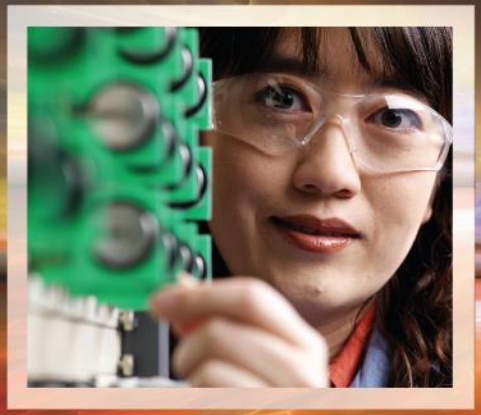

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# Automated Damage Analysis from Overhead Imagery

EVAN JONES
ANDRE COLEMAN
SHARI MATZNER

*Pacific Northwest National Laboratory*

DISCOVERY *in Action*

U.S. DEPARTMENT OF ENERGY

# PNNL – FY2015 at a Glance

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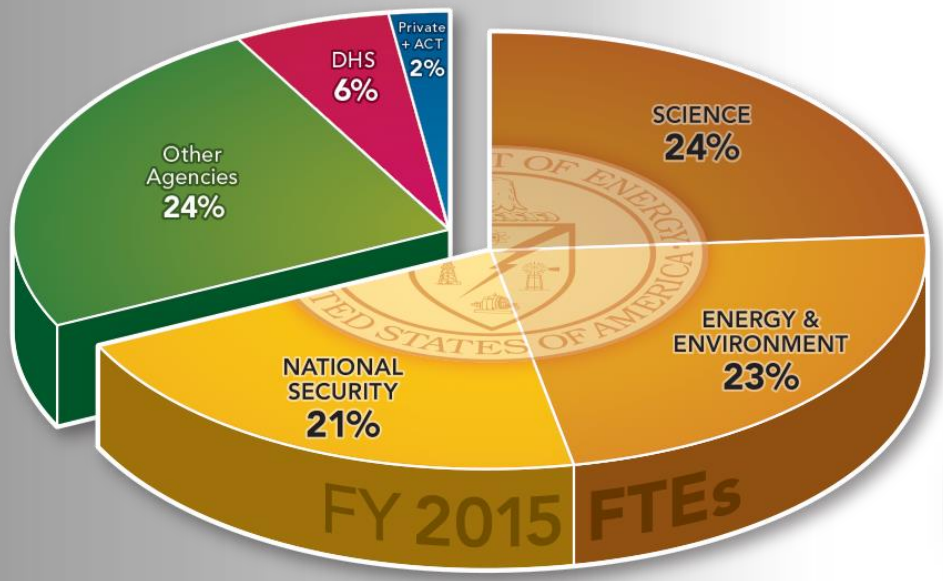
- $955 million in R&D expenditures
- 4,400 scientists, engineers and non-technical staff
- 78 U.S. & foreign patents granted
- 2 FLC Awards, 3 R&D 100 (FY14)
- 1,048 peer-reviewed publications

- Mission-driven collaborations with government, academia and industry
- DOE's top-performing lab for past eight years; a premier chemistry, environmental sciences and data analytics laboratory




# Situational awareness is key to rapid power restoration.

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- Remotely sensed imagery can provide situational awareness
- Automated processing and analytics increases the value of imagery and can provide actionable information
- Decision support systems need to be flexible and able to consume data as it becomes available

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# Imagery can provide situational awareness.

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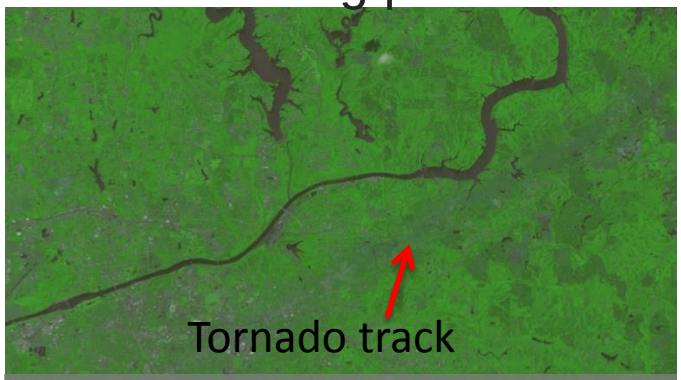
## Multi-spectral Satellite Image

