



# Map901: Building Rich Interior Hazard Maps for First Responders

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University of Memphis

In collaboration with City of Memphis

PSCR, 7/9/2019

# DISCLAIMER








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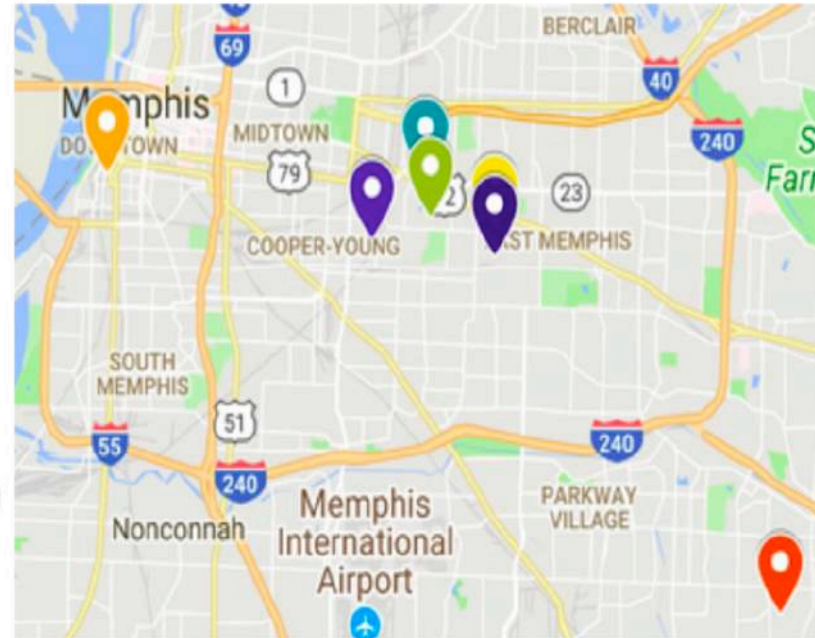
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# Map901



- Collaboration between City of Memphis and U. Memphis
- Survey 7 facilities, 172,800 square meter
- 3D point cloud, 360-degree camera images, other sensor data
- Annotate data with objects of interest to public safety agencies

-  FedEx Institute of Tech
-  Hickory Hill CC
-  John S. Wilder Tower
-  Liberty Bowl
-  Memphis Central Library
-  National Civil Rights Museum
-  Pink Palace Museum





# Survey Equipment



Velodyne  
LiDAR  
sensor



Insta360 Pro  
2 camera



Reach RS+ GPS  
(RTK GNSS Receiver)



Digi-Sense 20250-29  
Sound Meter

GVI LiBackpack 50



Digi-Sense Temperature  
/RH Recorder

- By mounting the camera to the LiBackpack, we collect both LiDAR and 360-degree image data sets simultaneously to assign RGB info to LiDAR data later.
- GPS locations of external points are used to geo-reference 3D LiDAR point cloud data.
- Temperature, humidity and sound information are collected separately by two other sensors.



Integrated System

# Data Format



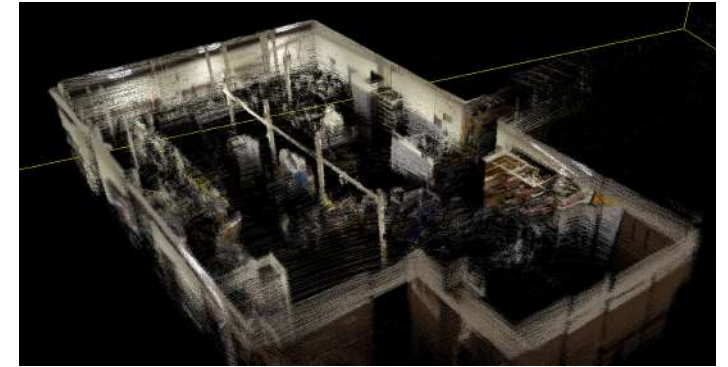
Data	Format
point cloud	ASPR LAS 1.4-R13 with point data format 7
360 degree video	4K 30fps encoded in H.264 stored in MP4
GPS data	NMEA format

- ASPR LAS format 7 allows integration of color and user-defined classes to facilitate labeling of objects.

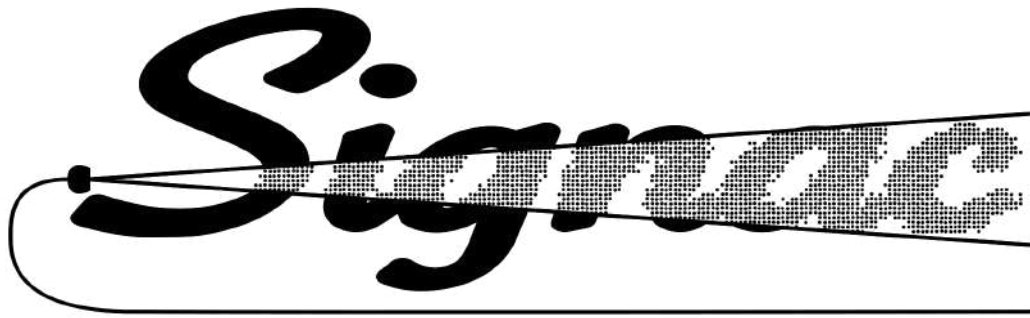
# Best Practices in LiDAR Survey



- Open all the doors before the survey
- Avoid capturing moving objects during the survey
- Avoid exiting and entering interior spaces through the same threshold when the doorway is narrow
- Do not repeat a route already traveled
- Scan one or two floors at a time and stitch the data together



Videos of a student surveying the Pink Palace



- Challenge: difficult to survey small rooms
  - Lidar vertical field of view only 30 degrees
  - Captures top part of small rooms; cannot see floor
  - Wearer does not have room to move and capture more detailed result
- Developed a custom solution Signac for surveying small rooms.
- Dual cameras provide pose (top) and depth (bottom)
  - Intel® RealSense™ T265
  - Intel® RealSense™ D435
- Raw camera data recorded to attached laptop and processed into PLY result

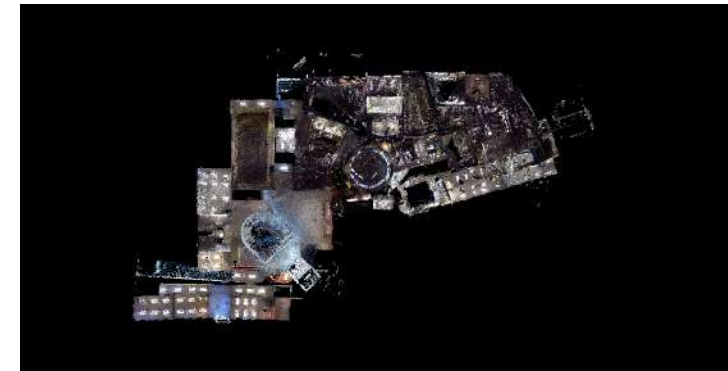
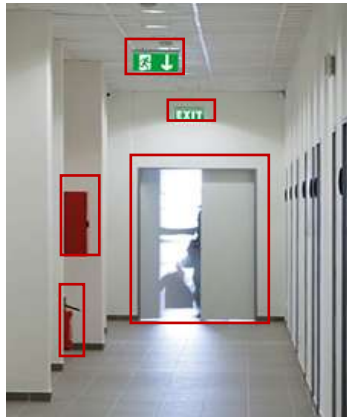
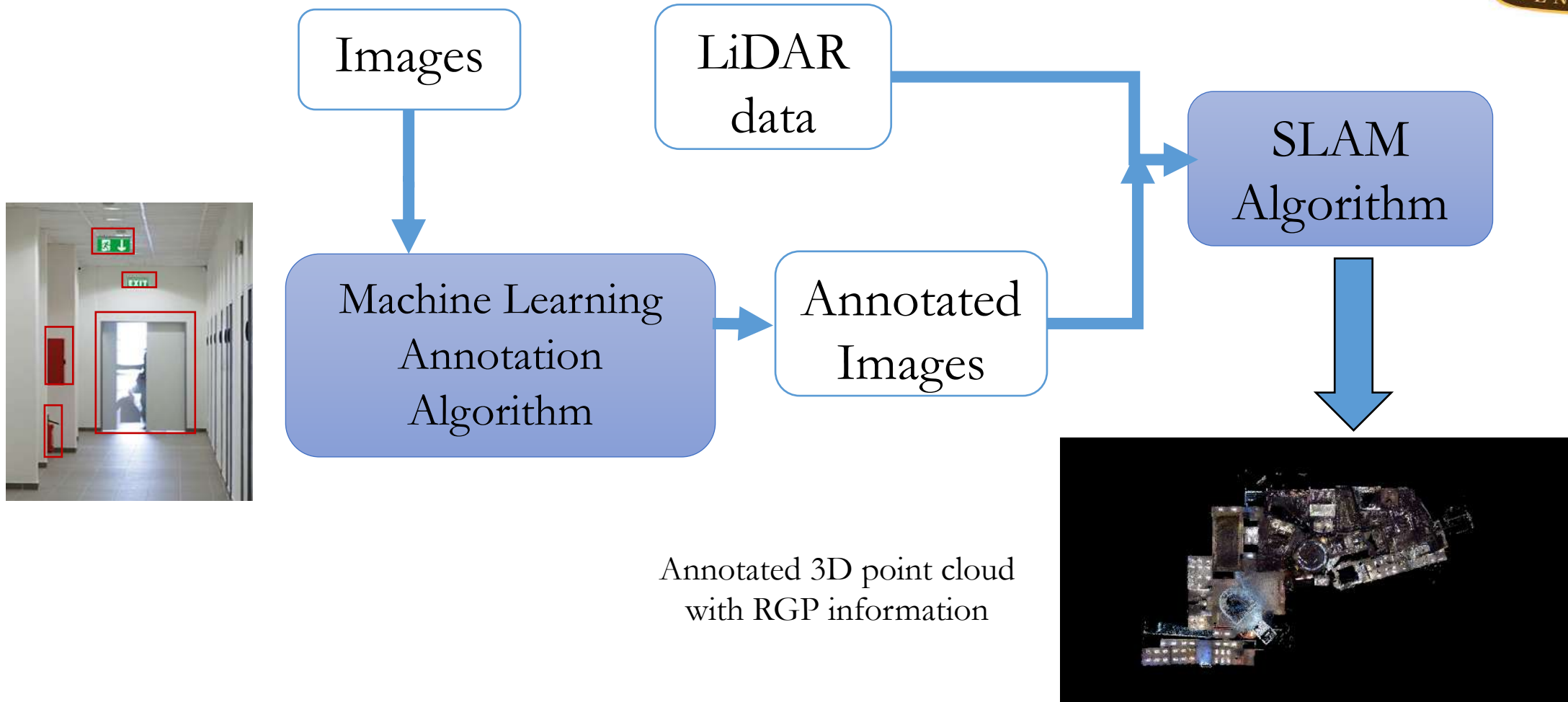


