Complex Adaptive Systems of Systems (CASoS) Engineering

Complex Adaptive Systems of Systems (CASoS) are vastly complex physical-socio-technical systems which we must understand to design a secure future for the nation.

CASoS include people, organizations, cities, infrastructure, government and ecosystems. Many of humanity's largest problems such as Global Climate Change and Conflict End Games involve CASoS.

While the problems are disparate, the theories, technologies, tools, and approaches to enable effective engineering efforts focused on the solution of CASoS problems are consistent.

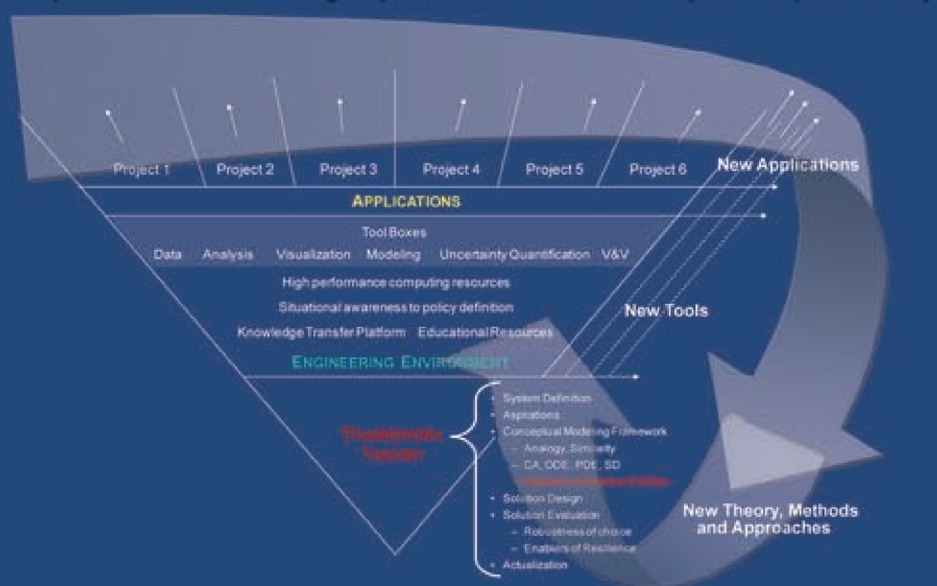
CASoS Engineering Aspirations:

Predict	**Monitor**
Prevent or Cause	**Prepare**
Recover or Change	**Control**

* A Roadmap for the Complex Adaptive Systems of Systems CASoS) Engineering Initiative, Robert J. Glass, Arlo L. Ames, William A. Stubblefield, Stephen H. Conrad , S. Louise Maffitt, Leonard A. Malczynski, David G. Wilson, Jeffery J. Carlson, George A. Backus, Mark A. Ehlen, Keith B. Vanderveen, and Dennis Engi, Sandia National Laboratories SAND 2008-4651, September 2008

CASoS Engineering Framework

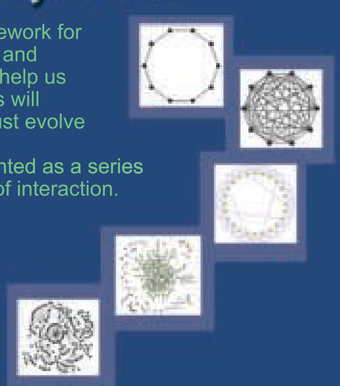
The high level structure of the CASoS Engineering framework has its basis in methodological theory which evolves as it is applied to projects and real-world problems. The Workbench of tools and approaches evolves as projects continue to develop in time through the infusion of new capabilities and understanding. Implementation leads to discovery which improves theory.



* CASoS Engineering Framework and the Process of its Application Version 1.0, Arlo L. Ames, Robert J. Glass, Walter E. Beyeler, Sandia National Laboratories SAND Report, 2010

Infrastructures as Complex Adaptive Systems

Complexity science provides methods and a framework for simulation and analysis of abstract infrastructures and infrastructure interdependencies. These methods help us understand how/why some types of infrastructures will fail and the direction that a given infrastructure must evolve or be 'pushed' to reduce the probability of failure.
An infrastructure is a network that can be represented as a series of nodes, connected to each other by some form of interaction.



