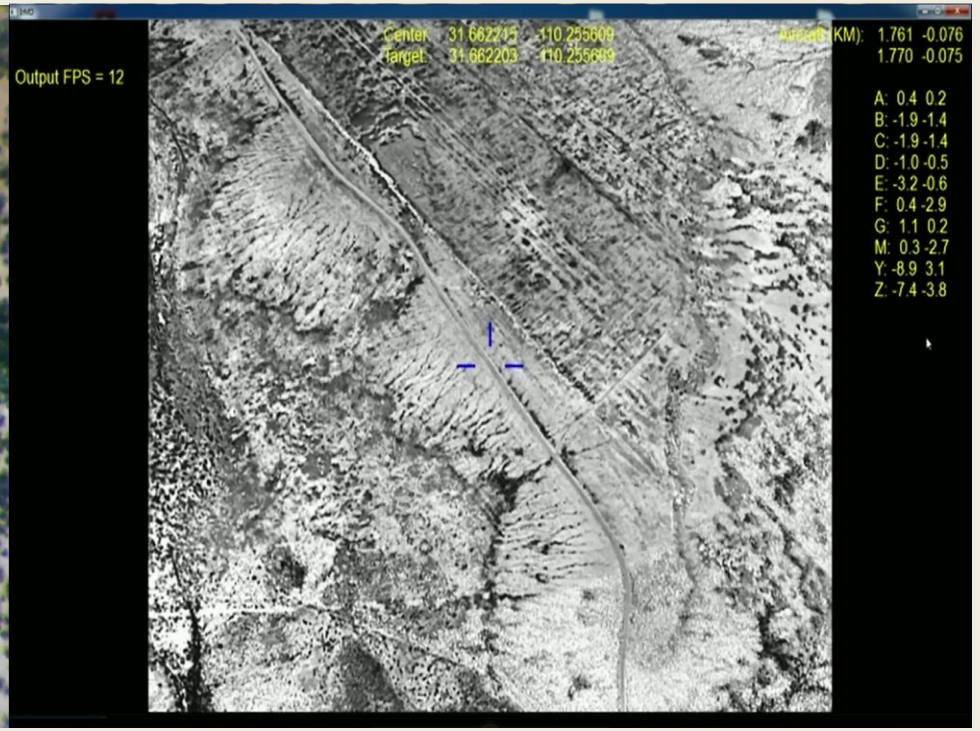
Novel Image Processing Techniques for Passive Wide Area Infrared Motion Detection Using Multi-Purposed EO/IR Assets

William Hughes
U.S. Army Research Laboratory
Adelphi, MD, USA

At the Army Research Lab, we love to invent and develop new sensors, but in a resource constrained environment, the best answer is not always to develop new sensors

- Topics
  - The problem set
  - What if?
  - The How
  - Results
  - The Future
  - Conclusion
  - Questions?

"Soda Straw" vs WAMI Problem



Narrow FOV imagery (2.8º above) provides great ISR over roughly a football field size area, but finding targets can be difficult (e.g. there are 422 football fields / square mile)

In wide FOV imagery (27º above) targets are so small that again they can be hard to find. There is a vehicle in this image below the right spoke of the blue crosshairs

Problem Set

Wide Area Motion Imagery (WAMI) systems on manned air platforms provide excellent search and surveillance capabilities, but these are not deployed in enough numbers to meet military needs

- WHY?
  - Cost to build
  - Cost of operations and sustainment
  - Large operational and logistics footprint

The cost of deploying and operating purpose built, dedicated WAMI platforms can be prohibitive.

What If?

What if the current of the shelf EO/IR sensors used on a wide variety of manned and unmanned aircraft, aerostats and towers systems could be multi-purposed to provide some of the capabilities of a dedicated WAMI systems?

There are over 4700 of these systems deployed in US military applications and a large number in coalition forces as well.

L3 Wescam
MX-Series
> 1,700 Fielded

Raytheon
MTS Family
> 1,000 Fielded

FLIR
Star SAFIRE 380-HD
> 1,000 Fielded

Lockheed Martin
Apache Arrowhead
> 1,000 Fielded

What If?