# Signac Result

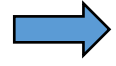
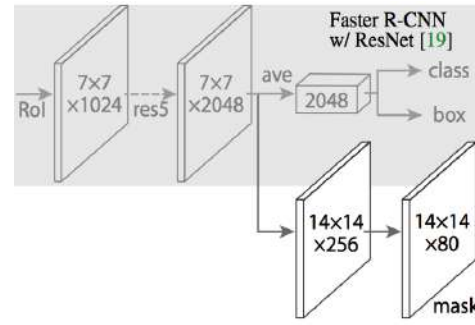




# Data Processing Workflow



# Image Annotation



Equirectangular Images

Mask R-CNN

Annotated images

- Goal: annotate image data with **public safety objects**, e.g., fire extinguishers, building control panels, utility shutoff, exits (49 labels)
- Use Mask R-CNN [1] and Inception-ResNet-v2 [2] to label objects
  - Mask R-CNN provides pixel level segmentation with bounding boxes.
  - Inception-ResNet-v2 classifies objects and refines bounding boxes.
- Store bounding boxes and class labels in a JSON format (for annotating the corresponding point cloud)

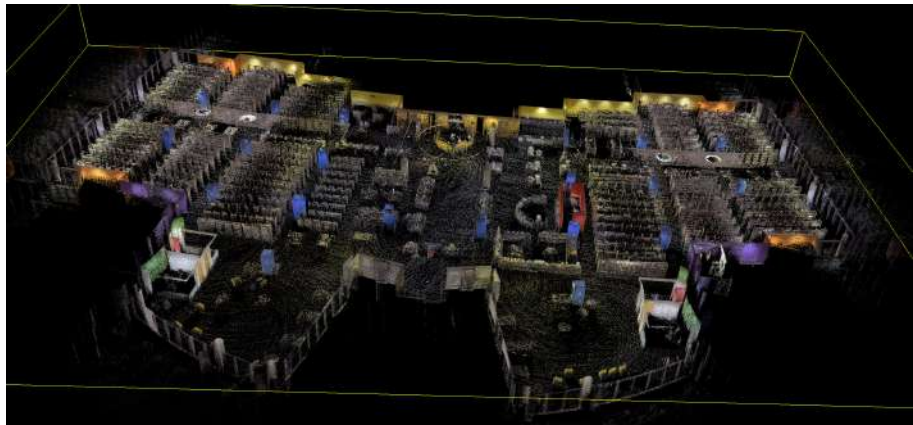
[1] K. He, G. Gkioxari, P. Dollr, R. Girshick, Mask R-CNN. ICCV 2017

[2] Inception-ResNet-v2, <https://github.com/tensorflow/models/tree/master/research/object-detection>



# Fusing Lidar and 360 Degree Images

- Project Lidar points before SLAM onto equirectangular image
  - align lidar and video time and angle, then the points are colored automatically
- Use SLAM on colored points to create final result



Memphis Central Library



Hickory Hill Community Center



# Data Sharing and Facility Access

- Data sharing
  - Provided preliminary data to OGC pilot members
  - Use existing ArcGIS platform for first responders in the city and county to access the data
  - Public data platform ([data.memphistn.gov](http://data.memphistn.gov))
- Future facility access
  - two years beyond the end date of the grant for testing and evaluating alternative technologies
  - 2 facilities: Memphis Central Library and FedEx Institute of Technology



# Map901 GIS Web App

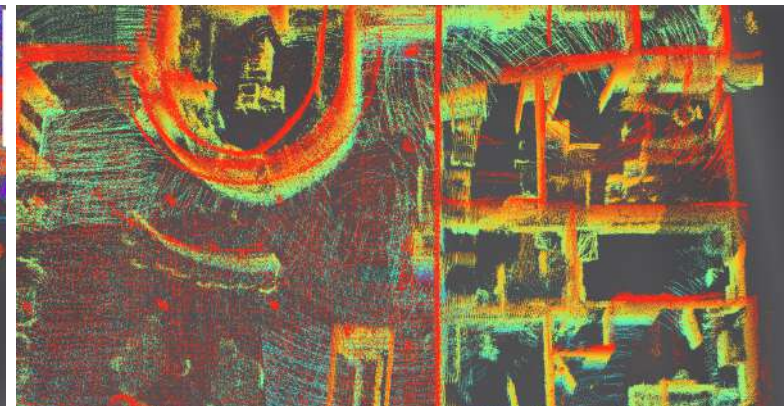
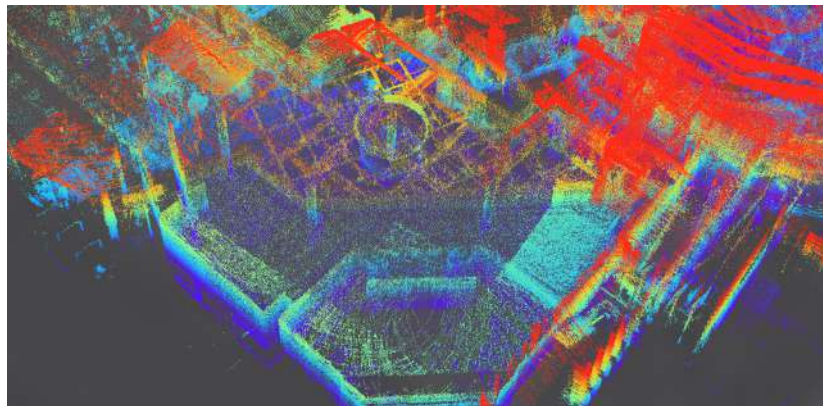
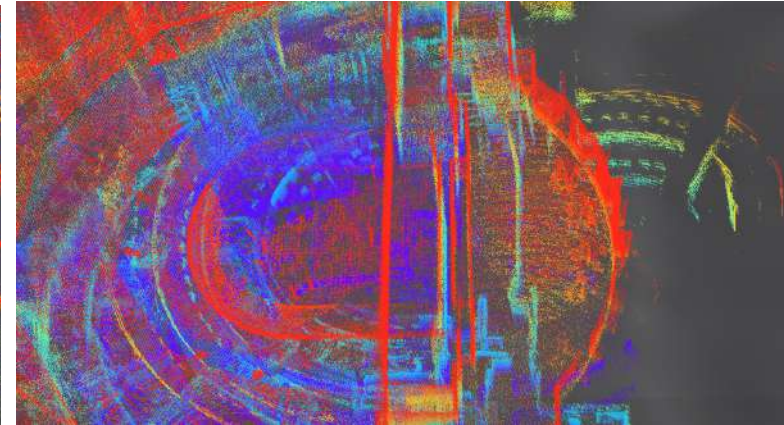
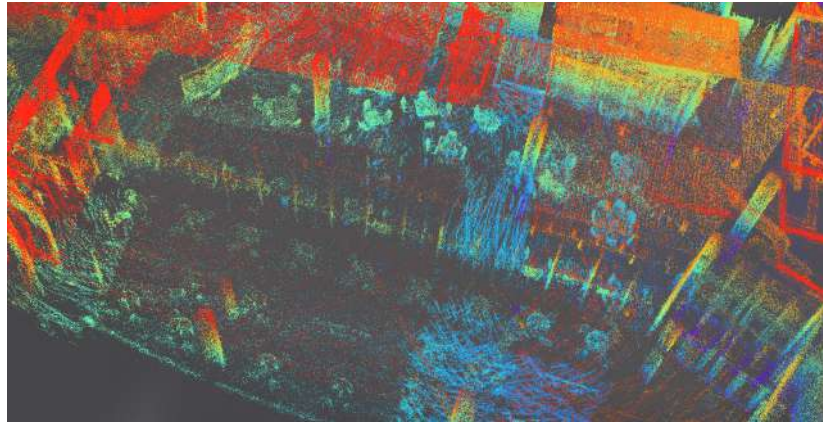
## Platform

