# UAS TECHNOLOGY AND USE CASES


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Award #1539070

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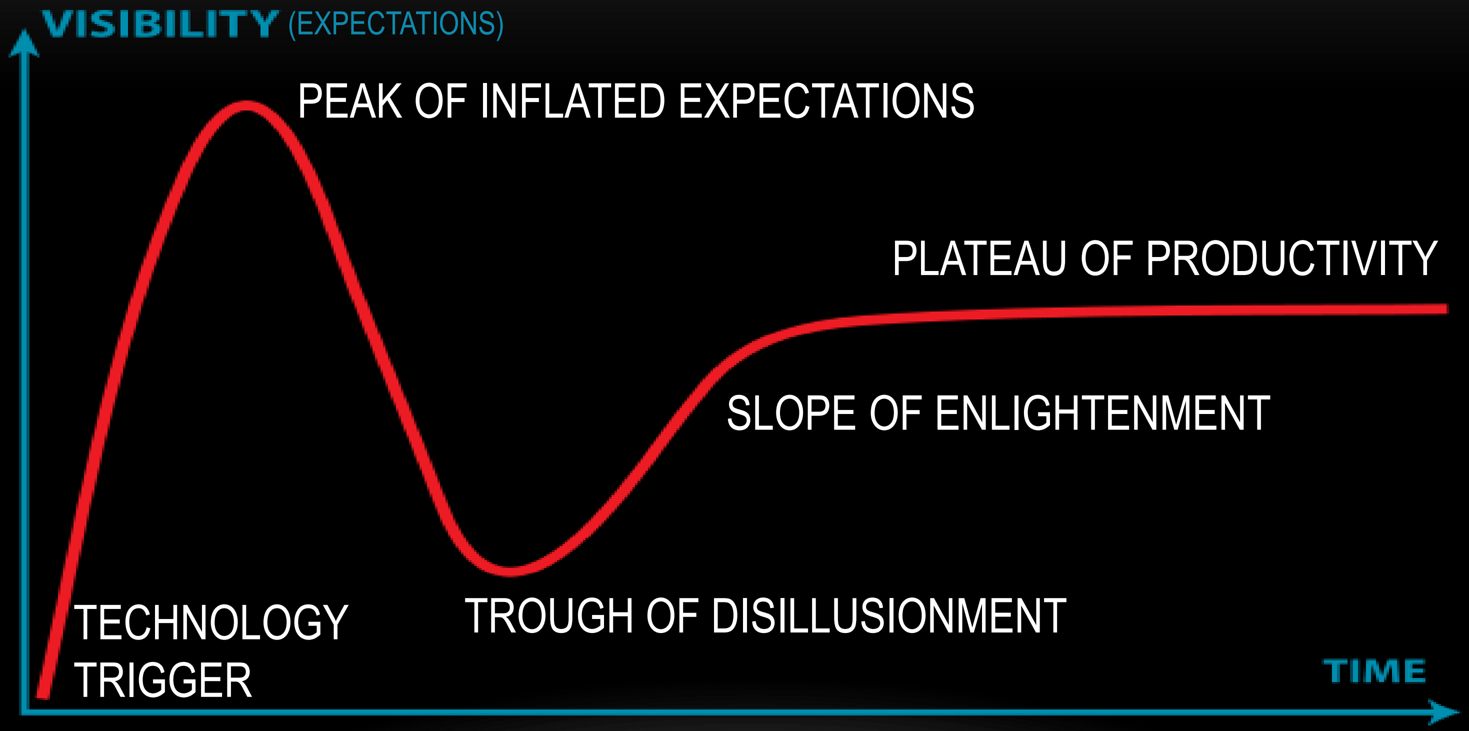
# THE UAS HYPE



# WHERE THE PROBLEM BEGINS

When someone says:

“Why don’t we just use a UAV?”

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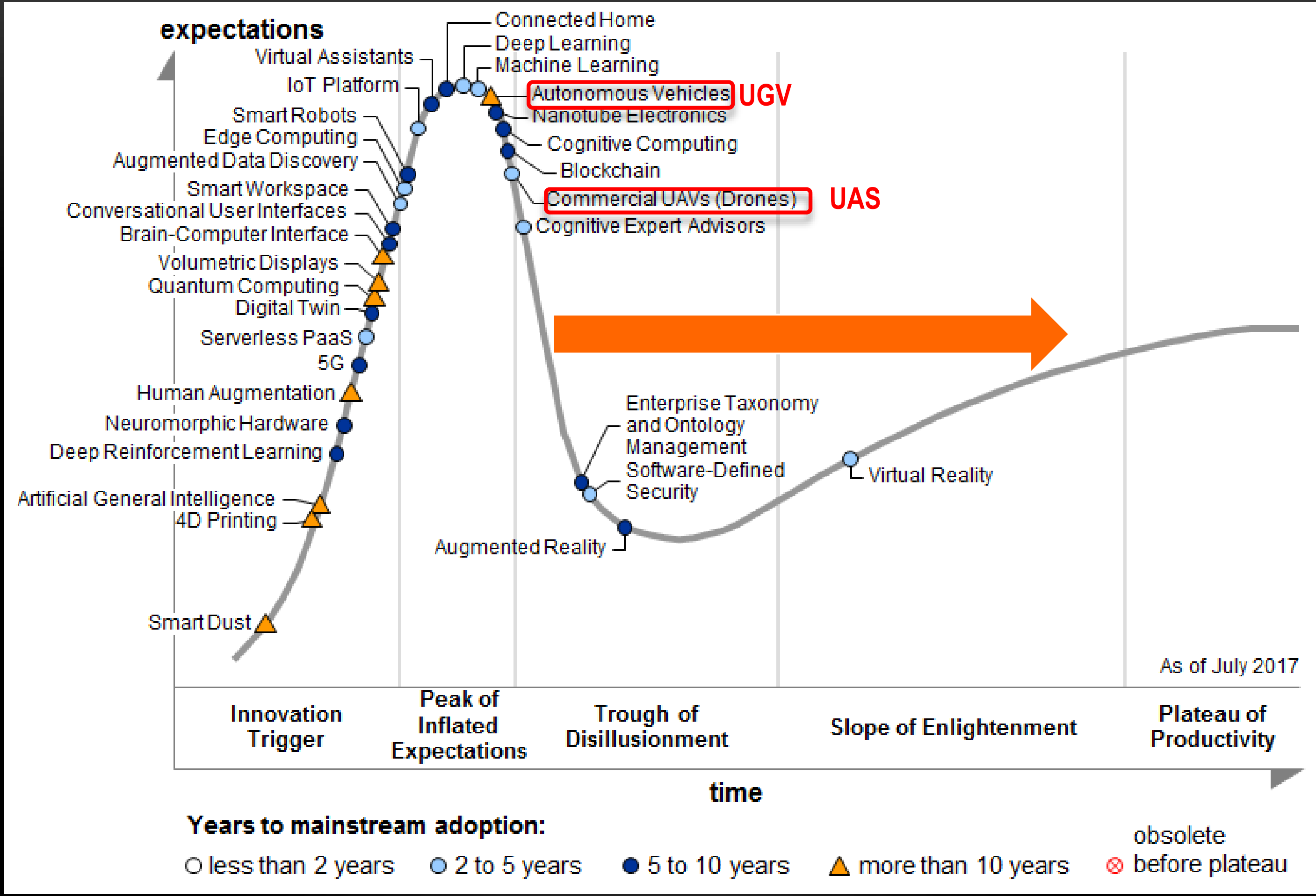
expectations
Virtual Assistants
IoT Platform
Smart Robots
Edge Computing
Augmented Data Discovery
Smart Workspace
Conversational User Interfaces
Brain-Computer Interface
Volumetric Displays
Quantum Computing
Digital Twin
Serverless PaaS
5G
Human Augmentation
Neuromorphic Hardware
Deep Reinforcement Learning
Artificial General Intelligence
4D Printing
Smart Dust
Connected Home
Deep Learning
Machine Learning
Autonomous Vehicles
UGV
Nanotube Electronics
Cognitive Computing
Blockchain
Commercial UAVs (Drones)
UAS
Cognitive Expert Advisors
Enterprise Taxonomy and Ontology Management
Software-Defined Security
Augmented Reality
Virtual Reality
As of July 2017
Innovation Trigger
Peak of Inflated Expectations
Trough of Disillusionment
Slope of Enlightenment
Plateau of Productivity
time
Years to mainstream adoption:
less than 2 years
2 to 5 years
5 to 10 years
more than 10 years
obsolete before plateau

# THE LAST GENERATION OF DRIVERS

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# THE UAS BIG DATA DIVIDE

- Most consumer SUAS are good at doing only one thing – *taking pretty pictures*; this is *usually* not a big data problem (yet)

- Most high end (i.e., military) UAS do collect Big Data, but they also have Big Data resource support
- Emerging UAS (e.g., precision agriculture, delivery) fall in between – worst of both worlds: some of the capability with none of the supporting infrastructure

Predator GCS

# AUTONOMOUS TECH - WHERE ARE WE AT NOW?

## On the ground

Early adopter and regulatory transition stage into consumer market

## On the water

Large scale proof of concept and R&D applications driven by remote sensing

## In the air


Transitioning from military to commercial applications with limited regulatory approval


