Automated Damage Assessment for Event Response from Overhead Imagery

Shari Matzner

Jerry Tagestad

Sadie Montgomery

Andre Coleman

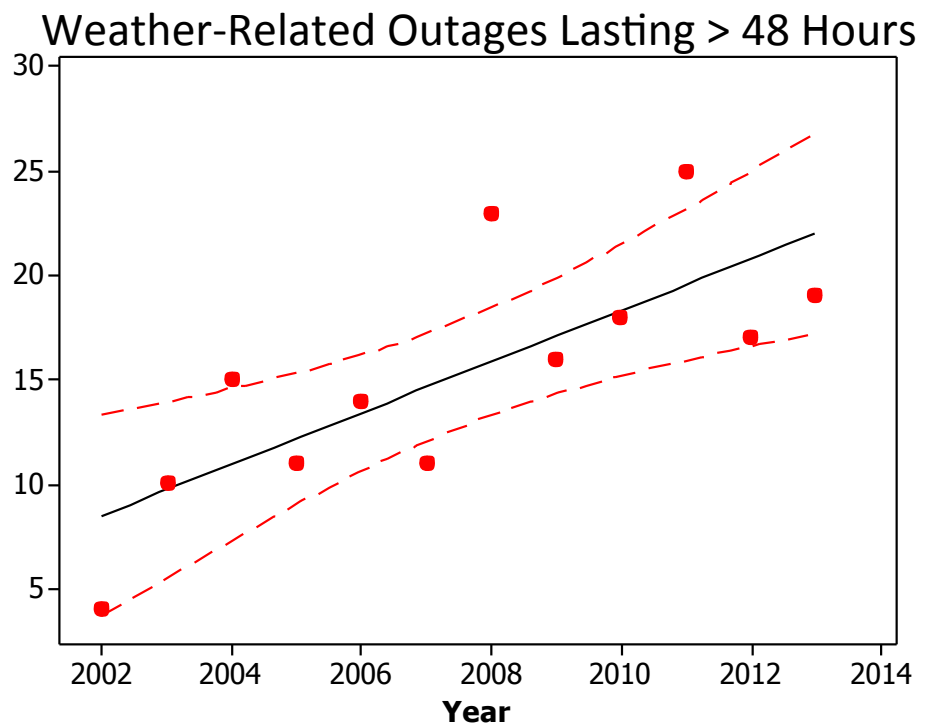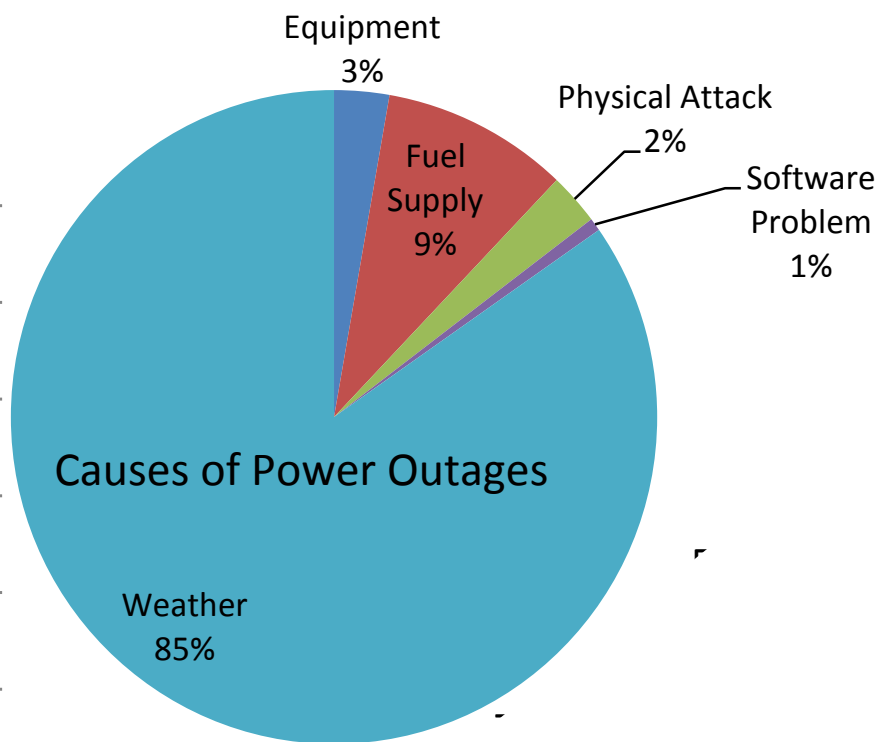Tom Warfel

