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AERIAL SURVEYS

# Drones for Planning, Monitoring and 3D: Current and Future

DVRPC Information Resources Exchange Group

June 8, 2016

Presenter: David Day, CP, GISP

Keystone Aerial Surveys, Inc.

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# Keystone Aerial Surveys, Inc.

- Based in Philadelphia, PA with offices in Los Angeles, Tucson and Tyler, TX
- Founded in 1963 to provide remote sensing throughout the US
- 21 manned survey aircraft
- 22 mapping sensors including 8 UltraCam digital cameras and 2 Optech LiDAR systems (including new Galaxy delivered June 14th!)
- Provide post production services from large format digital, LiDAR and UAS imagery


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# Keystone UAS

- UAS approved:
  - Altavian Nova F6500 (fixed wing), R8400 (Rotorcraft)
  - DJI Phantom 3, Inspire 1 Pro and DJI S1000 (Rotorcraft)
  - 3D Robotics X8-M (Rotorcraft)
  - SteadiDrone Mavrik X4 and Mavrik X8 (Rotorcraft)
  - Keystone is approved for all types of mapping, remote sensing and imagery – except closed set television and film capture


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# My Bio

- Started with Keystone in 1995 as an aerial photographer
- Developed Information Technology and Digital Post Processing departments
- Have been hands on with imagery post processing software for nearly 10 years
- Application Development Certification, Certified Photogrammetrist and Geographic Information Systems Professional (GISP)
- Currently Executive Vice President and Director of UAS Division
  - Oversee all manned and unmanned flight operations, camera systems and post production
- Authored or Co-Authored 7 research papers, many with mentor Dr. Ricardo Passini, BAE systems.

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# Current Regulations

- Must have a 333 exemption to legally fly UAS for commercial purposes
- Exemptions are from the FAA for specific airframes and organizations\persons
- Hobbyists are not required to obtain exemptions
- Exemption holders must have a Certificate of Authorization (COA) to fly their exempted aircraft
- All flights involving commercial operations must be performed under 333 and COA or they are ILLEGAL!

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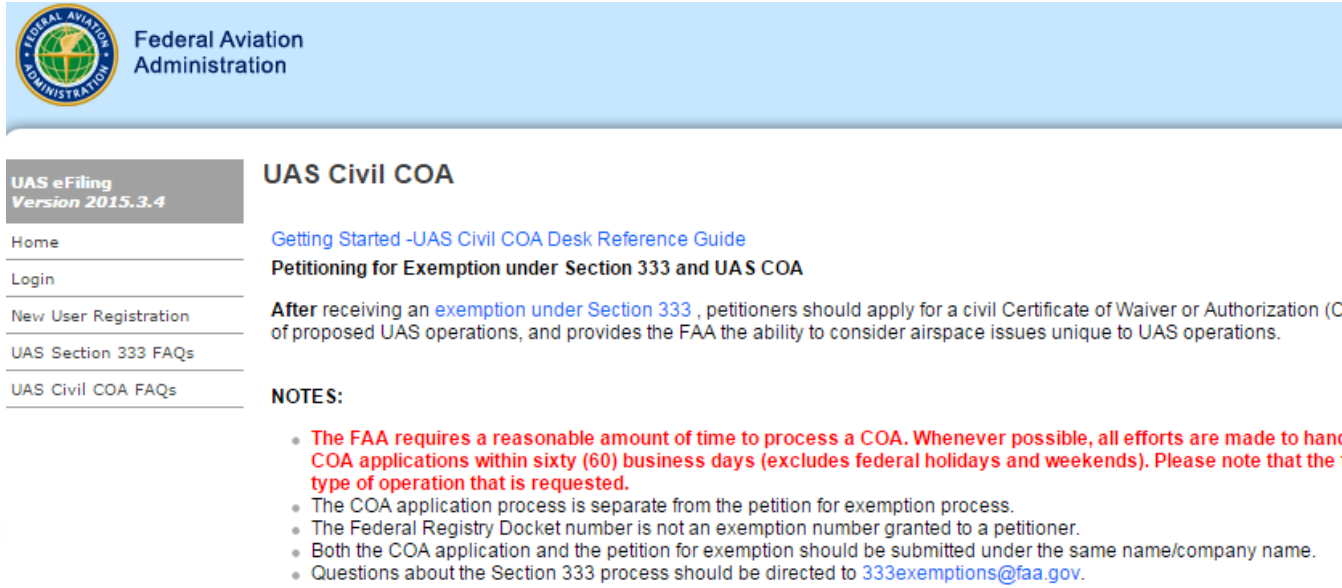
# Current Regulations – 333 Key Rules

- UAV must be under 55 lbs. and speed not to exceed 100 mph
- UAV must be operated at 400 feet AGL or below
- UAV must be operated within visual line of sight of pilot and one observer (cannot daisy-chain observers/pilots)
- Pilot must hold a commercial, private, recreational or sport pilot certificate
- Operations cannot be at night
- Operations must be in VFR conditions (500 ft. below clouds)

# Current Regulations – 333 Key Rules

- All operations must be 500 feet from buildings, vessels, persons and vehicles not participating in the operation
- Exemption holders receive a blanket COA with the restriction flights must be 5 nm from public airport with a tower, 3 nm from most other public airports and 2 nm from public heliport, gliderport or seaport
- Access to Civil COA process is granted to 333 holders

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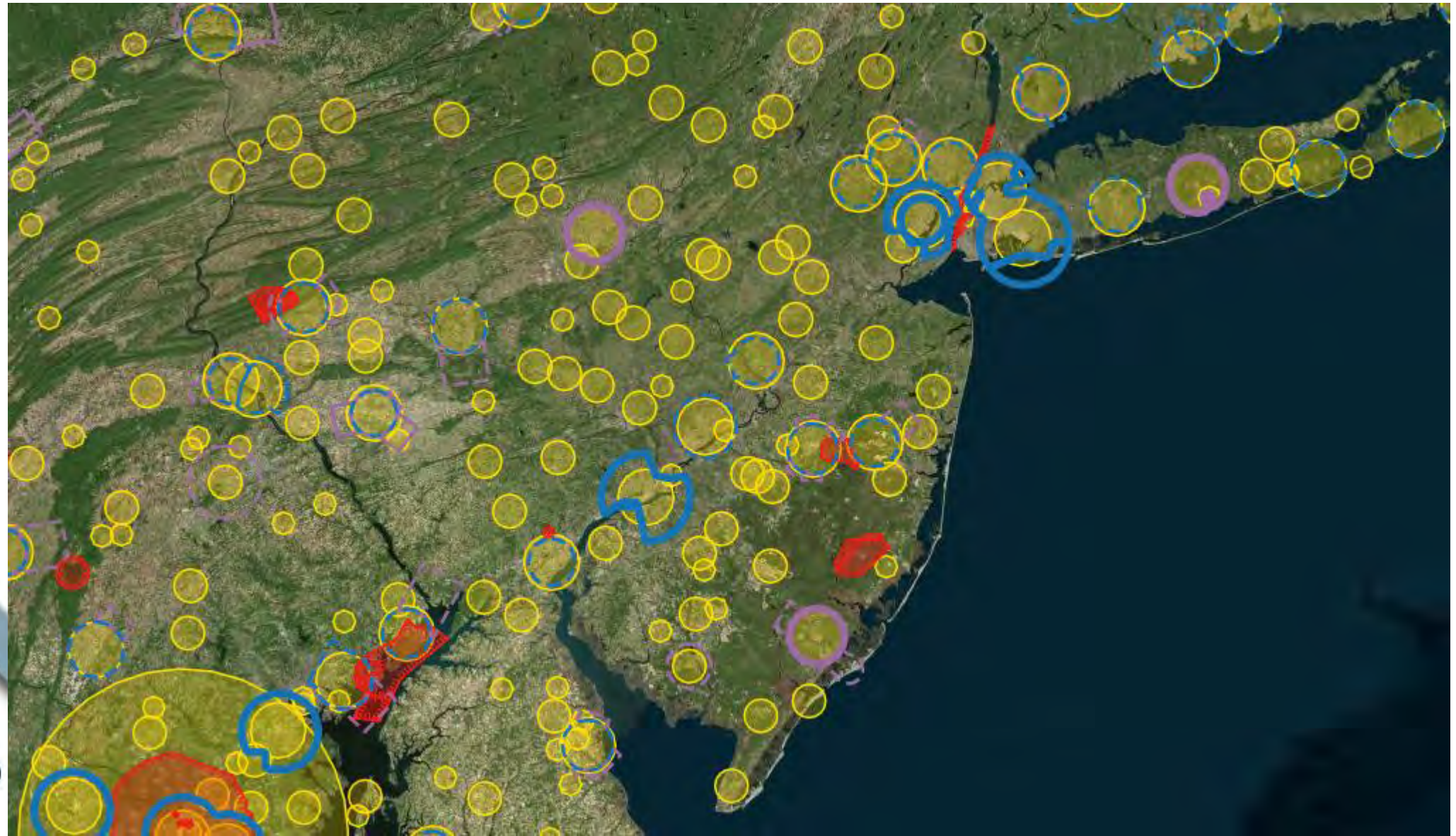
# Current Regulations – Blanket COA Rules



