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Critical Infrastructure Simulation & Analysis

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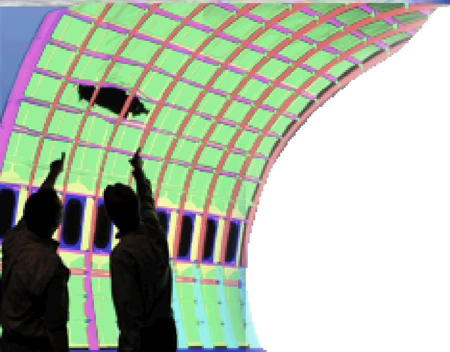

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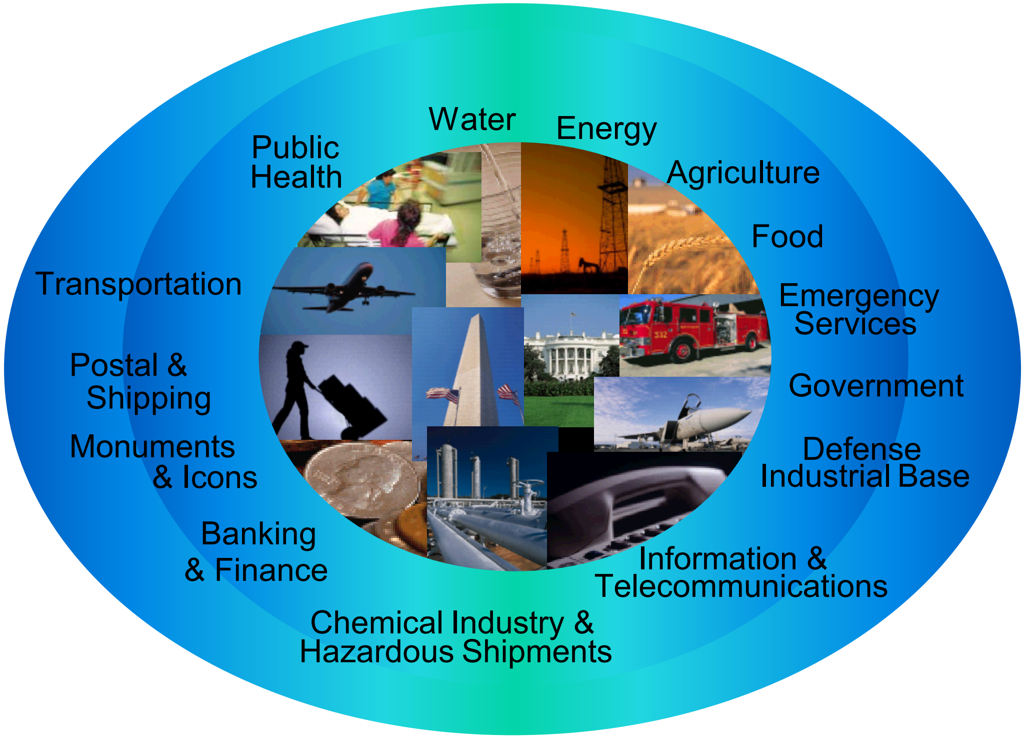
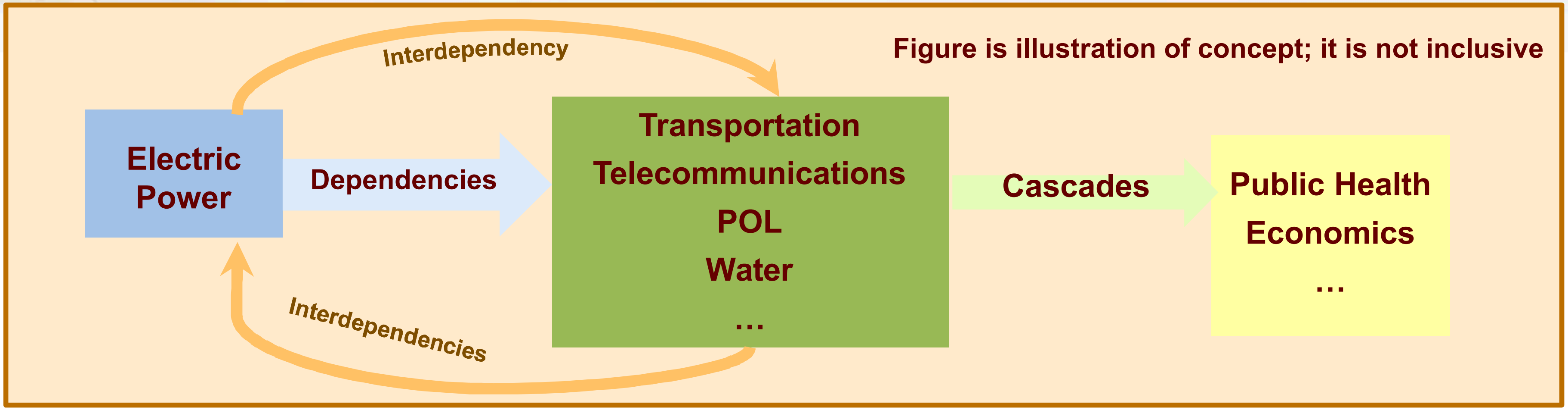
Goal of Infrastructure Simulation and Analysis