What if we could develop a small airborne real-time processing system which automates wide FOV detection and tracking of moving targets that are invisible to the human eye in the raw IR data that these current EO/IR sensors can already collect?

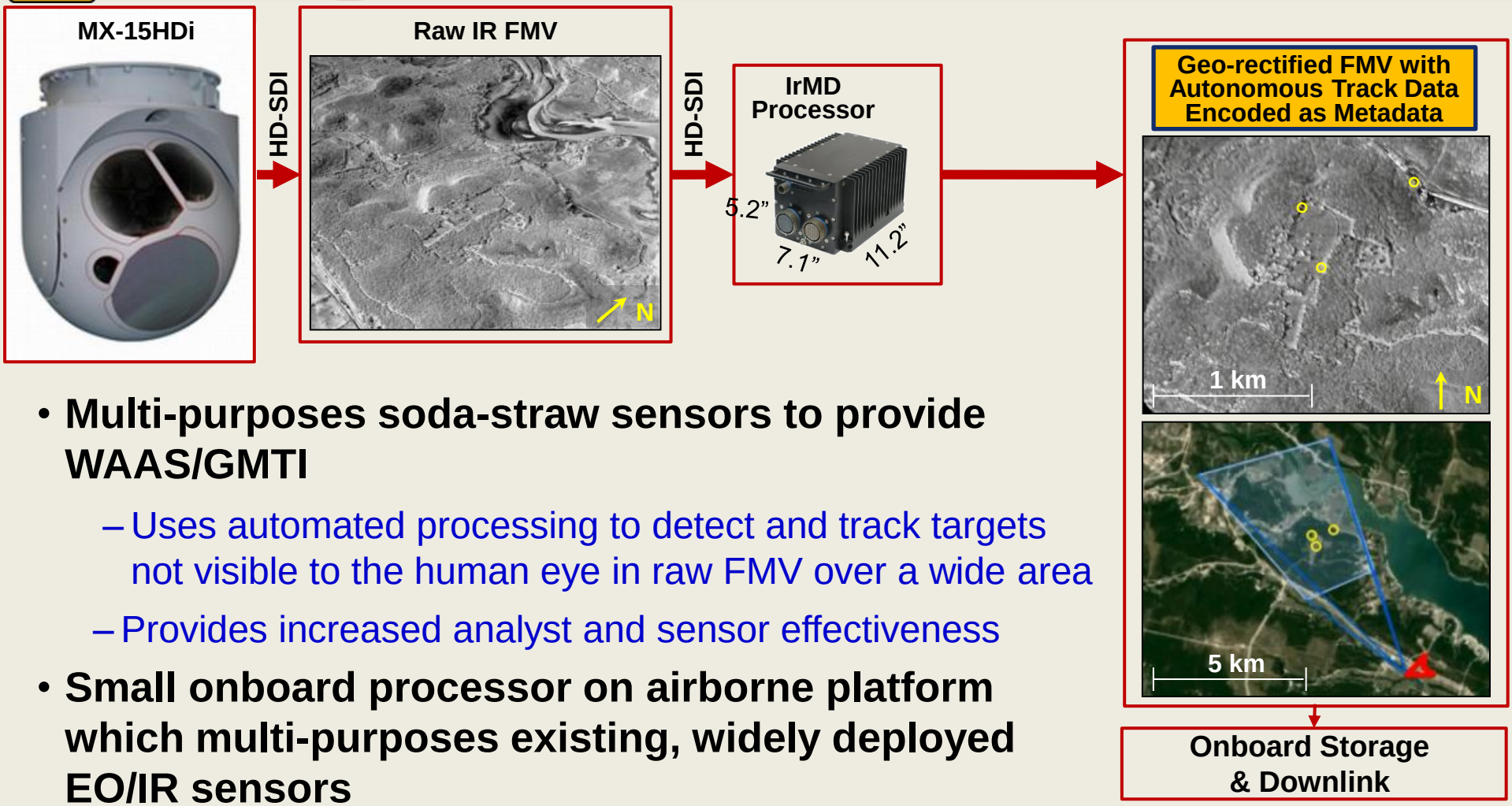
What would we want from that?