ESRI ArcGIS Online

- Web Based GIS Platform
- Able to host large amounts of data
- Simple Easy to use interface

## Functionality

- Navigation
  - Pan/Zoom/Rotate
  - Bookmarked Views
- Floor by Floor Display
- LIDAR symbology
  - Color
  - Elevation
  - Intensity
- Change Underlying basemap
- Measure Distance Hazards



# Team and Collaboration



- City: Mike Rodriguez, Wendy Harris, Gertrude Moeller, Joseph Roberts
- U Memphis: Lan Wang, Eddie Jacobs, Junaid Khan, Mazhar Hossain, Tianxing Ma, Thomas Watson, Brandon Simmers, Meg Homeyer, Abigail Jacobs



# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City

Hancock County Mississippi Emergency Management Agency

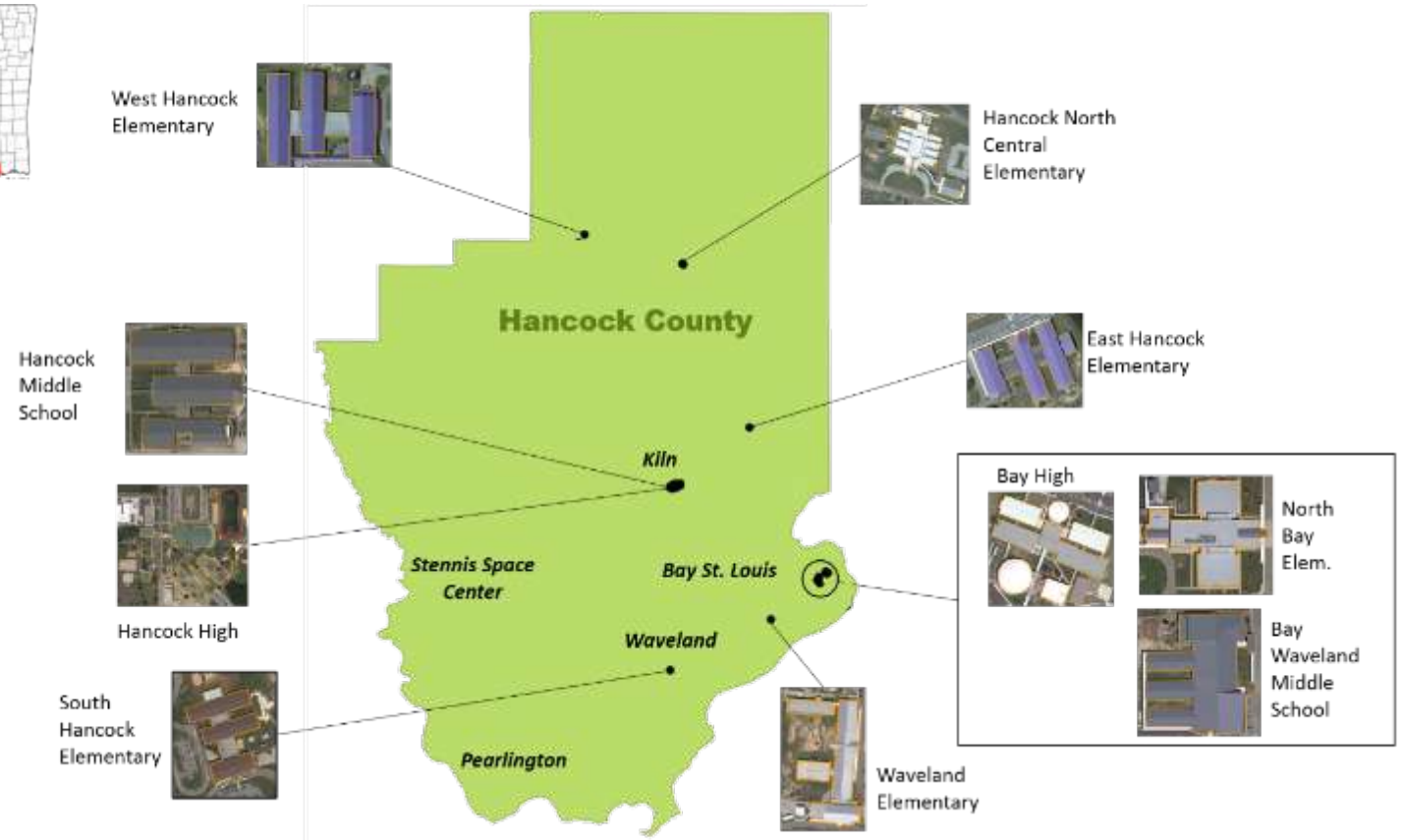
– Partnered locally with NVision Solutions Inc.

**Project:** Create indoor maps of public buildings using LIDAR

**Location:** 10 public schools comprising 1,201,082 sq ft of indoor space. Includes USDA Designated Rural Areas and SBA HubZones. Mix of older high schools and newer elementary schools rebuilt after Hurricane Katrina to similar specs.



1. Hancock High School – 309,347 sq. ft.
2. Bay High School – 142,762 sq. ft.
3. Hancock Middle School – 139,662 sq. ft.
4. Bay Middle School – 104,630 sq. ft.
5. North Hancock Elementary – 89,541 sq. ft.
6. East Hancock Elementary – 91,640 sq. ft.
7. South Hancock Elementary – 92,560 sq. ft.
8. West Hancock Elementary – 90,039 sq. ft.
9. North Bay Elementary – 64,415 sq. ft.
10. Waveland Elementary – 76,486 sq. ft.



# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City

**Public Safety Applications:** EMA coordinates with fire and law enforcement for any significant crisis and takes the lead for natural disasters.





# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City

## Key Deliverables

- 10 attributed, lidar data sets for 10 public schools
- Vector data set for relevant public safety indoor features
- Mississippi Automated Resource Information System (MARIS) data download page
- Any open-source software tools developed



## “Reach” Goals

- Automated feature recognition and annotation
- Immersive VR Headset display
- Lightweight, open-source classification software