Provide fundamentally new modeling and simulation capabilities for the analysis of critical infrastructures, their interdependencies, vulnerabilities, and complexities.

These advanced capabilities improve the robustness of our Nation's critical infrastructures by aiding decision makers in the areas of policy assessment, mitigation planning, education, training, and near real-time assistance to crisis response organizations.



Critical Infrastructures are Massively Interconnected



- **Dependency**: Each infrastructure, while important on its own, is also dependent on other infrastructures to function successfully. Transportation, Telecommunications, Petroleum, Water (and others) require electric power to function.
- **Interdependency**: The dynamic of being mutually dependent upon each other. For example, transportation is dependent upon electric power to pump fuel and electric power is dependent on transportation and petroleum to deliver fuel for power generating plants. Such dynamic feedback loops can exist within a single infrastructure or among multiple infrastructures.
- **Cascade**: A series of infrastructure dependencies in which a stress in one sector or on one element causes disruption in the next. In the example above, loss of electric power causes the loss of wastewater treatment which causes a public health emergency.

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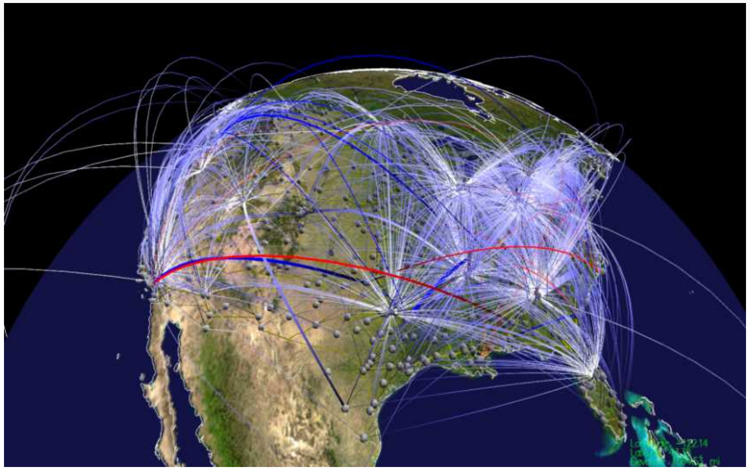
Why We Model

- **The domains in which we work are:**
  - Large
  - Complex
  - Dynamic
  - Adaptive
  - Nonlinear
  - Behavioral



Agent based supply chain disruption model

- **Too complex for mental models to be effective decision tools**
- **Identify when/where things break, and any cascading effects**
- **Quantifying 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 rational choice is to…**

  Experiment with models, *not* the system

  Gain expert operational insight through modeling

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What We Want to Know About Critical Infrastructures

- **Are certain systems, networks, parts of the country more at risk than others? Why?**
- **Have interdependencies increased the risks or have they changed them?**
  - What conditions have to exist to cause cascading failures?
  - What size of event has to occur to initiate cascading failures?
- **Are there trends in the evolution of the infrastructures toward more vulnerable conditions or configurations?**
- **Are we repeating any mistakes from the past or have we really learned from them?**
- **How do the risks to infrastructures impact national security?**
- **How can we reduce the risks to infrastructures?**
  - Can we afford to reduce those risks?
  - Over what timeframe?

