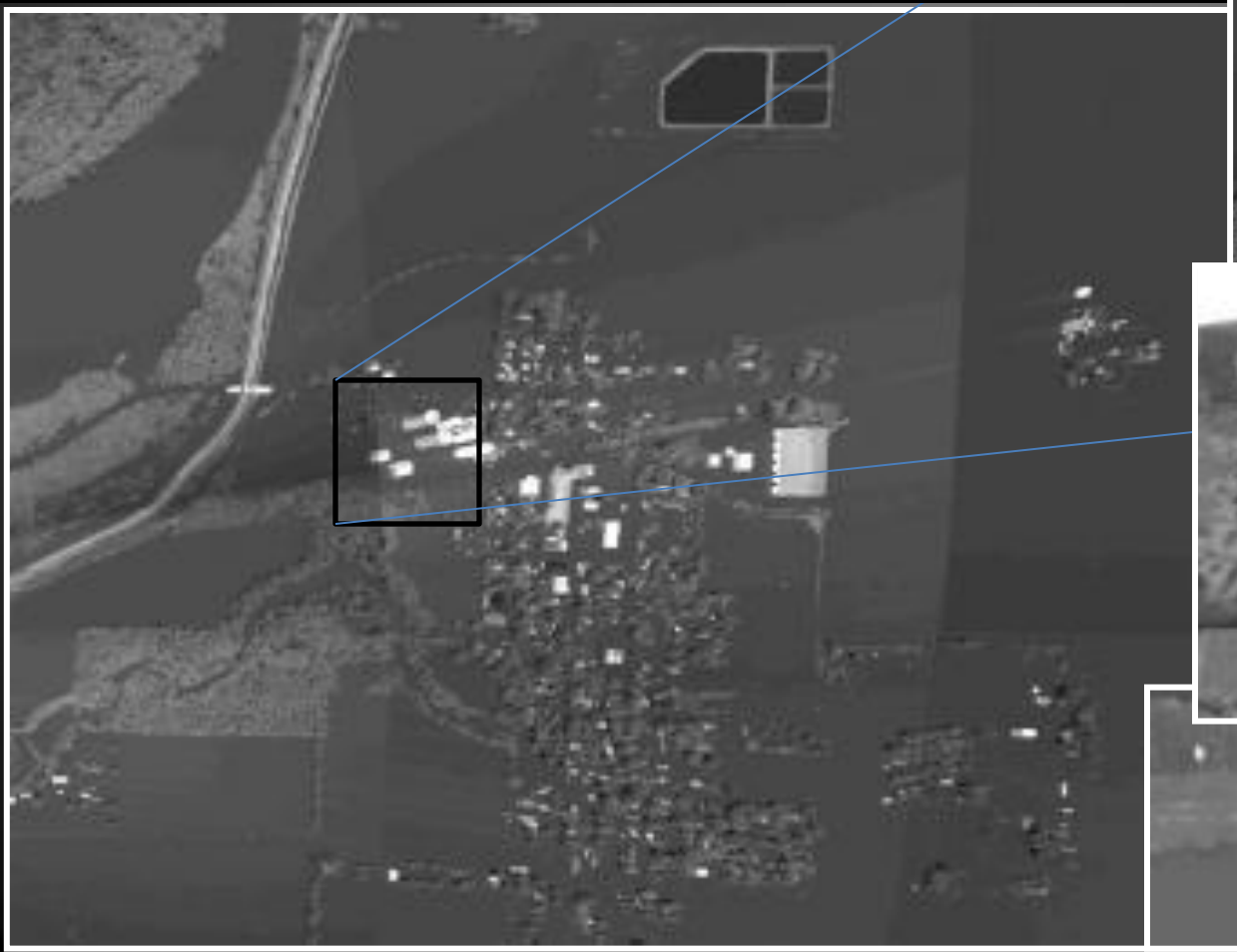


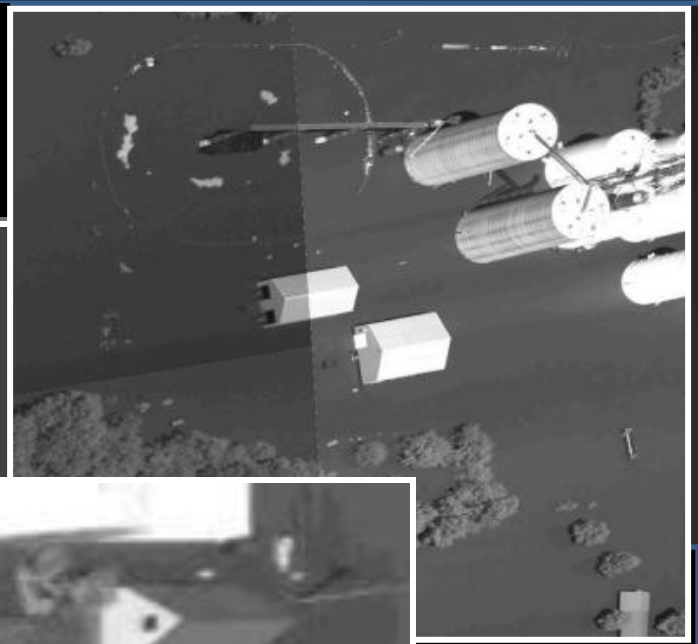
Persistent Surveillance Systems

Emergency Response

Iowa Floods

>1,000 sq miles surveyed in one flight





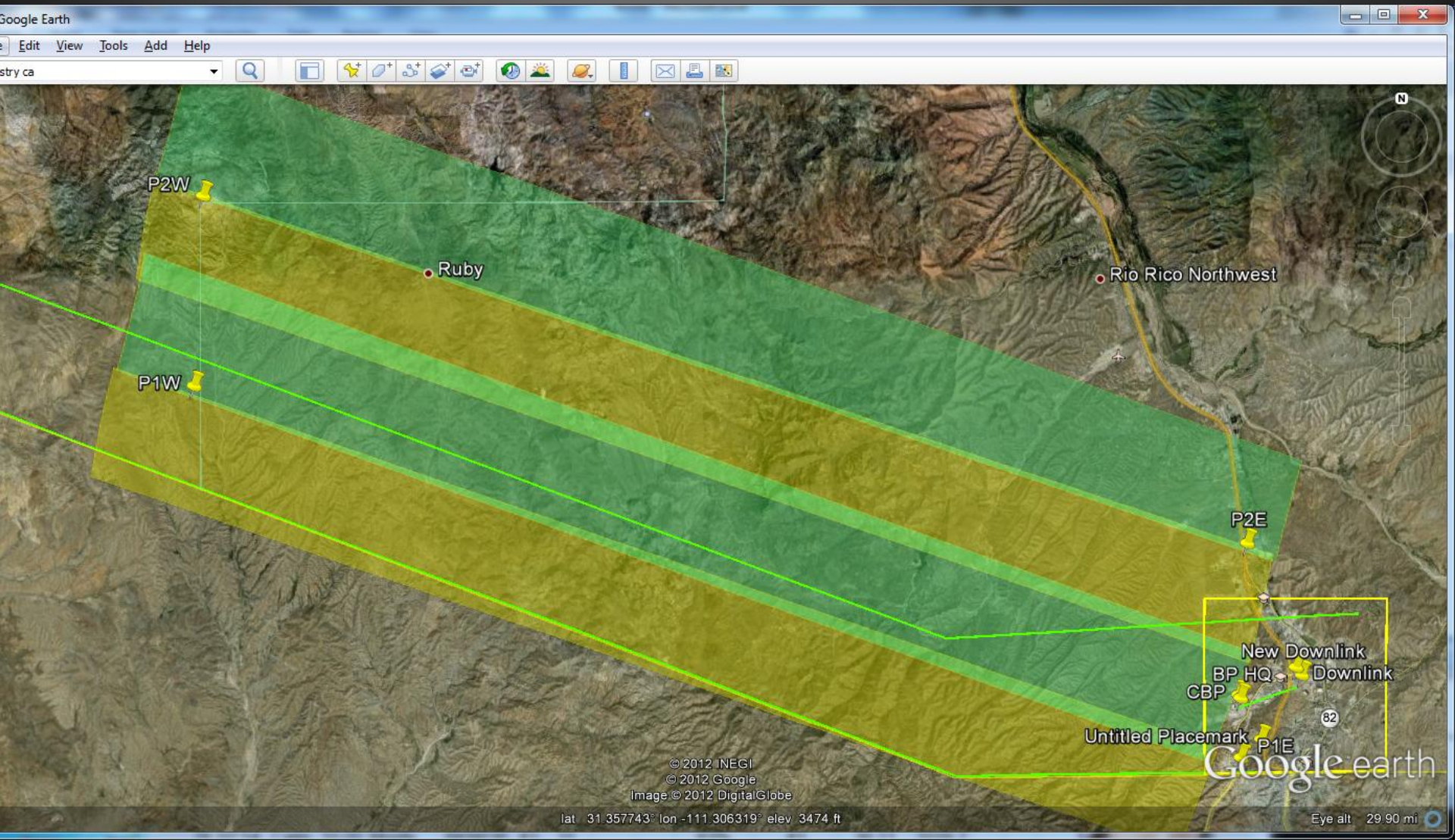
Persistent Surveillance

Multiple Simultaneous Border Crossing Surveillance
El Paso 3/18/10 flight

-- Back track stopped cars to look for starting location and stash houses and other coordinated vehicles
-- Identify driving characteristics and prior crossing to predict other suspect cars
-- Identify potential coordinated and multiple crossing cars to stopped cars (cars they met with prior)
-- Connected additional suspect cars to border crossing times and lanes to obtain photo and license plate info

Persistent Surveillance Systems

Border Coverage Area
Up to 600 square miles per hour



Persistent Surveillance Systems
Border Surveillance Operations

Persistent Surveillance Systems

User Need Analysis

Dayton Ohio Example

Persistent Surveillance Systems

Unmet Need: Dayton Crime Example

In 2010, Dayton had 28,245 reported crimes

- 1,509 were violent crimes
- 8,890 major property crimes

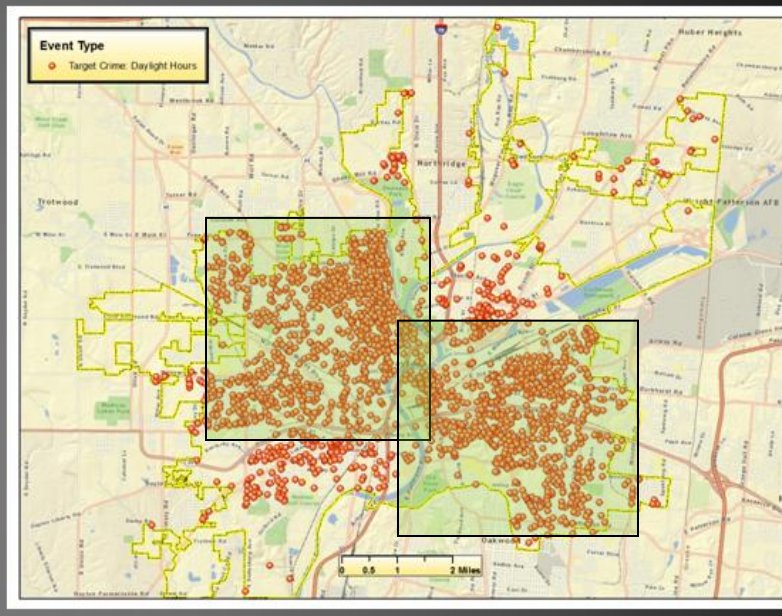
Dayton's case closure rate is 14% for property crimes

2010 FBI UCR Crime Data Table 25 Case Clearance Rates

- Similar to U.S. case closure rates for U.S. cities.
- Most cases go unsolved for lack of evidence, leads, or witnesses

Per capita - Dayton's crime ranks

- 39th in violent crime
- 22nd in property crime
- Roughly **1 of 14 citizens** **or** **1 of 4 families** will be a victim of major crime each year.