- Real-time, onboard, airborne processing
- Rugged flight worthy packaging
- Weight of less than 15 pounds (7Kg)
- Cost less than $50,000 USD per unit
- Power consumption of less than 500 watts
- Does not inhibit normal sensor function
- Very small operational footprint
- Make the operators job easier and provide relevant data

The How?

- **The "what if" evolved over several years to be ARL's InfraRed Motion Detection (IrMD) project with a goal of enabling WAAS detection and tracking of vehicles and dismounts using existing FMV sensors via a low cost, low SWaP-C front-end processor**

- **IrMD provides the ability to enhance weak signals through multi-frame filtering and detect in a track-before-detect manner which enables detection of targets not visible to human eye – increasing operator efficiency & effectiveness**



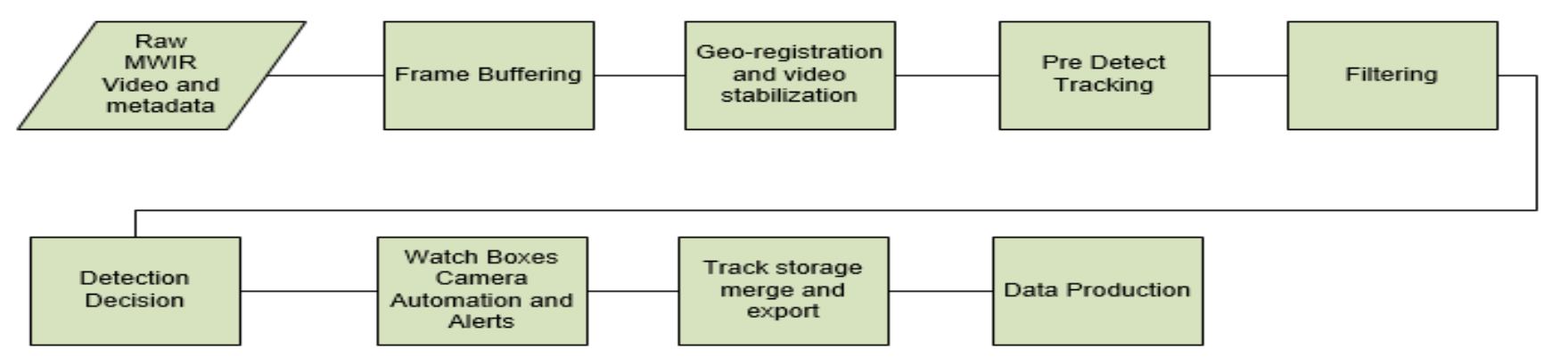
- **Multi-purposes soda-straw sensors to provide WAAS/GMTI**
  - Uses automated processing to detect and track targets not visible to the human eye in raw FMV over a wide area
  - Provides increased analyst and sensor effectiveness
- **Small onboard processor on airborne platform which multi-purposes existing, widely deployed EO/IR sensors**
  - MX-15/20, Star SAFIRE, CSP/MTS, Apache Arrowhead (over 4,700 currently deployed assets)

The How: Details

- **The algorithms used in IrMD processing are quite similar to those used in "super resolution enhancement" In fact it was research into super resolution enhancement of video that triggered the concept that IrMD real-time processing was possible**

- **I refer you to the full symposium paper for details and references but let's explore some key steps**

