InSPIRE

Innovation Summit for Preparedness & Resilience

Research in Public Safety

NAPSG Foundation

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01 Introduction

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Meet the presenters

Chad Council

Bojan Cukic, PhD

Kate Kapalo, PhD

Sonny Kirkley, PhD

Wenwu Tang, PhD

Objective

Explore current research in public safety and provide an opportunity for attendees to engage with panelists about research challenges, priorities, and impacts.

Why?

Kevin Kay, NAPSG Foundation

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Underlying problem

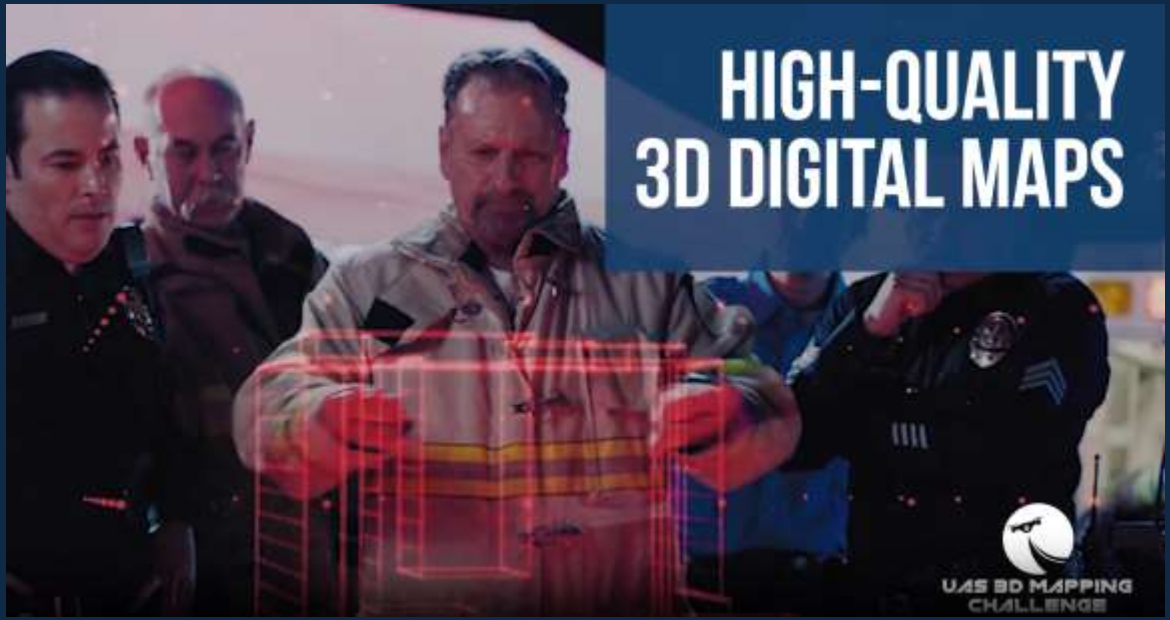
How do we get from here → To here?

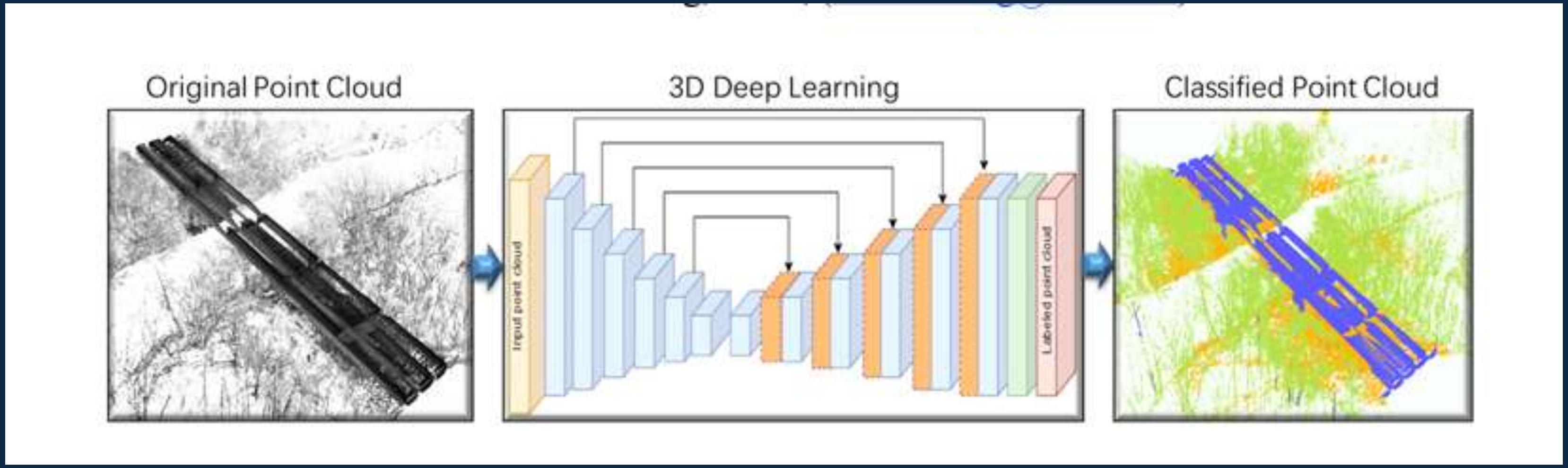
Operational Need

E.g., need to identify the best way to segment search areas/predict the appropriate amount of resources and workload

Technical Solution

Utilization of best practices, POST, and other research into PAWSAR through MITLL (and then wider applicability for items like wildfire evacuations)





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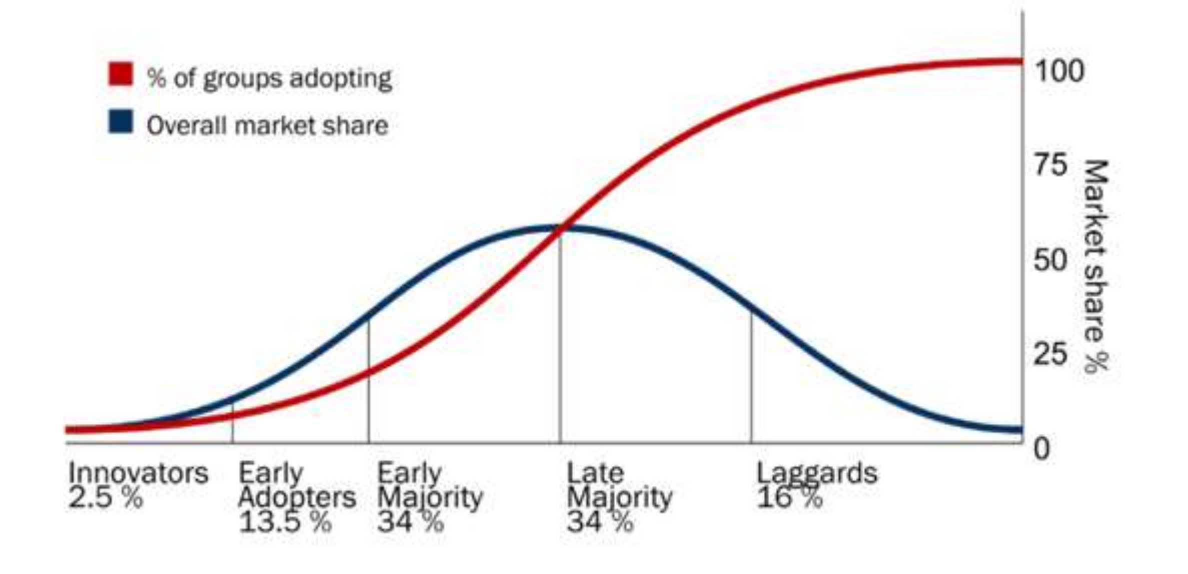
Accelerating Adoption

TRL	
9	Actual system “flight proven” through successful mission operations
8	Actual system completed and “flight qualified” through test and demonstration (ground or space)
7	System prototype demonstration in a space environment
6	System/subsystem model or prototype demonstration in a relevant environment (ground or space)
5	Component and/or breadboard validation in relevant environment
4	Component and/or breadboard validation in laboratory environment
3	Analytical and experimental critical function and/or characteristic proof-of-concept
2	Technology concept and/or application formulated
1	Basic principles observed and reported



Different Fields

Research

Operations

Developers

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02 | Research

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UI/UX

Kate Kapalo, PhD, WFCA

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First In, Left Out: Why We Can't Afford to Ignore User Experience

Katelynn Kapalo, Ph.D.
Senior Research Scientist

WESTERN FIRE CHIEFS ASSOCIATION

My Background

Background: Human factors psychology (PhD in Modeling and Simulation)

My work focuses primarily on leveraging computational modeling and simulation-based environments to better support first responders.

→This really translates to mean that I focus on the end-user experience with technology in the context of training and operations.

Applied Sciences Center for Resilience Studies

Build lasting relationships between communities, government, industry, and academia to improve society and build community resiliency through research and development

WESTERN FIRE CHIEFS ASSOCIATION

Evolution of Firefighting

Changes in the construction industry have led to rapidly produced composite materials that burn hotter and faster than ever before

Firefighters realistically must take one course (~4 hours) in fire behavior from Firefighter I to Fire Officer IV (NFPA 1021; IFSTA)

A lack of situation awareness (SA) is typically contributing factor in near miss reports and is often implicated in line-of-duty death (LODD) reports

WESTERN FIRE CHIEFS ASSOCIATION

The Problem: How Do We Address These Challenges?

Technological Innovation

Due to rapid advances in technology, first responders will eventually (and in some cases already do!) have access to building information, sensor data, and fire protection system data in real-time

Perception & Performance

The presentation and display of this information has not been fully evaluated from the *human performance* perspective

Need to design user interfaces that support incident command while preventing information overload and with human processing constraints in mind

How Does UX Apply?

When considering how we approach design of user interfaces, we must factor in the limitations of human senses, while also addressing the operational environment.

Ubiquitous Computing

Theoretical Background

“Anytime, anywhere computing” (Weiser, 1991)

Examples of Ubiquitous Computing

- Natural User Interfaces
- Context-Aware Applications
- Automated Capture & Access

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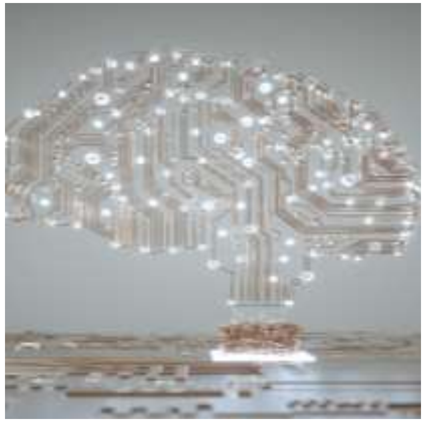
Situated Computing

Embedded Tools

Computers to be conceptualized as "embedded tools"



Embodied Cognition

- Exploits our physical skills
- Emphasizes the relationship between the ***environment and the task***

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Benefits of Enhanced User Interfaces

Communication

Different communication modalities (avoiding *over-reliance* and increased workload)

Situation Awareness

Increased situation awareness and enhanced decision making

Collaboration

Increased efficiency of collaboration

Information Quality

Enhanced accuracy and availability of information

Our Research

Task: Boots on the Ground

Tactical: Community

Strategic: Envisioning the Future

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Current Research Efforts

Community Risk Reduction

- Investigating privacy, motivation, and trust in preparedness
- Two-way communication and data-sharing between first responders and communities
- Focused on ***residential structures, which differs from traditional paradigms***

International Association for Fire Safety Science (IAFSS)

- Evaluating research gaps and obstacles to successful fire safety research (research roadmap)
- Collaborative effort with RMIT, Massey, Lund, NSW (international-level project)

Connect with us!

Applied Sciences Center

Chief (ret.) Bob Horton, Director of Applied Sciences Center
Horton@wfca.com

Kate Kapalo, Ph.D.
Kapalo@wfca.com
321-276-8330

WESTERN FIRE CHIEFS ASSOCIATION

MIT Lincoln Laboratory

Chad Council

NAPSG Foundation

InSPIRE

Predictive Analytics for Wide Area Search and Rescue

TI90-42

National Alliance for Public Safety GIS

InSPIRE 2023

Chad Council

23-Oct-2023

LINCOLN LABORATORY
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

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MIT Lincoln Laboratory

DoD Federally Funded Research and Development Center


Massachusetts Institute of Technology


MIT Lincoln Laboratory, Lexington, Massachusetts

Technology in Support of National Security

- **System architecture engineering**
- **Long-term technology development**
- **System prototyping and demonstration**


Air, Missile and Maritime Defense


Homeland Protection & Air Traffic Control


Cyber Security and Information Sciences


Communication Systems


Engineering


Advanced Technology


Space Systems and Technology


ISR and Tactical Systems

Facilities: **2.1 million sq. ft.**

Humanitarian Assistance & Disaster Relief Systems

Mission: Develop and deploy new technologies to address the most complex disaster and humanitarian challenges

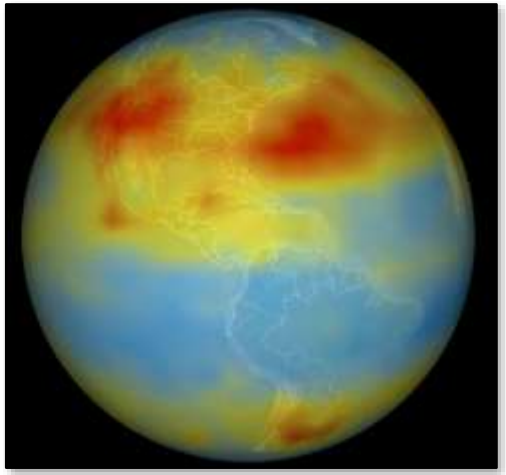
Natural and Man-Made Disasters

Extreme storms, major earthquakes, etc.

Humanitarian Challenges & Global Crises

Conflict, instability, human exploitation, global aid

Climate & Environment



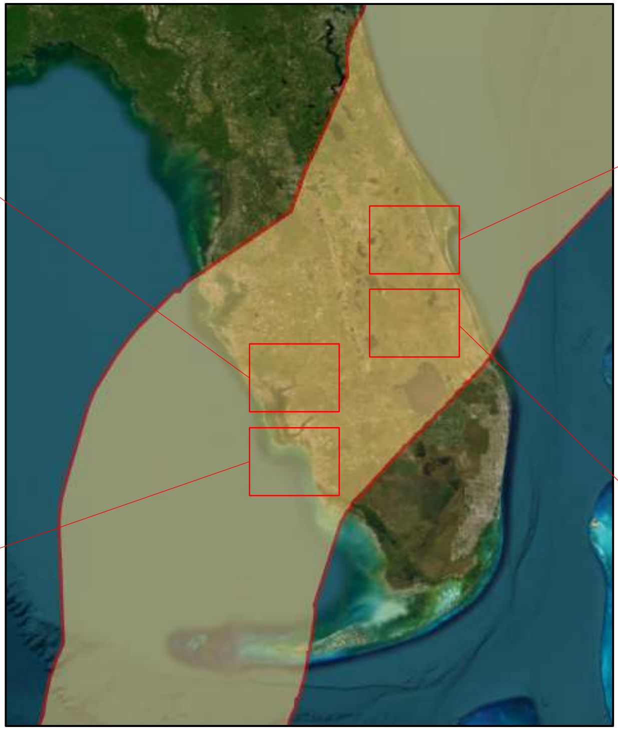
Global risks to life, habitability, and livelihoods

Enduring and Emerging Global Health Needs

Public heath, social well-being

Vision: wide-spread adoption of technologies that revolutionize HADR responses domestically and internationally

The Wide Area Search Challenge



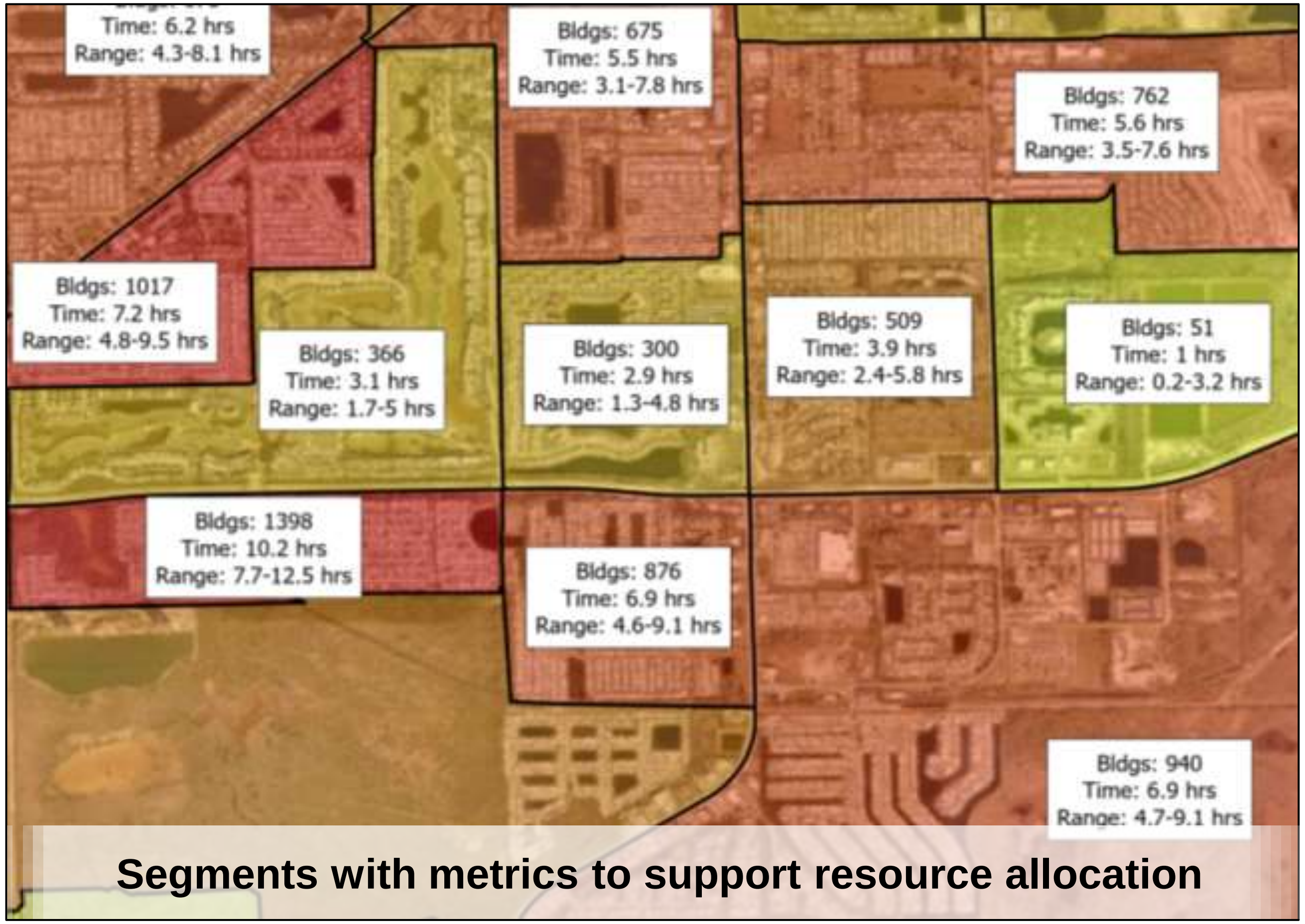
Path of Hurricane Ian

Searching for an unknown number of people within an undefined boundary presents unique resource allocation challenges that can be supported through predictive analytics

Images: Hurricane Ian damage photos, various news outlets

Wide Area Search Resource Allocation

Area segmented for WAS[1]



Segments with metrics to support resource allocation

Scaling USAR[2] resources for wide area events is only partially informed by data.
Over allocating is costly, while under allocating delays aid to survivors

1. WAS: Wide Area Search
2. USAR: Urban Search and Rescue

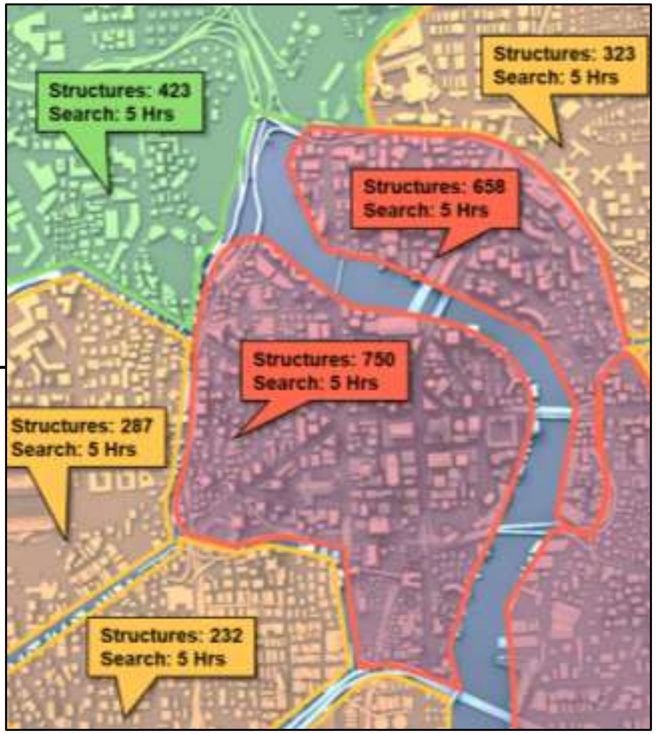
Required Components

Performance Under Different Conditions

Expected Conditions in an Area

Automated Urban Segmentation

Generate:
Segments of equal work



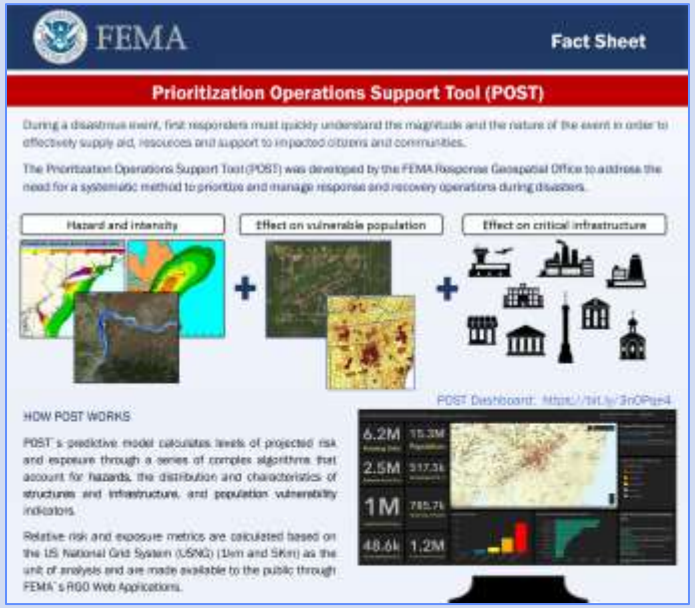
Intelligent Auto-Search Segmentation

To segment an area based on equal performance under specific conditions, we must characterize that performance, predict those conditions, and partition based on those metrics.

Opportunities for Predictive Analytics

Squads	4
Structures Searched	2,187
Search Area	10 km²
Search Time	9 hours
Structures per hour per squad	60.75

Establishing Search Production Rates


FEMA Fact Sheet

Prioritization Operations Support Tool (POST)

During a disastrous event, first responders must quickly understand the magnitude and the nature of the event in order to effectively supply aid, resources and support to impacted citizens and communities.

The Prioritization Operations Support Tool (POST) was developed by the FEMA Response Geospatial Office to address the need for a systematic method to prioritize and manage response and recovery operations during disasters.

Hazard and intensity + Effect on vulnerable population + Effect on critical infrastructure

POST Dashboard: https://bit.ly/3nOPqe4

HOW POST WORKS

POST's predictive model calculates levels of projected risk and exposure through a series of complex algorithms that account for hazards, the distribution and characteristics of structures and infrastructure, and population vulnerability indicators.

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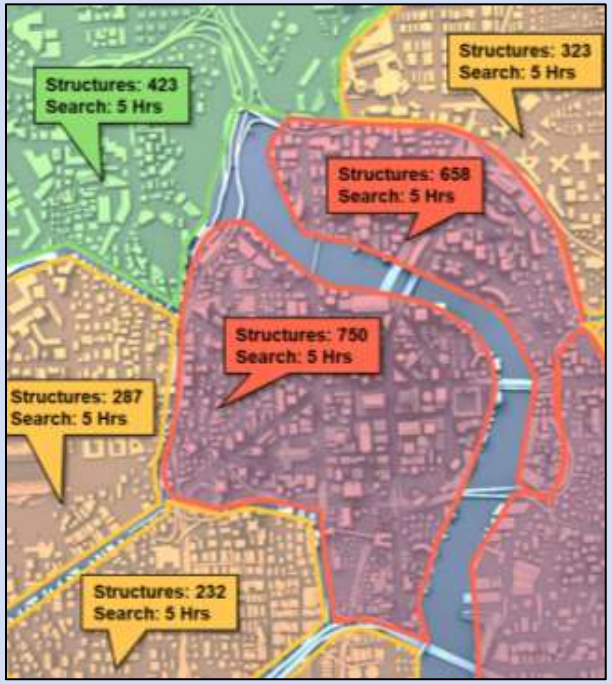
Correlating FEMA Damage Forecasts to Damage Observations



Intelligent Auto-Search Segmentation

Establishing search performance metrics that are relative to damage conditions, combined with damage forecasting, enables urban areas to be auto-segmented equally according to expected levels of work.

USAR Data Overview

Structures

	Unaffected
	Affected
	Minor
	Major
	Destroyed
	Unknown

Hazards

	Animal Hazard
	Fire Incident
HM	Hazardous Material Incident
	Flood/Water Level
	Route Blocked
!	Other Hazard

Search Interactions

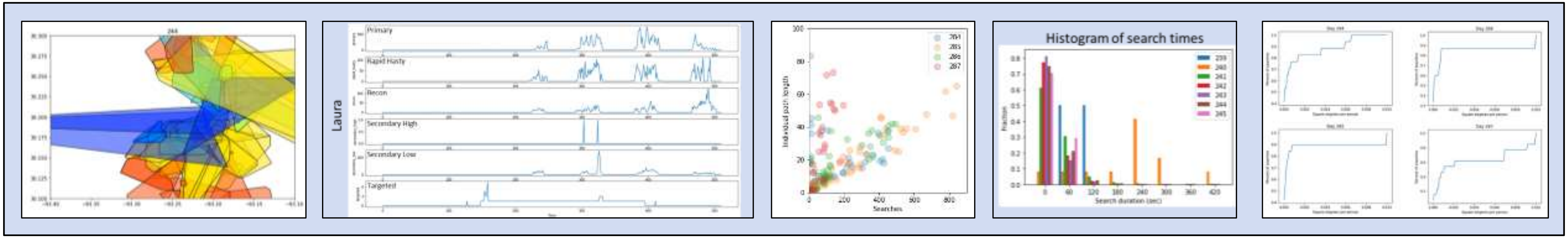
X	Searched Per Rules of Engagement (ROE)
R	Rescued
E	Evacuated
A	Assisted
	Shelter in Place
V	Human Remains Removed
	Animal Evacuation

Follow Up Required

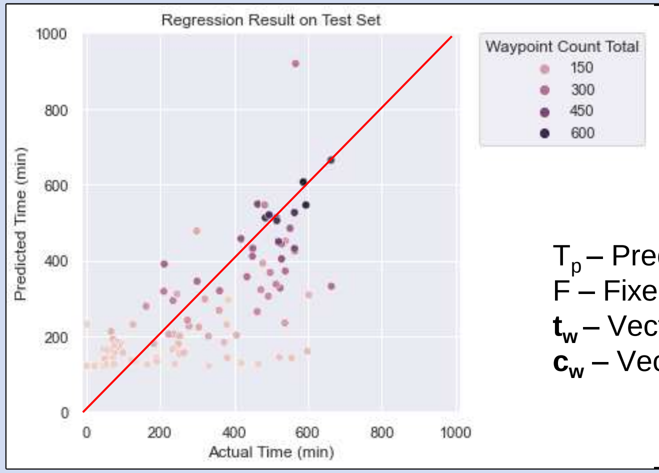
V	Victim Detected
V	Victim Confirmed
V	Human Remains Detected
V	Human Remains Confirmed
	Targeted Search

Federal and State USAR teams use mobile applications to collect standardized observations as spatiotemporal data

Data Exploration and Iterative Approaches



Numerous exploratory analyses conducted to understand the data and determine applicability to end goal

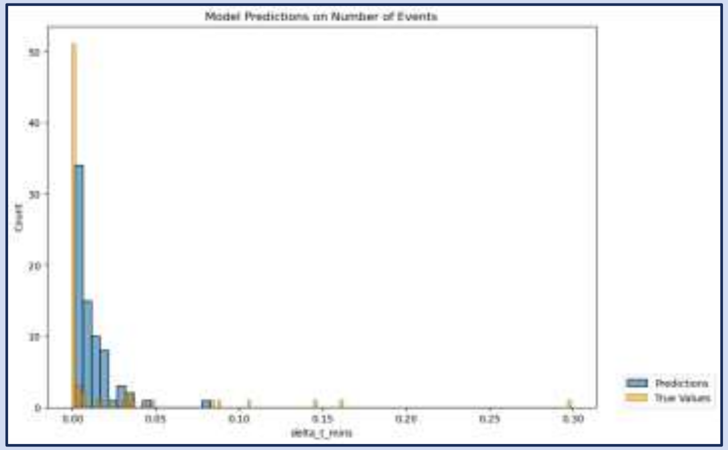


Model

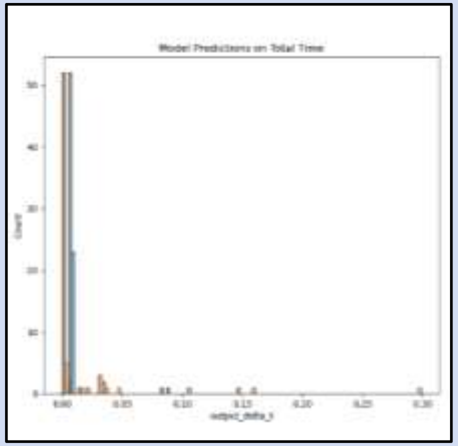
$T_p = F + \mathbf{t_w}'\mathbf{c_w}$

T_p – Predicted search time
F – Fixed time
$\mathbf{t_w}$ – Vector of durations per waypoint category
$\mathbf{c_w}$ – Vector of counts of each type of waypoint

Linear Regression Modeling: Underperforms



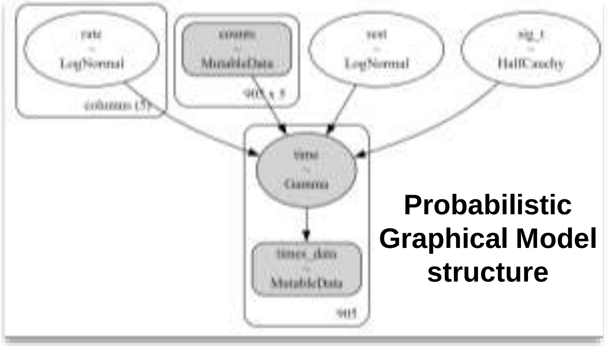
Random Forest



Neural Network

Machine Learning Approaches: Insufficient Data Quality

Bayesian Inference of Building Clearance Times
(Production Rate)

