Advanced Modeling Techniques Investigation

The National Infrastructure Simulation and Analysis Center (NISAC), a program under the Department of Homeland Security's (DHS) Infrastructure Protection/ Risk Management Division (IP/RMD), provides advanced modeling and simulation capabilities for the analysis of critical infrastructures, their interdependencies, vulnerabilities, and complexities. These capabilities help improve the robustness of our nation's critical infrastructures by aiding decision makers in the areas of policy analysis, investment and mitigation planning, education and training, and near real-time assistance to crisis response organizations.

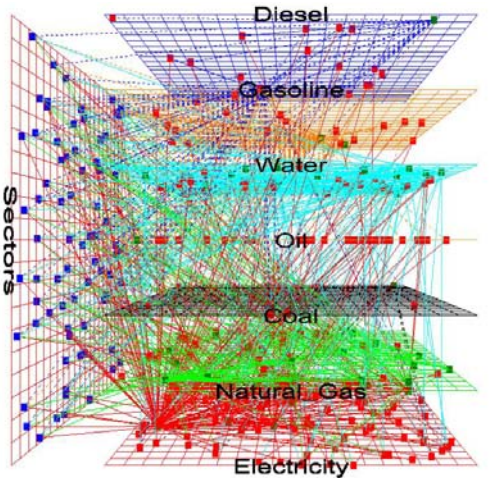
NISAC is a partnership between Sandia National Laboratories (SNL) and Los Alamos National Laboratory (LANL), integrating the two laboratories' expertise in infrastructure disruption/vulnerability modeling and simulation.

Advanced Modeling & Techniques Investigation (AMTI)

The AMTI effort is a long-term investment in understanding critical infrastructures and their interdependencies. Our purpose is to identify and develop theories, methods, and analytical tools that are useful for understanding the structure, function, and evolution of complex interdependent critical infrastructures.

Critical Infrastructures are formed by a large number of components that interact within complex networks. As a rule, infrastructures contain strong feedbacks either explicitly through the action of hardware/software control, or implicitly through the action/reaction of people. Individual infrastructures influence others and grow, adapt, and thus evolve in response to their multifaceted physical, economic, cultural, and political environments.

Simply put, critical infrastructures are complex adaptive systems or "CAS".

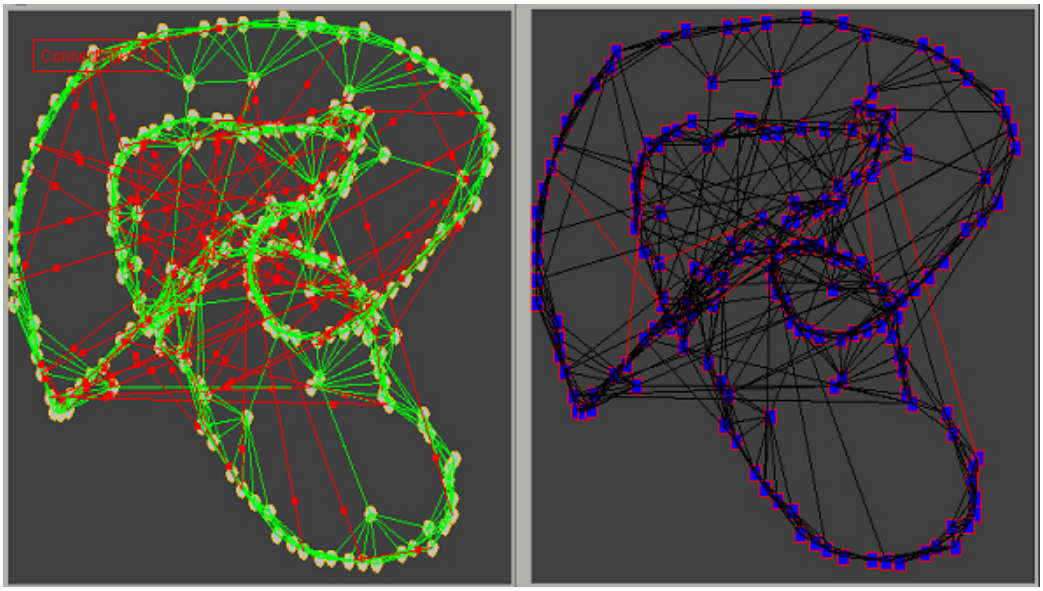


The complexity of the interdependent and ever changing systems that comprise critical infrastructures makes understanding and modeling them difficult. Fortunately, there has been a great deal of basic research over the past few years focused on understanding complex adaptive systems and developing theories to explain how they behave under stress. This fundamental research has begun to explain the evolution of generic complex network structures, and to identify their vulnerabilities and strengths.

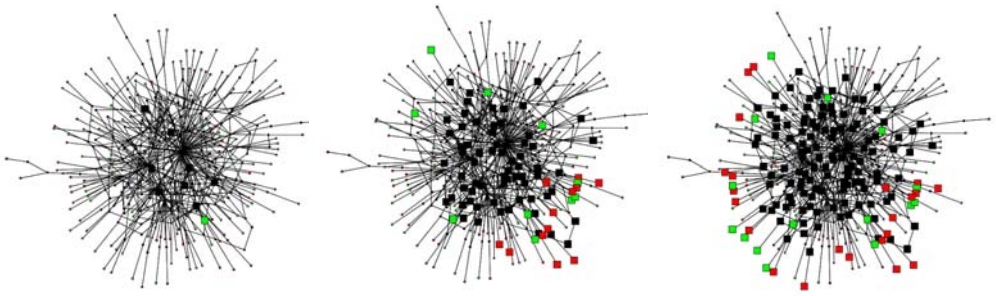
Future Critical Infrastructure Protection development must apply and extend the results of complexity theory to model adaptive interdependent infrastructures. Such efforts will allow us to better understand how general features, such as network connectivity and operational pressures, influence system robustness, determine operating margins, and control system behavior and evolution. This perspective may also disclose strategies to make critical infrastructures more robust by strengthening a given set of components, or through the formulation of appropriate long range policy whereby an infrastructure or set of infrastructures evolves robustness over time.

Examples: Cascading failure

The susceptibility to cascading failure can result from the structure and operation of a single infrastructure network, but also from the interdependencies among infrastructures that create additional pathways for propagating disturbance, along with feedback and control.



Above, an abstract simulation of interacting stylized networks is shown. The network on the left depicts "physical" influences among nodes, such as those created by power transmission lines or transportation systems. The network on the right depicts an associated information exchange network. The topology of the latter follows the physical network in this simulation, but also adds additional information links (shown in red) representing social connections or other paths of information exchange. Over time, the physical network nodes add and remove links in order to reduce their exposure to unstable nodes. Their perception of instability is provided by the links in the information network. In another example simulation below, we show the development of a major outage from the failure of a single transmission station in a stylized, abstract, high voltage power transmission grid.



Network topology: scale-free

Small symbols are functional, enlarged symbols are nodes that have failed

Red: Generators
Green: Consumers
Black: Transmission stations:

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