The How: Processing Details

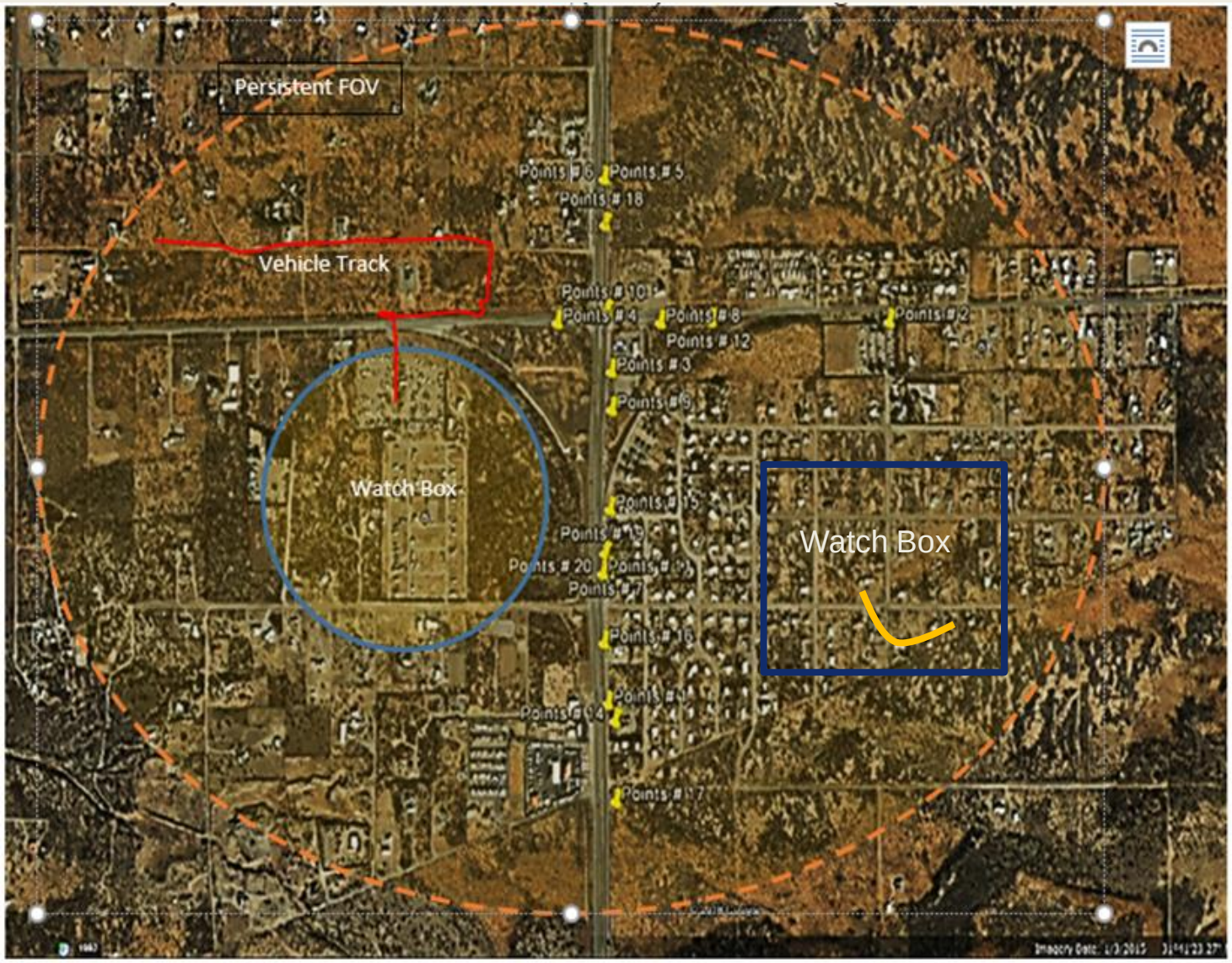


- High precision image stabilization and geo-registration using well registered 3d models
- Detection is achieved by filtering through many frames at a time in a rolling buffer, which has the effect of increasing the signal-to-noise ratio
- Multiple levels of filtering based on signal size, object size, motion and other factors eliminate false positives and feed the detection decision
- A track-before-detect approach further enables weak signal tracking by beginning tracks before conclusively declaring targets
- Detection declaration occurs on reaching a defined target threshold with multi-criteria objective functions which identify consistent frame-to-frame movement vs random noise
- Tracks are not exported until the detect declaration is made

The How: Operation and Automation

A typical ConOp might be operator configured multiple watch boxes defining areas of high interest while still tracking all movers within a wider area