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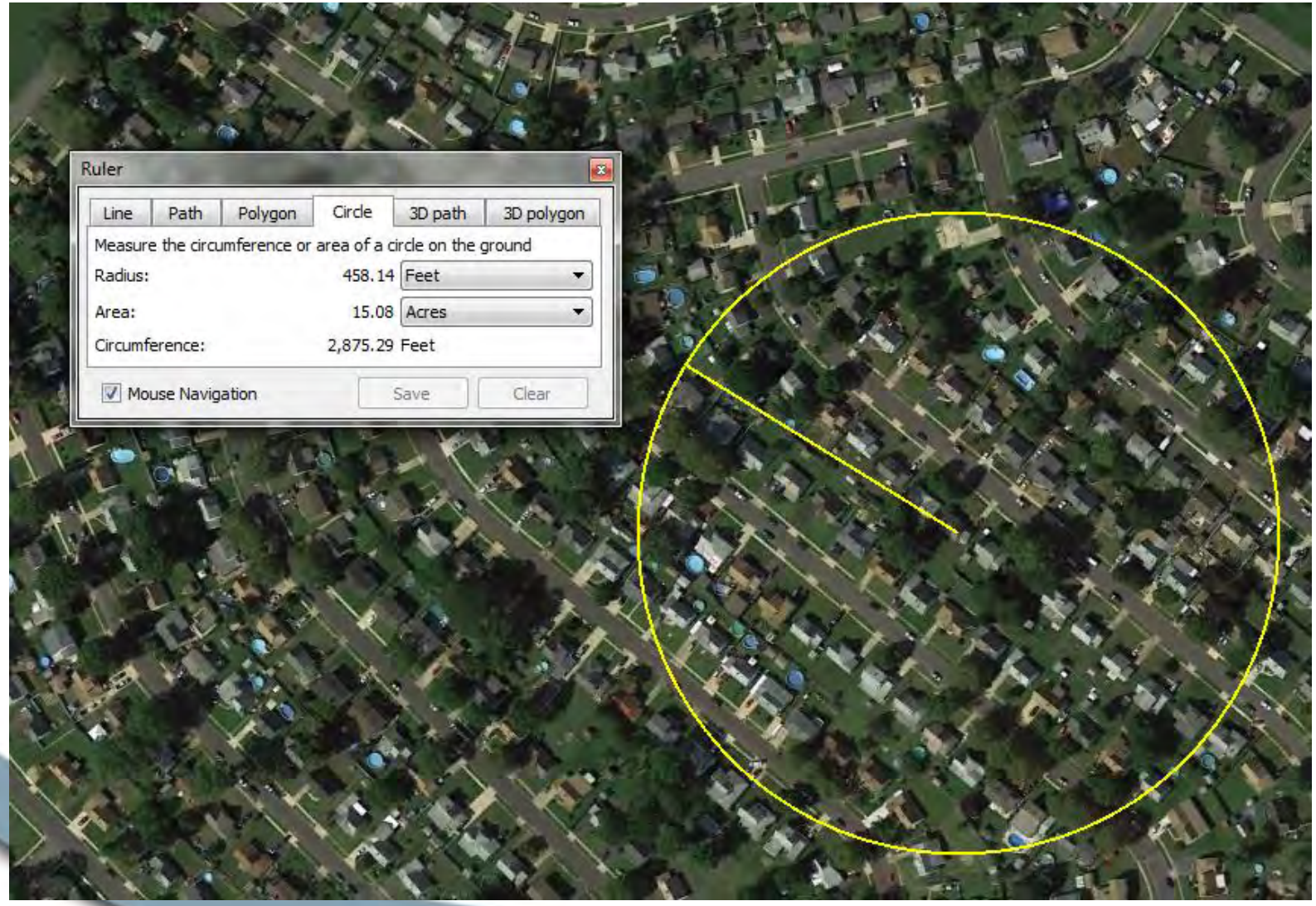


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# Risk Mitigation

- Keystone uses experienced pilots incurring costs of training flights and manufacturer training
- Spent extensive time developing its Flight Operations Manual and Standard Operating Procedures for UAS operations
- Checklists for deployment, pre-flight and post-flight are always used and updated
- Weather, wind speeds, etc. are monitored and a UAS risk assessment worksheet is filled out prior to a mission


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# Advantages\Disadvantages

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# Disadvantages

- Drones are NOT a tool for State, County, or even City mapping projects
- Short comings:
  - Beyond Line of Sight not legalized
  - Short Battery Life\Range
  - Maximum altitude of 400 feet reduces scale options
  - Payload capability <55lbs
  - Most sensors are not 4 Band
  - Ground control is still necessary for most UAS

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# Advantages

1) Resolution:

- Flying at 1200ft with a Cessna and large format camera 2cm GSD is possible
- Most UAS data will be acquired at <2cm GSD
- Rule applies for density of LiDAR as well
- Quality will vary based on sensor – often quality needs to be made up through quantity

2) Frequency\timeliness – Able to fly a site repeatedly, on specific dates under most cloud conditions and under/beside for unique views

3) Costs are generally less, but for larger areas the prices are similar and for remote areas it can be much more

4) UAS can be ideal for small scale\high resolution 3D solutions

5) 3D's – Dull, Dirty and Dangerous

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# Current Products

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# Current Products

Ortho Photo (basemap) with Two types available:

- precision for mapping\engineering
- “quick and dirty”

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# Current Products

3D point clouds:
From photo and
LiDAR


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# Current Products

3D point cloud Video

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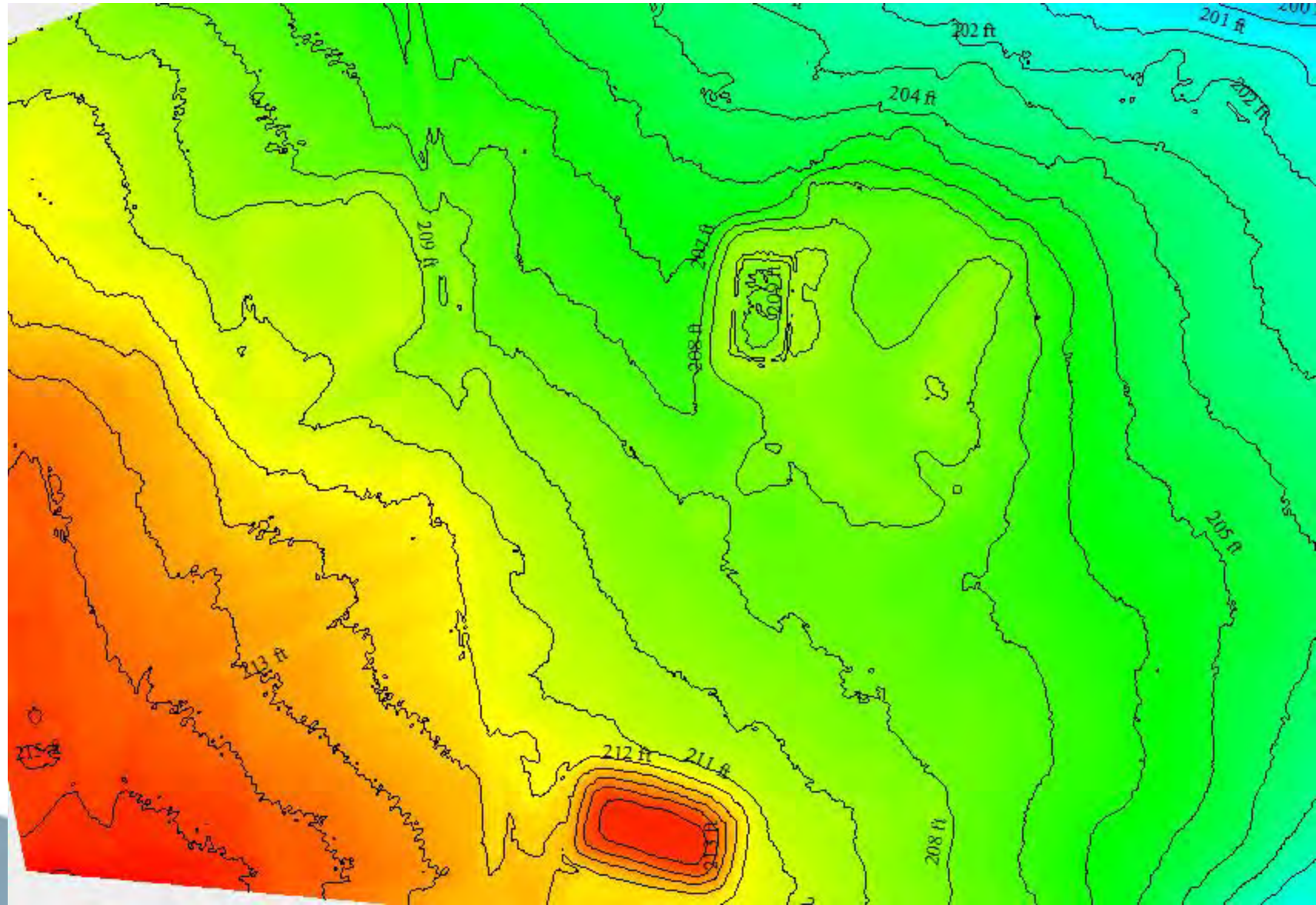
# Current Products

Bare Earth DEM with raw Contour Lines

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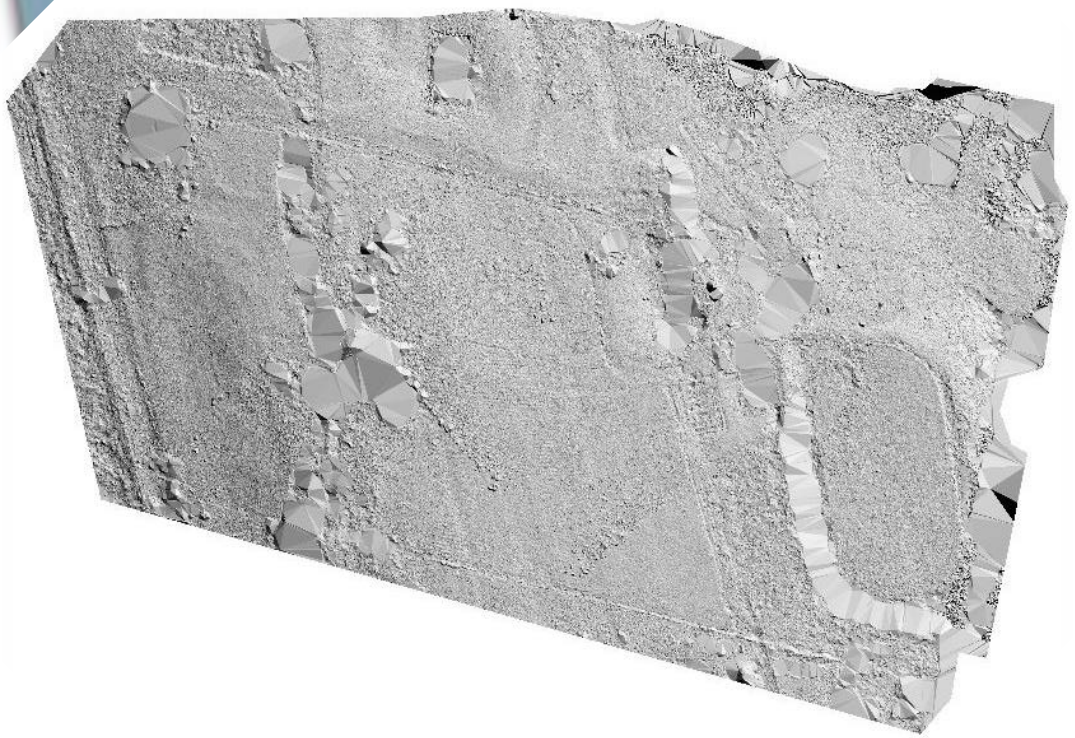
# Current Products



