SAND2021-8338C

Sandia National Laboratories

Modeling for Real-World Decision Support: A History and Retrospective

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26 July 2021

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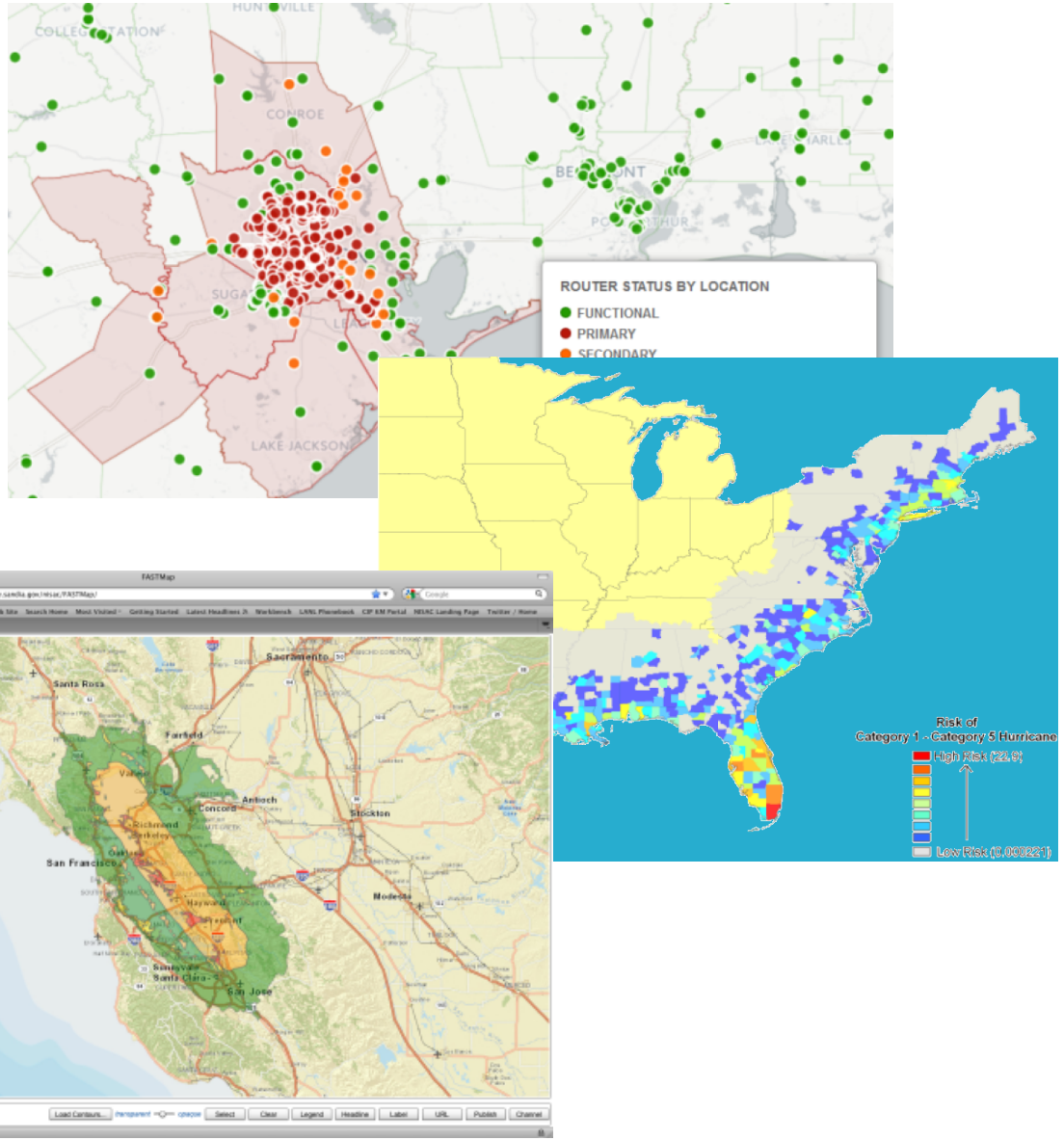
Overview

- Goals
- Considerations
- Implications for Model Building
- Ongoing challenges
- Lessons Learned

Goal of Infrastructure Simulation and Analysis

Aid decision makers with

- Policy effects
  - Potential effects of policy or regulatory action
- Consequence analysis
  - Quantify impacts of disruption
- Mitigation planning
  - Minimizing consequences
- Education and training
  - Improve response



Why Model?

