INL/CON-23-72833-Revision-0

Storm-DEPART (Damage Estimate Prediction and Recovery Tool)

June 2023

Ollie Gagnon, Mary S Klett

Changing the World's Energy Future

Idaho National Laboratory

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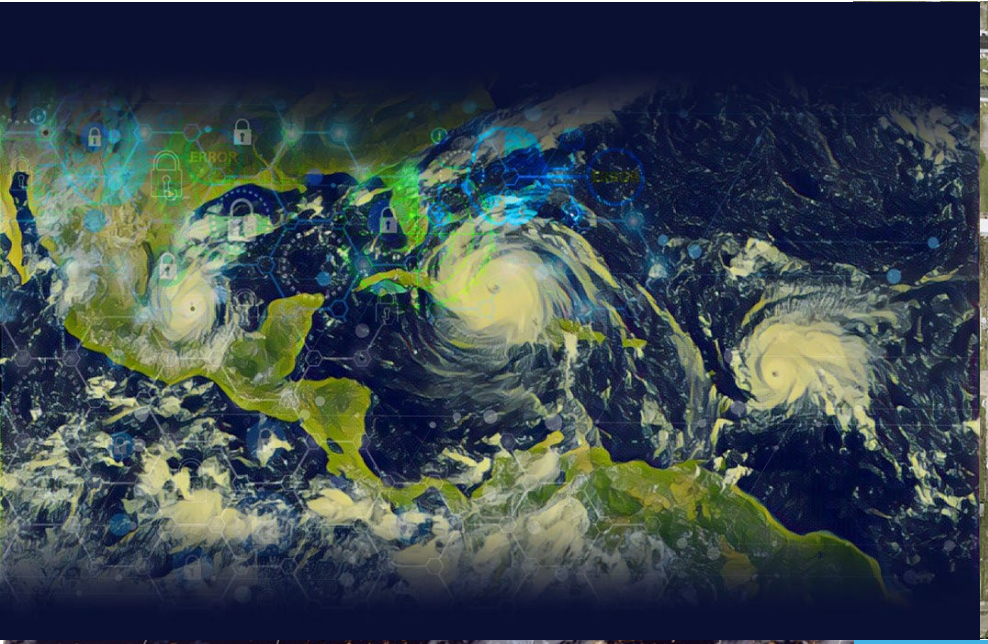
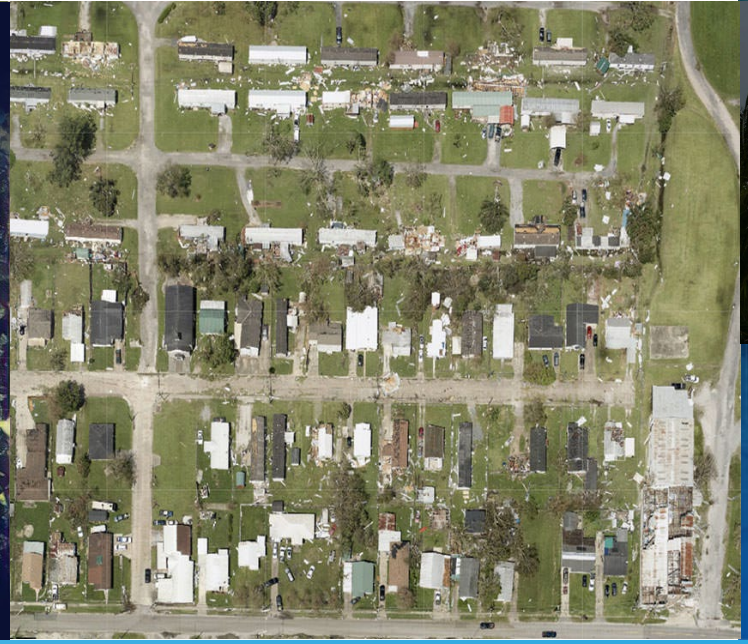
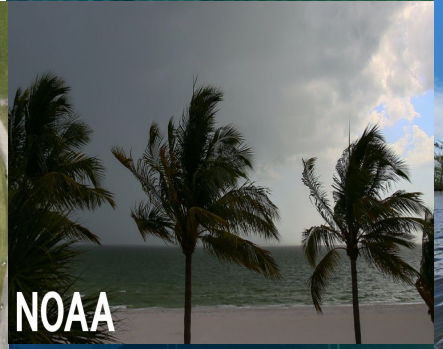
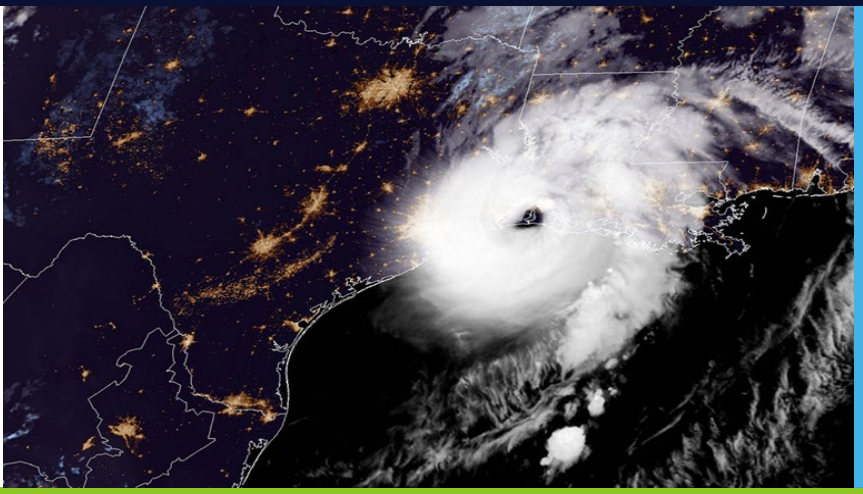