## Potential Impacts

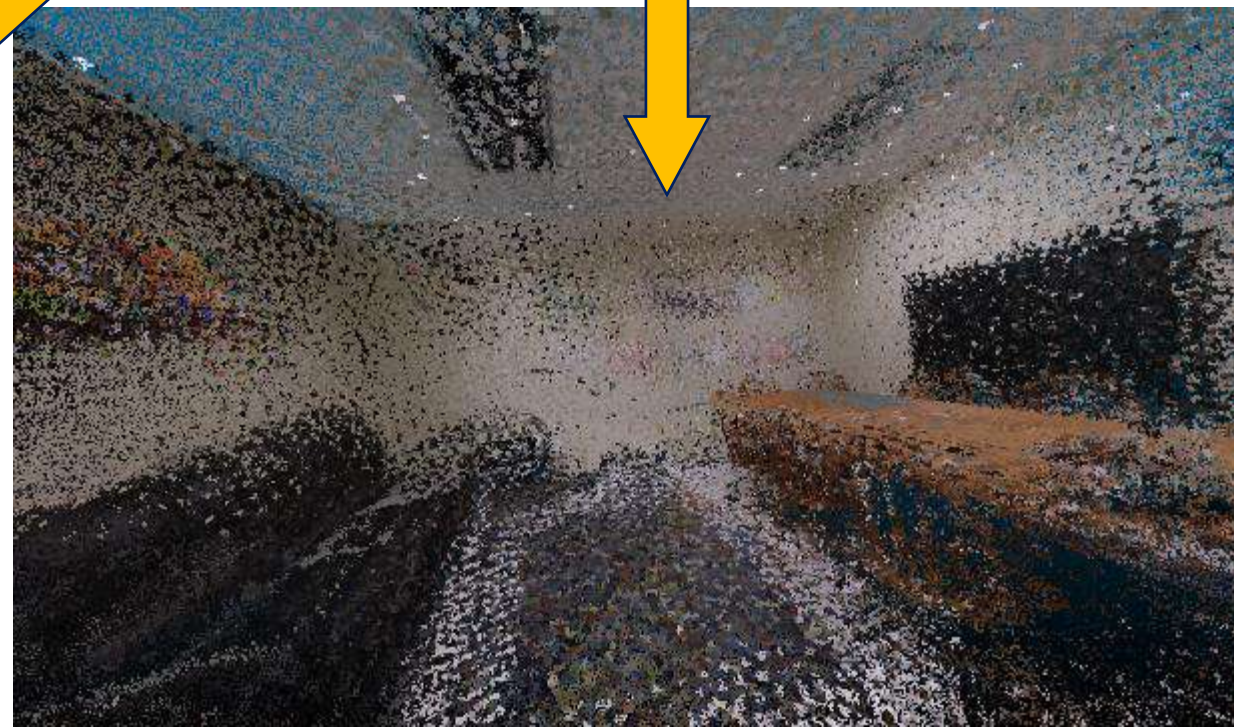
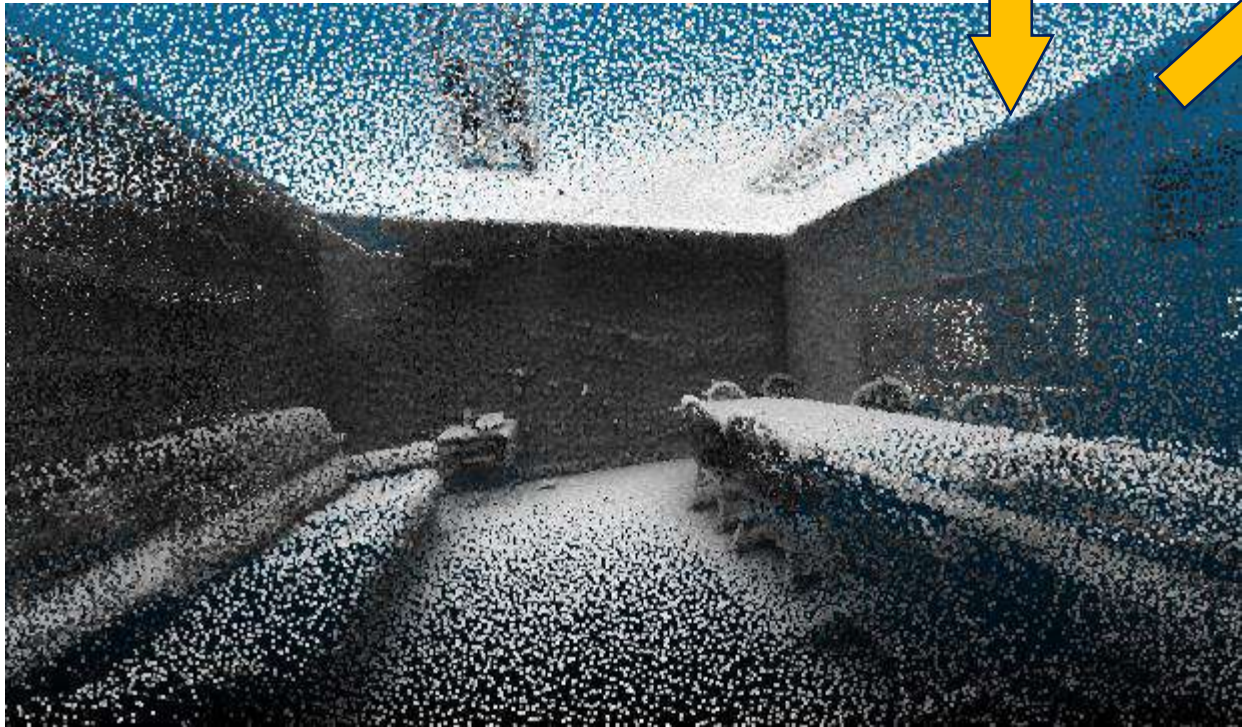
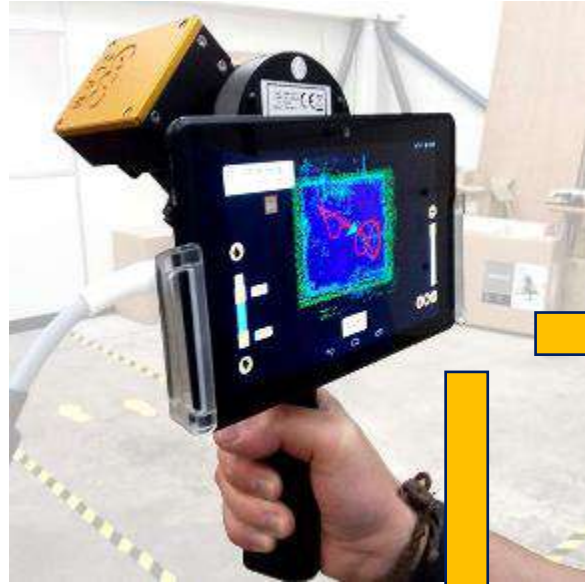
- New and improved approaches in public safety tactics
- Common standards and best practices for indoor maps
- Increased public/private research into indoor mapping due to high-quality, widely available reference datasets
- Increase in derivative technology research
- Open-source tools to make processing indoor data and creating maps easier
- Recognition of US as a global leader in Indoor Mapping technology

access aid alarm automated bench book  
building chair connections control defibrillator desktop  
door electric emergency entrances equipment  
escape exit external extinguisher fire gas hazmat ifak individual  
kit microwave offs oven panels person pillars rack refrigerator roof  
routing server shelf shut sign sink structural  
suppression systems table toaster tv  
utility water

# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City

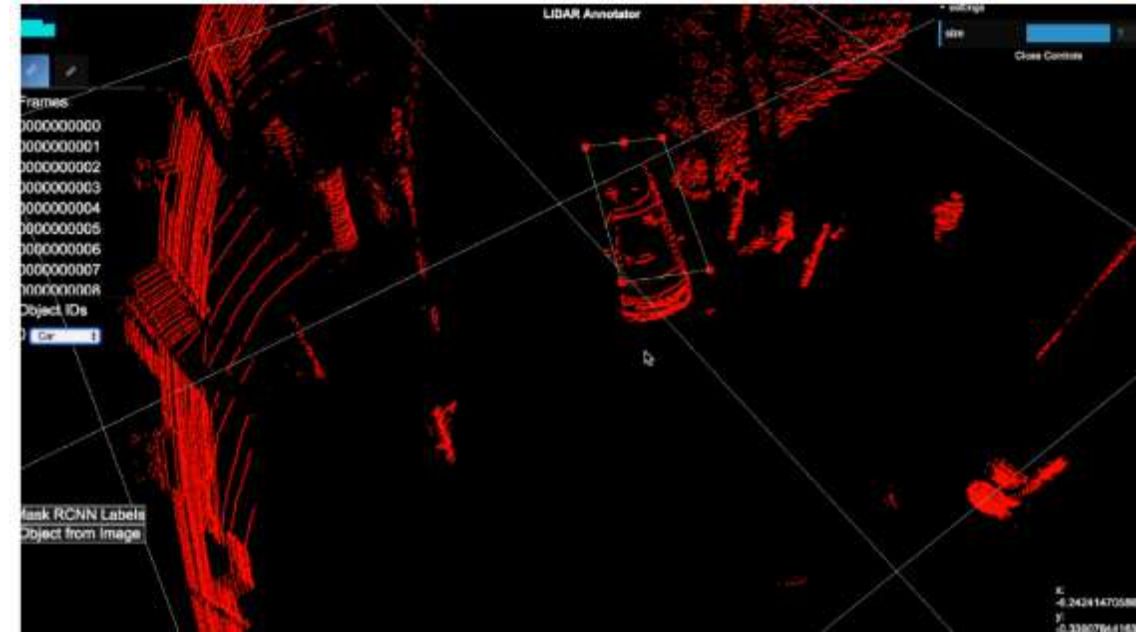
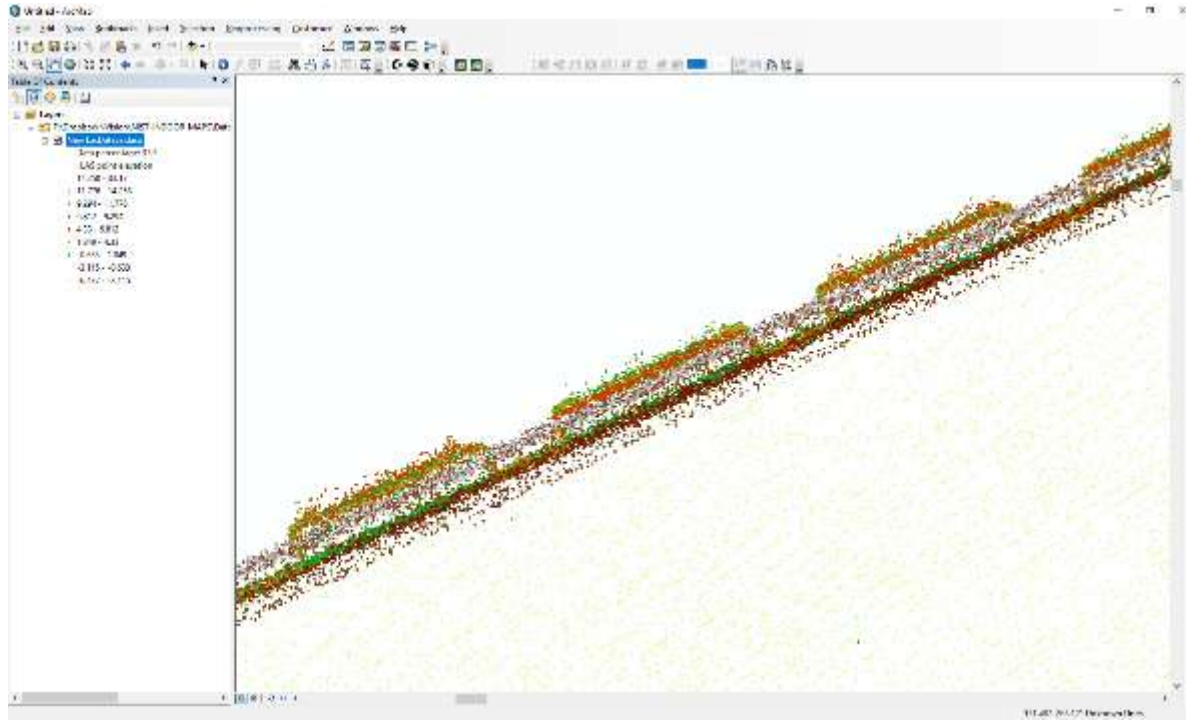


