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# Infrastructure Modeling at SNL

A multi-scale, multiplex approach

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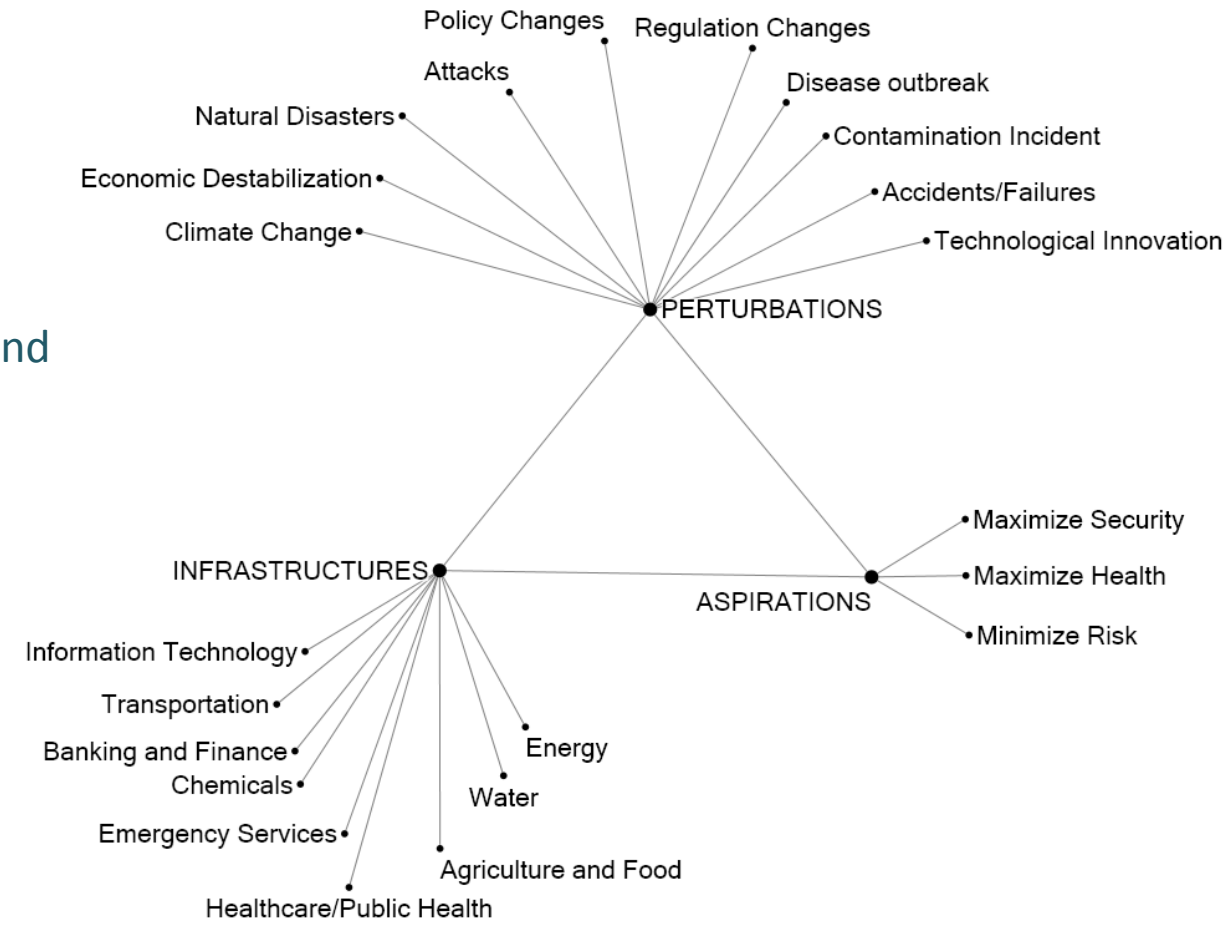
# The Infrastructure Space