SCIENTISTS WORKING ON DRONES
THAT COULD HELP PREDICT TORNADOES

# TYPES OF UAS

- Fixed wing vs. rotary wing

Long range highway inspection with remote sensors

Bridge and contact sensor inspection

# APPLICATIONS TO TRANSPORTATION

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# UAS MISSIONS AND APPLICATIONS IN THE FIELD

- Emergency

First Response

- Imaging

Remote Inspection

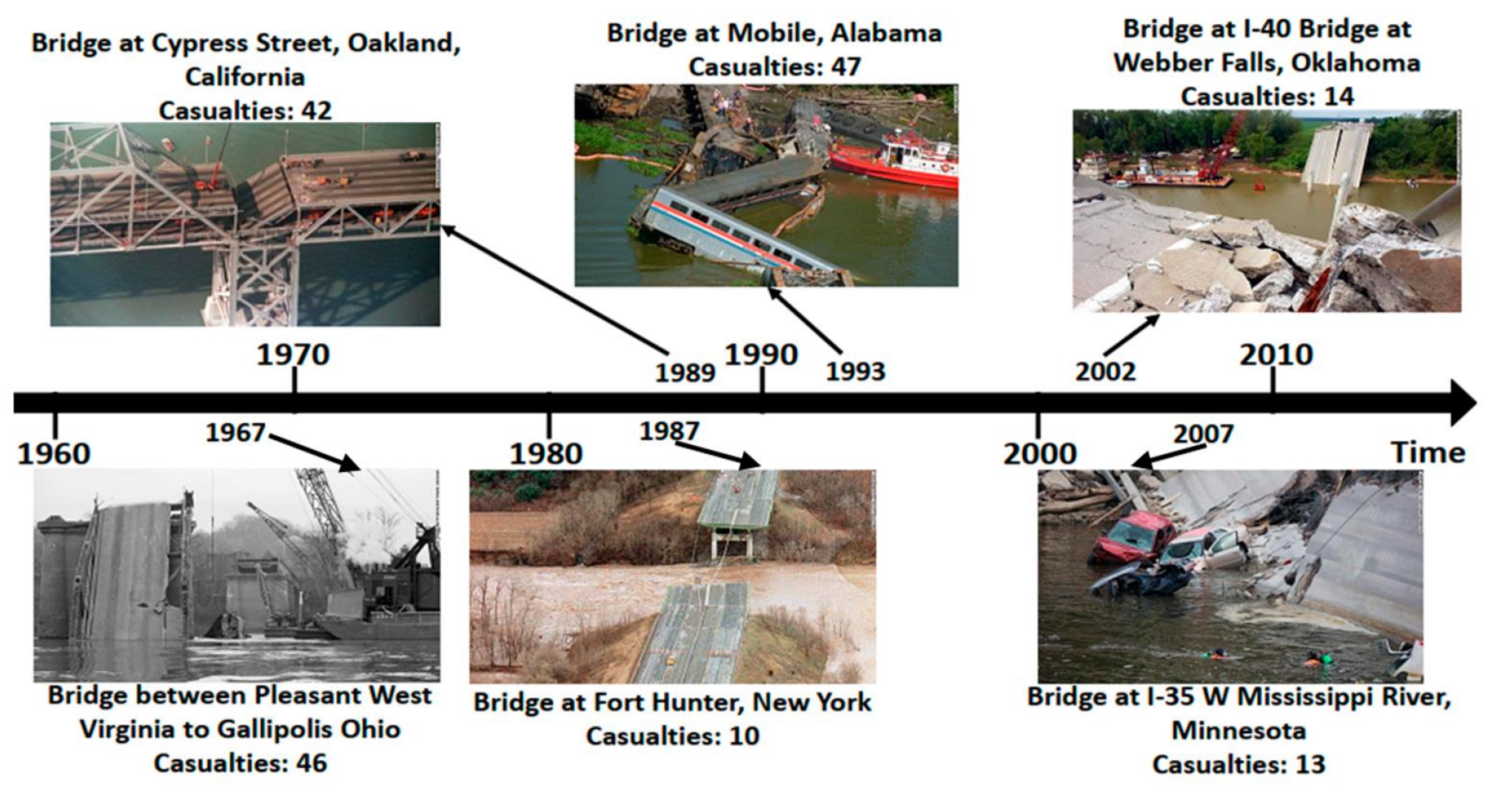
Delivery

- Servicing

Contact Inspection

- Sensing

# BRIDGE DISASTERS



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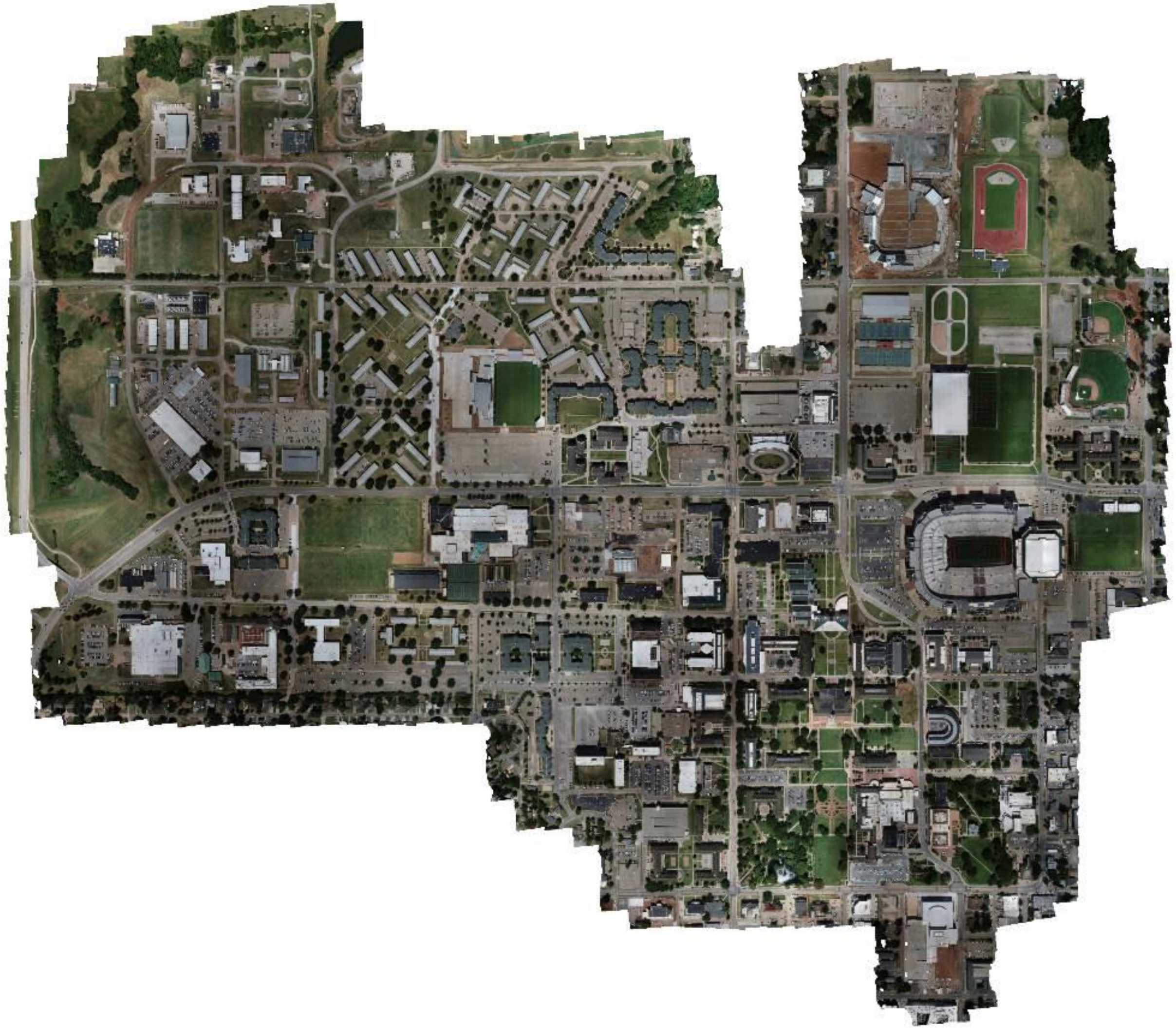
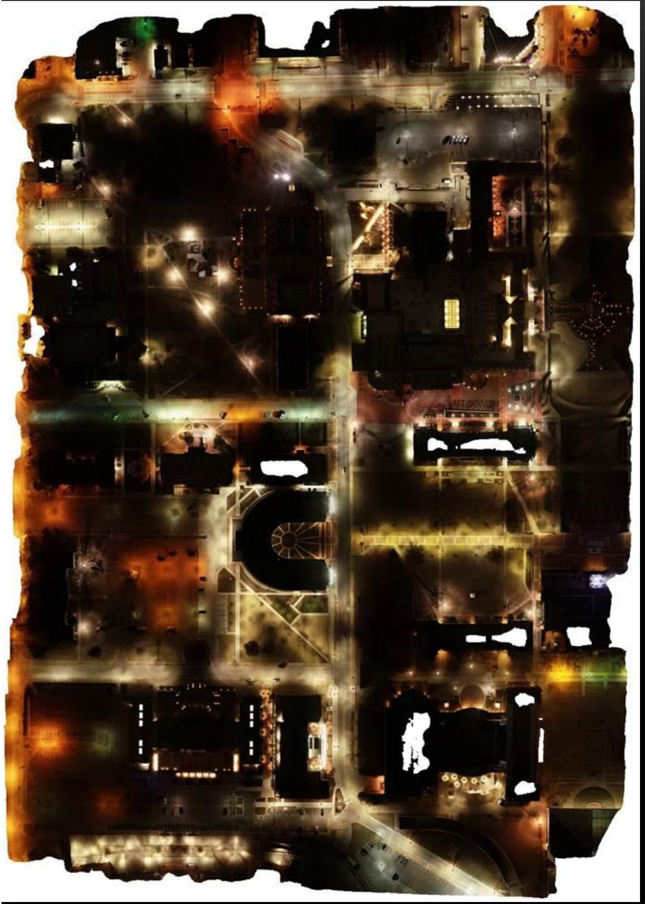
# BRIDGE INSPECTION

- Provide tools for maintenance and engineers to acquire more data more effectively

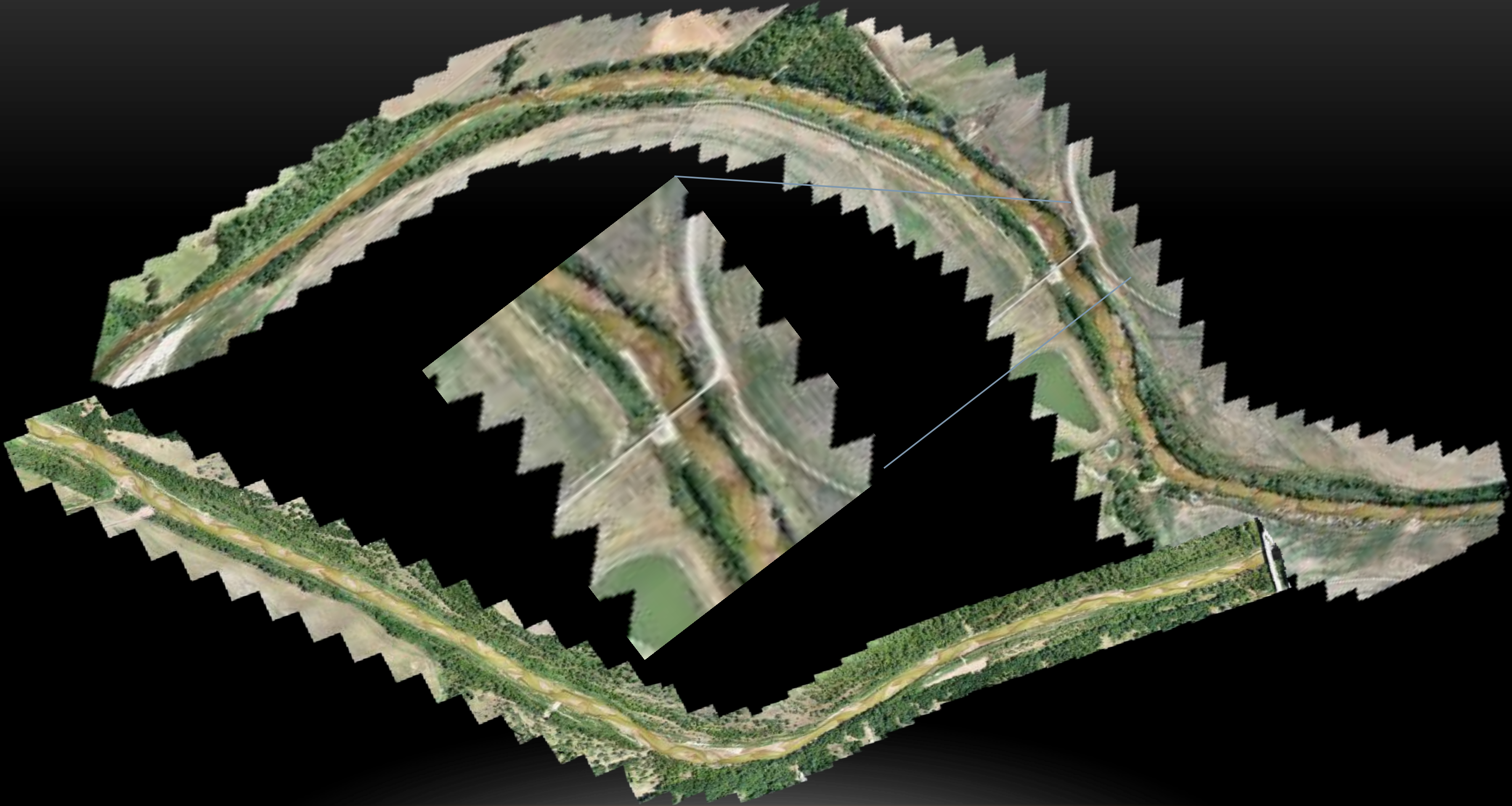


Hampton Inn
EXIT





Example of light study on OSU campus captured at night




Country Club & McElroy Rd
1:15 PM

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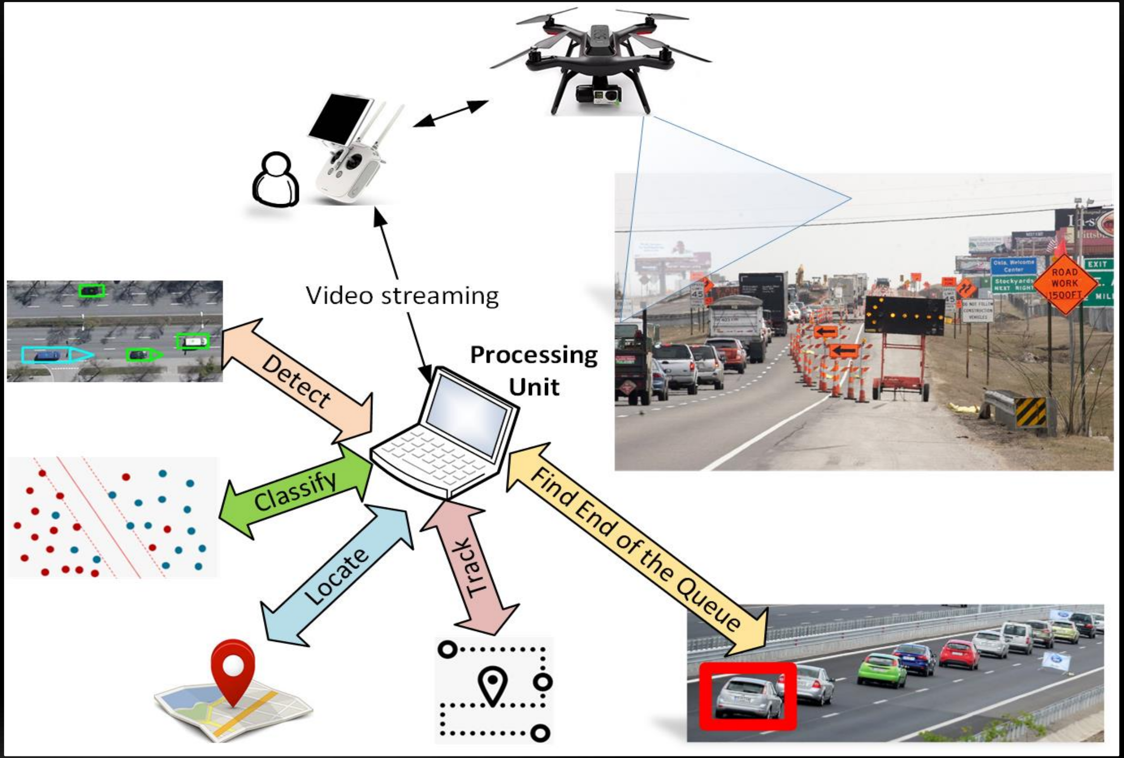
# TRAFFIC MANAGEMENT