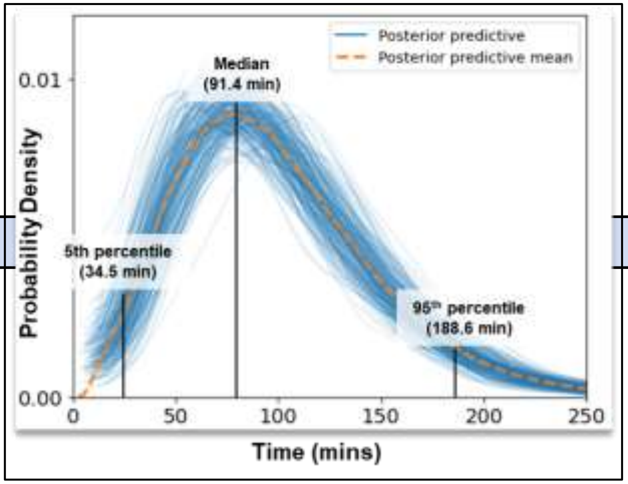


Probabilistic Graphical Model structure

- **Waypoints are not always recorded immediately, must infer clearance time for batches of structures with different damage distributions.**
- **Solution: Probabilistic Graphical Model of the clearance time of each batch of structures.**
- **Using Bayesian Inference, estimate probability distribution of clearance times for any given input batch**

Unaffected	Affected	Minor	Major	Destroyed
50	0	0	20	50

Input Distribution of Structures and Damage Categories



Estimated clearance time probability distribution for input

Fastest	Median	Slowest
34.5 min	91.4 min	188.6 min

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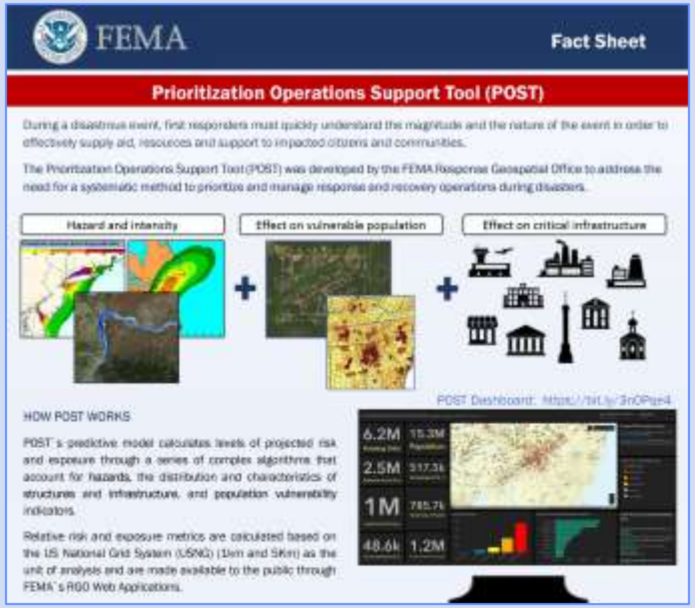

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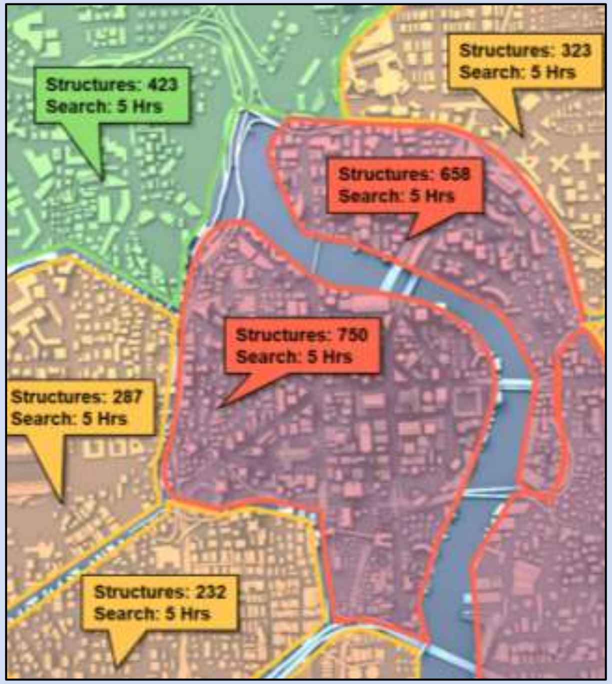
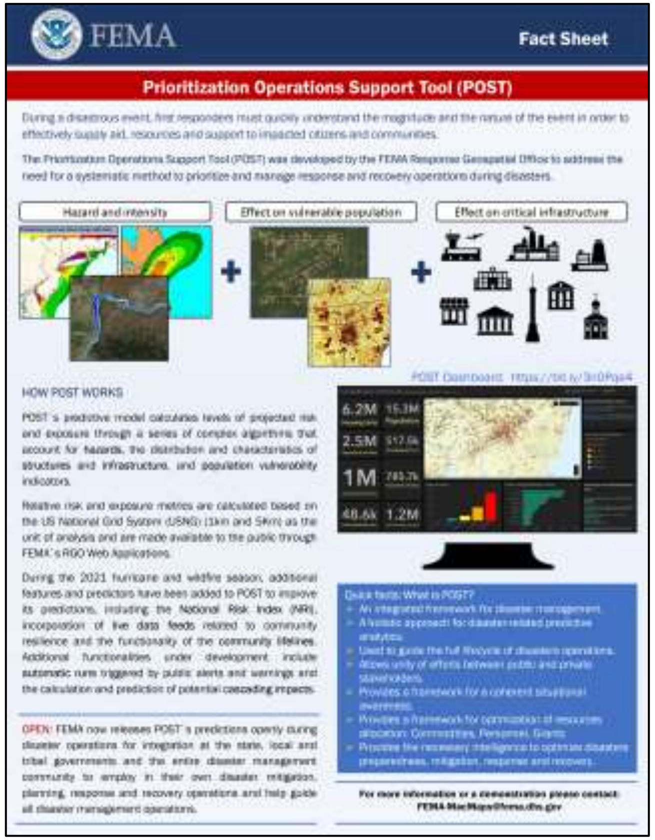


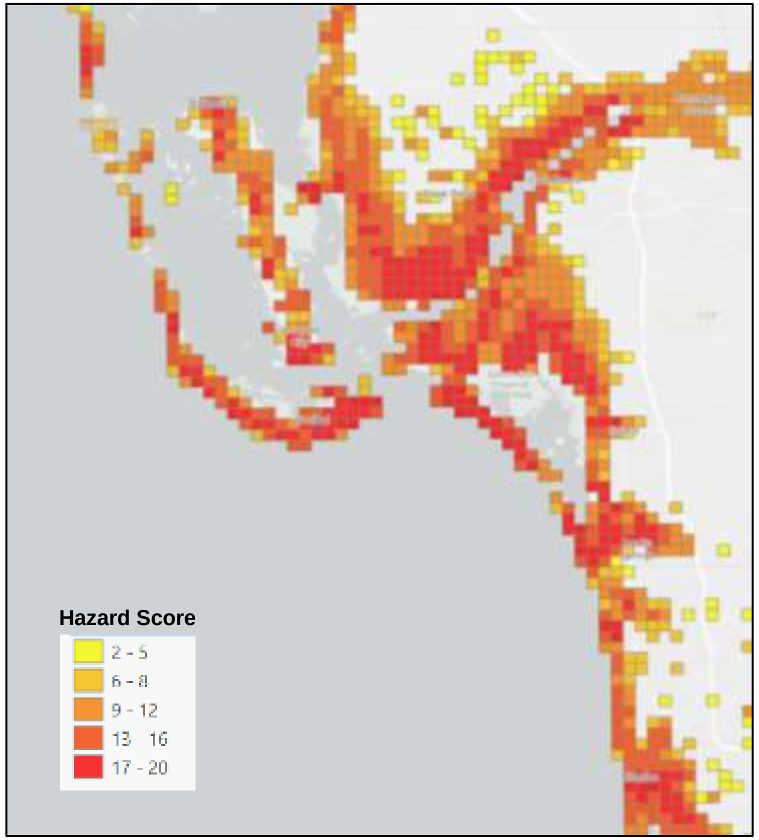
Intelligent Auto-Search Segmentation

Establishing search performance metrics that are relative to damage conditions, combined with damage forecasting, enables urban areas to be auto-segmented equally according to expected levels of work.

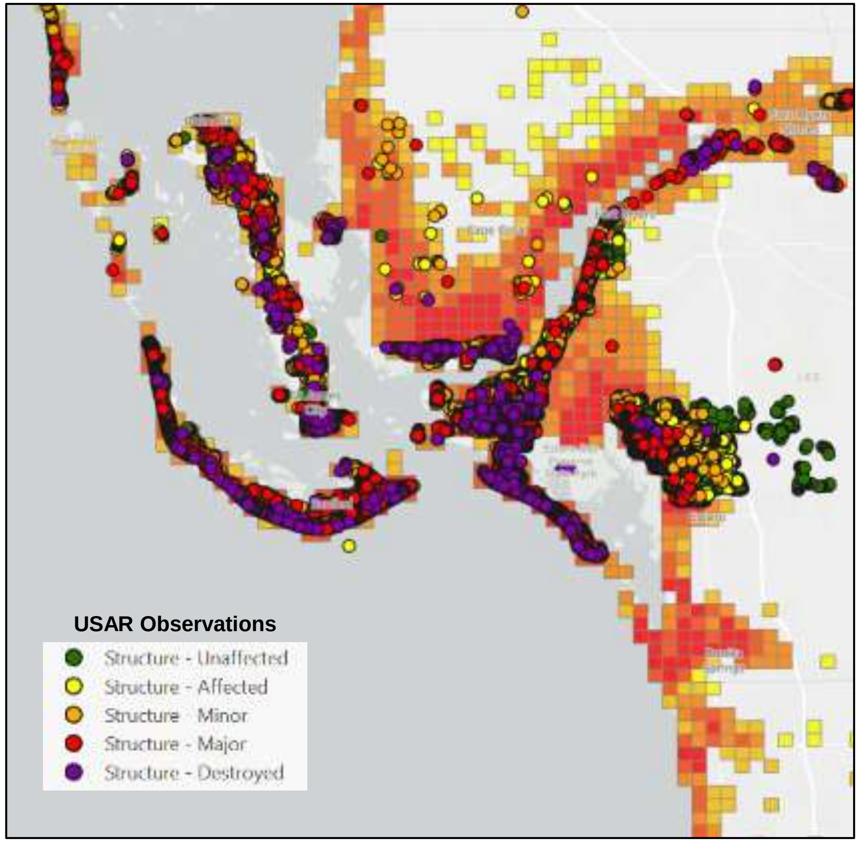
FEMA TEMPO[1] / POST[2] Overview



POST Fact Sheet



Sample Output for Hurricane Ian

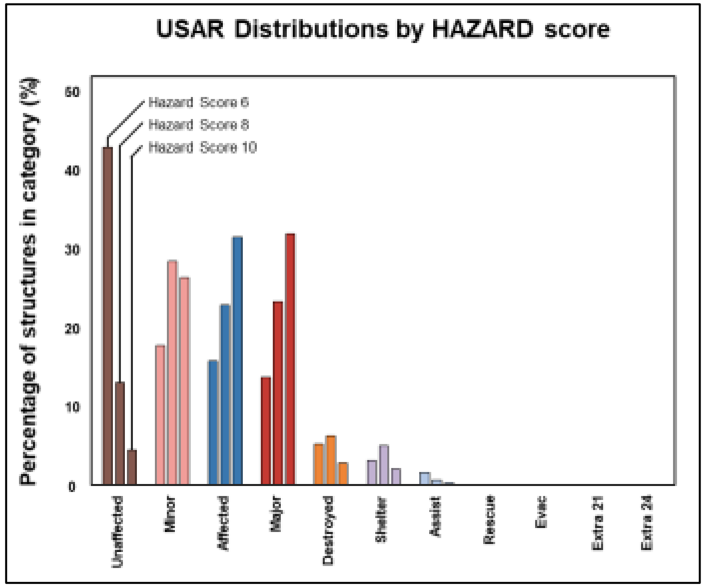


USAR Observations for Hurricane Ian

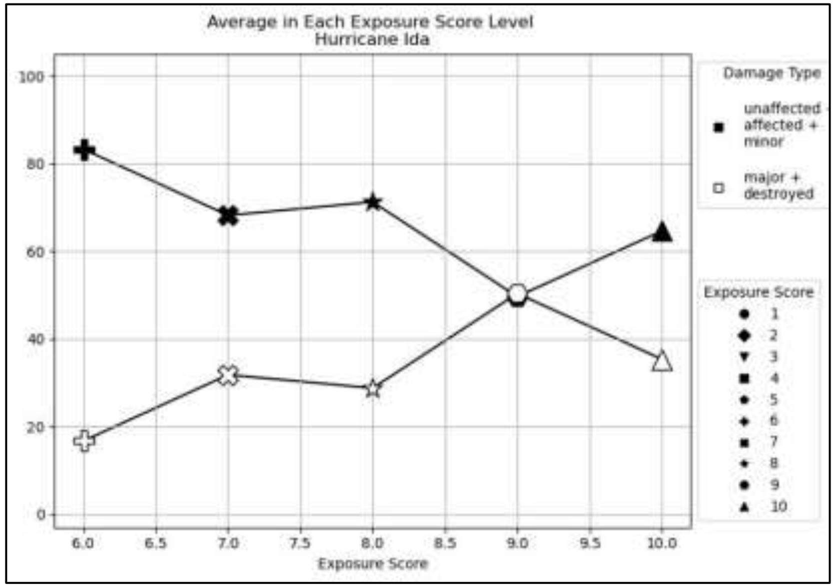
This continuously evolving product combines multiple impact models to provide several decision making insights at the 1km/US National Grid scale.

1. TEMPO: Tool for Emergency Management Prioritization and Operations
2. POST: Prioritization Operations Support Tool

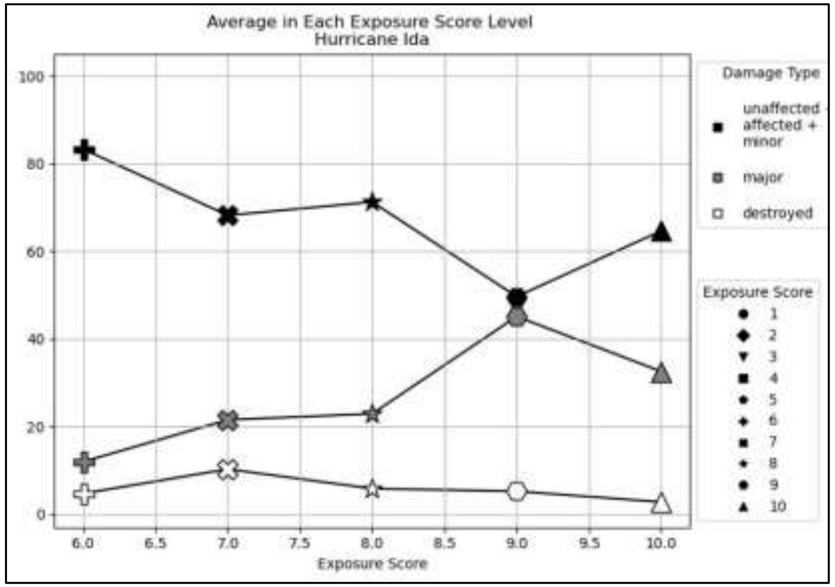
Exploring POST Predicted vs. Observed Damage



USAR Damage Distribution
By Hazard Score



USAR Damage Distribution
By Exposure Score

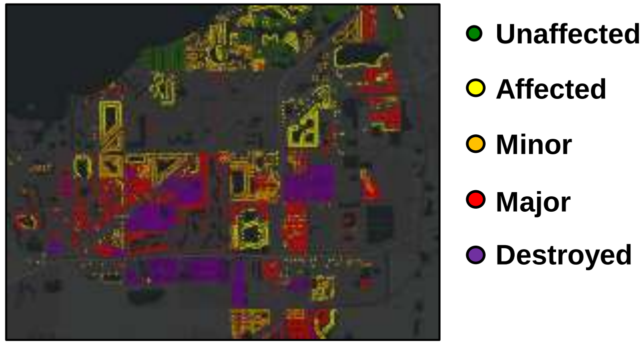


USAR Damage Distribution
By Exposure Score, Grouped

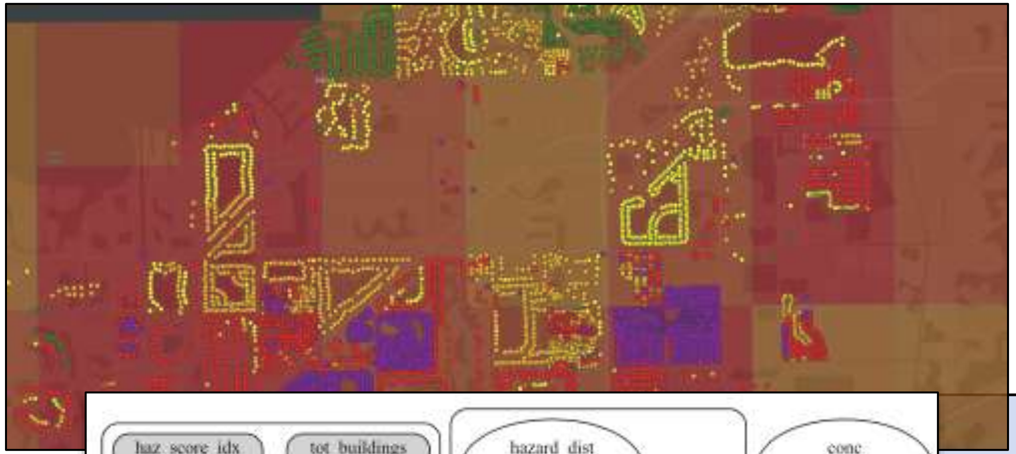
Analyses show a relationship between POST output and observed damage but the relationship is not linear

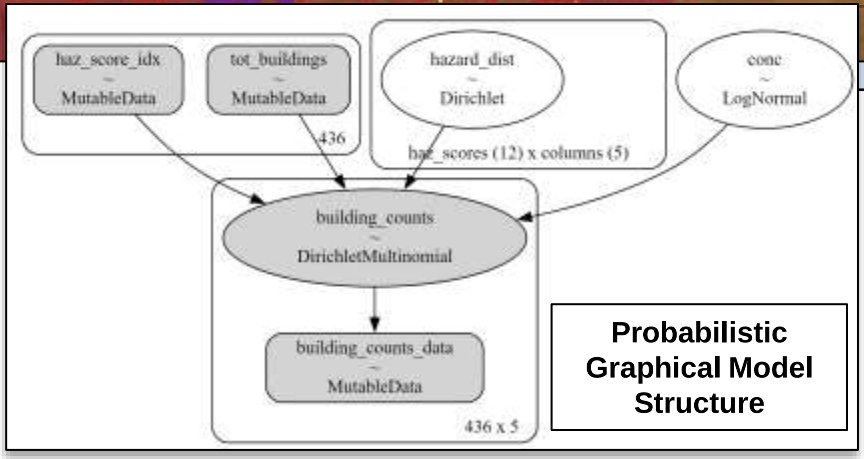
TEMPO Hazard Score vs. Observed Damage

POST Hazard Scores

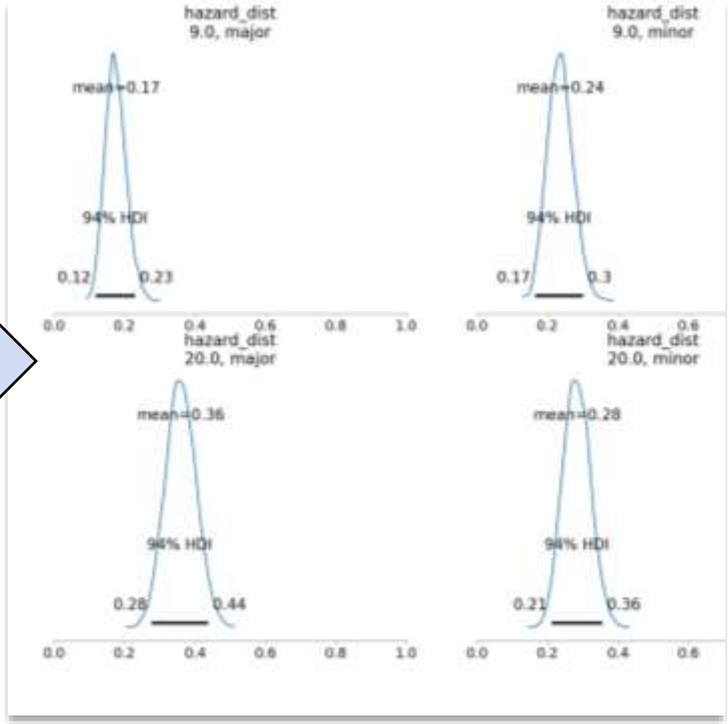


Structure Damage Observations





Probabilistic Graphical Model Structure



A Dirichlet-Multinomial distribution is created to model the probability distributions of building damage levels under different POST hazard scores

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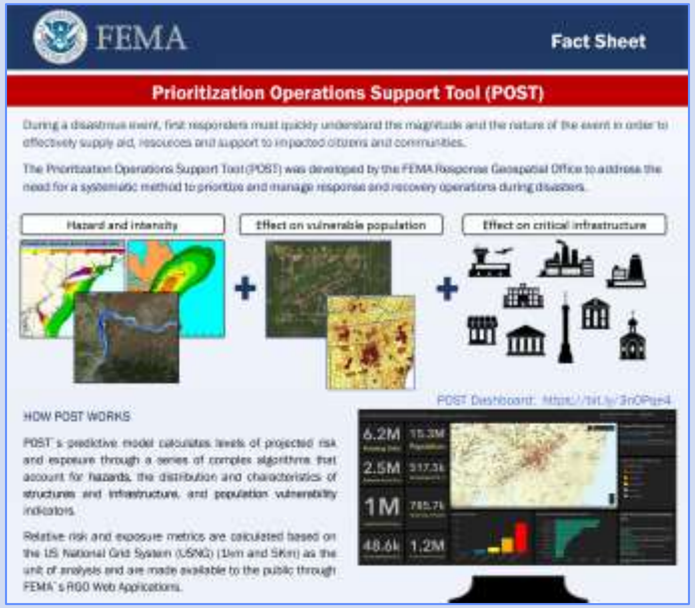
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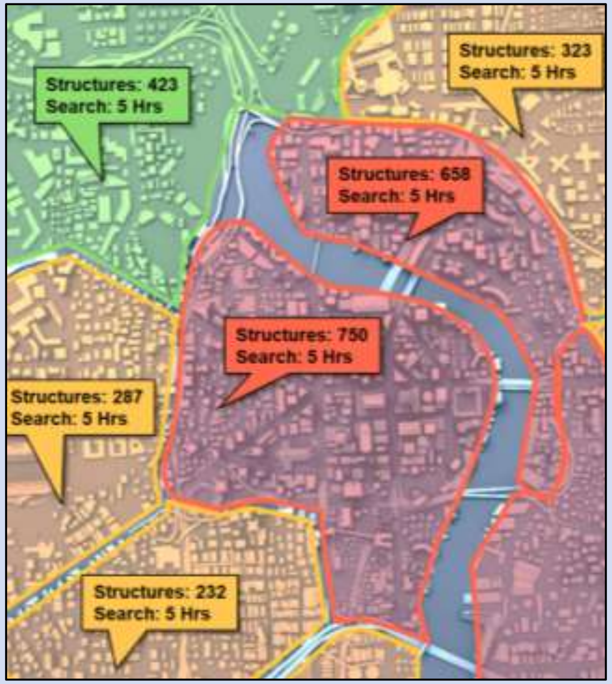

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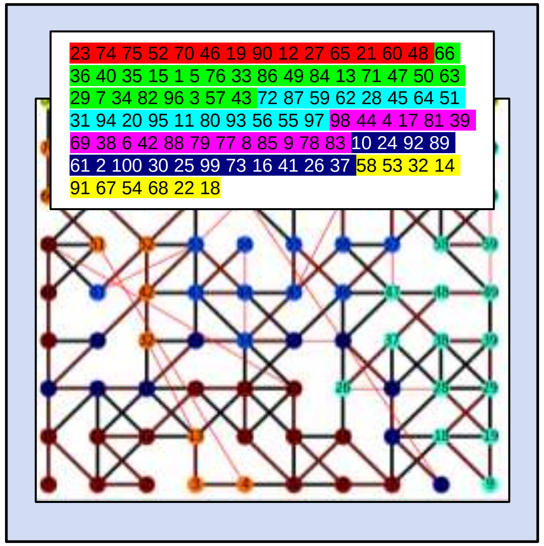
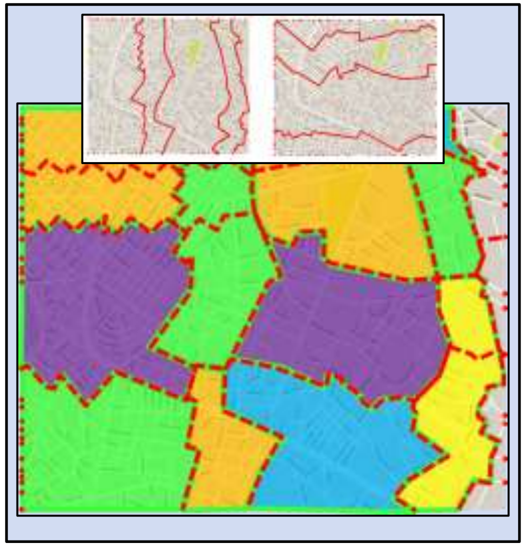
Iterative Approaches

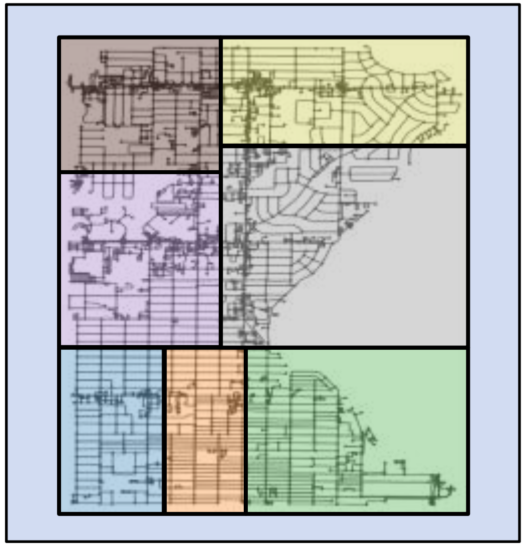


Genetic Algorithm

k-Means Clustering



Division Filtration



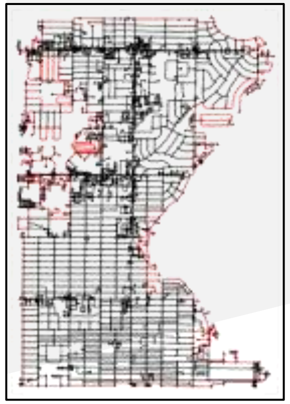
Half-Splitting

	Genetic Algorithm	k-Means Clustering	Division Filtration	Half-Splitting
Boundaries				
Rules				
Evenness				
Performance				

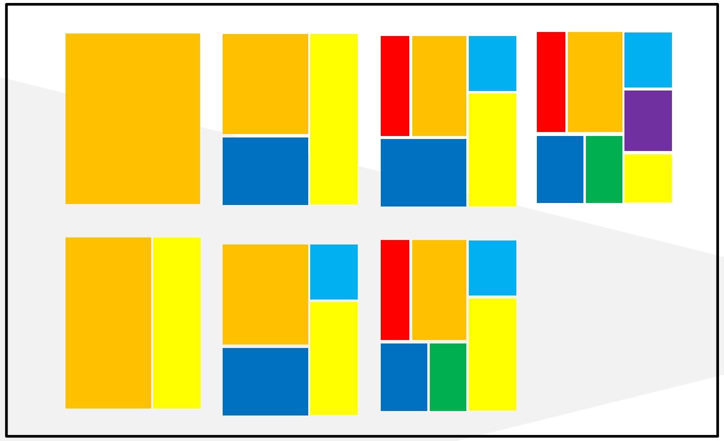
Goal: Divide city into compact areas of equal effort, bounded by straight edges, roads, and rivers.