Operator could do other tasks and be prompted with an alert when objects enter or move within the watch boxes



- **When an alert is triggered IrMD can automatically slew the cameras and take a close up still image or short video clip of the target object so the operator can see what triggered the alert.**

The How: Enterprise Challenge 2016

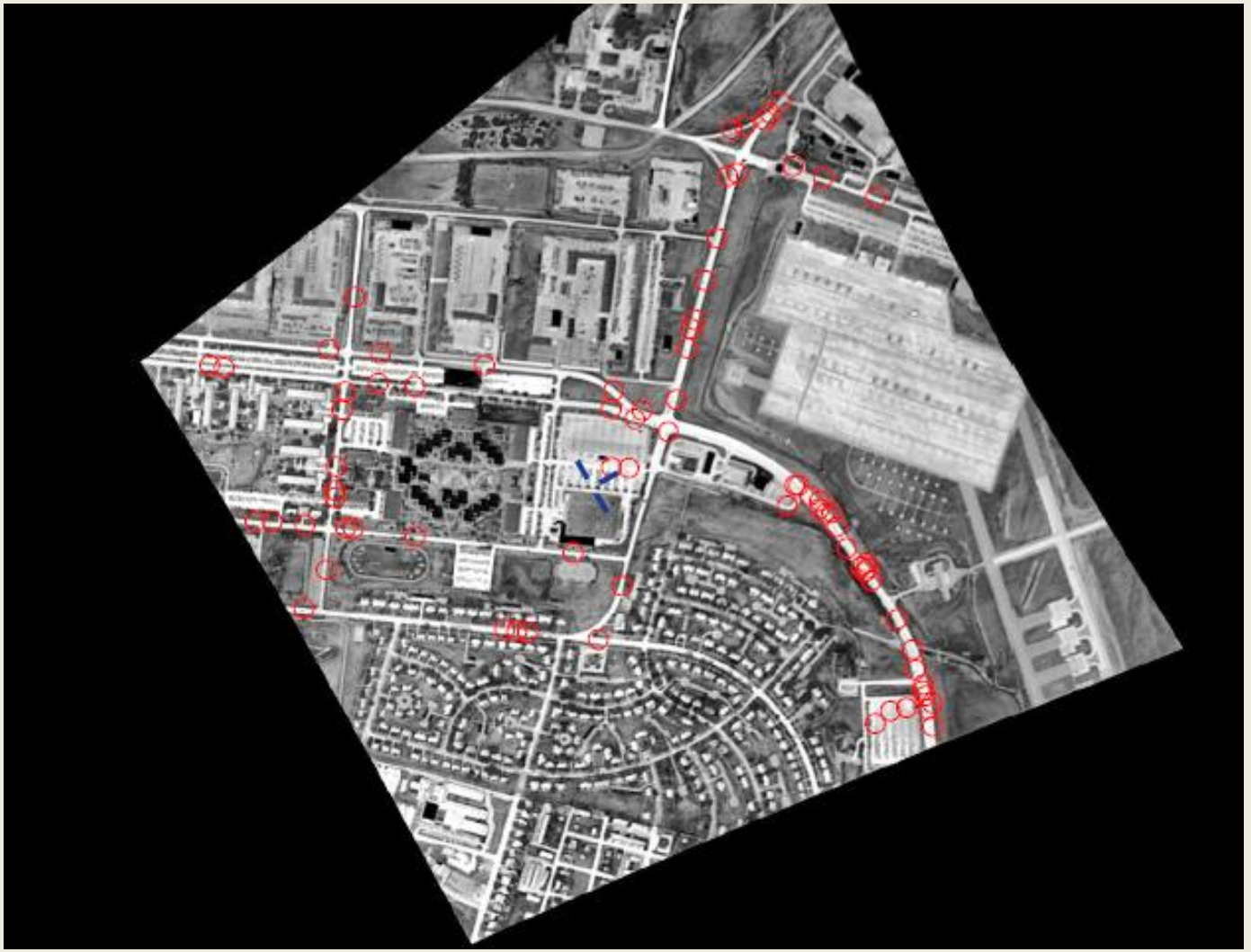
- Surrogate Aircraft: Gipps GA8; Hi-res screen (left rear seat); IrMD screen (right rear)
- MX-15 and omni antenna in pod; Processors, video encoders, data link, & power in rack

