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Infrastructure Interdependencies

Presentation to Hawaii Public Utilities Commission

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Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Topics

- What Causes Cascading Failures?
- What do cascading failures look like?
- What measure can be taken to mitigate or prevent cascading failures?
- What happens when the cascading failure occurs?
- What are we doing at Sandia to understand these types of events?

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What Causes Cascading Failures?

- Interdependencies cause cascading failures
  - The set of human, equipment, physical location connections between elements of a series of interconnected systems
- They also bring us great benefits
- What can we say about interdependencies?

  Key Axioms of Interdependency
  - Infrastructure Systems are Interconnected
  - Humans are in the Loop
  - Machines are in the Loop, too
  - Timing is Essential
  - Co-Location is also Interdependence

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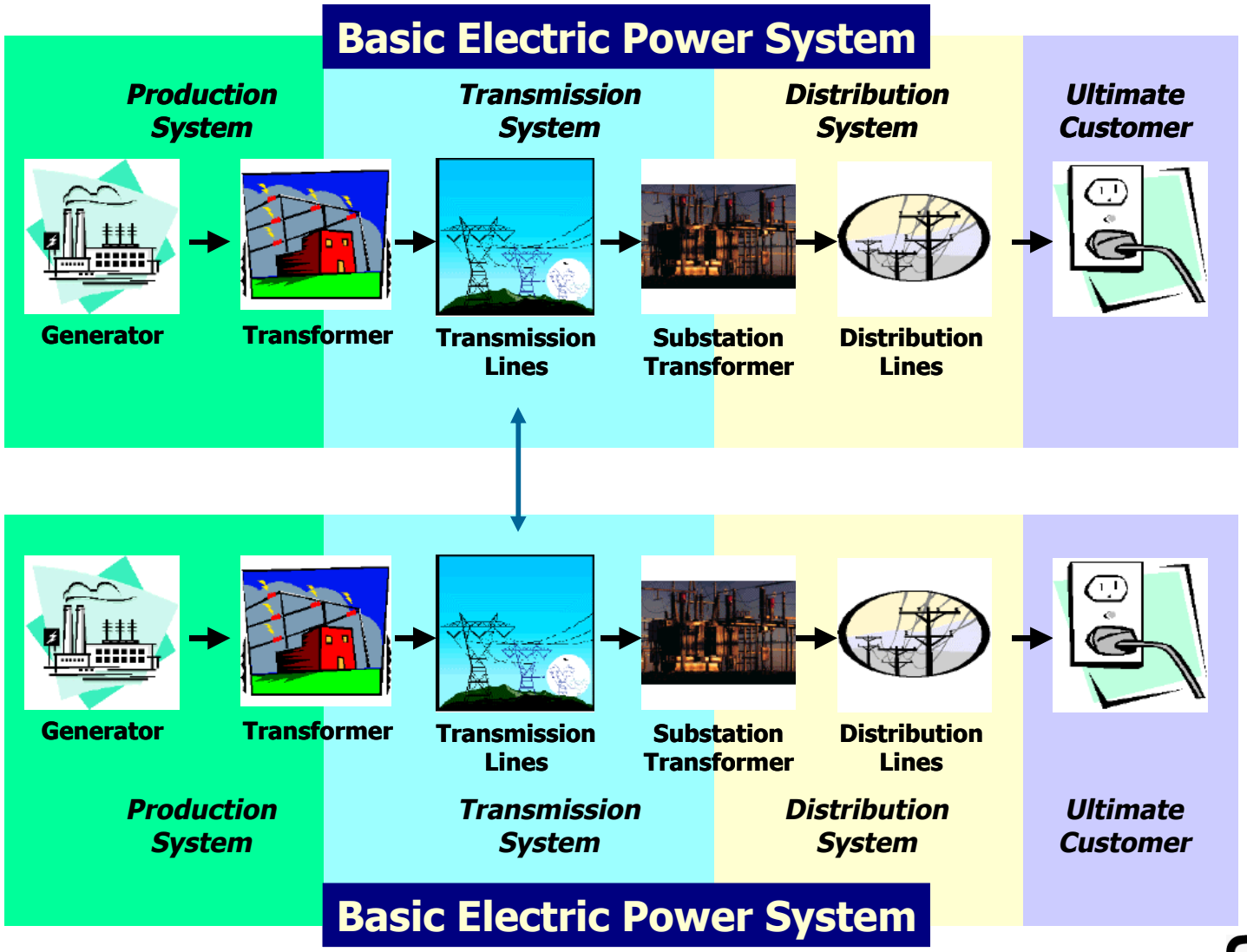
Infrastructure Systems are Interconnected