June 8, 2023



Storm-DEPART

Damage Estimate Prediction and Recovery Tool

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Strategic Advisor
Critical Infrastructure Security and Resilience

Idaho National Laboratory

INL is uniquely capable of addressing challenges to the nation's energy and security future

INL Values

Excellence, Inclusivity, Integrity, Ownership, Teamwork, and Safety

INL Vision

INL will change the world's energy future and secure our critical infrastructure.

INL Mission

Discover, demonstrate and secure innovative nuclear energy solutions, clean energy options and critical infrastructure.

Addressing Energy and Security Challenges at Scale

$1,630 M	FY22 Total Operating Cost
5,500+	Employees
569,178	Acres
890	Square Miles

4	Operating reactors
12	Hazard Category II & III non-reactor facilities/ activities
50	Radiological facilities/activities
17.5	Miles railroad for shipping nuclear fuel
44	Miles primary roads (125 miles total)
9	Substations with interfaces to two power providers
126	Miles high-voltage transmission lines
3	Fire Stations

National & Homeland Security's Vision for the Future

- Scale Cyber Informed Engineering
- **All-Hazards Infrastructure Resilience**
- Increased Supply-Chain Security
- Secure Wireless Communication
- Nuclear Nonproliferation Risk Reduction
- Next Generation Materials Science

Aligning and adapting our capabilities to meet evolving national security challenges.

National and Homeland Security Focus Areas

Storm-DEPART

Industrial Cybersecurity

Improving infrastructure security through cyber threat analysis, vulnerability assessments, and engineer expertise

Infrastructure Resilience

Strengthening infrastructure resilience through dependency analysis, risk assessments, and visualization tools

Nuclear Security

Preventing the illicit use of nuclear or radiological materials through detection, forensics, security, and safeguards

National Defense

Advancing defense community solutions through materials science, armor development, explosives and radiological materials analysis