Hillshade

Flow Accumulation Modeling

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# Current Products

3D Meshes

- Draping\merging of point cloud and ortho photo to create a 3D scene
- Often referred to as 2.5D

# Current Products

True 3D:

- Use of vertical and oblique imagery to create a true 3D environment

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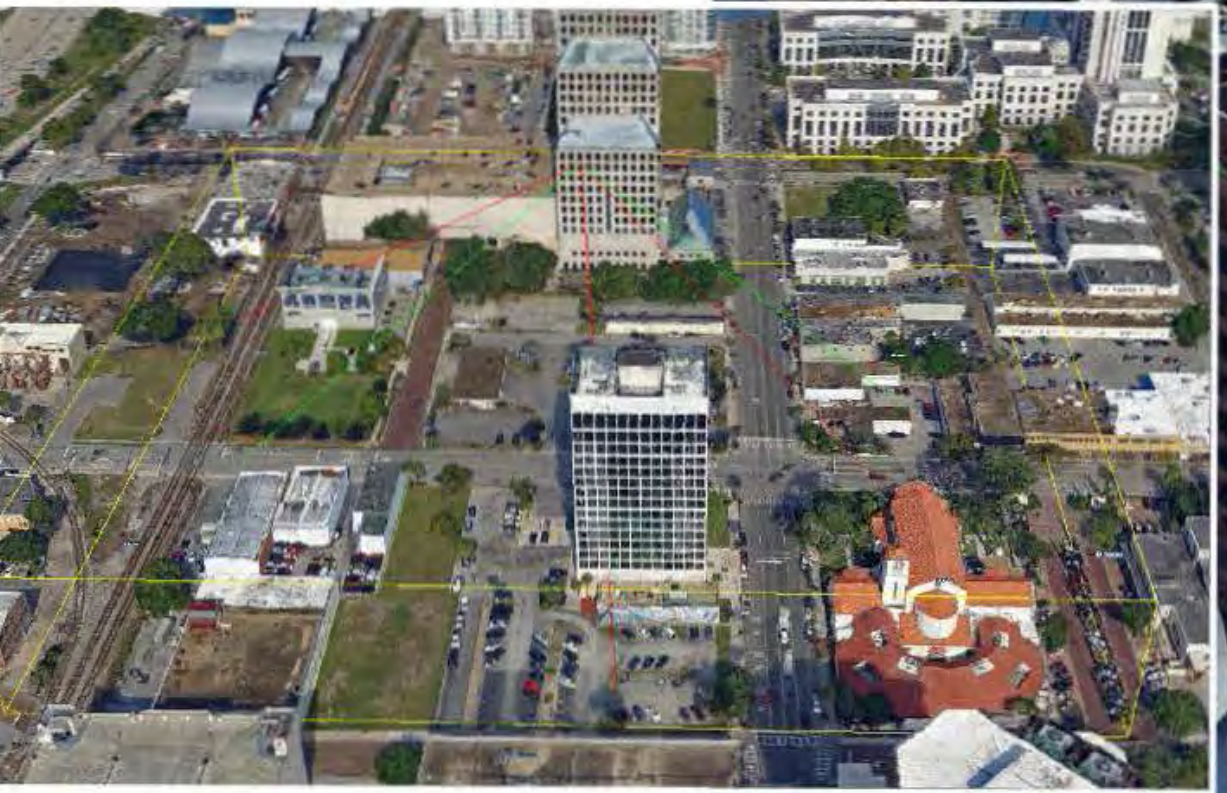
Skyline






Query | Distance | Area — Measurement

Contour Map | Slope Map | Best Path | Terrain Profile | Flood | Volume — Terrain Analysis

Line of Sight | Viewshed | Threat Dome — Line of Sight

Shadow | Selection Shadow | Shadow Query — Shadow

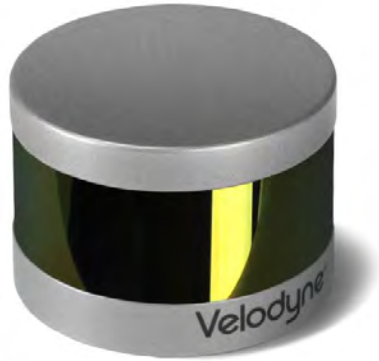
# Current Products

LiDAR:

- Great for determining height values and generating point clouds nearly as dense as photogrammetrically derived clouds
- Accuracy uncertain at this point and vary greatly by device
- Cost for highest accuracy systems is prohibitive
- Insurance for a $200,000 system to be mounted on a UAV?

Systems:

- Velodyne VLP-16 “Puck” ($8,000)
- Reigl VUX-1UAV ($200,000) plus RiCopter UAS
- YellowScan LiDAR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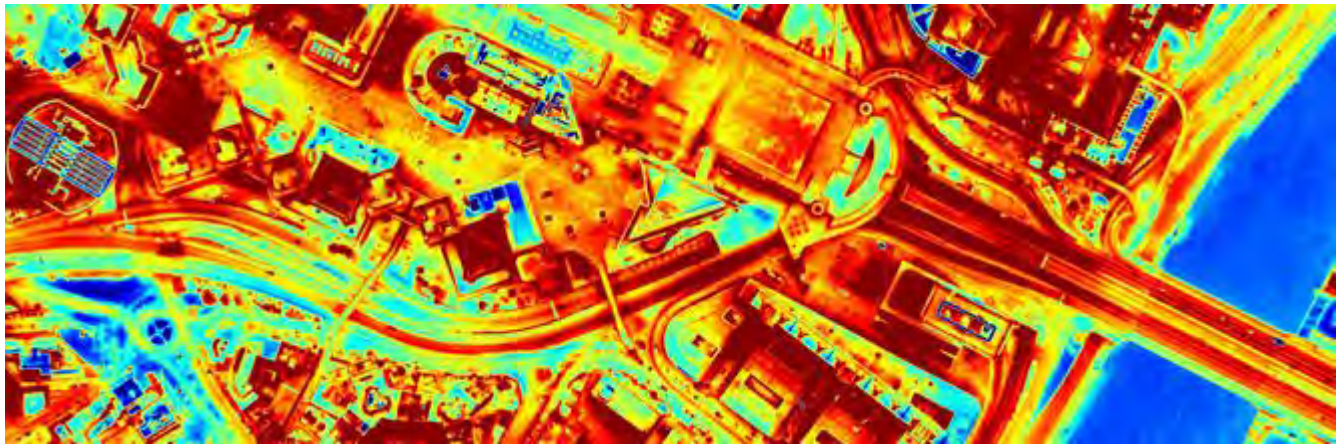
# Current Products

Thermal: Limited to daytime flight

- Current applications are limited to power line inspection, crack inspection and indoor use.
- FLIR partnering with DJI is a major step

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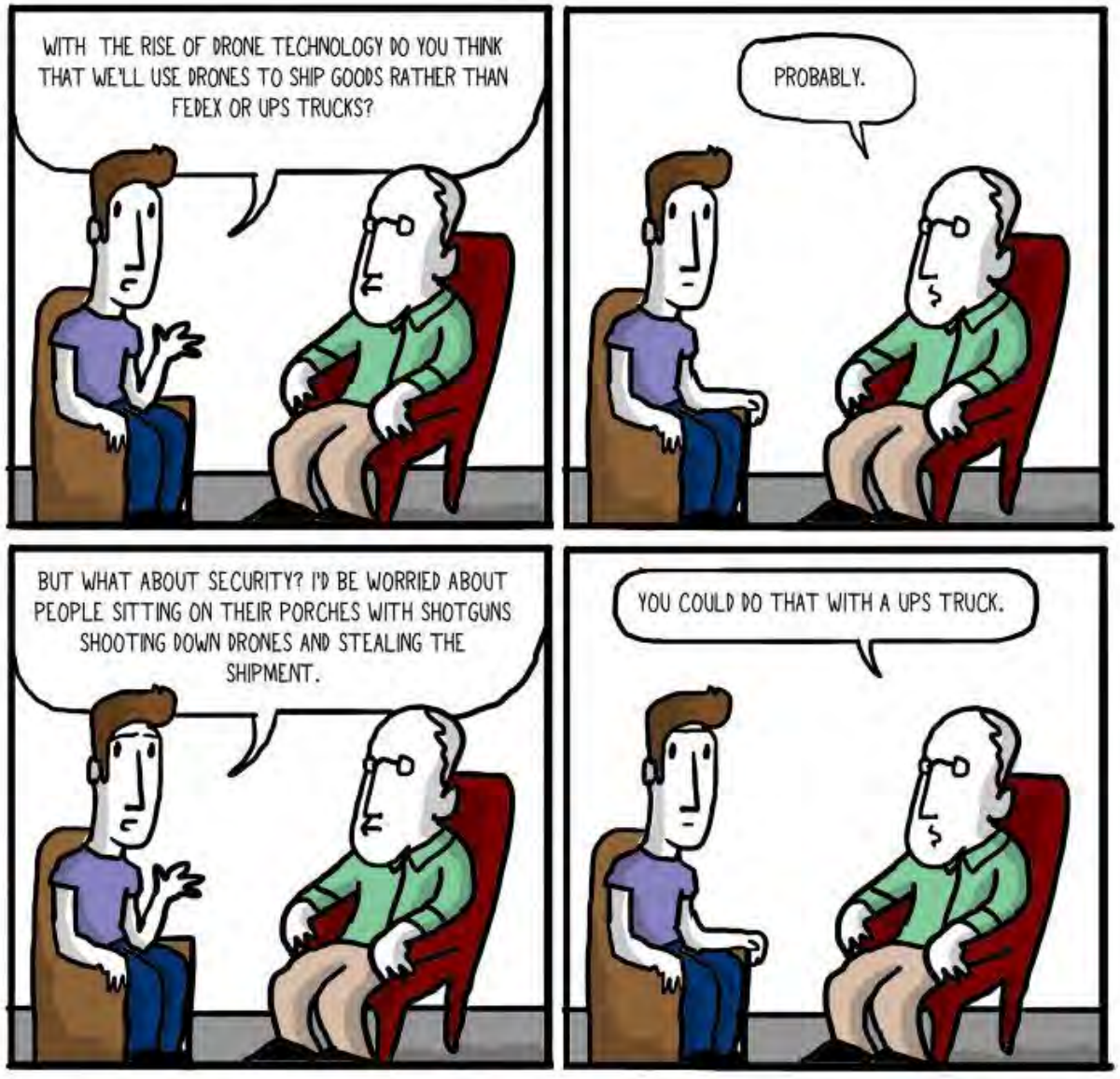
# Current Applications

Package Delivery?

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# Current Applications

Inspection for Bridges, Piers, Towers, Windmills, etc.