► Extreme weather events are the primary cause of power outages that affect thousands of people.

Causes of Power Outages

- Equipment 3%
- Fuel Supply 9%
- Physical Attack 2%
- Software Problem 1%
- Weather 85%

Weather-Related Outages Lasting > 48 Hours

Data: Reported outages from 2002 - 2013

Homeland Security
Science and Technology

2

Situational awareness is key to rapid power restoration.

▶ Remotely sensed imagery can provide situational awareness.

▶ Automated processing increases the value of imagery.

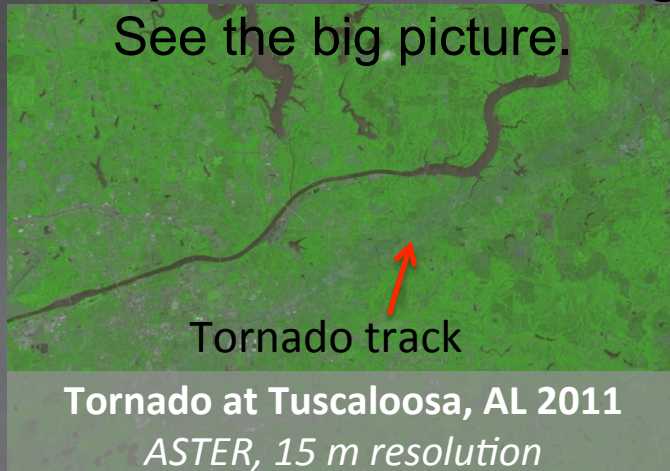▶ Decision support systems need to be flexible, able to consume whatever data is available.

Imagery can provide situational awareness.

Multi-spectral Satellite Image
See the big picture.

Tornado track

Tornado at Tuscaloosa, AL 2011
ASTER, 15 m resolution

Natural Color Aerial Image
See details.

Road blocked

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

Synthetic Aperture Radar
See at night, through clouds.

Yellow = flooded

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

4

Homeland
Security
Science and Technology
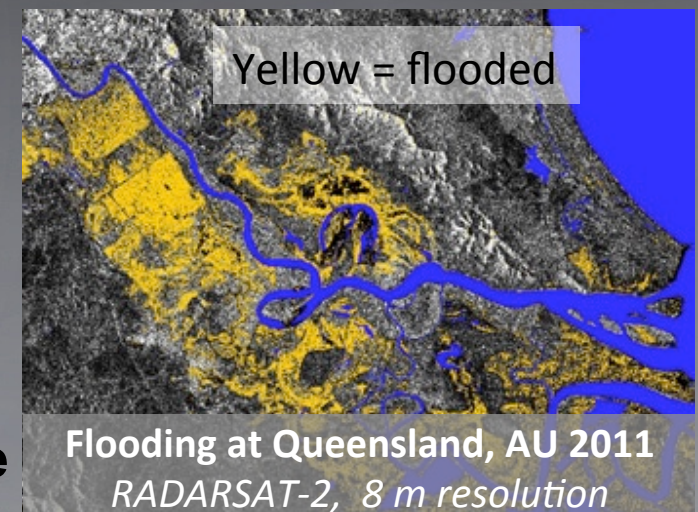
Imagery can be acquired within 24 hours of an event.

Image Copyright DigitalGlobe

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.

Image Copyright PlanetLabs

UAVs are the future of disaster response.

Automated processing increases the value of imagery.

► 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.