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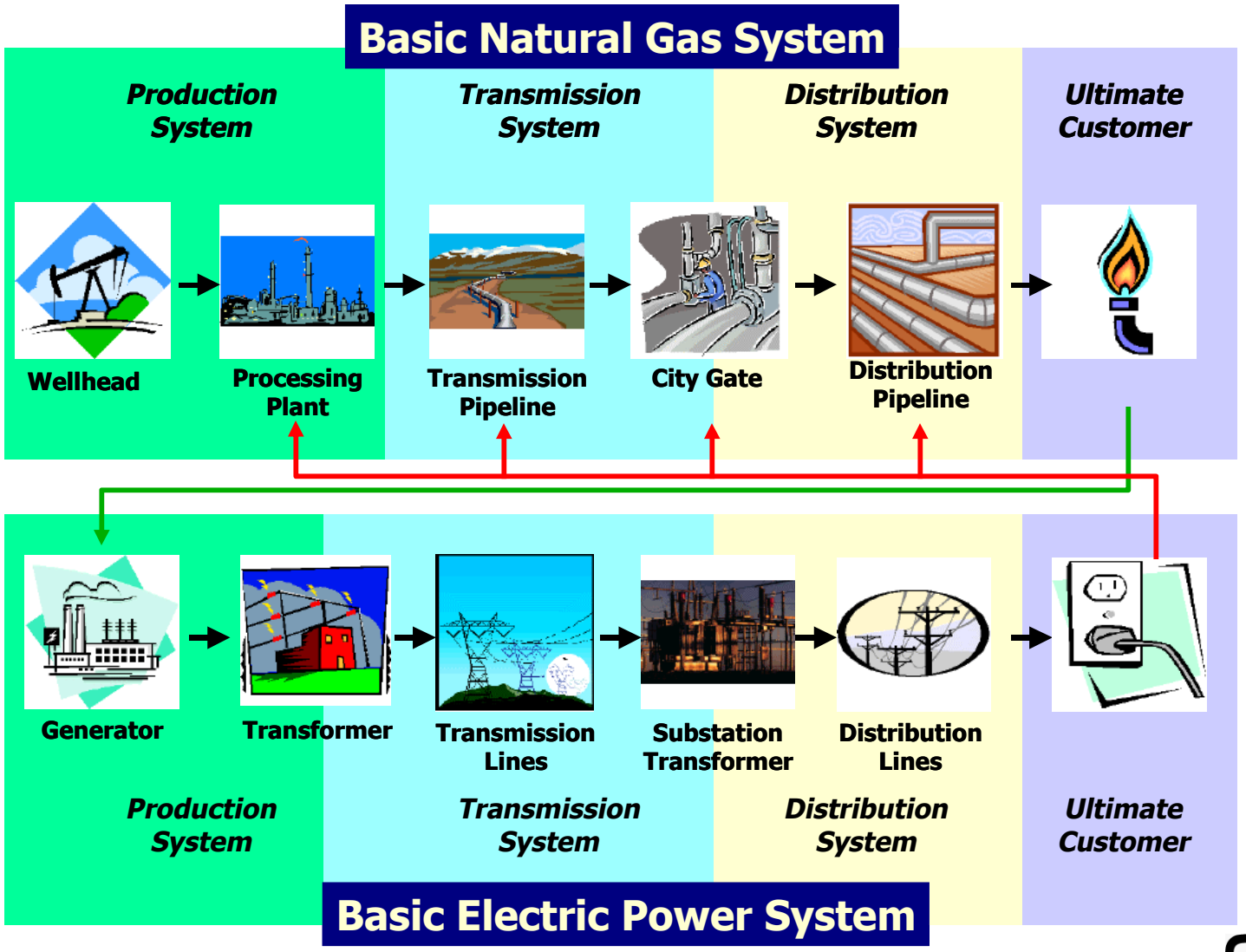
Infrastructure Systems are Interconnected