- Keystone has partnered with WSP\PB to provide this service to DRBA
- Provides access to areas not previously accessible
- Saves time and money when performing exterior/interior crack inspection
- Lower cost may allow for more frequent inspections (but will not replace manual inspections completely)
- Able to record what was seen for reference later (documentation/studies)
- Reduces risk to inspection crews
- Soon will be able to map the surface of the road and towers above traffic

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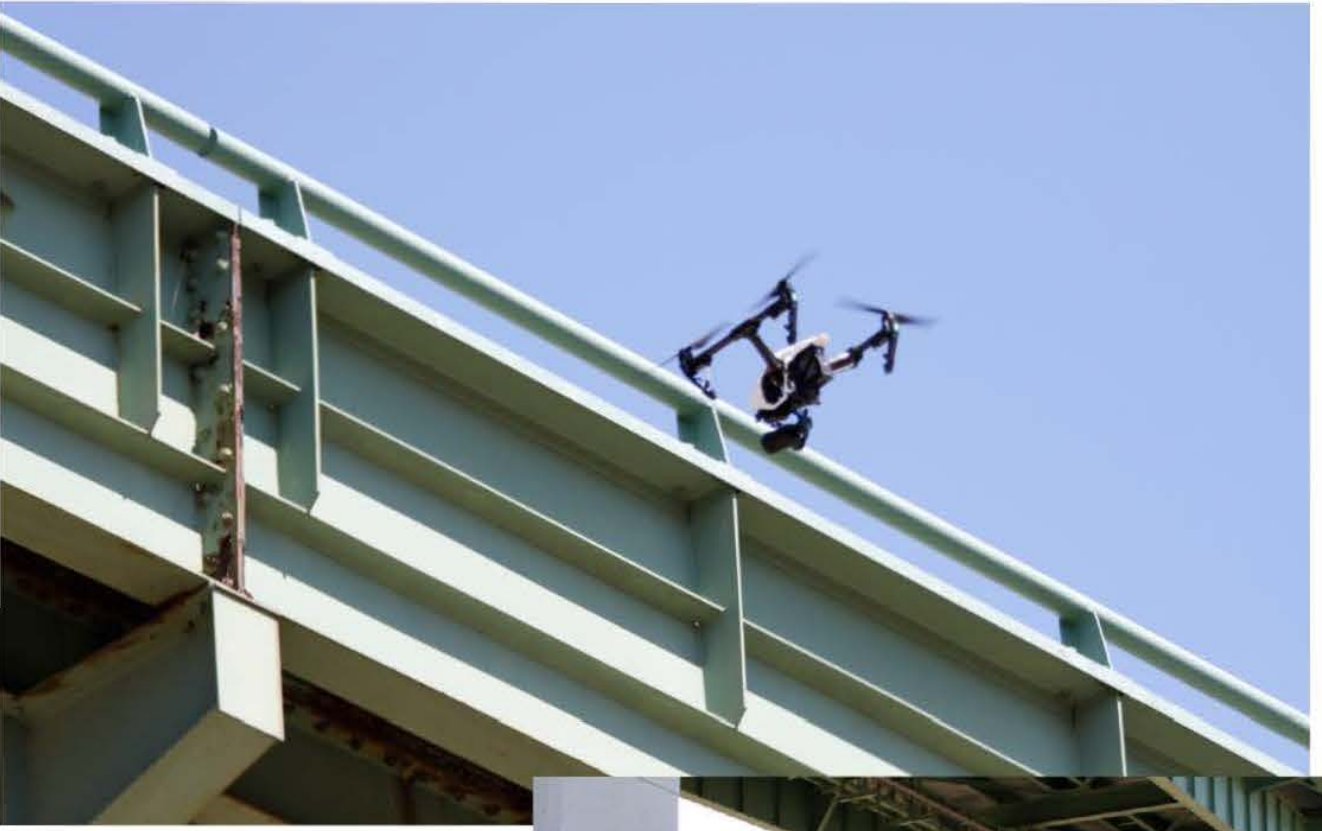

# Current Applications

Stockpiles: Landfills, Mines, Quarries for Volumetric Calculations

- Safer than sending surveyors into dangerous location
- Cheaper than manned flights
- Repeatable under most weather conditions
- Accurate enough for inventories


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# Current Applications

Construction Job Sites:

- Planning stage: Typical contours, orthos, height models and mapping
- During:
  - Monitoring of progress for job site updates and client updates
  - For “As Built” documentation of utilities and underground services
- After completion: Complements 3D laser scanning for BIM (15min in air as opposed to days on the ground)

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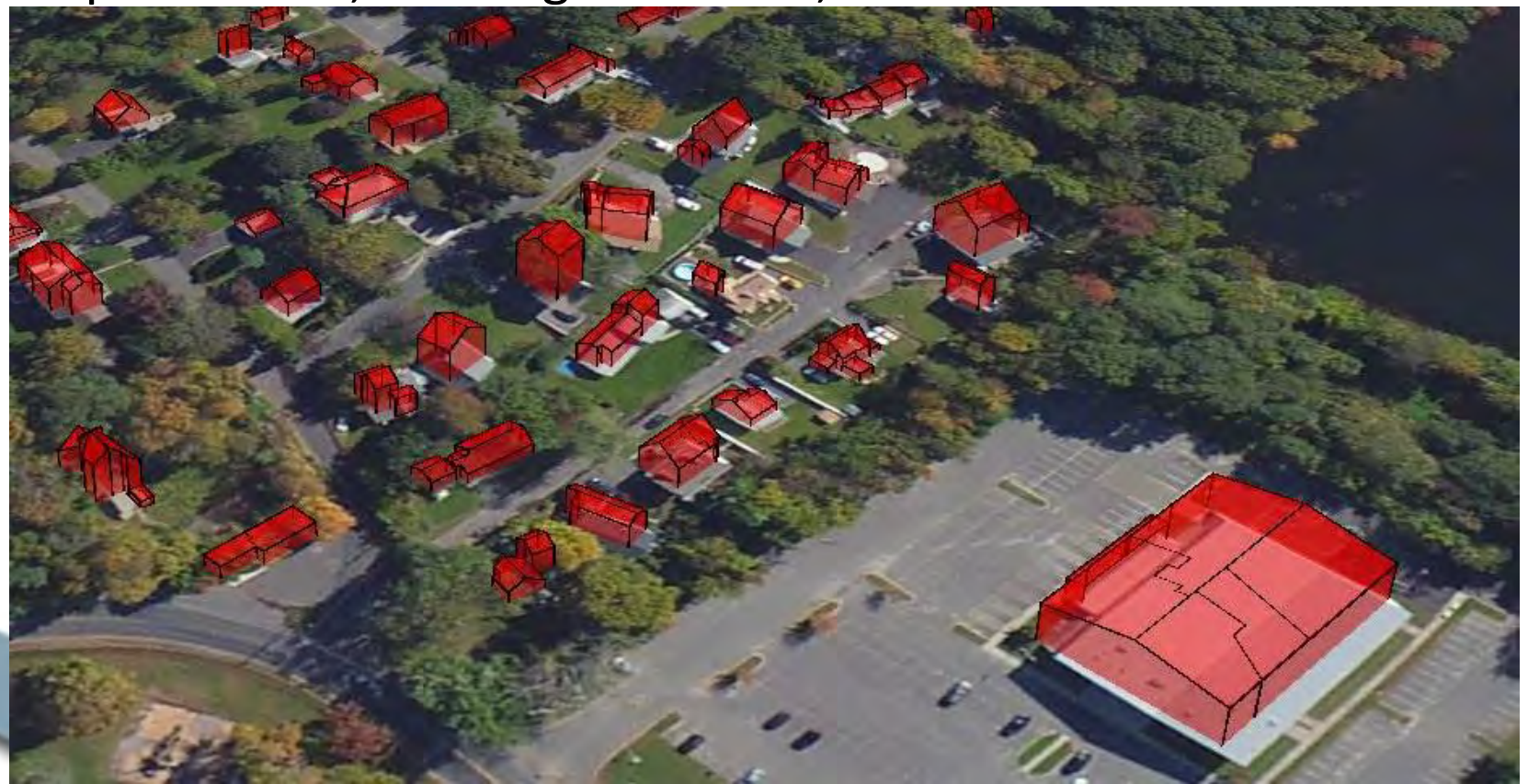
# Current Applications

Automated 3D Building Extraction

- Can be done from LiDAR or imagery point clouds
- Automated process used for building blocks for true 3D
- Can be joined with parcel data, building attributes, etc. in a 3D GIS



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# Current Applications

3D GIS – Bentley Systems: Software to create “3D reality mesh”

- Worked with helicopter flyer to capture and generate a 3D model of Philadelphia for the Papal Visit
- ESM Productions used the model in their planning of the events around the visit
- This application of UAS data is only limited by regulations and will explode due to the cost saving vs. helicopter for small areas
- Read more: https://www.bentley.com/en/project-profiles/aerometrex_3d_model_phila

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# Current Applications

Mapping:

- Currently limited by regulations and tools available
- For small applications, however, UAS data offers new levels of detail

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# Mapping Accuracy Testing

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# Keystone Accuracy Testing

- Keystone flew a privately owned barn in northeastern, PA in December of 2015 with two UAS.
- Each flight lasted approximately 15 minutes.
- Flight was in a circular pattern with alternating elevations.
- DJI X5 camera was approximately 35 ft. above terrain
- Sony A7R was approximately 68ft. above terrain
- Simultaneously, 38 control points were surveyed on the barn and ground


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# Equipment Used

- DJI Inspire 1 Pro with a DJI Zenmuse X5 camera
  - 16 MP with a 15 mm lens
  - Unobstructed views
- SteadiDrone Mavrik with a Sony A7R camera
  - 36 MP with a 35mm lens
  - PixHawk Autopilot – customizable platform

- Pixel size for DJI averaged 0.25cm NADIR and averaged 0.43cm on barn
- Pixel size for the Sony averaged 0.25cm as well but was 0.56cm on barn as it averaged 137 ft. away from structure