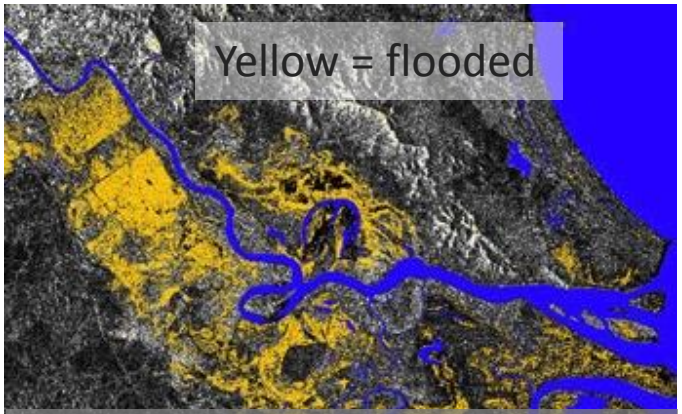
See the big picture.




**Tornado at Tuscaloosa, AL 2011**
*ASTER, 15 m resolution*

## Synthetic Aperture Radar

See at night, through clouds.




**Flooding at Queensland, AU 2011**
*RADARSAT-2, 8 m resolution*

## Natural Color Aerial Image

See details.


**Hurricane Ike at Galveston, TX 2009**
*NOAA, 34 cm resolution*

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# Motivation and Objectives

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- Provide science-driven R&D to help increase energy resiliency and minimize downtime
  - Focus: Natural Disasters
- Apply remotely-sensed imagery and analytics to improve situational awareness in large-scale outage events
- Rapid image acquisition and validation of workflow for different types of events
- Develop automated image-based detection and characterization of damage to provide electric utilities actionable information within 24 hours of a large-scale outage event
- Determine appropriate business model and transition the algorithms and/or outputs to electric utilities and/or 3rd party service providers

# Benefits

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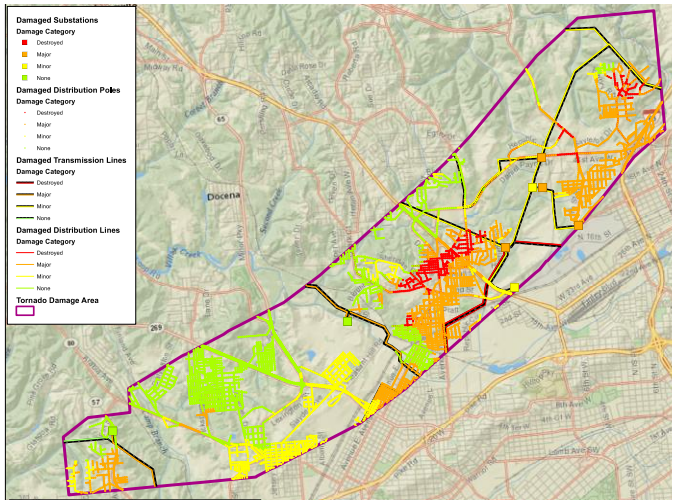
- Understand the degree and extent of potential damage to assets consistently across the service area
- Improve response and accuracy of estimated time to recovery
- Effective planning/decision making, prioritization, and resource allocation for restoration activities
- Identify high-risk areas and potential access barriers
- Minimize downtime and increase resource efficiency



# Remote Sensing

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- The right imagery for the event…

| | | Imagery Type | | | | | |
|---|---|---|---|---|---|---|---|
| YES / MAYBE / NO | | RGB ($) | Multi-Spectral ($) | Thermal ($$) | RADAR ($$) | Hyper-spectral ($$$) | LiDAR ($$$) |
| Event Type | Fire | YES | YES | YES | NO | YES | NO |
| | Flood | MAYBE | YES | NO | YES | YES | YES |
| | Tornado | YES | YES | NO | YES | YES | MAYBE |
| | Hurricane | YES | YES | NO | MAYBE | YES | MAYBE |
| | Ice Storm | NO | NO | MAYBE | MAYBE | MAYBE | MAYBE |
| | Earthquake | YES | YES | NO | YES | NO | MAYBE |