# Overarching Goal:
# Understand Risks and Engineer Solutions

Requires Multi –Scale and Multi-Network/System Modeling and Analysis

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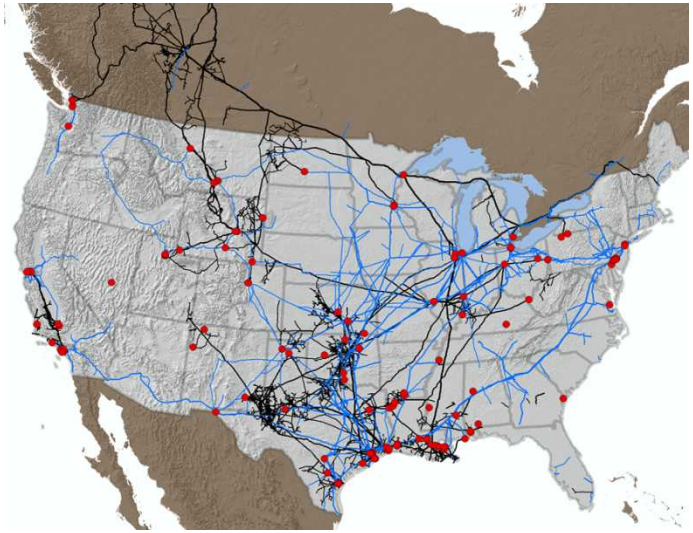
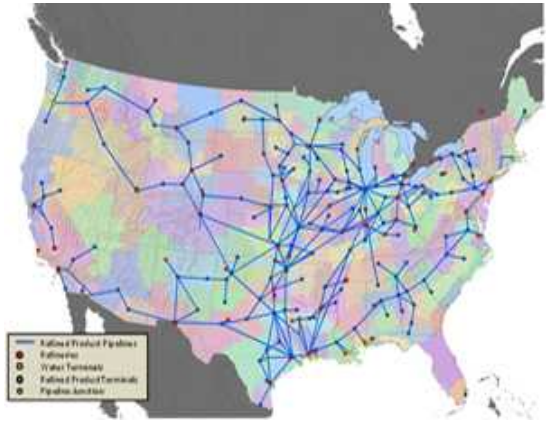
# Energy – Petroleum Fuels: Networks

- Goals:
  - understanding risks of specific incidents (hurricanes, earthquakes, equipment failures)
  - identifying effective risk mitigations
- Approach:
  - incident and scenario-based analyses
  - national network model
- Developed for the National Infrastructure Simulation and Analysis Center (NISAC) (http://www.sandia.gov/nisac/)





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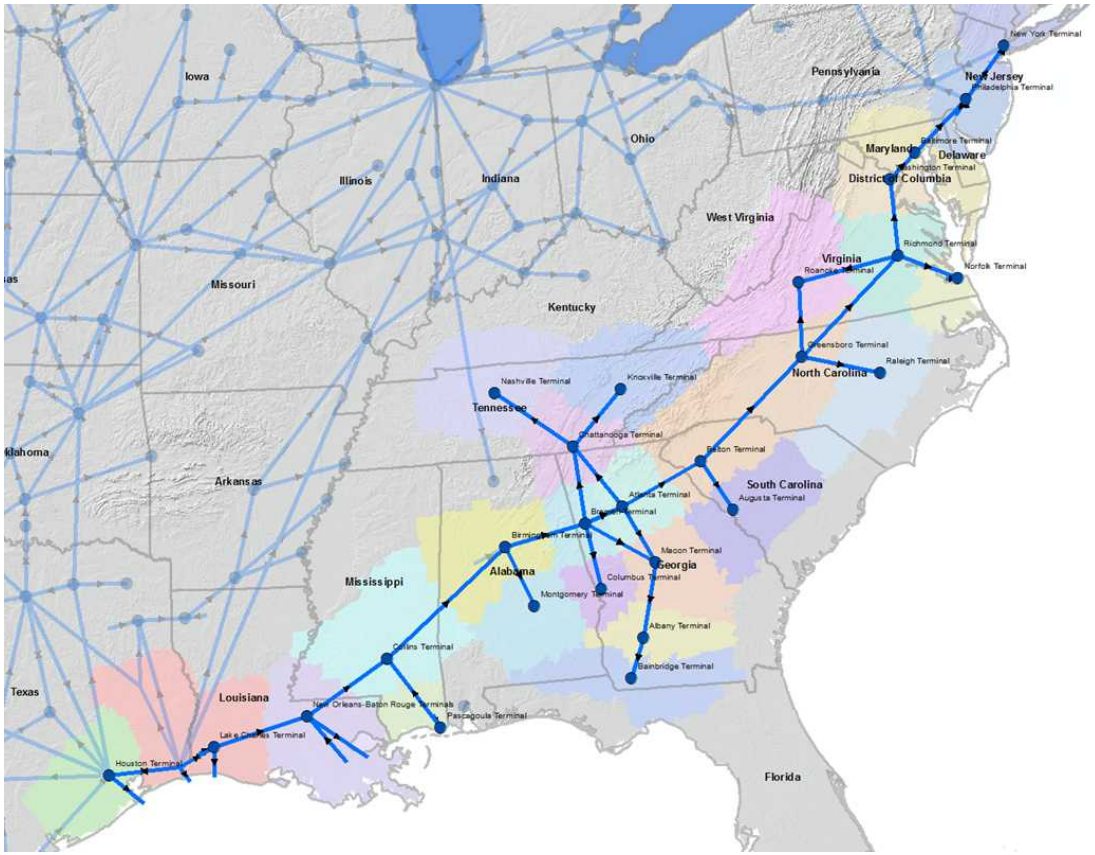
# NISAC National Transportation Fuel Model