There are different decision and analysis lifecycles

Consequence Effects Management

Intentional
- Terrorist (IED, CBRN)
- Significant decision rollout

Accidental

Natural
- Hurricane
- Earthquake
- Flooding …

Pre-event Planning

Crisis or Action Management

System Restoration/Recovery/Evolution

Interdependencies

Event Impacts on
Missions
Functions
Infrastructures
Assets
Population
Economy
Resources/Environment

Planning — **Event/Response** — **Recovery/Improvements**

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Range of Capabilities Are Necessary

Realistic → Abstract

Decreasing detail, computation and development time

Data on system elements	High-fidelity models - individual infrastructure elements	Systems models of aggregate supply - demand dynamics	Generic, highly abstracted network models
Only know what is measured or monitored - limited to specific set of conditions **For existing systems only**	Detailed simulation of changes in conditions or behaviors **For complex systems and detailed phenomenology**	Effects of conditions and limitations on system operation **For trade-studies and planned systems**	Simulation and identification of vulnerabilities of different network topologies to disruptions **For quick-turnaround answers**

Program Capabilities

- Interdependencies and System Modeling
  - The interdependencies and system modeling capability provides the foundation for all products including asset prioritization, earthquake planning scenario, and other impact analyses.
- Economic and Human Consequences
  - A mixture of proprietary commercial software and in-house modeling and simulation capability to provide first-in-class estimates of population and economic impacts.
- Asset and Facility Operations Modeling
  - Infrastructure operators interact with infrastructure systems by making decisions based on constraints and opportunities. Modeling these interactions allows prediction of likely infrastructure operator responses to external events and the possible infrastructure impacts caused by those decisions.
- Fast Integrated Hazards Analysis / Integrating Architecture
  - A common integrated simulation environment to provide consistent consequence estimates across event analyses and to expand event scenarios to multiple cascading events. The National Infrastructure Simulations and Analysis Center (NISAC) Integrating architecture uses a common integrated simulation environment to provide consistent consequence estimates across event analyses and to expand event scenarios to multiple cascading events.

Capturing Complex Interdependencies

National Infrastructure Simulation & Analysis Center (NISAC) Mission

- **Improve the understanding, preparation, and mitigation of the consequences of infrastructure disruption.**