- Traditional policing strategies, community based policing, intelligence-driven policing, and community involvement while having some impact, has not adequately addressed the problem.

The cost of crime to Dayton is significant

- Dayton's total cost of crime is over $317M per year or over $2000 per person per year.

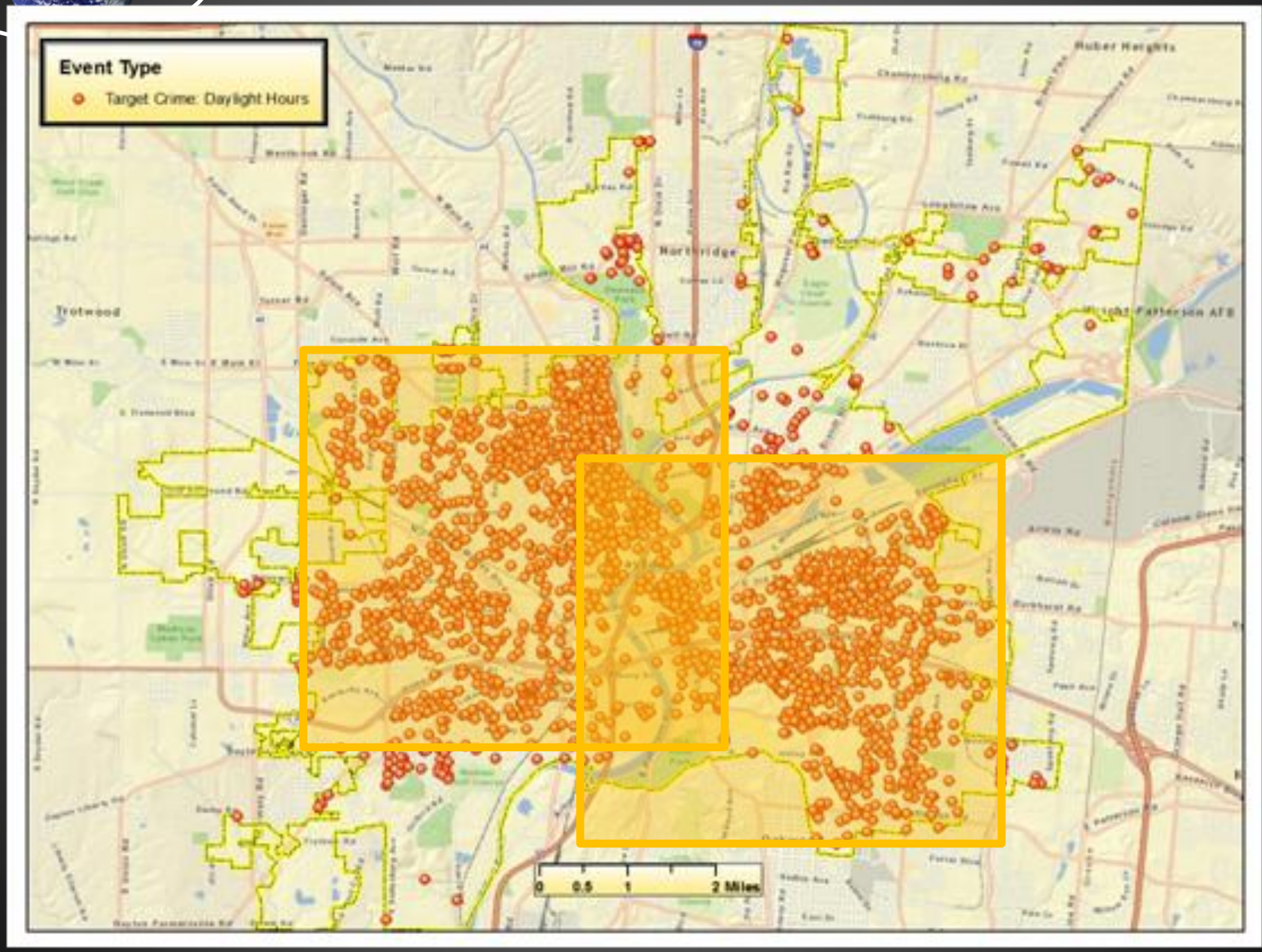
  Based on the cost of crime from a recent National Institute of Justice - Urban Institute study and the number of FBI reported Dayton crimes
- Does not include the impact on quality of life, home prices, and economic development in our community.

Avoiding even a fraction of this crime would provide significant value to the community.

Dayton represents just one of over 200 US cities of similar size and circumstance

Persistent Surveillance

Dayton Crime Daylight Hours



Persistent Surveillance Systems

Cost of Crime

http://www.rand.org/jie/centers/quality-policing/cost-of-crime.html

The cost of crime is significant. The national Institute of Justice has sponsored many studies on the cost of crime to a community. Using the results of one of these studies conducted by the Rand Center on Quality Policing the cost of crime in Dayton is calculated to be $480M per year. This is calculated by multiplying the number of crimes in a given category by the cost of crime from the study.

Cost of Crime Dayton

Cost of Dayton Violent Crime

Type	Number	Cost per crime	Total Cost
Murder	34	$8.649,216	$294,073,344
Rape	93	$217,866	$20,261,538
Robbery	782	$67,277	$52,610,614
Aggravated Assault	602	$87,238	$52,517,276
Total Violent Crime			$419,462,772

Cost of Dayton Property Crime

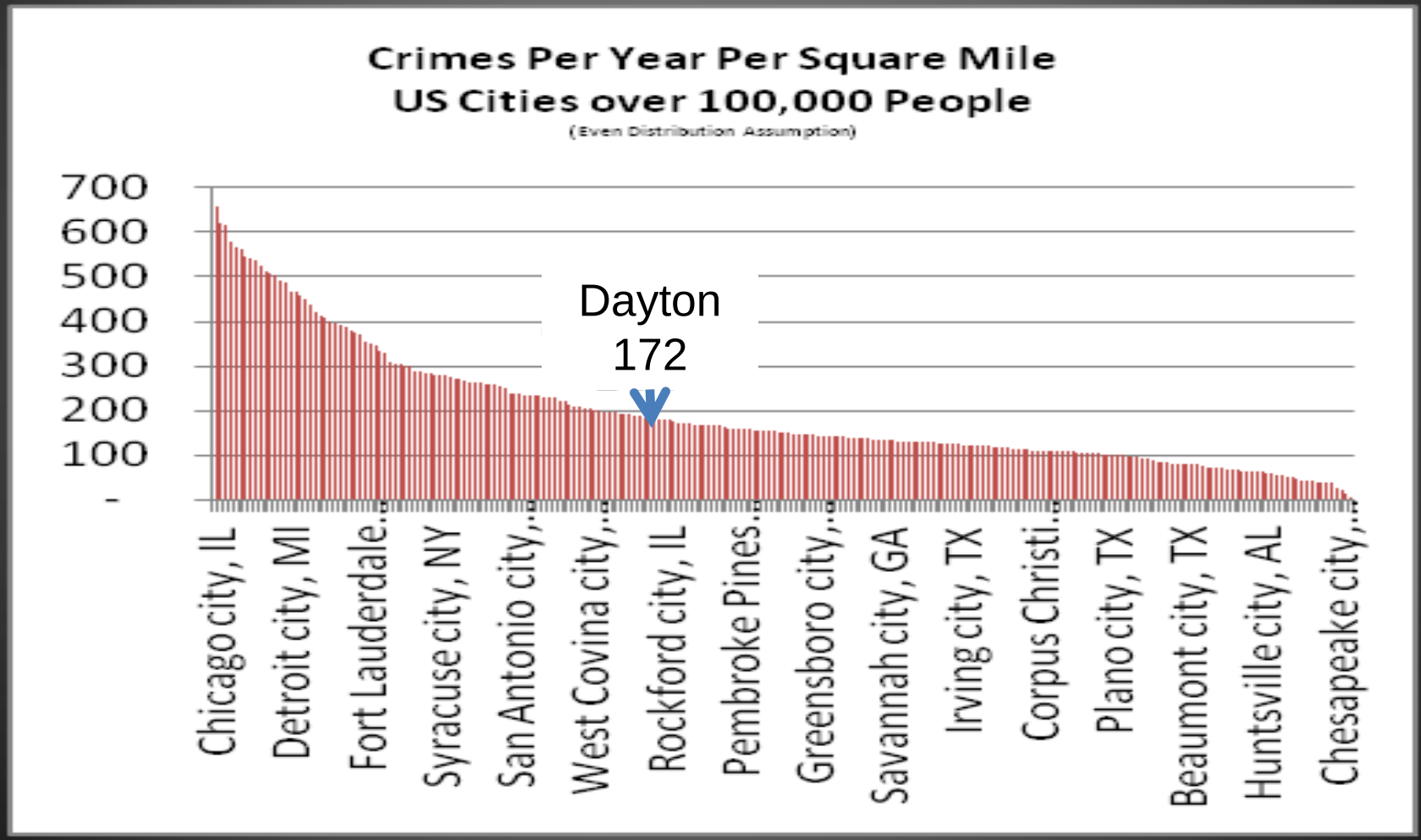
Burglary	3,390	$13,096	$44,395,440
Larceny	4,882	$2,139	$10,442,598
Auto Theft	673	$9,079	$6,110,167
Total Property Crime			$60,948,205