# Automated processing increases the value of imagery.

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- PNNL is developing algorithms for different image types to automatically extract damage information.

| Algorithms | Multispectral | | | SAR | | | Natural Color |
|---|---|---|---|---|---|---|---|
| | LR | MR | HR | LR | MR | HR | HR |
| Change Detection | ■ | ■ | | ■ | ■ | | |
| Rubble Detection | | | ■ | | | | ■ |
| Flood Mapping | | | | ■ | ■ | ■ | |
| Downed Tree Detection | | | ■ | | | | ■ |
| Burn Mapping | ■ | ■ | | ■ | ■ | | ■ |

■ Algorithm is applicable

LR = Low Resolution
MR = Medium Res.
HR = High Res.

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# Imagery can be acquired within 24 hours of an event.

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Satellite operators offer "rapid acquisition" to support first responders.

NOAA's Remote Sensing Division mobilizes its airborne sensor for emergencies.


New micro-satellite constellations promise "real-time" coverage.

UAVs are the future of disaster response.

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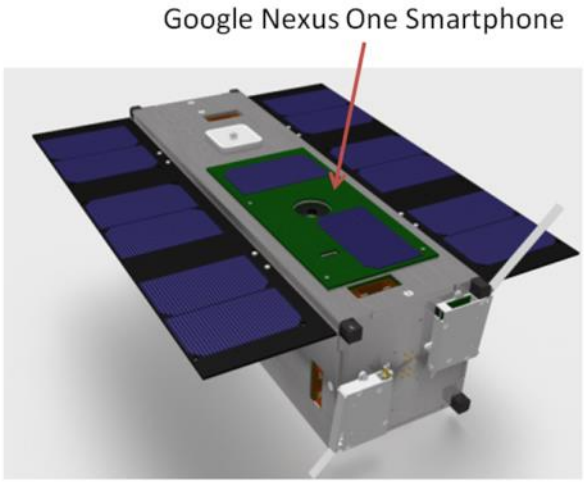
# Miniature Satellites for Rapid Imagery Collection



- Characteristics
  - Low Earth Orbit
  - Low cost technologies
  - Rapid build and launch
  - Constellations or “swarms”
  - Single sensor & lower resolution




| Miniature Satellite Class | Weight Range |
|---|---|
| **Picosatellite** | < 1 kg (< 2.2 lb) |
| **Nanosatellite** | 1-10 kg (2.2 - 22 lb) |
| **Microsatellite** | 10-500 kg (22 – 1,102 lb) |

# Change can indicate damaged areas.



- Change detection compares a “before” image and an “after” image.
- The challenge is to distinguish between changes due to the weather event and other changes.

Breezy Point fire, Queens, NY 2012


Source: Google Crisis Maps

# Automated processing extracts damage information.

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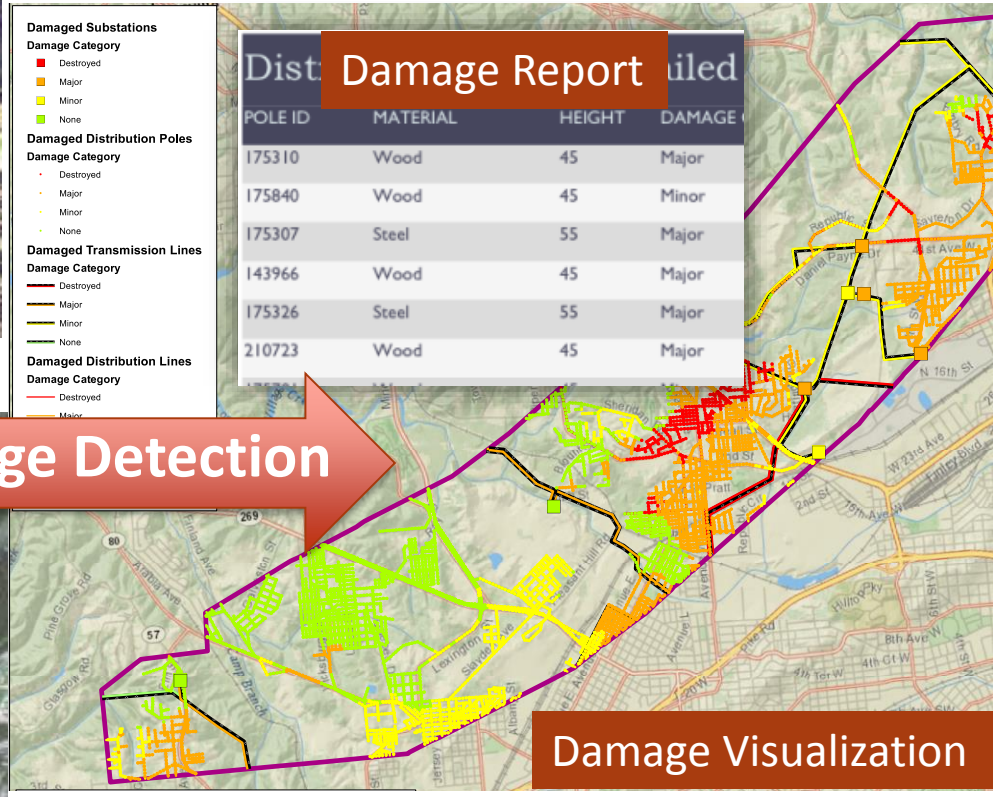
BEFORE