Homeland Security
Science and Technology

6

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.
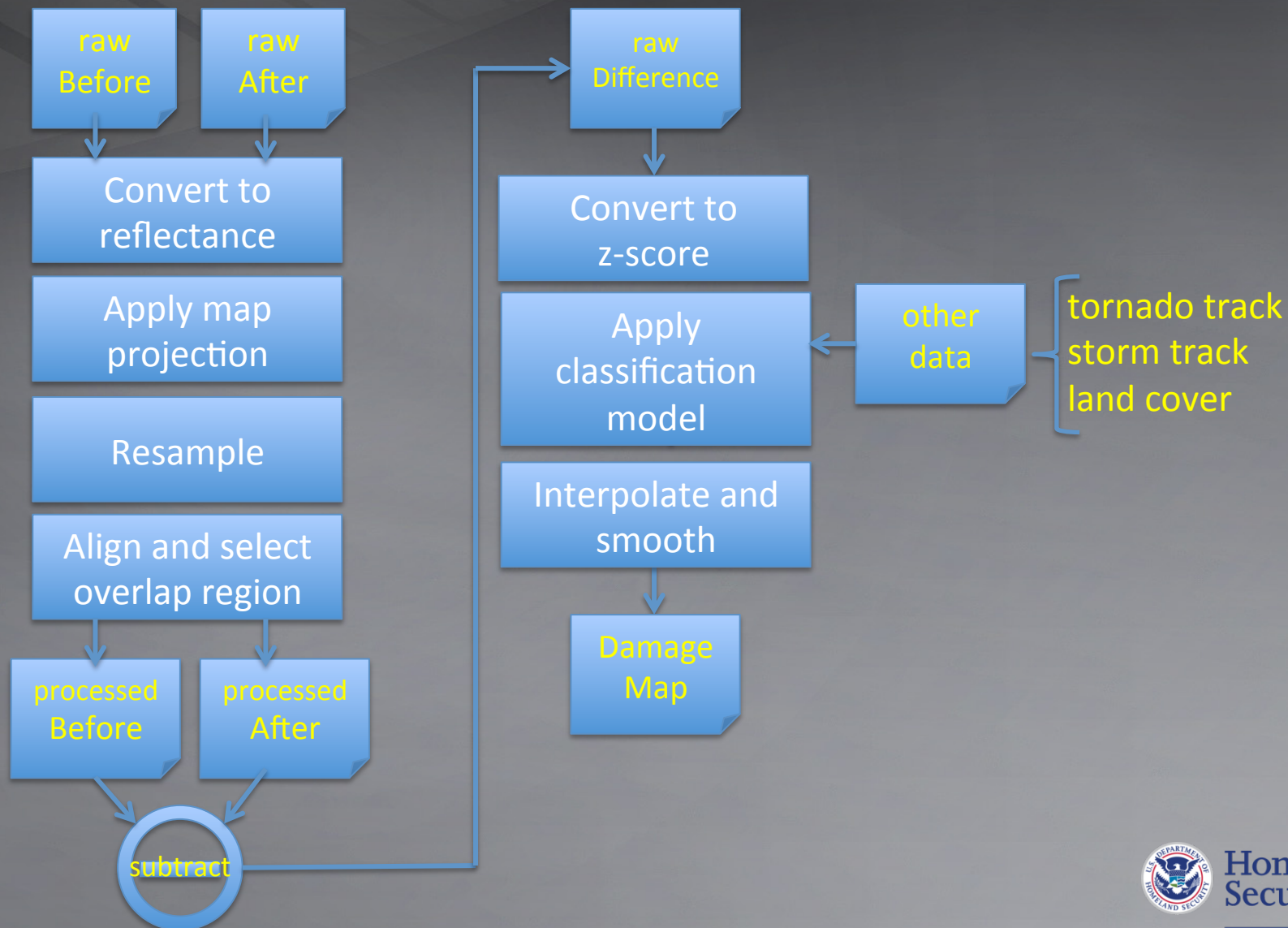
Breezy Point fire, Queens, NY 2012

Before

After

Source: Google Crisis Maps

Homeland
Security
Science and Technology

Change Detection Algorithm

raw Before → Convert to reflectance → Apply map projection → Resample → Align and select overlap region → processed Before, processed After → subtract

raw After → Convert to reflectance

subtract → raw Difference → Convert to z-score → Apply classification model → Interpolate and smooth → Damage Map

other data ← tornado track, storm track, land cover

Automated processing extracts damage information.