Total Cost of Part 1 Crimes $480,410,977

Dayton Population 142,000 Cost per Person $3383 per year per person

Persistent Surveillance Systems

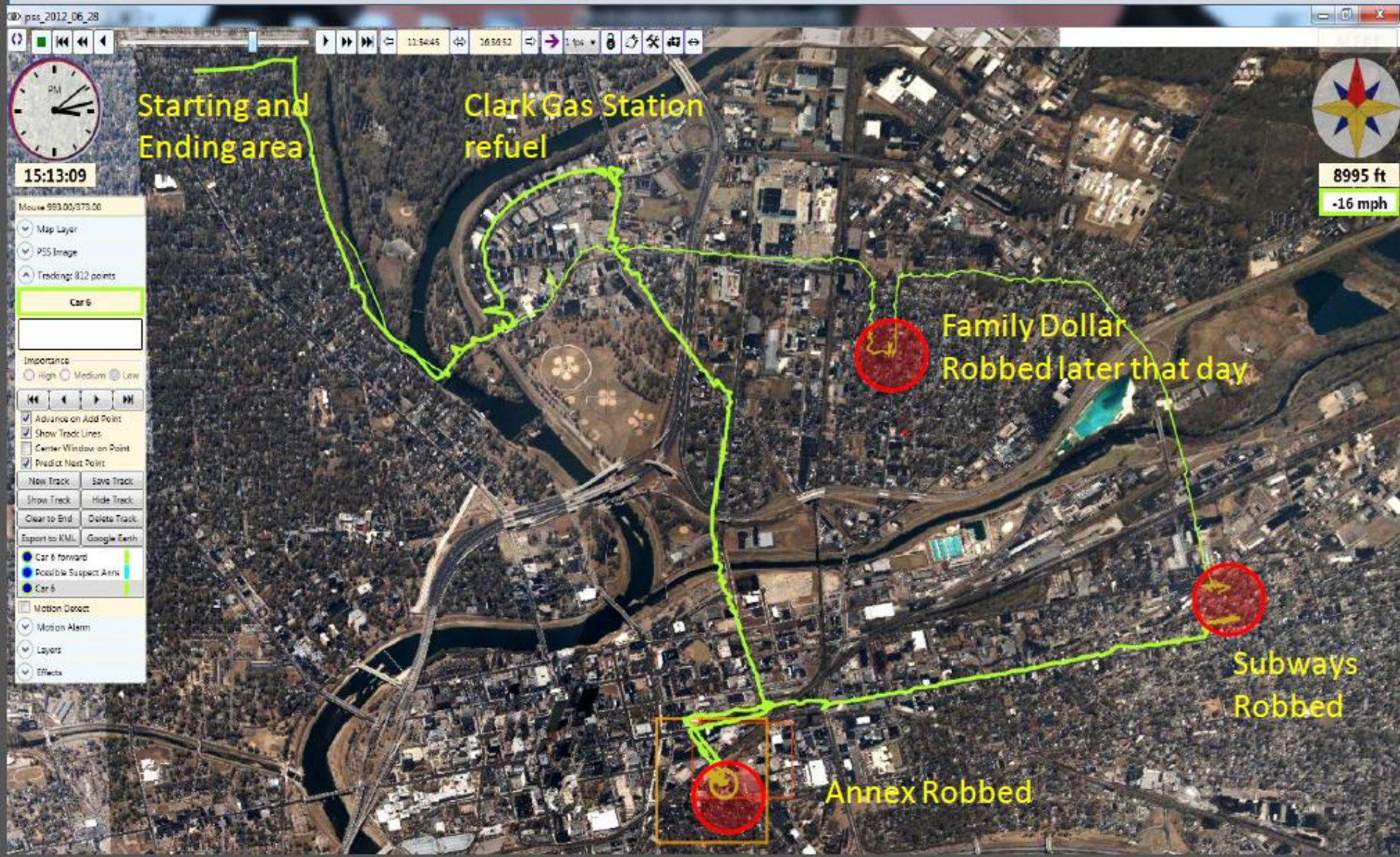
Crimes per Square Mile Per year



Dayton PD Review of Other Surveillance Technologies

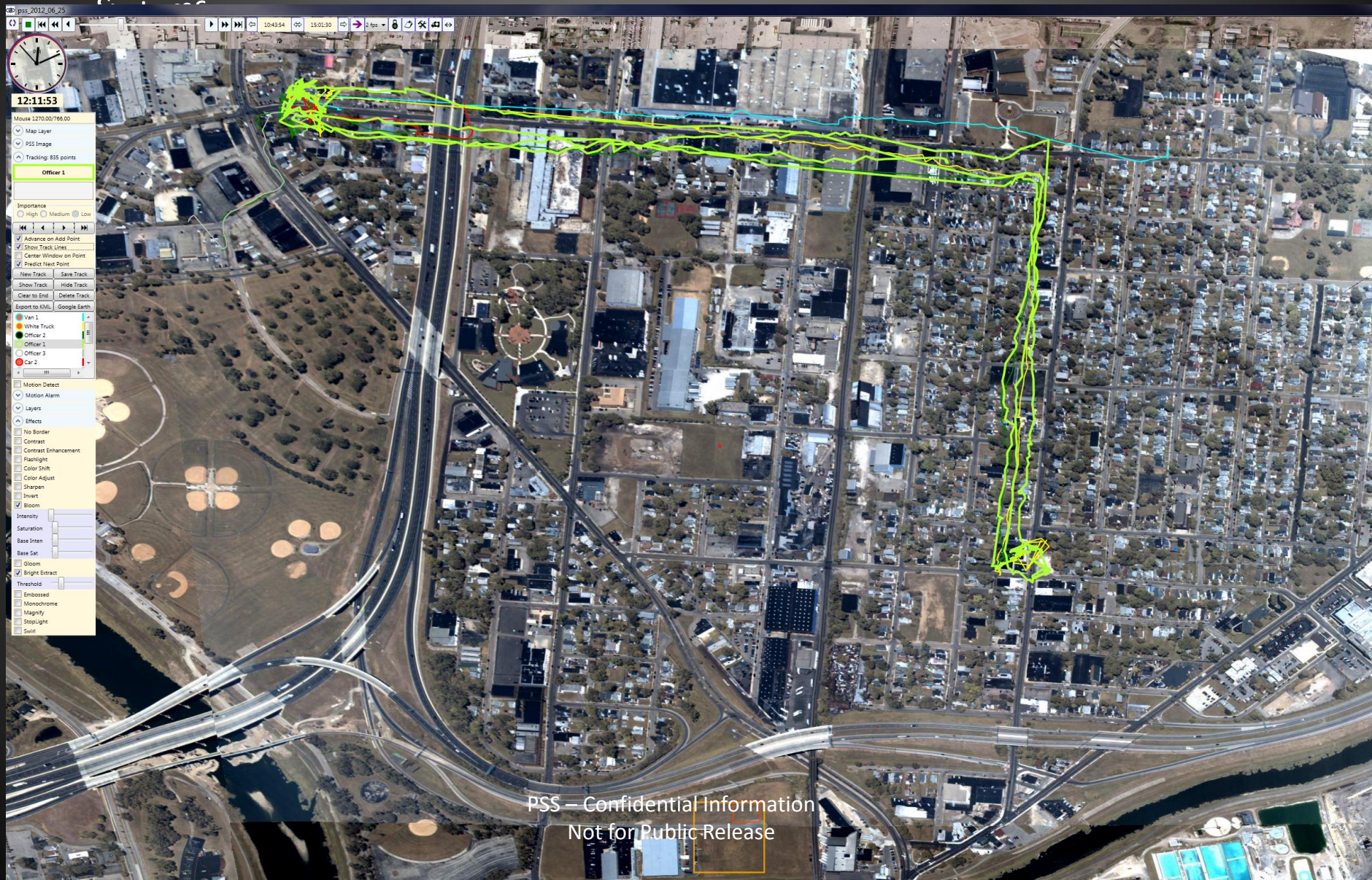
- **Ground-based Cameras – Widely Deployed by Police Departments**
  - A recent Urban Institute report Baltimore invested over $8M in cameras and operating costs to cover an area of **1.19 sq miles. = $6.7M per square mile**
  - The net return cited in the report, while positive, is also lower then Dayton would hope for. Dayton is looking for a more effective solution.
- **Police Helicopters - Traditional Airborne Surveillance**
  - **Cost of procurement ($4-7M) and operating ($1.25M per year)** is beyond the available resources of the department for the perceived benefit.
  - Small coverage area of the camera systems does not allow it to be effective in investigating most of our targeted crimes.
  - Dayton PD's previous experience with police helicopters in the 1990 did not indicate a large return on investment.
- **Other Sensors Considered**
  - Dayton PD is considering adding additional sensors such as automatic license plate readers (Currently deployed), shot spotter gunshot detection system, red light cameras, and speed cameras
  - **These systems would augment the wide area surveillance systems.**

Robbery Spree Captured
Single Perpetrator - 3 locations



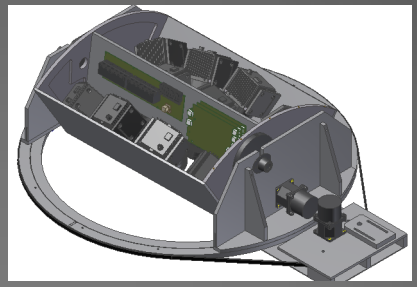
Dayton House Burglary

Officers directed by PSS caught up to suspect before he got out of his car – With stolen goods in it



Persistent Surveillance Systems

Podded HawkEye II on Cirrus or AirVan



- Aircraft: Cirrus SR-22 with Pod
  - Provides greater time on station
  - Enhanced communications package
- Hawkeye II 192 Megapixel Color WAAS system
- Spot Beam (high resolution characterization EO and IR cameras)
- Existing System Integrations
- Additional Data Storage
- Upgraded Command Center
- Additional Analyst Workstations
- Enhanced wireless mesh (multi-link)
- Upgraded Highly Mobile Command Vehicle
- Mobile command trailers