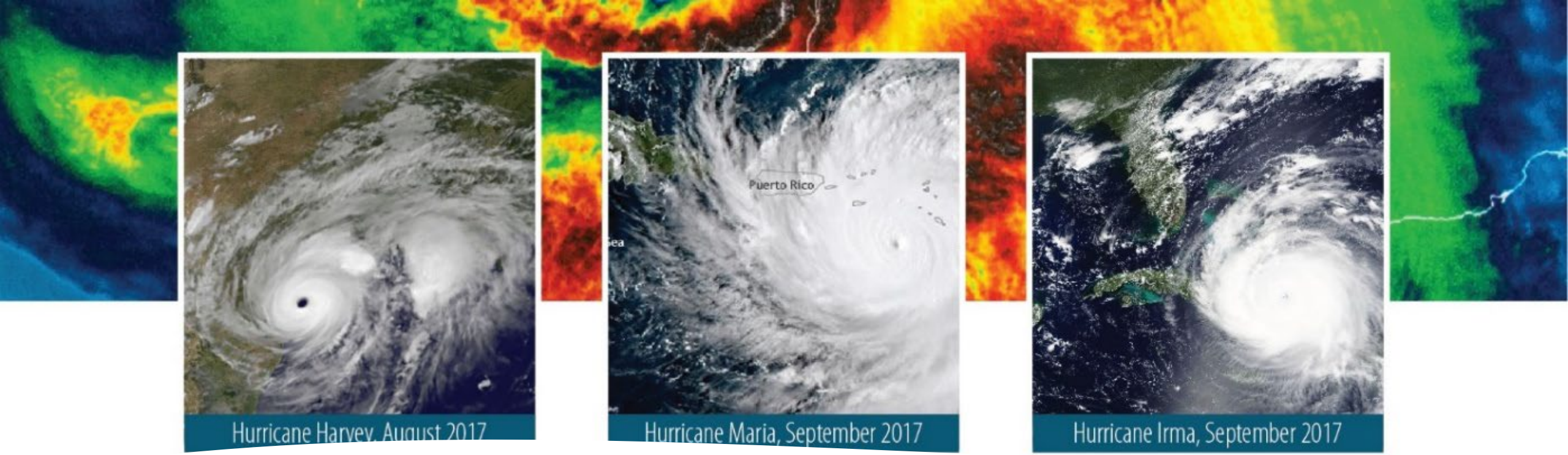
Workforce Development

Accelerating the talent pipeline through collaborative research programs and new education models

INL Resilience Optimization Center Overview

IROC is: A National Center for Advancing Systems Resilience and Risk Management

We Deliver: Innovative, interdisciplinary infrastructure resilience solutions through applying laboratory-wide capabilities and expertise.



Why Resilience?

- **11.2** average number of billion-dollar disasters per year 2001-2022, compared to **4.3** in 1980-2001
- **$145B** in damages to the US from disaster in 2021
- Estimated cost of cyberattacks globally is **$400B annually**
- Only **5%** of organizations have business continuity, cyber security, and physical security plans
- American Society of Civil Engineers rated U.S. Infrastructure a **C-** in 2021

Natural Disaster Response and Recovery

56

The number of weather and climate disasters in the U.S. in the past three years (2019 to 2021) with losses exceeding $1 billion.

$2.155 trillion

The total approximate cost of damages from weather and climate disasters in the U.S. from 1980 to 2021.

17.2

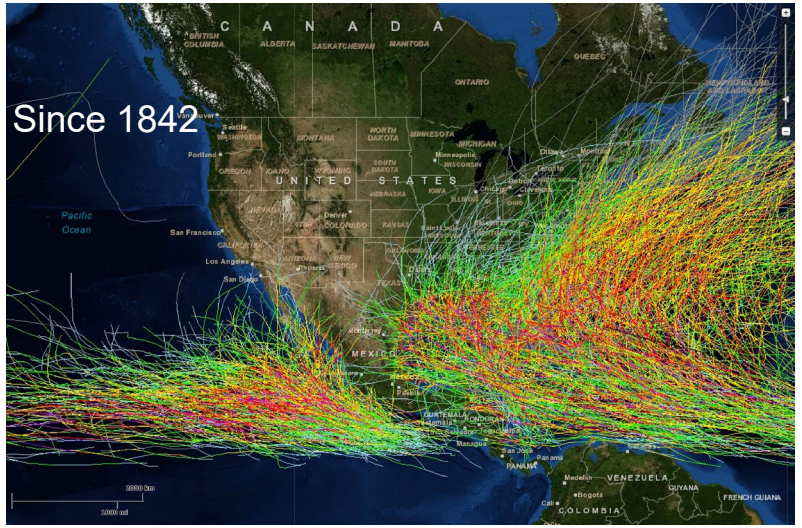
The average annual number of weather and climate disasters from 2017 to 2021. In 2021 alone, the U.S. experienced 20 billion-dollar disasters.