Source: National Agricultural Imagery Program (NAIP)

2011 Alabama: 62 confirmed tornadoes across the state; 262,000 customers without power.




AFTER

Source: WorldView-2, Resolution: 2 m, Area: 125 square miles

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# Rubble indicates damage.

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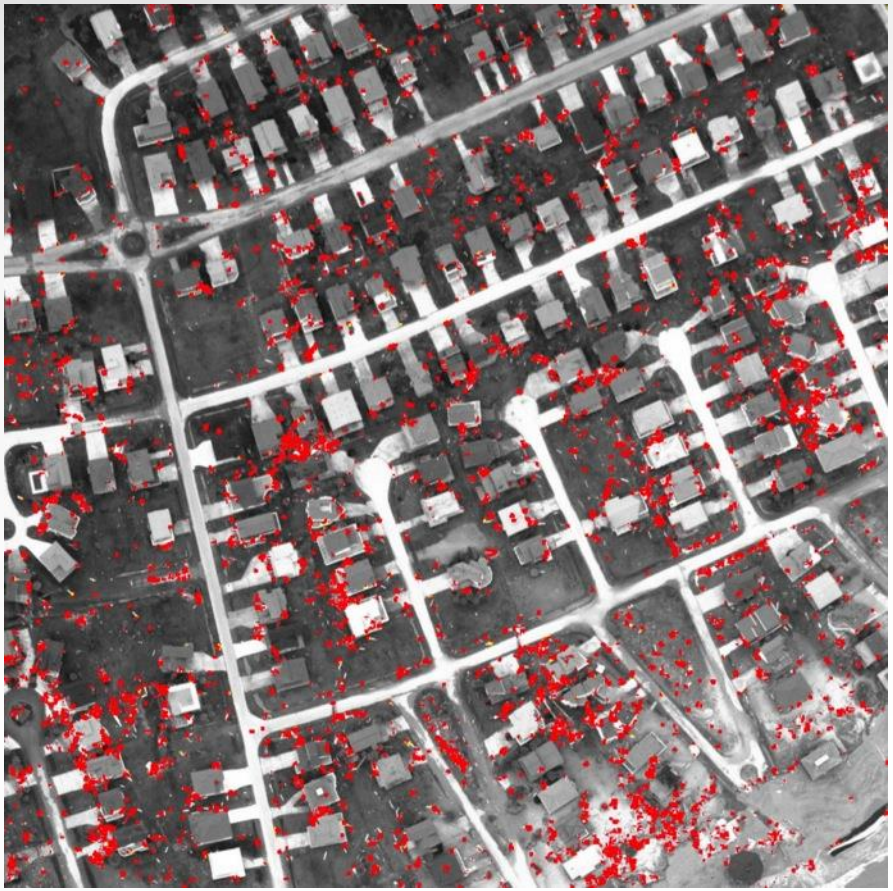
Original image.

Rubble detections (red).



