Innovative Uses of Unmanned Aerial Vehicle (UAV) Technology

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Agenda

- WSDOT Maintenance Operations small Unmanned Aircraft Systems (sUAS) Program Overview
- Washington State Patrol sUAS Applications
- University of Massachusetts – Research and Traffic Studies/Applications
- UAV Demonstration

UMass Amherst

Maintenance Operations sUAS Program

First Steps

- FAA Part 107 Certification
- Knowledge Exam
- Register all drones between 0.55lbs and 55lbs with the Federal Aviation Administration (FAA)
- UAV Flight Training

Limitations and Rules

- Line-of-sight
- 400’ Above Ground Level (AGL)
- Weather conditions
- People & property

Airspace

- Airspace
  - Class A, B, C, D, E (restricted)
  - Class G (unrestricted)
- Low Altitude Authorization and Notification Capability (LAANC) system
  - Uses mobile applications such as AirMap, UASSidekick, and Kittyhawk
  - Waiver

DJI Matrice 600 Pro

- Large, Enterprise-grade drone
- 6 Props powered by 6 batteries
- 3 Real-Time Kinematic (RTK) GPS Sensors (centimeter accuracy)
- 13Lb Payload
- Cost: $4,999
- Camera not included, ZENMUSE X5R $2,599

Camera Specs

- **M600**
- ZENMUSE X5R
- 4K Video @ 24-30 FPS
- 16 Mega Pixels
- 512 GB SSD
- Plus 128 Micro SD

- **PHANTOM 4 PRO**
- BUILT IN CAMERA
- 4K Video @ 24-60 FPS
- 1 inch CMOS Sensor
- 20 Mega Pixels
- 128GB Micro SD

DJI Mavic Air 2

- Ultra Portable Fits in Backpack and Deploys Quickly.
- Cost: $1,399 Fly More Combo DJI Smart Controller
- 30 Minutes Fly Time Per Battery (3 batteries 90 mins)
- Max Distance 6.2 miles
- Max Speed 42 MPH
- Wind Resistance 23 MPH

DJI Mavic Pro 2 Dual

- Portable, Enterprise Drone
- Cost: $2,699 not including extra accessories
- Optional Fly more package $419
- 4k UHD Video
- FLIR Thermal Camera
- Multiple Attachments
- Obstacle avoidance

DJI Phantom 4 Pro

- Small, Prosumer-grade
- Cost: $1,499 not including extra accessories
- Obstacle avoidance

Physical and Software Equipment

- Apple or Android mobile device
- EarTec Ultra-Light HD-Remote headsets
- DJI Go (M600)
- DJI Go 4 (Mavic Air 2)
- DroneDeploy (3D/2D Maps.)
- DJI PRO Controller

Battery Considerations

Mavic Air 2:

Comes with three batteries

250-watt inverter used for field charging

$115 each

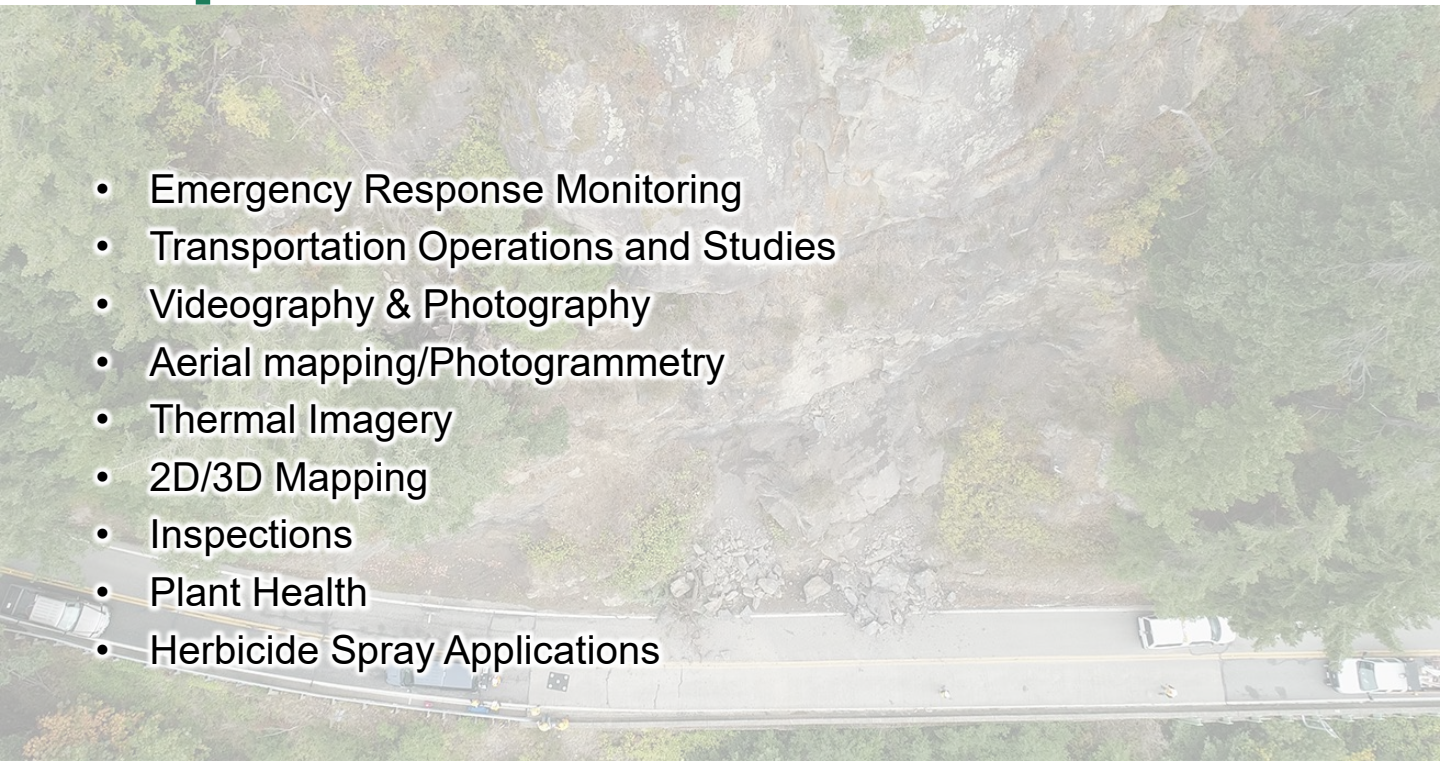
Flight time 30 min - each battery

Matrice 600 Pro:

- Requires six batteries to fly
- Four sets can be charged and cycled using a 2000-watt generator in the field
- $245 each
- Flight time 30 min each set of six

Drone Mapping Software

Implemented/Planned Uses



- Emergency Response Monitoring
- Transportation Operations and Studies
- Videography & Photography
- Aerial mapping/Photogrammetry
- Thermal Imagery
- 2D/3D Mapping
- Inspections
- Plant Health
- Herbicide Spray Applications

Emergency Response

Before/After Traffic Studies for Ramp Meter Installations

Documentation

- WSDOT statewide sUAS Coordinator SharePoint
- Roger Millar's Secretary Executive Order E 1097.02 Unmanned Aircraft Systems
- WSDOT Aviation sUAS User's Manual M 3134
- Federal Aviation Administration Registration *FAA Drone Registration*
- Contact me if you'd like more information!

Washington State Patrol (WSP) sUAS Applications

Crime Scene Documentation

Available WSP Tools

- Baseline- coordinate measurement system
- Total station- laser measuring with or without pole prism
- 3D laser scanner- time of flight or laser scanning
- GNSS- Precision mapping using satellites
- sUAS- Photogrammetry from aerial photos

Courtesy Trimble.com

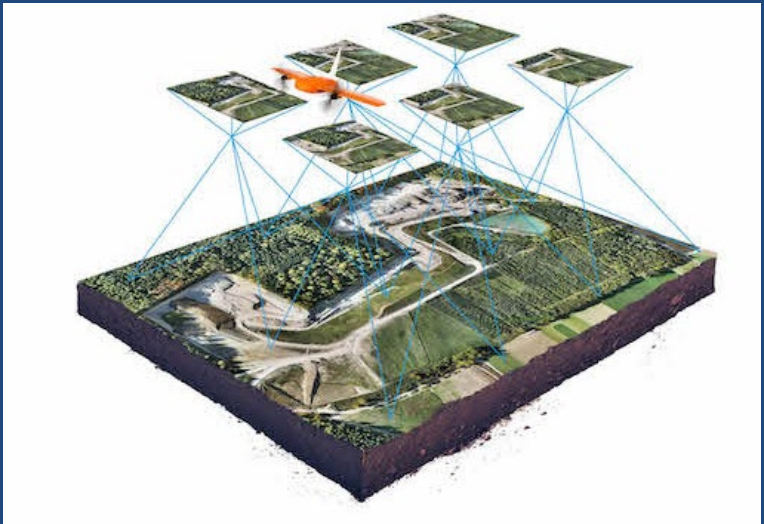
Courtesy everythingrf.com

WSP Operations

Usually, one person operation that is approx. 80% more time efficient than all others.