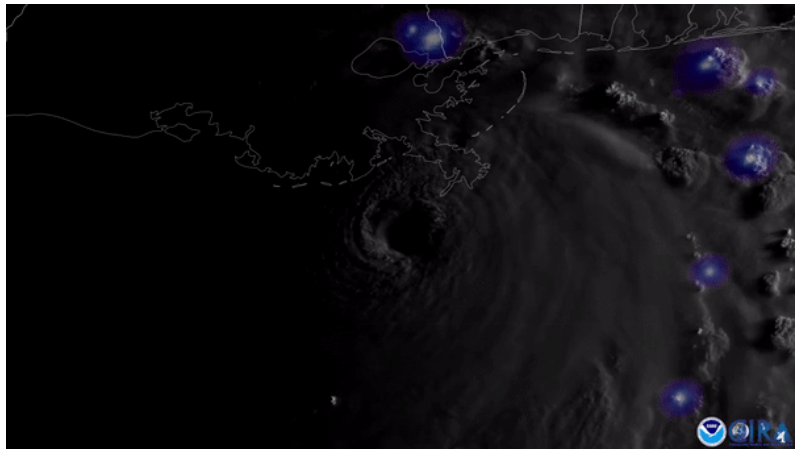
Of all recorded weather disasters in U.S. history, tropical cyclones — known as hurricanes have caused the most deaths and destruction

Source: NOAA Office for Coastal Management

Natural Disaster Response and Recovery (cont.)

- Between 1980-2021, tropical cyclones were responsible for the most deaths (6,697) and caused the most damage (over $1.1 trillion total)
- Hurricane Laura (Category 4) made landfall in southwestern Louisiana (August 2020); most expensive weather event of the year ($19 billion)
- Hurricane Delta (Category 2), made landfall six weeks after Hurricane Laura in nearly same location ($2.9 billion)
- Hurricane Ida (Category 4) made landfall in southeastern Louisiana (August 2021) as the most expensive weather event of the year ($75 billion)