Half-Splitting With Iteration Cleanup

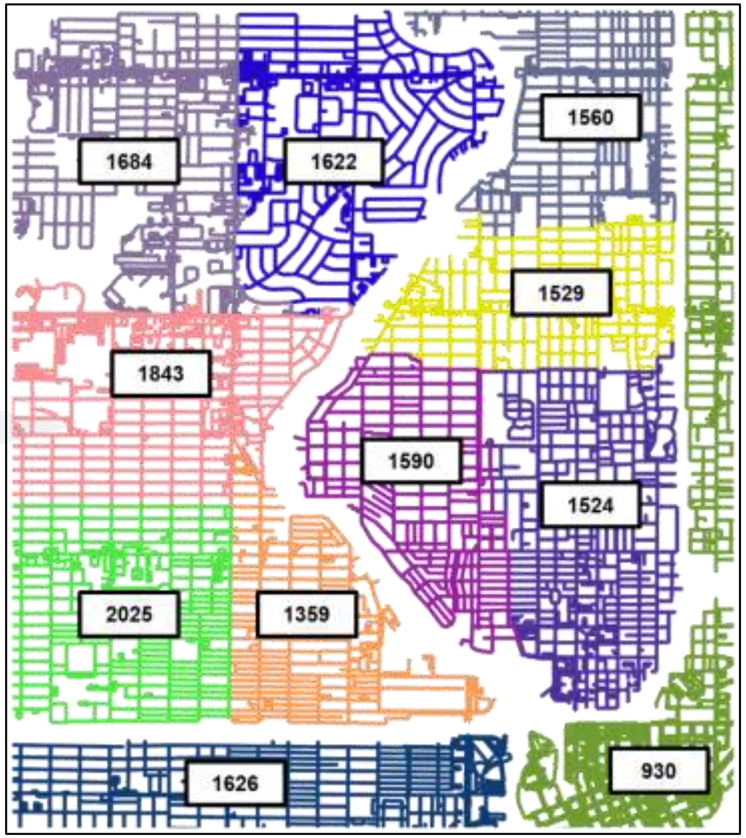
Preprocess:
Remove bridges and highways.
Find connected components



Identify edges on the perimeter



Visual representation of **half-splitting algorithm (HSA)**. Known valid and terminating algorithm on continuous spaces

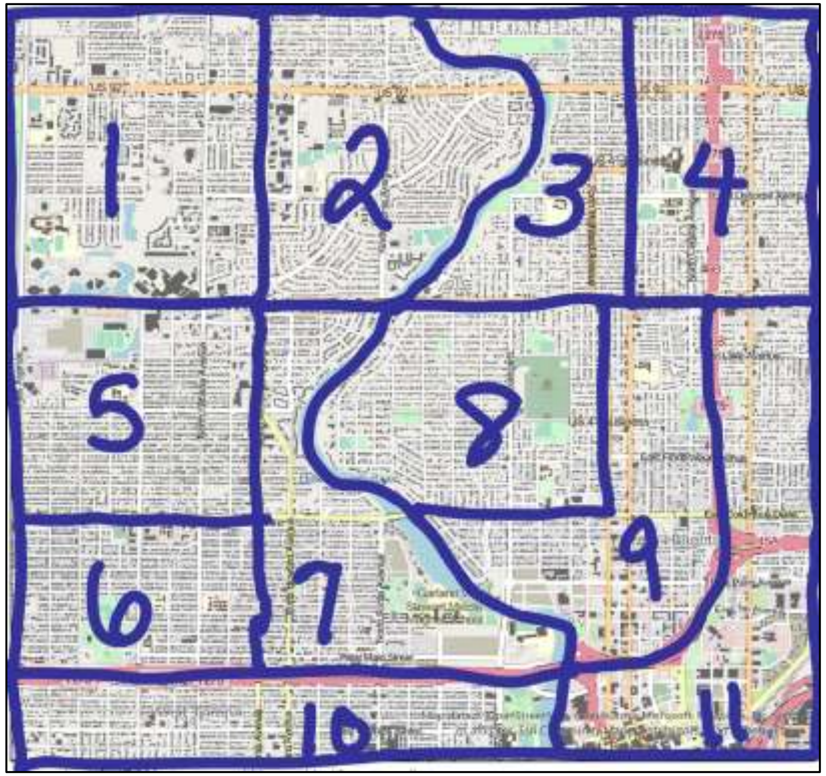


Segments with near-equal building counts

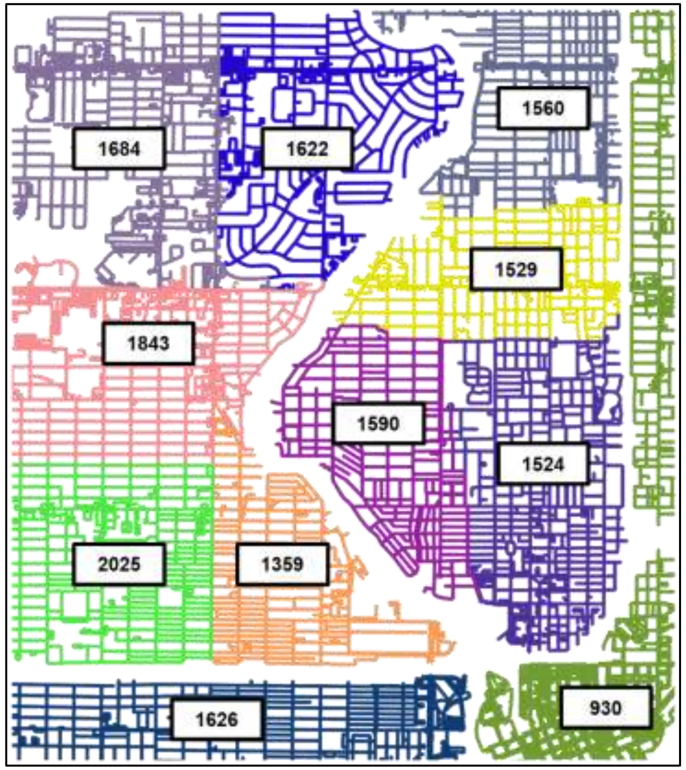
Resulting algorithm divided the test area into segments that were sized within 15% of optimal

Comparison

Approximately 17,000 structures in 10 mi^2
Tampa, FL



Experienced Manual Segmentation

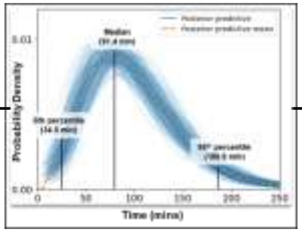


Automated Segmentation

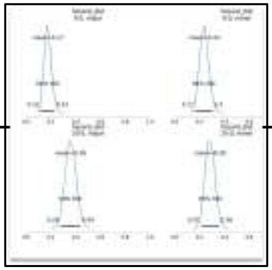
**Initial comparison with human experts show very high agreement.
Some differences due to edge location of algorithm input data**

Applying Research To Operations

Performance Under Different Conditions

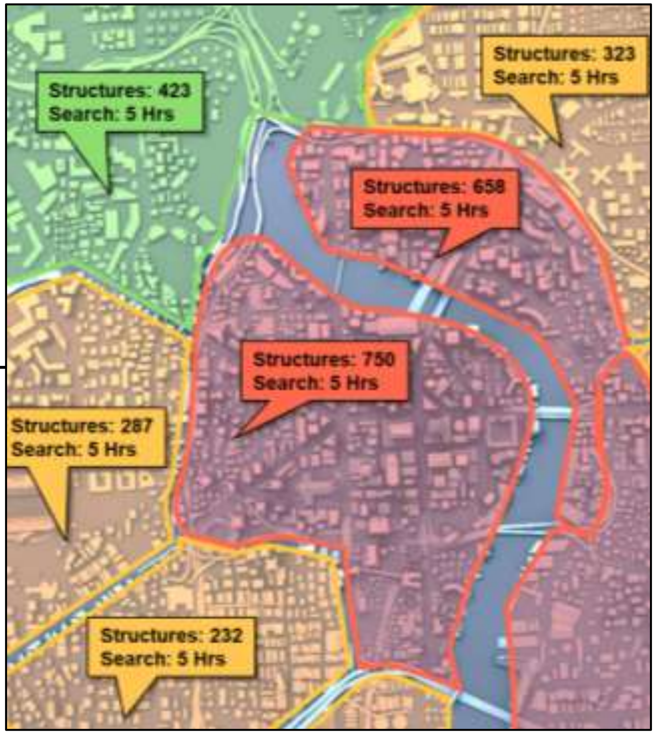


Expected Conditions in an Area



Automated Urban Segmentation

Generate:
Segments of equal work

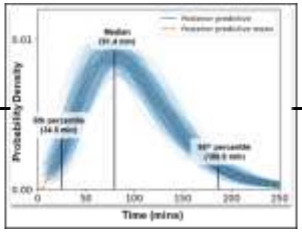


Intelligent Auto-Search Segmentation

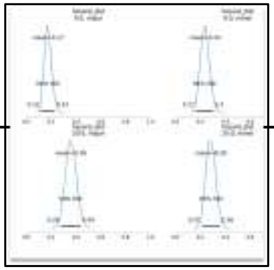
A demonstration pipeline was built around static polygons for input while the segmentation research continued

Applying Research To Operations

Performance Under Different Conditions



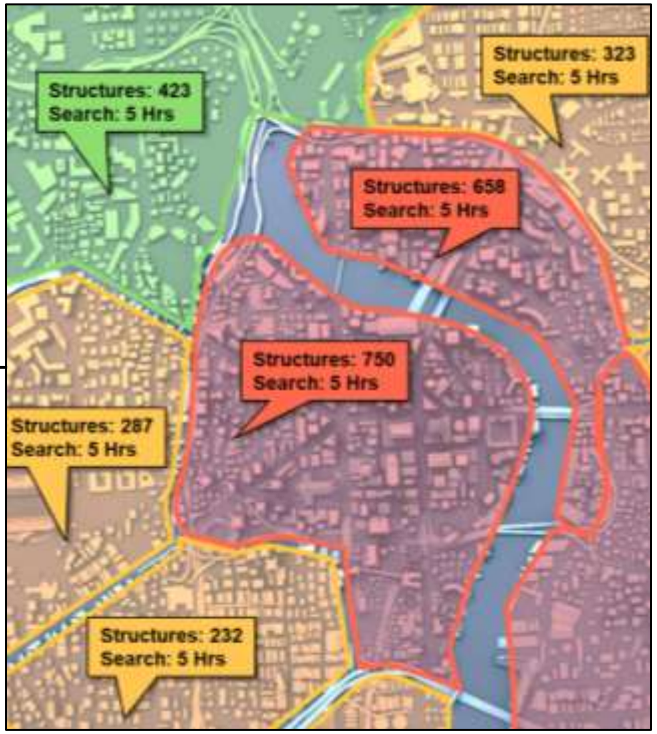
Expected Conditions in an Area



Automated Urban Segmentation

Census Block Groups

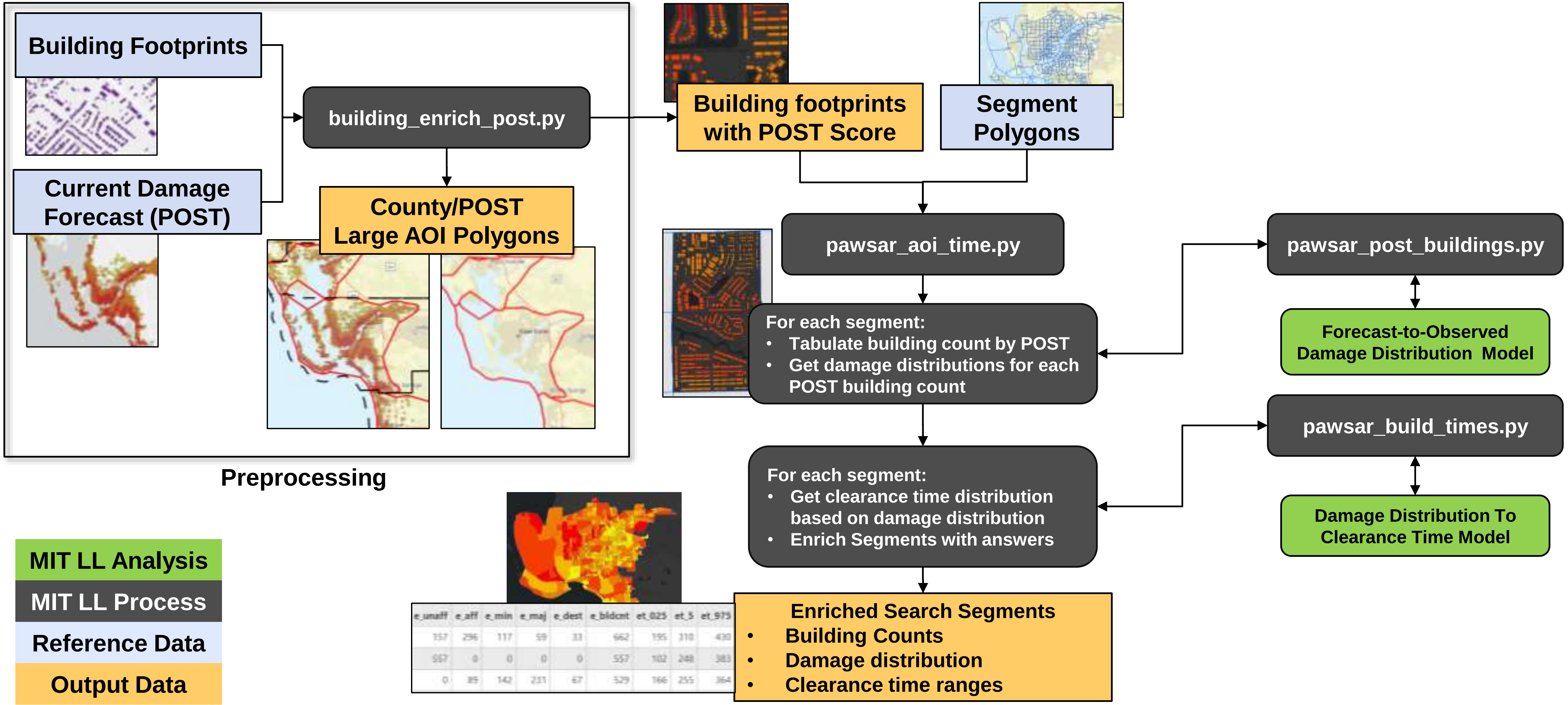
Generate:
Segments with estimates of work time.



Intelligent Auto-Search Segmentation

A demonstration pipeline was built around static polygons for input while the segmentation research continued

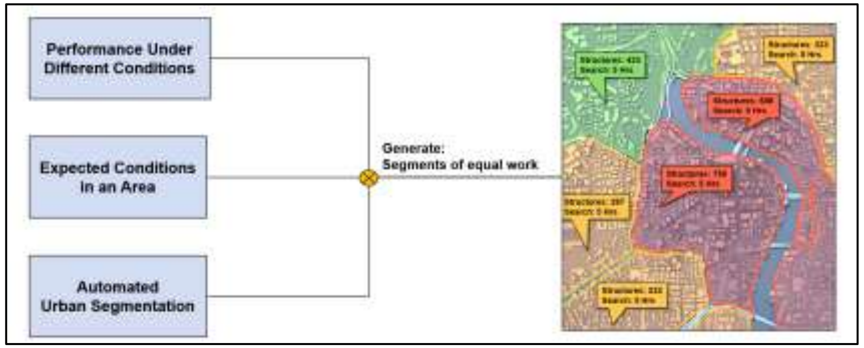
Intermediate Pipeline Implementation



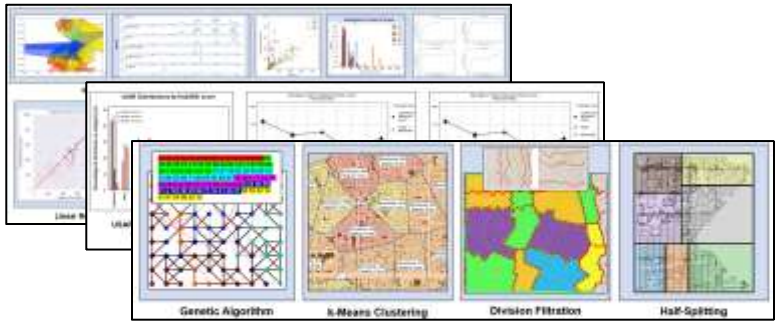
e_unaff	e_aff	e_min	e_maj	e_dest	e_bldcnt	et_025	et_5	et_975
157	296	117	59	33	662	195	310	430
557	0	0	0	0	557	102	248	383
0	89	142	231	67	529	166	255	364

R&D Summary

Research Question: Can we intelligently scale and assign USAR resources for hurricane responses?

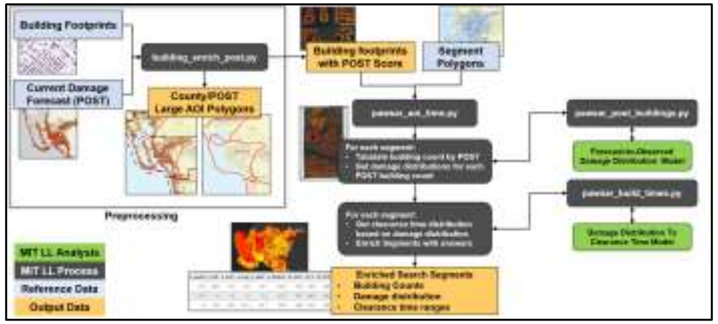


1. Concept Development



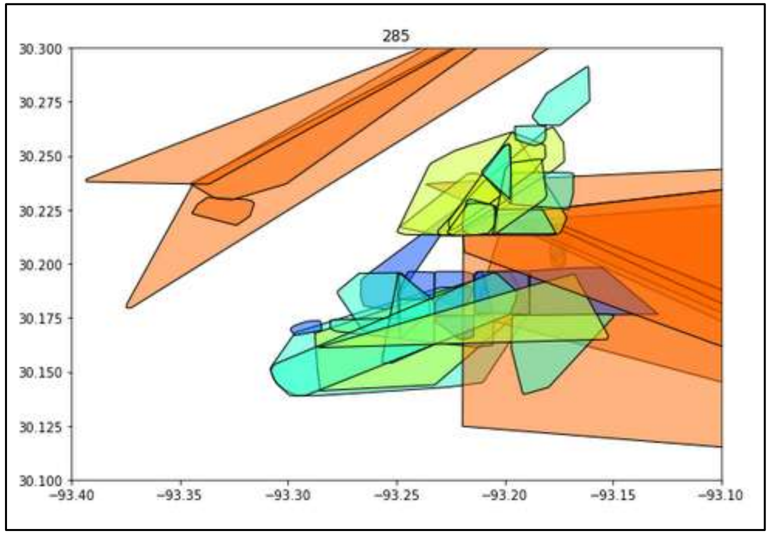
3. Iteratively Research Each Line of Effort

2. Identify Lines of Effort



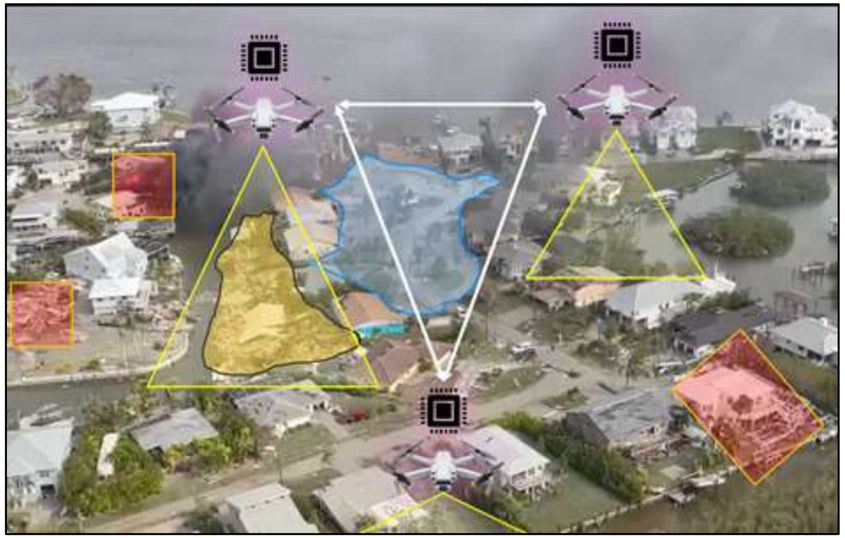
4. Test Concept With Research Results

Research Generates New Questions



Convex Hulls for USAR Movements
Hurricane Delta

Area Coverage Rates for Recon and Intel



Notional sUAS[1] Swarm for USAR

Studying movement of USAR teams and studying remote sensing support for USAR drove a new question:
Could a cooperative swarm of small uncrewed aerial systems provide USAR teams with boundaries and damage cluster identification faster than current methods? What does the human/machine team look like?

1. sUAS: Small Uncrewed Aerial System

Summary

- Research and development can be a slow and iterative process
- Complex problems can be broken into component parts that are interdependent
- We developed a proof-of-concept prototype that is Technology Readiness Level 4.
- New ideas for additional research emerged: sUAS Swarm Support
- Future work:
  - Validation outside of the laboratory
  - Formalization of requirements
  - Validation in parallel with an operation
  - Testing/demonstration during an operation
  - Iterative improvements until accepted by users
  - Integration into operational environment
  - Deployment and user training

Acknowledgements

MIT Lincoln Laboratory

- Chad Council
- Dr. Dieter Schuldt
- Dr. Jeff Liu
- John Aldridge
- Grace Kessenich
- Kendrick Cancio
- Consuelo Cuevas
- Thomas Garcia Lavanchy
- Rajmonda Caceras

USAR Community

- National Search and Rescue Geospatial Coordination Group
- National Alliance for Public Safety GIS
- FEMA Urban Search & Rescue
- FEMA Response Geospatial Office
- State Urban Search and Rescue

Contact: Chad.Council@ll.mit.edu

UNCC Research

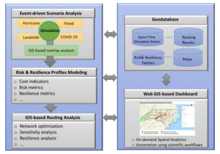
Bojan Cukic, PhD, UNC Charlotte
Wenwu Tang, PhD, UNC Charlotte

Public Safety Research At the University of North Carolina at Charlotte

Bojan Cukic
Dean and Professor
College of Computing and Informatics
The University of North Carolina at Charlotte



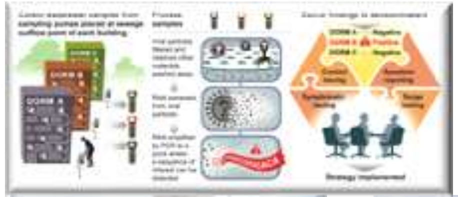


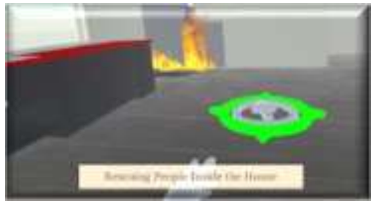



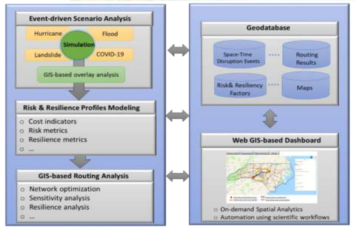
InSPIRE: Innovation Summit for Preparedness & Resilience, November 16-17th, 2023
The Dubois Center at UNC Charlotte, North Carolina

Public Safety Research At UNC Charlotte

- Implementing Building-Level **SARS-CoV-2 Wastewater Surveillance** on a University Campus
- **Immersive** Technology of **Firefighting** and Public Safety
- Personalized Training, Privacy and Fairness
- Inspecting Road Networks using **Multiple Robots**
- Low-Light **Collision Scene Reconstruction**
- Spatial analysis and mapping of **crime**
- **Railway safety and trespass** studies via social media data mining
- Transportation Infrastructure-based Perception and Control for **Traffic Safety**
- **Hurricane** studies
- GIS-based tools for analytics of transportation risks and resilience in response to **extreme events**

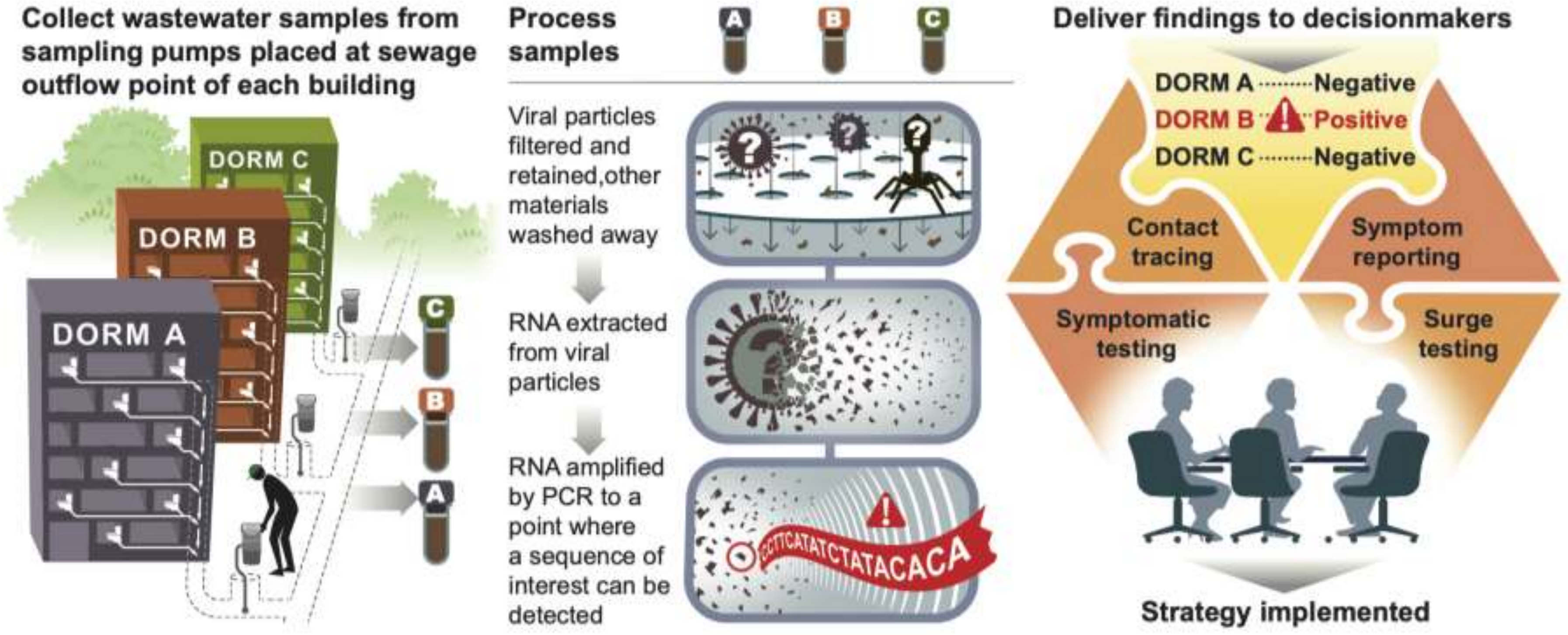



Implementing Building-Level SARS-CoV-2 Wastewater Surveillance on a University Campus

Cynthia Gibas, Kevin Lambirth, …, Don Chen, Srinivas Akella, Wenwu Tang, Jessica Schlueter, Mariya Munir
Bioinformatics and Geonomics, Bioinformatics Research Center, Engineering Technology and Construction Management
Computer Science, Geography and Earth Sciences, Center for Applied GIScience, Civil and Environmental Engineering



Gibas, Cynthia, Kevin Lambirth, Neha Mittal, Md Ariful Islam Juel, Visva Bharati Barua, Lauren Roppolo Brazell, … Jessica Schlueter & Mariya Munir, 2021. "Implementing Building-Level SARS-CoV-2 Wastewater Surveillance on a University Campus." *The Science of the Total Environment*, March, 146749.

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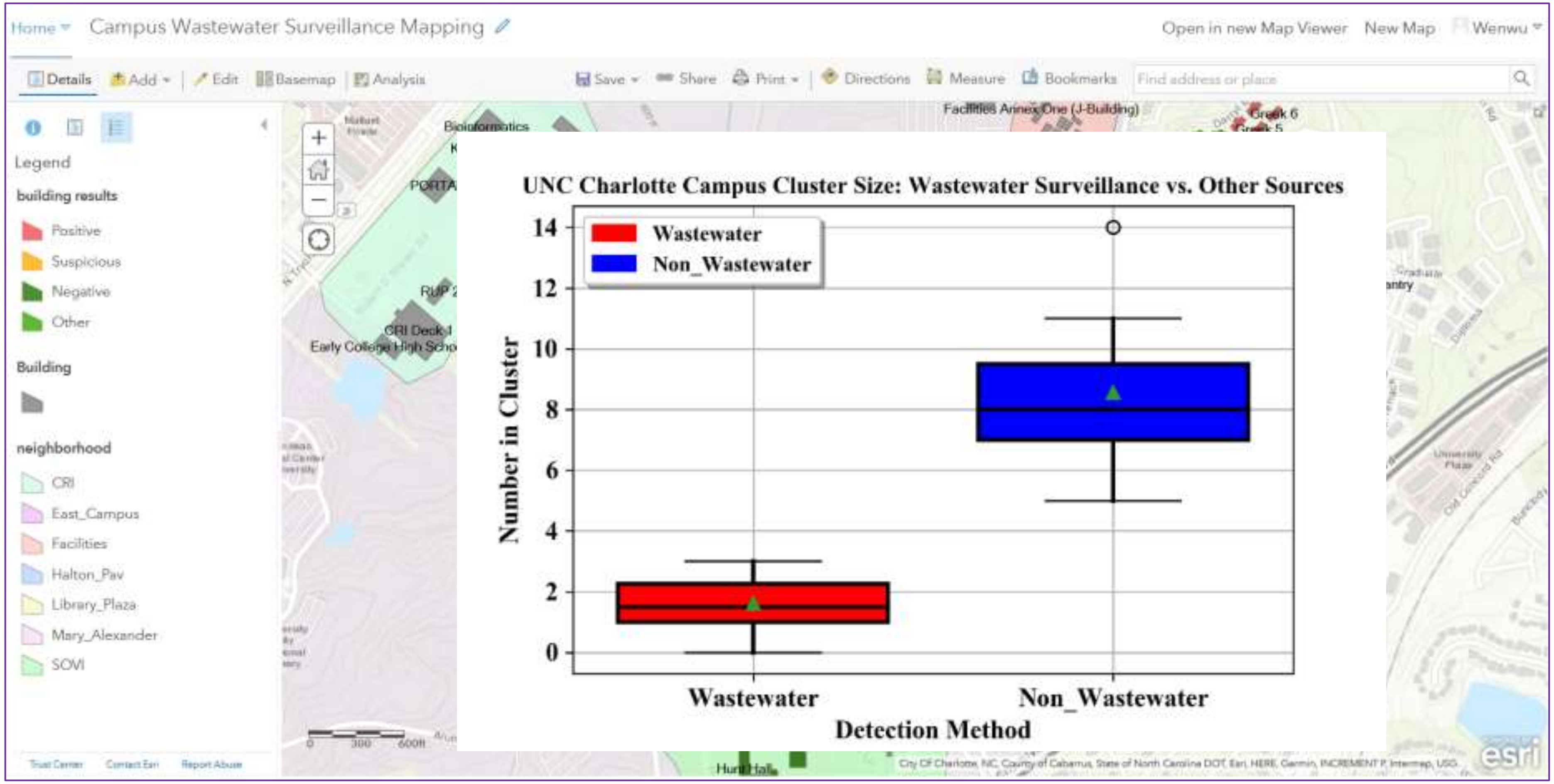
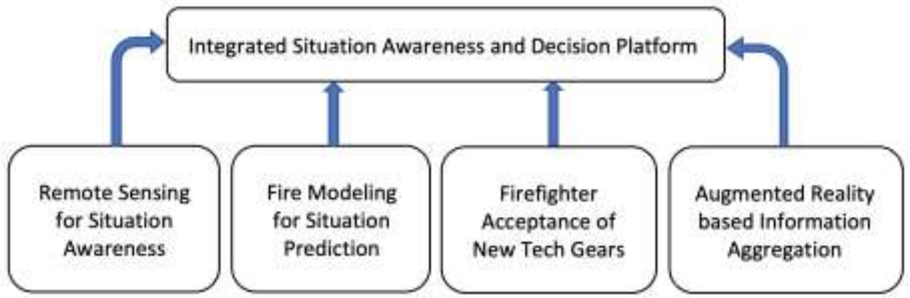
Wastewater surveillance on UNC Charlotte Campus