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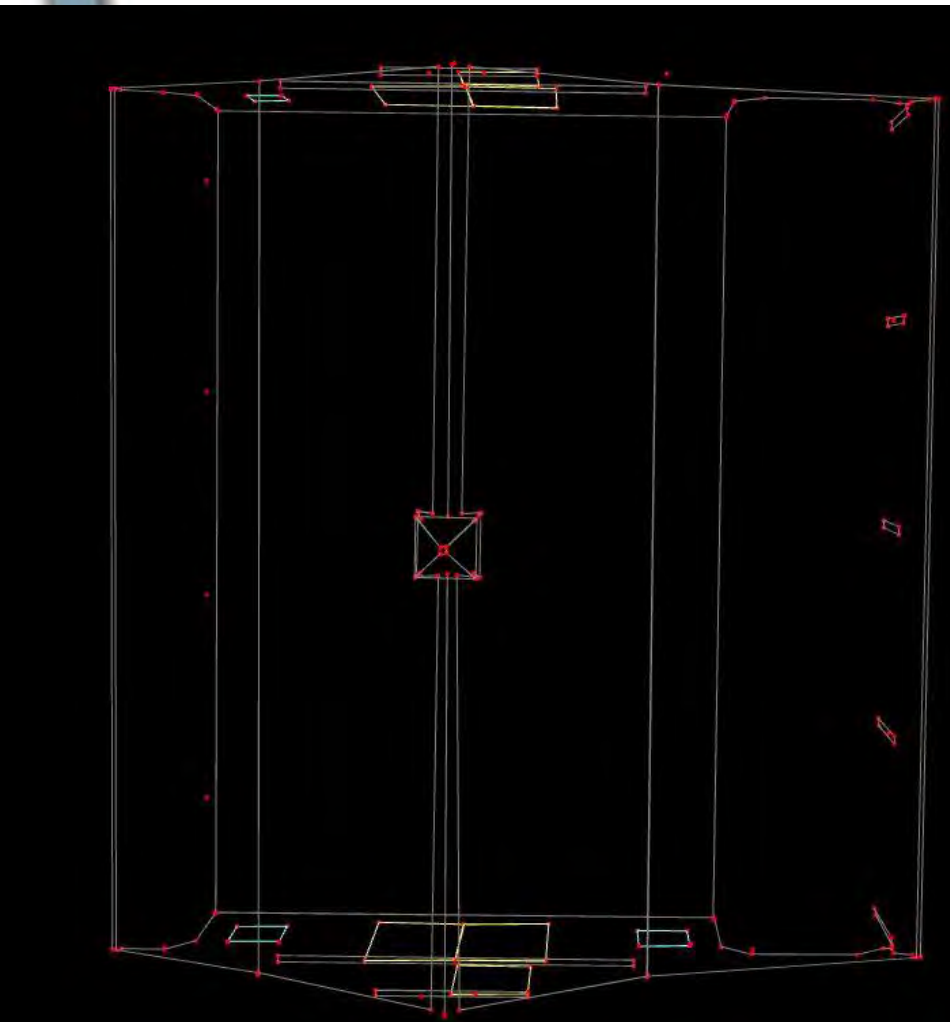
# Results – Check Points

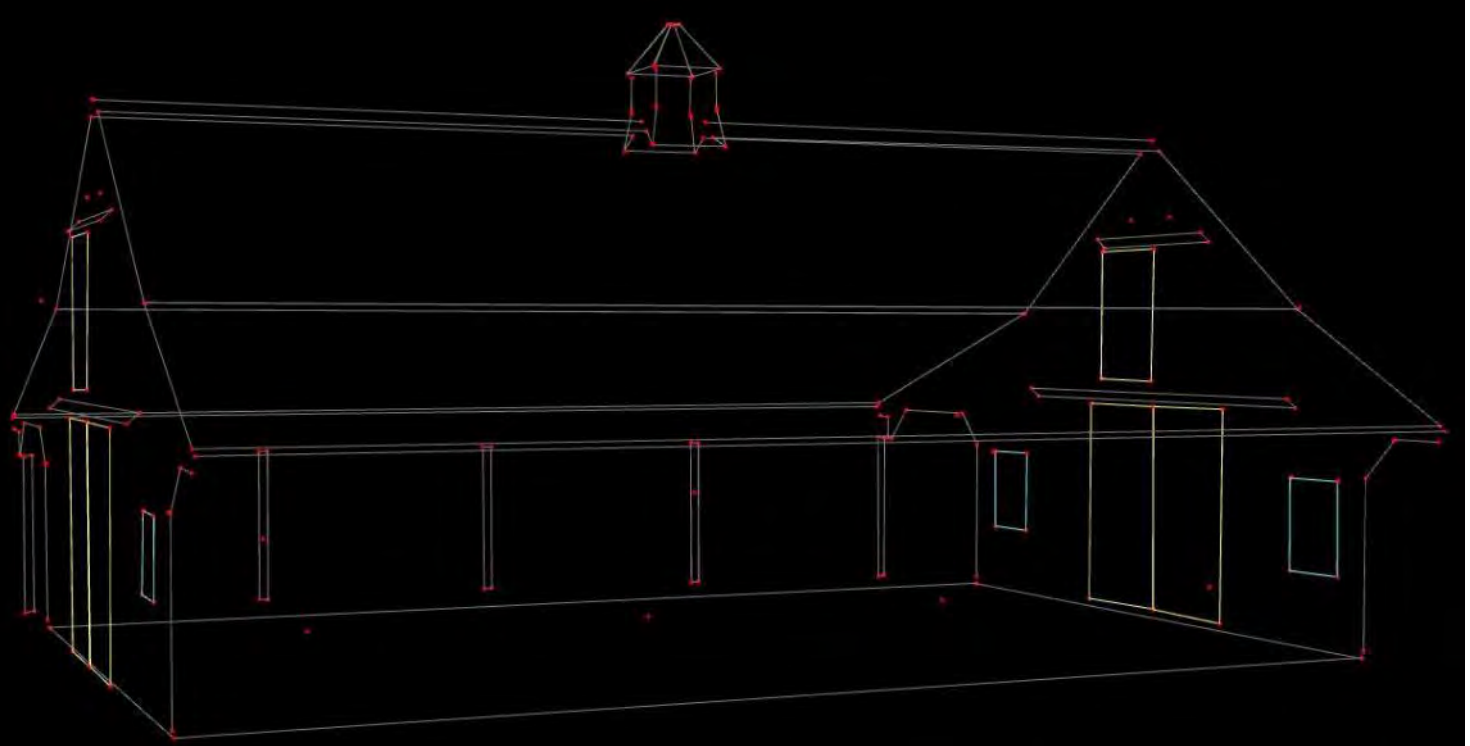
- All of the tests resulted in absolute error values of 0.60 inch or less in X, Y and Z.
- The Sony A7R tests generating 1 or 1.5 pixel accuracy for both types of tests.
- With residuals evenly distributed among X, Y and Z, it is a stable and impressive solution.
- DJI X5 pixel size of 0.17 inch and Sony A7R pixel size of 0.22 inch
- DJI MP of 16 is not recommended by Datumate, but still tested well
- With limited time of trial, blunders were not investigated.

| Check Point Residuals (Inches) | | Absolute Mean | | | Min | | | Max | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Camera | Test | X | Y | Z | X | Y | Z | X | Y | Z |
| DJI X5 | High Control | 0.34 | 0.33 | 0.28 | 0.01 | 0.01 | 0.02 | 1.25 | 1.16 | 0.76 |
| DJI X5 | Low Control | 0.60 | 0.47 | 0.31 | 0.02 | 0.04 | 0.02 | 1.96 | 2.03 | 1.12 |
| Sony A7R | High Control | 0.20 | 0.31 | 0.28 | 0.01 | 0.04 | 0.05 | 0.72 | 0.77 | 1.10 |
| Sony A7R | Low Control | 0.14 | 0.37 | 0.24 | 0.00 | 0.02 | 0.03 | 0.47 | 1.44 | 0.75 |

Mean, Min, Max of Absolute Residuals in Inches (Comparison of Surveyed Location and Measured) for Check Points

# Results





# Future Developments

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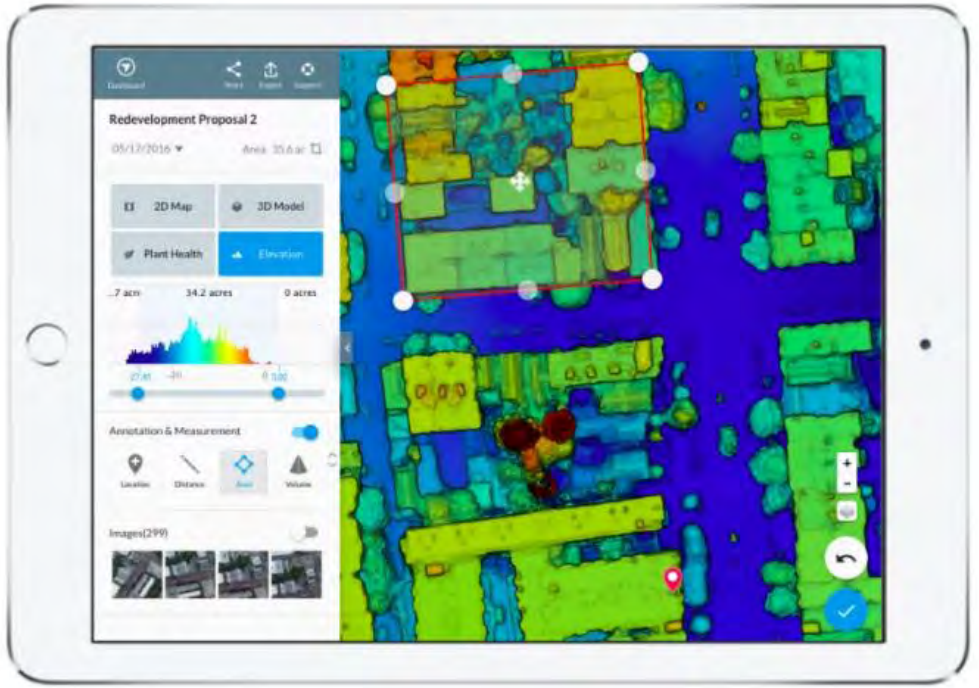
# Near Future

Regulations:

- New Part 107 rules released by the FAA will likely provide relief from:
  - Mandatory visual observer
  - 500ft rule for non participants
  - Night flights?
  - Civil COA requirements in most cases
  - Need for 333 exemptions in most cases
  - Need for a pilot to be flying the aircraft – will introduce a new certificate type

# Near Future

- LiDAR – higher accuracy/lighter weight
- Miniaturization of Inertial Measurement Units and GPS for removing the need for Ground control
- Longer battery life and heavier payloads
- Detection using other sensors (pipeline leak detection for example)
- Multiple sensor payloads
- Near real-time mapping – Drone Deploy

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# Not Too Distant Future

Who can say what applications will become commonplace?