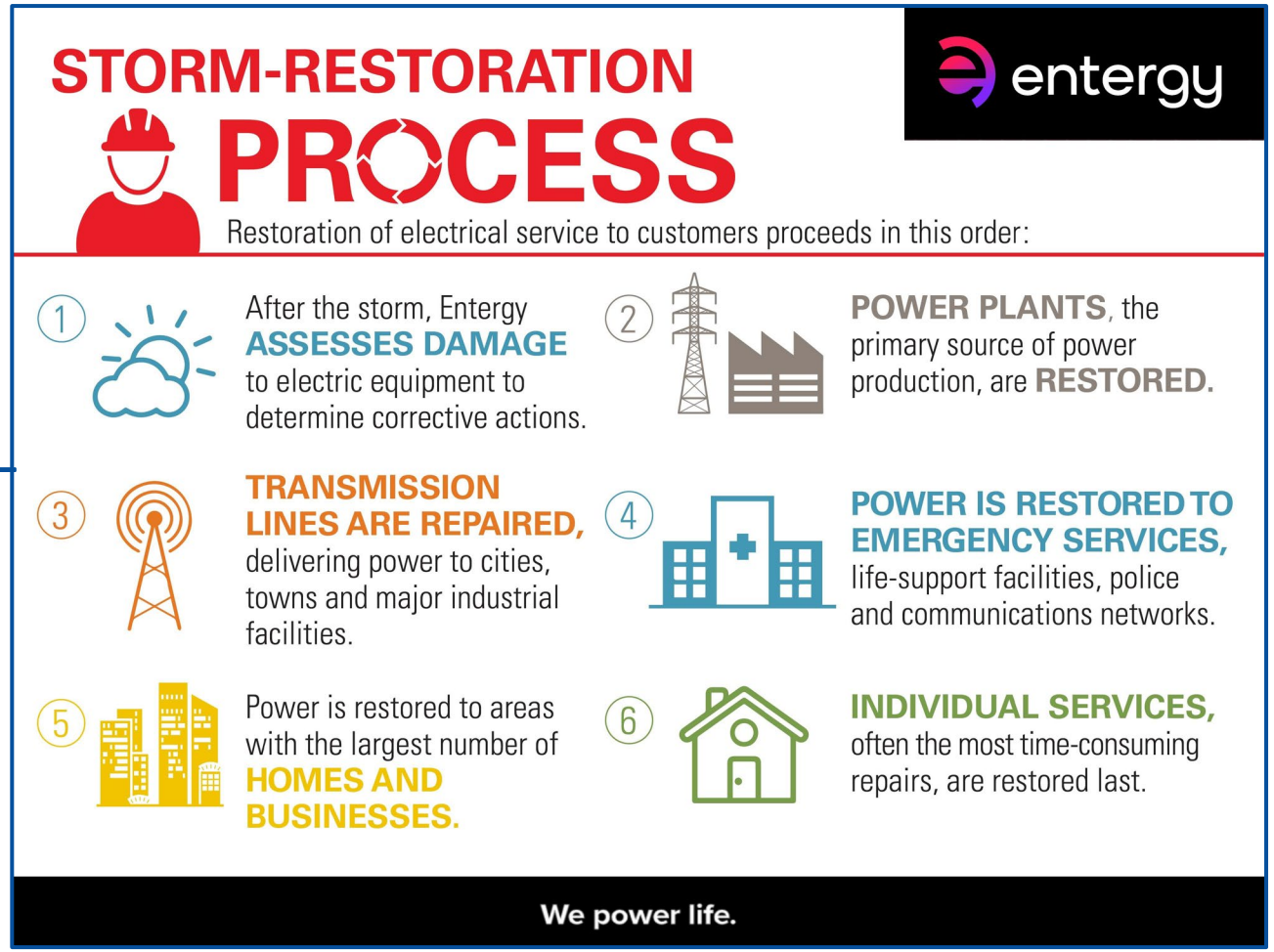




Source: NOAA

Natural Disaster Response and Recovery (cont.)

- Hurricanes damage electricity infrastructure throughout wide swaths of the U.S. leaving electric utilities with a massive amount of restoration work
- Each new weather event increases the need for rapid and accurate prediction and recovery estimations for critical infrastructure
- Utilities must mobilize restoration crews from other regions at considerable expense