Quick Removable Cirrus Pod

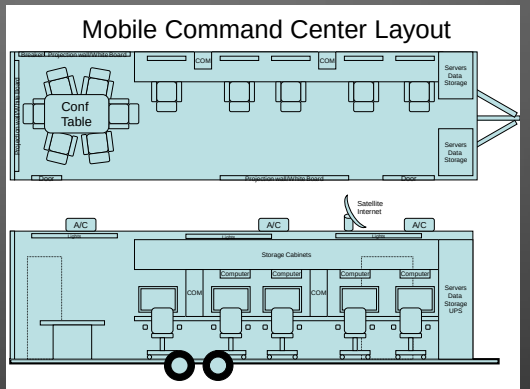
Cirrus SR-22

Add 300 mbs Ground Links

Cirrus SR-22 with Surveillance Pod

Up-level Command Center

Mobile Command Center Layout



Up-level Highly Mobile Command Vehicle

Persistent Surveillance Systems

Air Claw$_{tm}$

Affordable, Turn-Key, Multi-INT Capability

Kodiak Quest Platform with Integrated Airborne Analysis Center

+

Wide Area Surveillance

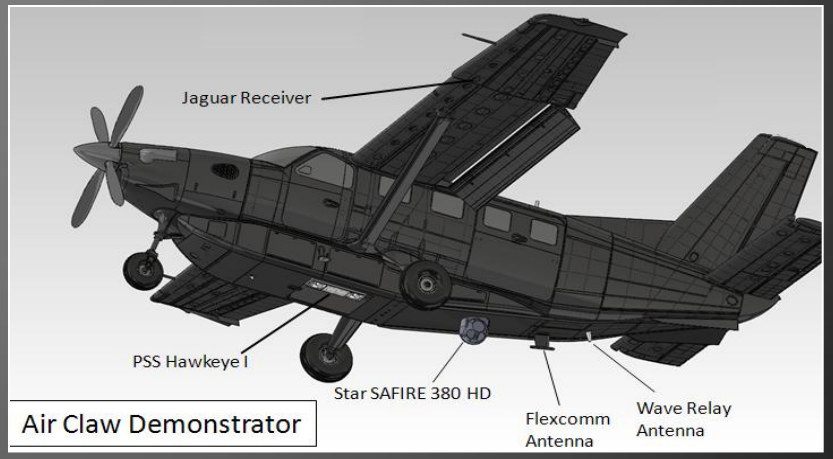
+

FMV (EO & IR)

+

Track, Tag, Locate

- **Affordable Multi-INT Package – Fully Integrated with Real-Time Datalink**
- **PSS is Northrop Grumman's Exclusive Worldwide WAAS Provider**
- **Full turn-key solutions provided as Product or Service with full support & warranty package**
  - **Maintenance**
  - **Supply Chain**
  - **Logistics**
- **Agent/Analyst On-Board Capability**



Air Claw Demonstrator

NORTHROP GRUMMAN

Persistent Surveillance Systems

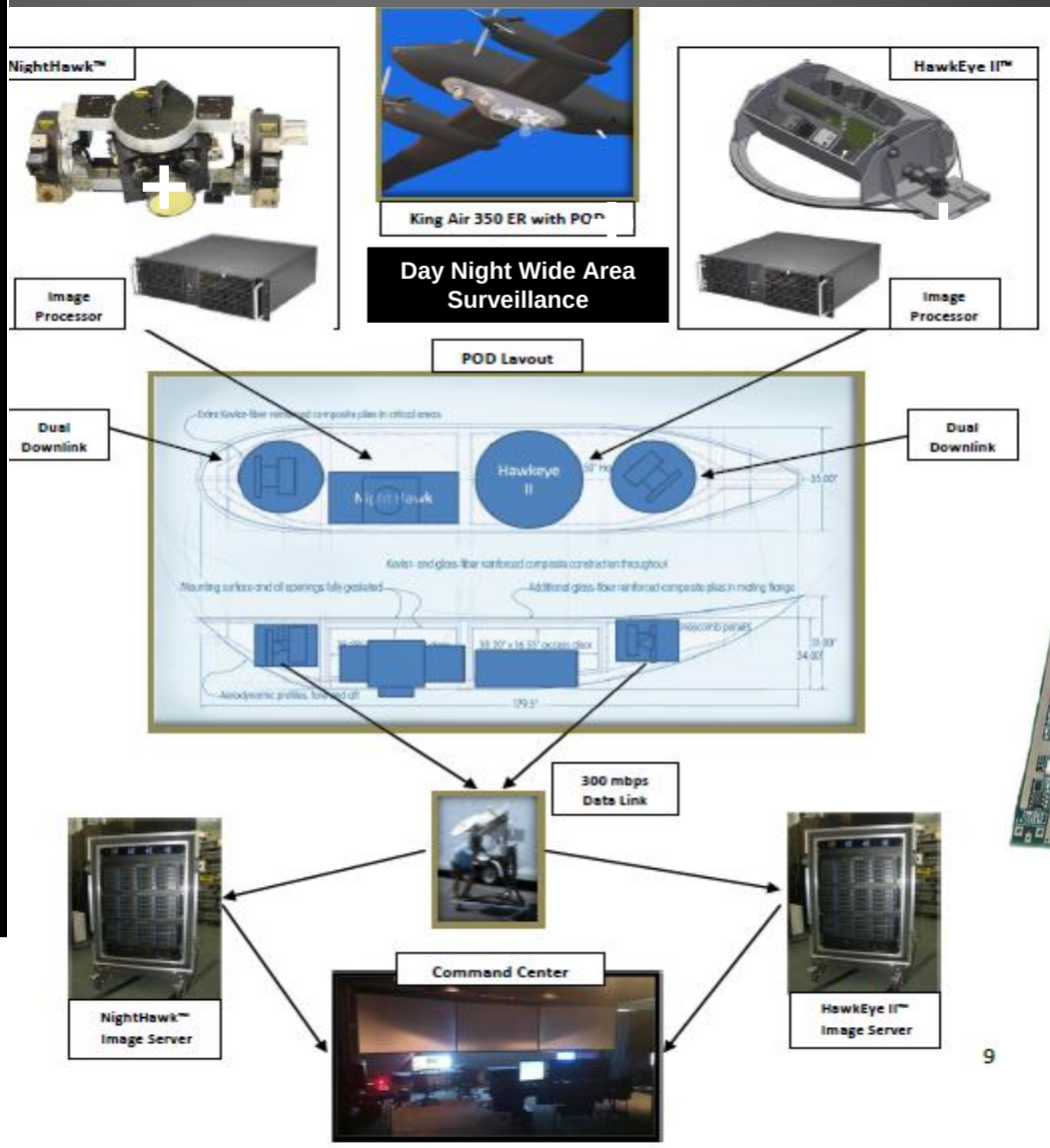
Talon Sentinel

Day Night Wide Area Surveillance and Multi-INT Capability

- King Air 350 ER
- Full Multi-INT Package – Fully Integrated with Real-Time Datalink
- On-Board Agent/Analyst

Includes
- Hawkeye II WAAS system
- NightHawk MWIR WAAS
- Integrated FLIR 380 HD
- Airborne Processing / Analysis
- Secure Broad Band Comm
- Deployable Command Center
- Mobile Command Center
- 200TB Image Server
- PSS Image Analysis Tool Kit

- Full turn-key solutions provided as Product or Service with full support & warranty package
  - Training
  - Maintenance
  - Supply Chain
  - Logistics



FMV (EO & IR)

Track, Tag, Locate

United Technologies

NORTHROP GRUMMAN

Persistent Surveillance Systems

Cirrus SR-22T

Airframe and Powerplant

Continental TSIO-550-K
315 HP Turbocharged Engine
Cirrus Airframe Parachute SystemTM (CAPSTM)
Airbag Seatbelts (Front Seats)
Single Movement Power
Lever Dual Side Yoke
Hartzell 3-Blade Lightweight Composite Propeller
Built-in Oxygen System
60/40 FlexSeatingTM - Seats up to 5 Standard Interior
5 Year,2000 hrs Spinner-to-Tail Warranty
The Cirrus Progressive 400-hour inspection

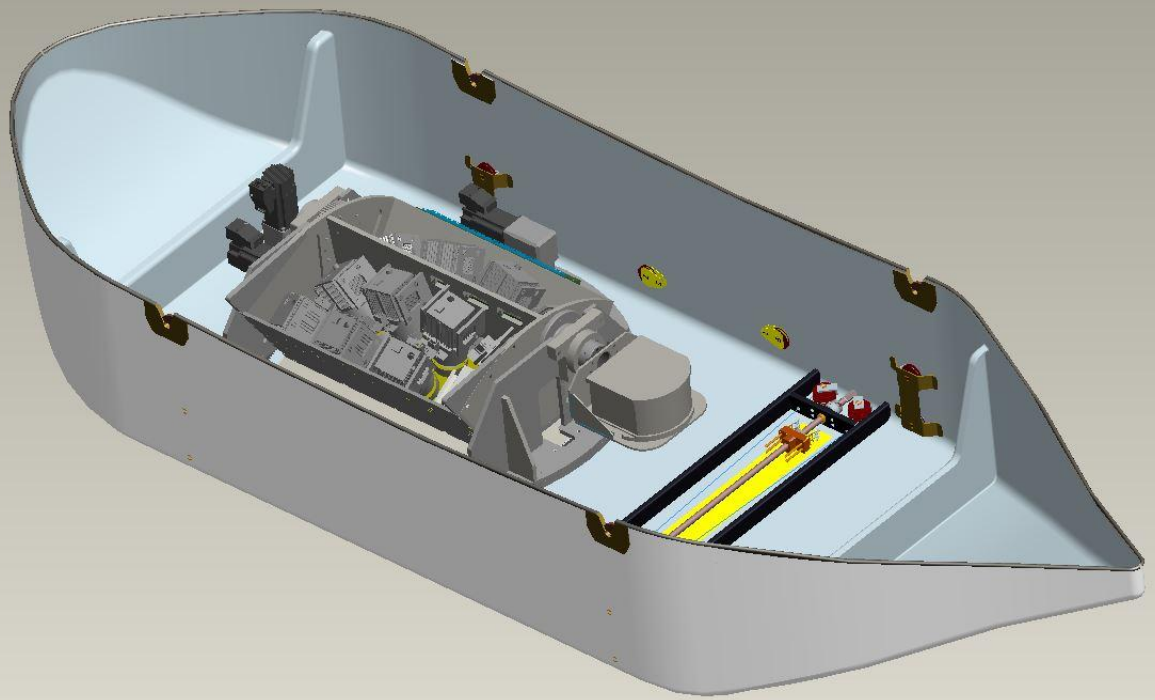
Avionics

Cirrus PerspectiveTM by Garmin® Cockpit
Synthetic Vision Technology
10" Screens
GMA 350 All-digital Audio Panel Keyboard Controller
Dual WAAS GPS/Comm/Nav Radios Engine & Fuel Monitoring
ADS-B Transponder
406 MHz ELT
FliteCharts® & SafeTaxi® (Only available for US, subscription required)
XM® Weather & Audio (Subscription Required)
Garmin GFC700 Autopilot with ESP
•Dual AHRS
•Hypoxia Check/ADM
•Blue Level Button