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# Not Too Distant Future

- Sub-millimeter pixel sizes and accuracy
- Beyond Line of Site operations will be commonplace: Amazon and Google will spearhead this but the mapping community will benefit
- Large aircraft for mapping – Commercial version of Predator (I would call it “Dove”)
- Persistence – Solar power, tethered, mid-air refueling, auto battery exchange, etc.
- Ubiquitous – News media will make a drone above you a chance for your 15 minutes of fame, *not* an invasion of privacy
- Swarming – multiple coordinated UAS

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# Thank You!

Contact Us
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# Self-driving cars, land use, and the future(s) of car ownership

DVRPC Information Resource Exchange
Group
June 08, 2016

Erick Guerra
Assistant professor of City & Regional Planning
University of Pennsylvania

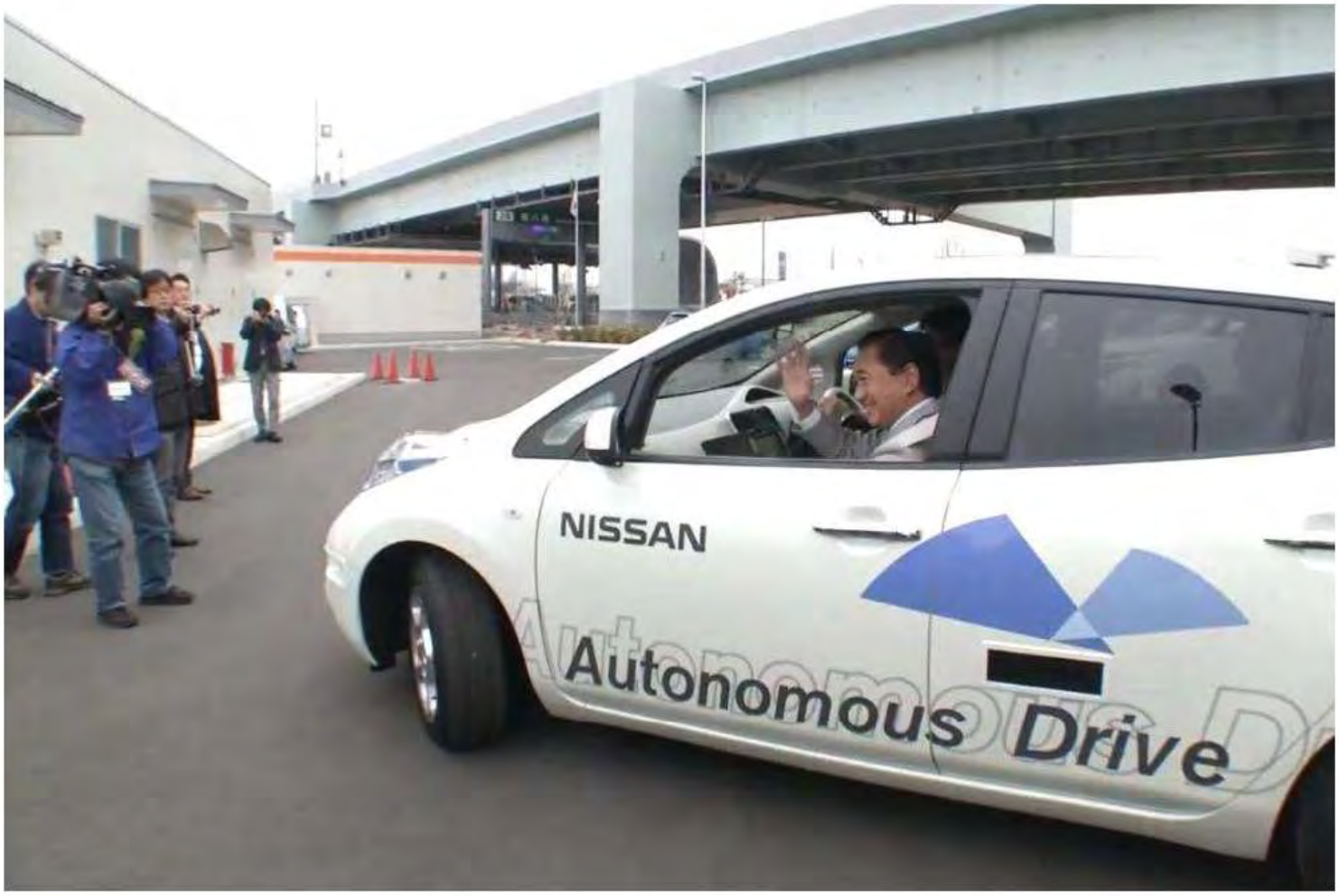
# Rapidly improving autonomous vehicle technology

2004: No teams' autonomous vehicles completed DARPA's 150-mile challenge

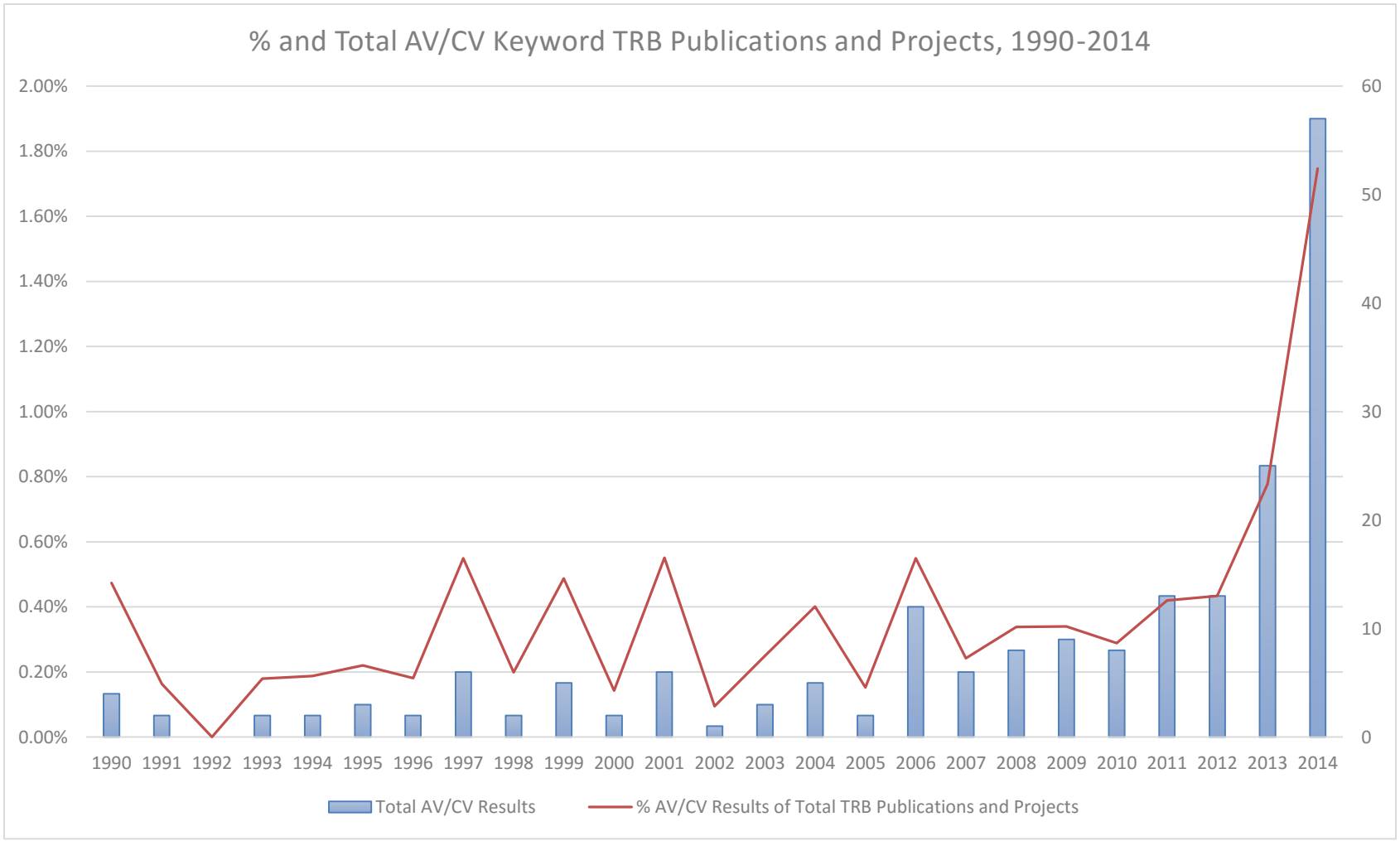
2005: Six teams completed the challenge (including teams from Stanford, CMU, UPenn, and MIT

# Existing prototypes


# Market-ready in four years?



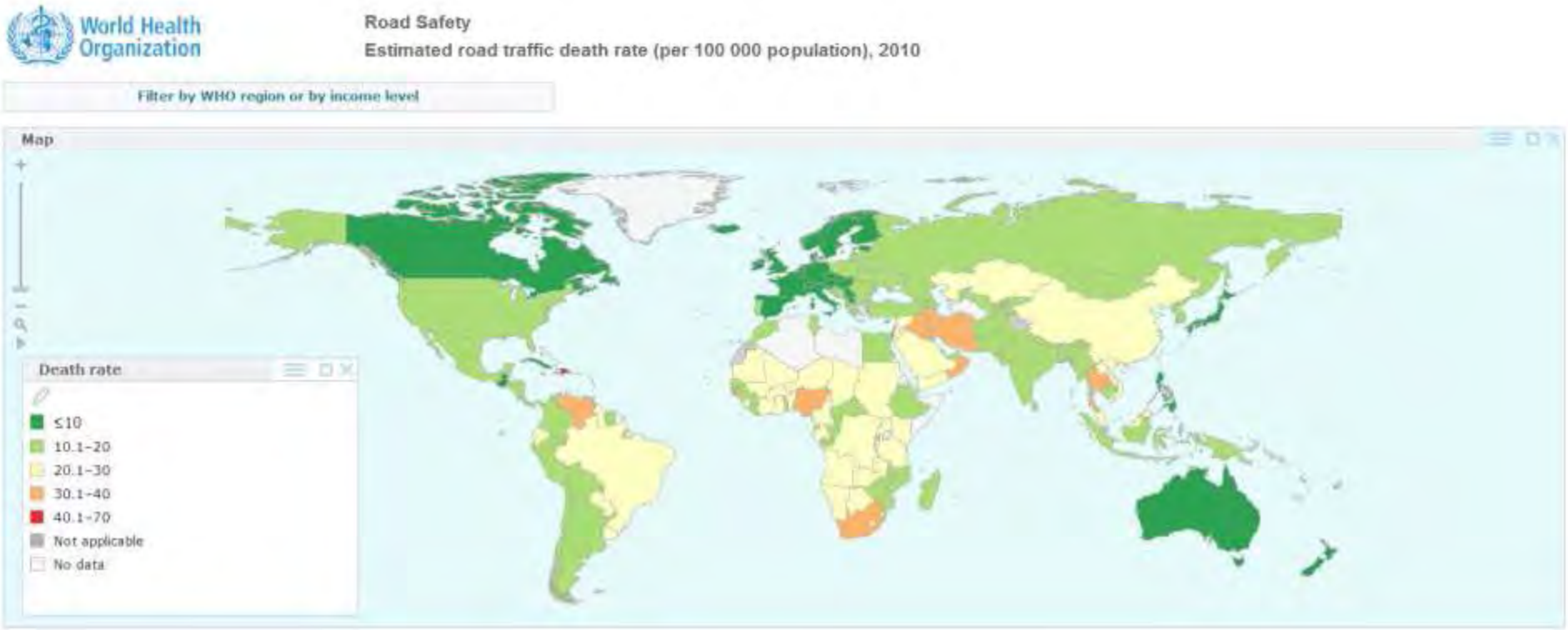
# Rapid Increase in Research over the Past Few Years



# Two big planning questions

1) How will automated vehicle technologies change cities?
2) How should an uncertain but potentially transformative technology influence today's planning and investment decisions?