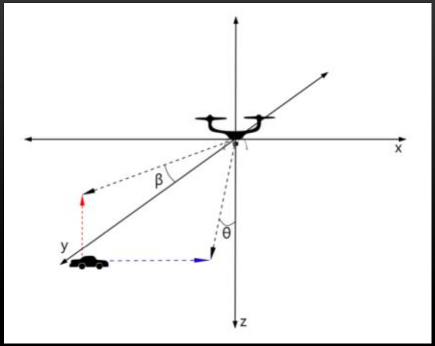
UAS-Assisted Work Zone Traffic Management:

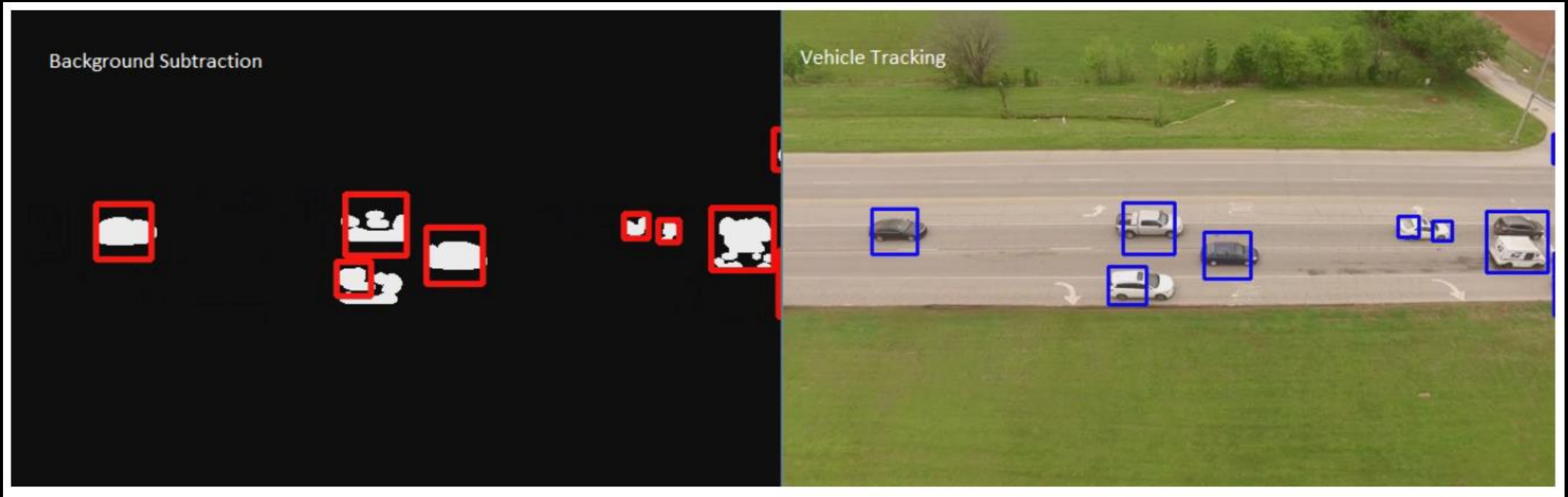
- Efficient, reliable and safe Intelligent Transportation Systems (ITS) traffic data collection and dissemination technology for smart work zone traffic management using low-cost UAS
- Real-time detection, classification, location, and tracking for queue monitoring



# TRAFFIC MANAGEMENT

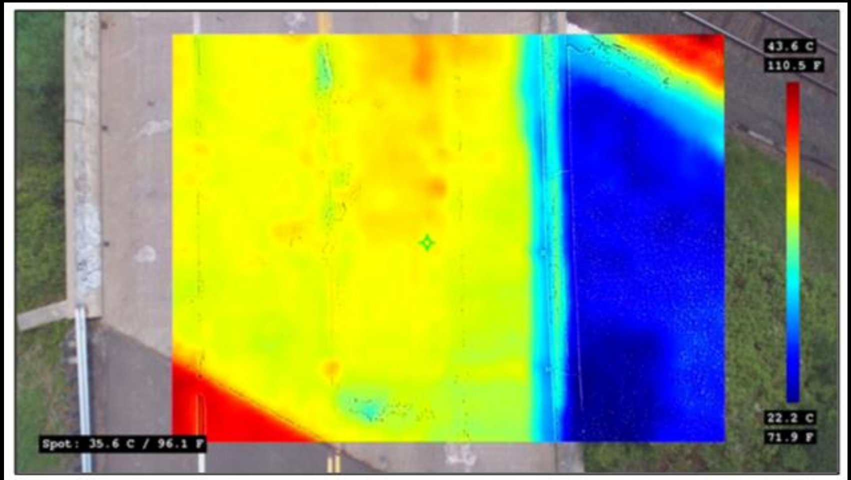
Drone Monitoring → Traffic Count → Real-Time Warning

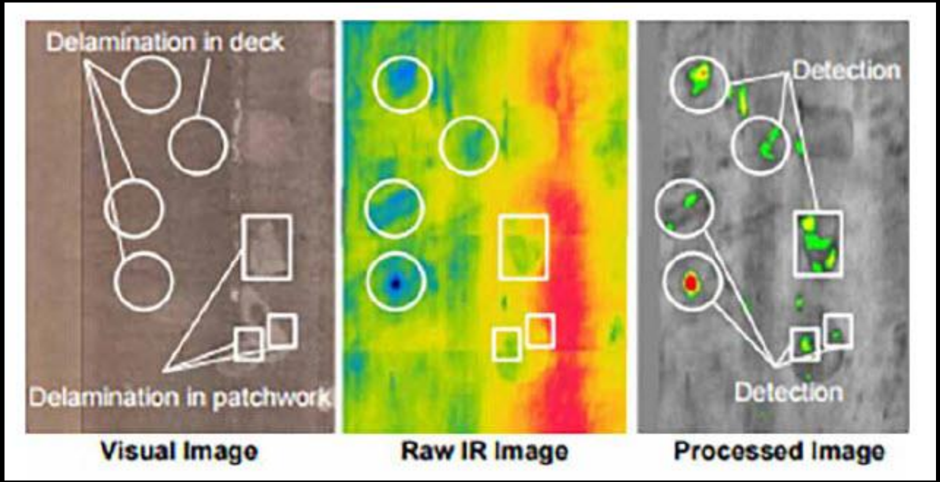


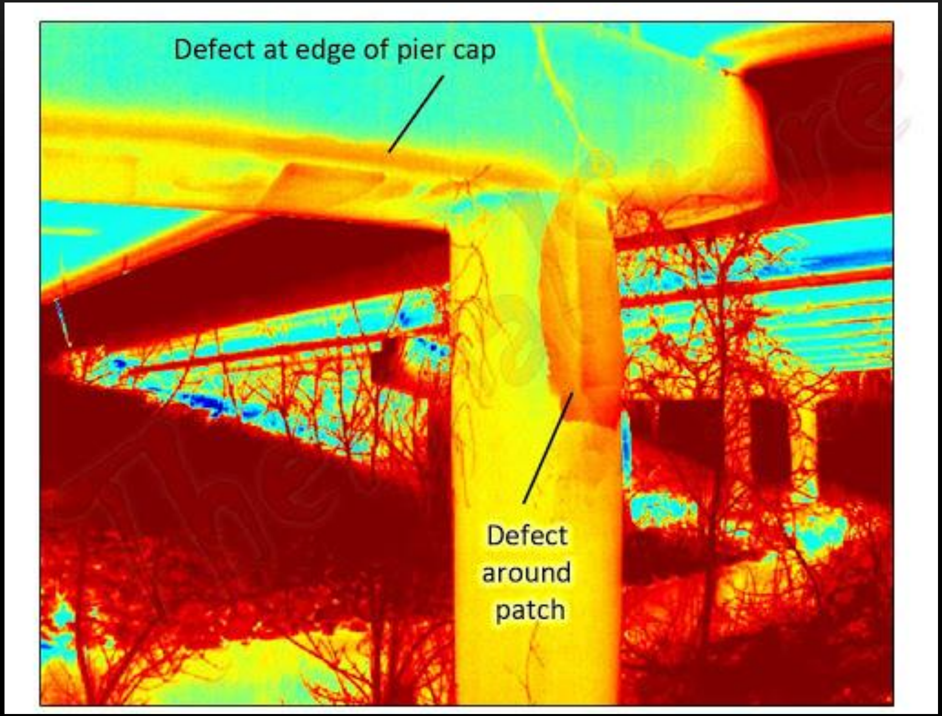



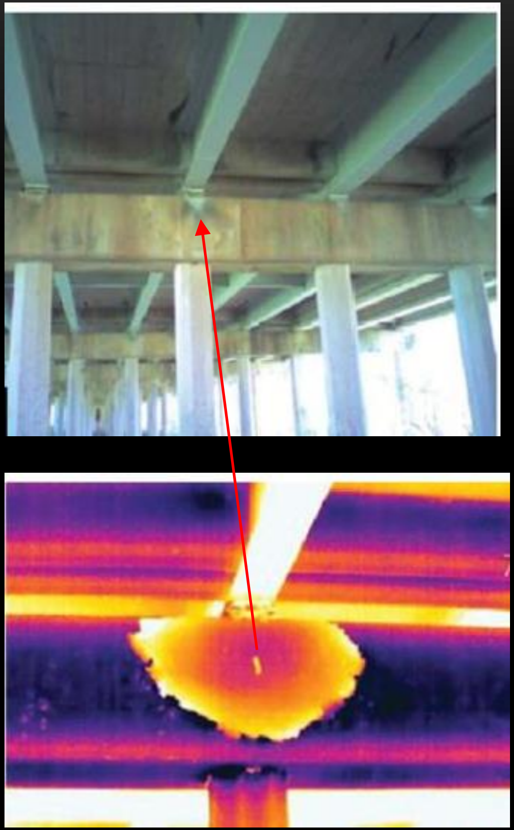
# NON-VISIBLE IMAGING (IR)

- Detection of spalling and delamination with mobile scanning, both visual and infrared




Defect at edge of pier cap
Defect around patch



# PHOTOGRAMMETRY

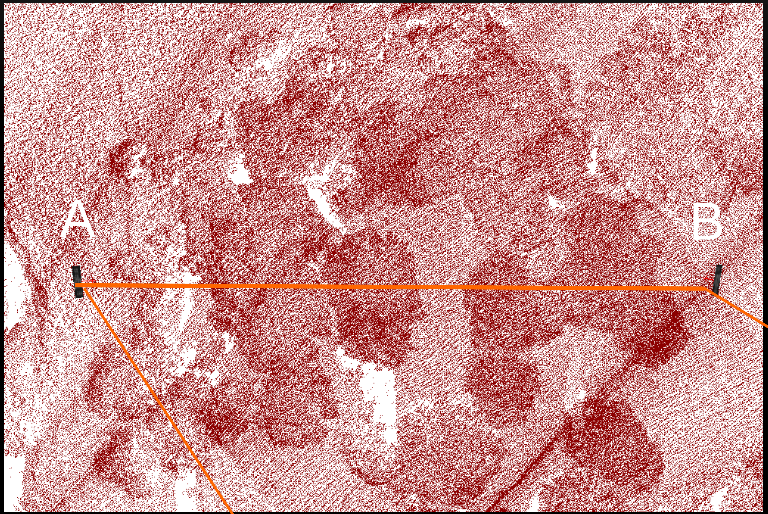
Structure from motion

- Only needs regular RGB imagery
- High resolution mapping in a matter of hours
- Ground control points (GCPs) can be used during processing to geolocate model to survey grade accuracy
- Resolution and detail depends on camera and flight altitude