Identify when/where things break, and any cascading effects

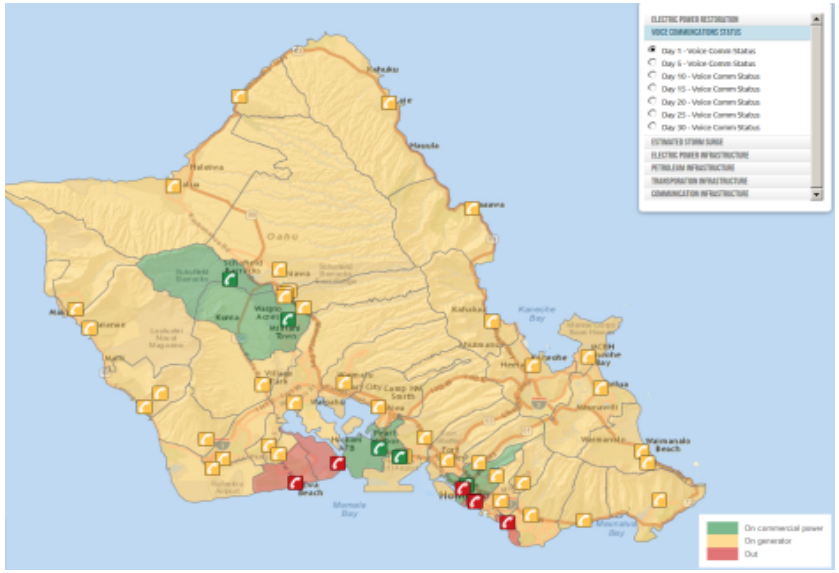
- Cannot experiment on the system

Quantify consequences of disruptions in very complex systems

- Loss of a single asset or node within a particular system due to a directed attack
- Regional disruptions due to a natural disasters or large scale attacks

The domains are:

- Large
- Complex



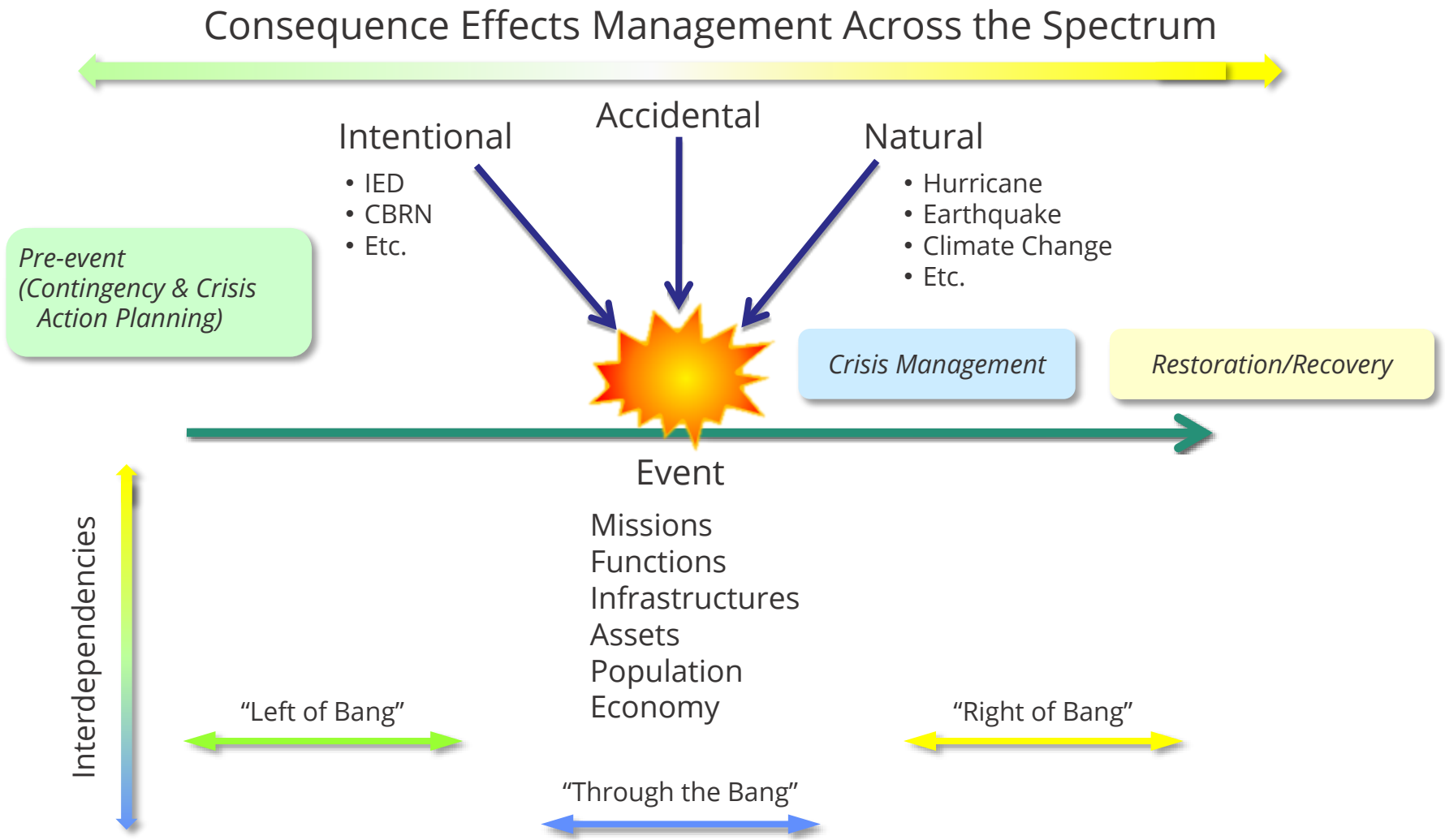
Communication Disruption Modeling

The responses are:

- Dynamic
- Adaptive
- Nonlinear
- Behavioral

Too complex for mental models to be effective decision tools

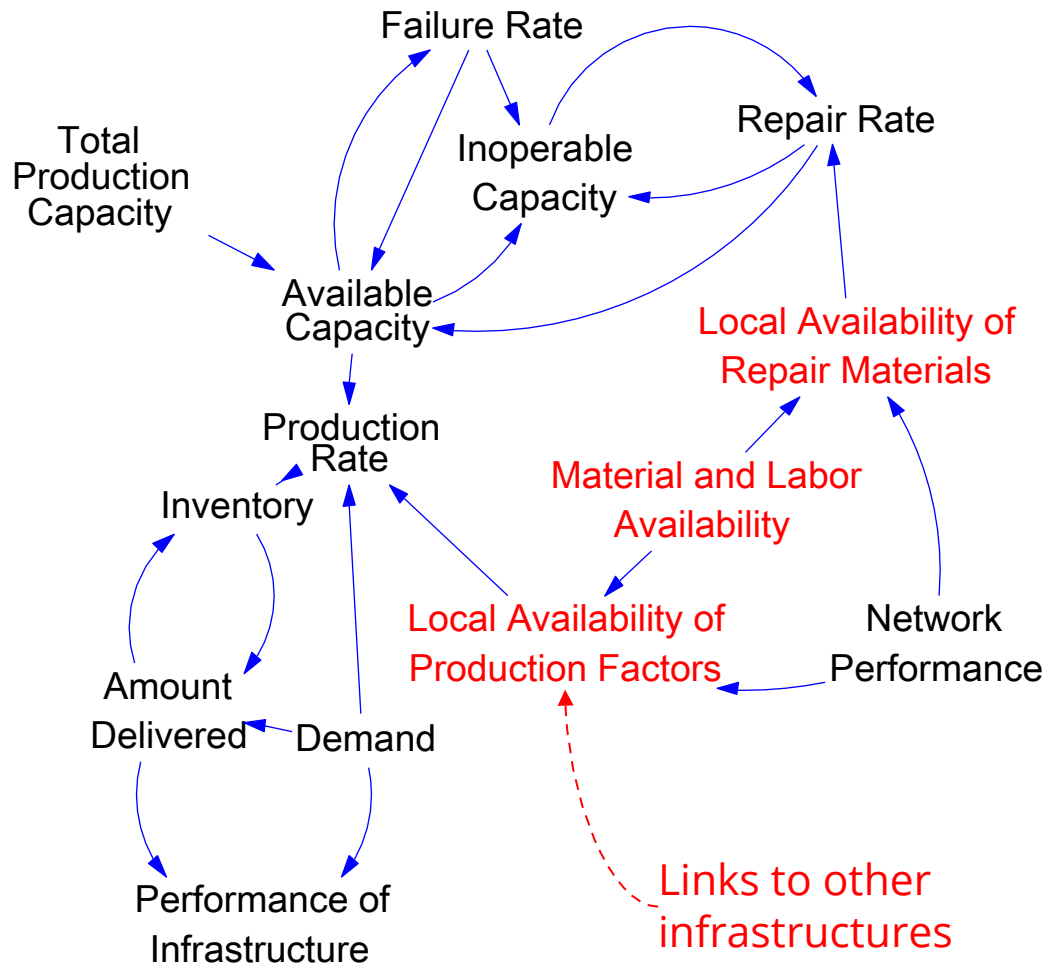
Where are Models Most Effective?