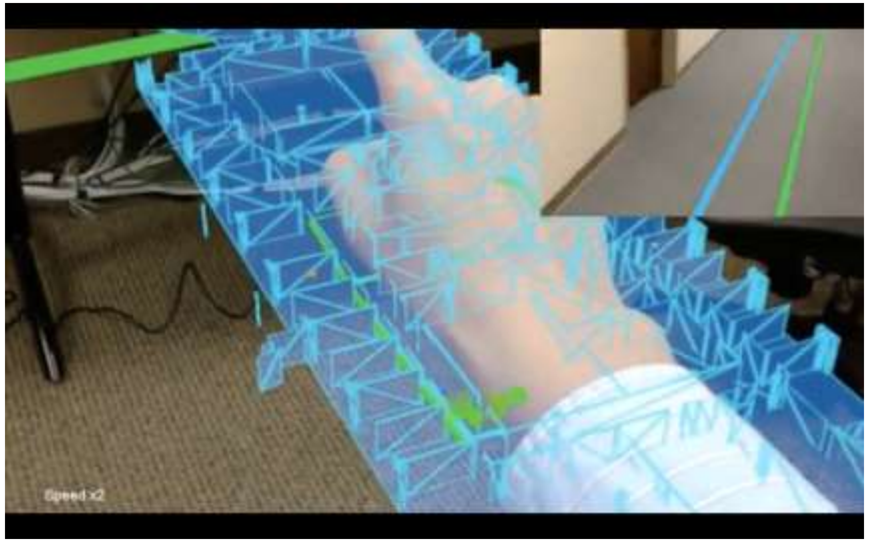


Immersive Technology of Firefighting and Public Safety

Aidong Lu, Weichao Wang, Aixi Zhou, Wei Zhao (CCI)

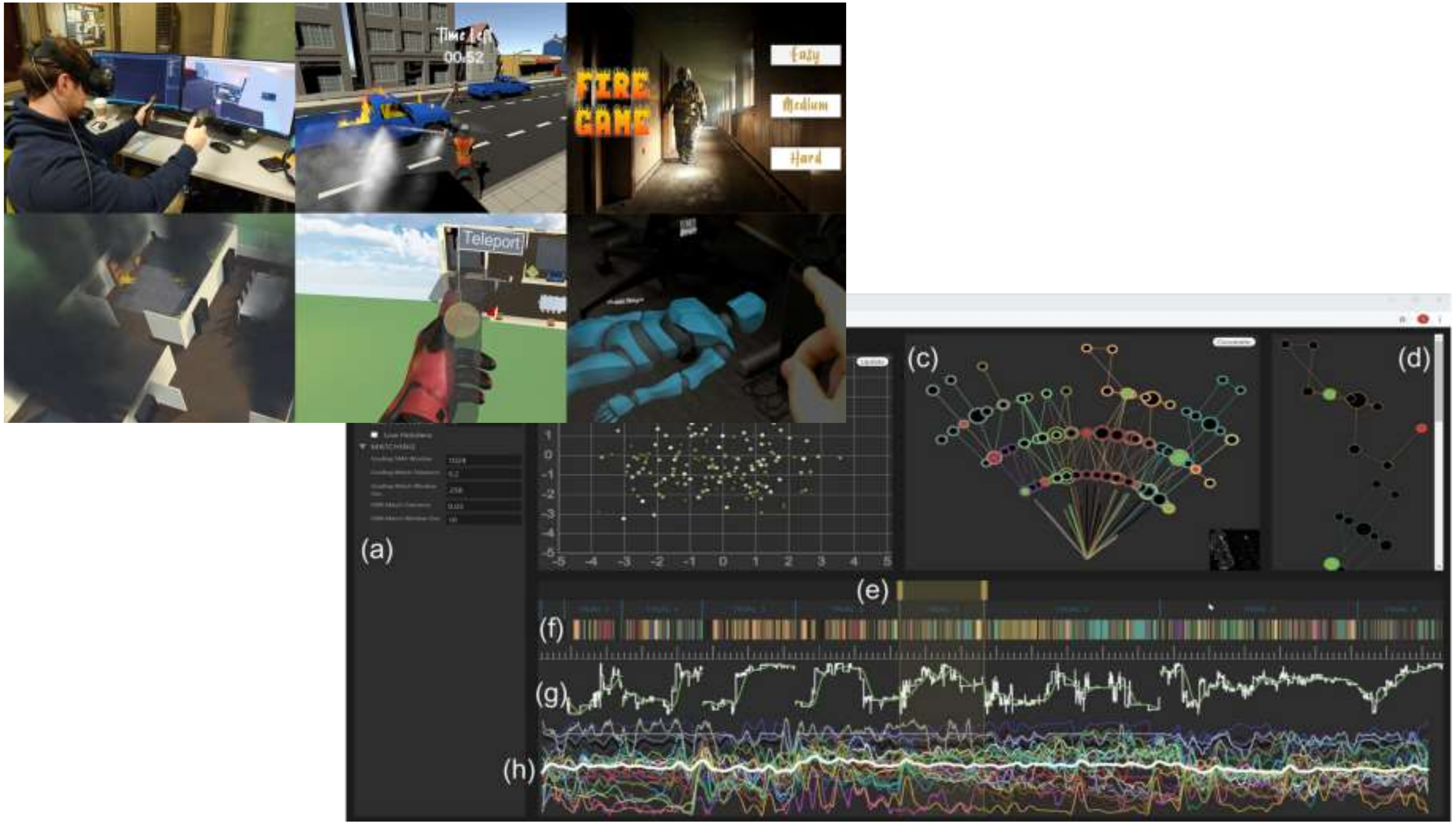
- Enhance firefighting through novel augmentation technologies





Personalized Training, Privacy and Fairness

Aidong Lu, Depeng Xu, Weichao Wang, Alexia Galati (CCI)

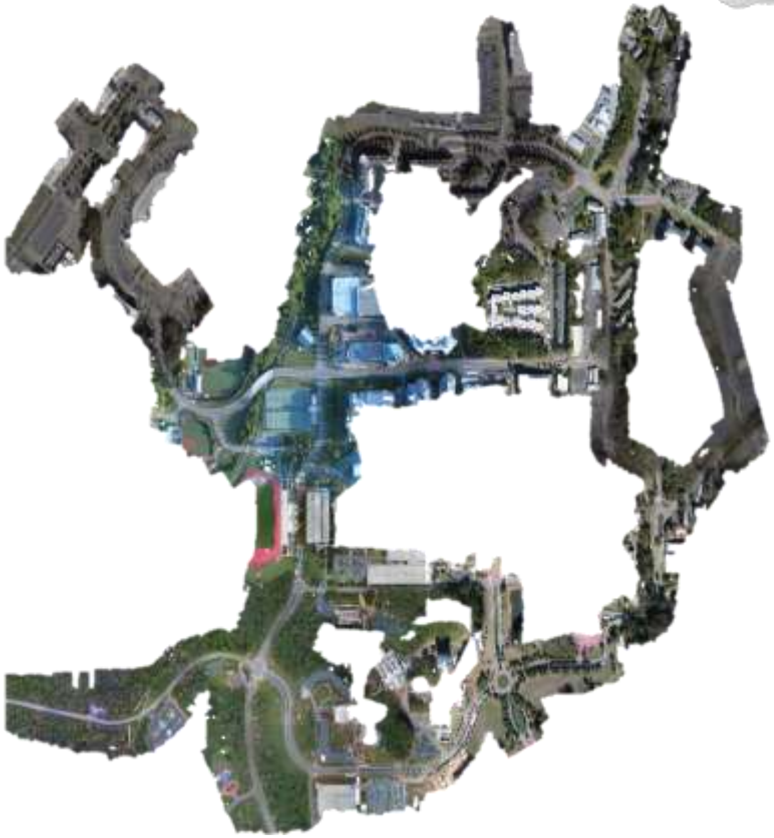


OUTREACH: CLT FIRE AND POLICE ACADEMY

UNIVERSITY OF NORTH CAROLINA CHARLOTTE

Inspecting Road Networks using Multiple Robots

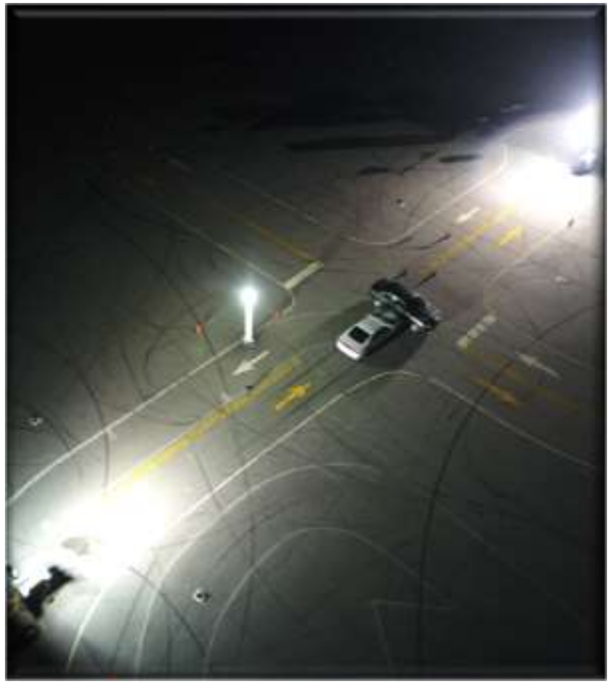
Saurav Agarwal, Ninh Nguyen, Srinivas Akella from CCI

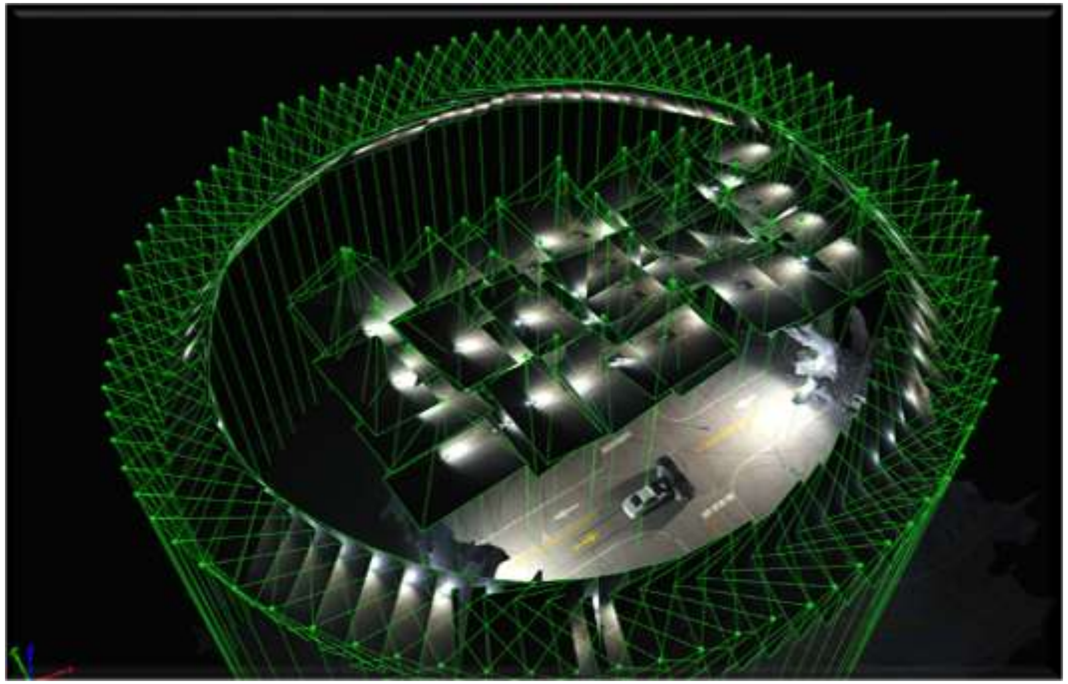


THE UNIVERSITY OF NORTH CAROLINA SYSTEM

Low-Light Collision Scene Reconstruction

Sayantan Datta, Srinivas Akella from CCI





How do we obtain investigation-grade reconstructions for low-light scenes?

RTI INTERNATIONAL

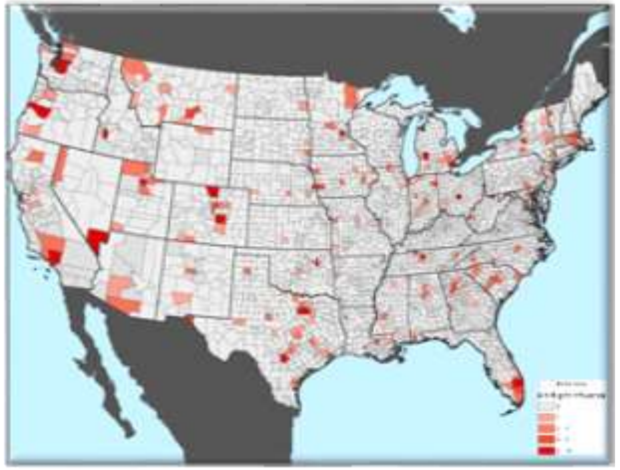
STATE OF NORTH CAROLINA DEPARTMENT OF TRANSPORTATION

NORTH CAROLINA HIGHWAY PATROL

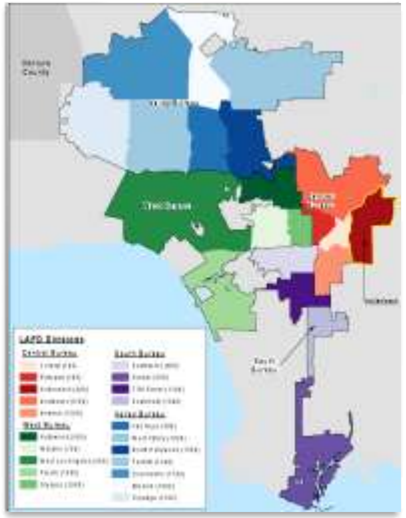
Spatial Analysis and Mapping of Crime

Dr. Shannon Reid (s.reid@charlotte.edu)
(Criminal Justice)

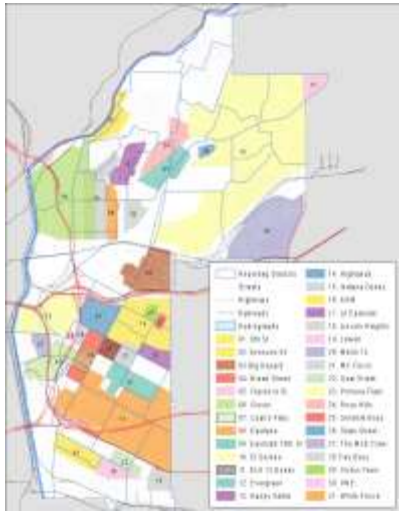
Mapping Daily Stormer (white power website) APIs



LAPD Police Divisions



Hollenbeck Divisions Gang Territories



Gang Rivalry Networks in Space

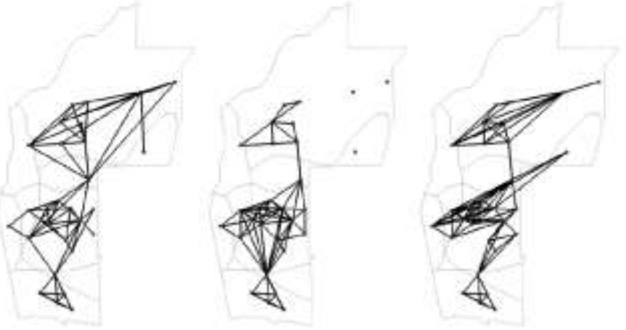


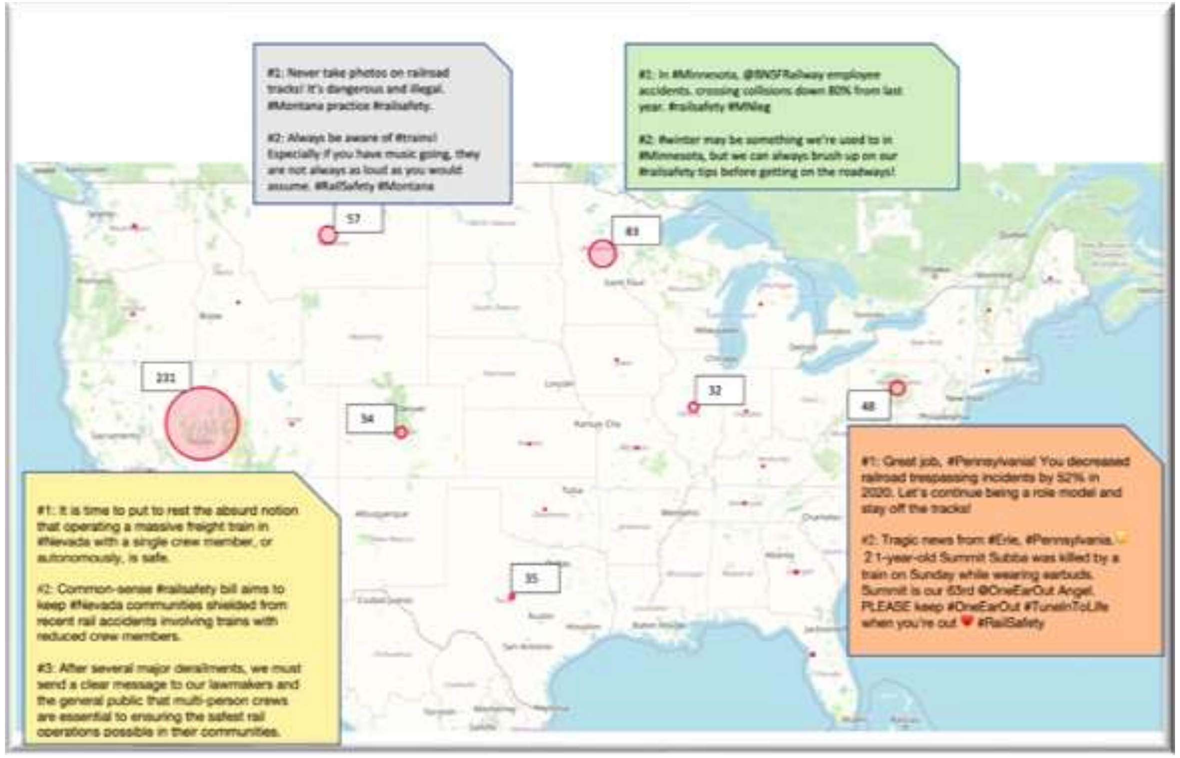
Fig. 4. A visual comparison of the observed rivalry network (left), GTG (center), and BMN (right). Here, a node of the network represents a set space, and an edge represents a rivalry between two gangs.

Public Perceptions of Railroad safety and Trespassing via Social Media Data Mining

Yuting Chen, Wenwen Dou, & Shrabani Ghosh
(Engineering Technology & Construction Management, Computer Science; Yuting.Chen@charlotte.edu)

- Topic modelling
- Emotion analysis
- Organization tags
- Geographical hashtag analysis

No.	Topic Examples	Count
1	Derailment	488
2	Teach children railroad safety	463
3	Didn't see train coming	195
4	September safety week	152
5	Stay off the tracks	115
6	Railroad trespassing-year high	58
7	Support railroad safety	53
8	Trespassing incidents-serious injured	28
9	Remove headphones	17
10	Private property, no trespassing	13

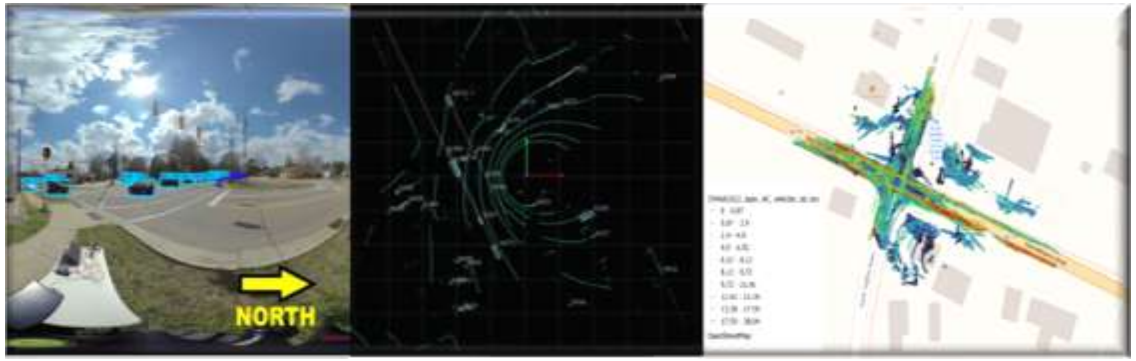


Data collection: twitter data from January 2017 to May 2022, including 93,239 tweets

Transportation Infrastructure-based Perception and Control for Traffic Safety

Lei Zhu, Ph.D. Assistant Professor of Industrial and Systems Engineering
lzhu14@charlotte.edu

- Pilot at an intersection of Apex, NC; Cost-effective and compatible solutions
- **Safety detection – near misses, crash prevention, signal control, micro-mobility**



CV view LiDAR view Trajectory analysis

Hurricane Studies

Shen-En Chen
(Civil and Environmental Engineering; schen12@charlotte.edu)

Source: NASA

(Photo Credit: Shenen Chen)

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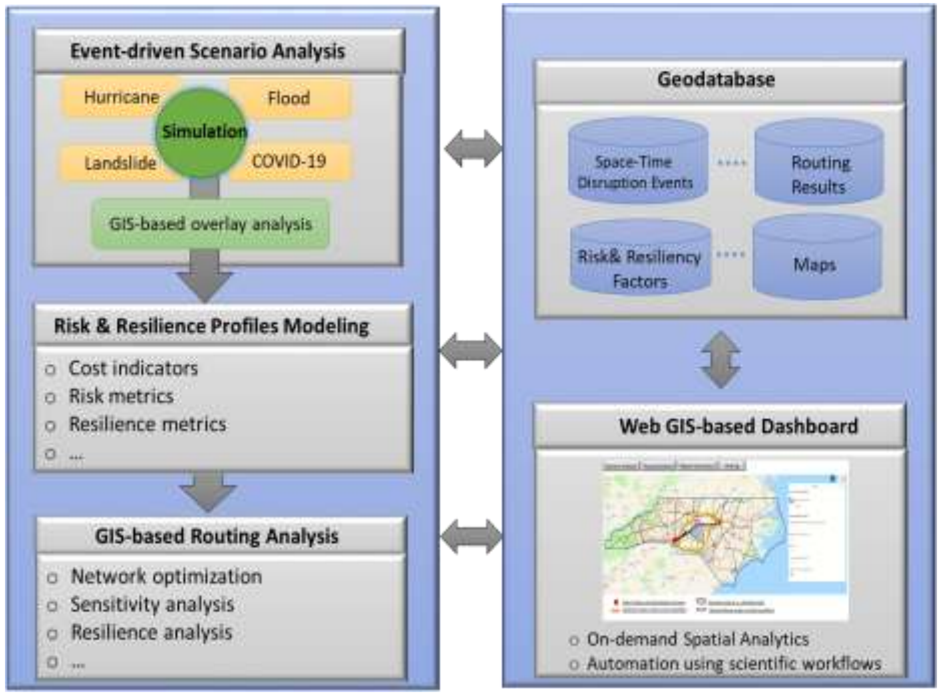
CHARLOTTE

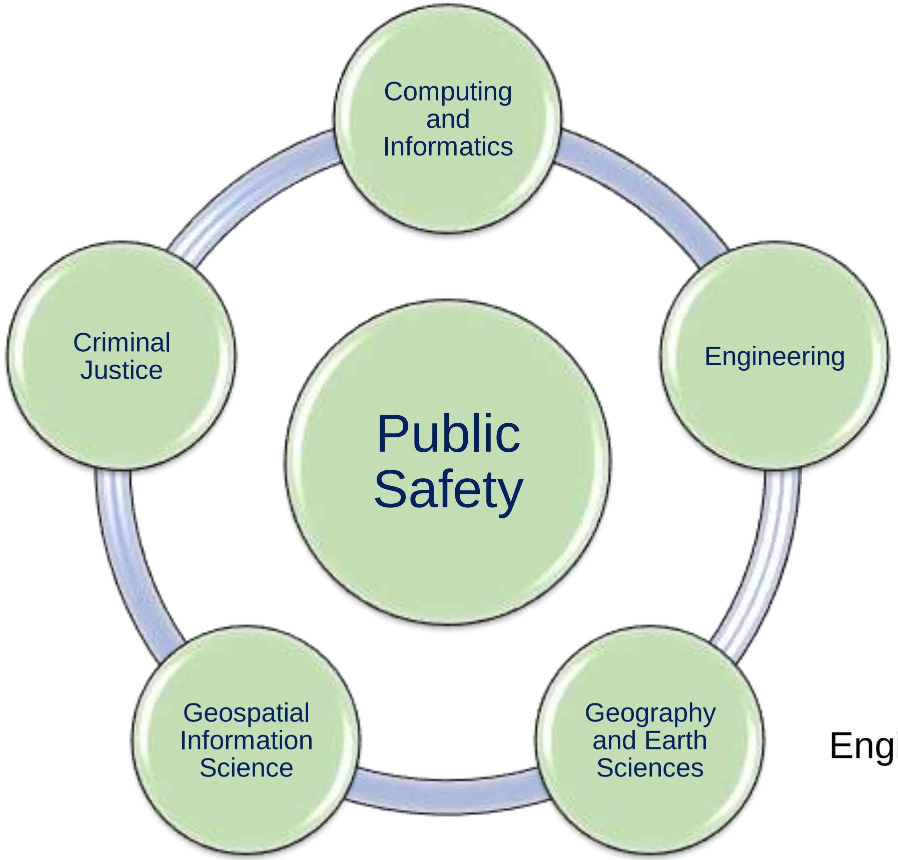
Geo-FRIT: A Web-based Geospatial Analytics Tool for Quantifying Freight Risk and Resilience in Transportation

Wenwu Tang, Wei Fan, Eric Delmelle, Shen-En Chen
Center for Applied GIScience – Center for GeoSpatial Sensing and Analytics
Geography and Earth Sciences
Civil and Environmental Engineering

Extreme Events



Public Safety Research At UNC Charlotte



Integration
Transformation
Innovation

College of Computing and Informatics
Computer Science
Bioinformatics and Geonomics
Center for Applied GIScience
Center for Geospatial Sensing and Analytics
Geography and Earth Sciences
Criminal Justice and Criminology
Civil and Environmental Engineering
Industrial and Systems Engineering
Engineering Technology and Construction Management
School of Data Science

Thanks! Questions?

Bojan Cukic, Dean and Professor

Email: bcukic@charlotte.edu

Deep learning-based detection of 3D hydraulic structures from point cloud data

Wenwu Tang[1,2]
Shen-En Chen[3]
John Diemer[2]
Craig Allan[1,2]
Matthew S. Lauffer[4]

[1] Center for Applied Geographic Information Science
[2] Department of Geography and Earth Sciences
[3] Department of Civil and Environmental Engineering
The University of North Carolina at Charlotte
[4] Hydraulics Unit
NC Department of Transportation

InSPIRE: Innovation Summit for Preparedness & Resilience
11/16/2023

Acknowledgement

- North Carolina Department of Transportation (NCDOT)
- Steering and Implementation Committee from NCDOT:
  - Matthew Lauffer, John W. Kirby, Tom Langan, Gary Thompson, Paul Jordan, Mark Swartz, Mark Ward, Derek Bradner, Brian Radakovic, Kevin Fischer
- This study is supported by the NCDOT project entitled “DeepHyd: A Deep Learning-based Artificial Intelligence Approach for the Automated Classification of Hydraulic Structures from LiDAR and Sonar Data”
  - PIs: Drs. Wenwu Tang, Shenen Chen, John Diemer, Craig Allan from the University of North Carolina at Charlotte
  - Graduate Assistants: Tianyang Chen, Tarini Shukla, Zachery Slocum, Navanit Sri Shanmugam, Vidya Subhash Chavan
- Matthew Macon, Rodney Hough, Donald Early, Photogrammetry Unit, NCDOT

Introduction

- Point cloud data, collected through Geiger and terrestrial LiDAR and bathymetric sonar technologies, provide rich information in terms of hydraulic structures and associated site conditions (Chen 2012; Prendergast and Gavin 2014; Bisio 2017).