RGB orthomosaic of DEM model

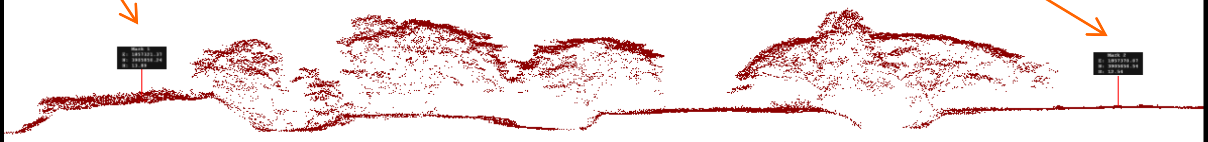

Example image of riverbed and bridge digital elevation model (DEM) with GCPs

# POINT CLOUD GENERATION




Bird view

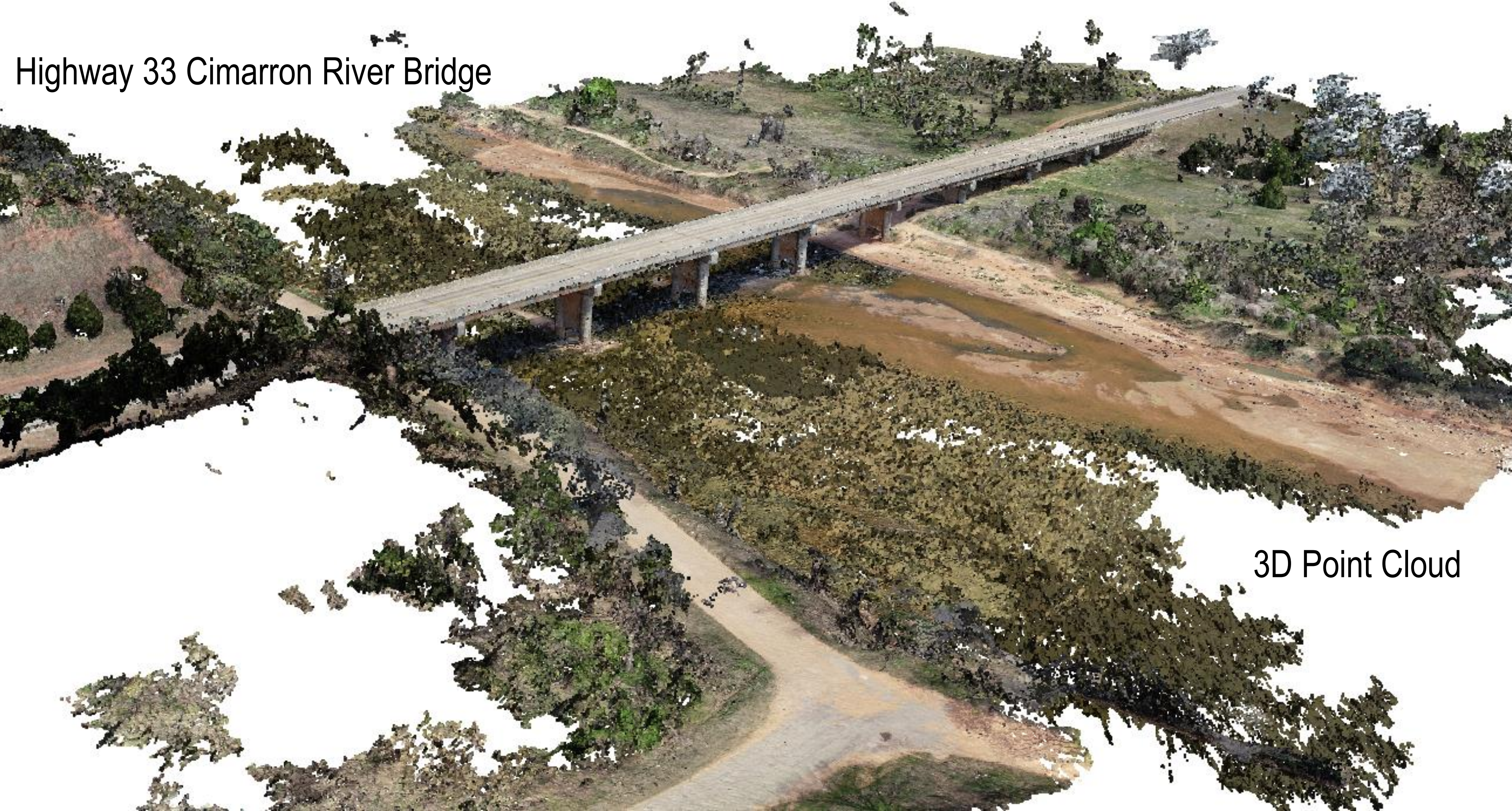
Looking from Pt. B towards A



Cross section between mark A and mark B (depth 5m)

University of Freiburg

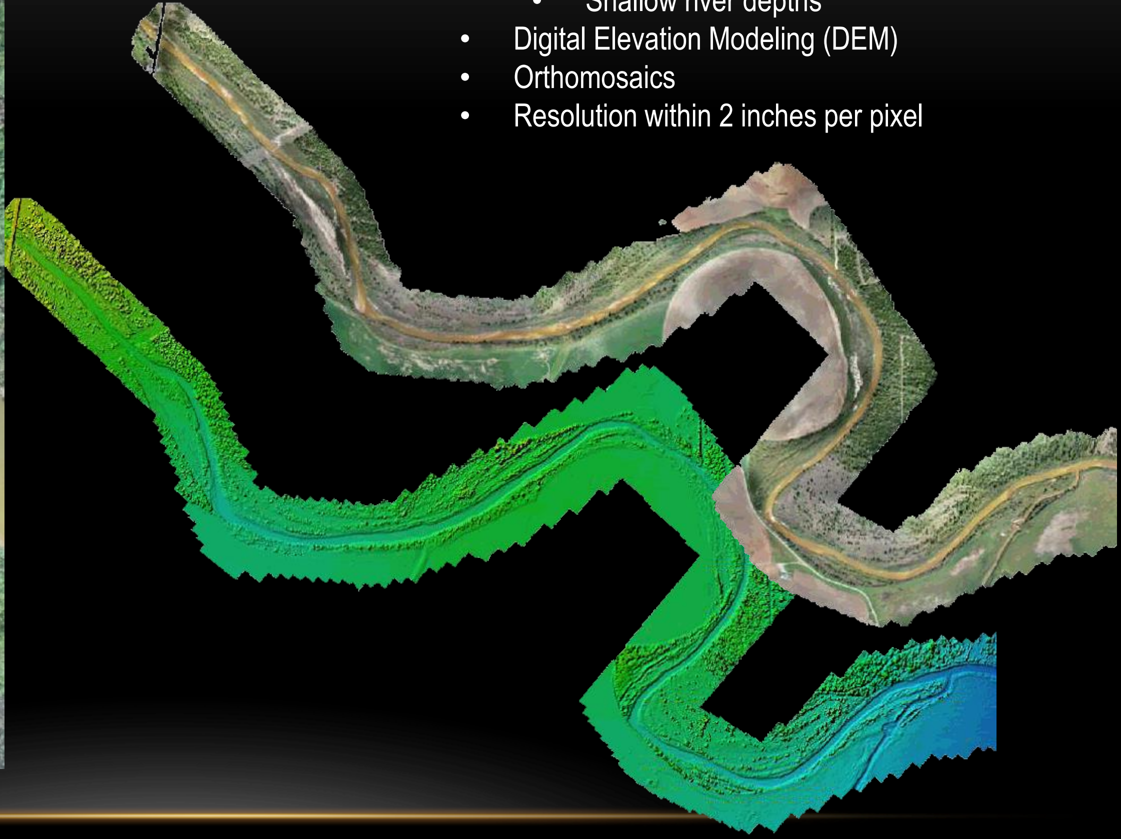
# Highway 33 Cimarron River Bridge



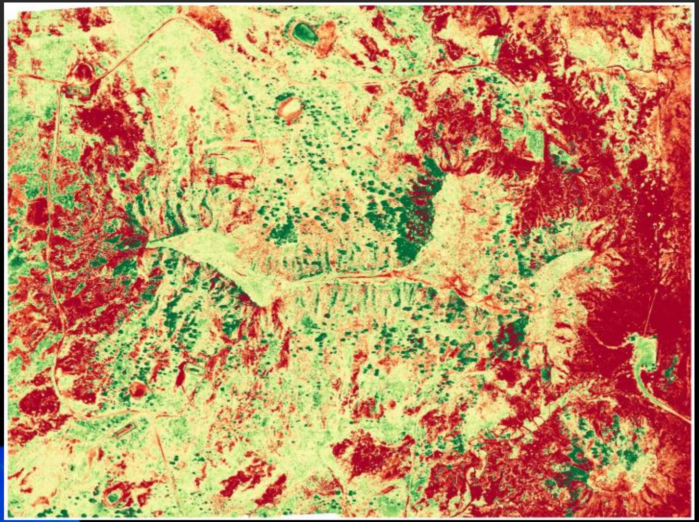
3D Point Cloud

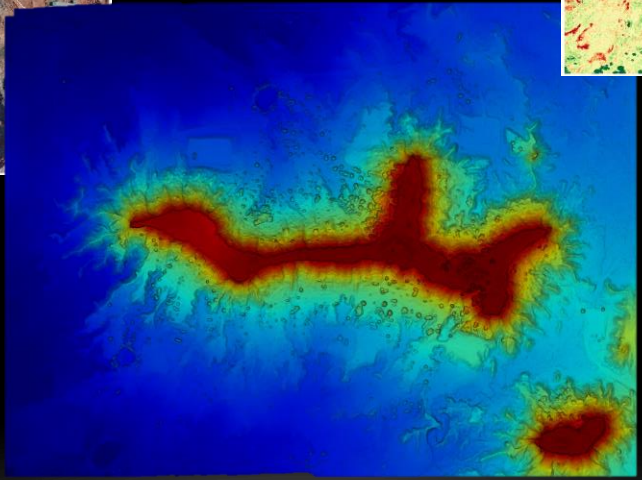
# South Canadian River

- Using UAS to remotely sense
  - Surface velocity
  - River bank width
  - Shallow river depths
- Digital Elevation Modeling (DEM)
- Orthomosaics
- Resolution within 2 inches per pixel