Source: Entergy

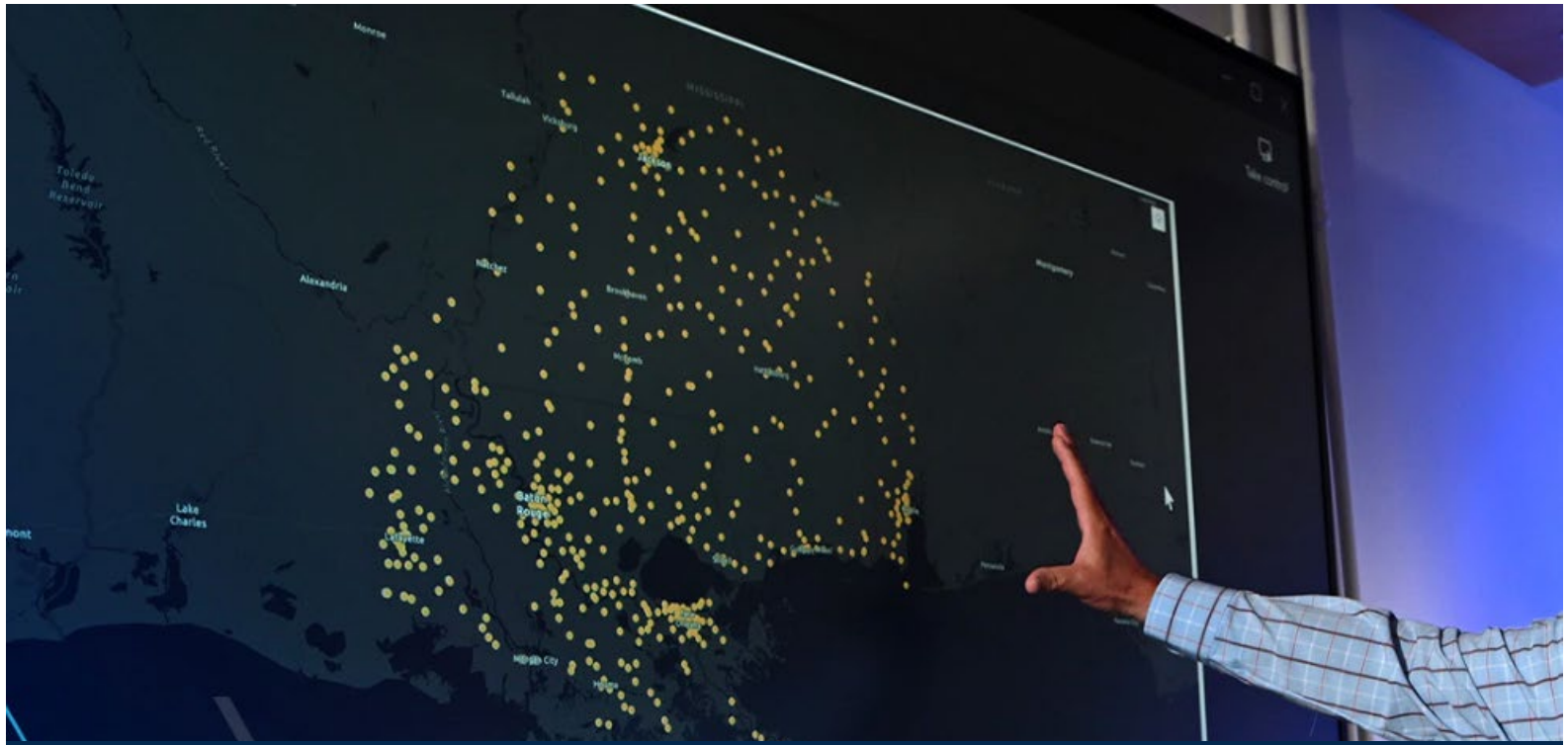
Hurricane Laura Restoration (2020)

- More than 14,000 distribution poles
- Approximately 4,800 transformers
- Approximately 30,000 spans of distribution wire
- More than 30,000 crossarms
- Approximately 1,900 transmission structures damaged or destroyed
- More than 300 substations
- Approximately 225 transmission lines
- 25,314 workers from 31 states and 24 other electric utility companies supported restoration