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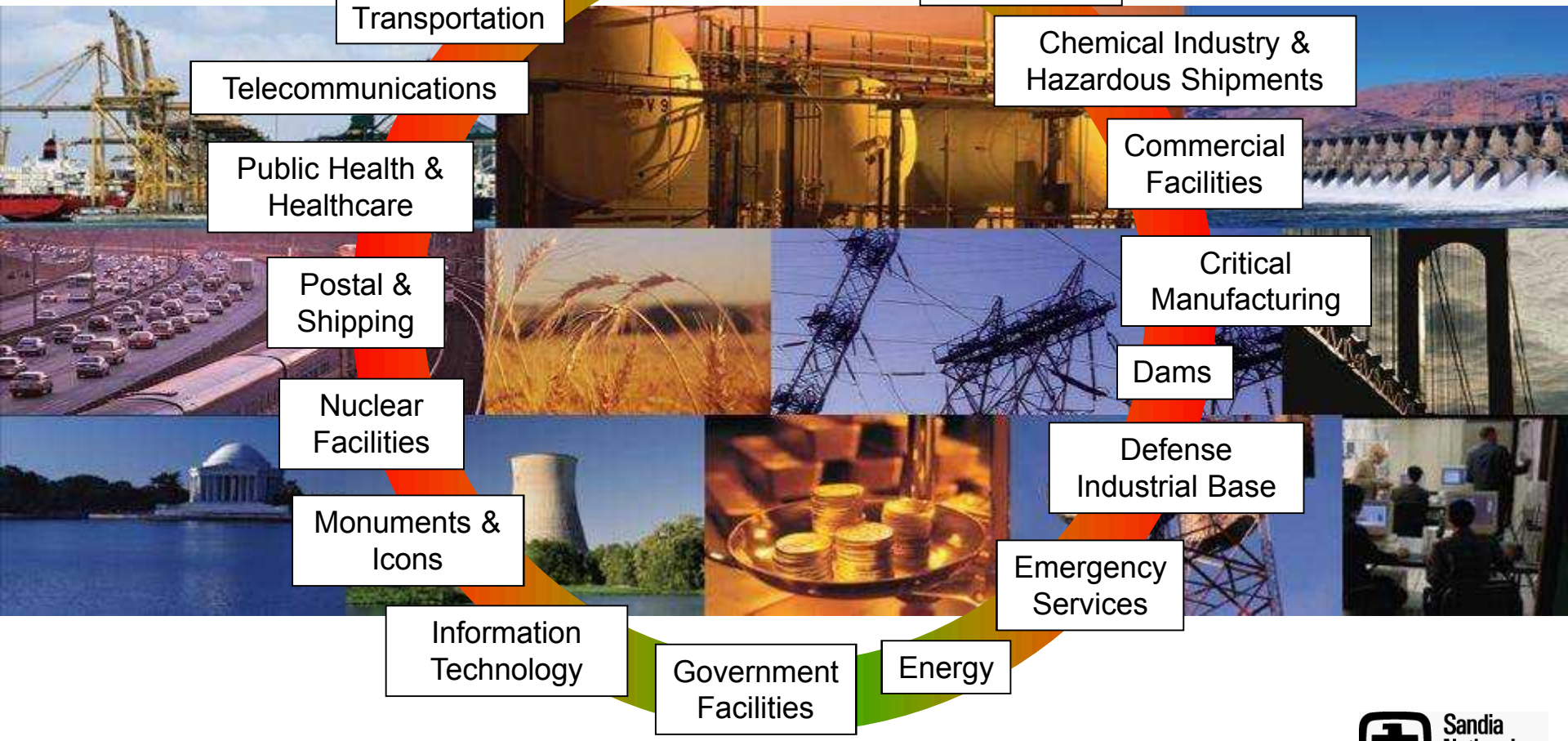
Infrastructure Systems are Interconnected



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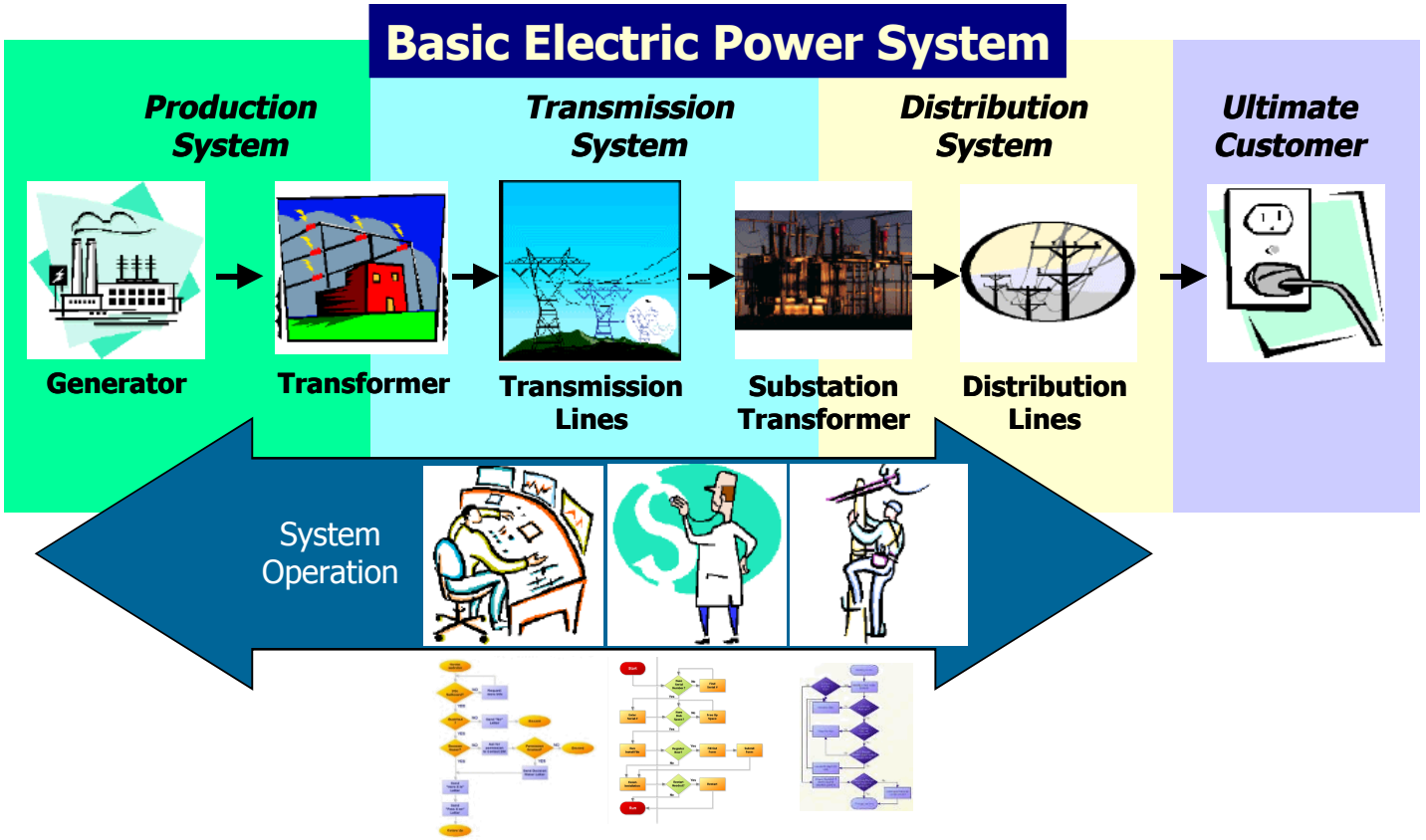
Humans are in the Loop