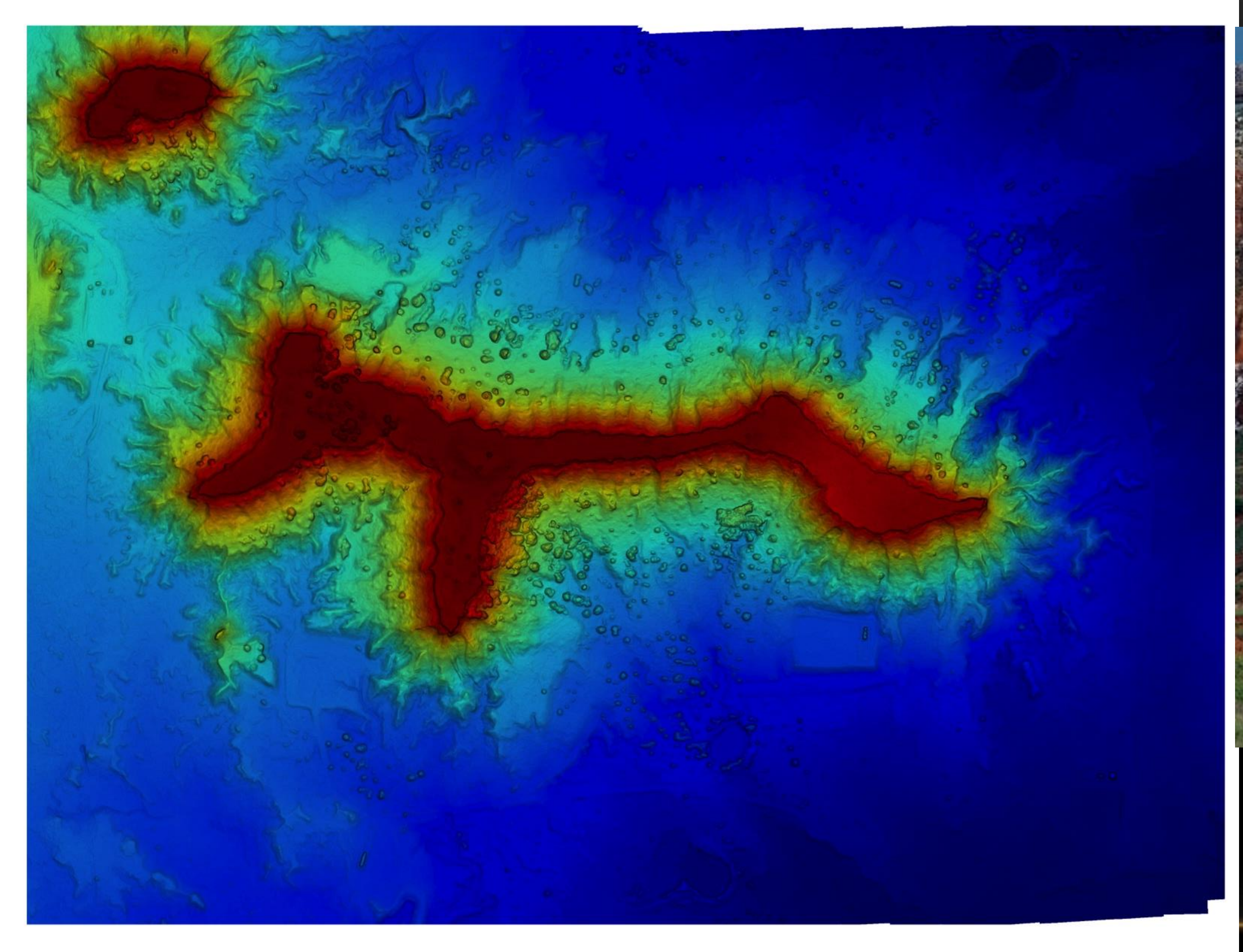


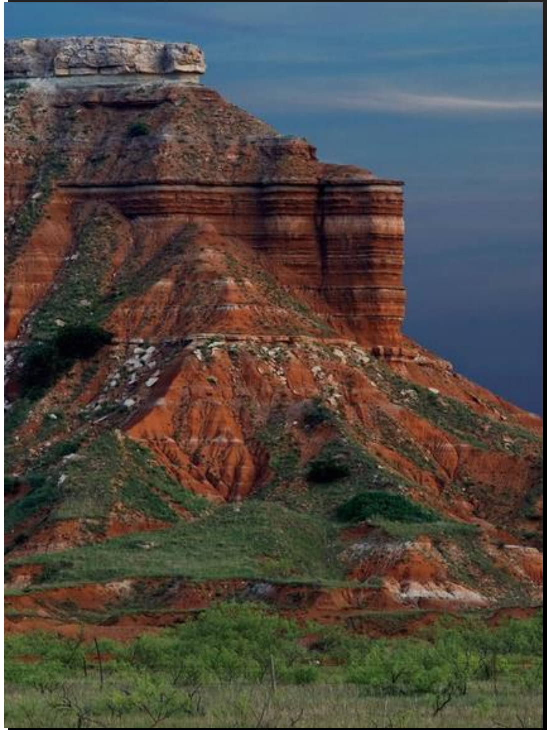
# TERRAIN AND FOLIAGE





# OKLAHOMA “MOUNTAINS”





Gloss Mountain State Park
Peak Elevation Change:
200 ft

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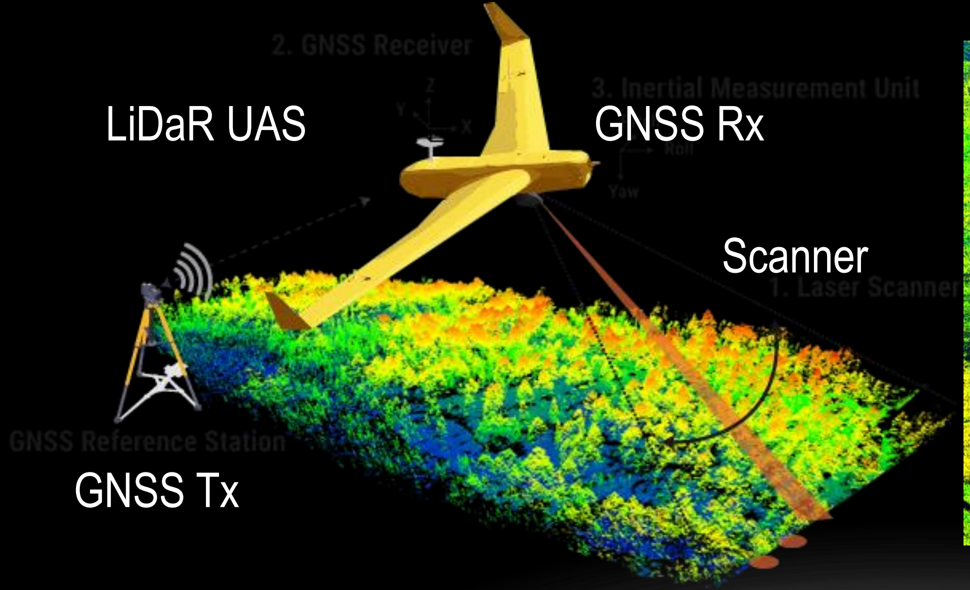
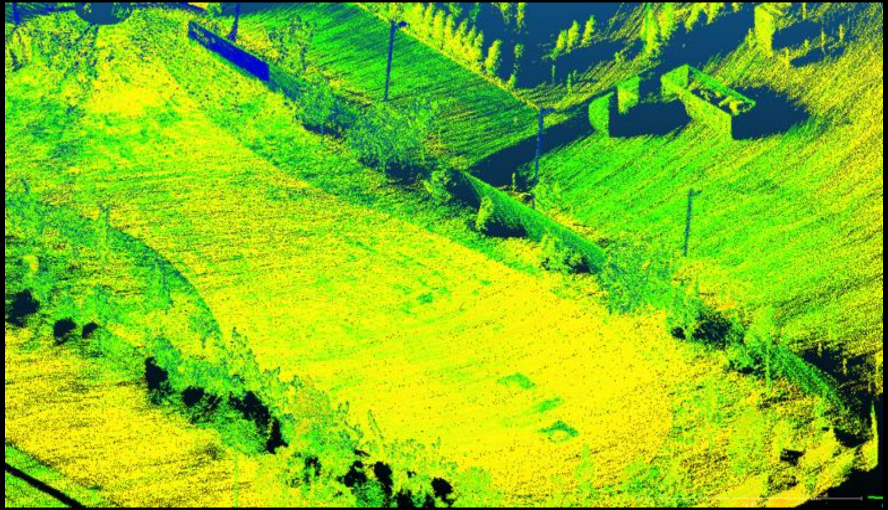
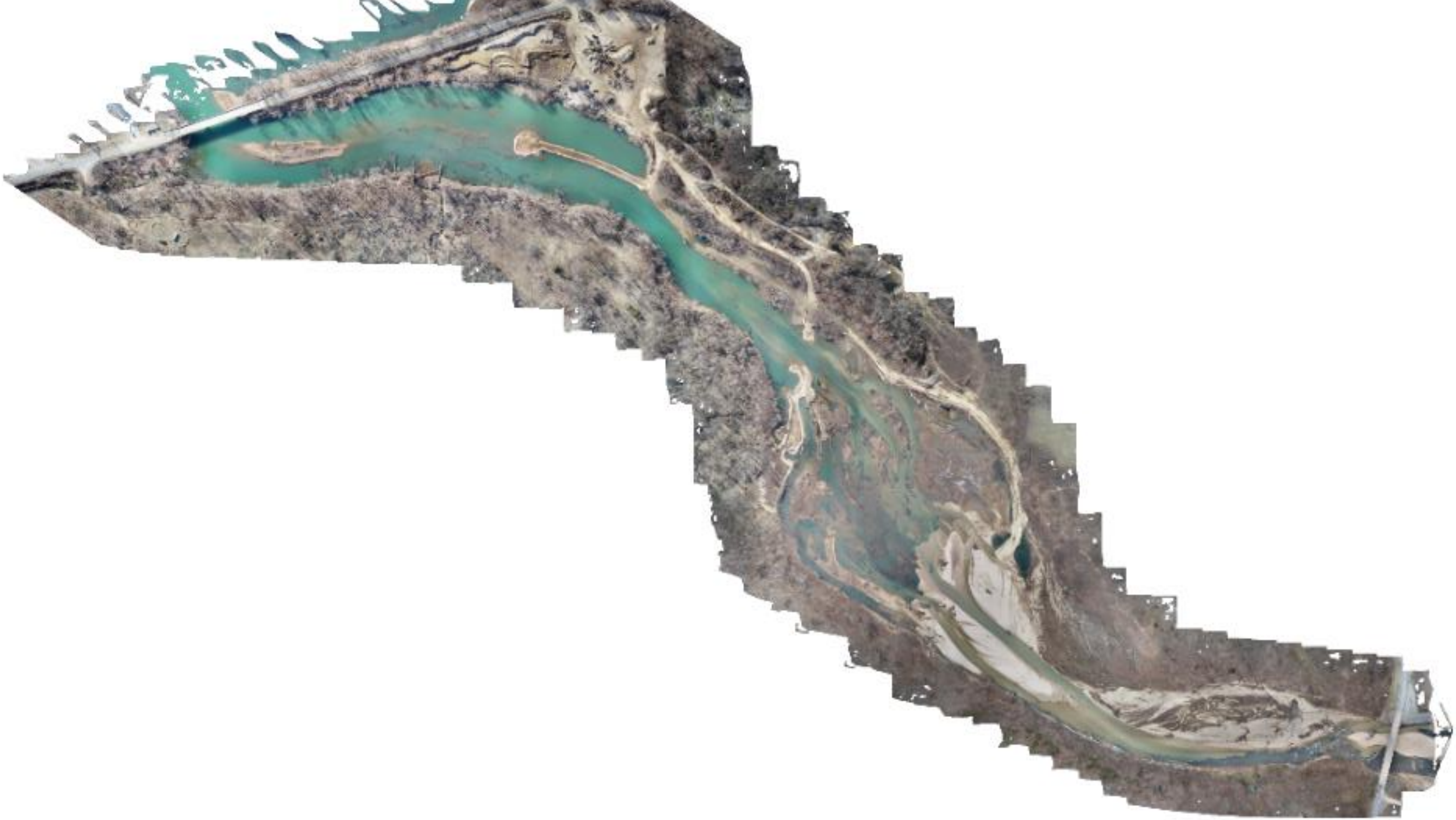
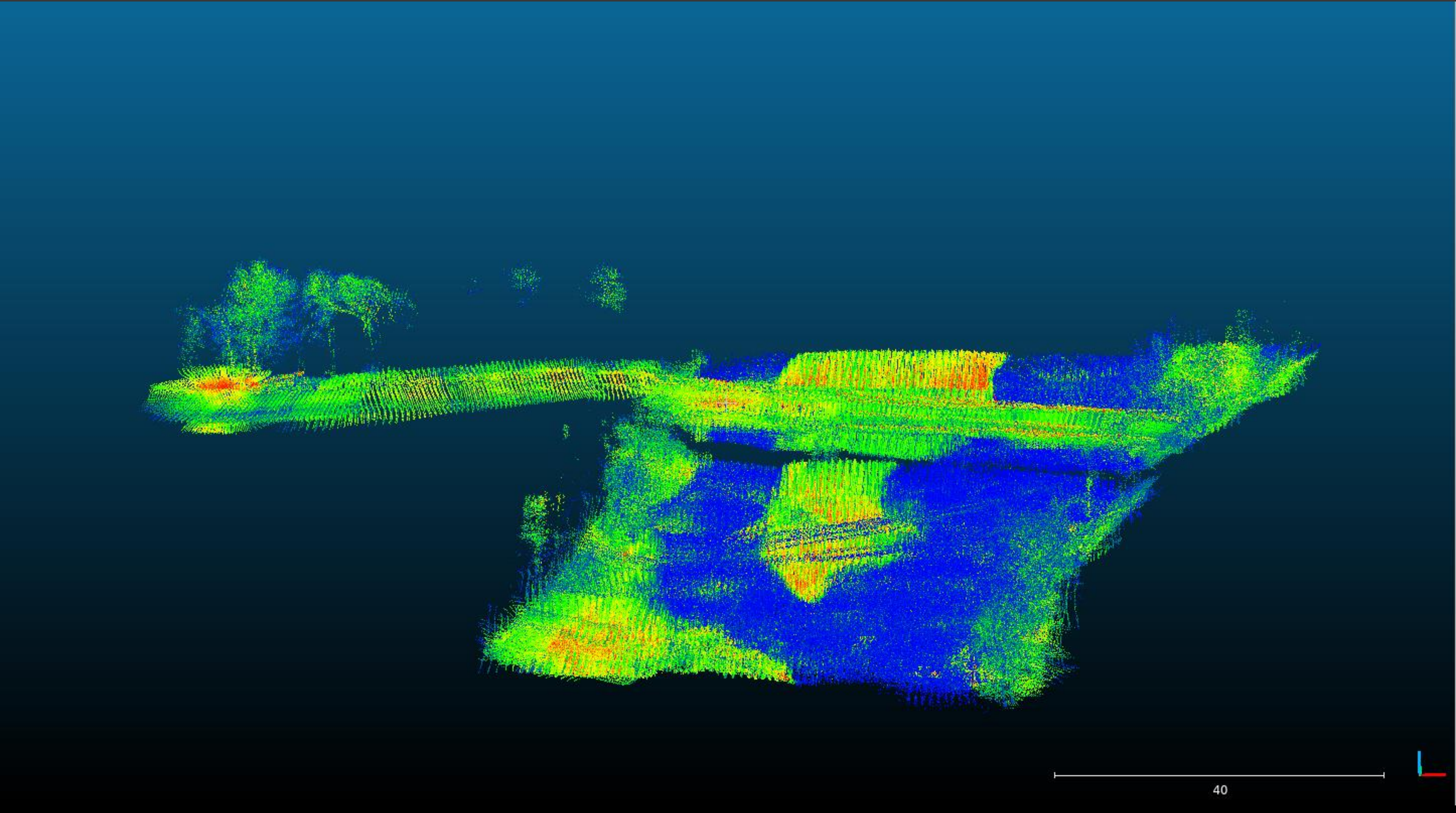
# LIDAR