Modeling an Infrastructure

Elements

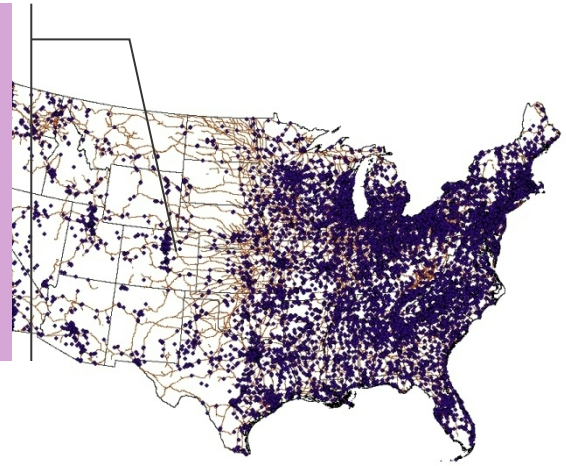
- Production
  - Labor
  - Materials
- Demand
- Failure Rate
- Repair Capacity
- Dependencies

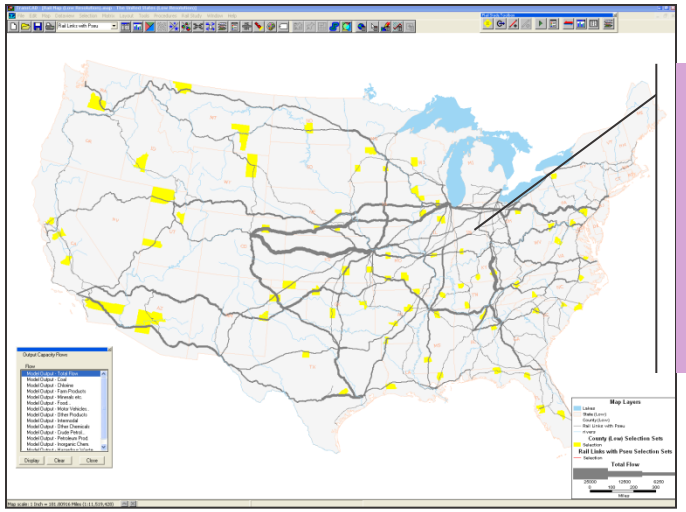


Infrastructures are Capacity Limited and Resource Constrained in Normal Operation

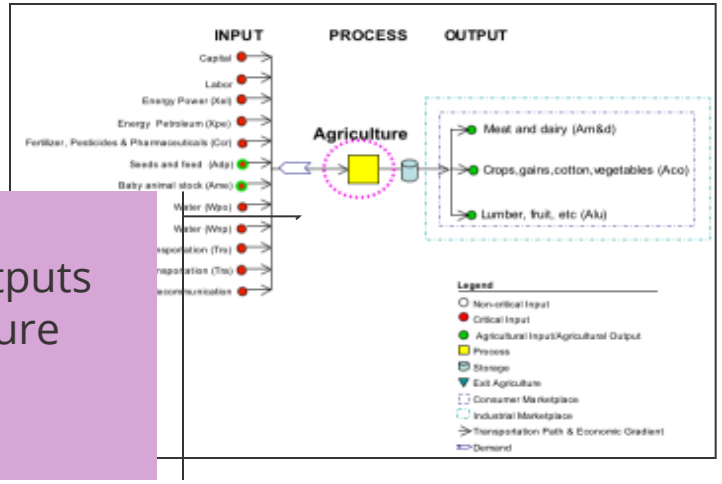
Different Questions May Lead to Different Approaches

Spatial/Physical
- Location of key assets
- Asset characteristics
- Co-location
- Impacted assets and ratios