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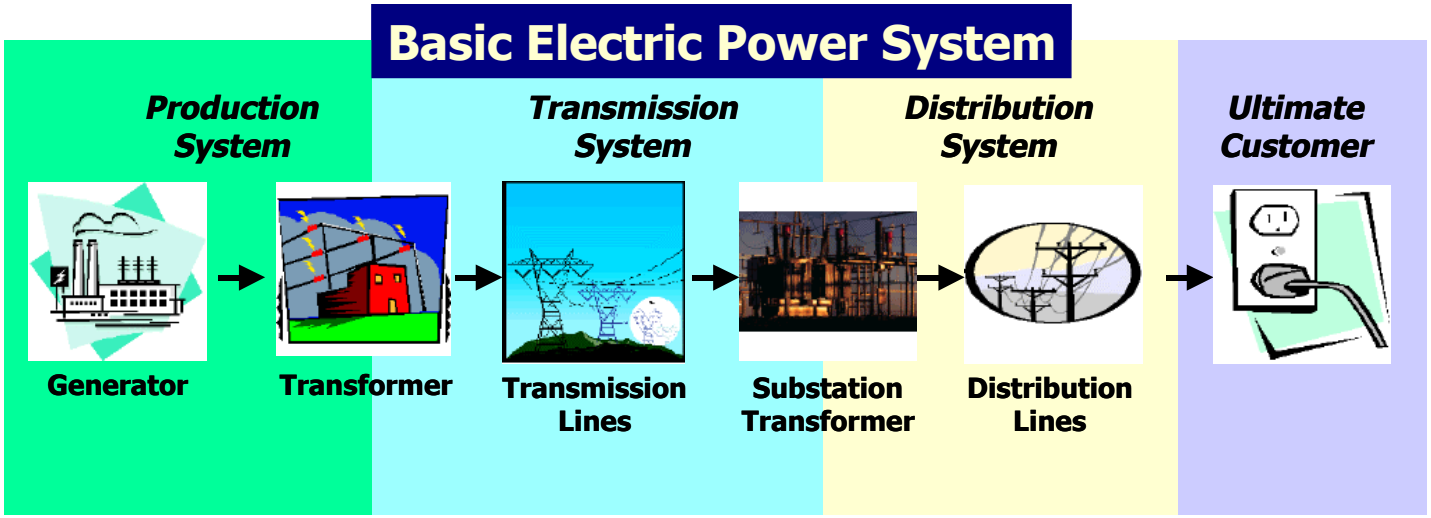
Machines are in the Loop, too



- Each element composed of physical components
- Physical components include limitations on the physical performance of the component
- These rules exist for the physical protection of the components (primarily) and the system as a whole (hopefully)

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Timing is Essential

- Timing and Information
  - The "Just In Time" (JIT) Nature of the Infrastructure
    - Traditionally, Electric Power (along with telecommunications) has been the most JIT of the infrastructures (production to consumption)
    - Layering of a market structure has increased the number of JIT layers involved in day-to-day operations
      - This increases the potential for disruption
- Information from other infrastructures
  - Is critical to reducing the potential for disruption
  - Is a dual-edged sword
    - Information can help you mitigate
    - Information could be used to litigate against you