- Requires ground reference station and independent IMU solution, with high cost & setup time, but provides detailed point clouds in near real-time



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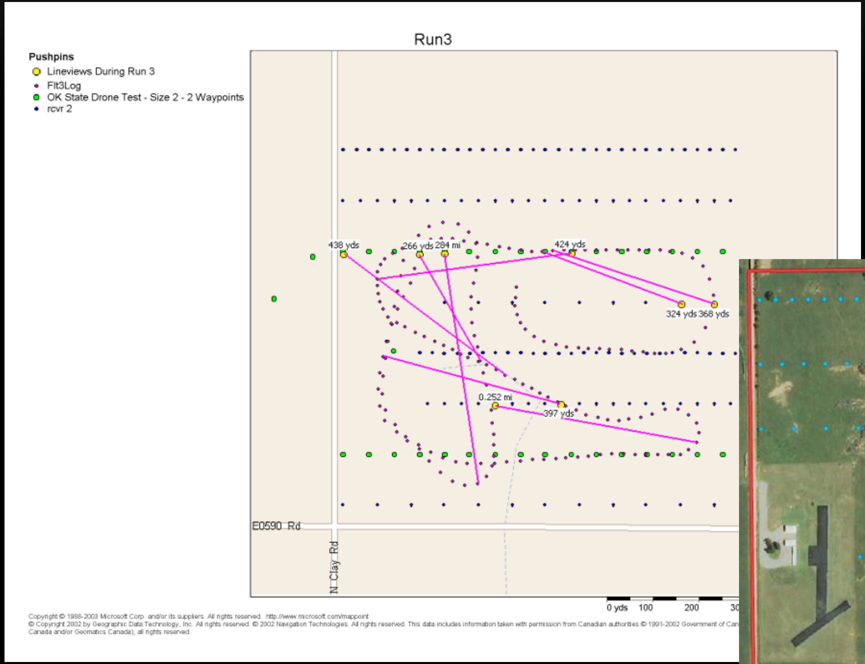
# CONTACT SENSING

- Contact sensing possible, but requires
  - Specialized drones
  - Light weight low power sensors

Elios UAS in contact with bridge soffit and abutment


Elios UAS rolling inside a steel beam

# DEPLOYABLE SENSORS



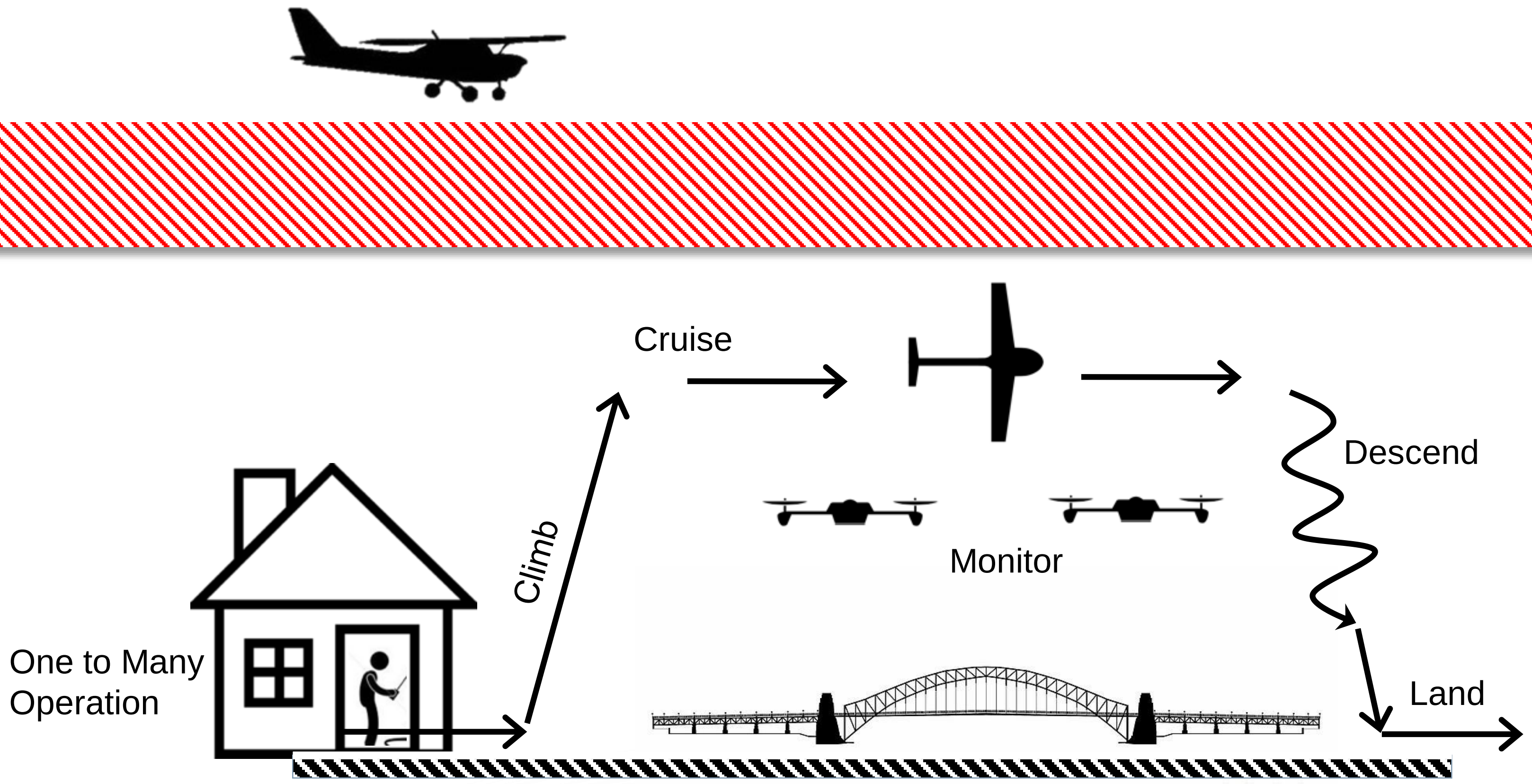



Wireless Seismic

*The drones are designed to carry a number of DARTs simultaneously.*

# EMERGENCY MEDICAL DELIVERY

# FUTURE: AUTONOMOUS BLOS SWARMS



# TAKE AWAY

- Great promise in UAS for road, bridge, and infrastructure inspection
- There is a need for research, training and education
  - *Short term: Part 107 and device specific flight training*
  - *Long term: the amount and type of training is still unknown*
    - *Data analytics, including image/sensor analysis and operation*
    - *In the future, flight training will not be necessary ("self flying" systems), but data analysis will be required*
  - *Developments in autonomy, vehicle systems and payloads will open new opportunities in environmental monitoring*
- The future depends on <u>both</u> technical and regulatory developments in the industry

# BACKUP

# CREW ROLES AND TASKS

| Role | Operational Tasks | Non-operational Tasks |
|---|---|---|
| Flight Director | Observer, flight safety, data management, logbook | Team liaison, time planning, logistics |
| Vehicle Operator (PIC) | Aircraft control, flight planning | Vehicle maintenance |
| Payload Operator | Camera control and data collection, system checks | Maintenance, safety and security |

# PART 107 RULES

- Released by the FAA in June 2016
- Unmanned aircraft must weigh less than 55 lbs (25 kg)
- Visual line-of-sight (VLOS) only; the unmanned aircraft must remain within VLOS of the remote pilot in command and the person manipulating the flight controls of the small UAS. Alternatively, the unmanned aircraft must remain within VLOS of the visual observer.
- Daylight-only operations, or civil twilight (30 minutes before official sunrise to 30 minutes after official sunset, local time) with appropriate anti-collision lighting.
- Maximum altitude of 400 feet above ground level (AGL) or, if higher than 400 feet AGL, remain within 400 feet of a structure (tower or building).
- Must yield right of way to other aircraft.

# PART 107 RULES

- Operations in Class B, C, D and E airspace are allowed with ATC permission. Operations in Class G airspacallowed without ATC permission.
- Minimum weather visibility of 3 miles from control station.
- May use visual observer (VO) but not required.
- First-person view camera cannot satisfy “see-and-avoid” requirement but can be used as long as requirement is satisfied in other ways.
- No person may act as a remote pilot in command or VO for more than one unmanned aircraft operation at one time.
- No operations from a moving aircraft; no operations from a moving vehicle unless the operation is over a sparsely populated area.
- No careless or reckless operations or carriage of hazardous materials.

# REMOTE PIC REQUIREMENTS

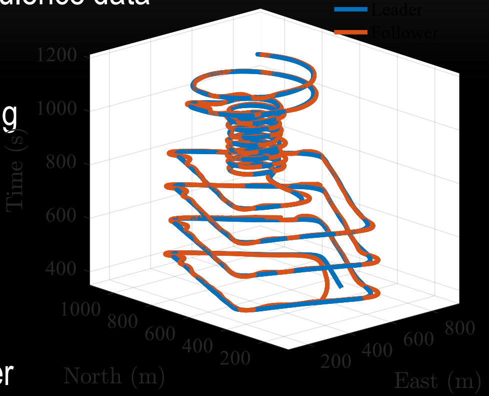
- A person operating a small UAS must either hold a remote pilot airman certificate with a small UAS rating or be under the direct supervision of a person who does hold a remote pilot certificate (remote pilot in command).
- To qualify for a remote pilot certificate, a person must:
  - Demonstrate aeronautical knowledge by either:
    (1) Passing an initial aeronautical knowledge test at an FAA-approved knowledge testing center; or
    (2) Hold a part 61 pilot certificate other than student pilot, complete a flight review within the previous 24 months, and complete a small UAS online training course provided by the FAA.
  - Be vetted by the Transportation Security Administration.
  - Be at least 16 years old.