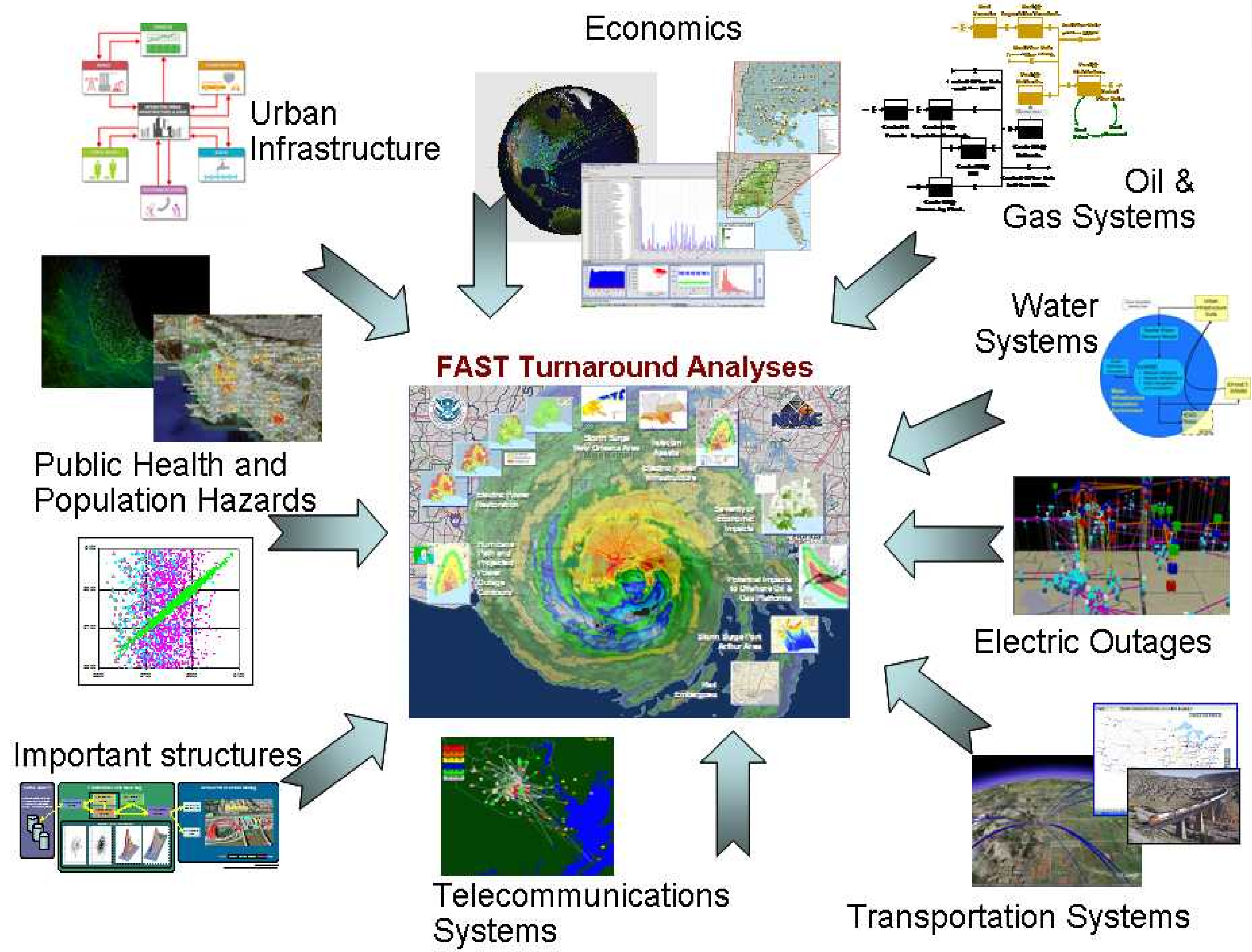
- **Provide a common, comprehensive view of U.S. infrastructure and its response to disruptions.**
  - Scale & resolution appropriate to the issues
  - All threats

- **Built an operations-tested DHS capability to respond quickly to urgent infrastructure protection issues.**
  - 24/7 when needed

- **Use the unequalled and extensive reachback capabilities of Sandia and Los Alamos National Laboratories as premier United States National Security Laboratories**

NISAC provides comprehensive, quantitative analyses of the nation's infrastructures and their interdependencies against all threats (e.g., natural, accidental and malevolent) in support of homeland security concerns for DHS