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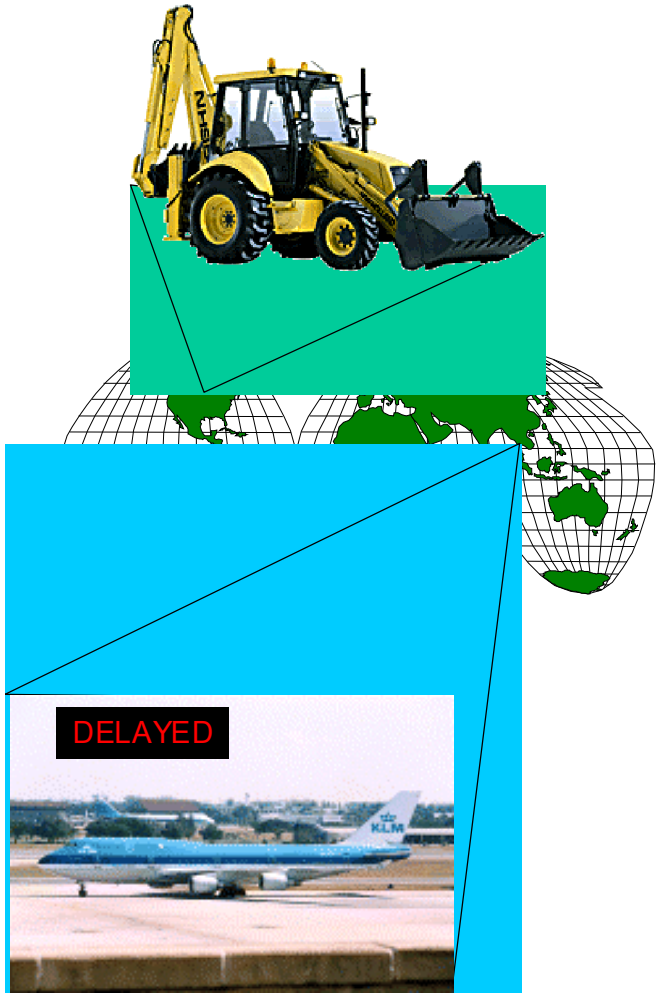
Co-Location is also Interdependence



YAHOO! FINANCE AP Associated Press

NW Airlines Loses Communication

EAGAN, Minn. (AP) -- Northwest Airlines lost most of its communications lines systemwide for about 2 1/2 hours Tuesday when an independent contractor hit a fiber-optic cable, leading to cancellations and delays around the country.

Passengers aboard planes were not in danger, but Northwest temporarily suspended boarding additional flights until the problem was fixed, said spokeswoman Mary Beth Schubert.

About **130 of the airline's 1,700 daily flights were canceled** systemwide, and an undetermined number were delayed. Schubert said communications lines went down just after 2 p.m. CST, affecting reservations and baggage information and the airline's electronic ticketing system.

Major delays were reported in Detroit, where about 30 flights were canceled, according to Northwest spokesman Doug Killian.

Another 19 were canceled in Minneapolis, with the remainder scattered around the system. **Some delays also were experienced in Singapore and Bangkok**, he said.

Northwest's Web site also was out of service because of the severed cable.

Kim Bothun, a spokesman for U S West, the telecom that owns the fiber-optic cable, said the **line was cut by a competitor McLeod USA, a local and long-distance telecommunications company based in Cedar Rapids, Iowa**. She said it is not uncommon for telecommunications companies' cables to be very close to each other.

Calls to McLeod USA were met with a busy signal Tuesday night.

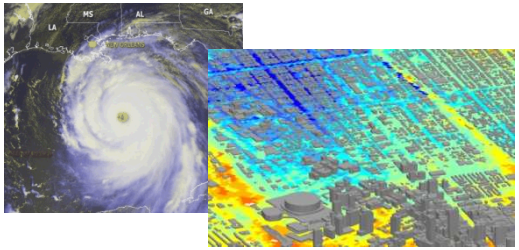
Northwest officials said the airline expected to be back to normal operations by Wednesday morning.

Passengers scheduled to fly on Northwest Tuesday evening were given the option of rescheduling their flights.

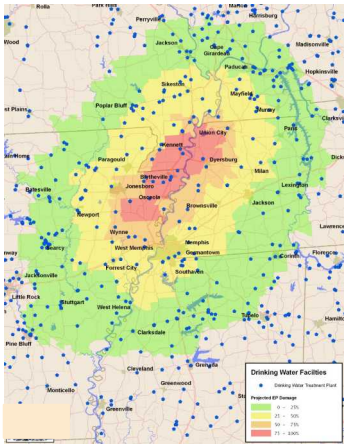
"NW Airlines Loses Communication", AP via Yahoo! Finance, published 21 March 2000 8:59 PM ET. Similar article from CNN available at http://money.cnn.com/2000/03/21/companies/northwest/

What do Cascading Failures Look Like?