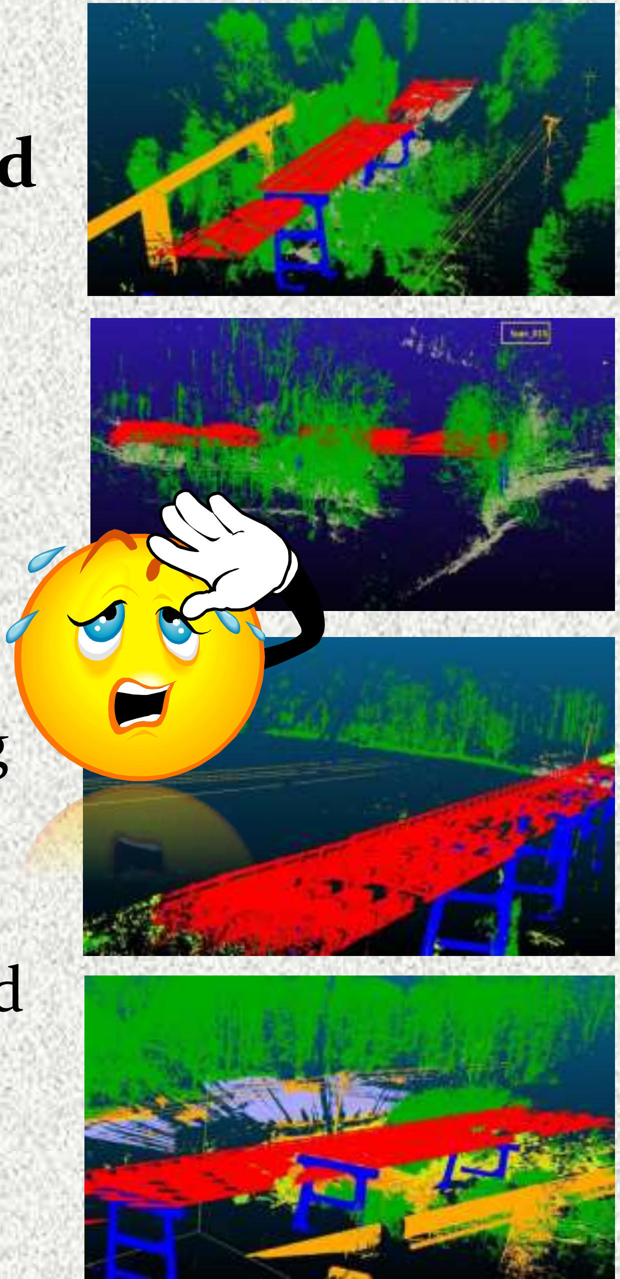
LiDAR 2D image of a bridge

LiDAR 3D scan from the same bridge

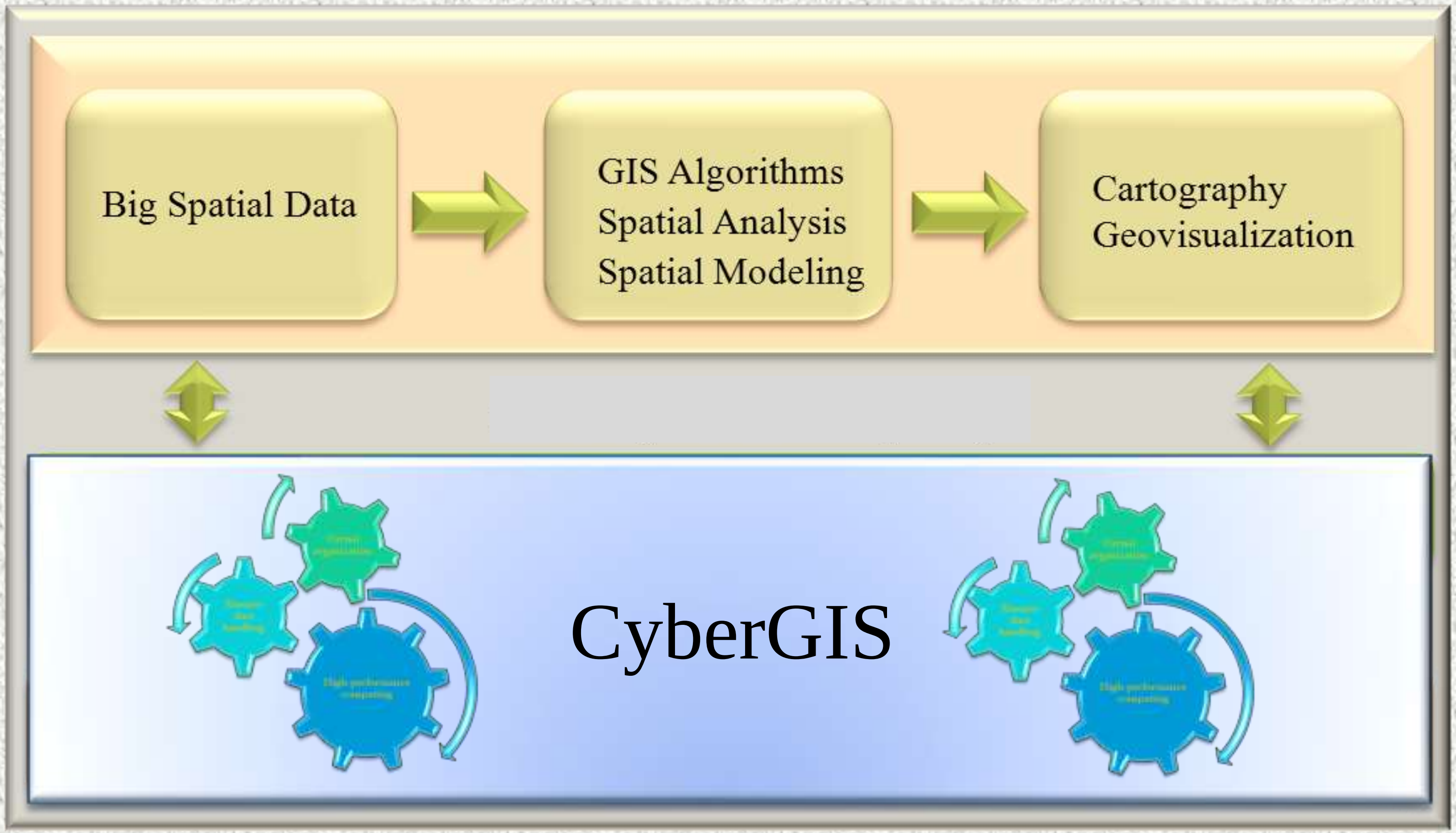
The bridge is located in Gaston County, NC

Current Issues

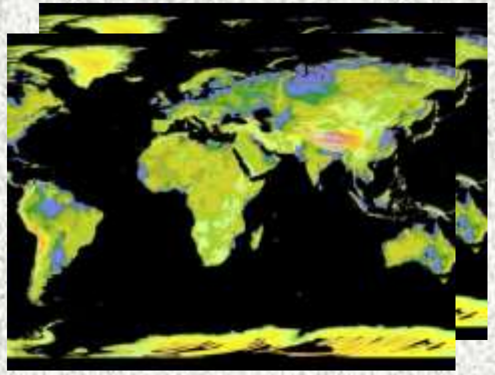
- However, **the efficient processing and classification** of point cloud data to generate **3D hydraulic features** of interest represent a grand challenge because
  - The volume of the point cloud data involved is often huge (a **big data analytics challenge**; see Tang and Feng 2017),
  - Hydraulic features of interest are often **complicated** in terms of their shape and structural changes over time (see Chen 2012; Watson, Chen et al. 2011).

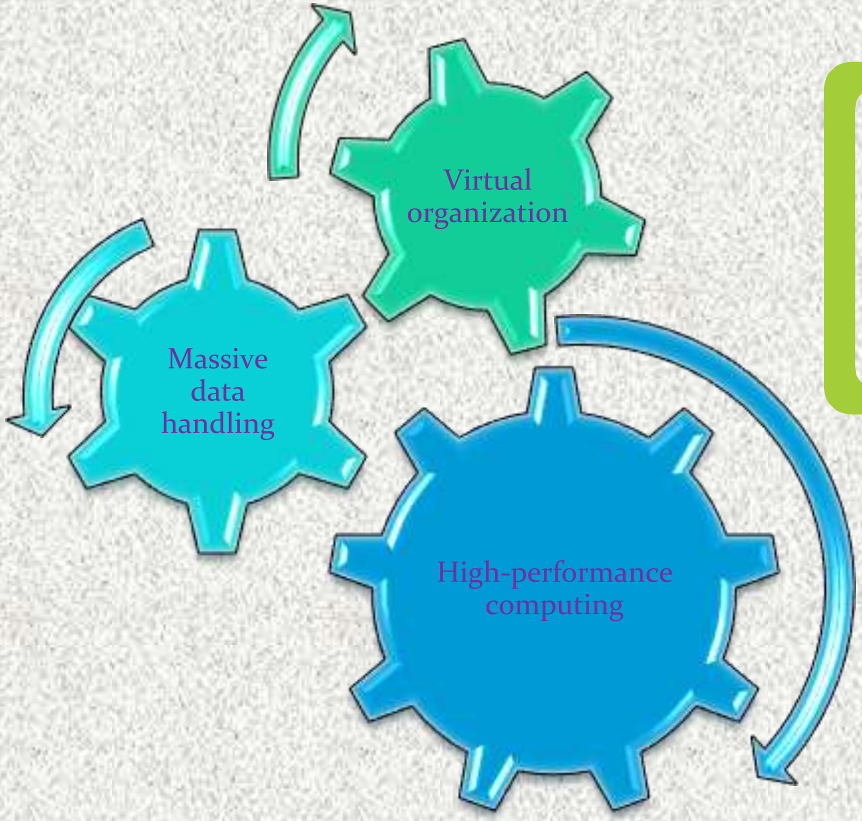


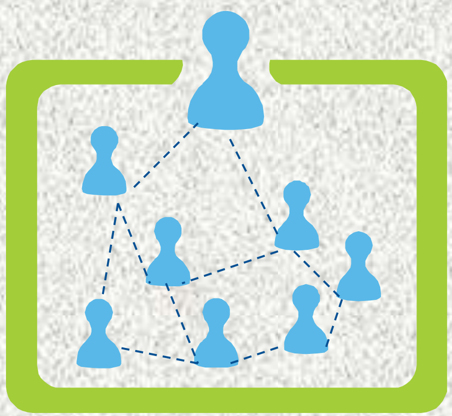
CyberGIS for Big Spatial Data Analytics



Cyberinfrastructure







Ranger at TACC (62,976 cores)

http://www.tacc.utexas.edu/fileadmin/templates/SubtacctemplateStaticDropdown/images/ranger.jpg
http://www.nasa.gov/multimedia/imagegallery/image_feature_1545.html

Data Collection

Field Data Collection

- **Terrestrial LiDAR data and intensity images** of hydraulic structures for sites (including bridges, culverts, and pipes)
  - FARO Focus S 350
- **Bathymetric sonar data** for at least one of those sites using an unmanned NC DOT bathymetric surveying boat
- Use **UAS (drone) technologies** to collect geotagged pictures and videos of the hydraulic structures
  - DJI Phantom 4 Pro V2.0
- Collect topographic info via **GPS and total station** to field truth the LiDAR and sonar results
  - GPS (rented): Trimble R10 GNSS receiver
  - Performance of Network RTK
    - Horizontal: 8mm+0.5ppm
    - Vertical: 15mm+0.5ppm
  - Virtual Reference Station(VRS) network:
    - North Carolina VRS network by NC Geodetic Survey
- Sonar system:
  - Lowrance HDS Live 7 (version 8.3)

Image and information source: https://www.dji.com/phantom-4-pro
https://www.kwipped.com/rentals/product/topcon-gts220-total-station/1535
https://www.faro.com/en-gb/products/construction-bim-cim/faro-focus/
https://www.lowrance.com/globalassets/inriver/resources/000-14416-001_09.jpg?w=1000&h=500&scale=both&mode=max&quality=70
http://trl.trimble.com/docushare/dsweb/Get/Document-889531/TrimbleR10_Model-2_GNSSReceiver_UserGuide.pdf

Fieldwork Snapshots

Survey Sites in NC

Site #2

Site #6

Site #14

Site #11

Site #3

Site #7

Site #16

Site #5

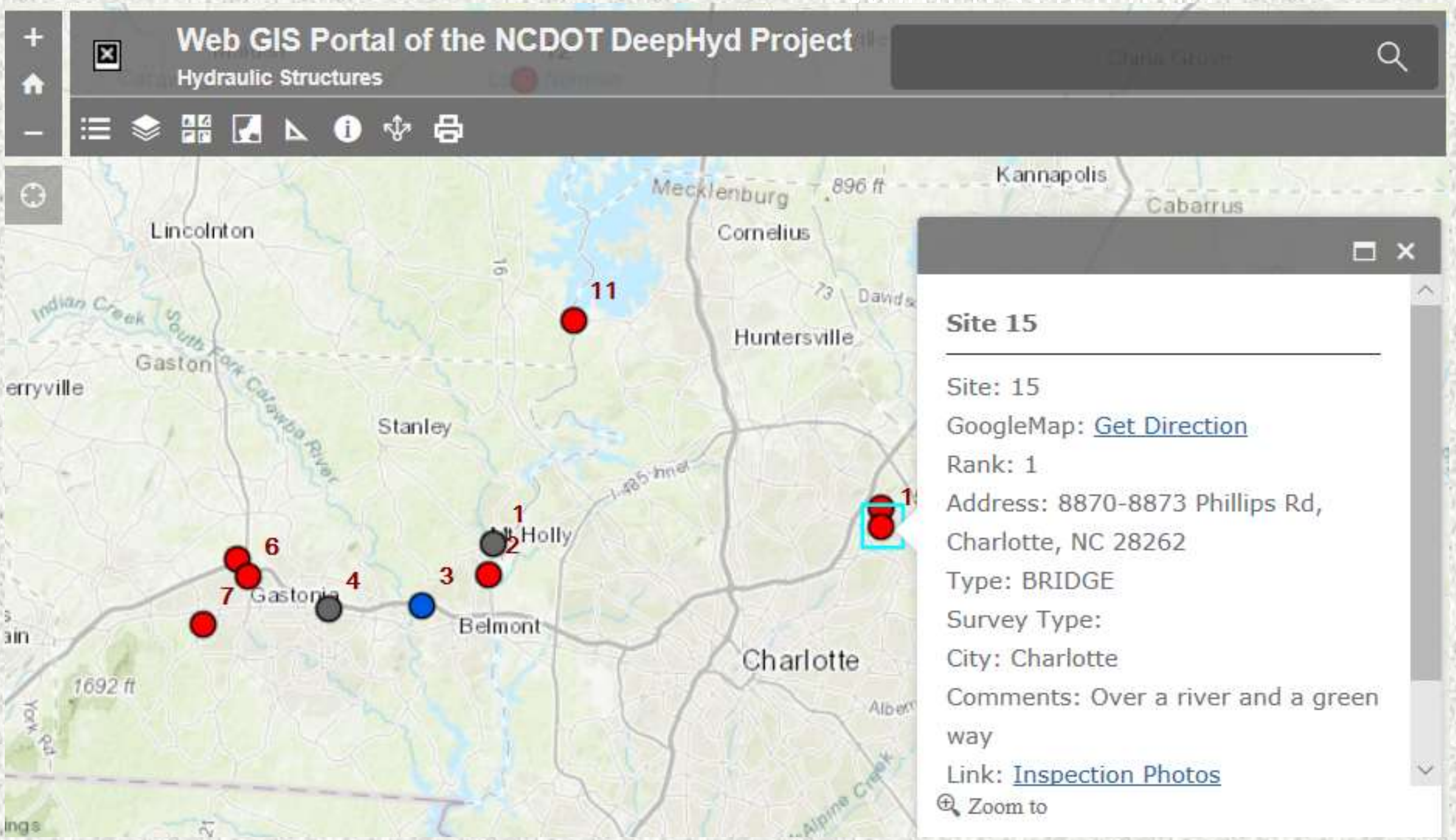
Site #8

Site #	# LiDAR Scanning	# Sonar Points	# total station points	# Drone images	# camera images
Site 2	1		86		308
Site 3	2		98		157
Site 5	1		241		220
Site 6	2		101		363
Site 7	1		95		251
Site 8	3		168		398
Site 11	5	824			
Site 14	1		205		420
Site 15	1			181	213
Site 16	4	1095	127	109	
Site 17	4	3,180			

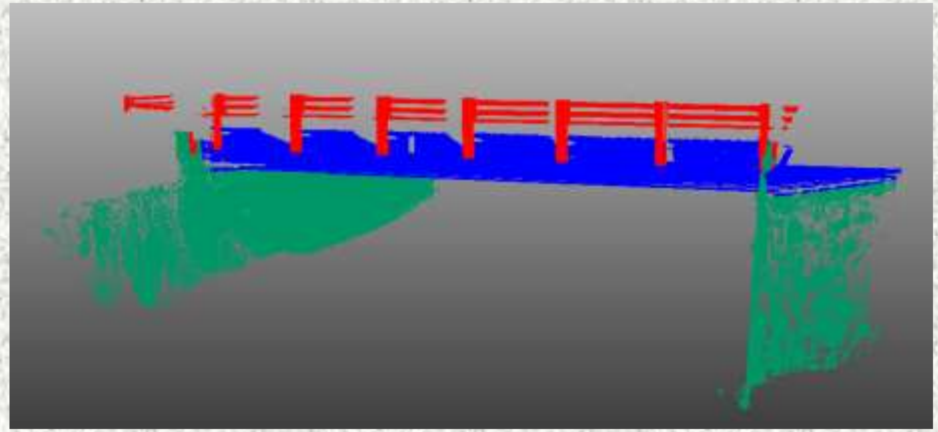
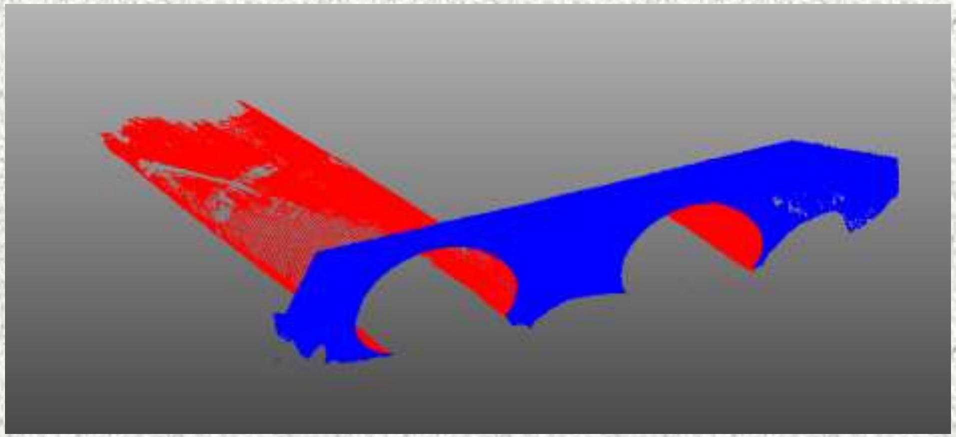
Web GIS Dashboard

- Web-based mapping of study sites
- Web 2.0 technologies
  - WordPress for content management system

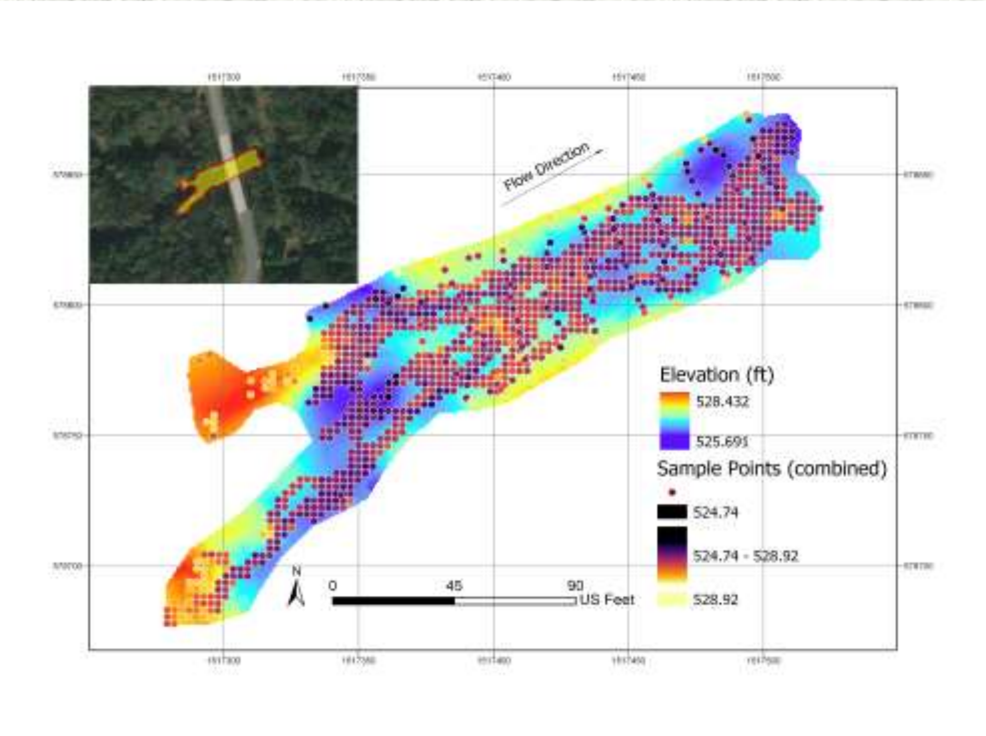
Website:
https://cybergis.uncc.edu/deephyd/
https://cybergis.uncc.edu/deephyd/index.php/study-sites/
WordPress reference:



Point Cloud Data

Sonar data collection



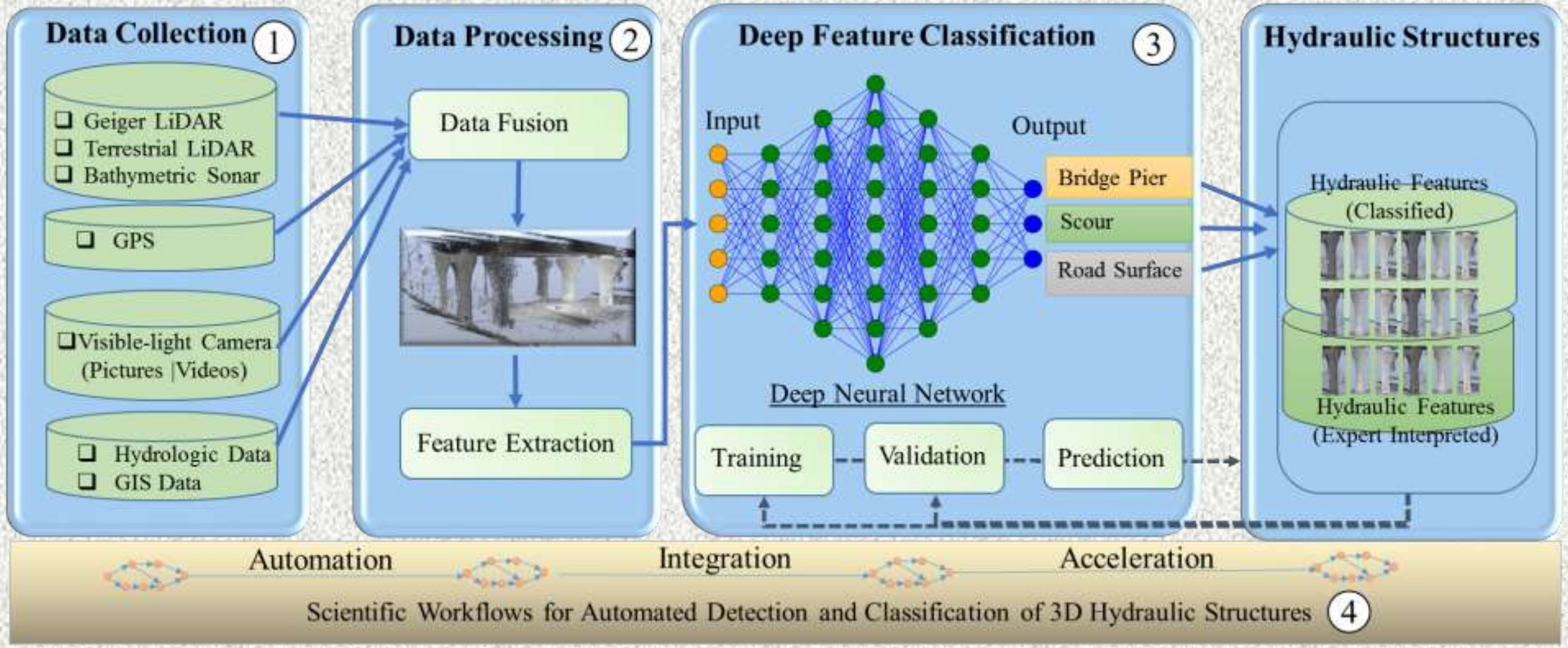
Bathymetric map based on sonar and Virtual Reference Sy Site #16

- Data were collected using VRS, total station and sonar (single beam echosounder)
- Accuracy of sonar data estimated by calculating residual (elevation from VRS – elevation of stream bottom)

Deep Learning Framework: DeepHyd

Framework

- We have been developing **DeepHyd**, a novel spatially explicit 3D modeling framework and software package that are based on **deep learning** as a cutting-edge artificial intelligence approach for automated and reliable classification of hydraulic structures from point cloud data.



Artificial Intelligence

- Deep learning for 3D object detection
  - Combine unsupervised and supervised learning for a hierarchical representation of features of interest (Erhan et al. 2010; LeCun et al. 2015)
    - **Outperform** conventional machine learning algorithms (see Zheng, Tang, and Zhao, 2019)
    - Ideal for **feature detection and classification** (Yu et al. 2015)

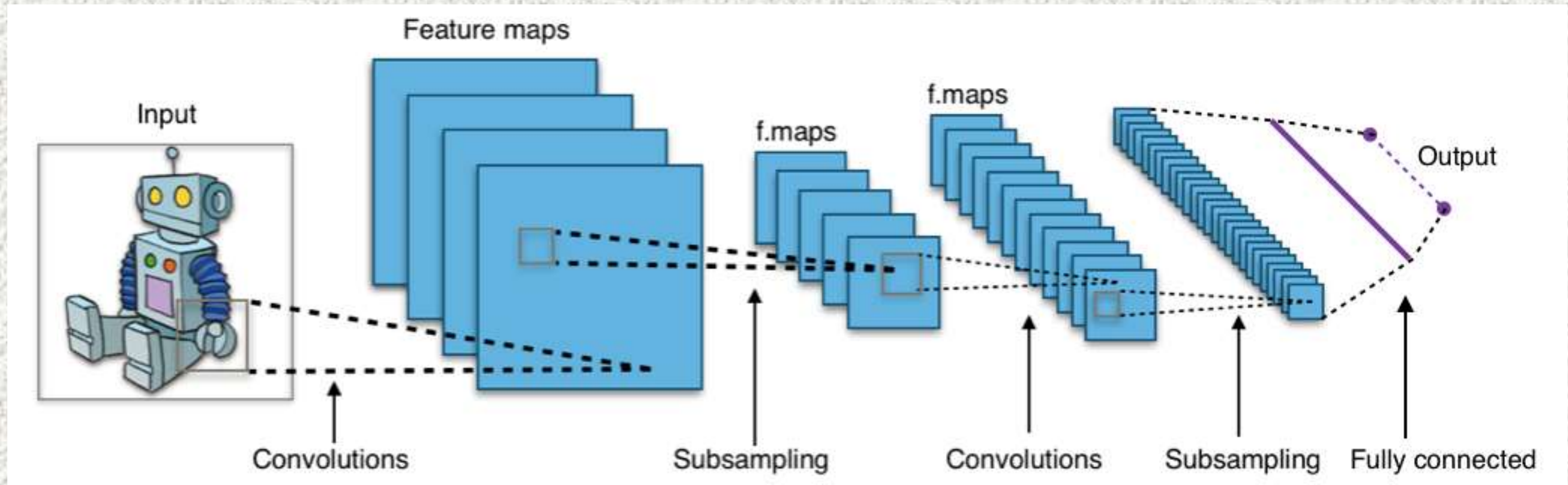
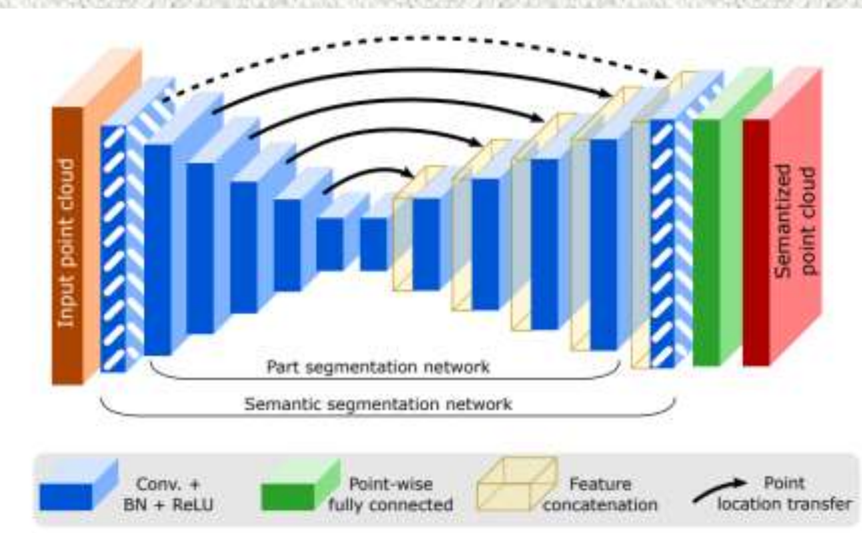


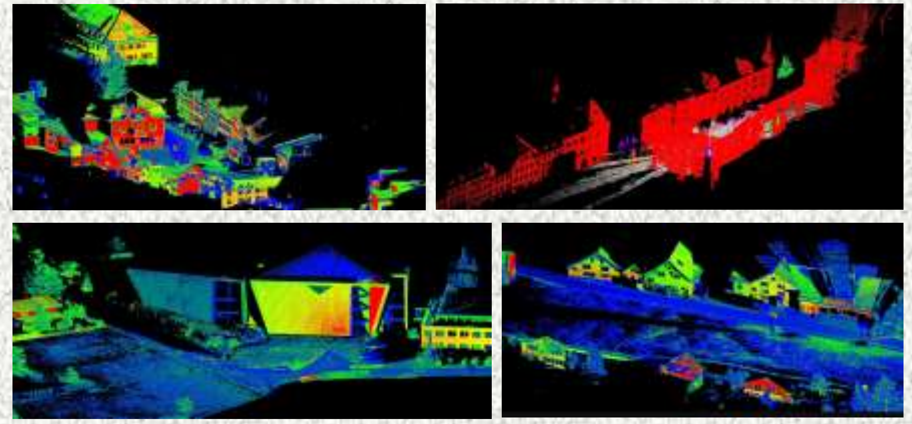
Image source: https://upload.wikimedia.org/wikipedia/commons/8/81/Deep_learning.png
https://en.wikipedia.org/wiki/File:Typical_cnn.png

Convpoint: Continuous Convolutions For Point Cloud Processing

- Boulch (2020) proposed a new deep learning-based framework for 3D semantic segmentation, named ConvPoint, which hits the rank #1 performance on the large-scale 3D benchmark (http://www.semantic3d.net/).



Segmentation networks proposed by Boulch (2020)



Demonstration of the 3D benchmark

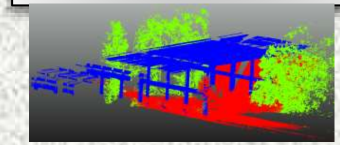
Framework of Scientific Workflow for Automation

*Demo of SfM process
Imagery (left) to point cloud (right)

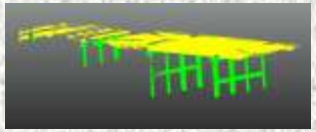
Structure from Motion (SfM) to construct 3D point cloud from imagery

Use the two trained models to predict the labels of each point:

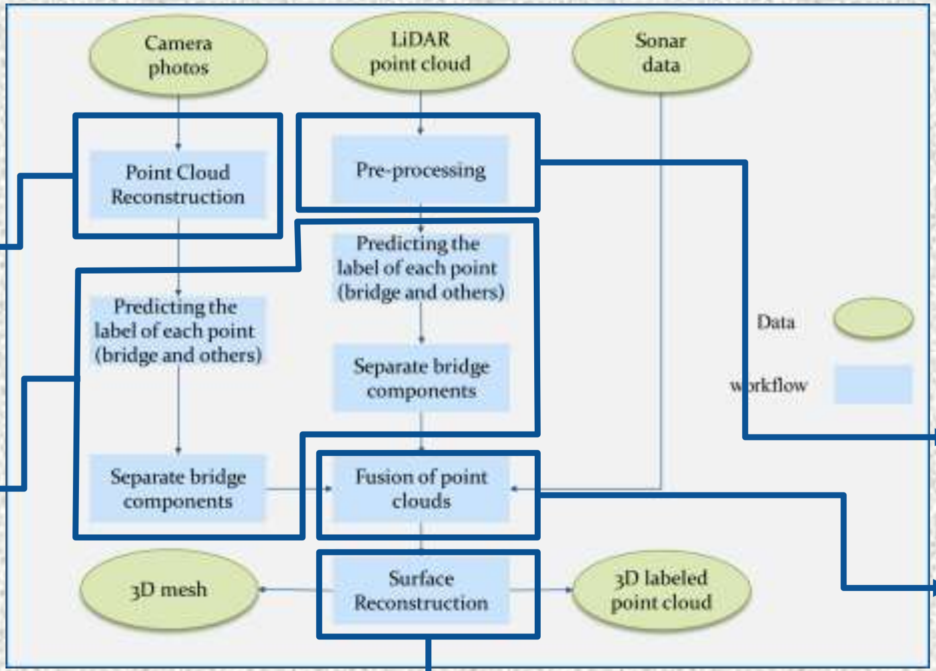
1. Detect bridge from the point c loud
2. Detect different bridge components from point cloud of the detected bridge



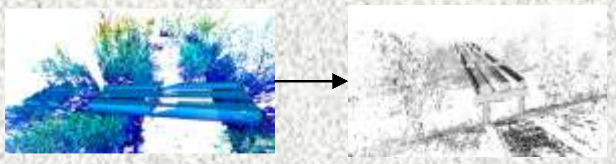
*Prediction results of detected bridge from the scene



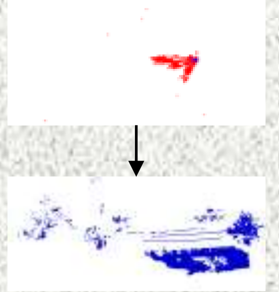
*Prediction results of bridge components



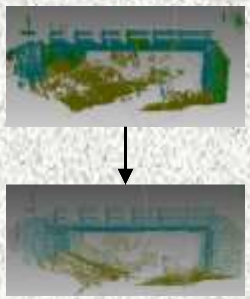
Adopt surface reconstruction methods to convert point cloud to polygon mesh or other types of 3D model (based on NCDOT requirement).