sUAS (Photogrammetry)

UAV/DRONE PHOTOGRAMMETRY



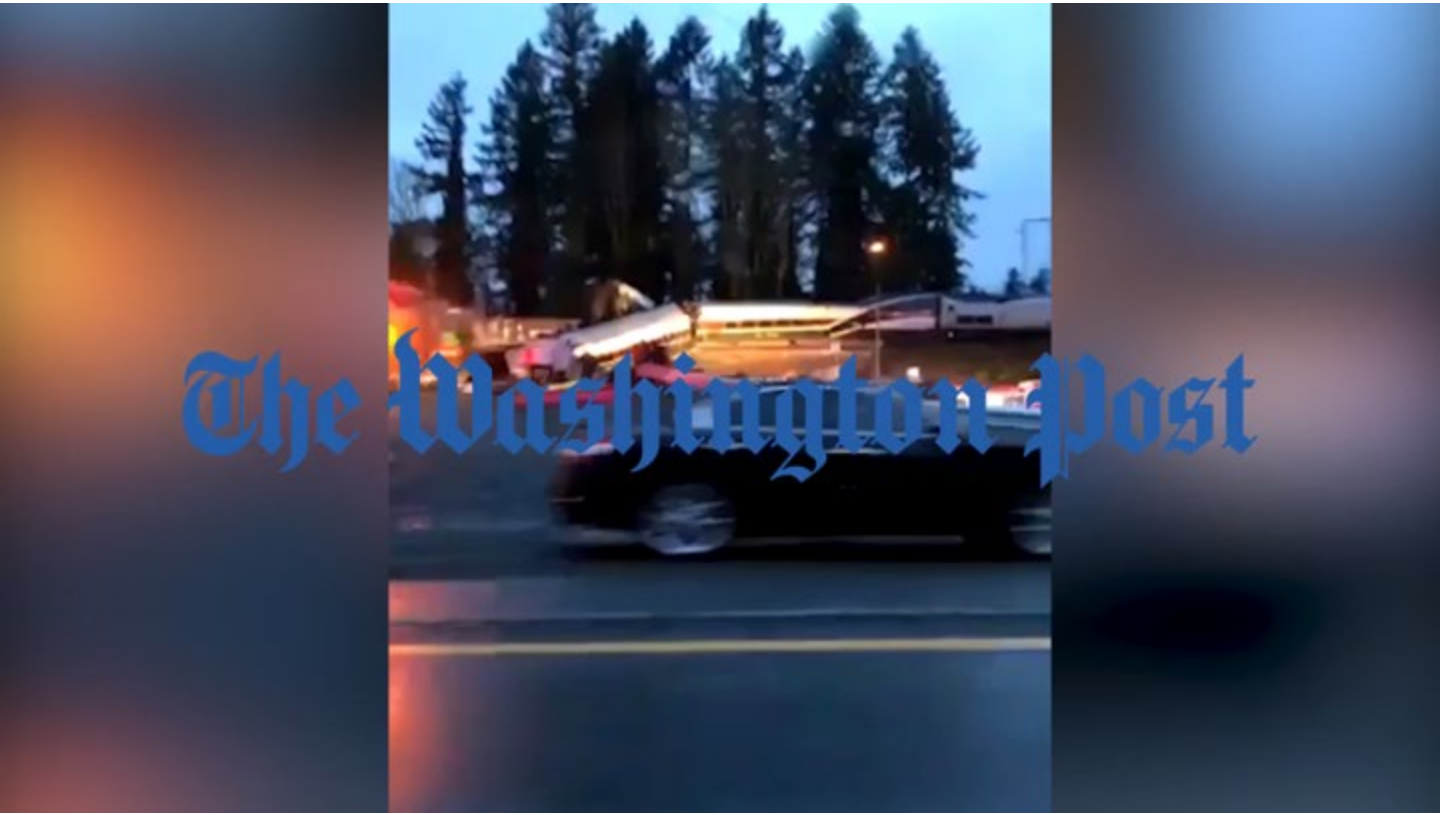
How it Works

- Photographs are taken with front and side overlap. The photographs are encoded with GPS data obtained by the UAV. The photogrammetry software (Pix4D) identifies matching pixels in the photographs and in combination with GPS data triangulates to place that pixel and the ones around it in relative and actual 3D space.