- **Natural**
  - Accident
  - Drought
  - Earthquake
  - Flood
  - Heat Wave
  - Hurricane
  - Ice Storm
  - Landslide
  - Pandemic
  - Space Weather
  - Tsunami
  - Volcano
  - Wildfire
- **Terrorist**
  - Biological
  - Chemical
  - Cyber
  - Explosive
    - IED
    - VBIED
    - aircraft
  - Insider
  - Nuclear
    - Physical Assault
    - Radiological

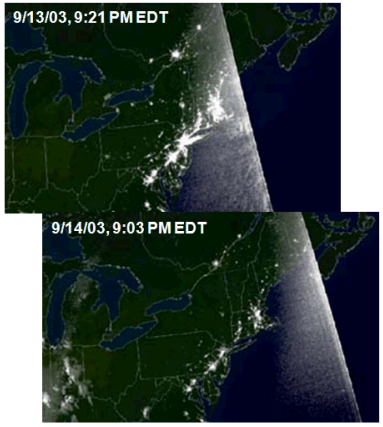


Hurricane (flooding)

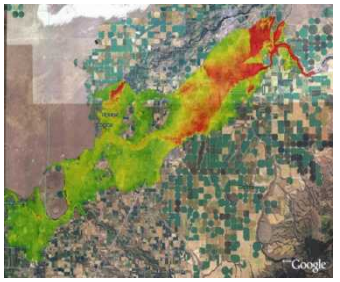


Earthquake

Cascading Blackout



Images: NOAA



Dam Break

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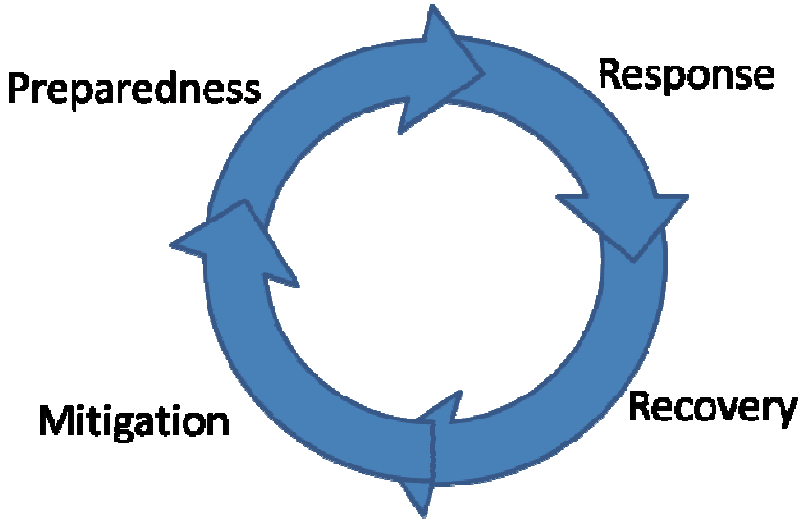
What measures can be taken to mitigate or prevent cascading failures?

- The measures you can take depend on where you are in the response life cycle
  - In mitigation
    - build a better system
      - understand and measure resilience
  - In preparedness
    - plan to act
    - learn from error
  - After the event
    - Respond as planned



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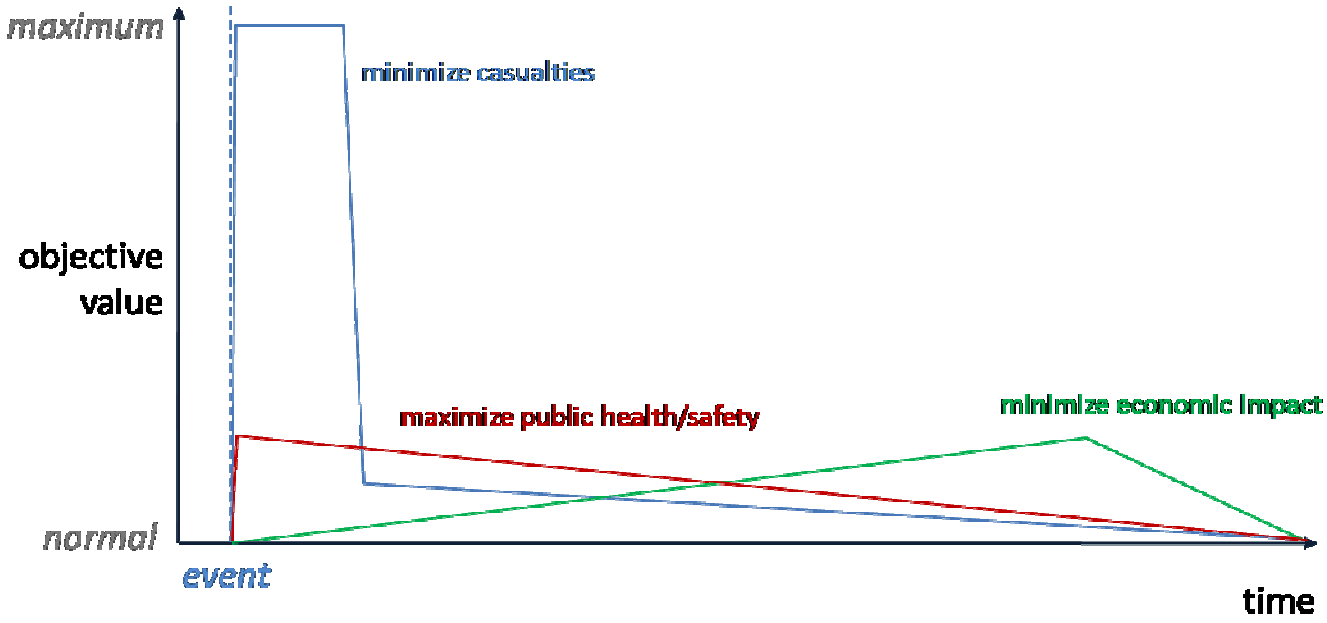
What happens when the cascading failure occurs?