- The functionality of any asset (e.g. pipeline segment, refinery, terminal) can be degraded for any period of time to simulate specific disruptions.
- Each node in the network (e.g., refinery, tank farm, terminal) strives both to meet the demands of consumers and to maintain sufficient stocks of crude or refined products.
- Crude oil or refined products flow toward regions that are experiencing shortages by a diffusion-type process in which knowledge of the shortage propagates throughout the network over time.




Demand is aggregated at the fuel-terminal service area

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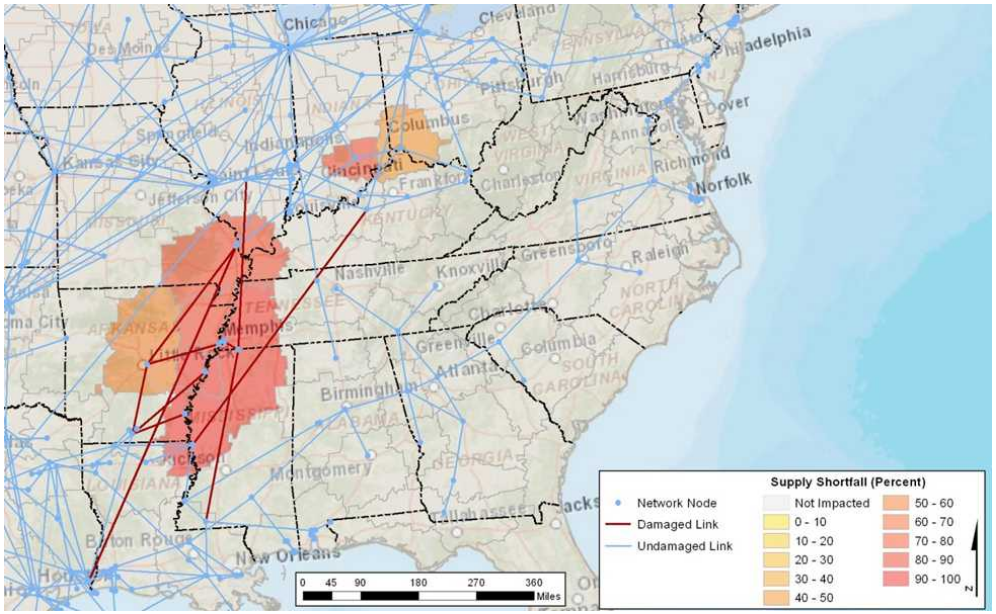
# Example Scenario: Central U.S. Earthquake

- The New Madrid Seismic Zone (NMSZ) stretches along the Mississippi River Valley from southern Illinois to Memphis
- A cluster of very powerful earthquakes occurred during the winter of 1811–1812.
- The U.S. Geological Survey estimates a 7 to10 percent chance of earthquakes with magnitudes equivalent to the 1811–1812 quakes occurring in any 50-year period *
- A similar cluster of earthquakes occurring today would cause extensive damage to oil and gas transmission pipelines




*(USGS, Center for Earthquake Research and Information Fact Sheet 2006-3125).