The How: Results from EC16

At EC16 IrMD went through it's initial flight testing

The capability to do detection and tracking of vehicles and dismounts was demonstrated

July 2017 the next flight test will occur and more advanced features such as watch boxes and automation will be demonstrated



The Future

The future demand more automation to assist operators, enable autonomous mission performance and reduce the impact of the data onslaught. As we look to the future, additional capabilities and improvements will be added to IrMD

- **Improved digital stabilization to improve geo registration and location accuracies**
- **improved dismount mover enhancement and tracking**
- **Further miniaturization for smaller, lower altitude UAV applications**
- **Addition of real-time object classification for automated data tagging and filtering of data to only objects of interest.**
- **Autonomous mission capabilities with the ability to predefine mission parameters and have the system stay silent in data collection mode until criteria for notification occurs**

The Future: Object Classification Automation

1. IrMD detects a mover in a target box
2. IrMD controls EO/Color and/or IR camera to zoom in and snap photos or video clips of object
3. Images passed to real-time classifier for object detection/classification
4. Classifier identifies objects as truck, car, motorcycle, etc.
5. This information is added to GMTI, FMV and image metadata to provide object tagging and used by IrMD to eliminate false alarms or further filter data for objects of interest

IRMD Outputs from this process would be tracks with objects classified and tagged in metadata.

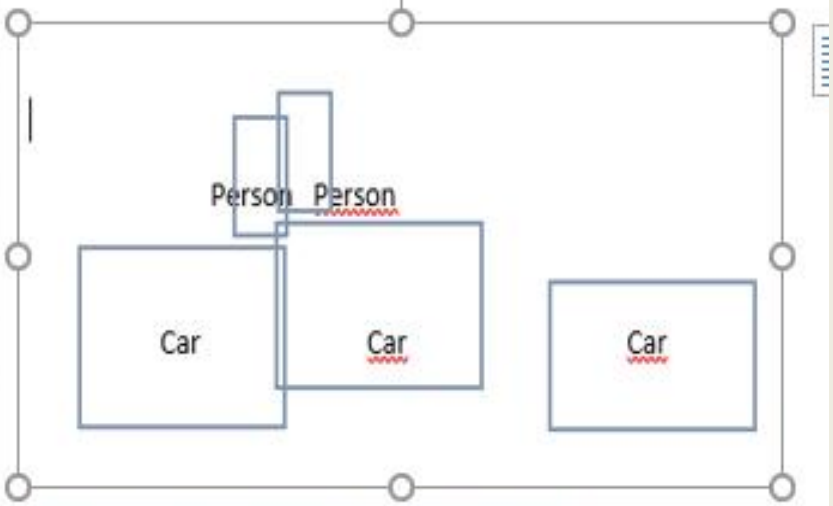


Figure 17- Object detection and Classification

Conclusions

Army Research Laboratory (ARL) Airborne IrMD program achievements:

- **Flight testing occurred at Enterprise Challenge 2016**
  - **System shown to effectively transform "Soda Straw" sensor into Wide Area Aerial Surveillance (WAAS) sensor using a plug-and-play processing unit on the aircraft**
  - **Wide-area autonomous tracking of ground vehicles and real-time ingestion of data products into processing and visualization tools was demonstrated**
- **Additional flight test scheduled for July and November 2017 (CUE)**
  - **Will include enhanced automation and dismount tracking and test in both sparse and cluttered (urban) environments**
- **Ruggedization and productization have produced a deployable system**
  - **16 pound rugged processor to be ready for additional flight testing in November and for deployment in 2018**
- **More than 1,000 platforms have been identified for potential IrMD deployment**
  - **Initial platforms belong to Army and SOF**
  - **Additional interest in applications for border patrol and maritime use**
- **Future areas for automation and other enhancements have been identified and efforts are underway**

Thank You

Questions?