Source: Entergy

Storm-DEPART

Damage Estimate Prediction and Recovery Tool

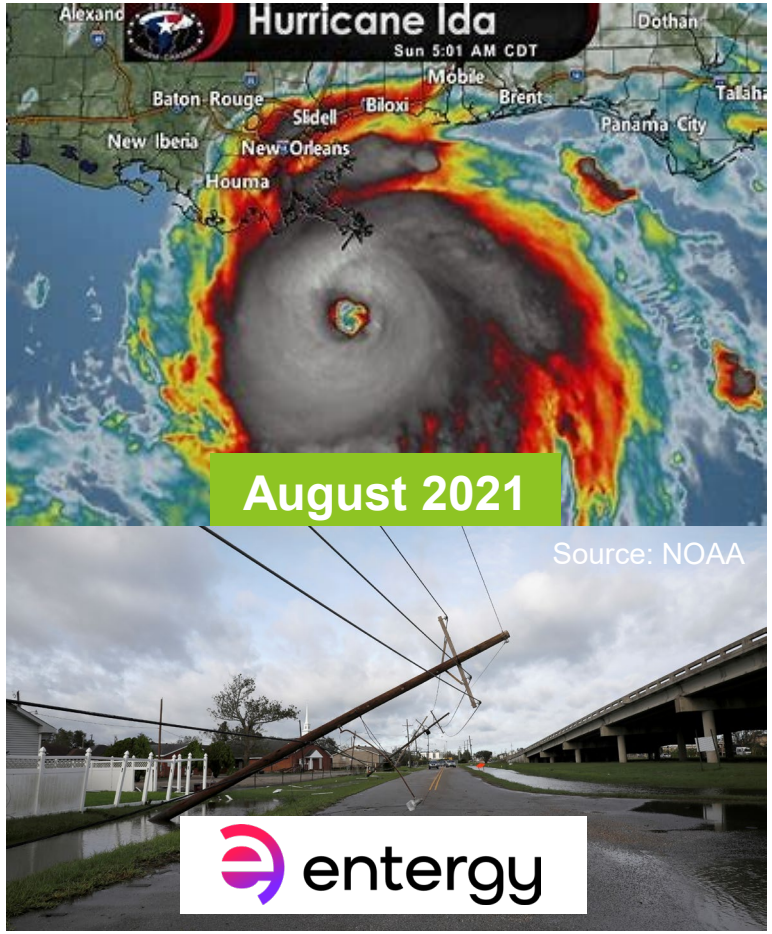


Storm-DEPART combines critical infrastructure inventory data with weather forecasts to predict weather-related damages to a critical utility service provider's assets.

Source: Entergy

Storm-DEPART Development and Deployment

- **January 2022:** Entergy requested partnership to solve modeling damage estimate prediction challenge
- **February 2022:** Initial prototype predicts power generation, transmission, and distribution damage
- **May 2022:** Tool used to predict hurricane impact during Entergy's Restoration Strategy Group Storm Exercise
- **August 2022 – April 2023:** INL and Entergy Strategic Partnership Project (SPP) Version-2 agreement
  - Material, logistics and resource modifications
  - Integration of actual distribution damages
  - Development of ice event damage prediction
- **May 2023:** Modifying agreement to enhance Version-2 to include refined customer outage predictions



Storm-DEPART Development and Deployment (cont.)

- **Inputs**
  - Level of effort per asset task (pole replacement, xarm replacement, etc.)
  - Task-to-worker-to-oversight ratios
  - Damage assessment/scouting productivity
  - Arrival schedule logistic constraints
  - Distribution resource ramp up and ramp down schedule
  - Asset inventory for:
    - Distribution
    - Transmission
    - Power Generation

Source: inl.gov

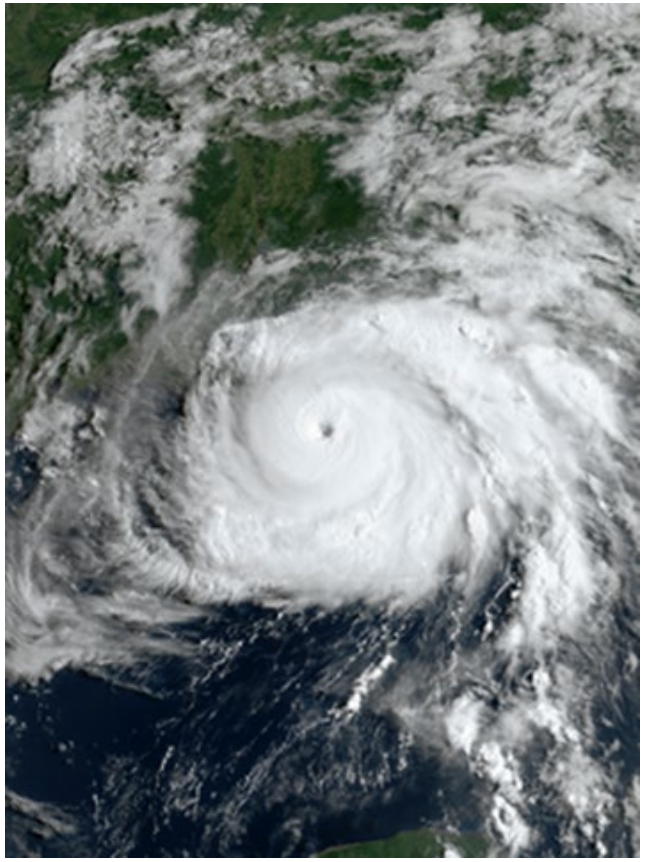
Storm-DEPART Development and Deployment (cont.)