Zeb-Revo RT



# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City

## Manual Lidar Annotation



**LATTE**

# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City



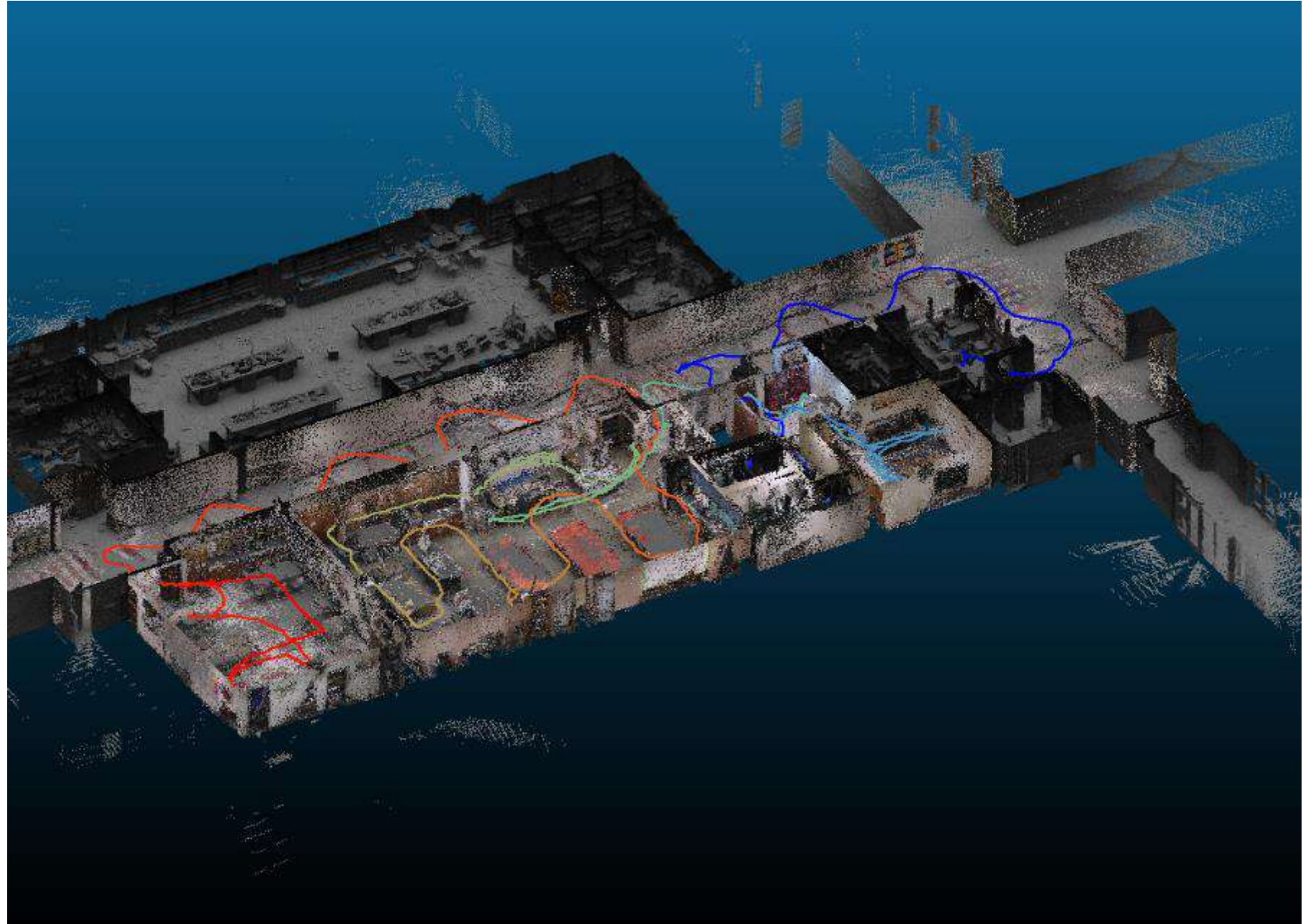
Automated, specific feature identification and classification



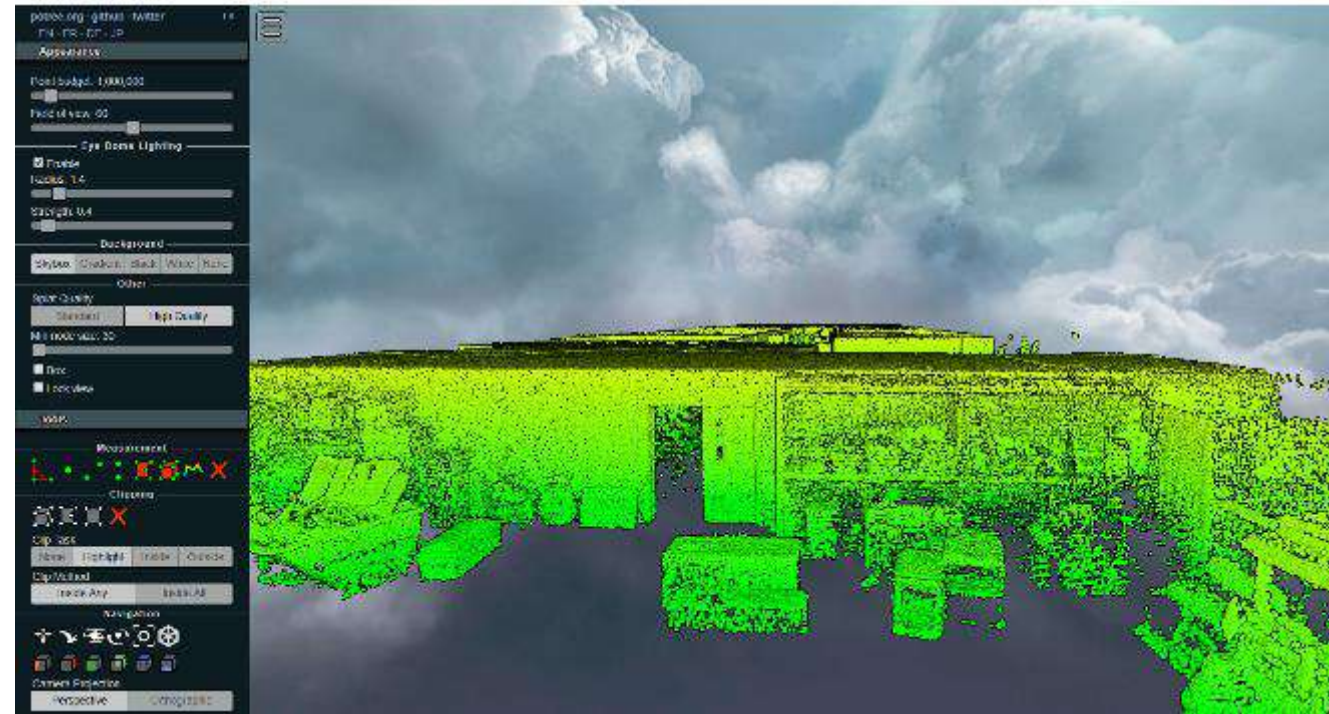
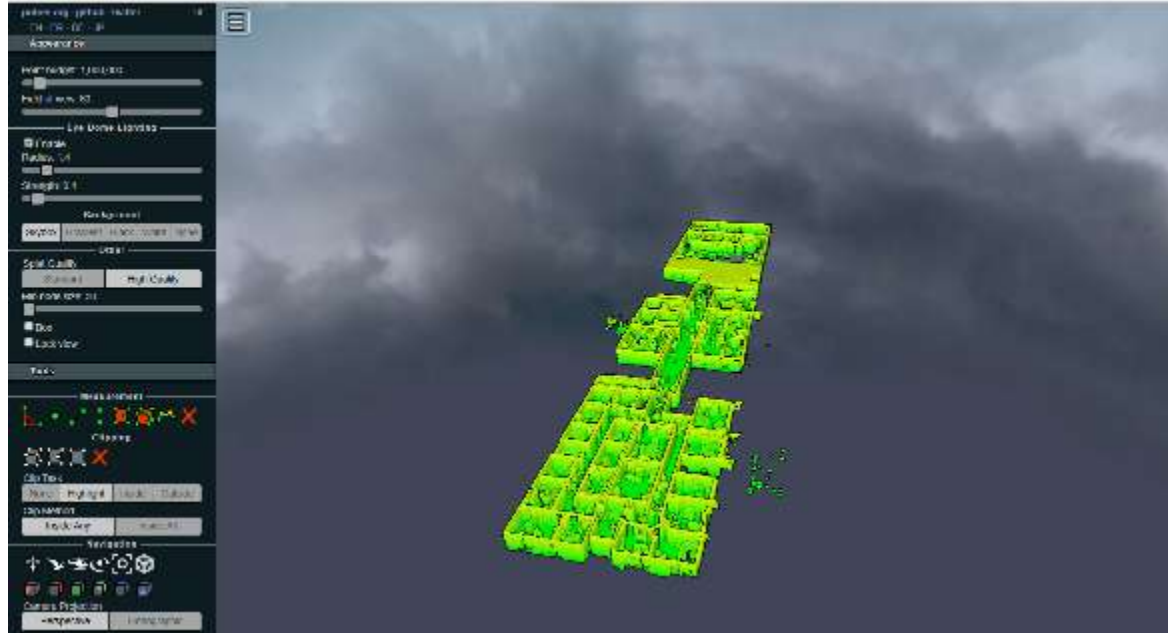
# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City



Scalable Lidar Classification??