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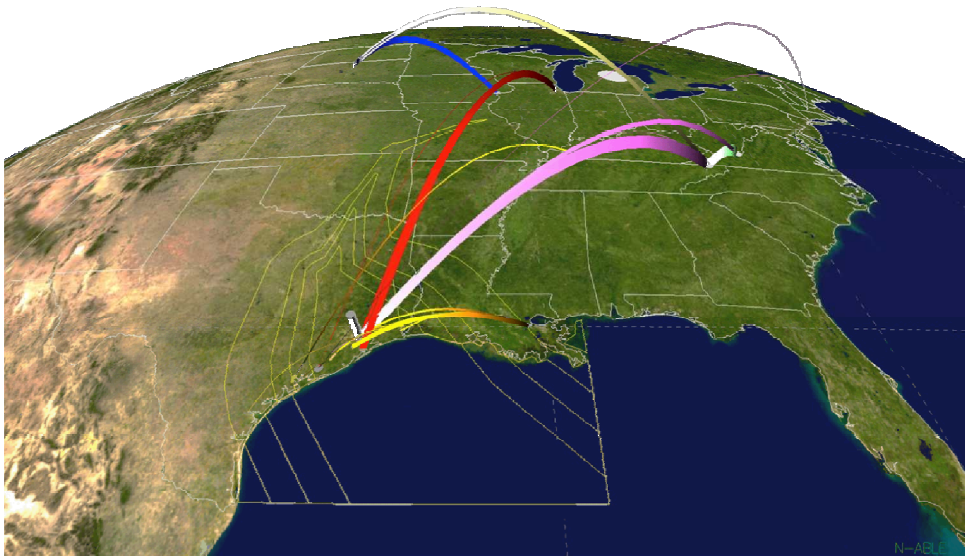
# Global Chemical Supply Networks

- Goals:
  - understanding risks of specific incidents (hurricanes, earthquakes, equipment failures)
  - quantify resilience
  - identify critical chemicals/processes
- Approach:
  - incident and scenario-based analyses
  - entity-based network model (Exchange)
  - agent-based economic model (NABLE)
- Developed for the National Infrastructure Simulation and Analysis Center (NISAC) (http://www.sandia.gov/nisac/)



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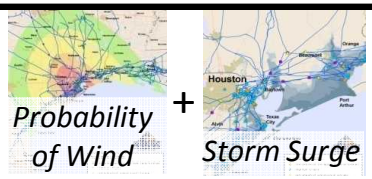
# Chemical Supply Networks (with interdependencies)

Example – Hurricane Impacts on Petrochemical Supplies

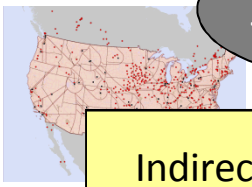



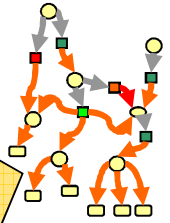

Disrupted Refineries

Disrupted Petrochemical Plants

Disrupted NG Compressors/Stations

Service Territories





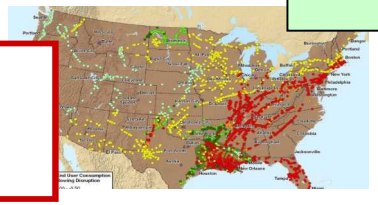
Gas Network Model

Indirectly Disrupted Petrochemical Plants

Petrochemical Network Model

Indirectly Disrupted Petrochemical Plants

Petrochemical Shortfalls



For more information see the following websites:
http://www.sandia.gov/CasosEngineering
http://www.sandia.gov/nisac/chemical.html

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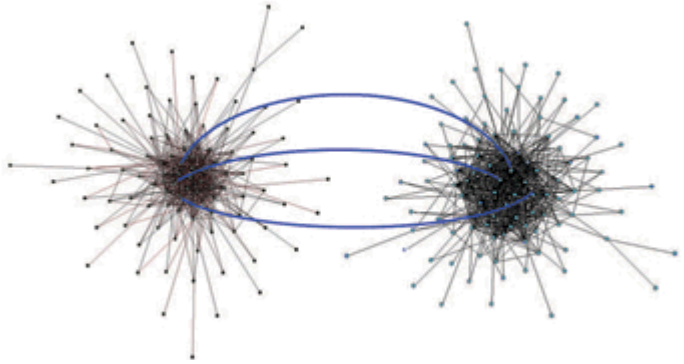
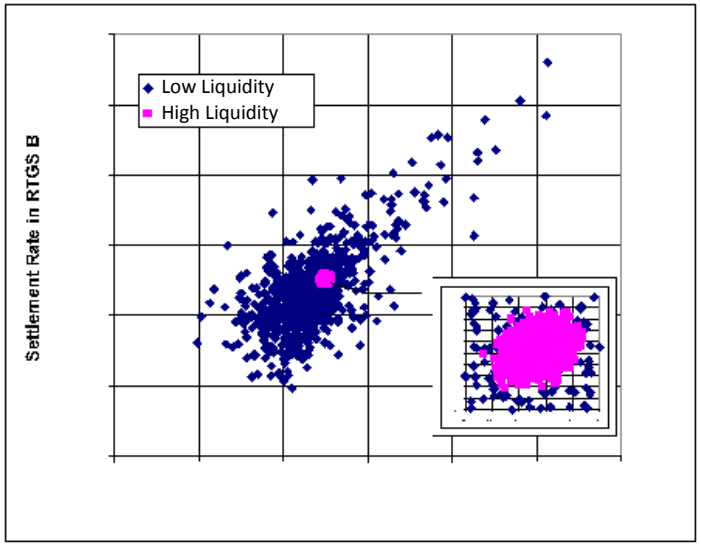
# Global Financial: Transaction Networks