# Primary impacts: road safety



# Primary impacts: road capacity

# Secondary impacts: enhanced personal mobility


Video link: https://www.youtube.com/watch?v=cdgQpa1pUUE

Nationally 9% of households don't own cars.
And 33% of people do not have licenses.

# Secondary impacts: economic restructuring

Americans employed as drivers in 2014

| Occupation | Number | Median pay | Entry level education |
|---|---|---|---|
| Bus drivers | 654,300 | 29,550 | High school |
| Delivery truck drivers | 1,273,600 | 27,530 | High school |
| Tractor trailor drivers | 1,701,500 | 38,200 | Postsecondary non-degree |
| Material moving machine operators | 650,600 | 31,530 | High school |
| Taxi drivers | 233,000 | 22,820 | Less than high school |
| **Total** | **4,513,000** | | |

Source: Bureau of Labor Statistics

# Secondary impacts: public transit

Line 14 in Paris

# Secondary impacts: public transit



On Bridj you can travel between the connected zones, inbound in the morning and outbound in the evening. When requesting a trip you'll receive directions to your pick-up and drop-off spots.

# Secondary impacts: parking

# Planning for automated vehicles

Testing and partial automation (5 to 20 years)

Full automation (no driver needed)

Two future scenarios

(1) Shared urban mobility

(2) Increased personal mobility

# Scenario 1: Shared urban mobility

- Shared point-to-point mobility,
- limited car ownership,
- reduced on-street and off-street parking,
- increased density and urbanity.

# Scenario 2: Increased personal mobility

- Increased car ownership and VMT,
- Mostly  privately owned,
- Zero-occupancy vehicles (picking up, dropping off, parking, etc.),
- Continued trend of increased long-duration commutes.

# How should we plan today for tomorrow's automated vehicles?

| Government level | Primary AV roles |
|---|---|
| Federal | • Set standards<br>• Fund research |
| State/Regional | • **Allocate large public investments**<br>• Regulate rules of the road<br>• Manage testing<br>• Manage highways |
| Local | • **Regulate land use**<br>• Manage local roads |

# Assertion 1. One scenario is better than the other

| | Shared mobility | Personal mobility |
|---|---|---|
| Benefits | • Increased mobility<br>• Increased safety<br>• Increased road capacity<br>• More valuable in-vehicle time<br>• Improved transit | • Increased mobility<br>• Increased safety<br>• Increased road capacity<br>• More valuable in-vehicle time |
| Costs | | • Increased VMT<br>• Increased land consumption<br>• Increased pollution<br>• Increased segregation<br>• Increased roadway required |

# Assertion 2. We'll probably see both scenarios

Expect variation across states, cities, and neighborhoods

**Features of cities and neighborhoods where each scenario is more likely**

| | **Shared Urban Mobility** | **Increased Personal Mobility** |
|---|---|---|
| Density | Medium to high | Low to medium |
| Transit service | Good | Poor |
| Land values | High and centralized | Moderate and dispersed |
| Rent gradient | Steep | Flat |
| Car ownership | Moderate | High |
| Parking | Priced or permitted | Free and ubiquitous |

# Assertion 3. There is time to adjust policy

Despite rapid advances, changes will not happen over night (as with smart phones).

- Impacts uncertain
- Technological and regulatory hurdles remain
- Vehicle fleet takes years to turn over (average personal vehicle is 11 years old)

Likely first movers:

- Taxi, freight, and transit industries
- The mobile office crowd
- Regions building new highway capacity (like HOV or HOT lanes, but for AVs)
- Closed facilities like retirement communities, tech campuses, and airports

# Assertion 4. Already influencing policy dialogues

"I absolutely believe that technology is going to transform mass transit in a way that very few people can see … It'll definitely be within 15 or 20 years, which is right when the light rail system for Greenlight Pinellas would be coming online."

-Florida State Senator Jeff Brandes (R) arguing against St. Petersburg regional transit plan. (Quoted from Fortune article by David Morris, November 2, 2014)

# Assertion 5. Policy makers can influence outcomes, but not control them

- Widespread disagreement on impacts, timing, and desired outcomes
- Powers are diffuse and agencies have limited mandates
- The technology is being driven by the private sector
- Major car and technology companies have a big stake

# Policy recommendations: beware the rosy future

DISPENSE WITH A HORSE

and save the expense, care and anxiety of keeping it. To run a motor carriage costs about ½ cent a mile.

THE WINTON MOTOR CARRIAGE

is the best vehicle of its kind that is made. It is handsomely, strongly and yet lightly constructed and elegantly finished. Easily managed. Speed from 3 to 20 miles an hour. The hydrocarbon motor is simple and powerful. No odor, no vibration. Suspension Wire Wheels. Pneumatic Tires. Ball Bearings. *Send for Catalogue.*

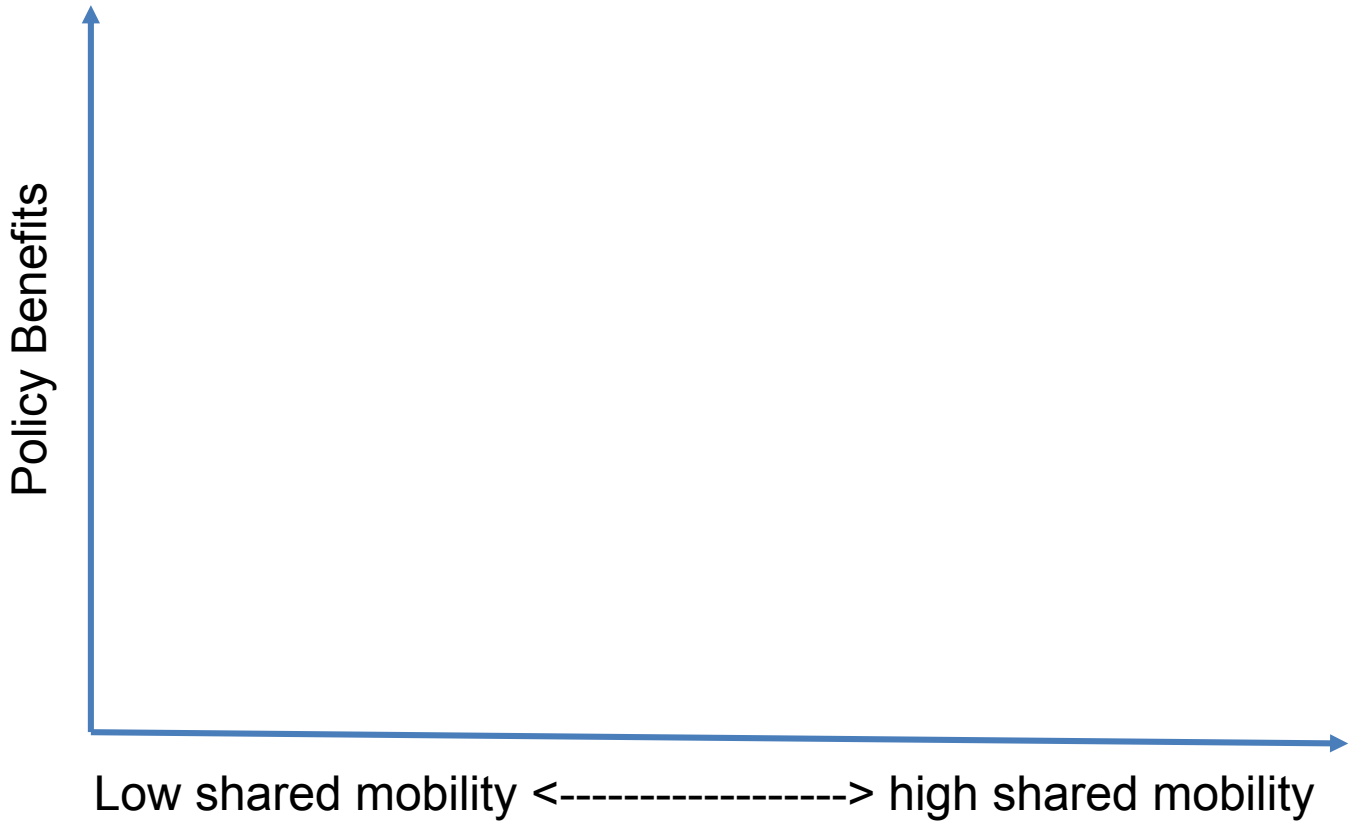
*Price $1,000. No Agents.*

THE WINTON MOTOR CARRIAGE CO., Cleveland, Ohio.