# 2018 NIST Public Safety Innovation Accelerator Program - Point Cloud City



# Indoor Mapping with Handheld LiDAR in Enfield and Storrs, CT

Paul Januszewski

Matt Mucci

Michael Carifa

Jason Parent

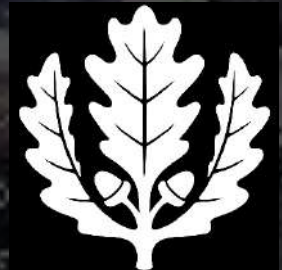
James Hurd

Tom Meyer

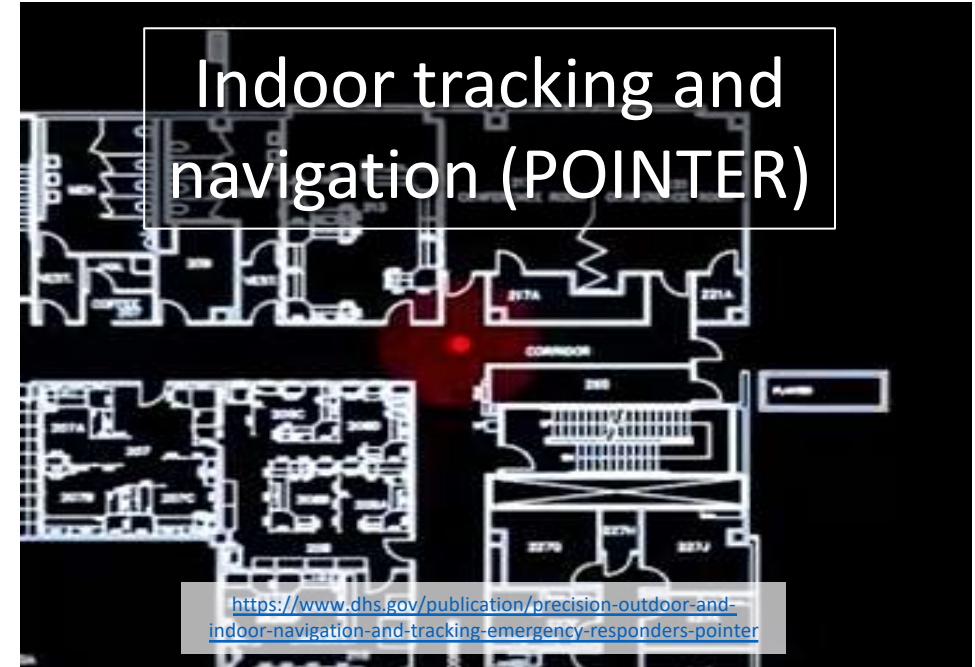


**Enfield Fire**

**UConn**  
UNIVERSITY OF CONNECTICUT



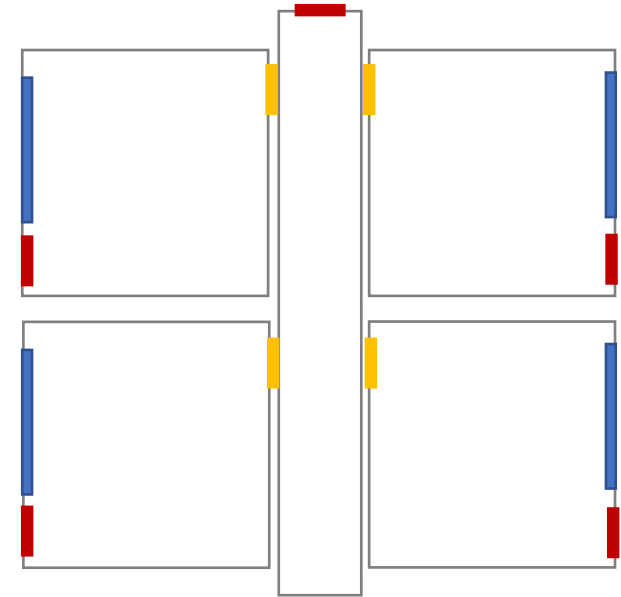
# The need for indoor navigation systems



- Disorientation is a major hazard for first responders.
- Thermal cameras are only part of the solution.
- Indoor navigation systems are the missing part of the solution.

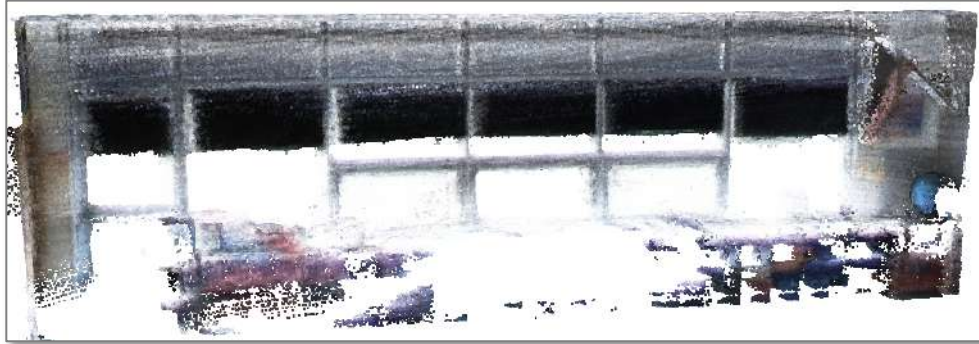


# Mapping for indoor navigation

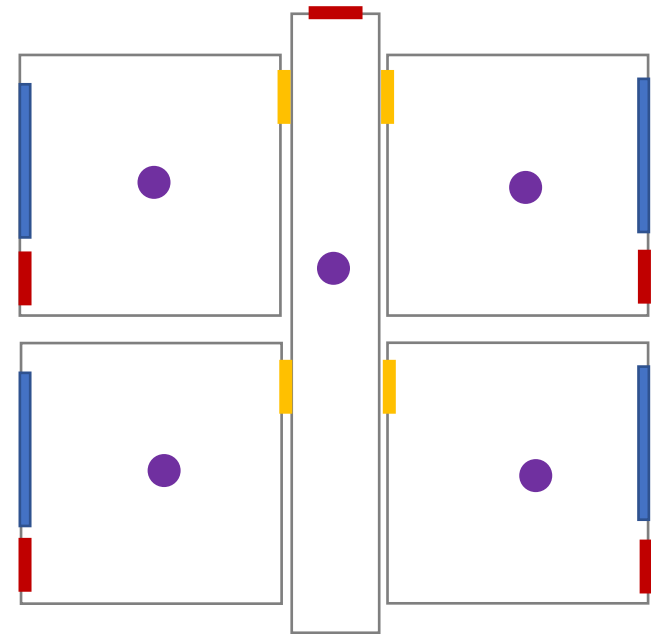


- Indoor navigation requires accurate maps.
- Light detection and ranging (LiDAR) can be used to map buildings “as built” accurately and efficiently.

# Project objectives



- Create database of point clouds annotated with items-of-interest.



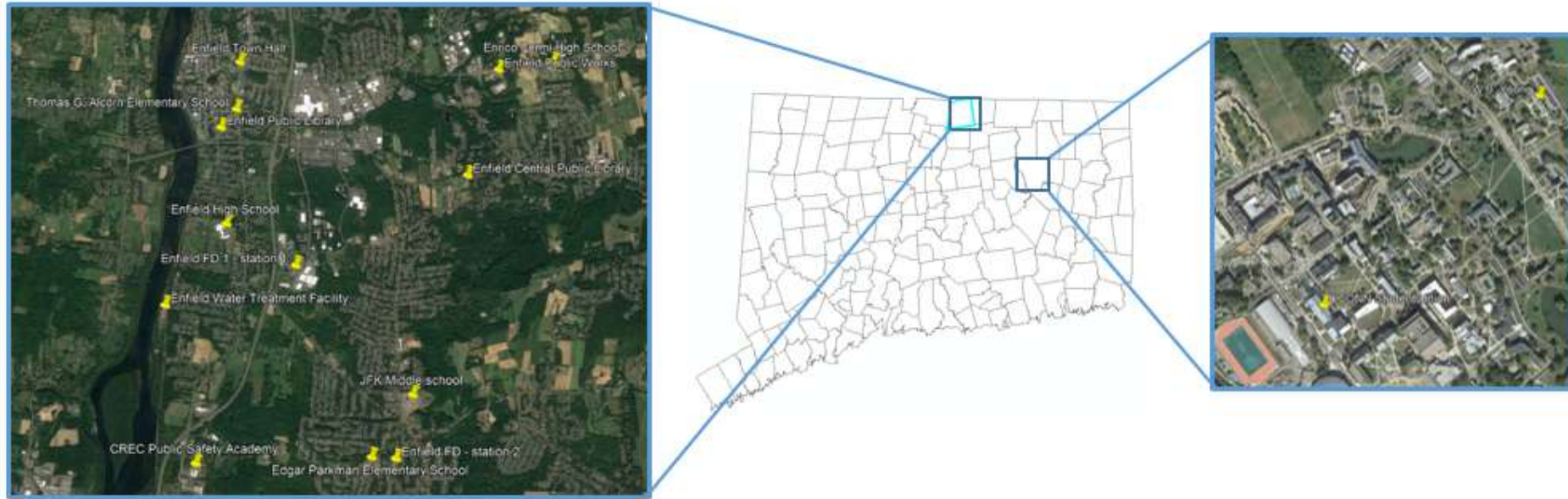
- Create floor plans showing items-of-interest.