- **Outputs**
  - Predicted damage
    - Distribution by company, region, and network
      - Includes bill of materials (BOM)
    - Transmission by company, grid, area, and line segment
    - Power Generation by plant and asset
  - Interactive calculator to adjust resource needs based on days to restoration and damages
  - Resource summary by network or area
  - Arrival schedule for potential lodging constraints

Weather and infrastructure data provides more accurate damage predictions, resource deployments and restoration estimates

Storm-DEPART Development and Deployment (cont.)

- Supports pre-incident planning and preparation by predicting damage to power generation assets, transmission grids, and distribution networks
- Uses factors such as ice accumulation, wind speed, duration, and gust forecasts combined with available participants' infrastructure data like class, height, type, age, location, wind rating, etc., to report predicted damages
- Intended for use by electric utilities to optimize restoration by understanding the extent of potential damage, supply chain constraints, and the quantity of worker and oversight resources needed
- Tool can model major weather events where storms have not been experienced recently, or at all, by allowing a utility service provider to apply a planning scenario and model expected damage



Source: NOAA

storm DEPART Home Configuration Incident Analysis Version

storm DEPART

Damage Estimate Prediction and Recovery Tool

Idaho National Laboratory (INL) and Entergy Corporation (Entergy) are partnering to develop a damage prediction, materials needed, and resource allocation modeling capability in order to support pre-incident planning and preparation. This project will be multi-phased with each building off lessons learned and identification of additional capabilities required. This product represents the initial operating capability (IOC).

Predicted Damage

Capabilities to predict damage to the distribution networks, transmission grids, communications assets, and power generation will be developed by applying wind, storm surge, and flooding forecasts to Entergy assets which will result in a report of predicted damages.

Projected Materials Needed

Based on predicted damages, a bill of materials (BOM) will be output. The extensiveness and level of detail for this BOM will depend on the replacement configuration specifications provided for each Entergy asset. The supply chain team will review this and report back with any limiting factors that need to be applied to the model. For example, if the BOM requires 500 widgets and there are only 300 available, this will need to be recorded and considered for the following step.

Estimated Resource Allocation

Based on the BOM and limiting factors, resource allocation needs will be generated. These are based on type of asset replacement, location (terrain) concerns, and materials available. Limiting factors can be introduced here in terms of available resources, minimum and maximum restoration times, and logistical constraints.

DEMONSTRATION

Capability Impact

Capability for predicting critical infrastructure inventory post-incident damage and estimated recovery support

Evolves with increased data collection, real world post-incident validation and verification, and new techniques resulting from research and development	Provides immediate and comprehensive analysis of weather-related damage predictions and recovery support	Allows organizations to make informed decisions on resource allocation and logistics before major weather incidents hit	Enhances ability to better prepare for and respond to disruptive events, increasing the resilience of a utility service provider's infrastructure assets

Damage Prediction and Resource Deployment Optimization

Next Development Phase (June 2023)

- Model Enhancement
  - Integrate flood and tidal surge predictions
  - Develop pre-incident customer outage prediction based on damages to the transmission, distribution, and feeder levels
- Model Connectivity
  - Connect Storm-DEPART and Dependency Wheel capability to support tropical and ice event infrastructure impact analysis.
- Data Refresh
  - Update data profile based on requirements gathering results, data sessions, and resiliency enhancements

Source: NOAA

Next Development Phase (cont.)

- Migration to Web-Based Application
  - Entergy hosted web-based application to include role-based access, customer outages predictions, historical data retention, and automatic feeds to other internal platforms
- Continuous Model Learning
  - Develop post-incident (tropical/ice) Storm-DEPART prediction accuracy analysis functionality to include customer outages breakdown
  - Conduct post-incident analysis of predicted versus actual damages for tropical and ice storm damages

Source: NOAA

Idaho National Laboratory