- How one dedicates resources is time- and event-type-specific
  - Duration of common objectives' prevalence changes with event type and with time from event occurrence

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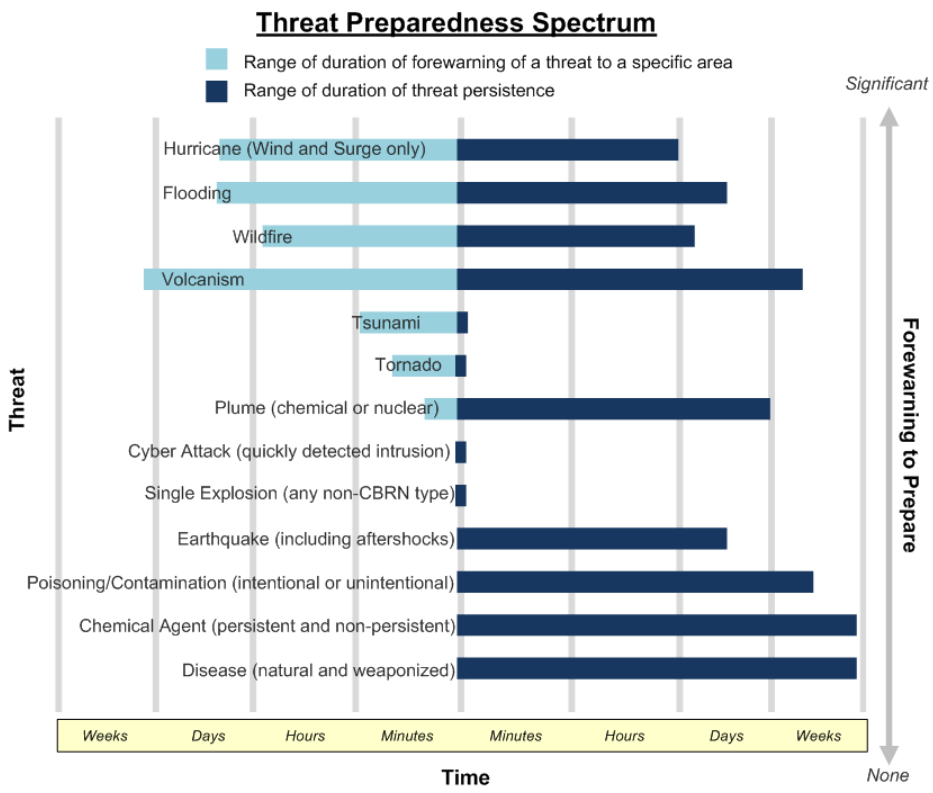
What happens when the cascading failure occurs?



- Event type really makes a difference in
  - Affected area
  - Resource requirements
  - Persistence of
    - Threat
    - Consequences
- Event type plays important role in defining response requirements

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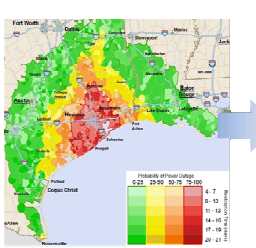
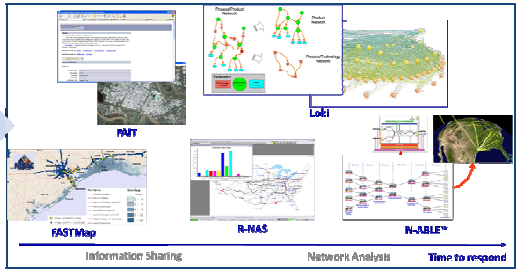
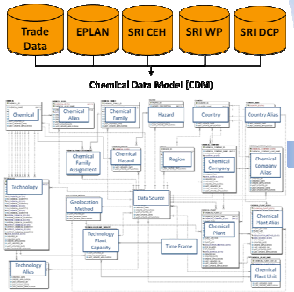
What are we doing at Sandia to understand these types of events?



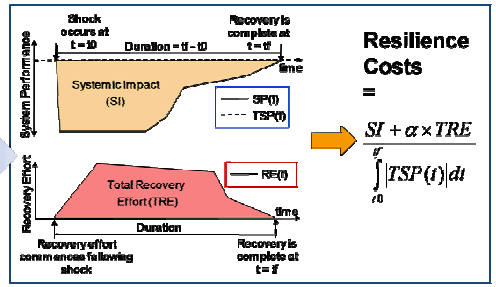
When disruptive effects occur...



...a suite of analytic capabilities can be brought to bear...



...all drawing on a common data model...