# Items-of-interest

- Exits, windows, fire alarm and suppression system components, utility shut-offs, etc.
- Useful for pre-plans, incident management, and building inspections.

```
no item of interest
non-exit door (frame)
exit door (frame)
fire door (frame)
window (frame)
fire alarm
fire alarm pull station
fire alarm control panel
fire extinguishers
emergency lighting
smoke detectors
exit sign
HVAC vent
sprinkler heads
sprinkler riser or standpipe
utility shut-offs
elevator
stairs
```

# Project buildings



- 12 buildings in Connecticut.
- 1.4 million square feet.
- Schools, administrative, industrial, academic.
- Built or renovated 1960 to 2016.

# LiDAR scanner – Paracosm's PX-80

- 300 pts/sec; range of 80m.
- Simultaneous RGB image collection with integrated spherical camera.
- Scan durations up to 30 minutes.
- Data collection by EFD personnel.



# PX-80 data outputs

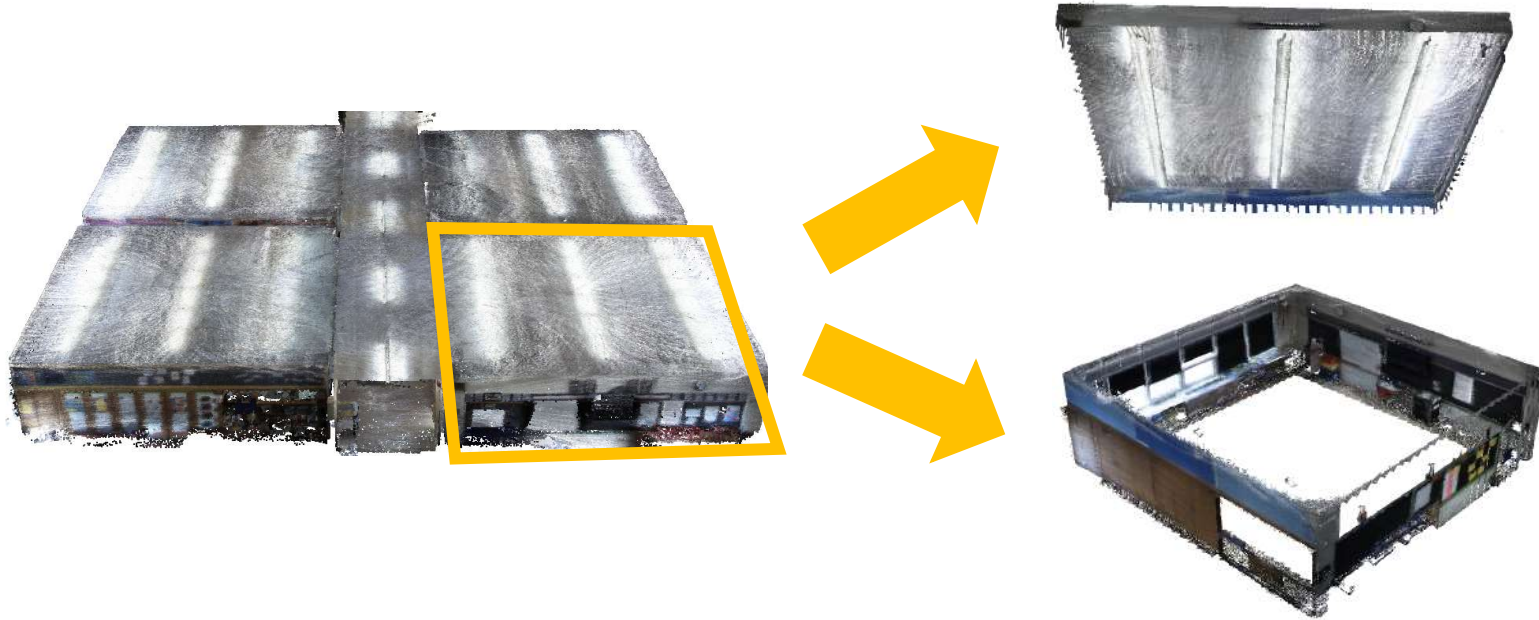


Colorized point cloud



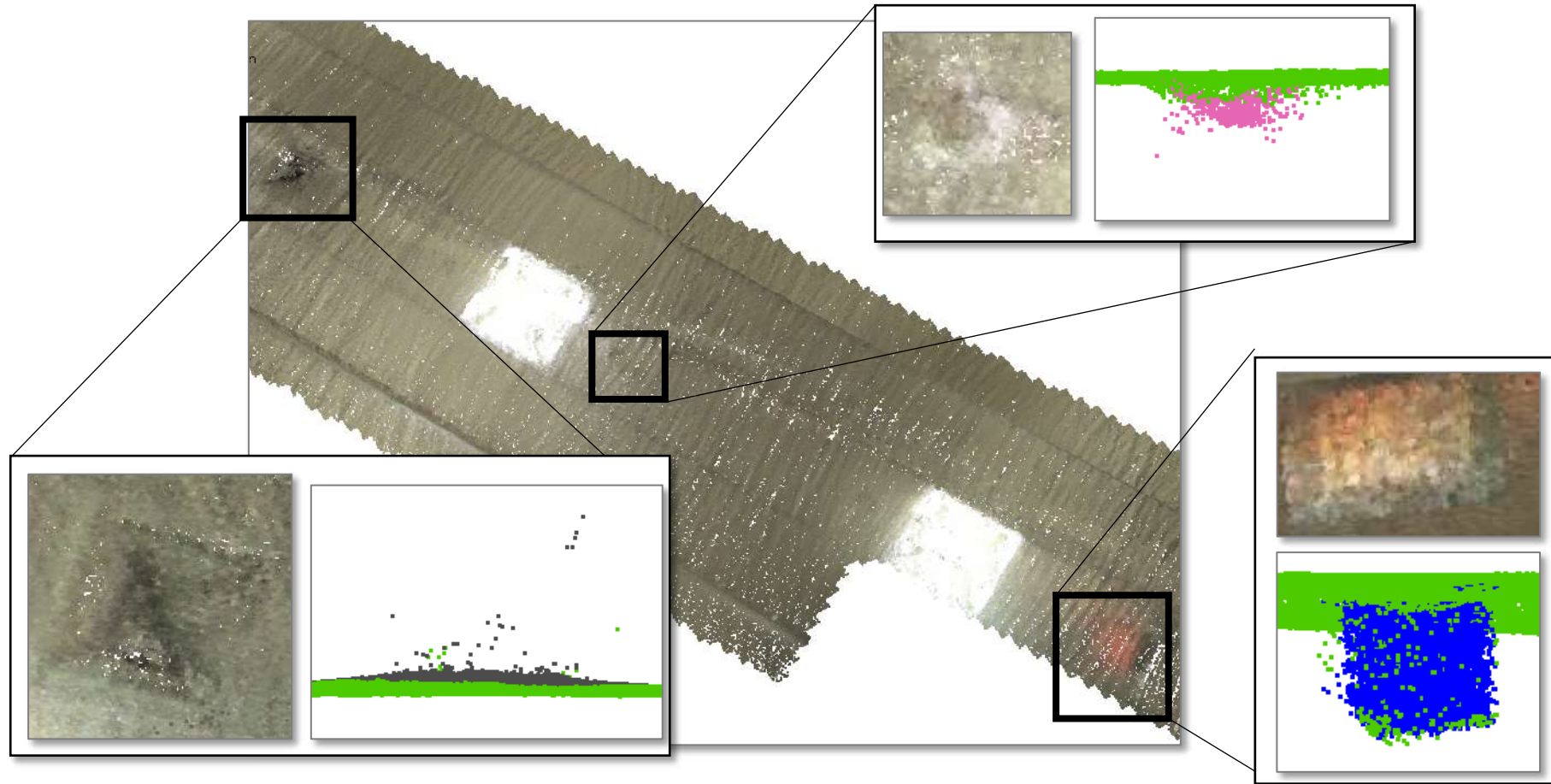
Spherical RGB (true color)  
imagery

# Point cloud processing



- Python scripts divide point clouds into subsets:
  - Smaller size improves graphics rendering for manual classification.
  - Separate ceiling from walls for easier classification.