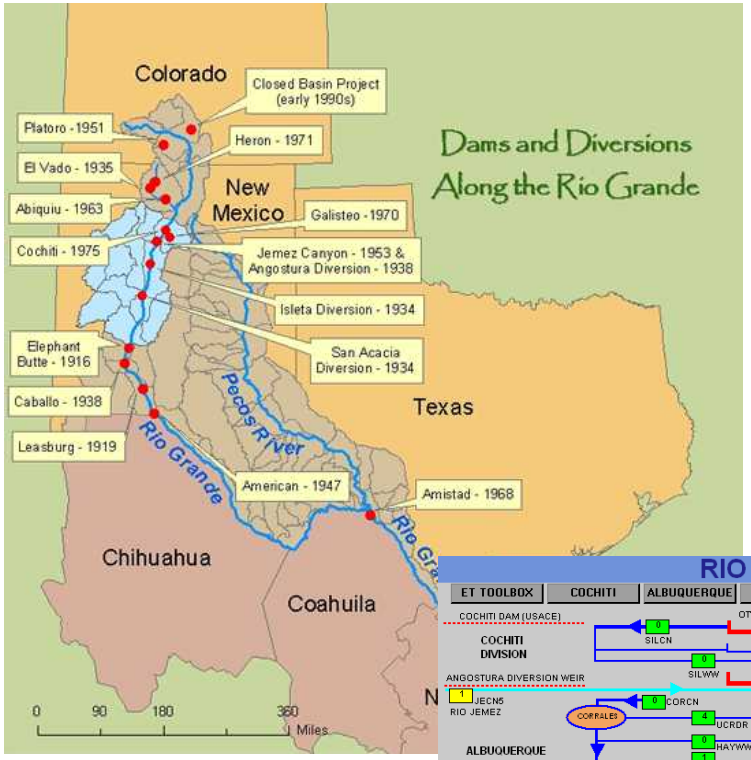
- Goals:
  - understanding risks to monetary systems
  - identify effective risk mitigation strategies
- Approach:
  - entity-based network model
- Developed for the National Infrastructure Simulation and Analysis Center (NISAC) (http://www.sandia.gov/nisac/)
- For publications see: (http://www.sandia.gov/CasosEngineering/payment_systems.html )