TRAIN DERAILMENT

December 18, 2017 – Inaugural Run - New Pt. Defiance Bypass Route

- Amtrak Passenger Train 501
  - Amtrak 501 consisted of 10 passenger railcars, a power railcar, a baggage railcar, and two (2) locomotives, one at either end.
  - The train departed the Tacoma Station at 7:17 a.m.
  - There were 77 passengers on board, with five (5) Amtrak employees, and one Talgo, Inc. technician
  - 48 degrees, wind 9 mph, visibility 10 miles, light rain
  - Derailment – 7:34 a.m.

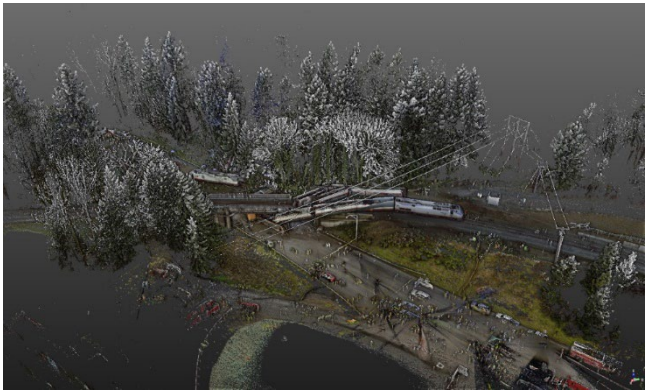

The Washington Post

WSP used 4 TX-5 scanners working simultaneously (82 scans with 4 scanners) approx. 3.5 hours total.

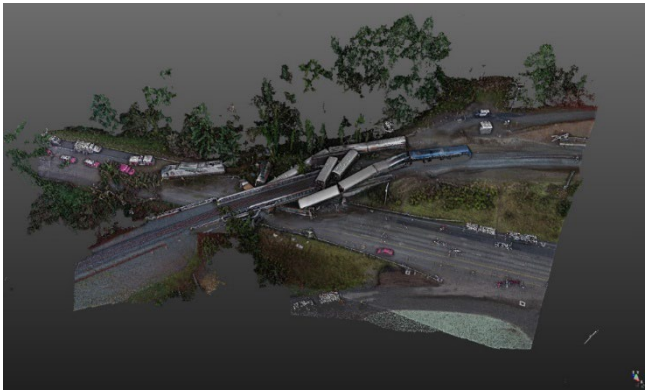
WSP detective simultaneously utilized photogrammetry with a DJI quad copter UAV taking overhead photographs flight time 89 minutes