CIRRUS SR 22					
Direct Operating Costs Per Hour		**Other Related Information**			
Fuel Cost Per Hour:	$65.23	**Fuel Cost Per Gallon:**	$5.93		
Loiter Mission Fuel Flow	11	**Fuel Type:**	100 LL		
Oil Cost Per Hour:	$2.00				
	$67.23				
Operating Reserve Cost Per Hour					
Engine Reserve Per Hour:	$22.70	**Average Engine Overhaul Cost:**	$45,406.00	2000	hrs
Prop Reserve Per Hour:	$7.00	**Average Prop Overhaul Cost:**	$14,000.00	2000	hrs
Total Reserves	**$29.70**	**Engine Manufacturer:**	Continental		

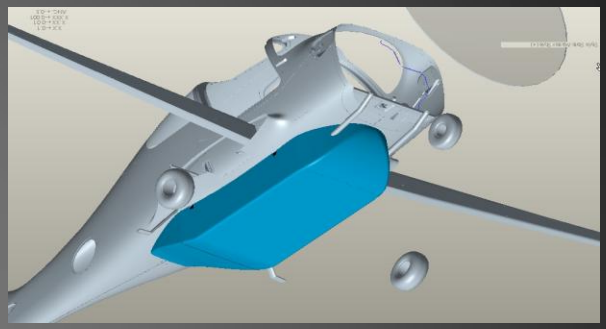
Persistent Surveillance Systems

Cirrus Surveillance Pod



The size of the HawkEye II system is exagerated in this image. In practice, the pod can house the HawkEye II system, a 15” deployable camera ball, and a 300 mbps High-Speed data link concurrently.

Hawkeye Surveillance Pod Specifications



SR-22 PSS Surveillance Pod	
Length	110”
Width	36”
Depth	11.5” – 13”
Weight	Empty 45 lbs Hawkeye II Conf 227 lbs
Attachment Points	4 quick disconnect
Drag Penalty	~6 knots

Weight and Balance	Lbs	Lbs
Gross Weight	3600	3600
Empty Weight	2342	2342
Total Payload	1258	1258
Fuel Full Tanks 92 Gal	552	552
Pilots (and Co-Pilot)	180	360
Available for Surveillance Payload	**526**	**346**
PSS Hawkeye System	227	227

Persistent Surveillance Systems

Analyst Station Options

Most camera operations and analysis is and will continue to be done by ground personnel

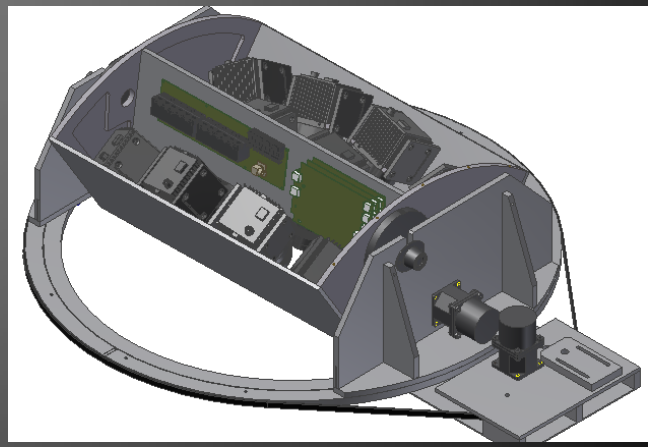
Remote Operations

- Pilot Laptop Station for Hawkeye Control
- Onboard analysts with analyst station
- Future Camlink video into MFD panel

Persistent Surveillance Systems

- HawkEye Imaging System Configurations
  - Removable Pod System
    - Full system Integrated Into fast removable pod
    - HEII Sensor, IPU, Comm, Spot Cameras
    - User station - controls in cabin
    - Cirrus SR-22 Initial Platform
    - Adaptable to Beech Baron 55 or 58, potential DA-42, 52
    - Cessna 337, 207, 206, Helicopters

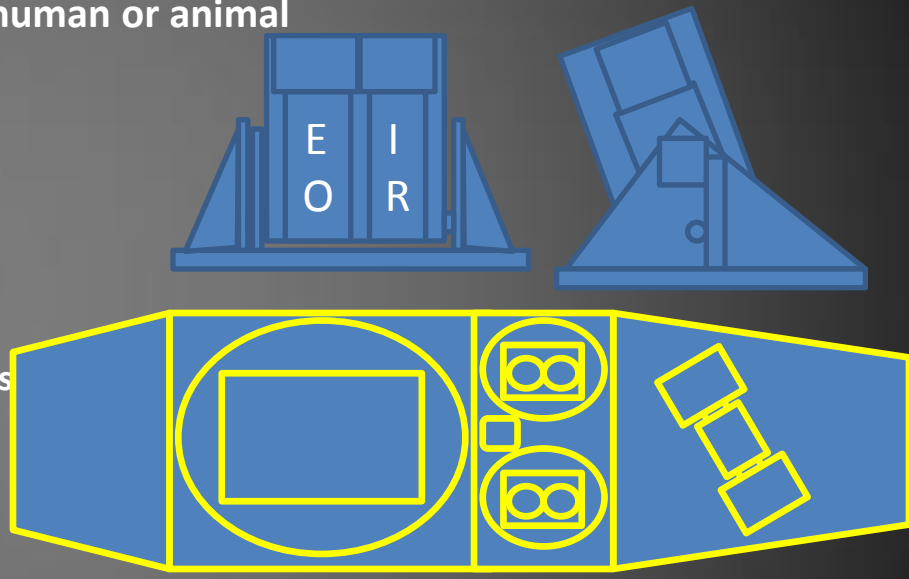
Same camera, Same equipment, same software only difference is camera mount / pointing method



Persistent Surveillance Systems

PSS Ultra High Resolution Characterization Camera

- **Designed to provide high resolution imagery for identifying/characterizing objects within WAAS imagery from aircraft.**
  - Make model of vehicle, color of clothes hair, human or animal
- **Dual Band Visible/IR**
  - Visible EO - Very high resolution spot beam
    - 800 mm image stabilized lens
    - 16 (4 hz) to 29 (1.8 hz) megapixel camera
  - MWIR or LWIR Spot Beam (Export controlled)
    - 1 Megapixel MWIR – 400mm lens
    - 600K Pixels with 200 – 400 mm dual length lens
- **Dual Mode**
  - Commandable Stare from iView
    - Click to point in iView
  - Step Stare Survey Mode
    - Survey mode covers large area periodically but systematically
    - Allows forensic matching of WAAS and spot imagery



- **Already implemented on Vision Series ground cameras**
- **Multiple characterization cameras possible on some aircraft**

Dayton Integrated Support Center (WAAS Demonstration Center)

Partnered with Dayton PD and City of Dayton

- Airborne, Ground Based Surveillance Operations
- Support ongoing police operations
- Integrated with Dayton PD Dispatch and Data Bases
- Analysts from ATIC, Sinclair, Clark State Community College Programs

- **Integrated Support Center**
  - Support of Dayton Police Department
  - Link Airborne and ground based camera systems within PSS software
  - Link Police dispatch, license plate readers, 911 calls and police data bases with PSS systems
  - Integrate shot spotter, automatic license plate readers, red light cameras, emergency alarms, commercial security cameras…

- **Continuously Available Demonstration location**
  - Plan 2-3 demonstrations per month of complete integrated system

Persistent Surveillance Systems

Dayton Operations

- Paid Op Supporting Dayton Police Department
  - High Crime areas
  - Airborne Ops - June July August
- Dayton Integrated Surveillance Center
  - Dayton demonstration Center
  - Allows us to show off our capabilities to others



Persistent Surveillance Systems

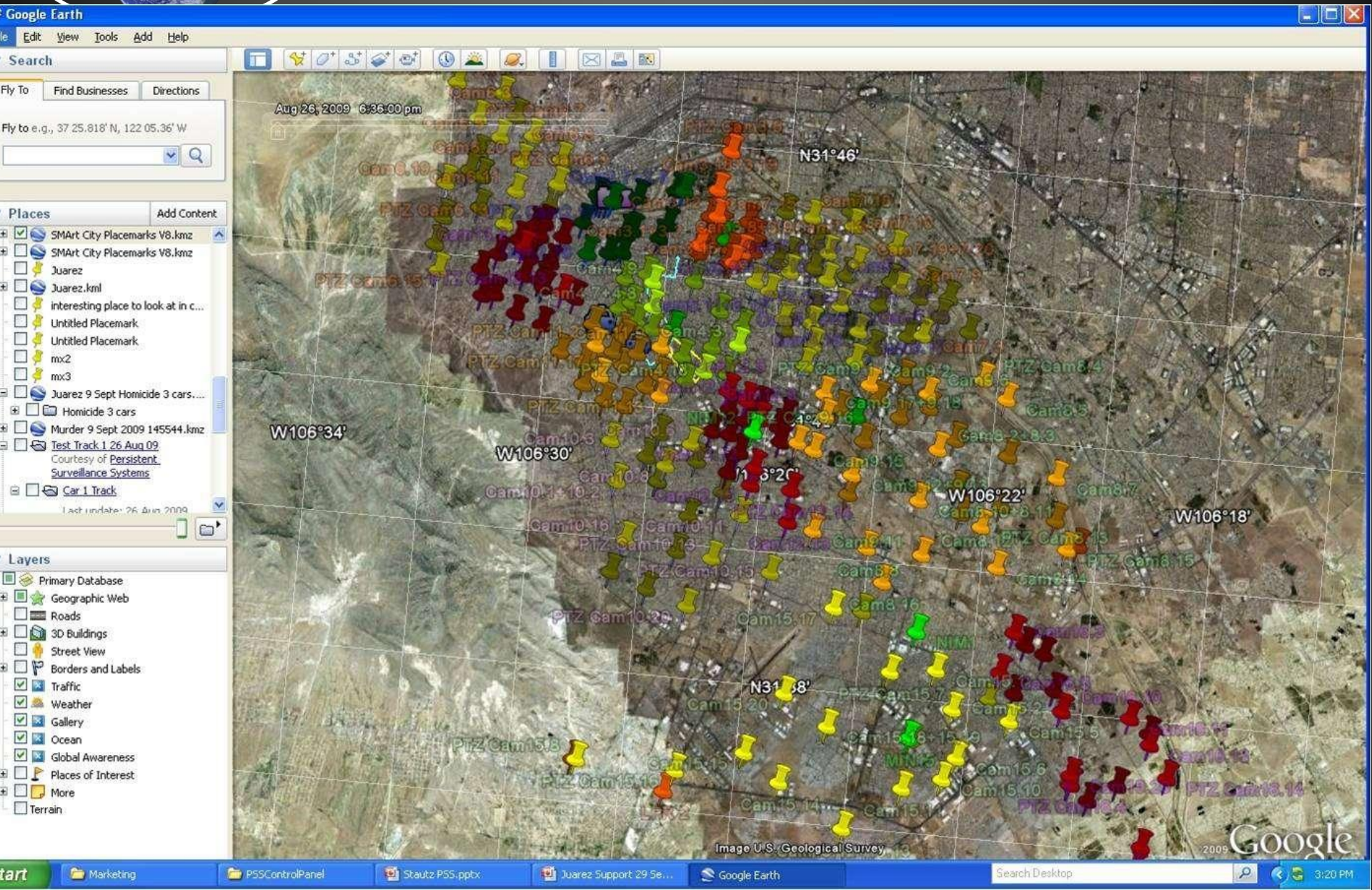
Surveillance Systems Integration

- Wide Area Surveillance
- Police and 911 Dispatch
- Ground Based Cameras
- Shot Spotter
- Automatic License Plate Readers
- Electronic Surveillance
  - Direction Finding and intercept