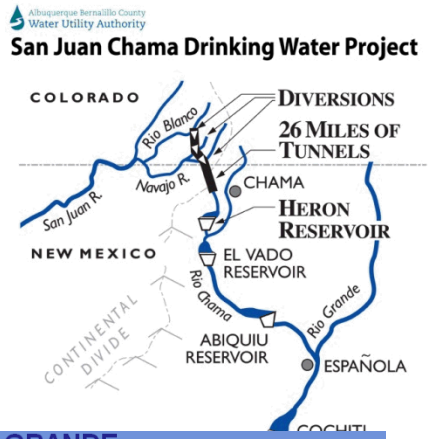


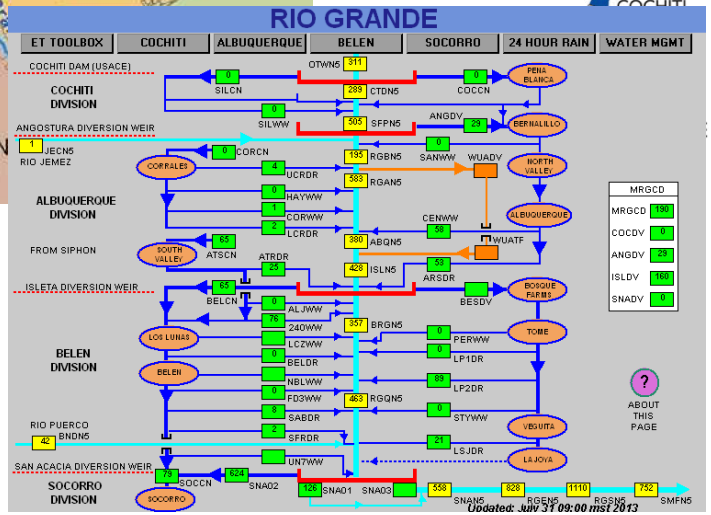


# Water Supply: Dynamic Systems, Networks

- Goal:
  - Understanding water supply and allocation risks
- Approach:
  - incident and scenario-based analyses
  - Watershed system dynamics model
- Multiple funding sources
  - Group model building
  - Workshops

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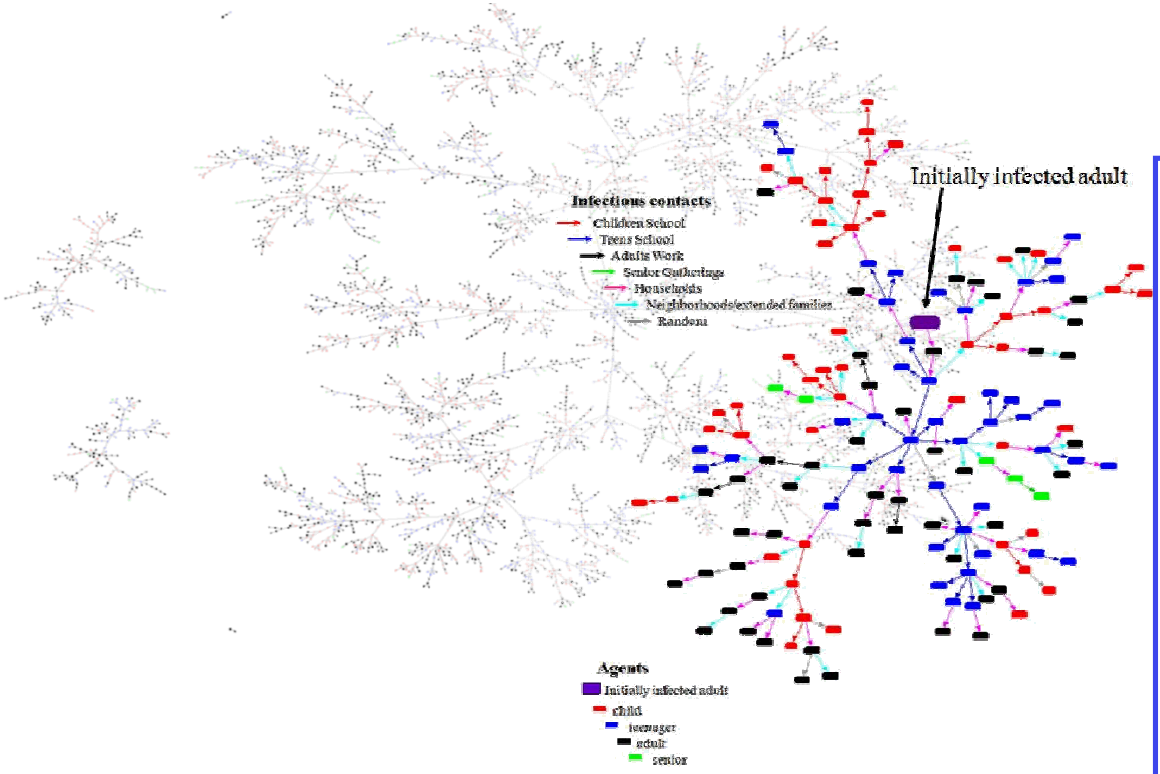
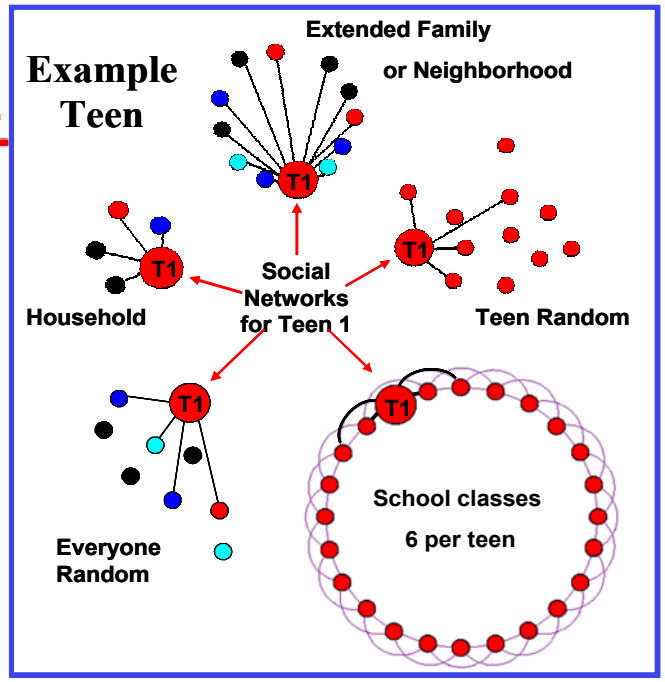
# Healthcare/Public Health: Individual-Based, Multinetwork