Nodes could be:
- Power plants, transformers, power grid users
- Computers and routers on the internet
- Institutions in a financial network
- Transportation hubs (airports)
- Telecommunications hubs
- People in a social network

Characteristics of such networks:
- Connectivity
- Clustering
- Path length (or degrees of separation)

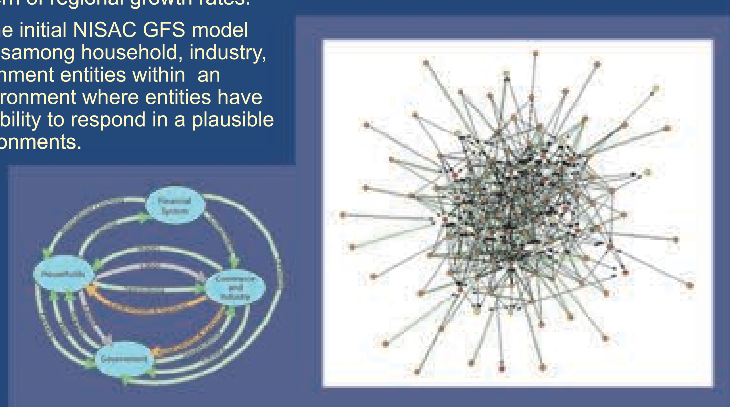
* Defining Research and Development Directions for Modeling and Simulation of Complex, Interdependent Adaptive Infrastructures, Robert J Glass, Walter E Beyeler, Stephen H Conrad, Nancy S Brodsky, Paul G Kaplan, and Theresa J Brown, Sandia National Laboratories, 2003

Global Financial Systems

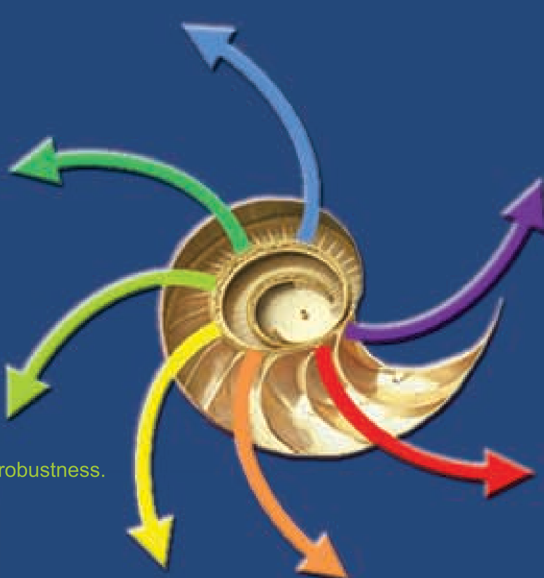
NISAC's focused capability development for the Global Financial System (GFS) integrates knowledge gained from analysis of financial institutions, technologies, and networks conducted over the past four years with advanced systems engineering philosophy and methodology.

NISAC's goal is to elucidate how the large recurrent instabilities in financial systems might arise, how they might be controlled, and how those controls might influence economic growth or shift the pattern of regional growth rates.

A multi-year project, the initial NISAC GFS model represents transactionsamong household, industry, commerce, and government entities within an adaptive decision environment where entities have demonstrated the flexibility to respond in a plausible way to changing environments.



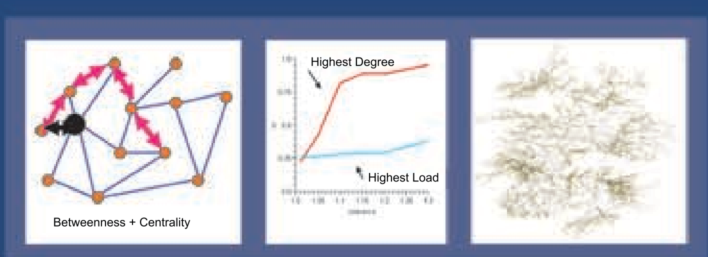
* NISAC Analysis of the Global Financial System (GFS): Definition, Aspirations, Conceptual Model Development and Initial Phase Implementation, Robert J. Glass, Walter E. Beyeler, March 2009



Congestive Failure in Power Grid and Fedwire

NISAC synthesized and extended the large variety of abstract cascade models and applied them to two very different critical infrastructures: the high voltage electric power transmission system and Fedwire.

For the stylized electric power grid, initial simulations demonstrated that the addition of geographically unrestricted random transactions can eventually push a grid to cascading failure, thus supporting the hypothesis that actions of unrestrained power markets (without proper security coordination on market actions) can undermine large scale system stability. Network topology also greatly influences system robustness.



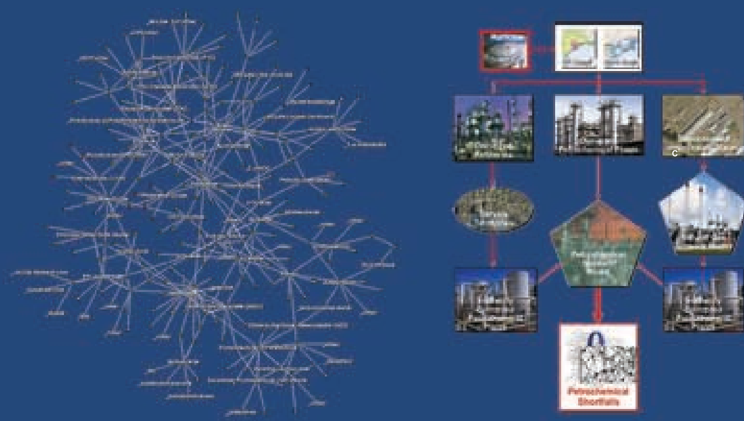
* Advanced Simulation for Analysis of Critical Infrastructure: Abstract Cascades, the Electric power grid, and Fedwire, Robert J. Glass, Walt E. Beyeler, and Kevin L. Stamber, Sandia National Laboratories, 2004

Petrochemical and Natural Gas Networks

The modeling toolkit was configured to analyze the impact of disruptions within the chemical sector and other sectors on petrochemical production and supply.