...to estimate consequences and to calculate resilience.

- **Supply Chain Analysis**
  - **Infrastructure-wide analysis**
  - **Multiple models with different perspectives**
  - **Use of a common data model**
  - **Allows for consequence analysis and resilience measurement**

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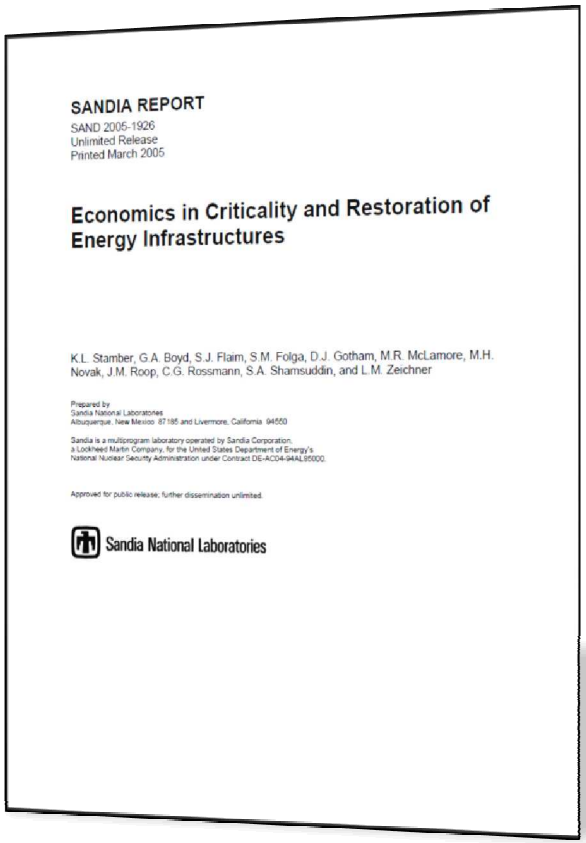
What are we doing at Sandia to understand these types of events?

- **Prioritization of Restoration of Energy Infrastructures (DOE/OE)**
  - **How do energy systems restore from a significantly disrupted state?**



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Economics in Criticality and Restoration of Energy Infrastructures

K.L. Stamber, G.A. Boyd, S.J. Flaim, S.M. Folga, D.J. Gotham, M.R. McLamore, M.H. Novak, J.M. Roop, C.G. Rossmann, S.A. Shamsuddin, and L.M. Zeichner

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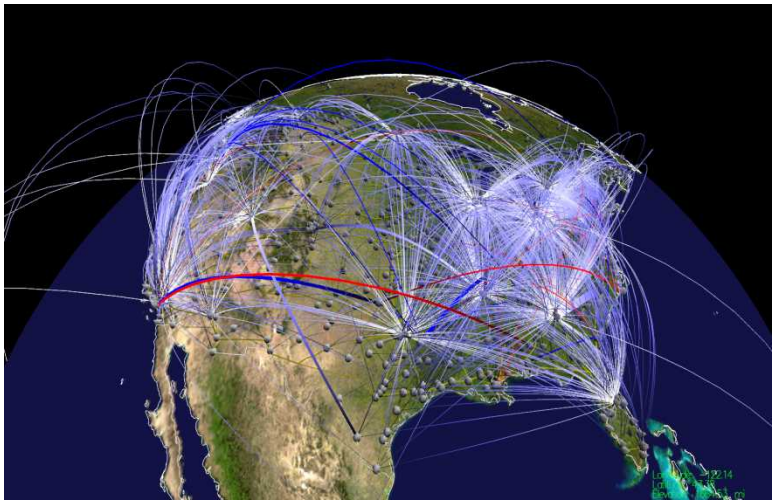
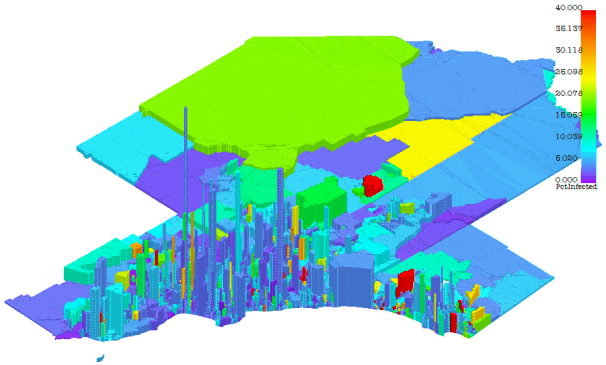
What are we doing at Sandia to understand these types of events?

National Infrastructure Simulation and Analysis Center (NISAC)

- DHS Program Lead by Sandia and Los Alamos National Laboratories
- Improve the understanding, preparation, and mitigation of the consequences of infrastructure disruption.
- Provide a common, comprehensive view of U.S. infrastructure and its response to disruptions.
  - Scale & resolution appropriate to the issues
  - All threats
- Built an operations-tested DHS capability to respond quickly to urgent infrastructure protection issues.
  - 24/7 when needed





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