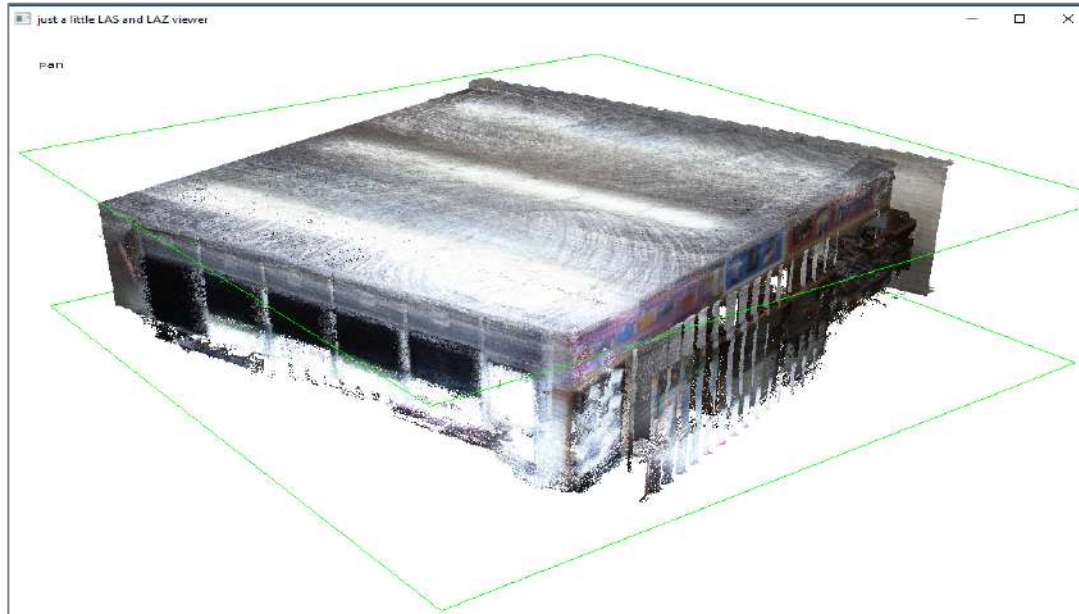
# Point cloud classification - auto



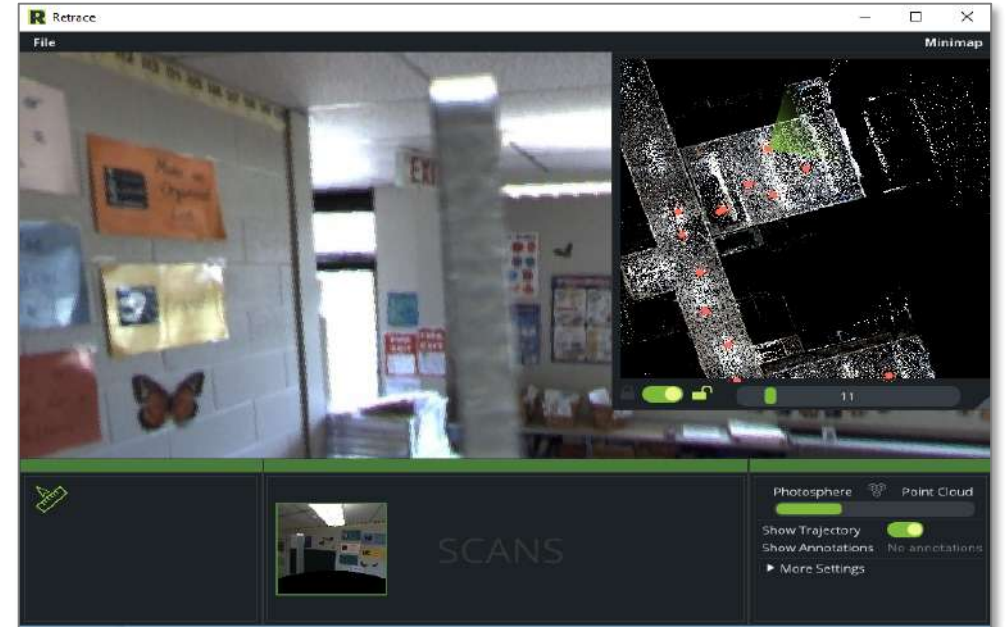
- Scripts created to classify small hard-to-see features.



# Point cloud classification - manual

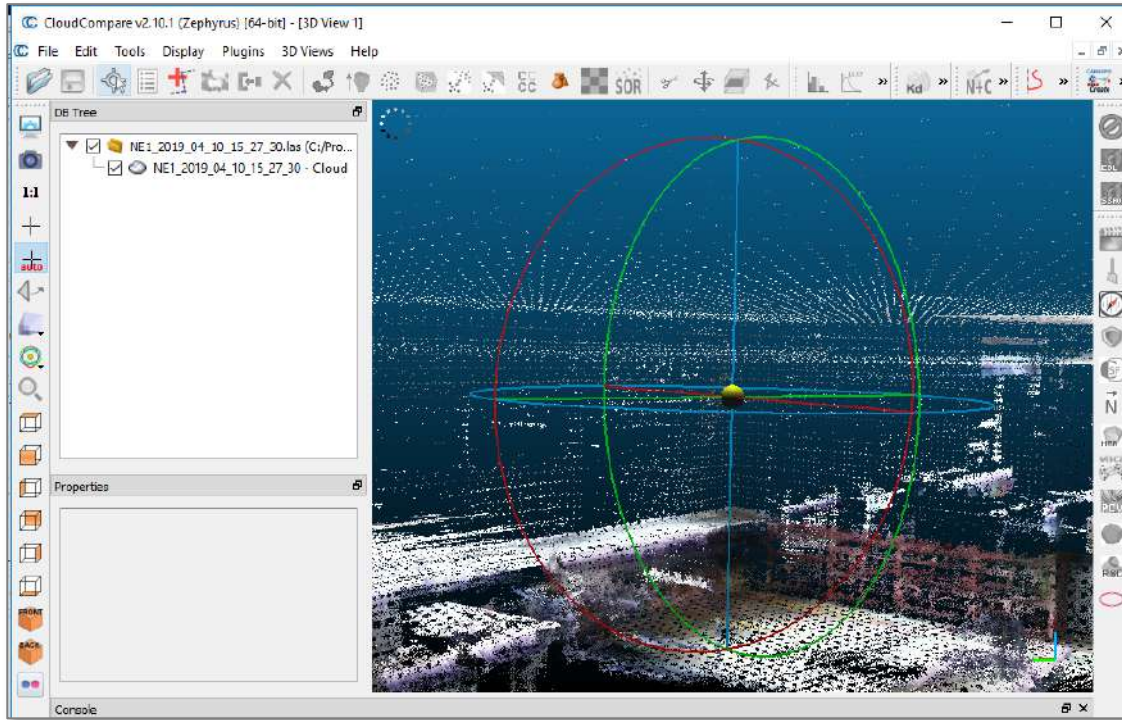


- Manual classification with Lasview (LAS Tools)
  - Classify remaining items.
  - Quality check.



- Reference imagery viewed in Paracosm's Retrace
  - Helps identify items in point cloud.

# Geo-referencing point clouds

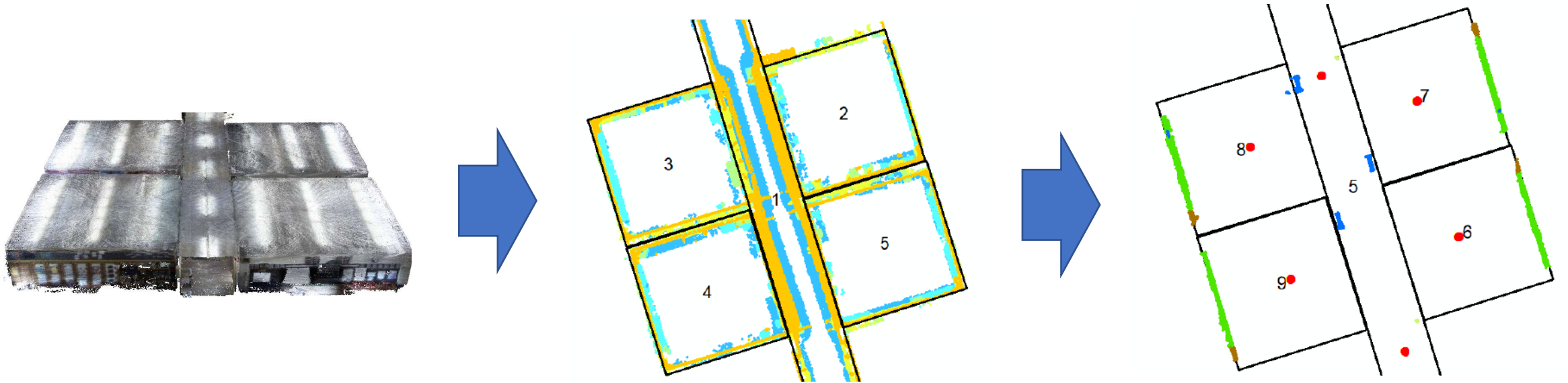


- Scans stitch together and georeferenced using Cloud Compare.



- Aerial imagery provides ground control points for georeferencing.

# From point clouds to maps



- Floor plans digitized from georeferenced point clouds using ArcGIS.
- Scripts will be created to automatically map locations of items-of-interest.

# Conclusions and lessons learned

- PX-80 scanner can be used effectively with little training or technical proficiency.
- Colors in the point cloud tend to be distorted.
- RGB images (viewed in Retrace) helped to locate features in the point cloud.
- Certain hard-to-see features were reliably classified by scripts using feature sizes and shapes.
- Lasview was low-cost and easy to use for manual classification.
- Developing scripts to subset and help classify point clouds greatly improved efficiency.

# Questions?

## Indoor Mapping with Handheld LiDAR in Enfield and Storrs, CT

Paul Januszewski

[pjanuszewski@enfieldfire.org](mailto:pjanuszewski@enfieldfire.org)

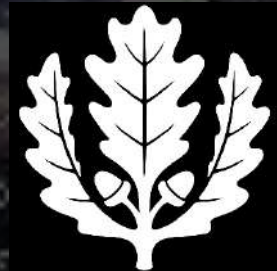
Jason Parent

[Jason.parent@uconn.edu](mailto:Jason.parent@uconn.edu)



**Enfield Fire**

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**#PSCR2019**

Come back for the  
**Next  
Session**  
2:25 PM