Scanner and UAV Data Brought Into Trimble RealWorks

- Scanner



- UAV



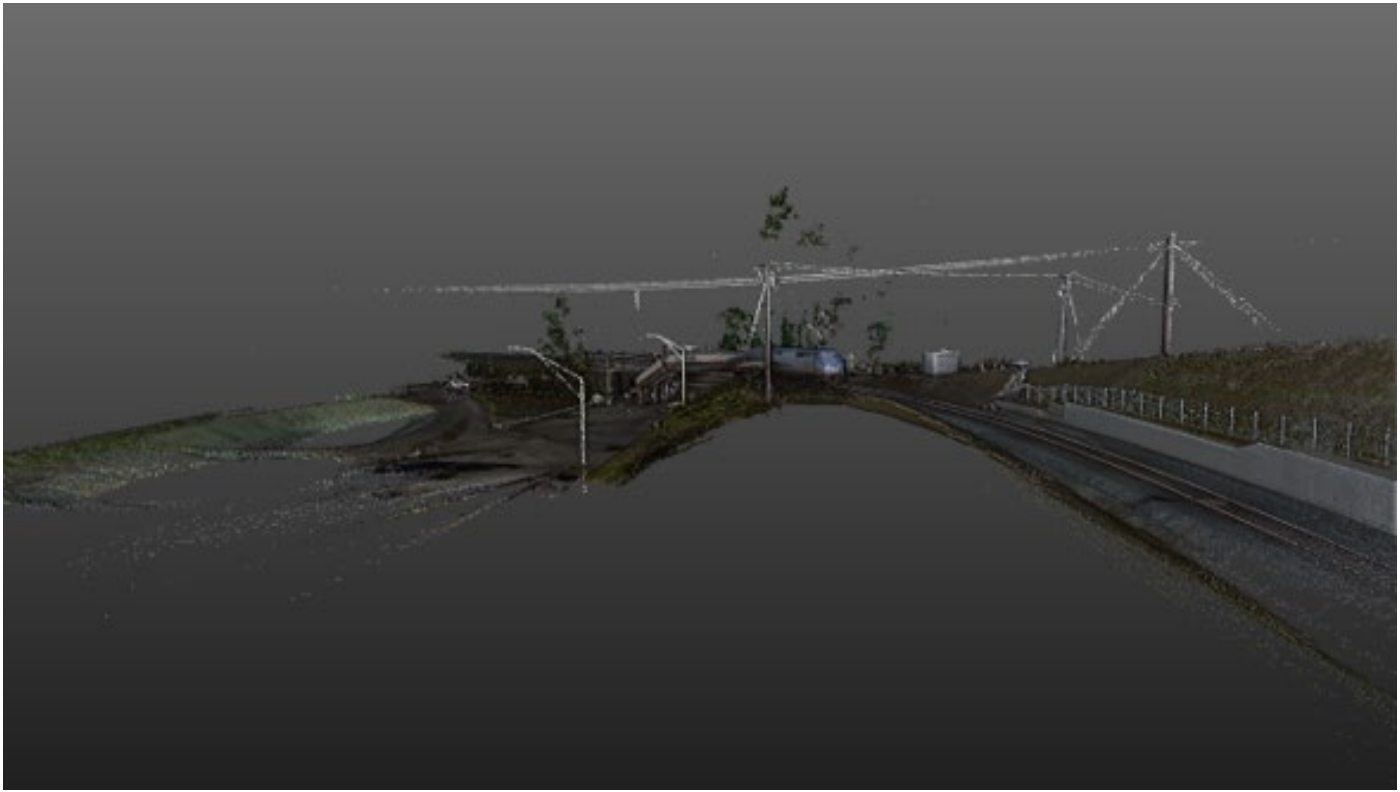
Closer Look at the Data Before Combined

- Scanner
- No top, great sides

- UAV
- Top great, no sides

Closer look at merged portion to highlight capabilities (top and sides together)

Point Cloud Animation (Trimble)

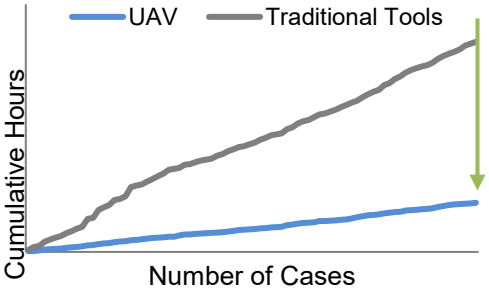


WSP Results

- Derailment scene completed documented by WSP detectives in 3.5 hours
- Final product delivered to NTSB within 24 hours
- Condensed point cloud was over 415 million measurable points (1.2 billion actual points captured)
- Photo realistic capture of the scene
- Actual aerial photos from the UAV to NTSB at scene
- Data is exportable in multiple formats through Trimble RealWorks
- Scene investigation was sped up significantly compared to traditional methods

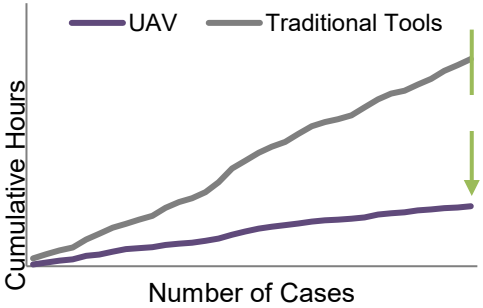
WSP Results – 2018 Road Closure Time Reduction

Detective (CID) Results



- 91 investigations
- 162.5 hours road closure time saved (77% reduction)
- At $350 per minute- saved $3,412,500

Front line Troopers (FOB) Results



- 35 investigations
- 38 hours road closure time saved (71% reduction)
- At $350 per minute- saved $798,000

Technical Questions for WSP?

If you have further questions regarding the WSP UAV program or any of the technology demonstrated in this part of the presentation, please reach out to Lieutenant Ryan Durbin.

Email: ryan.durbin@wsp.wa.gov

In memory of Detective Eric Gunderson, 39, who was instrumental in developing the WSP UAV program and this presentation. He sadly passed away last month after contracting COVID in the line of duty. He is greatly missed as a partner to our Joint Operations mission.

What is a UAS?

Unmanned Aerial System

Unmanned Aerial Vehicle (UAV)

Drone

Regulations

Operate a Drone, Start a Drone Program
(from FAA.gov)

Government agencies (including Federal, State, and tribal), law enforcement, and public safety entities have two options for operating drones under 55 pounds.