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# Rubble Detection Algorithm

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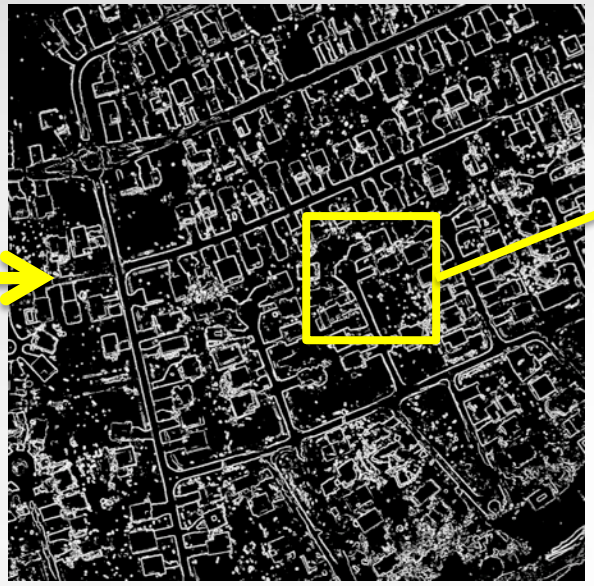
1. Convert color image to intensity (gray scale).

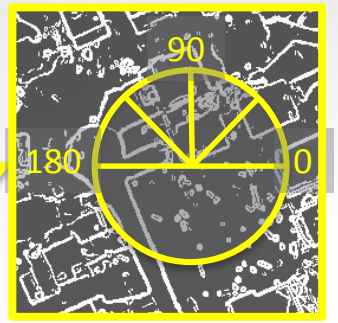
2. Calculate the gradient at each pixel.



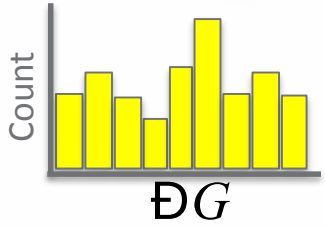
Magnitude: $|G| = \sqrt{\P x^2 + \P y^2}$

Orientation: $\text{Đ}G = \text{atan}\dfrac{\P y}{\P x}$

3. Calculate the entropy of the gradient orientation.




Gradient Orientation Histogram




Entropy:

$$H = -\sum_{\text{Đ}G} p \log p$$

$$p = \text{count}(\text{Đ}G)$$

Talbot, L. M. and Talbot, B. G. (2013). Fast-responder: Rapid mobile-phone access to recent remote sensing imagery for first responders. *In Aerospace Conference, 2013 IEEE,* pp 1–10. IEEE.