# RESOURCES

- https://www.faa.gov/uas/
- http://knowbeforeyoufly.org
- Pilot training from a certified flight center

# SWARMING

- **Goal:** Design and implement fixed-wing UAV leader-follower formation control algorithms, which are suitable for collecting turbulence data
- **Implementation:**
  - Pixhawk autopilot in FBWA communicating with Raspberry Pi 3
  - Wireless network over secure ad-hoc WiFi
- **Major Accomplishments:**
  - Successfully demonstrated leader-follower formation control with n fixed-wing UAVs
  - Designed control algorithm for *n* agents
- **Ongoing Work:**
  - Controller tuning (e.g., improved heading control)
  - Experiments with more than 2 UAVs
  - Streamline for field operations

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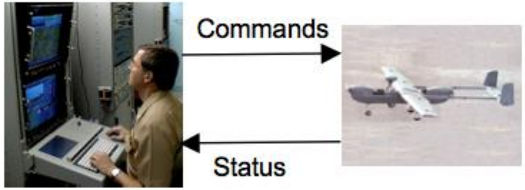
# CONTROL PARADIGM

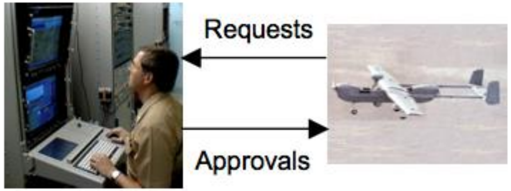
- *Different operator control paradigms provide different sets of strengths and challenges to command and control interface designers. As always, designers should examine potential methods for combining the aspects desired into hybrid approaches.*

### Direct Control



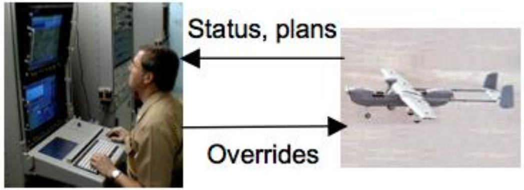

- Operator does all decision making and information processing
- Requires operator to constantly attend to vehicle
- High workload

### Management by Consent




- Vehicle performs planning and sends plan to operator for approval
- Vehicle performs no action without obtaining operator approval
- Operator highly interruption-driven
- Operator must react quickly to ensure vehicle safety for time critical actions
- Moderate workload

### Management by Exception




- Vehicle performs planning, sends plan to operator, begins execution
- Operator has ability to override vehicle actions, plans
- Operator must maintain awareness of situation
- Requires high degree of intelligence, autonomy for vehicle
- Low workload

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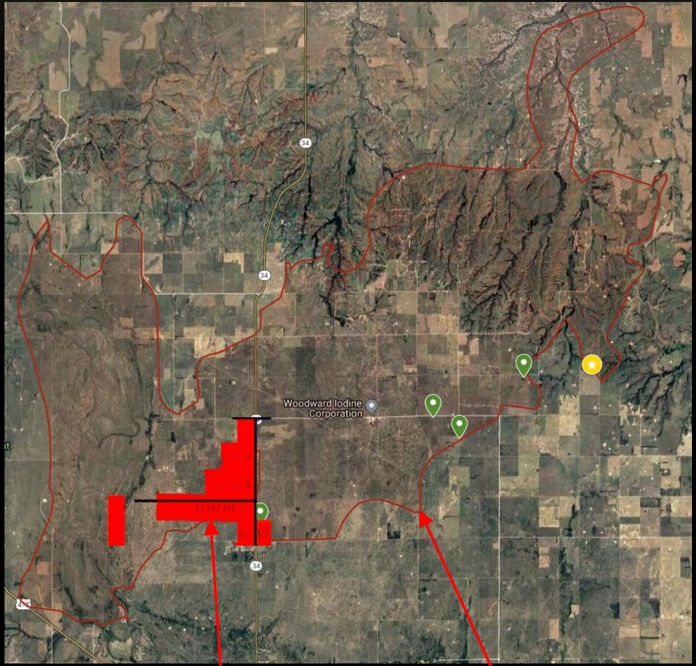
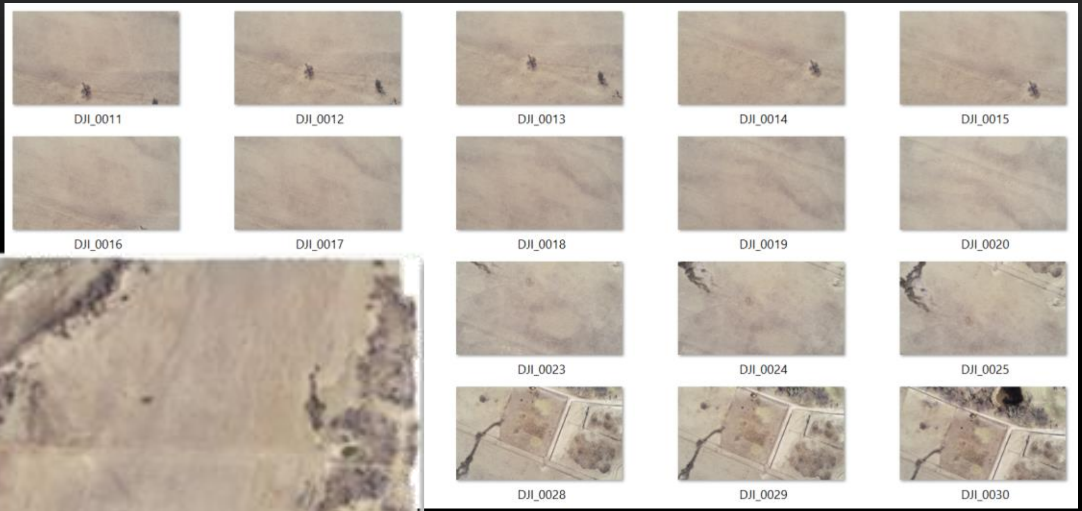
# Oklahoma emergency management wildfire response effort




Response flight area

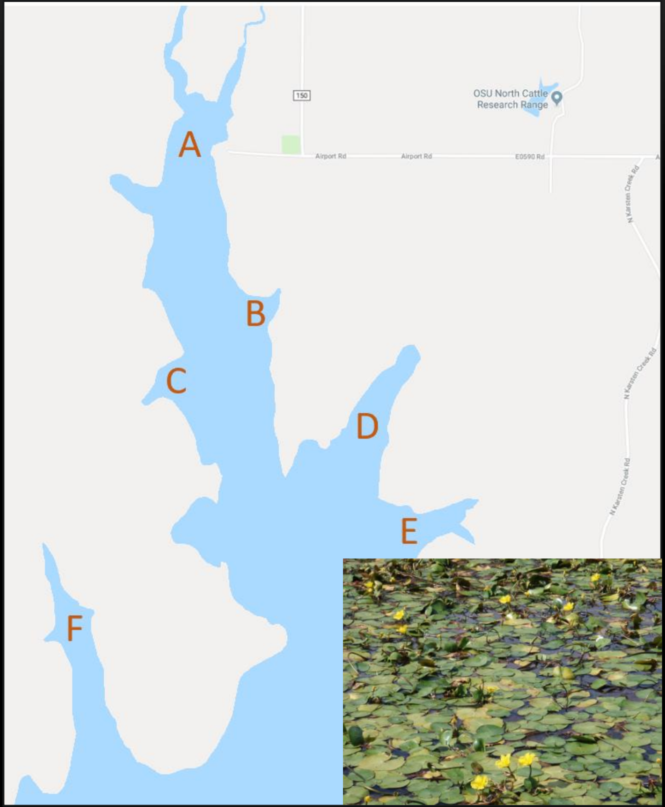
Wildfire area



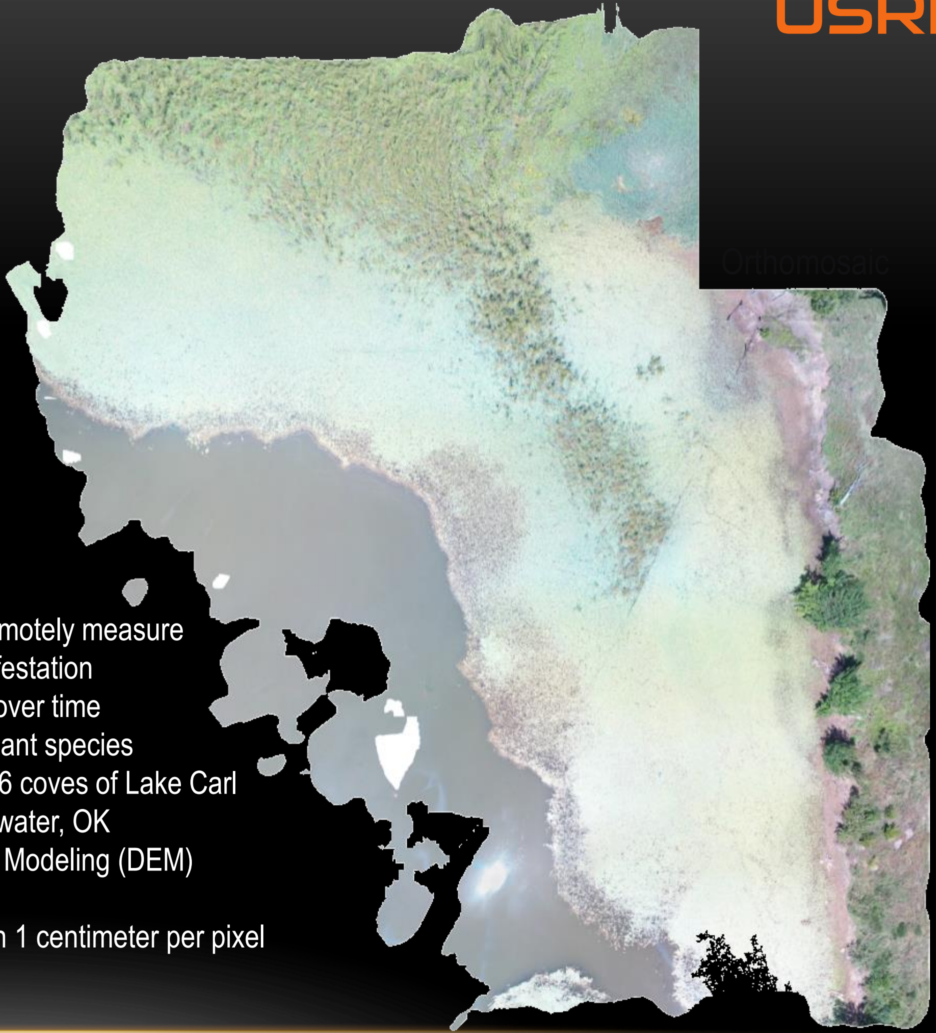


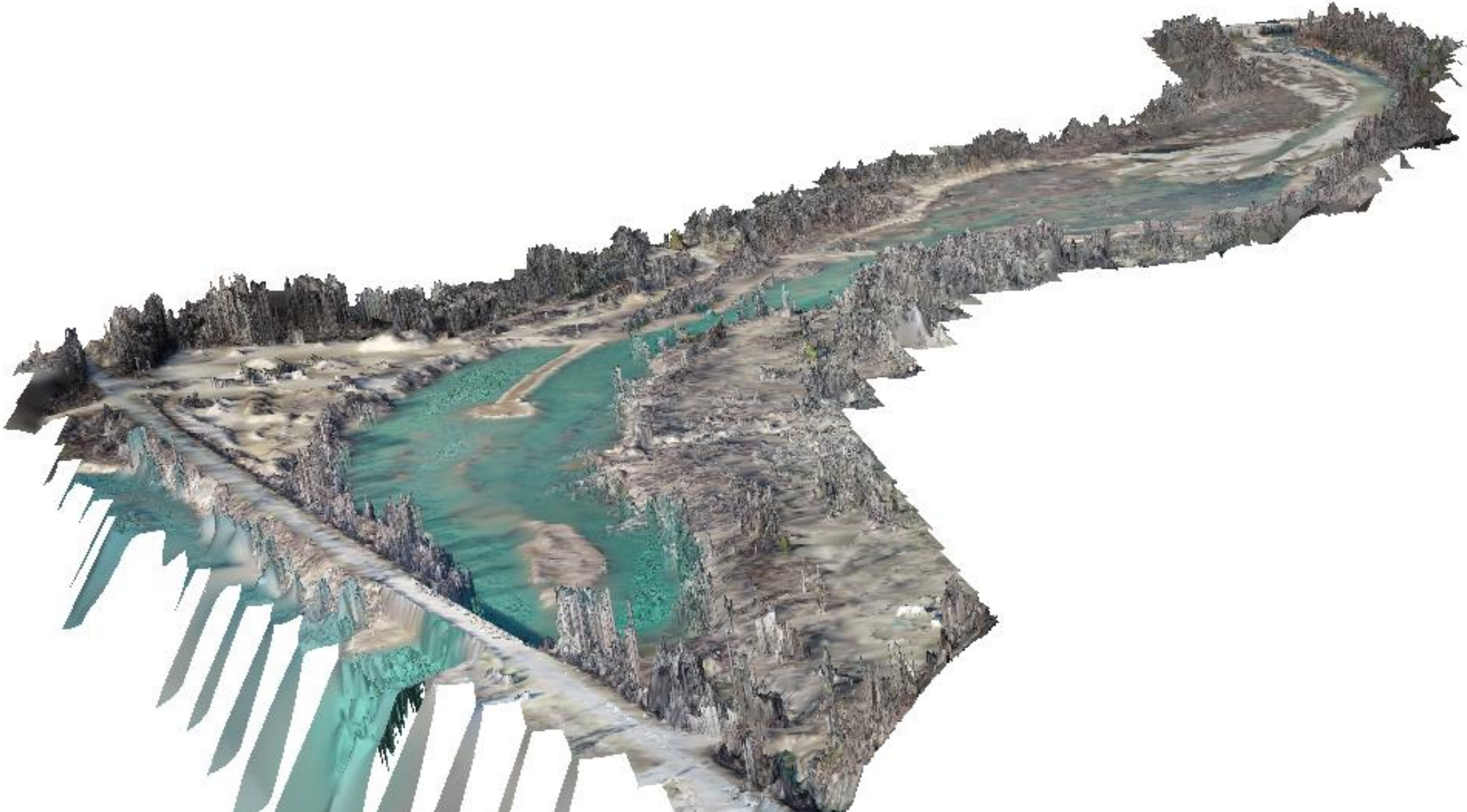
- Damage assessment
- Digital Elevation Modeling (DEM)
- Resolution within 1 inch per pixel