- Fly under 14 CFR part 107, the small UAS rule. Part 107 allows operations of drones or unmanned aircraft system (UAS) under 55 pounds at or below 400 feet above ground level (AGL) for visual line-of-sight operations only.
- Fly under the statutory requirements for public aircraft (49 U.S.C. §40102(a) and § 40125). Operate with a Certificate of Waiver or Authorization (COA) to be able to self-certify UAS and operators for flights performing governmental functions.

- Federal Regulations
- State Regulations
- Regional/Local Regulations
- Regulations for state agencies vs. individuals

Drones Approved for Use by US Department of Defense

- Skydio's X2-D
- Parrot's Anafi USA
- Altavian's M440 Ion
- Teal Drones' Golden Eagle
- Vantage Robotics' Vesper

Reference: Skydio.com

Part 107 Rule

- UAS must be **< 55lbs**
- UAS must be within **visual line-of-sight** of remote pilot or visual observer
- Operations only permitted during the **daylight**
- **Maximum altitude of 400 feet** above ground level or flown within 400 feet of a structure

- ***Operation over human beings or moving vehicles is not permitted***
- A person must hold a remote pilot certification if flying commercially:

Source: Gliem Aviation

Registering & Flight Insurance

Registering drones at faadronezone.faa.gov

- $5 per drone
- Must renew every 3 years

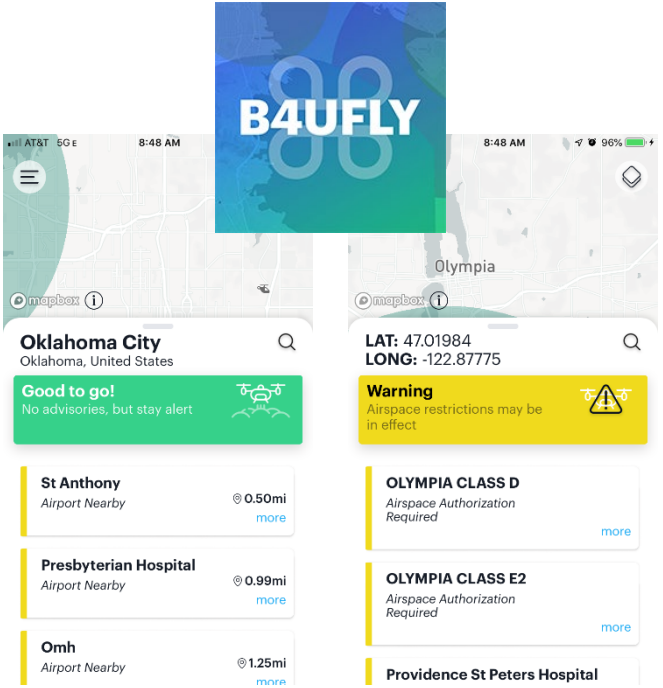
On demand vs. Insurance brokers

Flying Near Roads

- Safety is #1 priority
  - Begin flight away from moving vehicles so drone/flight team cannot be seen by drivers
  - If not possible, consider signage ("*Drone Survey Crew" or "Drones Ahead"*) and safety vests
  - Have a visual observer, multiple if possible
  - Do not fly directly over the roadway (Part 107)

Flight Considerations

- Federal, state, regional, and local regulations
  - Takeoff/flight location authority
- Distance from airports, wildlife refuges, military bases, prisons, National Parks, most State Parks, some schools
- Weather & temperature
- Magnetic interference/flight connection
- Insurance
- Batteries – phone/device and drone



Source: FAA

Collecting volume and speed data with UAS
Why is this useful?

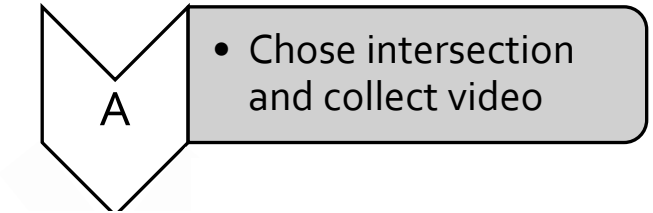
- Speed and volume data are important for many transportation studies
- Collecting data using traditional methods, such as radar, pneumatic tubes, manual turning movement counts (TMCs), etc. can be expensive
- Unmanned aerial vehicles have the potential to reduce hours required to collect speed and volume data
- Data collection can otherwise be difficult in rural areas/areas with challenging terrain