BEFORE

Source: National Agricultural Imagery Program (NAIP)

AFTER

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

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

Change Detection

Damage Report

Damaged Substations
Damage Category
- Destroyed
- Major
- Minor
- None

Damaged Distribution Poles
Damage Category
- Destroyed
- Major
- Minor
- None

Damaged Transmission Lines
Damage Category
- Destroyed
- Major
- Minor
- None

Damaged Distribution Lines
Damage Category
- Destroyed
- Major

POLE ID	MATERIAL	HEIGHT	DAMAGE
175310	Wood	45	Major
175840	Wood	45	Minor
175307	Steel	55	Major
143966	Wood	45	Major
175326	Steel	55	Major
210723	Wood	45	Major

Damage Visualization

Homeland Security
Science and Technology

9

Rubble indicates damage.

Original image.

Rubble detections (red).

Rubble Detection Algorithm

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

2. Calculate the gradient at each pixel.

3. Calculate the entropy of the gradient orientation.
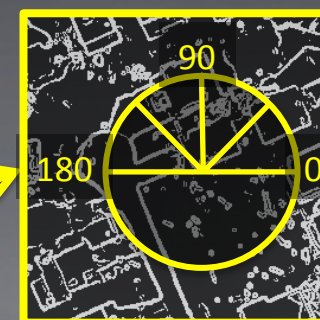
Gradient Orientation Histogram

Magnitude: $\left|G\right| = \sqrt{\partial x^2 + \partial y^2}$

Orientation: $\angle G = \operatorname{atan} \dfrac{\partial y}{\partial x}$

Entropy:

$$H = -\sum_{\angle G} p \log p$$

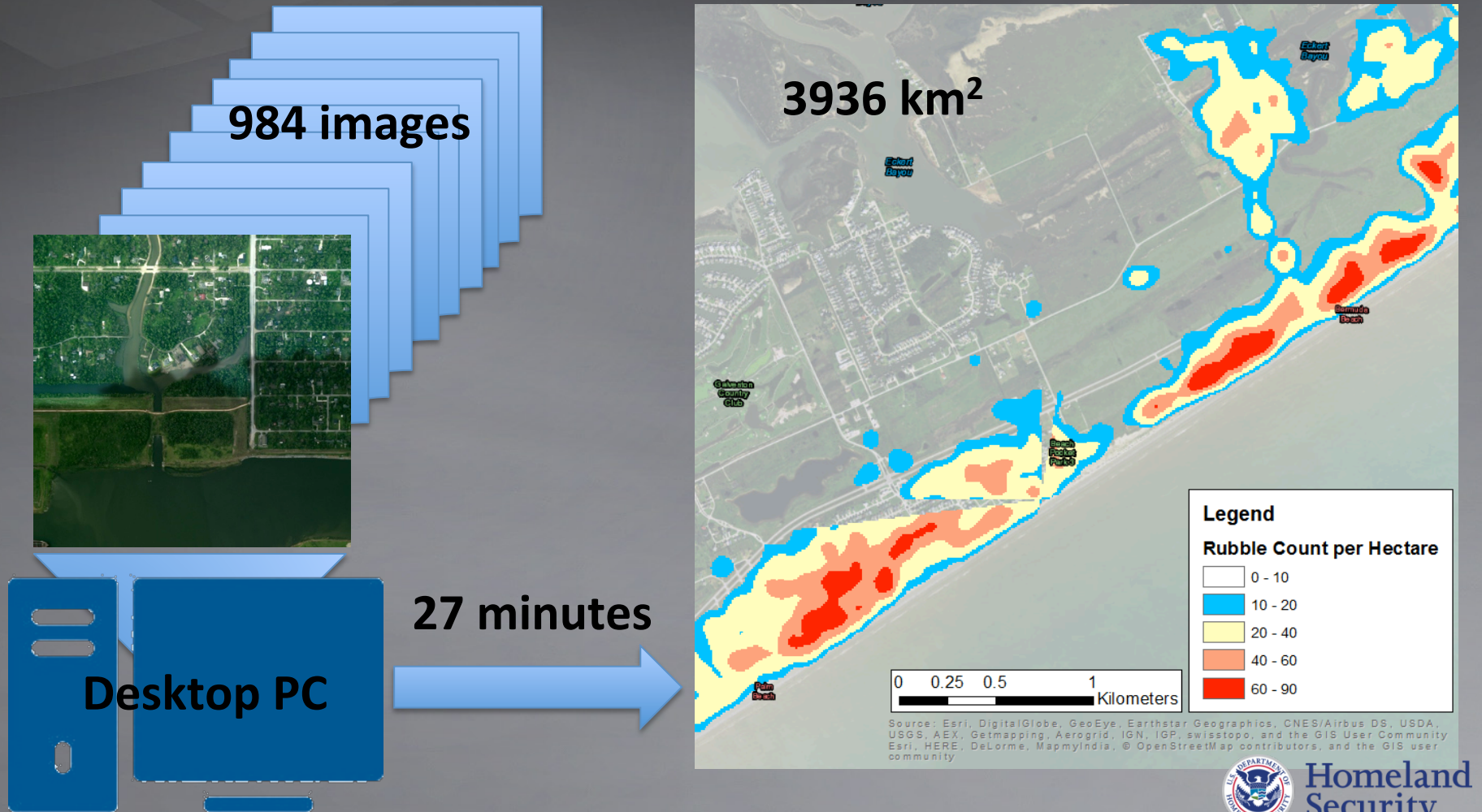$$p = \operatorname{count}(\angle G)$$

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.

Homeland Security
Science and Technology

# Automated processing quickly turns data into information.

Pacific Northwest
NATIONAL LABORATORY
Proudly Operated by **Battelle** *Since 1965*

984 images

Desktop PC

27 minutes

3936 km²

Legend
Rubble Count per Hectare

☐	0 - 10
☐	10 - 20
☐	20 - 40
☐	40 - 60
☐	60 - 90

0   0.25   0.5   1 Kilometers

Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community Esri, HERE, DeLorme, Mapmyindia, © OpenStreetMap contributors, and the GIS user community

Homeland Security
Science and Technology

Concept for Decision Support Using Automated Image Processing

Imagery

Electric Utility Data

Automated Damage Assessment
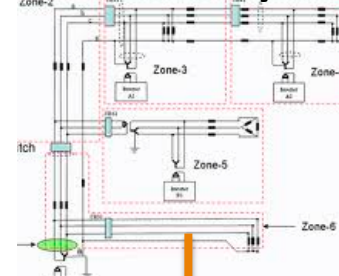
Data Fusion and Analytics

Backend

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

Operations Center

Substation A24

Field Crew

User Interface

Information is delivered using existing geospatial visualization applications.

- Space-Time Insight
- Google Earth
- ESRI

Homeland Security
Science and Technology

13

Summary

▶ Overhead imagery can provide situational awareness for decision support.

▶ Automated processing increases the value of imagery by rapidly extracting information.

▶ Decision support systems need to be flexible, able to consume whatever data is available.

Homeland
Security

Science and Technology

Next Steps

▶ Deploy the technology to electric utilities.

▶ Continue to develop new algorithms.

▶ Incorporate predictive analytics.

Acknowledgements

▶ This work is funded by the Department of Homeland Security Science and Technology Directorate.

▶ Thanks to our collaborators:
  ■ CenterPoint Energy
  ■ Consolidated Edison
  ■ MDA Geospatial Services
  ■ Space-Time Insight

Thank you.

► Questions?

Yellow = flooded

Tornado track

Road blocked