*Demo of the result of the surface reconstruction
From point cloud (left) to polygon mesh (right)



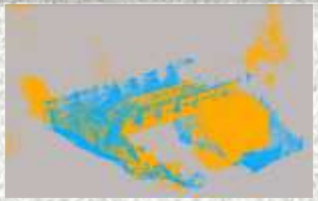
*Demo of outlier removal
Red are removed automatically



*Demo of Spatial sampling
From origin (top) to 1cm (bot)

1. Outlier removal tool by Open3D, an open-source python lib, to remove noise
2. Spatial sampling to 1cm

Adopt Iterative Closest Point from CloudCompare, an open source software, to register the point clouds



*Demo of fusion of point clouds
Blue and yellow are two point clouds. They are registered after this process

Acceleration of Deep Learning

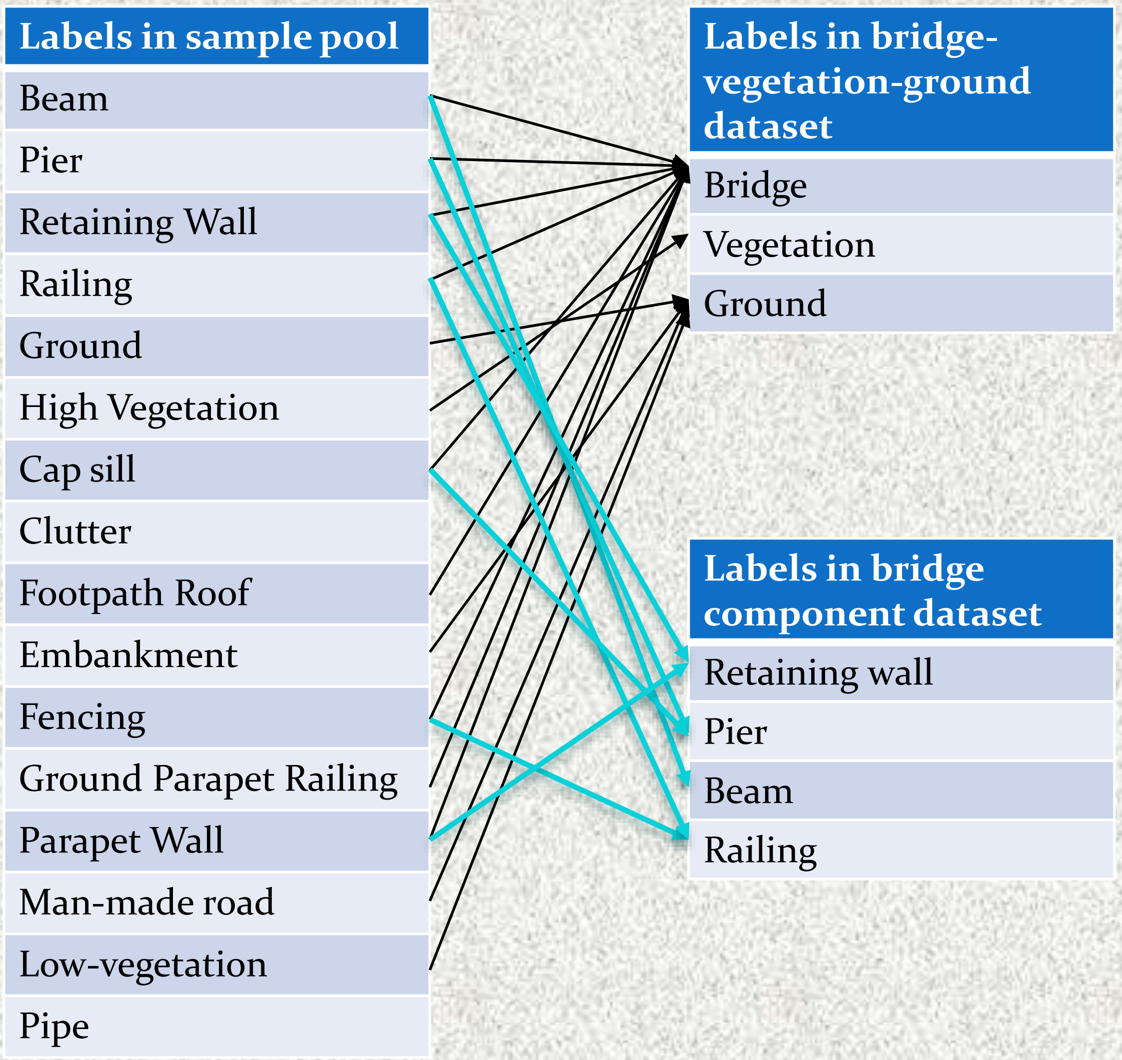
- Cyberinfrastructure-enabled **high-performance computing (HPC) capabilities** to resolve the big data-driven computational challenge of geospatial analysis and modeling in this project
  - **Parallel geocomputational algorithms** that deploy the processing, analysis, or modeling steps to HPC resources at Center for Applied GIScience (CAGIS) and URC (University Research Computing) at UNC Charlotte.
    - **Sapphire**: 288-CPU Windows cluster for advanced geocomputation!
    - Graphics Processing Units (GPUs) cluster at URC (24 advanced GPUs)

Image source: https://i0.wp.com/hanusoftware.com/wp-content/uploads/event_218867862.png?w=360&ssl=1

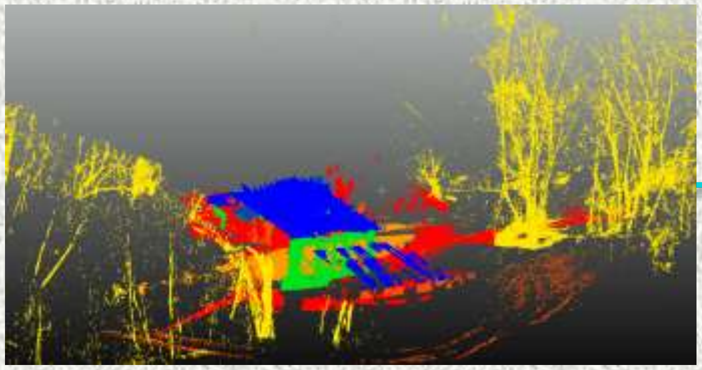
Results

Annotation of Samples

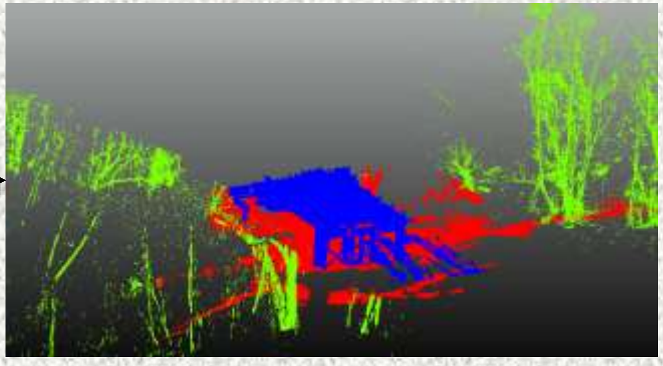
- Size of annotated sample pool:
  - Total # annotated scans: 41 (11 from study sites and 30 from previous scanning)
  - #classes: 16
- Two sample sets were generated from the annotated sample pool:
  - 1. Bridge-vegetation-ground dataset with 3-categories: bridge, vegetation, and ground
  - 2. Bridge component dataset with 4-categories: wall, pier, beam, railing



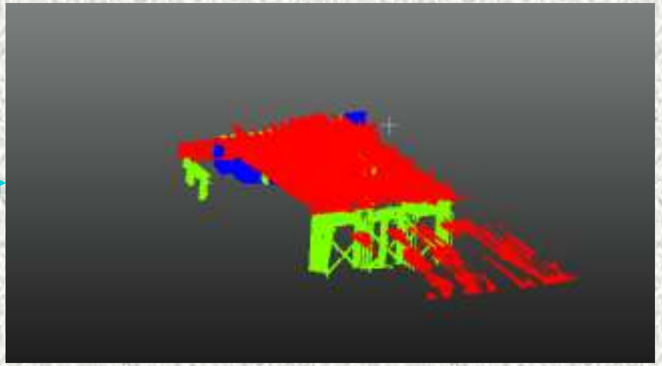
Demonstration of Annotated Samples



Data in annotated sample pool



Data in bridge-vegetation-ground dataset



Data in bridge component dataset

The annotated sample pool is aggregated to generate the two pools of datasets for training the two models.

*Colors represent different labels.

Statistics of the Two Pools of Labeled Datasets

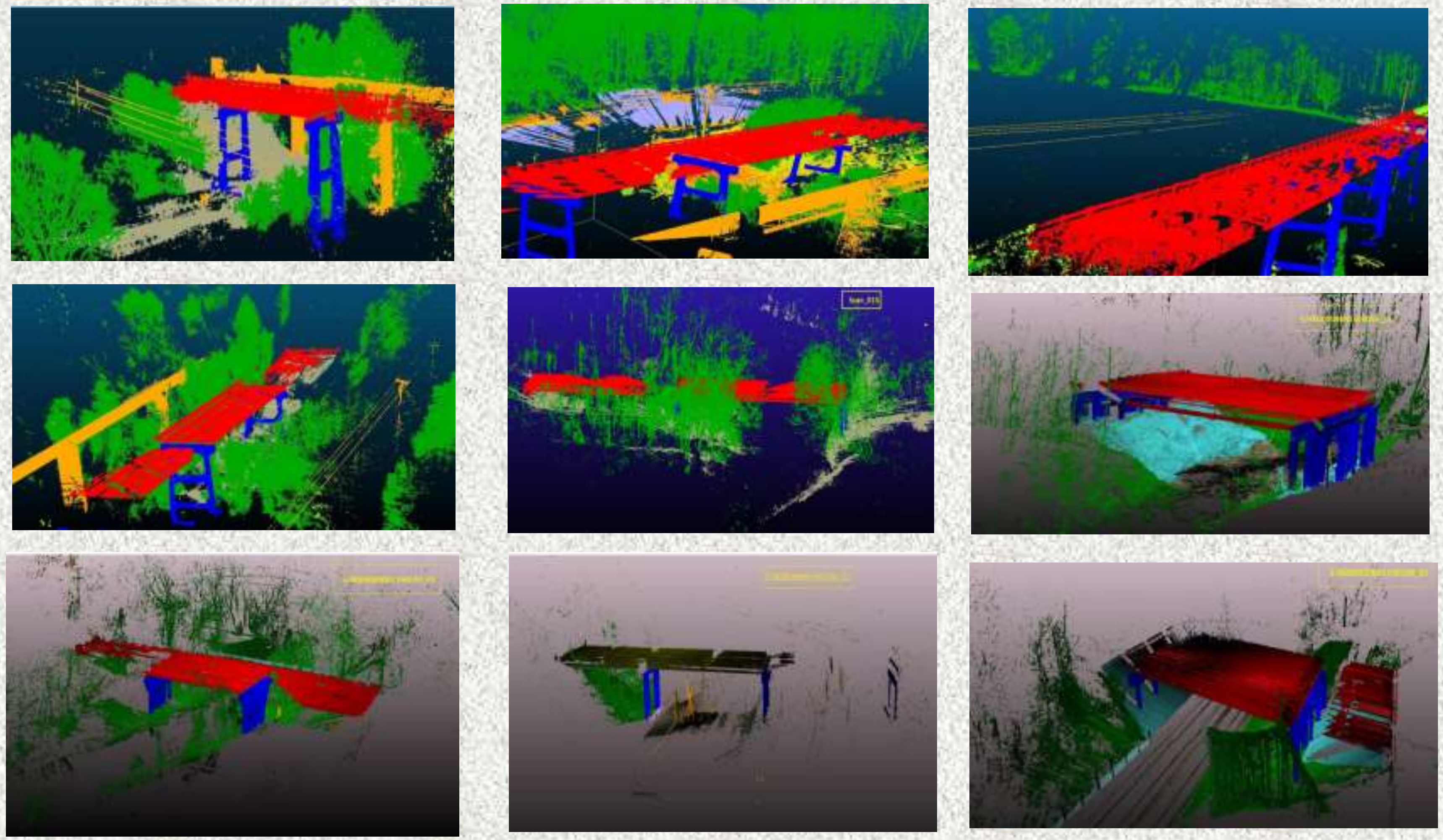
Bridge-vegetation-ground

Statistics/Labels	Bridge	Vegetation	Ground	Total
Total	109,354,102	35,122,404	62,993,247	207,469,753
Percentage	**52.71%**	**16.93%**	**30.36%**	100.00%

Bridge-component dataset

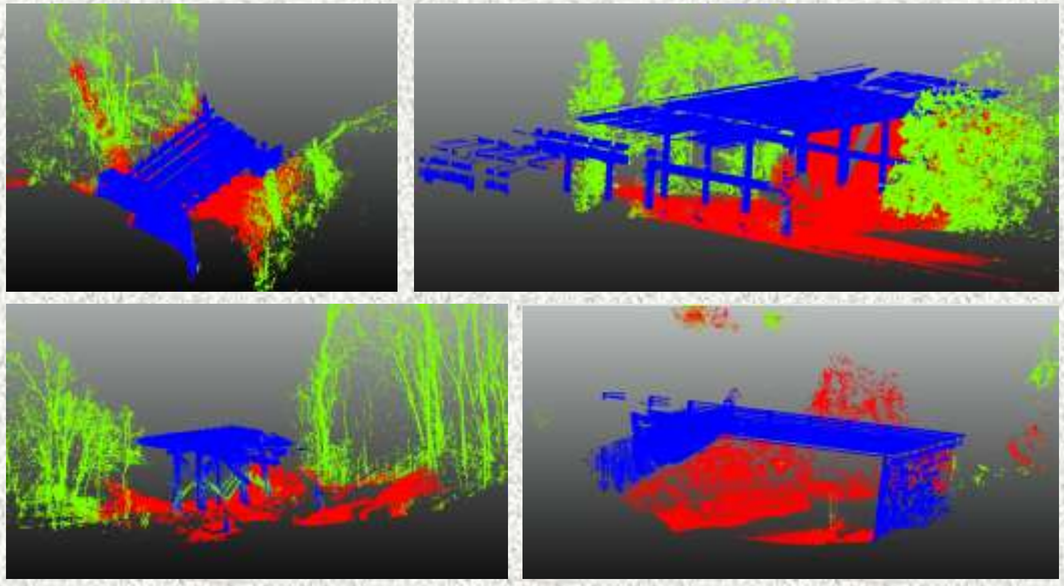
Statistics/Labels	Wall	Pier	Beam	Railing	Total
Total	6,949,996	17,673,431	76,778,145	4,818,671	106,220,243
Percentage	**6.54%**	**16.64%**	**72.28%**	**4.54%**	100.00%

Annotated Training Samples



Prediction Results on Validation Datasets

Bridge-vegetation-ground Model



Label	Color
Bridge	Blue
Vegetation	Green
Ground	Red

Confusion matrix in percentage

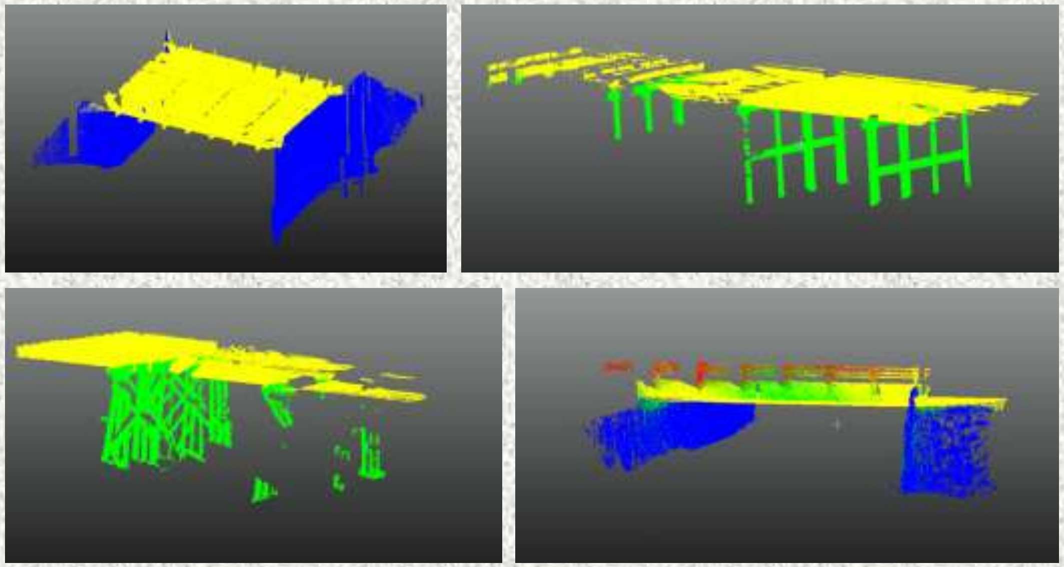
Origin/Pred	Bridge	Vegetation	Ground	Total
Bridge	**58.51%**	0.32%	0.24%	59.07%
Vegetation	0.02%	**9.91%**	0.29%	10.23%
Ground	0.30%	0.58%	**29.82%**	30.71%
Total	58.83%	10.82%	30.36%	100.00%

Performance metrics

Measure	Value
Overall Accuracy	98.38%
Average Accuracy	97.65%
Intersection Over Union (IOU)	94.67%
IOU_bridge	98.62%
IOU_vegetation	89.41%
IOU_ground	96.00%

Prediction Results on Validation Dataset

Detection of bridge components



Label	Color
Retaining wall	Blue
Pier	Green
Beam	Yellow
Railing	Red

Confusion matrix in percentage

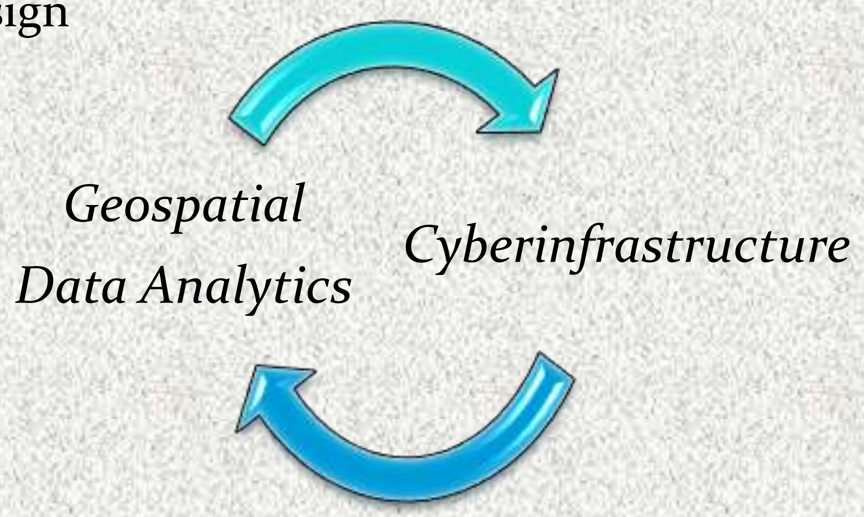
Origin/Pred	Retaining wall	Pier	Beam	Railing	Total
Retaining wall	**6.36%**	0.16%	0.07%	0.00%	6.58%
Pier	0.09%	**14.80%**	0.21%	1.57%	16.67%
Beam	0.08%	0.38%	**75.79%**	0.02%	76.27%
Railing	0.00%	0.13%	0.17%	**0.19%**	0.48%
Total	6.52%	15.46%	76.23%	1.78%	100.00%

Performance metrics

Measure	Value
Overall Accuracy	97.13%
Average Accuracy	80.90%
Intersection Over Union (IOU)	71.85%
IOU_wall	94.18%
IOU_pier	85.37%
IOU_beam	98.81%
IOU_railing	1.89%

Conclusions

- The cyberinfrastructure-driven approach **enables and empowers** the automation and acceleration of 3D point cloud classification using deep learning techniques that are **computationally demanding**.
- The DeepHyd framework and associated software package, driven by cutting-edge **deep learning** technologies, are well tailored to the **classification of 3D hydraulic structures** from point cloud data.
- This DeepHyd framework will provide substantial support for, e.g.,
  - Roadway drainage studies
  - Waterway hydraulic calculations and design
  - Evaluation of hydraulic structures



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Thank you!
Questions?

https://gis.charlotte.edu

03 | Break

CTIL/FRST

Sonny Kirkley, PhD, Indiana University

NAPSG Foundation

InSPIRE

Of challenges & innovators.

Sonny Kirkley

Director of User Experience

IU Crisis Technologies Innovation Lab

Adjunct Faculty

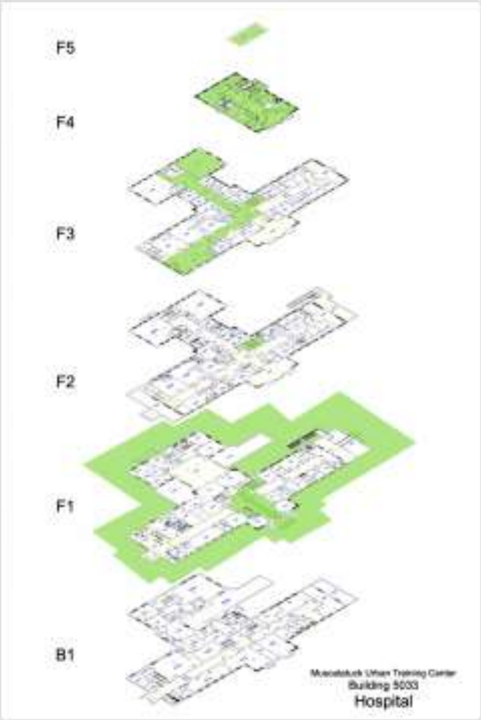
Human-Centered Computing

Luddy School of Informatics, Computing, and Engineering

INDIANA UNIVERSITY

CRISIS TECHNOLOGIES INNOVATION LAB

PERVASIVE TECHNOLOGY INSTITUTE


F5
F4
F3
F2
F1
B1
Building 5033
Hospital

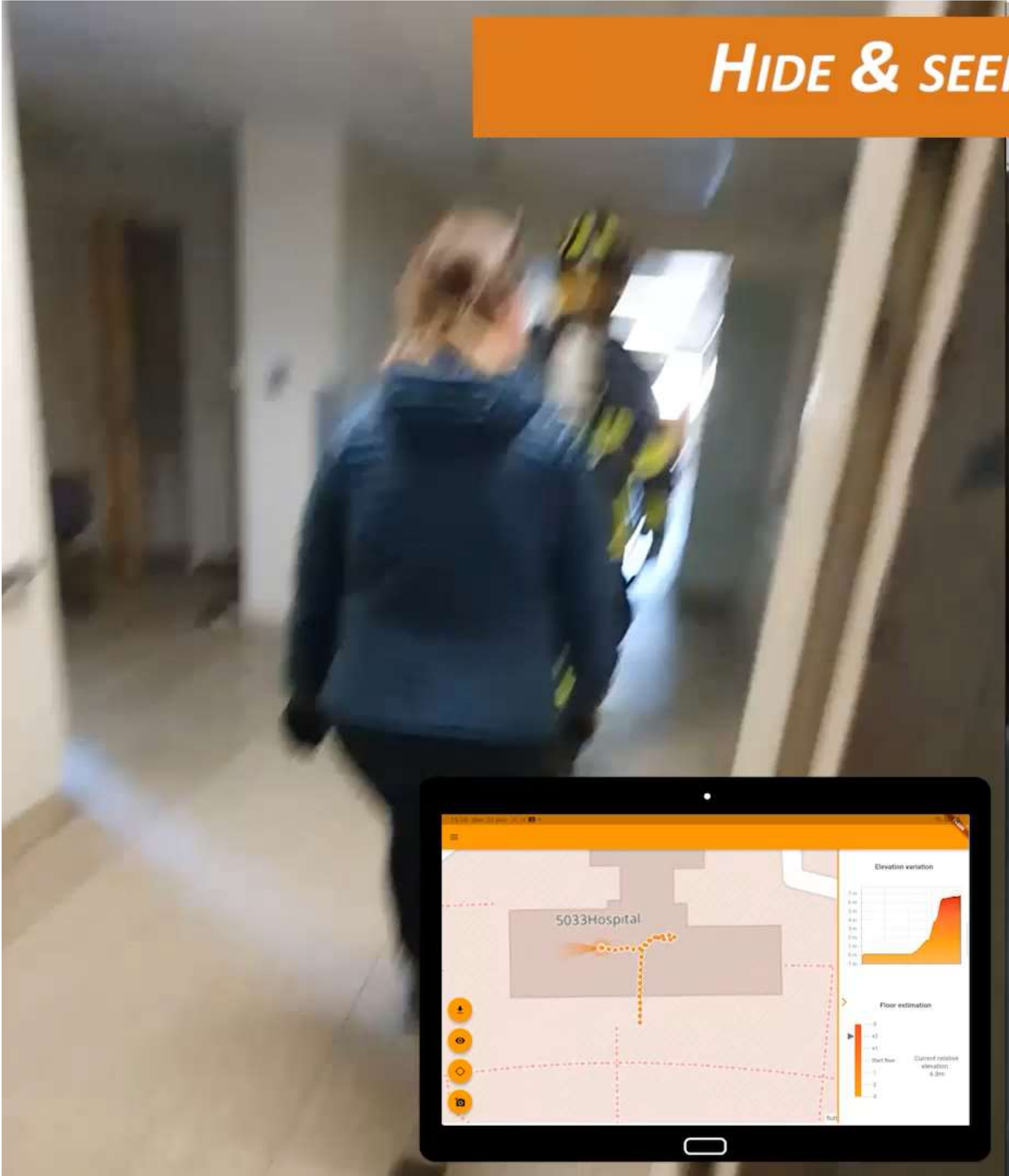

Building 5033
Hospital
Floor 1

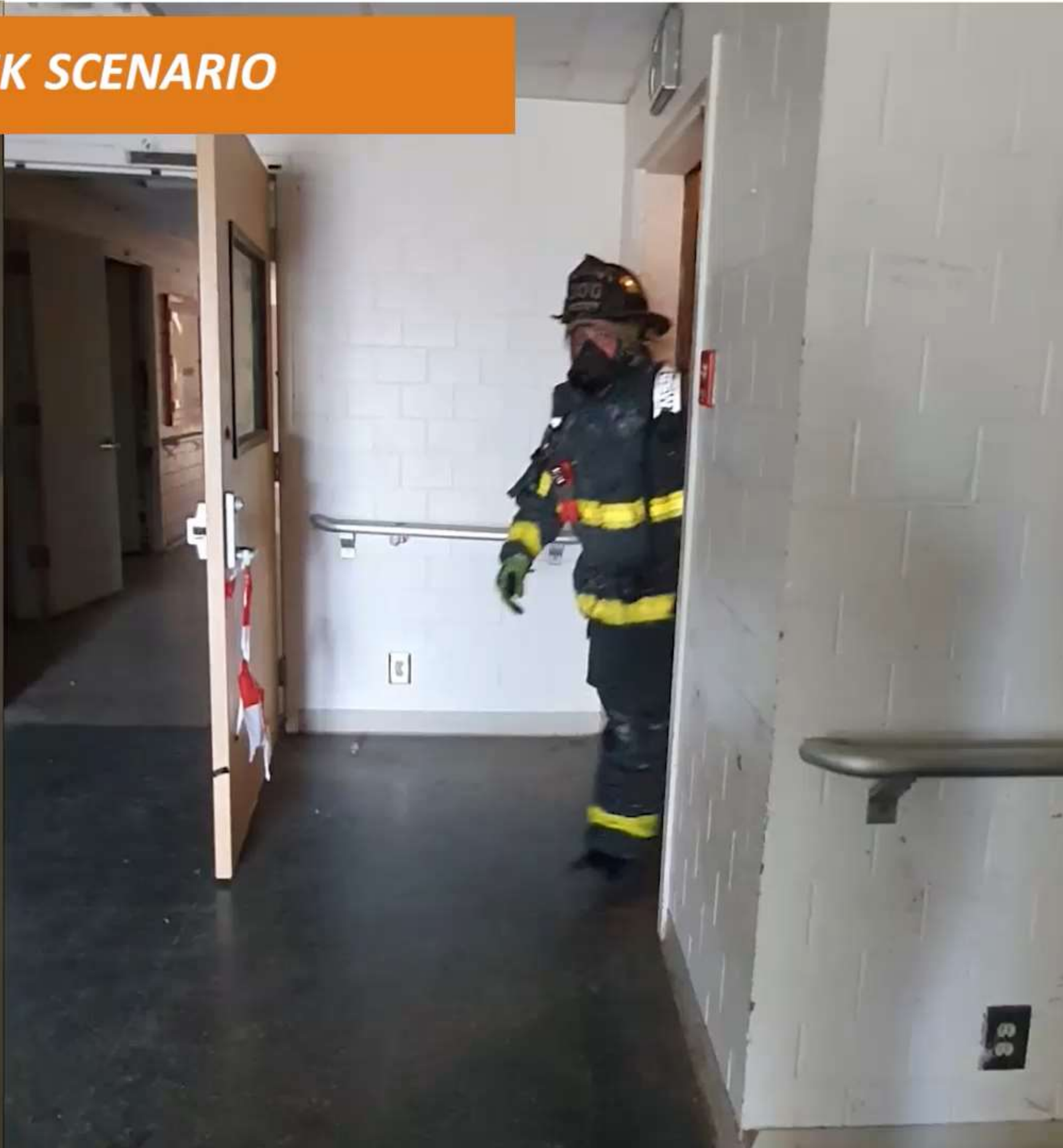

POLICE
O POS NKA
EV22 NEWCOMER
JOHN E. HINGELEY
MEMORIAL CLINIC &
SIMS
BURTON
MSA

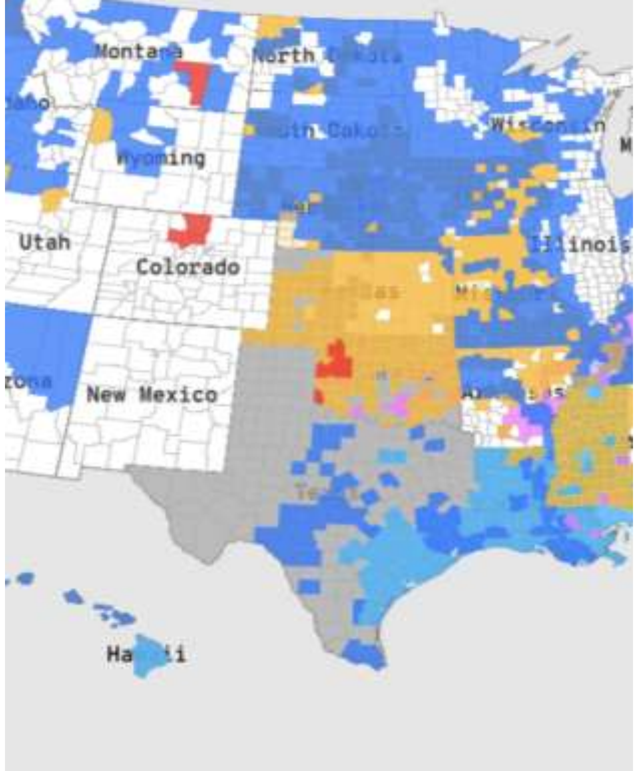

307


15:22 mer. 21 juin
5033Hospita
Elevation variation
8 m
7 m
6 m
5 m
4 m
3 m
2 m
1 m
0 m
-1 m
Floor estimation
+2
+1
Start floor
-1
-2
-3
Current relative elevation : 7.9m

HIDE & SEEK SCENARIO







CRISIS TECHNOLOGIES INNOVATION LAB

PERVASIVE TECHNOLOGY INSTITUTE

- Climate change is impacting planet with increasing both the frequency and intensity of crises and disasters
- Mission: Research and develop practical, efficient, effective, and equitable technologies and solutions to improve readiness and scale response to crises and disasters.