Aerial Image Processing General Background

Video frames

Source: Samuelsson. O. Vehicle Tracking Algorithm for Unmanned Aerial Vehicle Surveillance. No. June, 2012, pp. 1-76

Volume Data Collection



Volume Data Collection

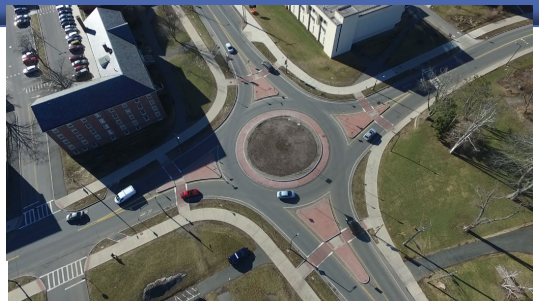
A

- Chose intersection and collect video

Volume Data Collection

A

- Chose intersection and collect video



Volume Data Collection

A

- Chose intersection and collect video

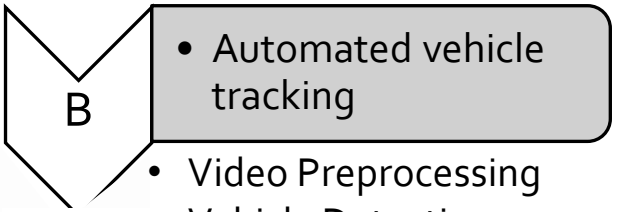
Phantom 3 Pro

- Data collected from 7am to 9am
- Drone's camera has FOV of 94 degrees

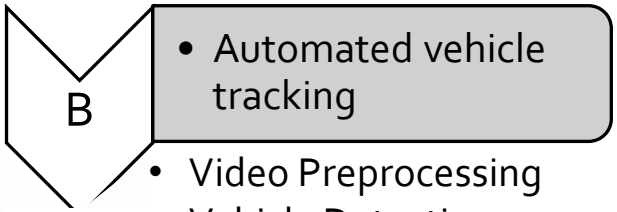
Phantom 3 Professional Specifications

- Weight: 1280 g
- Max speed: 16 m/s
- Max flight time: Approximately 23 minutes
- Voltage of battery: 15.2 V
- Max charging power: 100 W
- Operating temperature: 32 to 104 degrees F

Volume Data Collection



Volume Data Collection

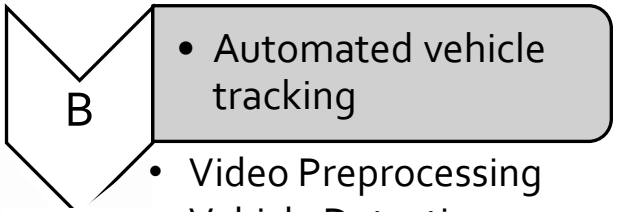


- Video Preprocessing
- Vehicle Detection
- Vehicle Tracking

Vehicle Detection

- Used computer vision
- Downsampled to 2 frames per second to preserve features in subsequent steps

Volume Data Collection



Vehicle Detection

- Deep learning framework called "You Only Look Once" (YOLO) v3 was used to identify vehicles
- New model needed to be created due to new perspective
- Open dataset from UAV images (Kharuzhy) used to create new model
- Minimal intervention needed once model is trained

Volume Data Collection

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Volume Data Collection

Vehicle Tracking

- Kalman filter was used to predict motion
- Based on the closeness of predicted location and observed, the detection will merge to vehicle track

Volume Data Collection

Timestamp	TL-TR	TL-BL	TL-BR	TR-TL	TR-BL	TR-BR	BL-TL	BL-TR	BL-BR	BR-TL	BR-TR	BR-BL
7:00:00	100%	64%	80%	100%	68%	N/A	67%	80%	N/A	76%	N/A	71%
7:09:20	N/A	80%	100%	N/A	90%	N/A	76%	75%	100%	86%	N/A	100%
7:19:00	100%	75%	85%	100%	92%	N/A	93%	96%	100%	94%	N/A	89%
7:28:20	100%	100%	100%	100%	90%	N/A	96%	89%	100%	88%	100%	89%
7:41:05	100%	100%	100%	83%	100%	N/A	94%	100%	86%	90%	N/A	89%
7:50:26	100%	100%	100%	100%	94%	100%	88%	92%	100%	95%	100%	100%
8:00:00	80%	92%	87%	100%	89%	100%	92%	90%	100%	100%	100%	86%
8:09:20	100%	100%	100%	83%	100%	100%	83%	94%	100%	100%	N/A	100%
8:21:00	100%	93%	95%	100%	88%	100%	85%	90%	100%	87%	75%	91%
8:30:20	86%	90%	100%	100%	94%	100%	83%	90%	83%	87%	100%	100%
8:47:41	100%	100%	91%	100%	93%	N/A	97%	89%	80%	88%	100%	86%
8:57:14	100%	100%	100%	N/A	80%	N/A	86%	89%	100%	95%	100%	100%