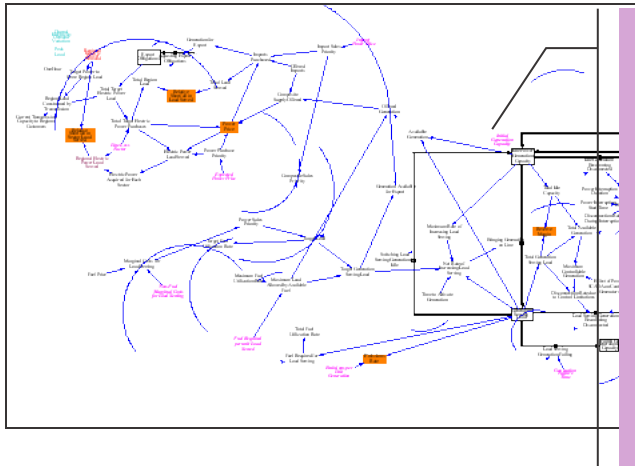




Network
- Flow of resources and goods
- Flow Capacity
- Critical Nodes



Supply Chain
- Inputs, Processes, Outputs
- Process ➔ Infrastructure
- Dependencies
- Basic Flows



System Dynamics
- Stocks/Flows
- Feedback Loops
- Interdependencies
- Structure ➔ Dynamics

- Interacting Networks

Modeling Challenges

Scope

- What is the infrastructure system or process you're modeling?
- What is the incident and duration you're interested in?
- Are there backup capabilities? Mitigations?

Data accuracy

- Where are the assets?
- How do they connect?
- What are the attributes?

Fidelity

- What do the assets or the system really depend on and how?

Interdependency compounds the usual model building difficulties

- Typically non-public information

Threats Bound Model Scope

Natural

- Drought
- Earthquake
- Flood
- Heat Wave
- Hurricane
- Ice Storm
- Landslide
- Pandemic
- Space Weather
- Tsunami
- Wildfire

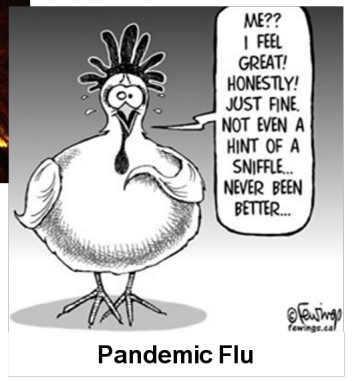
Terrorist

- Biological
- Chemical
- Cyber
- Explosive
- IED
- VBIED
- Aircraft
- Insider
- Nuclear
- Physical Assault
- Radiological

Hurricane Flooding

Terrorist Attacks

Wildfire



Pandemic Flu

Scope and Duration of Potential Disruptions

Critical Infrastructures are Massively Interconnected

Interconnections exist
- Within an infrastructure sector
- Across infrastructure sectors

This includes
- Dependencies
- Interdependencies

These dependencies and interdependencies include
- Humans in the loop
- Rules and other constraints
  - Functionally specific
  - Geographically specific
  - Treaties, regulations, etc.