Integrated Surveillance Center - Dayton Ohio

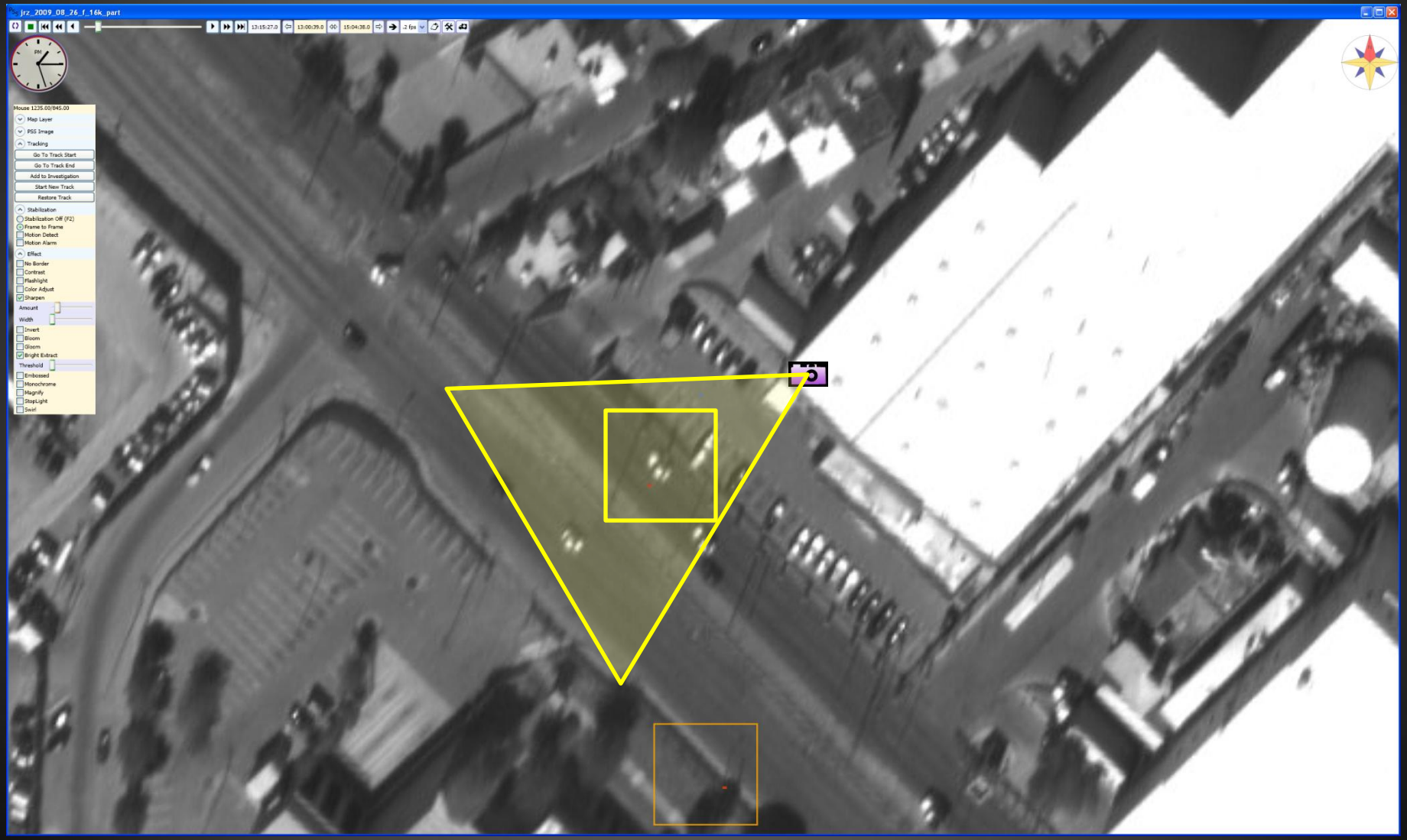
Persistent Surveillance

Ground Based Surveillance Cameras

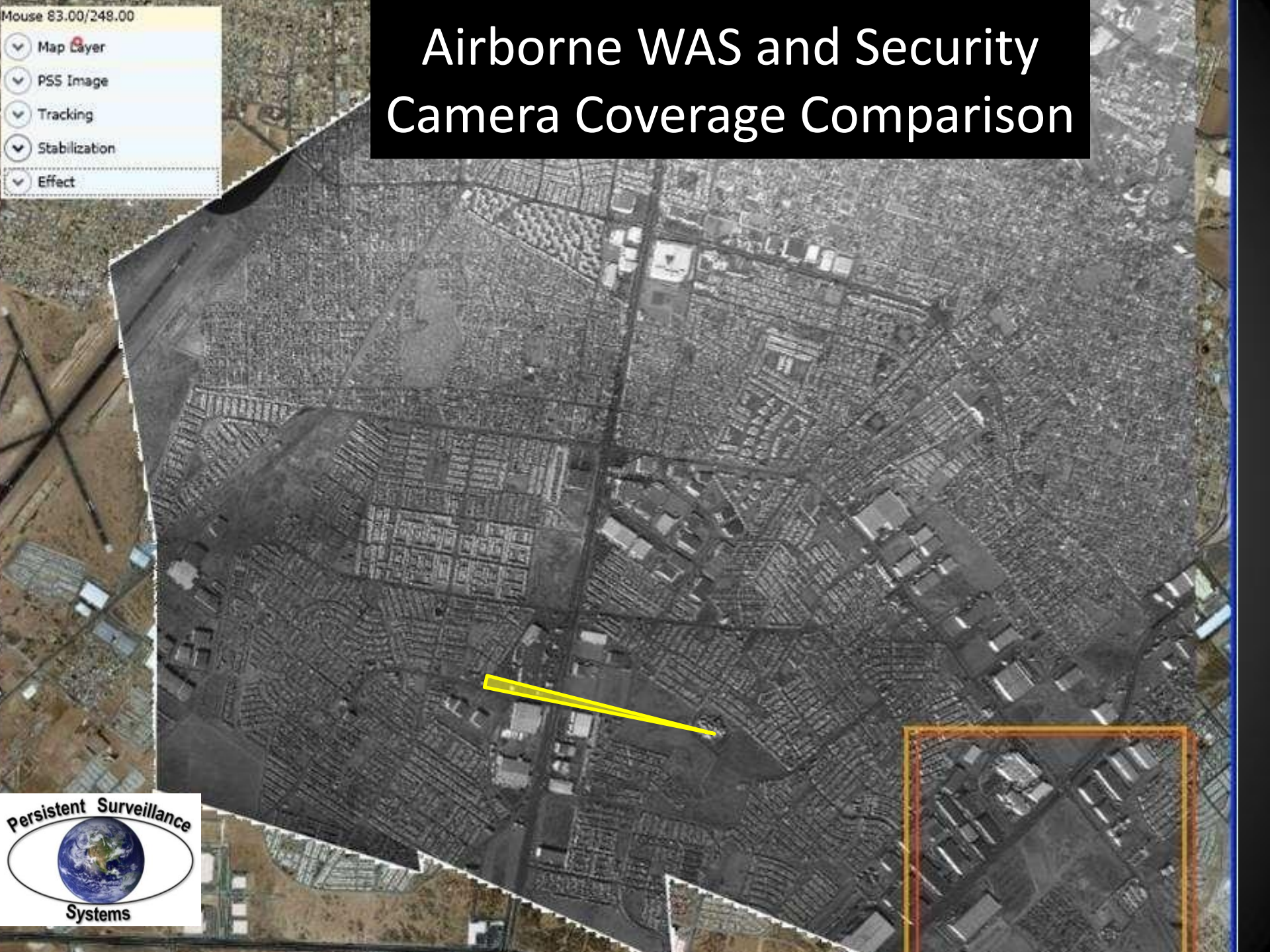


Persistent Surveillance Systems

Murder Car 1 in Camera 4.12 at 13:15:27

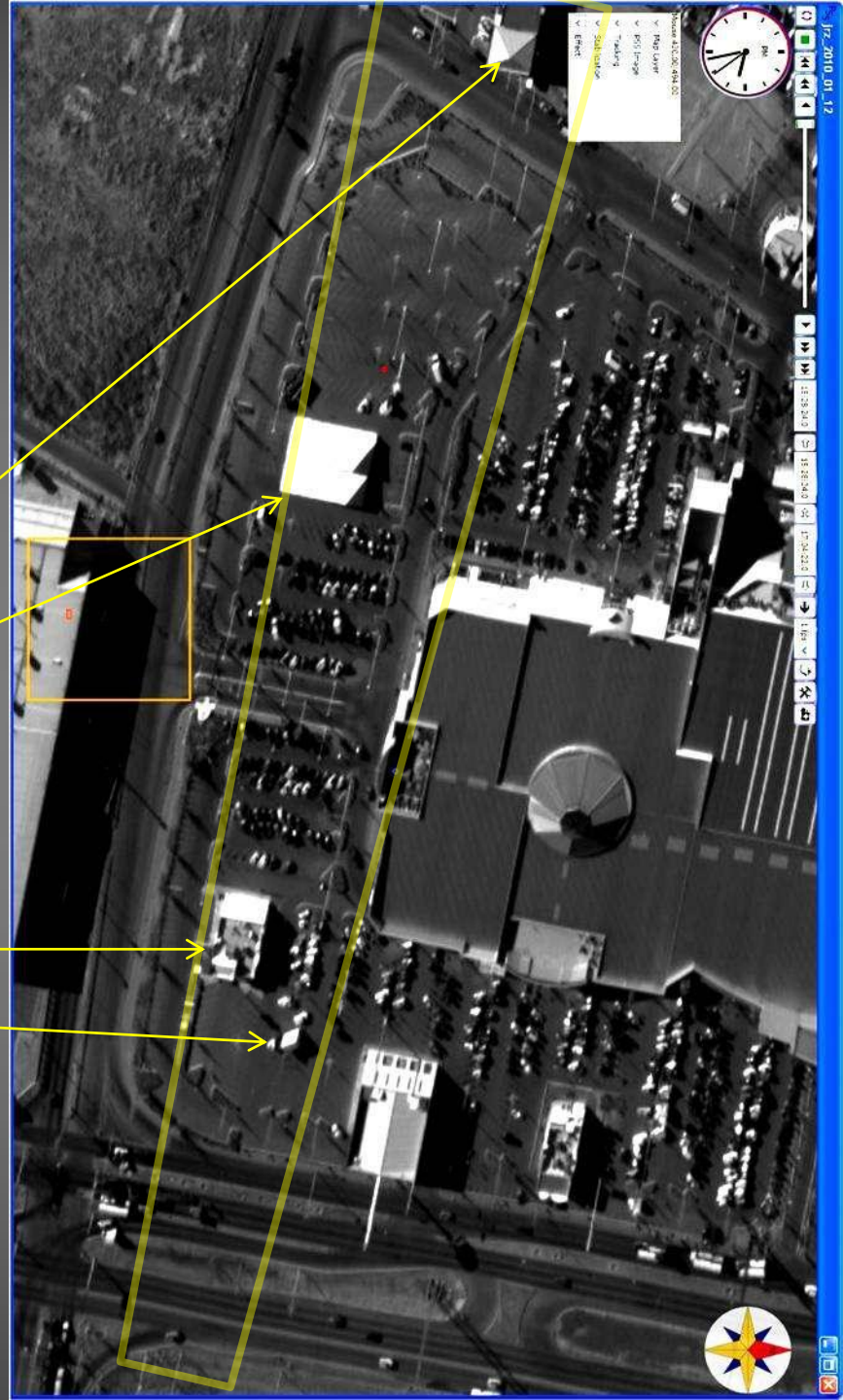


Airborne WAS and Security Camera Coverage Comparison



Persistent Surveillance Systems

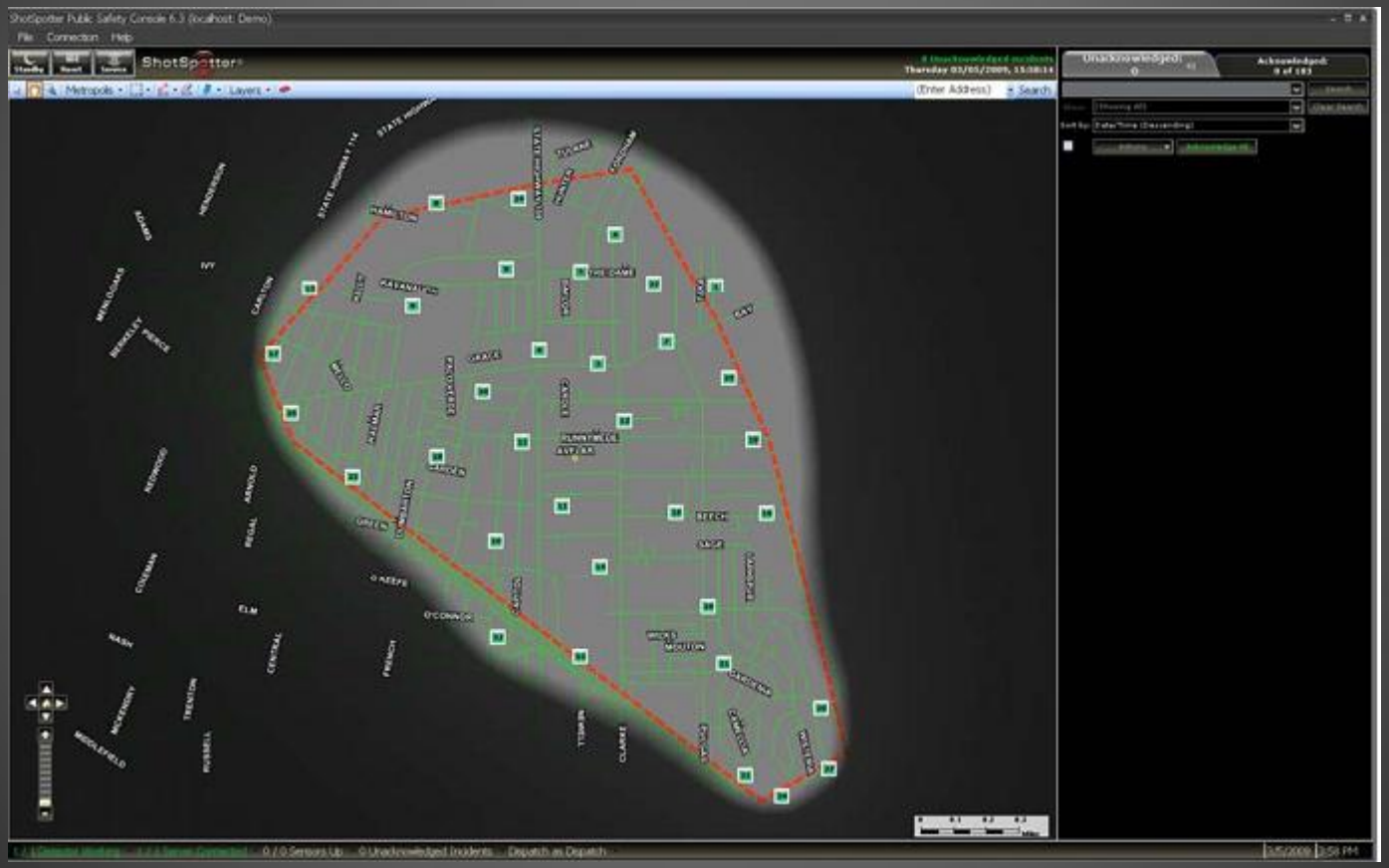
Airborne WAAS and Security Camera Coverage Different Perspectives



Persistent Surveillance Systems

Persistent Surveillance Systems

Shot Spotter
Gunshot Location System



ShotSpotter®