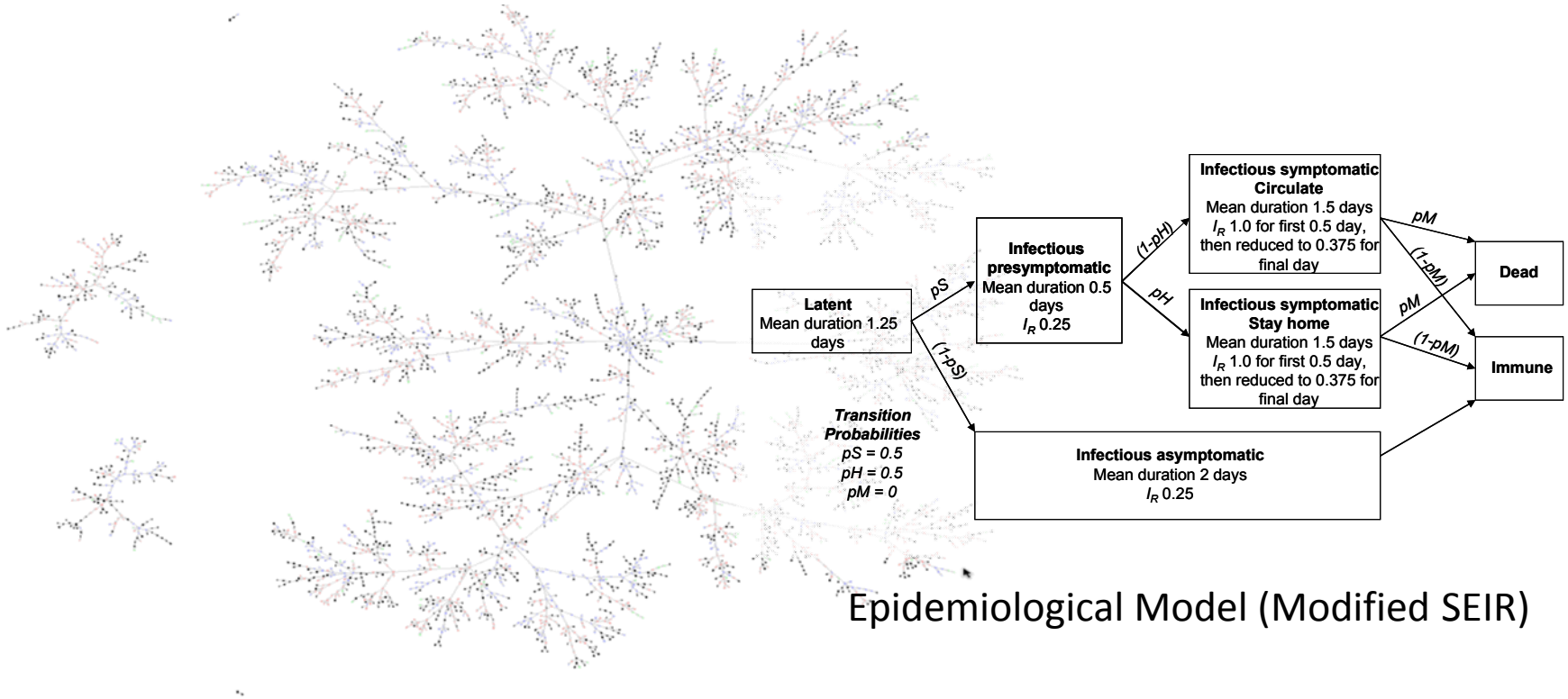



Multiple Social - Networks

Representative Population Contact Network

# Example Application of CASoS Engineering: Pandemic Planning




Epidemiological Model (Modified SEIR)