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# High Wind Damage

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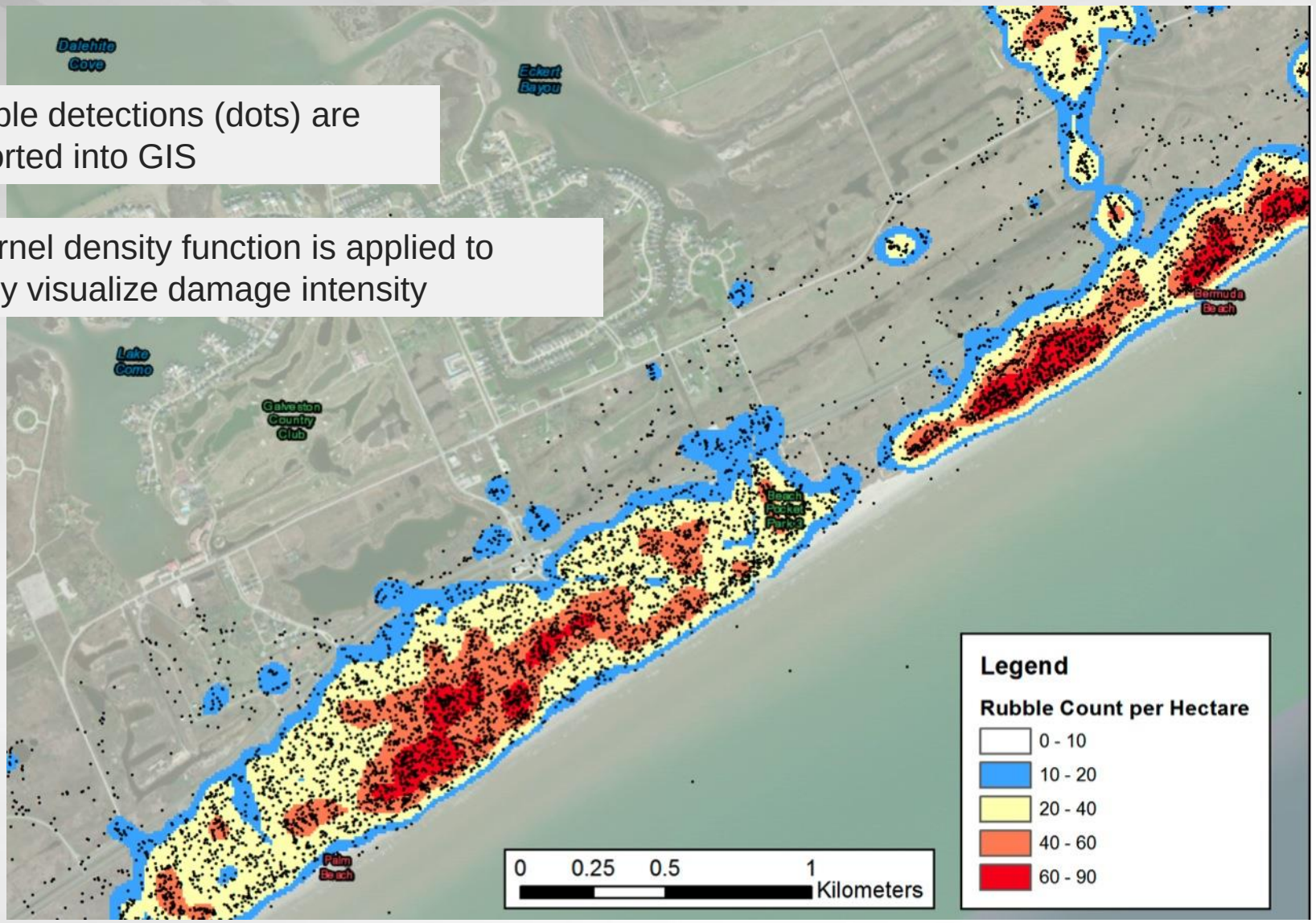
Rubble detections (dots) are imported into GIS

A kernel density function is applied to easily visualize damage intensity



# Automated processing quickly turns data into information.

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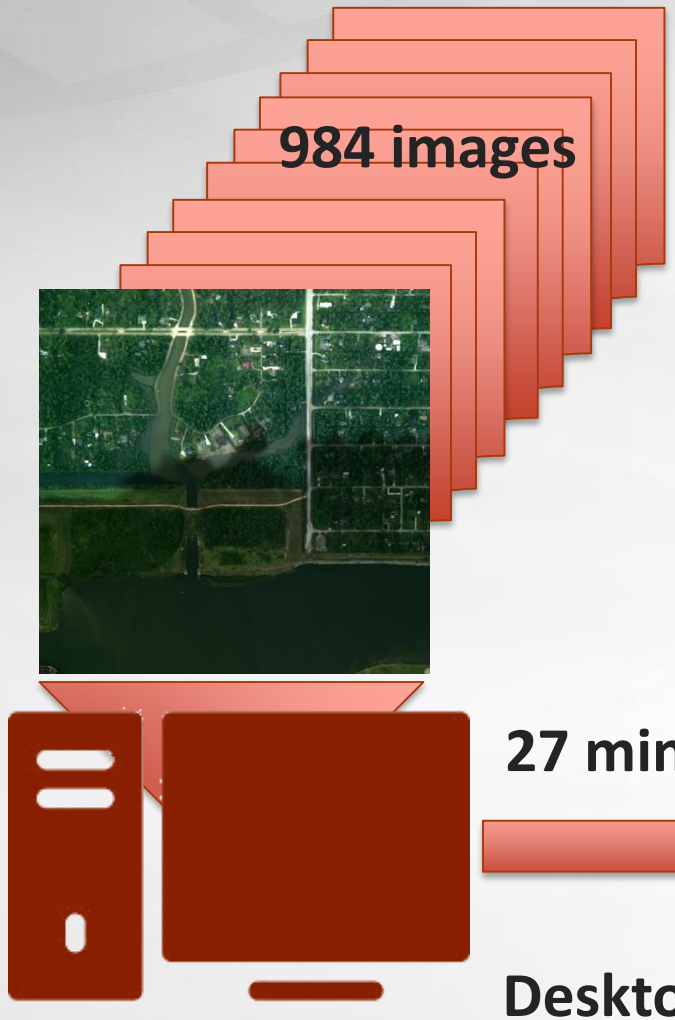