A short sample of questionable assumptions:

- Shared mobility is inevitable
- Pollution and GHG will decrease
- Congestion will decrease

# Policy recommendations: be flexible and consider both futures



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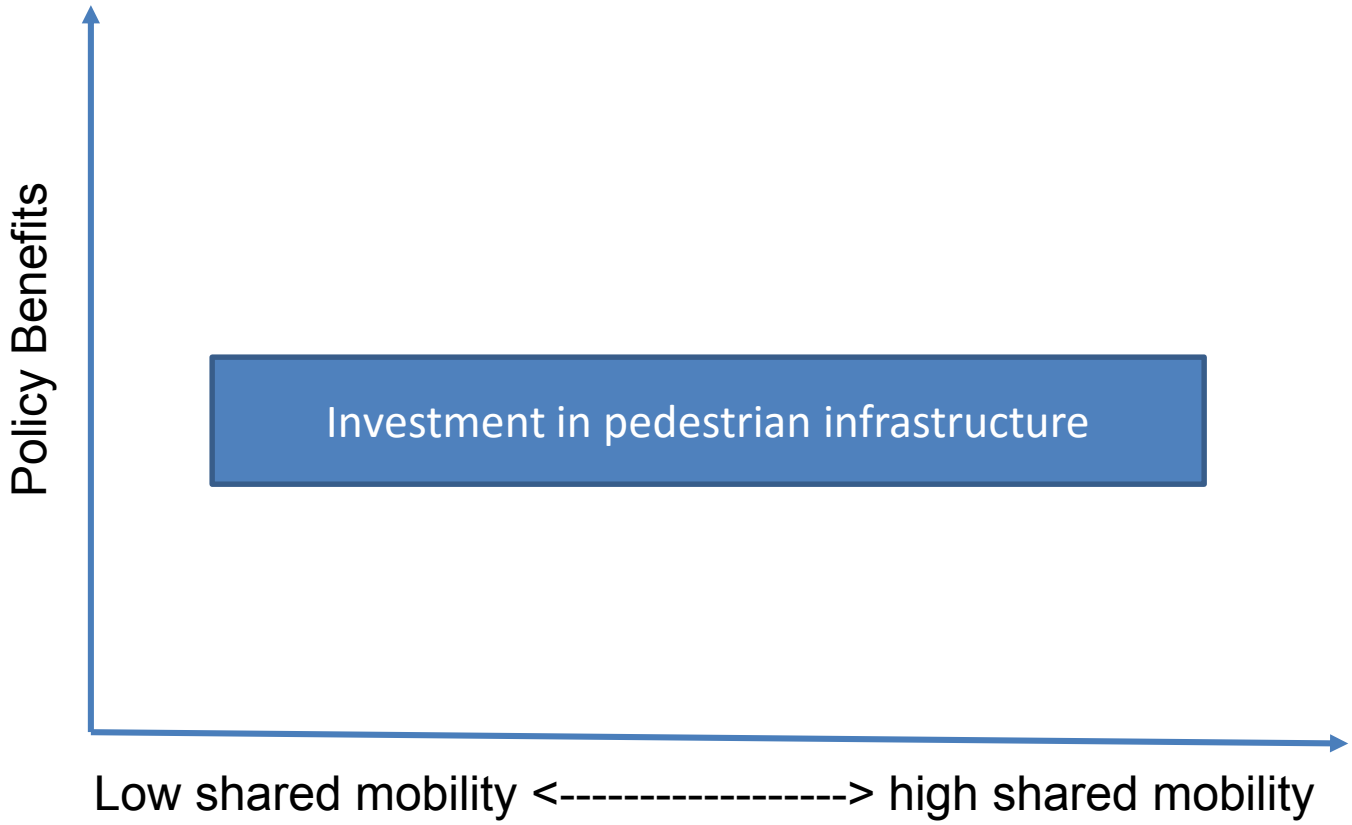

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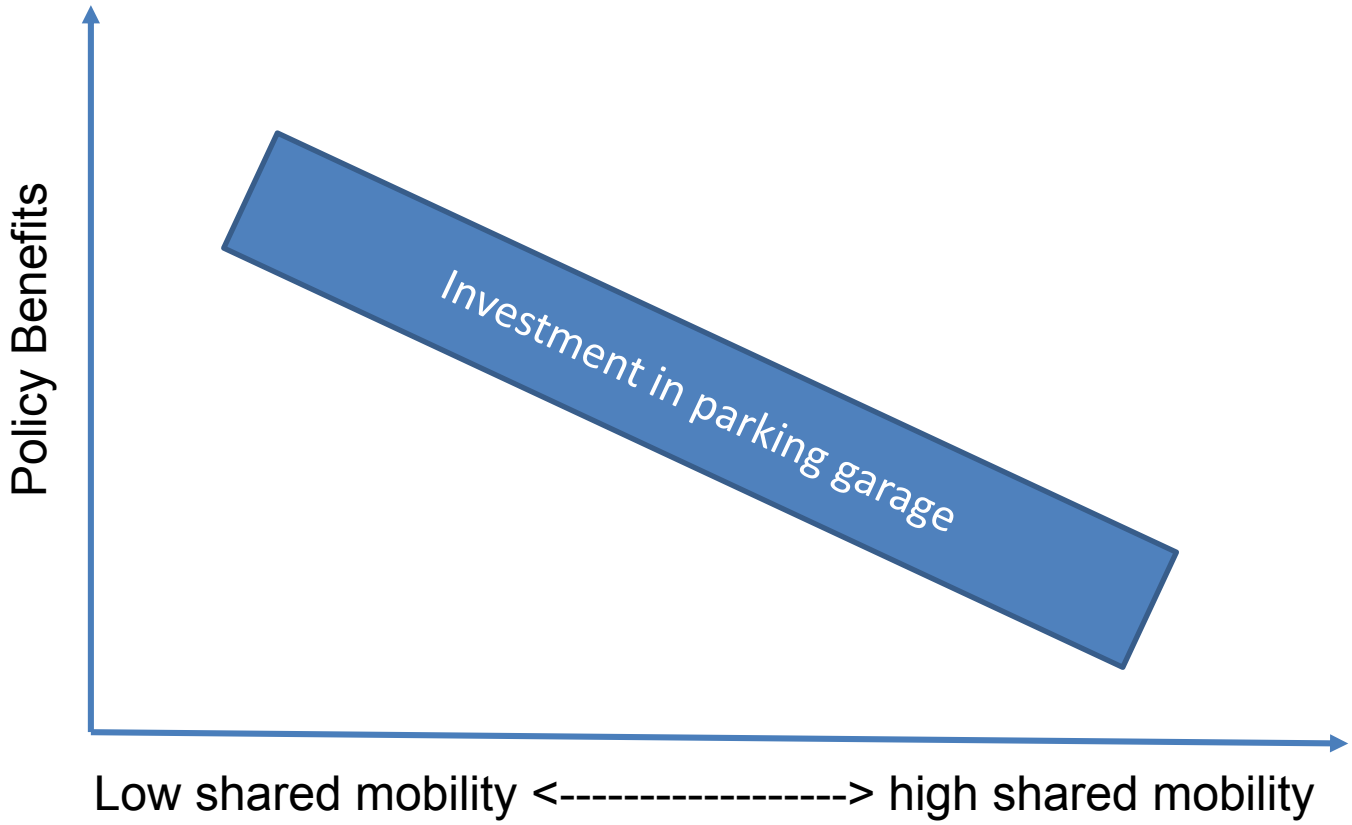
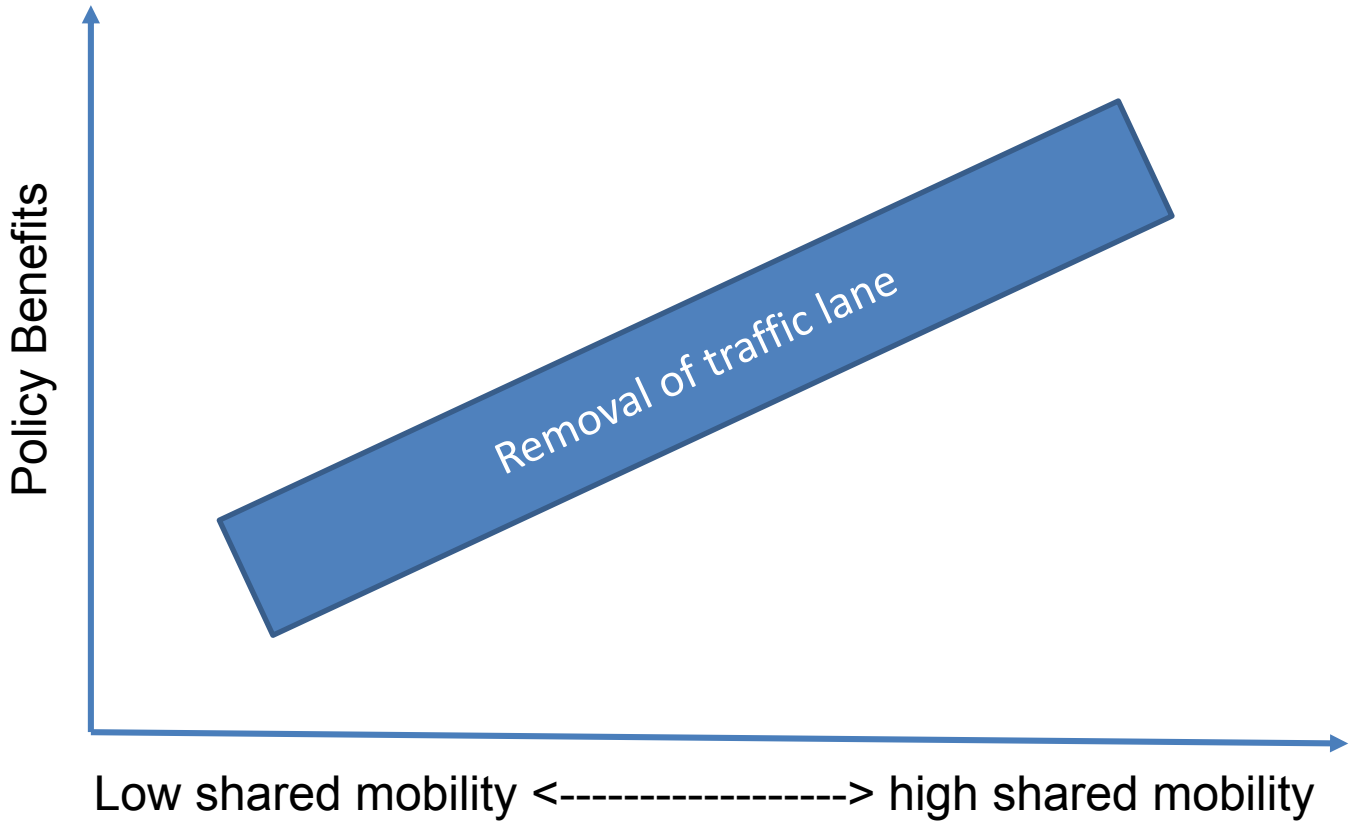


# Policy recommendations: be flexible and consider both futures



# Policy recommendations: focus on what already makes sense

Land use example: deregulate off-street parking regulations
AV argument: Parking decoupled from driving
Other arguments: “High cost of free parking”

Investment example: Widen freeway
AV argument: AVs likely to increase road capacity, especially on freeways.
Other arguments: “Triple convergence.” Expensive and unlikely to reduce congestion

# Thank You

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