Student Experiential Learning

Seeking partners for projects

Let us know if you are interested.

Engage with student teams.

Partner with CTIL staff.

FIRST RESPONDER Smart Tracking CHALLENGE

Solving the "Holy Grail" of fire service

- Infrastructure-free, indoor 3D first responder tracking technology at 1-meter accuracy
- $5.6 mil. prizes
- Funded by National Institute of Standards & Technology
- Authentic prototype testing scenarios at MUTC

FRSTchallenge.com

CRISIS TECHNOLOGIES INNOVATION LAB
PERVASIVE TECHNOLOGY INSTITUTE

Why is indoor tracking important

- Save lives, reduce injuries
- Better team coordination
- More effective response
- Adds value to information increasing situational awareness
  - Sensors, IoT devices

FRST Challenge Management

INDIANA UNIVERSITY
CRISIS TECHNOLOGIES INNOVATION LAB
PERVASIVE TECHNOLOGY INSTITUTE

Resultant

INDIANA iot LAB
FISHERS
INDIANAIOT.COM

gener8tor

R2 NETWORK

SAN FRANCISCO COMMUNICATIONS

Funded by

National Institute of Standards and Technology

PSCR PUBLIC SAFETY COMMUNICATIONS RESEARCH

Support from

FirstNet

Collaborating First Responders

Competition Focus

Contestant goals are to produce marketable prototypes that demonstrate indoor localization and tracking of first responders within 1-meter accuracy in a variety of buildings and structures without any pre-deployed infrastructure. Marketable prototypes are robust for first responder use cases, are scalable across diverse organizations and communities, and are affordable for first responder organizations.

Timeline

Phase 1: Concepts and Initial Design

Phase 2: Early Demonstration

Phase 3: Refined Prototype Demonstration

Phase 4: Live Field Testing

Phase 5: Live Public Demonstration

March 21, 2022	May 26, 2022	October 3, 2022	March 27-31, 2023	October 23-27, 2023

Initial Competing Teams

ZANSORS®

bc BUSINESSCRESCENDO

sysnav NAVIGATION TECHNOLOGIES

3 am

Adapti-Trace

AIKI SAVING LIVES

ATLAS Network

BANC3

NavigateIO
Infrastructure Free Location Intelligence

RescuNoMics
Quid est vita tarda

TrackerDLN

circle

KOLIADA

EPIC BLUE

ZOT<1m
ZUPTING OF TRACKING ERROR < 1 METER

ASCENT
Integrated Tech

THREE FIREFIGHTERS

THIRD WAVE

TEAM RAVENSWOOD
FRST CHALLENGE

One Smart Lab

Lost & Lucky Labs

NYU - FRST

Thrusight

OWL Integrations

Taber Innovations Group

CHARLI

PIERCE AEROSPACE

Tiami NETWORKS

IoTAI
PicoTags

ENGR Dynamics

FRST CHALLENGE

Final Teams

AdaptiTrace

ASCENT
Integrated Tech

bc BUSINESSCRESCENDO sysnav

CHARLI

EPIC BLUE

TEAM RAVENSWOOD
FRST CHALLENGE
SRI INTERNATIONAL • FREMONT, CALIFORNIA • BARGERSVILLE, INDIANA • CANTON, OHIO

Muscatatuck Urban Training Center

1000 Acres, 120 Structures, 1 mile of Tunnels



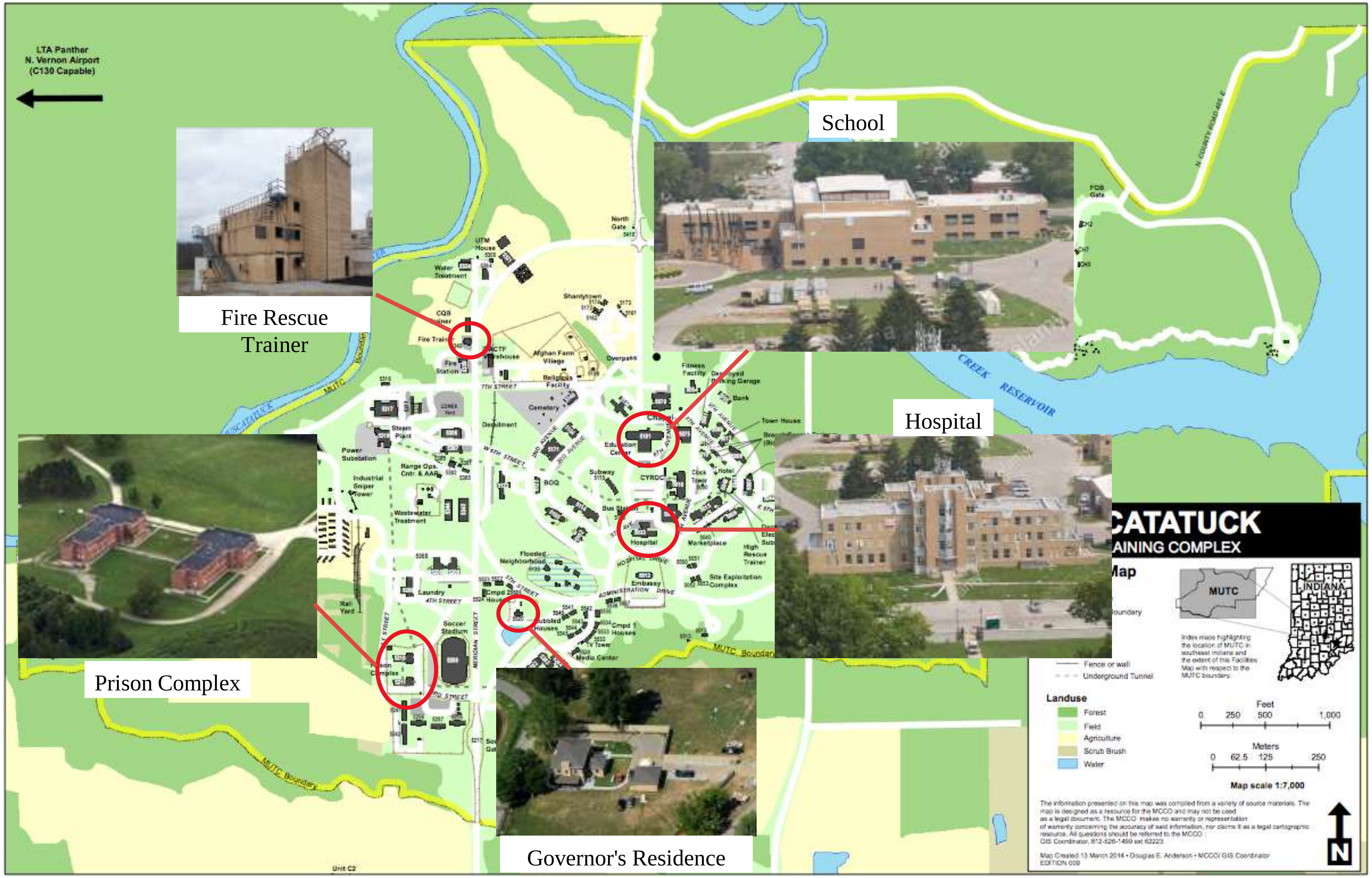









FRST Phase 4 - MUTC Field Test Buildings




311
MSA

Ground Truth Procedures

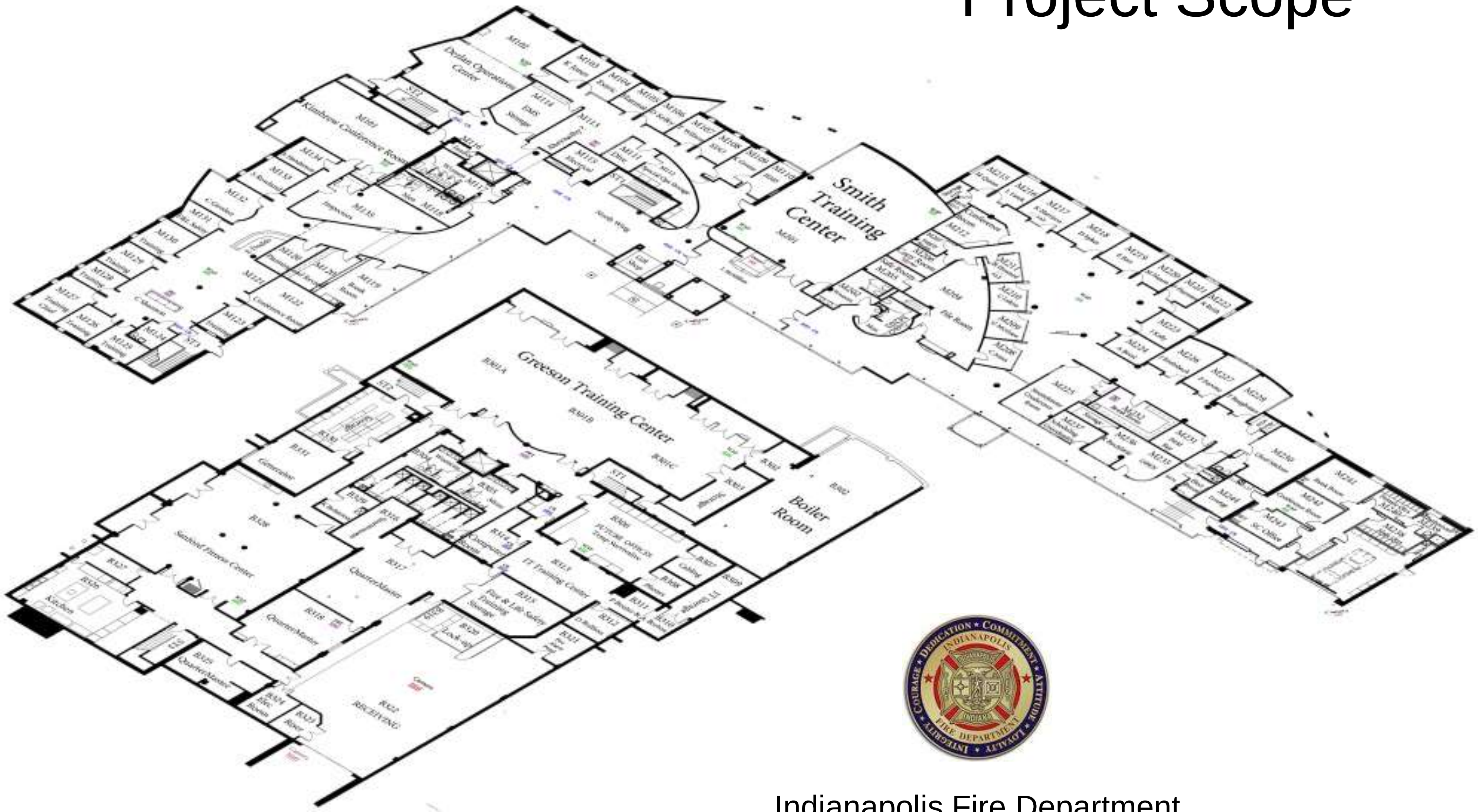
iSite

iSite

- iSite Project is focused on building realistic **testbeds** that can be used for **Technology Product Testing and Evaluation**
- Buildings modeled so far:
    - MUTC (8 buildings)
    - Indiana University (5 buildings)
    - Indianapolis Fire (HQ, Training Academy)
    - Indiana IoT Lab
- Work informed by iAxis Best Practices, OGC Standards
- Work with First Responders to assess fit into Public Safety Operations (e.g., Mutual Aid and Unified Command)

- Seeking partners who want to work with us on future iSite testbeds

Project Scope



100 Mechanical
- Boiler
- Elevator
- Accessible
- Stove

200 Electrical
- Photo Voltaic
- Indoor Electric
- Lighting Control

300 Plumbing & Gas
- Indoor Water
- Gas Shutoff Valve

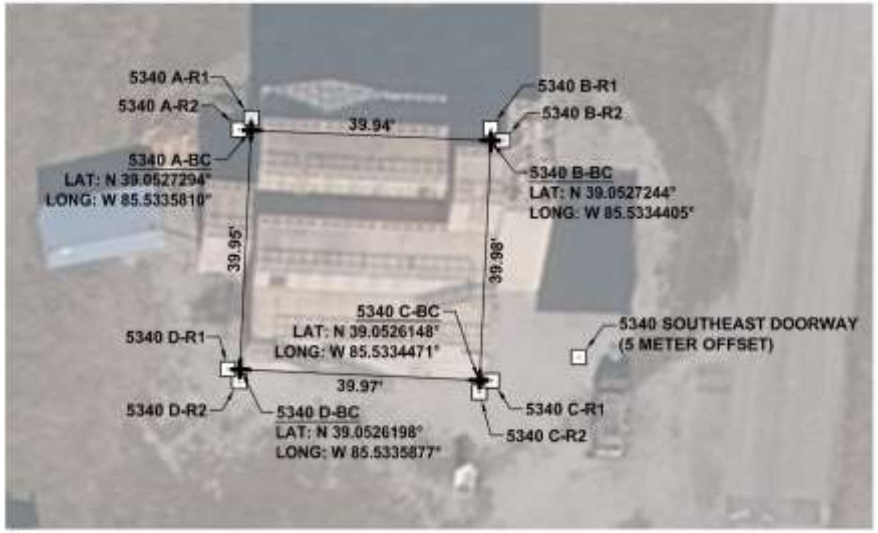
400 Telecom, IT & Security
- Telecom
- Video Cameras

500 Fire & Life Safety
- Entrance/EXIT
- Alarm/Annunciator
- Alarm Reset
- Knoxbox
- Fire Pull Box
- Sprinkler Riser
- Hose Cabinet
- Fire Extinguisher
- AED
- First Aid

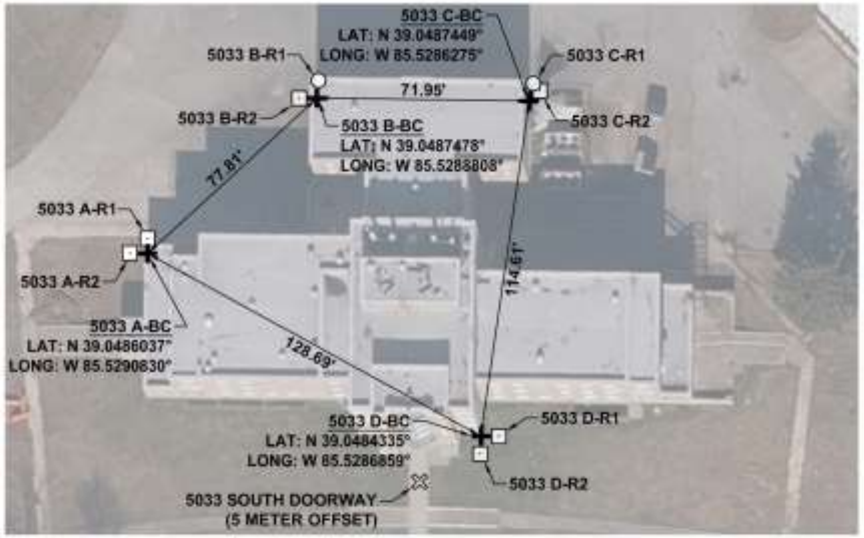
700 Other
- Hazmat

Indianapolis Fire Department
Headquarters Building

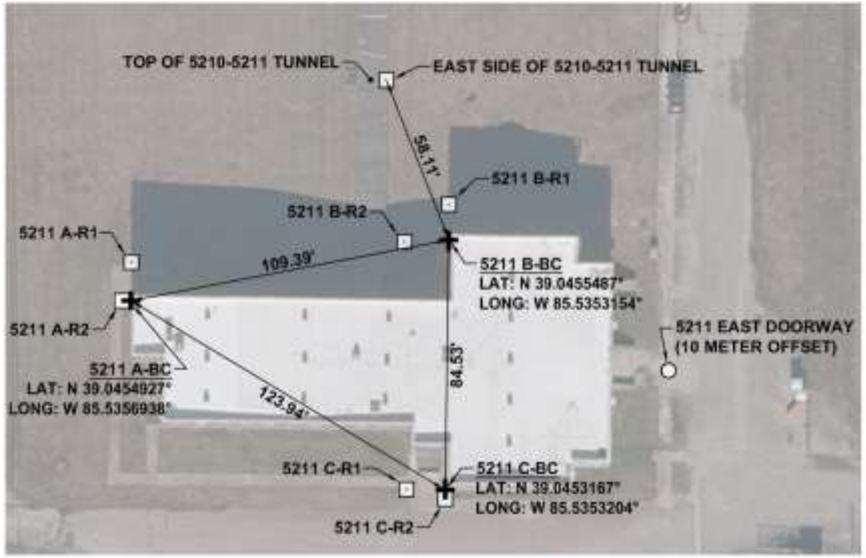
Survey & Ground Truth MUTC Test Buildings



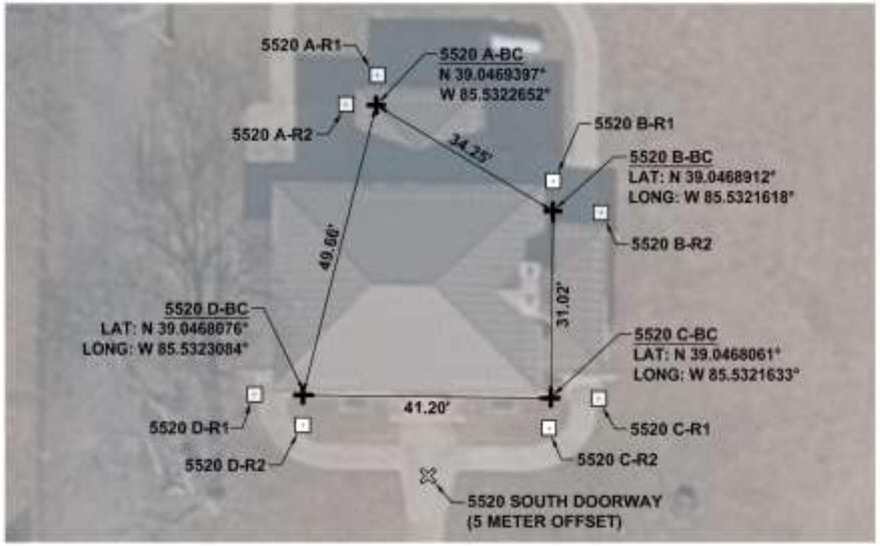
Fire Rescue Trainer



Hospital



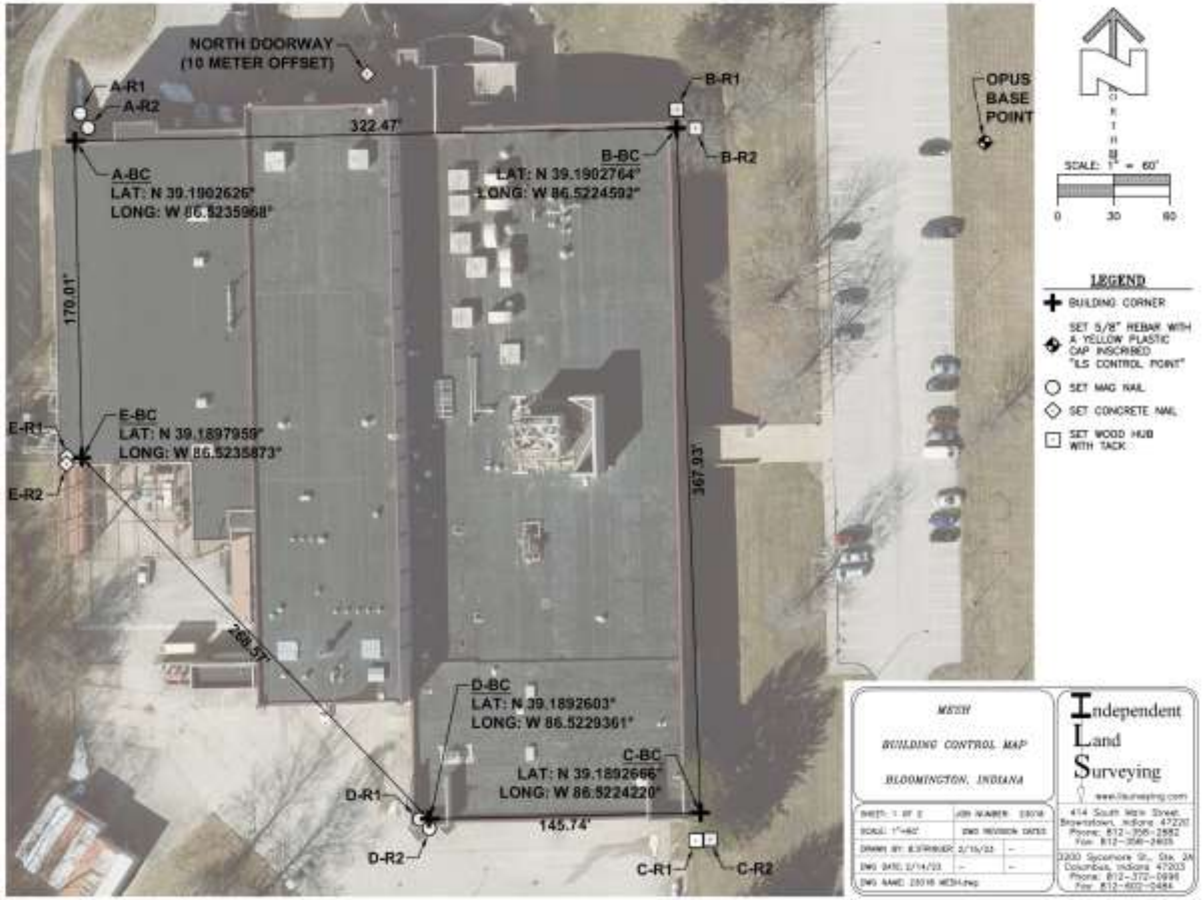
Prison Complex



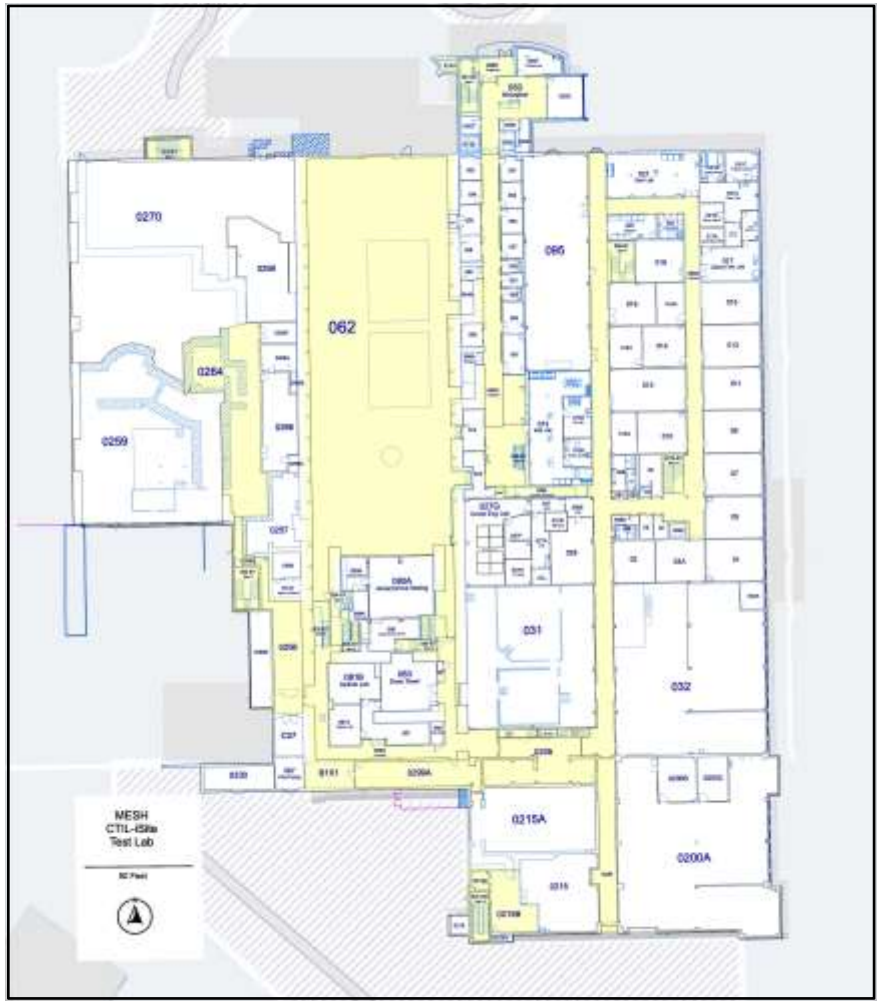
Governor's Residence

MESH Testbed Development

3) Survey Building Corners & Wall Length



4) Scale, Rotate, & Position CAD Model



MESH Testbed Development

5) Define Monument Positions & Path

Origin Point is 39.0467839, -85.5323501

Monument X/Y Coordinates in meters

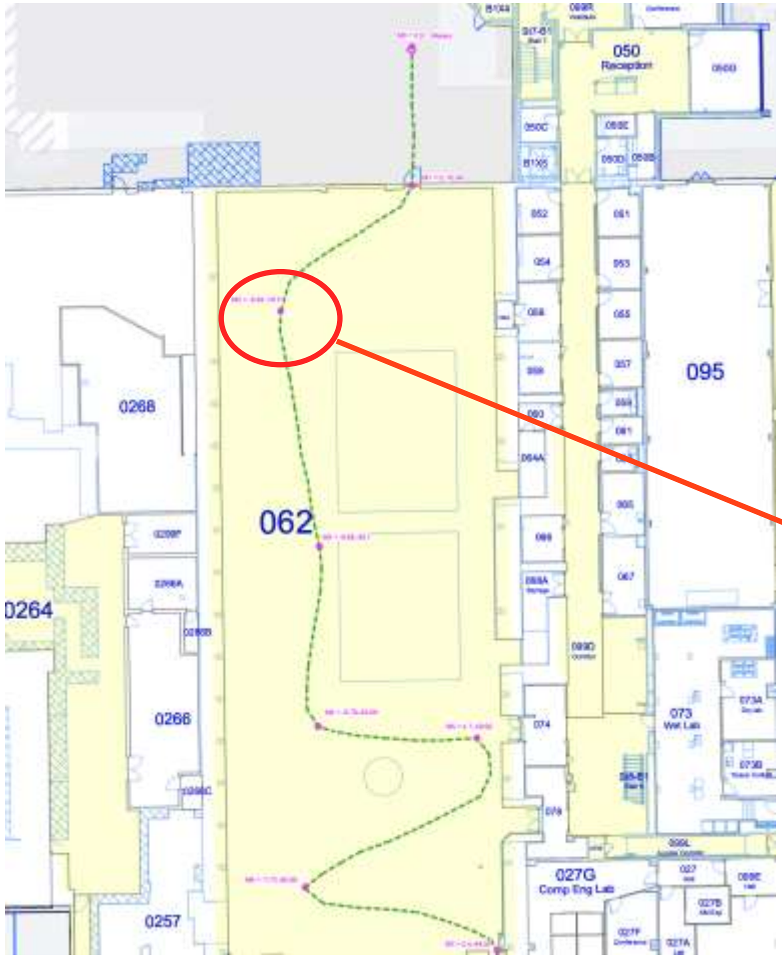
M1 = 9.42,11.76
M2 = 10.02,8.28
M3 = 11.91,8.752
M4 = 13.35,11.278
M5 = 12.745,7.955
M6 = 10.895,6.56
M7 = 7.426,6.536
M8 = 8.97,3.945

GPS Monument Points

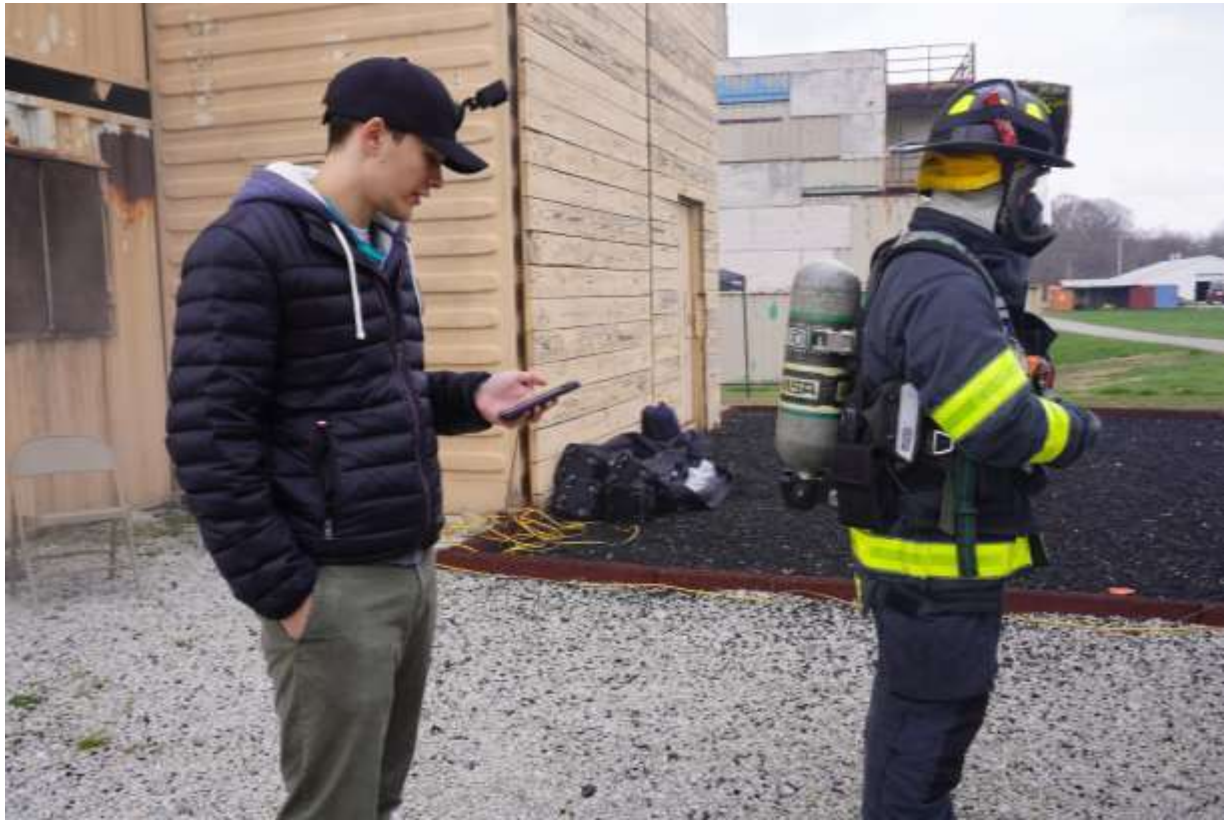
X/Y Origin Point = 39.0467839, -85.5323501