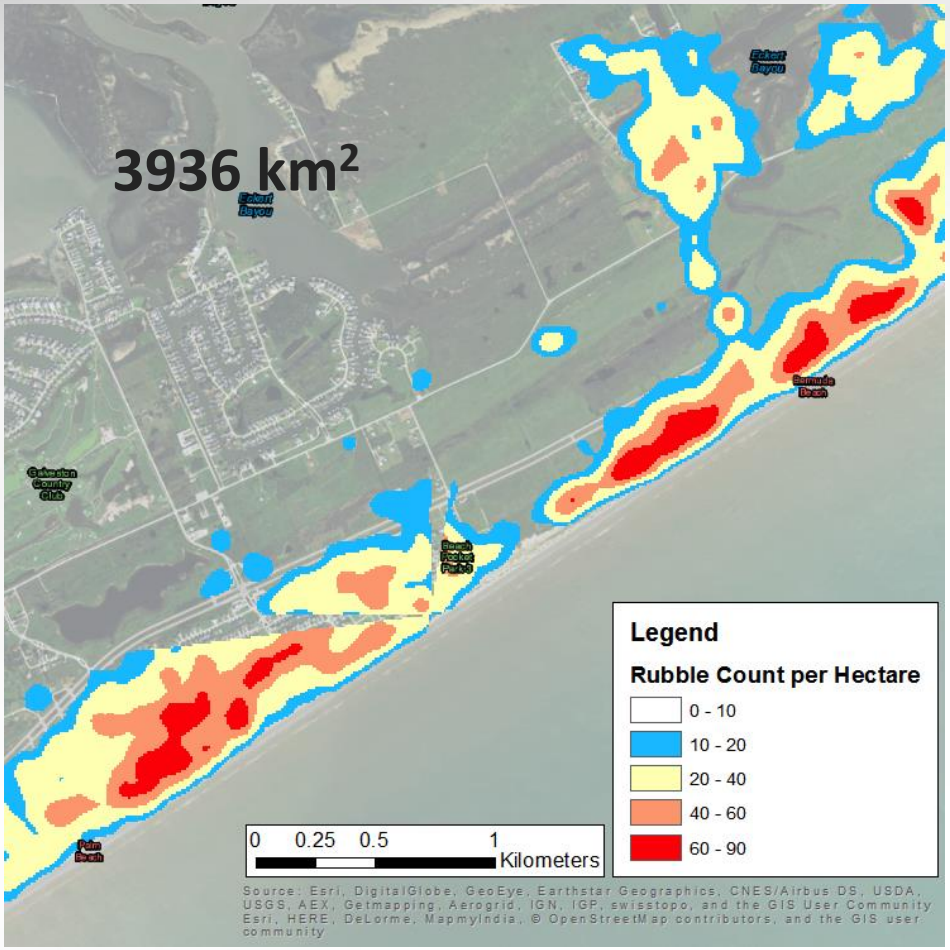


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# Concept for Decision Support Using Automated Image Processing

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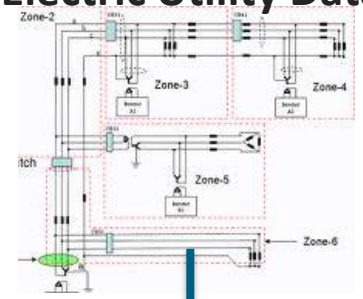
**Imagery**

**Electric Utility Data**




**Automated Damage Assessment**

**Data Fusion and Analytics**

**Backend**

The backend can be running anywhere, at multiple sites, removed from the affected area.

**Operations Center**


**Field Crew**

**User Interface**

Information is delivered using existing geospatial visualization applications.

- Space-Time Insight
- Google Earth
- ESRI

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# Thank you!


**Team Members**

Evan O. Jones (Project Manager) – Evan.O.Jones@pnnl.gov
Shari Matzner - Shari.Matzner@pnnl.gov
Andre Coleman - Andre.Coleman@pnnl.gov



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