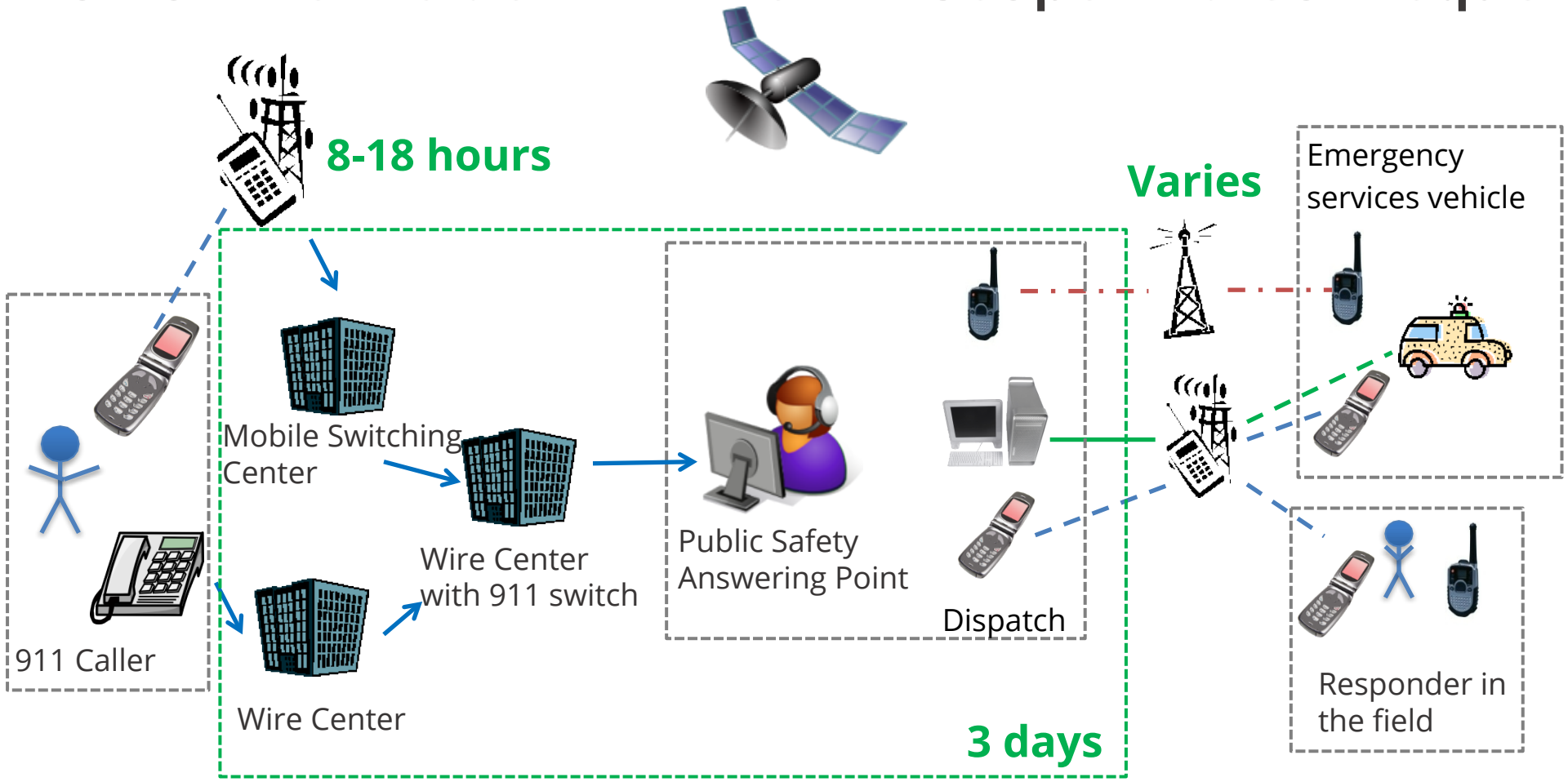
Dependencies and interdependencies can result in
- Unexpected consequences
- Cascading failures and impacts

History is increasingly full of long-tail events

Sandy 10 days post-landfall

Northeast blackout image courtesy of NOAA

Duration of the Incident Matters – Scope and Consequence



VoIP and cordless landline phones go out with power outage
Cell phones last for duration of charge and towers for 8-18 hours (battery or generator)
Landline phones last for duration of power at wire center usually 3 days on backup
Backup generators will need fuel which depends on transportation and the refined products supply chain

Examples of Data Challenges

Even the best data is necessary but not sufficient for model building

- Location can be inaccurate
- Connectivity and capacities are typically missing

Facilities are not always easy to recognize even from imagery

Dependencies are challenging to determine

Assume the infrastructure works and use subject matter expertise to ground assumptions

Lessons Learned

The system must be defined in relation to the incident and question being addressed

- Infrastructure are designed to deliver a good or service
- Questions relate to the ability to provide that in a damaged or disrupted state
- Evolve to mitigations, restoration timelines

Even the best data will be incomplete and inaccurate

For interdependencies details matter and are challenging to obtain

Length of time (incident/disruption/process) can change the dependencies and processes that need to be taken into account in the model

Building a Sustainable Program

Capability development to support decision makers' analytic needs

- Spectrum of analyses drives capability development
- Planned analyses
- Ad-hoc, rapid response analyses
- Exercise planning and support

Analyses drive capability development and vice versa

Challenges or What's Next?

Answers are expected to be provided

- Faster
- With more fidelity
- To a broader audience
  - Who in turn expect a series of area specific answers
- At lower cost

Being proactive

- Understanding and helping decision makers anticipate the evolution of infrastructure and options to increase resiliency before the fact (as opposed to addressing vulnerabilities identified afterward)

Infrastructures and their supply chains are global

- Understanding impacts of international incidents on national infrastructure

Summary

Infrastructures are complex systems with a variety of modeling challenges

- Data availability and quality
- Quantifying model bias and parameter uncertainty
- Huge numbers of runs required for multivariate testing

Capabilities and analyses span a range of infrastructures and hazards

Developed capabilities are used to support analytic efforts

Analyses drive additional capability development direction

- More detailed
- Faster
- Simplified (non-subject matter expert)