M1 = new google.maps.LatLng(39.0468879, -85.5322426),
M2 = new google.maps.LatLng(39.0468571, -85.5322358),
M3 = new google.maps.LatLng(39.0468613, -85.5322142),
M4 = new google.maps.LatLng(39.0468837, -85.5321978),
M5 = new google.maps.LatLng(39.0468542, -85.5322047),
M6 = new google.maps.LatLng(39.0468418, -85.5322258),
M7 = new google.maps.LatLng(39.0468416, -85.5322654),
M8 = new google.maps.LatLng(39.0468186, -85.5322478),

6) Survey and Mark Monuments Positions

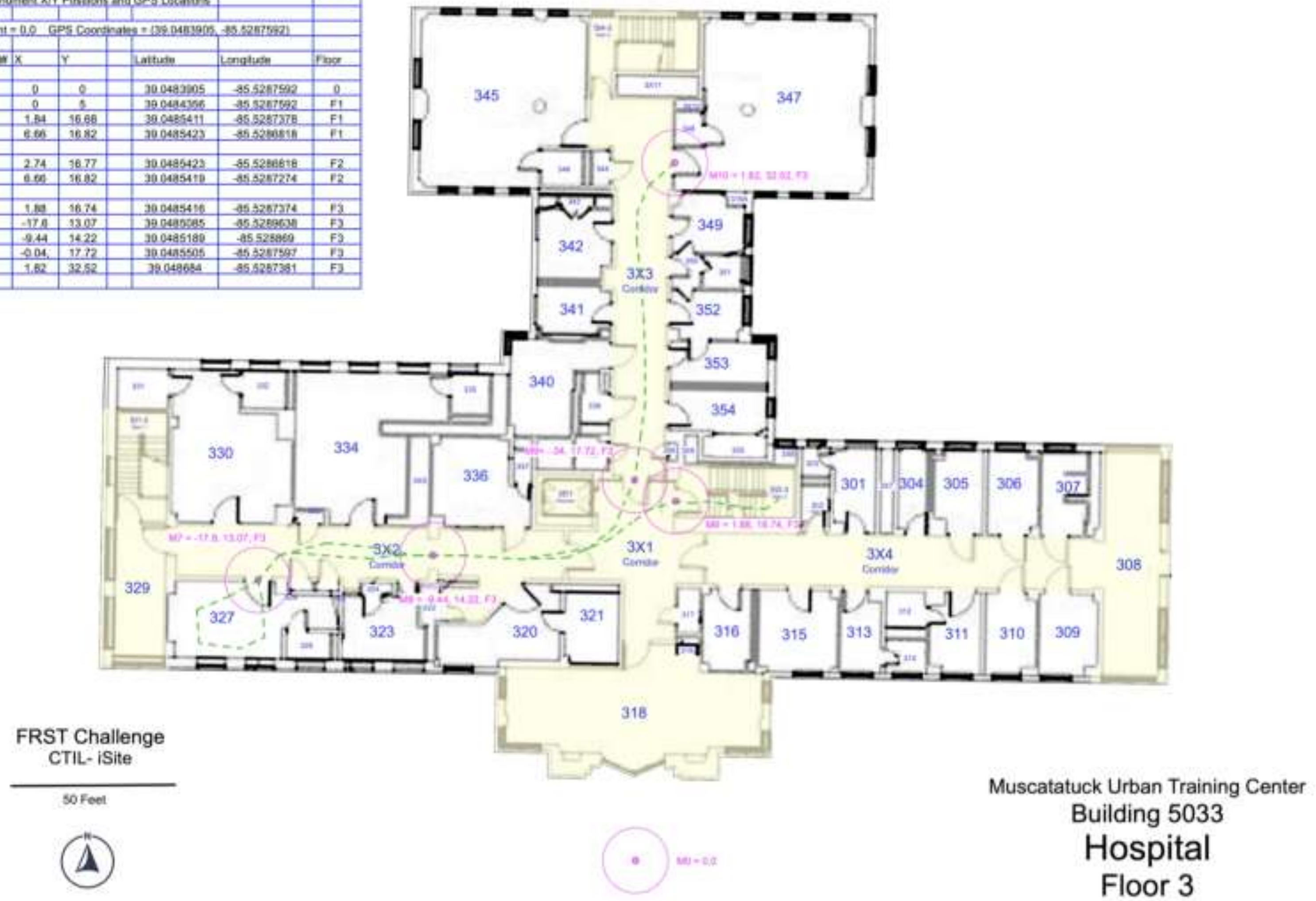


Data Collection in the Field

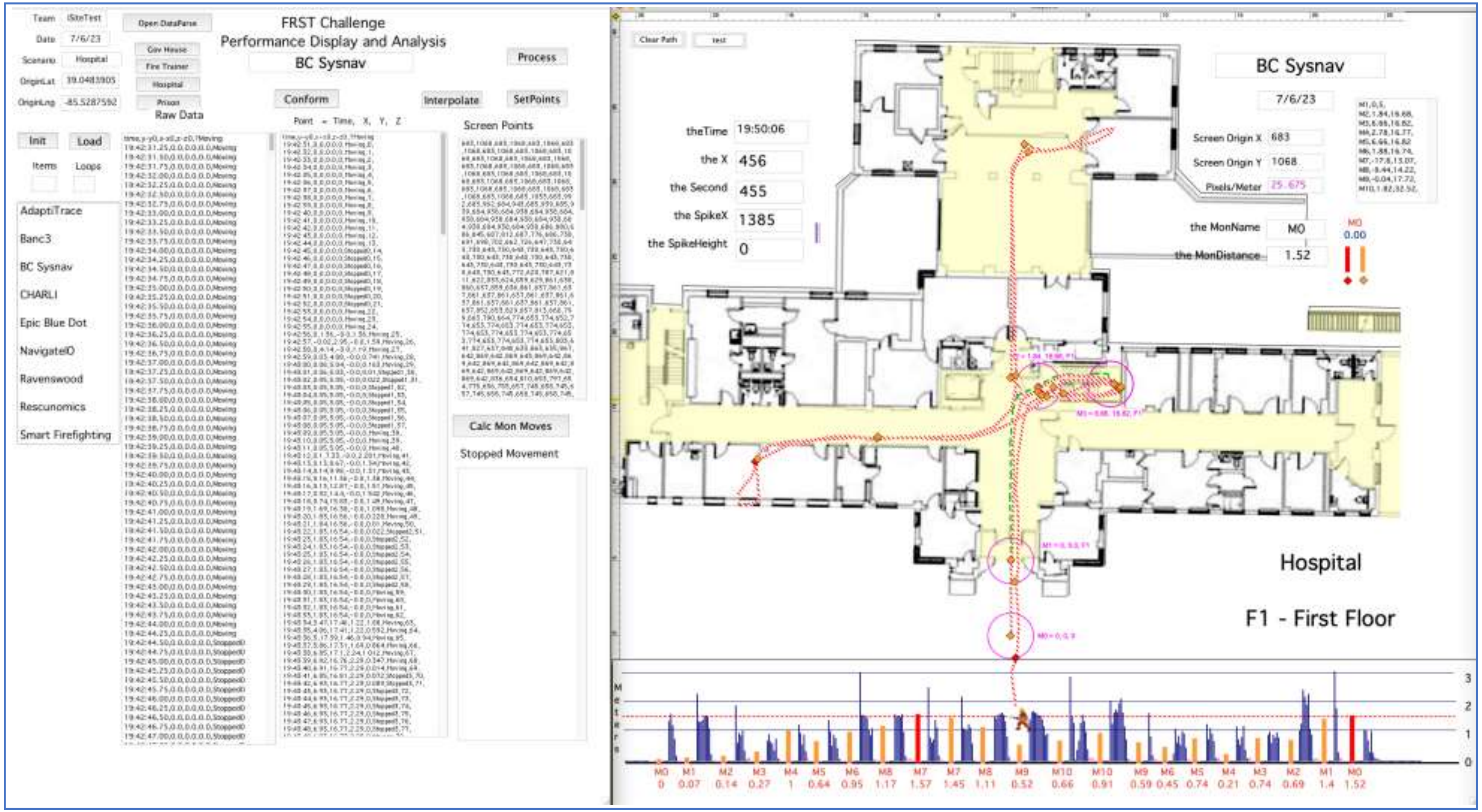


Calculate Monument X/Y Meter Location from Origin

B5033 Monument X/Y Positions and GPS Locations					
Origin Point = 0,0 GPS Coordinates = (39.0483905, -85.5287592)					
Monument#	X	Y	Latitude	Longitude	Floor
M0	0	0	39.0483905	-85.5287592	0
M1	0	5	39.0484356	-85.5287592	F1
M2	1.84	16.68	39.0485411	-85.5287378	F1
M3	6.66	16.82	39.0485423	-85.5286818	F1
M4	2.74	16.77	39.0485423	-85.5286818	F2
M5	6.66	16.82	39.0485419	-85.5287274	F2
M6	1.88	16.74	39.0485416	-85.5287374	F3
M7	-17.6	13.07	39.0485085	-85.5289638	F3
M8	-9.44	14.22	39.0485189	-85.528869	F3
M9	-0.04,	17.72	39.0485505	-85.5287597	F3
M10	1.82	32.52	39.048684	-85.5287381	F3



Create Track Replays on Static X/Y Floor Plans



FRST Signal Analysis Multi-Factor Criteria

Signal Quality

- a) Format Compliance
- b) Well Disciplined
- c) Stability
- d) Continuity

Target Accuracy

- a) 1 meter Bounding Cylinder Threshold
- b) Floor-Room Approximation

X/Y Accuracy

- a) Scale
- b) Articulation
- c) Drift
- D) Pattern Fidelity

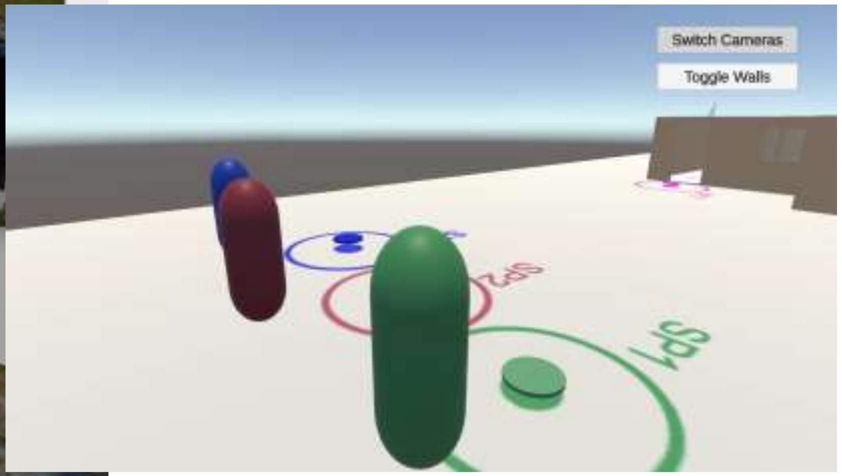
Z Axis

- a) Scale
- b) Elevation Fidelity

Ground Truth Procedures

IU3D Point Clouds

Experimental 3D modeling & VR/AR



Prototypes





Phase 4



Phase 5

Phase 5

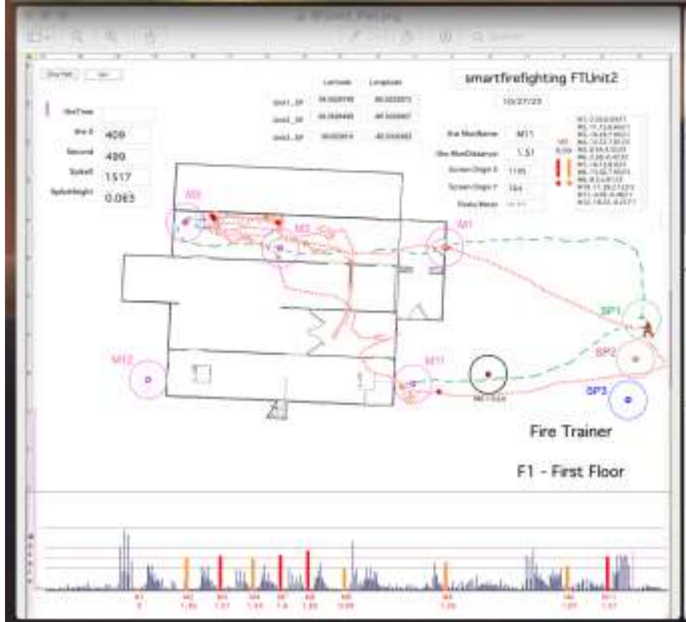
Phase 5

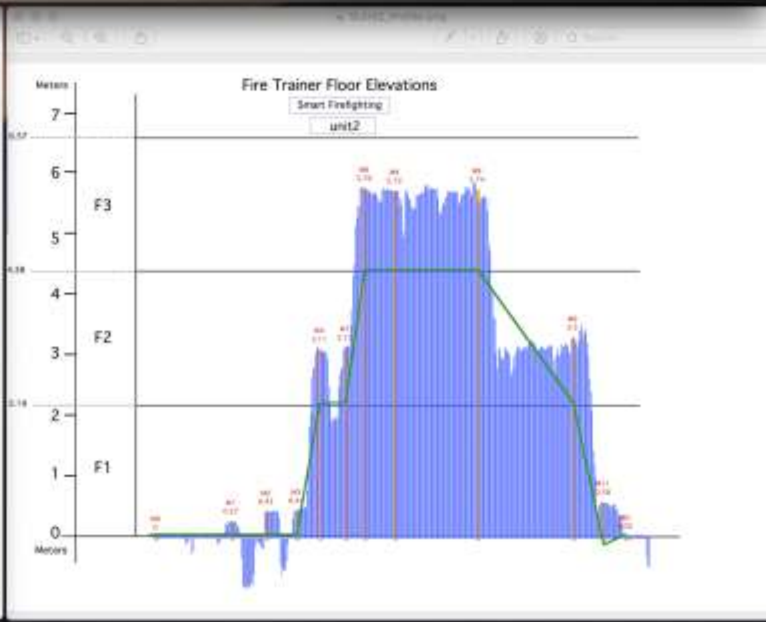


BURTON

Data Analysis

- iSite Maps
- GoPro Videos





Performance Plots & Profiles

Governor' Residence

FRST - iSite Signal Analysis
September 2023

Signal Quality

a) Format Compliance: seems OK

b) Well Disciplined: Long tail after end Monument

c) Stability: Seems unstable, with big distance spikes

d) Continuity: Poor, long gaps of no movement between M5-M7-M8, and M8-M4.

X/Y Accuracy

a) Scale: Seems a little wide-ranging

b) Articulation: Good in beginning, then hard to decipher.

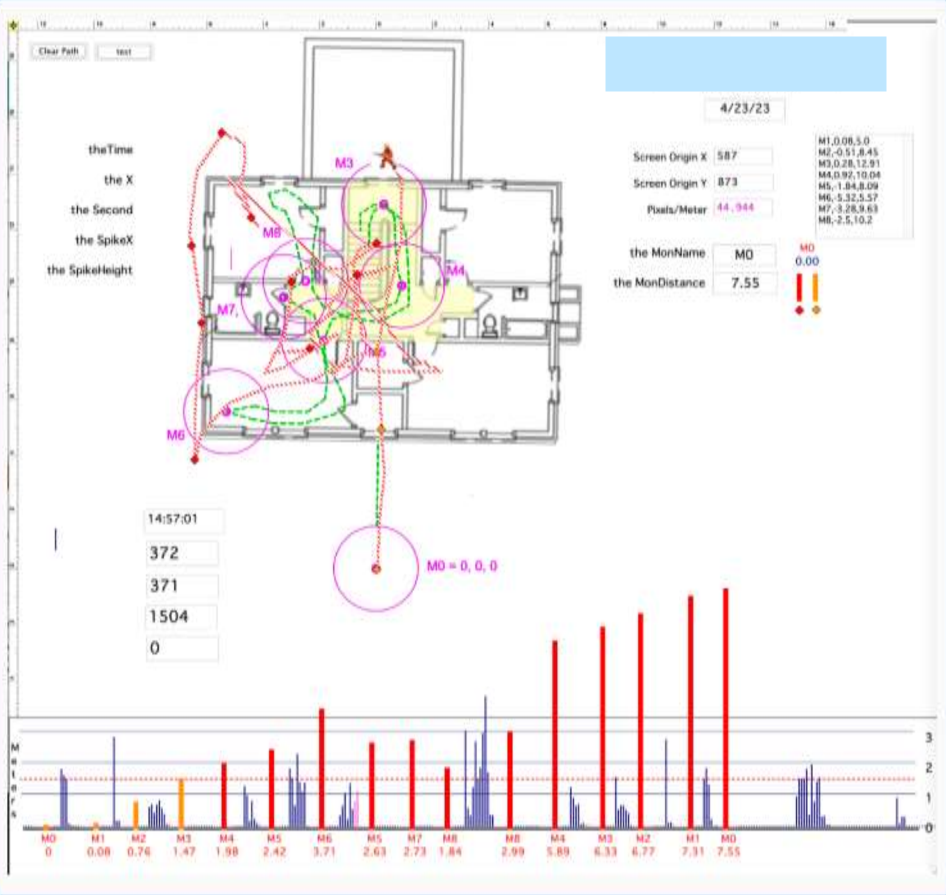
c) Drift: Marginal

D) Pattern Fidelity: Poor

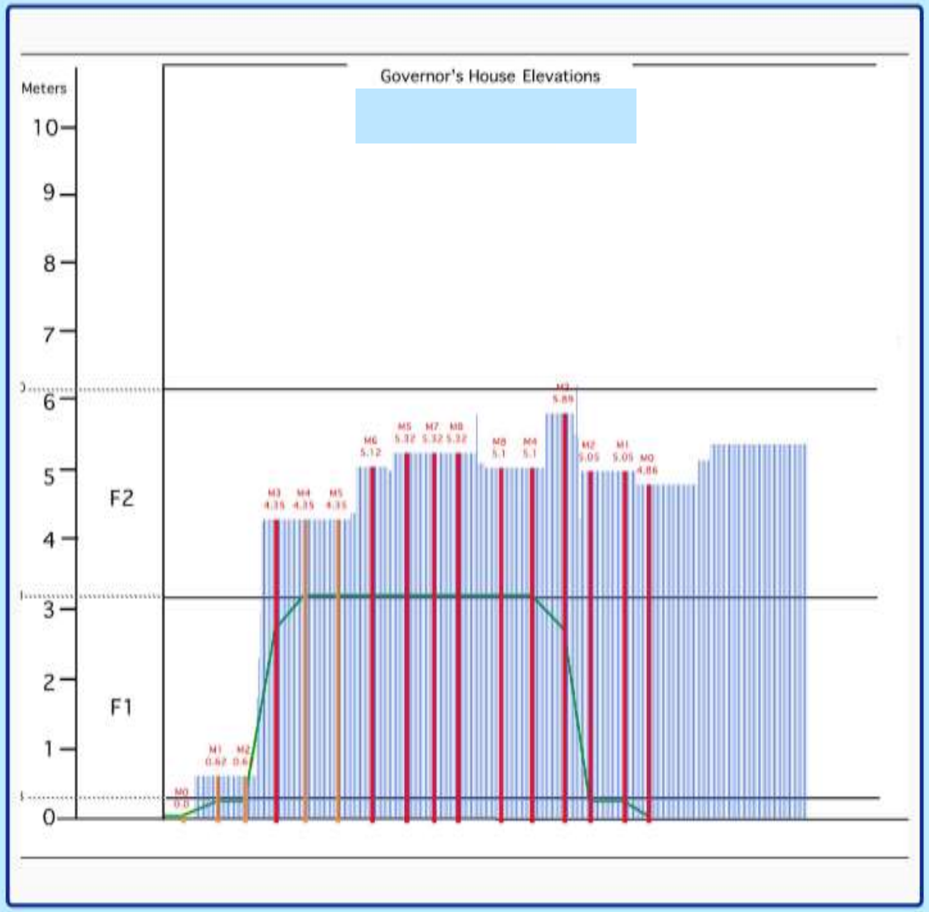
Z Axis

a) Scale: Medium

b) Elevation Fidelity: Goes Up OK, a little high, but can't come back Down.



X/Y Horizontal Plot



Z Axis Profile

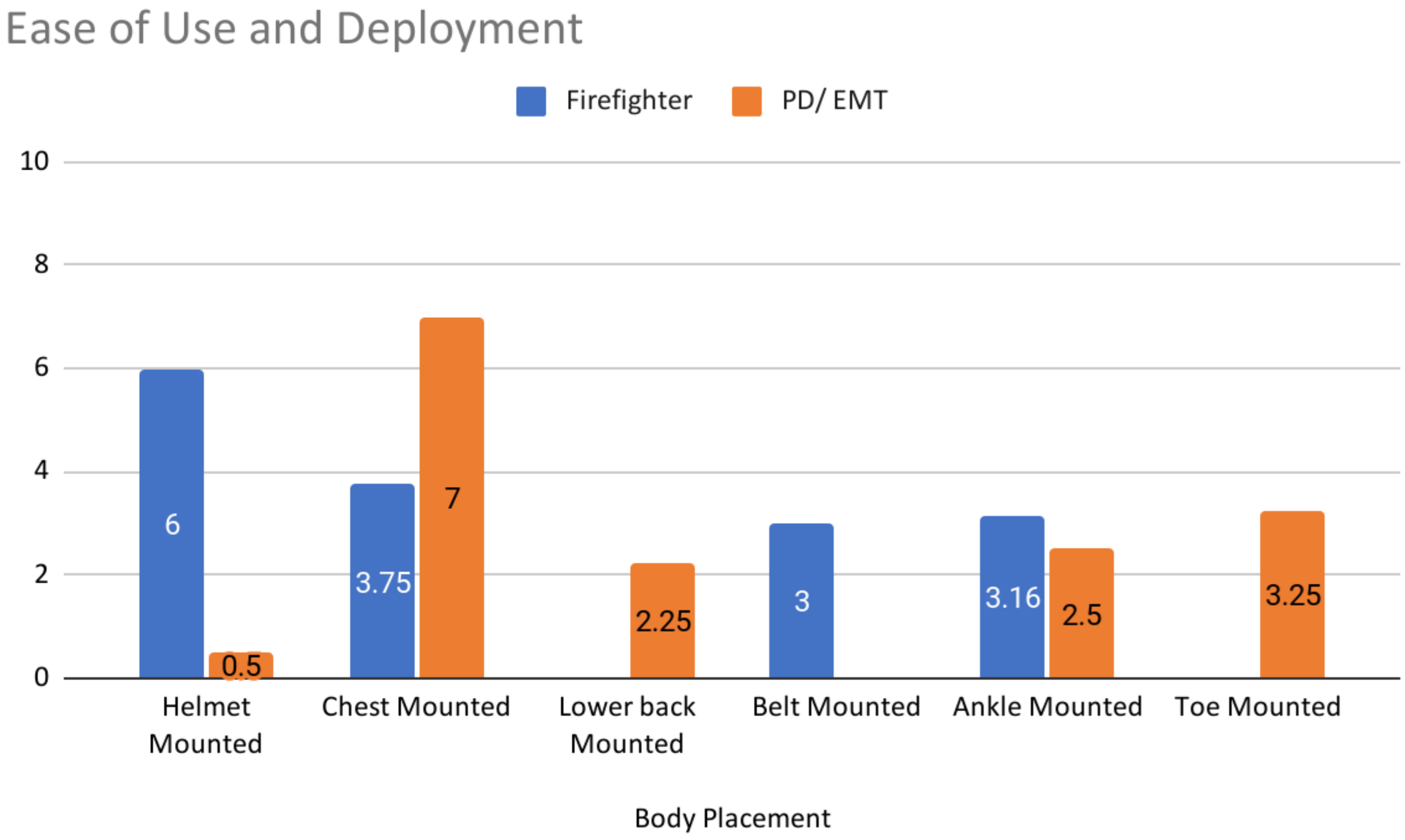
Ruggedization

- Heat
- Water
- Drop

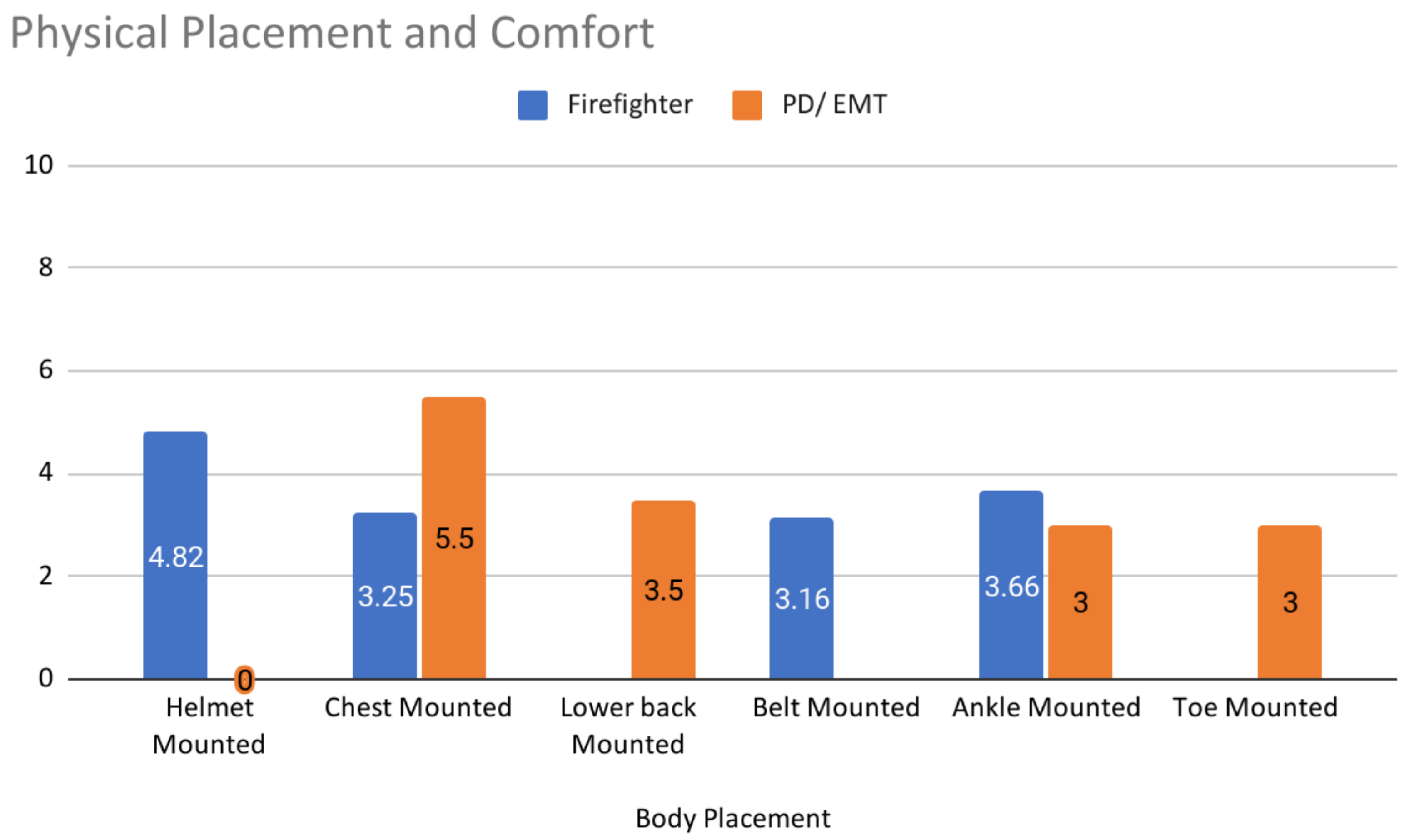
Criteria & Data Collection

- Three (03) measurement criteria for Usability Testing
  - Ease of use and deployment
  - Physical placement and comfort
  - Overall recommendation
- 59 survey responses, 20 interviews
- 3 Testing scenarios - Fire Trainer, Active Shooter, Fire and Tunnel Collapse
- 6 products tested
- 10 Role-players - 6 Firefighters + 2 Police + 2 Emergency Medical Technicians

Chest mount can be easily used and deployed by PD/ EMTs and Helmet mount for firefighters



Physical Placement on helmet aren't preferred by PD/ EMTs
and with chest mount being preferred



Physical Placement on helmet aren't preferred by PD/ EMTs
and with chest mount being preferred

Body Placement

Blinking lights don’t work for police

Public safety operations are complex

Demo Day-Interoperability & Stakeholder Engagement


LAY


BATTLE
FOGGER
EPIC BLUE

Outcomes

- Competition:
  - Teams used a combination of COTS and custom software and hardware
  - Some use of standards to guide development
- Future
  - Need ongoing testbeds to nurture these innovators and derisk government investment
  - Need to foster standards adoption and interoperability

  - **Professional communities must support innovators**

Together we can solve many of our most pressing challenges!

CRISIS TECHNOLOGIES INNOVATION LAB
PERVASIVE TECHNOLOGY INSTITUTE

ctil.iu.edu

Sonny Kirkley

ekirkley@iu.edu

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The PSIAP utilizes grants and cooperative agreements to stimulate critical R&D for public safety communications technology and provide access to cutting-edge technologies and applications that will enable responders to better carry out their mission to protect lives and property. For more information, visit pscr.gov

05 Panel Discussion

THANKS!

Do you have any questions?
admin@publicsafetygis.org
napsgfoundation.org/

@napsgfoundation

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