C

- Accuracy of technique

Accuracy

- Recall and precision both **averaged 93%**
- Accuracy was worse from 7:00am to 7:20am due to lighting

7:00am

7:20am

Speed Data Collection

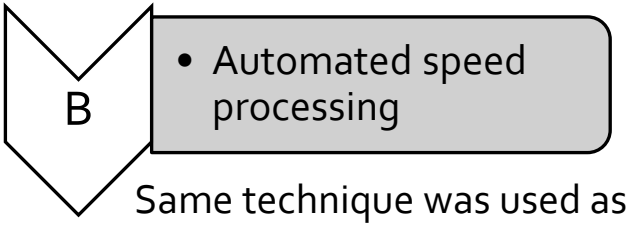
A

- Chose location and collect data

Route 9, Amherst, MA

- To track specific vehicle, an "X" was placed on top
- Drone flew at 100 meters (328 feet)
- Probe vehicle speeds were tracked using both speedometer and smartphone app

Speed Data Collection



Same technique was used as volume study, plus:

- Camera Calibration
- Speed Computation

Camera Calibration

- Transformed image coordinate system to world coordinate system

Speed Computation

- Computed the vehicle speed for all vehicle trajectories
- Computed speed based on distance measured in world coordinate system divided by time

Speed Data Collection

Direction Label	Actual Speed (mph)	Average Measured Speed (mph)	Relative Error
SB 1	45	48.8	8.4%
NB 1	44	47.5	8.0%
SB 2	50	52.9	5.8%
NB 2	51	52.4	2.8%
SB 3	55	59.5	8.3%
NB 3	54	57.3	6.2%
		Average:	6.6%

Takeaways

- UAS flights require training and background work
- Static camera 2.3% more accurate than UAS with same data processing
- However, much more flexibility with UAS, especially in difficult locations/terrain
- Automatic processing time for vehicle counts was approximately 1.8 hours per hour of video, compared to 6 hours of manual processing per hour of video
- Trajectory count accuracy of 93% during peak hours
- Traditional short term speed data collection versus UAS

Thank you to the work of Dr. Chengbo Ai, Dr. Cole Fitzpatrick, and Dr. Michael Knodler in the development and employment of this work.

Additional resources:

NCHRP Synthesis 20-05/Topic 52-04 (ongoing), Use of Unmanned Aircraft Systems for Departments of Transportation
MassDOT Report 19-010, The Application of Unmanned Aerial Systems In Surface Transportation
Scan 17-01, Successful Approaches for the Use of Unmanned Aerial System by Surface Transportation Agencies

Contact Information:

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Alyssa Ryan, alyssaryan@arizona.edu

Video UAV Flight Demonstration:
https://youtu.be/vGa7HDNyblw

UMassAmherst
College of Engineering
UMass Transportation Center

Demonstration Information

- A drone demonstration followed the live version of this presentation
- This demonstration consisted of the setting up of a drone flight of a Phantom 4 Pro version 2.0 DJI drone, including checks, and a short flight
- Similar information regarding this is demonstrated in the following videos:
  - Pre-check: https://www.youtube.com/watch?v=77t6uc2gVvU&list=PL65kukZorPdOdXH1M9KGRBfaEtwboOnPC&index=3
  - Linking remote controller: https://www.youtube.com/watch?v=rAynQ9Smzxg&list=PL65kukZorPdOdXH1M9KGRBfaEtwboOnPC&index=6
  - Calibration: https://www.youtube.com/watch?v=2WltMwrWlyM
  - Operating frequency: https://www.youtube.com/watch?v=1JFlYAG2mJE&list=PL65kukZorPdOdXH1M9KGRBfaEtwboOnPC&index=9
  - Flight I: https://www.youtube.com/watch?v=Vl1jp-8ZQmo&list=PL65kukZorPdOdXH1M9KGRBfaEtwboOnPC&index=4
  - Flight II: https://www.youtube.com/watch?v=ag6NgumueAU&list=PL65kukZorPdOdXH1M9KGRBfaEtwboOnPC&index=10