The natural gas sector was then modeled to determine the impact of changes within the natural gas system on natural gas transportation and supply.

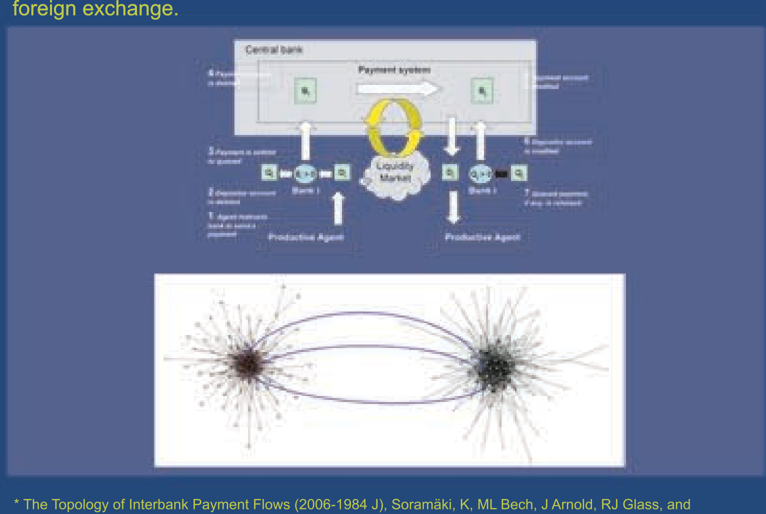
The two models are used in combination to examine condition-dependent behaviors and capacities in the petrochemical supply chain.



* National Infrastructure Simulation and Analysis Center Chemical Industry Project: Capability Report 2008, February 2009

Congestion and Cascades in Payment Systems

For the Banking and Finance infrastructure, the CASoS framework and modeling toolkit were applied first to payment systems, then extended to analyses of liquidity and credit risks in the context of interdependent interbank payment systems and foreign exchange. The work has attracted the interest and collaboration of the Federal Reserve, the European Central Bank, and international researchers. Modeling results have identified unexpected interdependencies arising from foreign exchange.

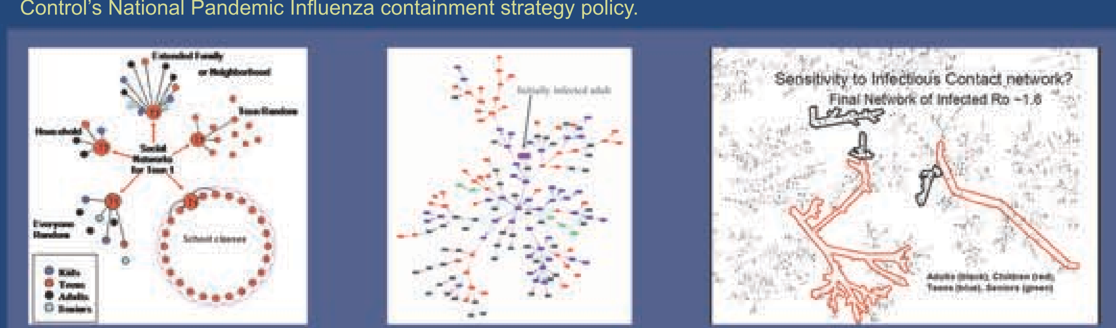


* The Topology of Interbank Payment Flows (2006-1984 J), Soramäki, K, ML Bech, J Arnold, RJ Glass, and WE Beyeler, Federal Reserve Bank of New York Staff Reports, no. 243, March 2006

Pandemic Influenza Containment Strategy

To identify an effective disease containment strategy, NISAC used a networked, agent-based model of a community of explicit, multiply-overlapping social contact networks. Model agents represent individual people who are linked to each other within and among groups to form a contact network reflective of a multiply overlapping, structured community using either fully connected, random, or ring networks for each group.

Eight containment strategy and numerous disease manifestations were analyzed. The strategy identified by NISAC analysts as most effective and robust to changing conditions was subsequently incorporated in the Center for Disease Control's National Pandemic Influenza containment strategy policy.



* Local Mitigation Strategies for Pandemic Influenza, Robert J. Glass, Laura M. Glass, Walter E. Beyeler, Sandia National Laboratories, 2005

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Contact: Robert J. Glass, Senior Scientist
Sandia National Laboratories
rjglass@sandia.gov

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