Integration of Multidisciplinary Skill Sets & Expertise



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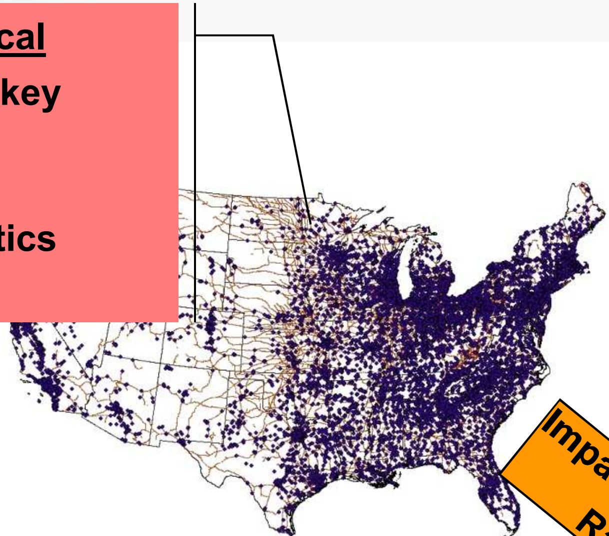
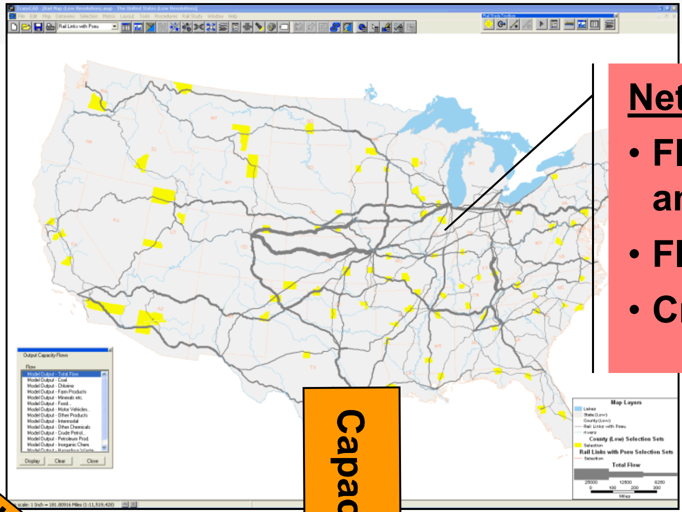
Multiple Viewpoints Are Used to Understand Critical Infrastructures

Spatial/Physical
- Location of key assets
- Asset Characteristics
- Co-location

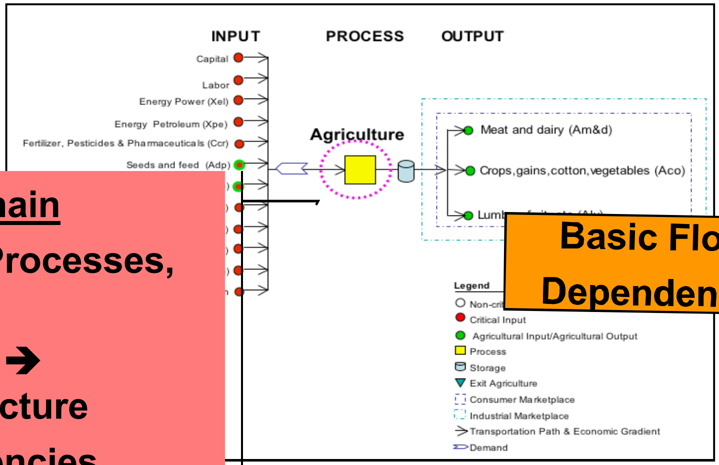




Network
- Flow of resources and goods
- Flow Capacity
- Critical Nodes

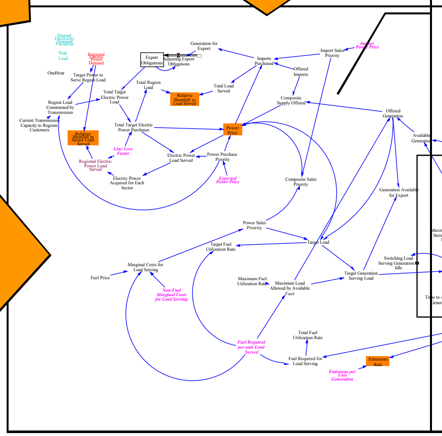
Impacted Assets Ratios

Capacities



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

Basic Flows Dependencies



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

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Modeling and Analysis of Infrastructure Dependencies

- Purpose of the analysis will determine modeling needs/fit
  - Time frame of concern
  - Capacity to absorb/respond/adapt/restore/recover = Resilience
  - Risk management (threat management (security; consequence management (design for n-1 failures; design for resilience to specified threats; plan for restoration/recovery); risk mitigation)
- Experiment on models
- Engineer solutions for complex adaptive systems and dynamic conditions
- Improve understanding of risks and solutions to aid decision making
- Cyber/physical domain work