Sense. Target. Protect.

Alternate Uses

- Oil Pipeline Surveillance
- Power Line Surveillance
- Corn Counting
- Emergency Response

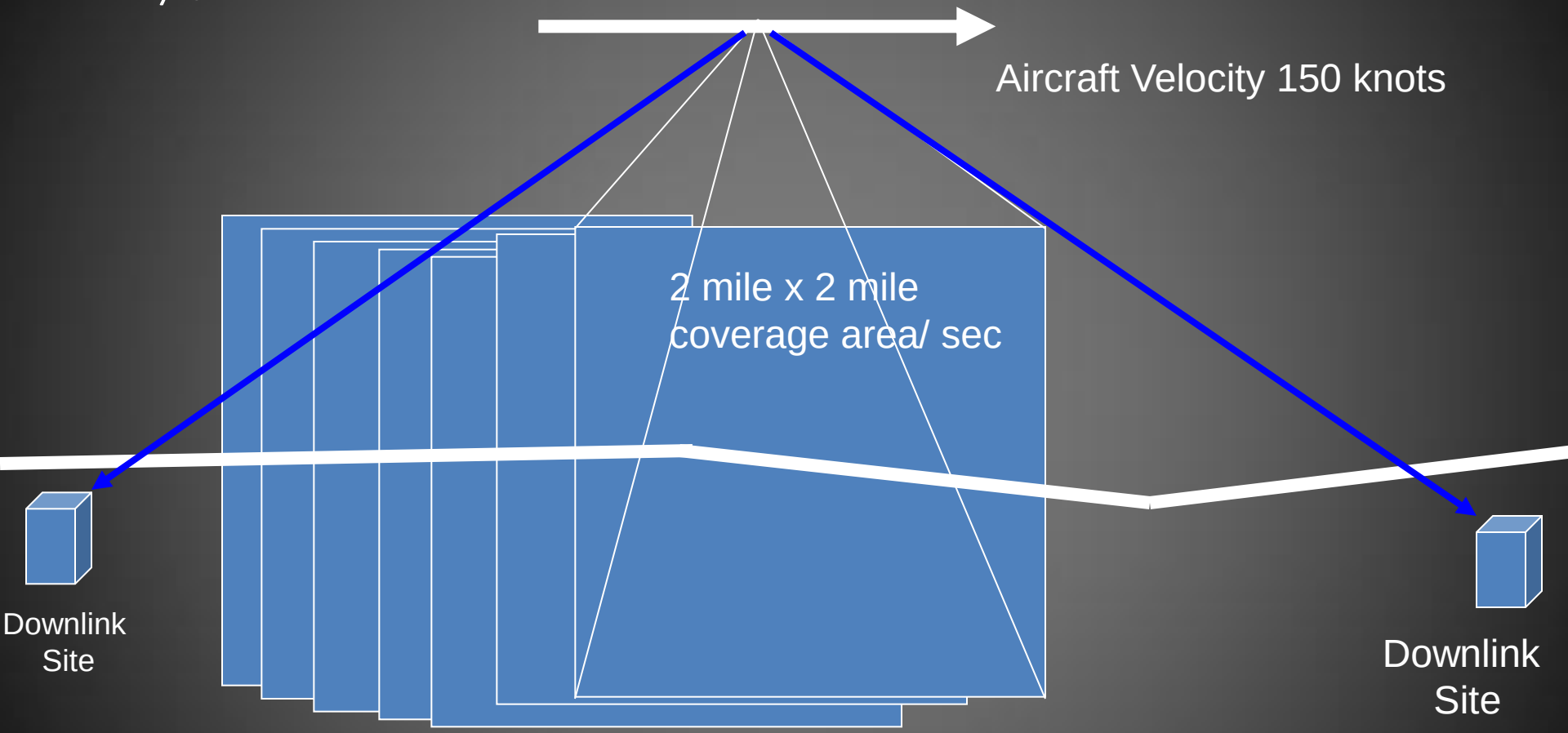
- Survey Mode

Persistent Surveillance Systems

Pipeline Surveillance

Persistent Surveillance Systems

Airborne Wide Area Camera Coverage Survey Mode



Multiple real time images allow for image to image change detection to automatically detect movement within the area

Pass by pass detection can highlight changes that occur between over flights

Iowa Floods

Survey Mode Operations

Imaged entire 160 miles of flooded rivers in slightly over an hour (Route shown)