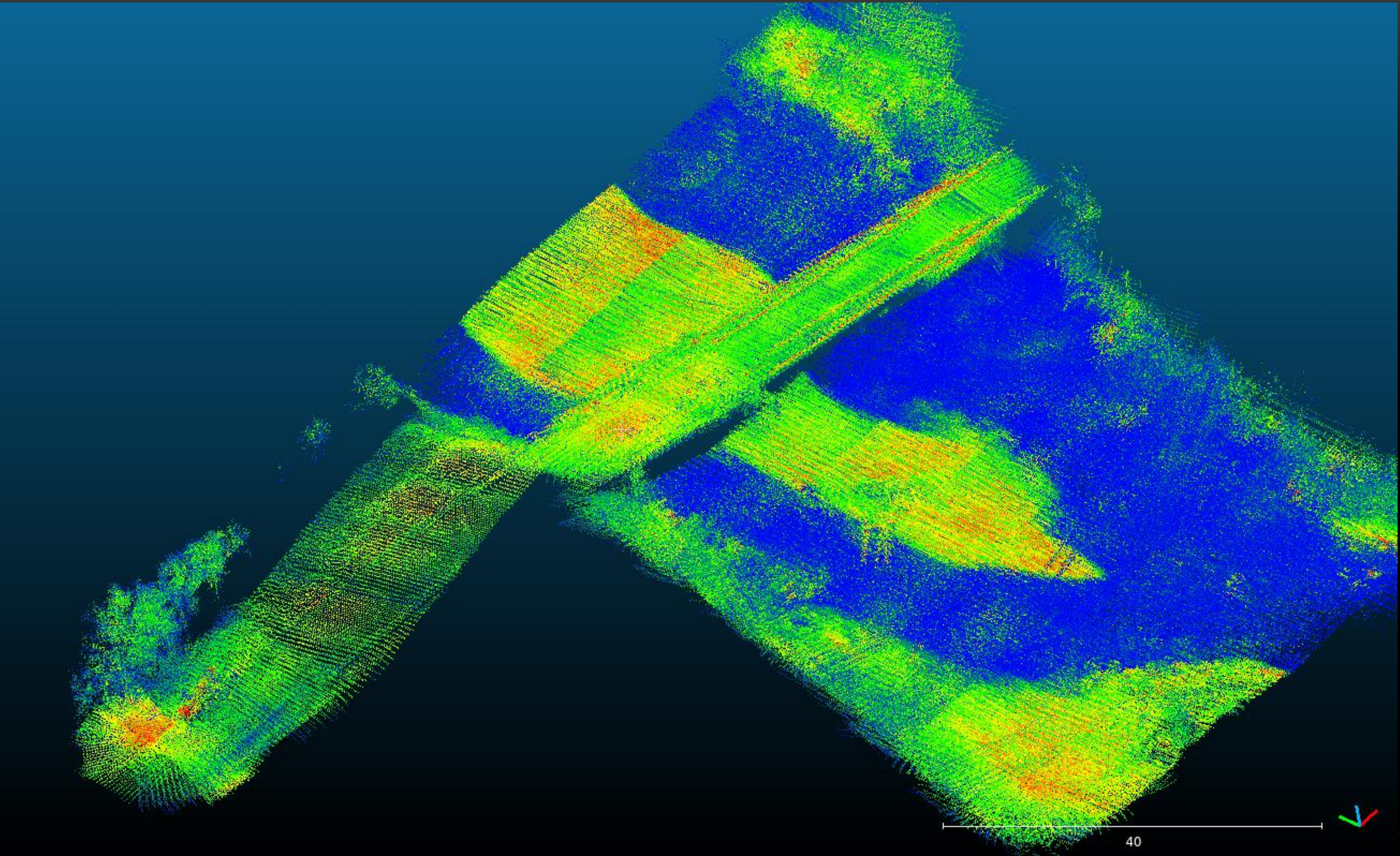
# Mapping of an invasive plant species




- Using UAS to remotely measure
  - Area of infestation
  - Changes over time
  - NDVI of plant species
- Observations in 6 coves of Lake Carl Blackwell in Stillwater, OK
- Digital Elevation Modeling (DEM)
- Orthomosaics
- Resolution within 1 centimeter per pixel



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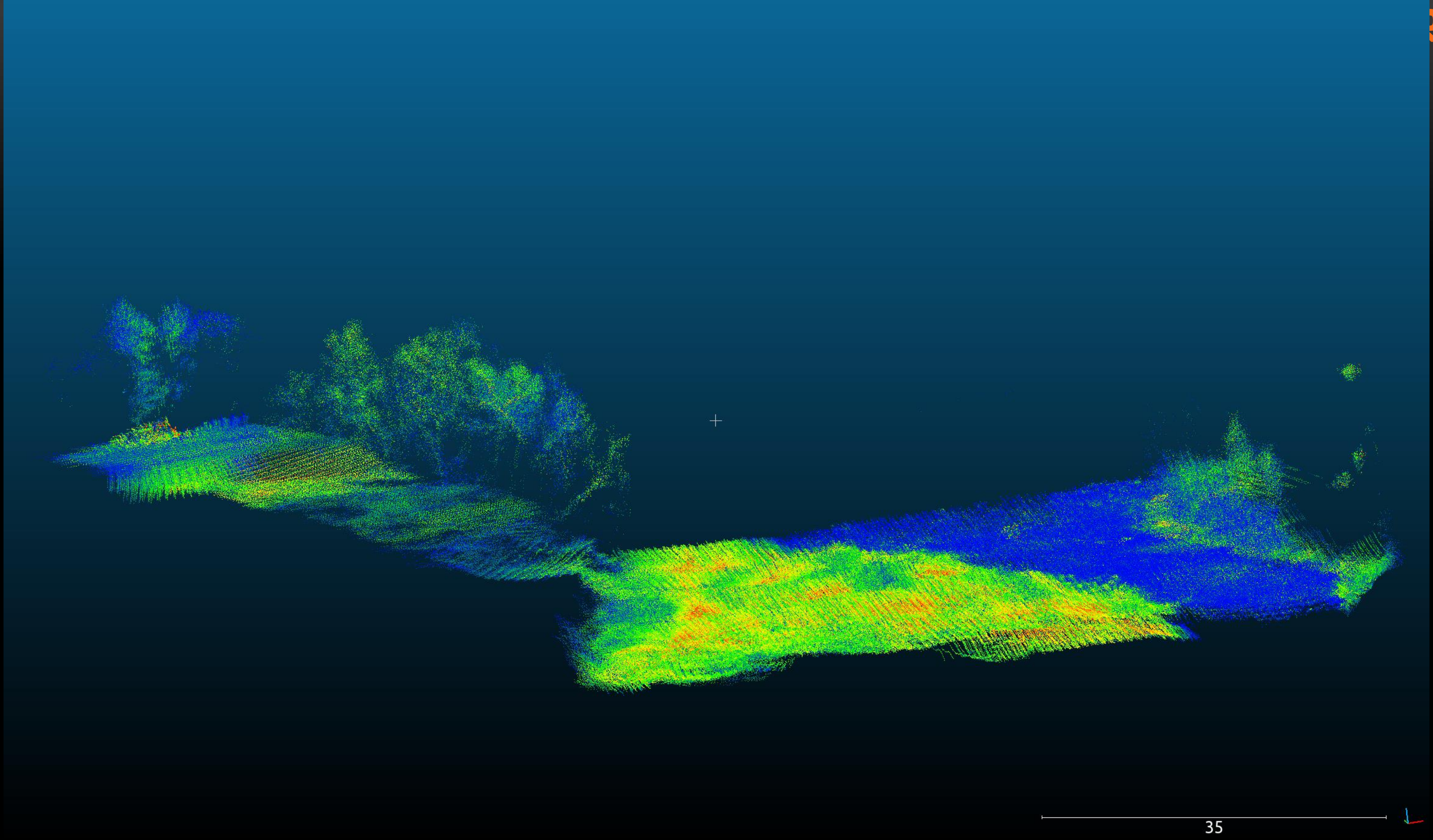
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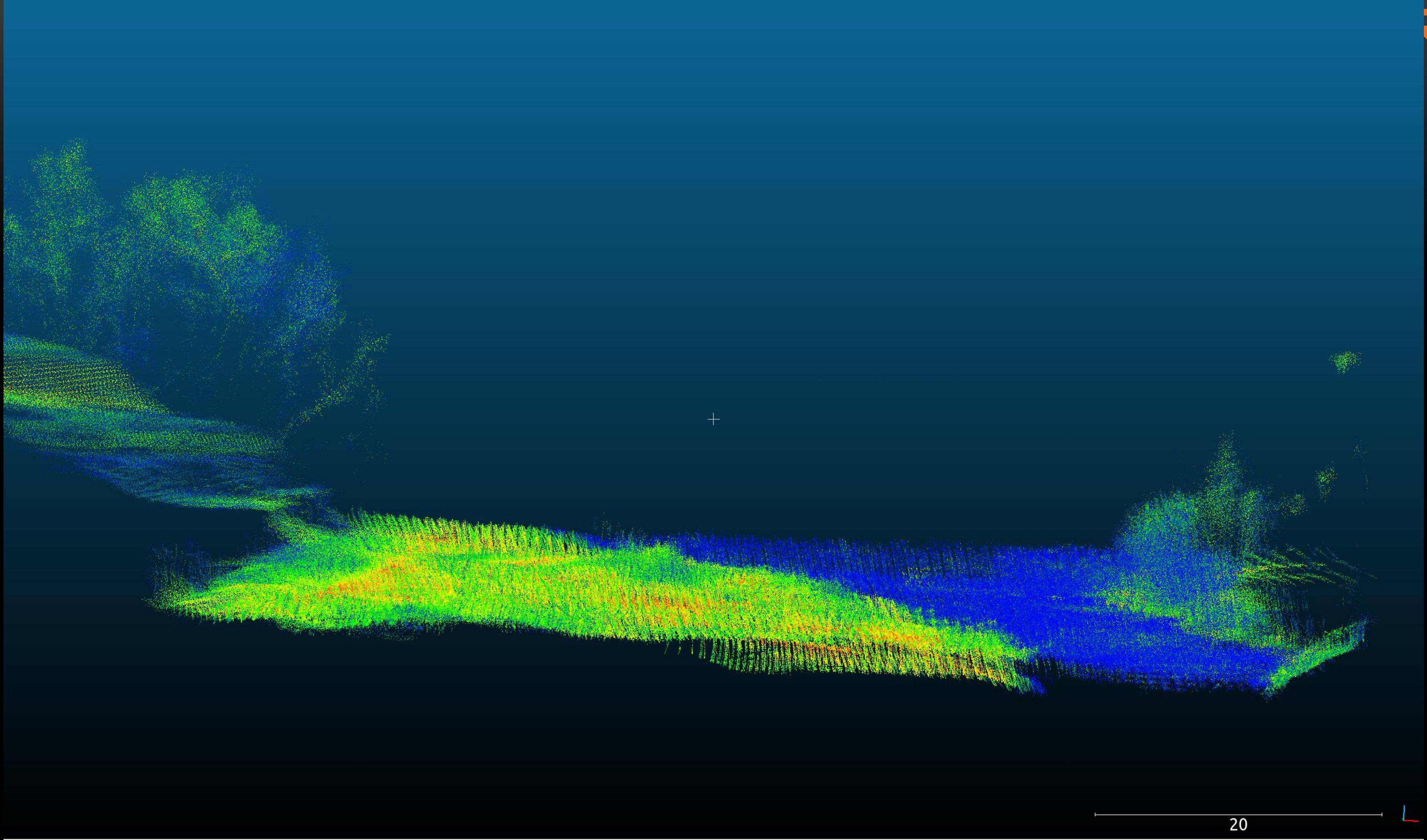
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# SPILLS AND CONTAMINATION