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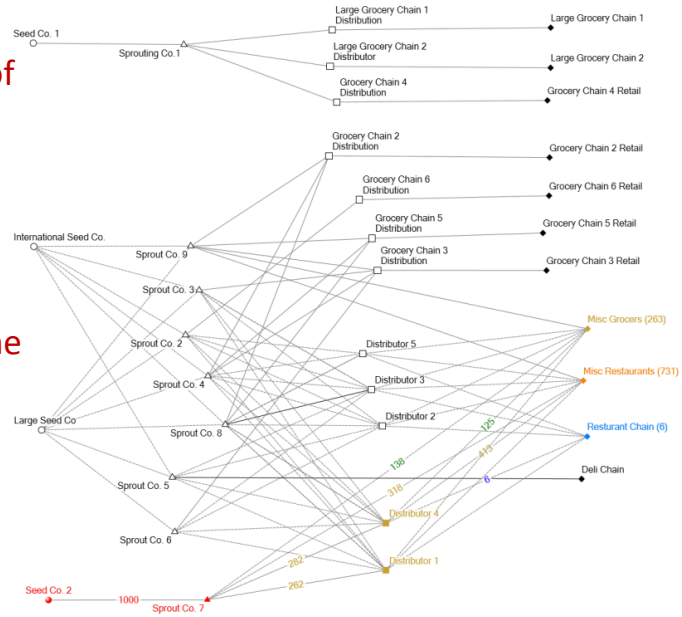
# Agriculture and Food: Stochastic Supply Networks

- Goals:
  - Improve understanding of vulnerabilities
  - Improve contaminant tracing (forward and backward) to reduce population health risks
  - Model animal disease spread
  - Evaluate risk mitigation strategies
- Approach:
  - Risk-based analysis
  - Exchange network models to represent supply chain dynamics and interactions
  - System dynamics models of interdependencies
  - Individual-based network models of disease spread
  - Stochastic mapping of conditional probabilities

Forward tracing of contamination produces the conditional probability contamination downstream in the supply chain for a specific contamination event




Backward tracing of contamination produces the conditional probability contamination exists at a sprout company if detected at a retail location

| | Sprout Co 1 | Sprout Co 7 | Sprout Co 2 | Sprout Co 4 | Sprout Co 10 | Sprout Co 8 |
|---|---|---|---|---|---|---|
| Large Grocery Chain 1 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Deli Chain | 0.00 | 0.18 | 0.27 | 0.18 | 0.09 | 0.09 |
| Sprout Co. 7 Customers | 0.00 | 1.00 | 0.00 | 0.00 | 0.20 | 0.00 |
| Grocery Chain 2 Retail | 0.00 | 0.07 | 0.13 | 0.40 | 0.53 | 0.20 |
| Misc. Grocers | 0.00 | 0.24 | 0.39 | 0.15 | 0.22 | 0.10 |
| Misc. Restaurants | 0.00 | 0.24 | 0.38 | 0.14 | 0.24 | 0.10 |
| Grocery Chain 3 Retail | 0.00 | 0.00 | 0.25 | 0.38 | 0.50 | 0.05 |
| Large Grocery Chain 2 | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Restaurant Chain | 0.00 | 0.24 | 0.38 | 0.14 | 0.24 | 0.10 |
| Grocery Chain 4 Retail | 1.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| Distributor 5 Customers | 0.00 | 0.11 | 0.11 | 0.11 | 1.00 | 0.00 |
| Grocery Chain 6 Retail | 0.00 | 0.00 | 1.00 | 0.00 | 0.06 | 0.13 |
| Grocery Chain 5 Retail | 0.00 | 0.00 | 0.13 | 0.40 | 0.53 | 0.20 |
| Unconditional Probability | 0.16 | 0.29 | 0.32 | 0.12 | 0.20 | 0.08 |

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