70 to 100 images per location

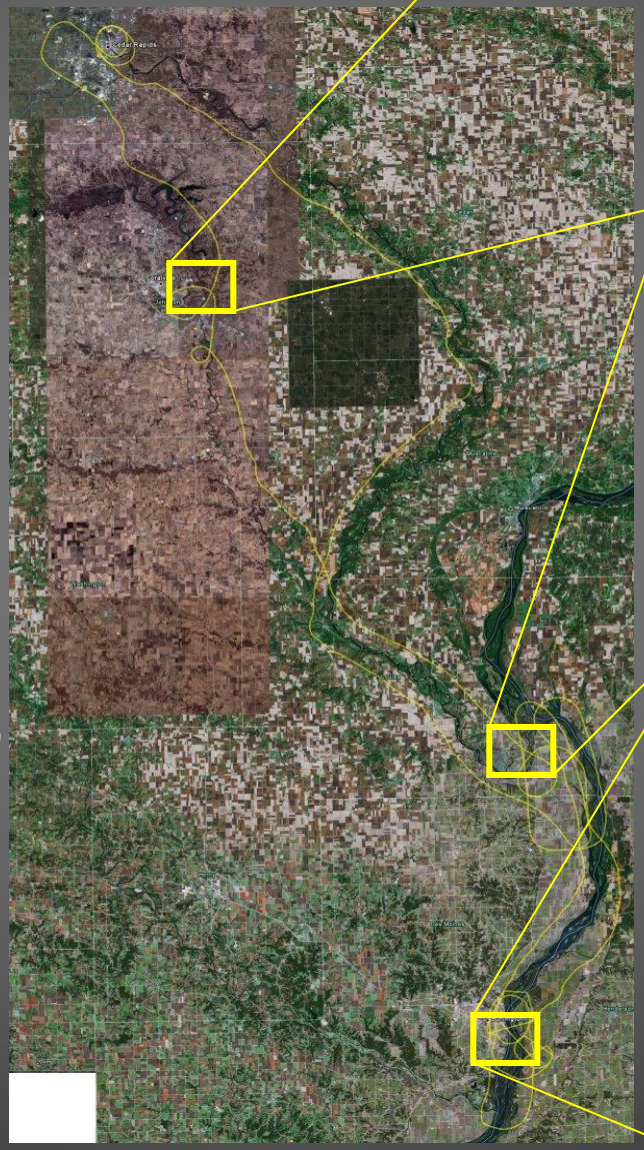
Circles over locations of particular interest

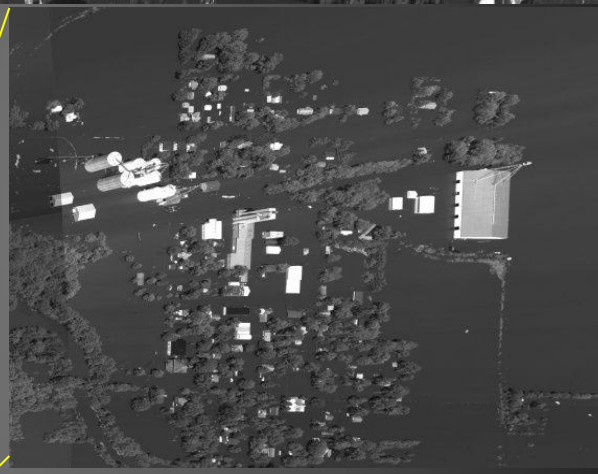
2 to 3 mile wide images

See individuals, vehicles, boats, and animals

Original images are 88 megapixels each

Images to right are highly subsampled.



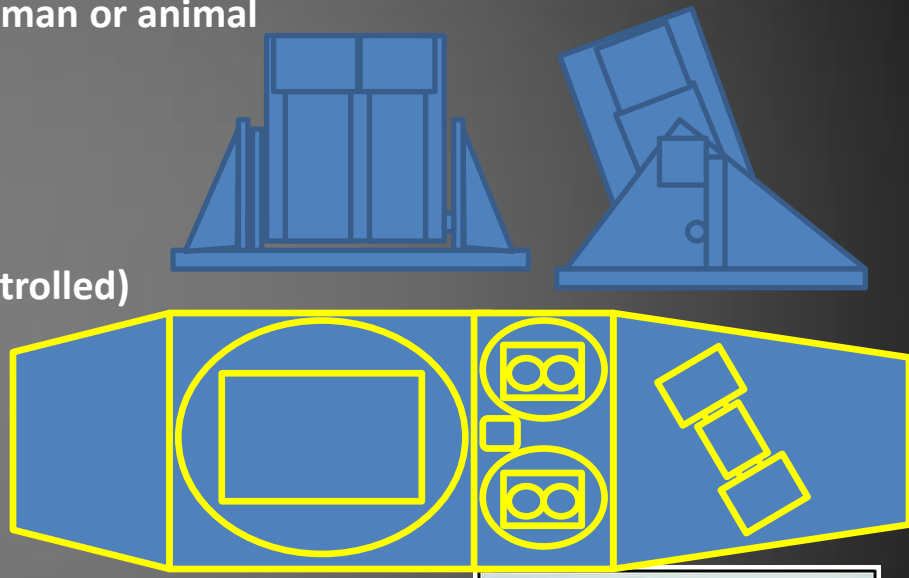


Airborne Spot Beam Coverage

- Provide very high resolution color imagery of immediate pipeline area
  - 16 Megapixel color E/O camera
  - 300 to 1200 mm lens
  - Co Bore Sighted LWIR, MWIR, and SWIR 2nd camera options available
  - Independently pointable (track pipeline)
  - Change detection
    - Looking for new objects, evidence of sabotage efforts, disturbed areas
  - Allows for investigation of identified objects in real time of after the fact

PSS Ultra High Resolution Characterization Camera

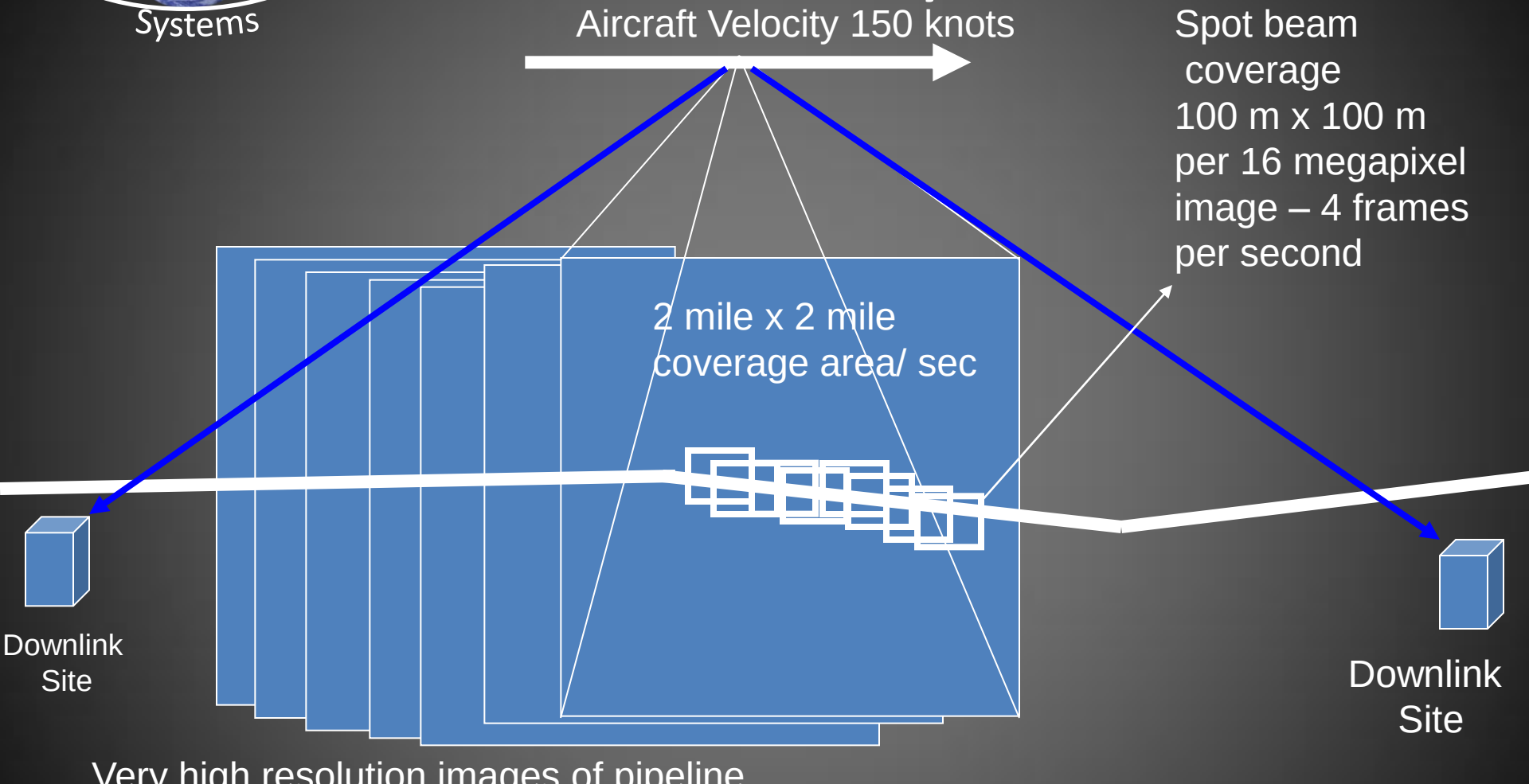
- **Designed to provide high resolution imagery for identifying/characterizing objects within WAAS imagery from aircraft.**
  - Make model of vehicle, color of clothes hair, human or animal
- **Dual Band Visible/IR**
  - Visible EO - Very high resolution spot beam
    - 200-800 mm image stabilized zoom lens
    - 16 (4 hz) to 29 (1.8 hz) megapixel camera
  - Optional MWIR or LWIR Spot Beam (Export controlled)
    - 1 Megapixel MWIR – 400mm lens
    - 600K Pixels with 200 – 400 mm dual length lens
- **Dual Mode**
  - Commandable Stare from iView
    - Click to point in iView
  - Step Stare Survey Mode
    - Survey mode covers large area periodically but systematically
    - Allows forensic matching of WAAS and spot imagery



- **Already implemented on Vision Series ground cameras**
- **Multiple characterization cameras possible on some aircraft**

Persistent Surveillance Systems

Spot Beam Coverage Survey Mode



Very high resolution images of pipeline

Multiple real time images allow for image to image change detection to automatically detect movement within the area

Pass by pass detection can highlight changes that occur between over flights