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Complex Adaptive System of Systems (CASoS) Engineering Initiative
http://www.sandia.gov/CasosEngineering/

Complex Adaptive Systems of Systems (CASoS) Engineering: Mapping Aspirations to Problem Solutions

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Definition of CASoS

Complex

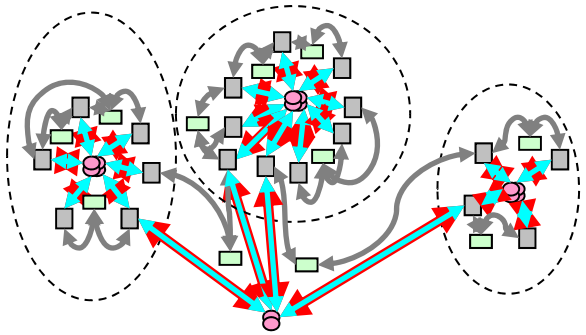
Interactions among elements produce emergent, non-linear behavior

Adaptive

Behavior changes over time due to interactions or conditions

System

A set of interacting entities that together serve a common objective



System of Systems

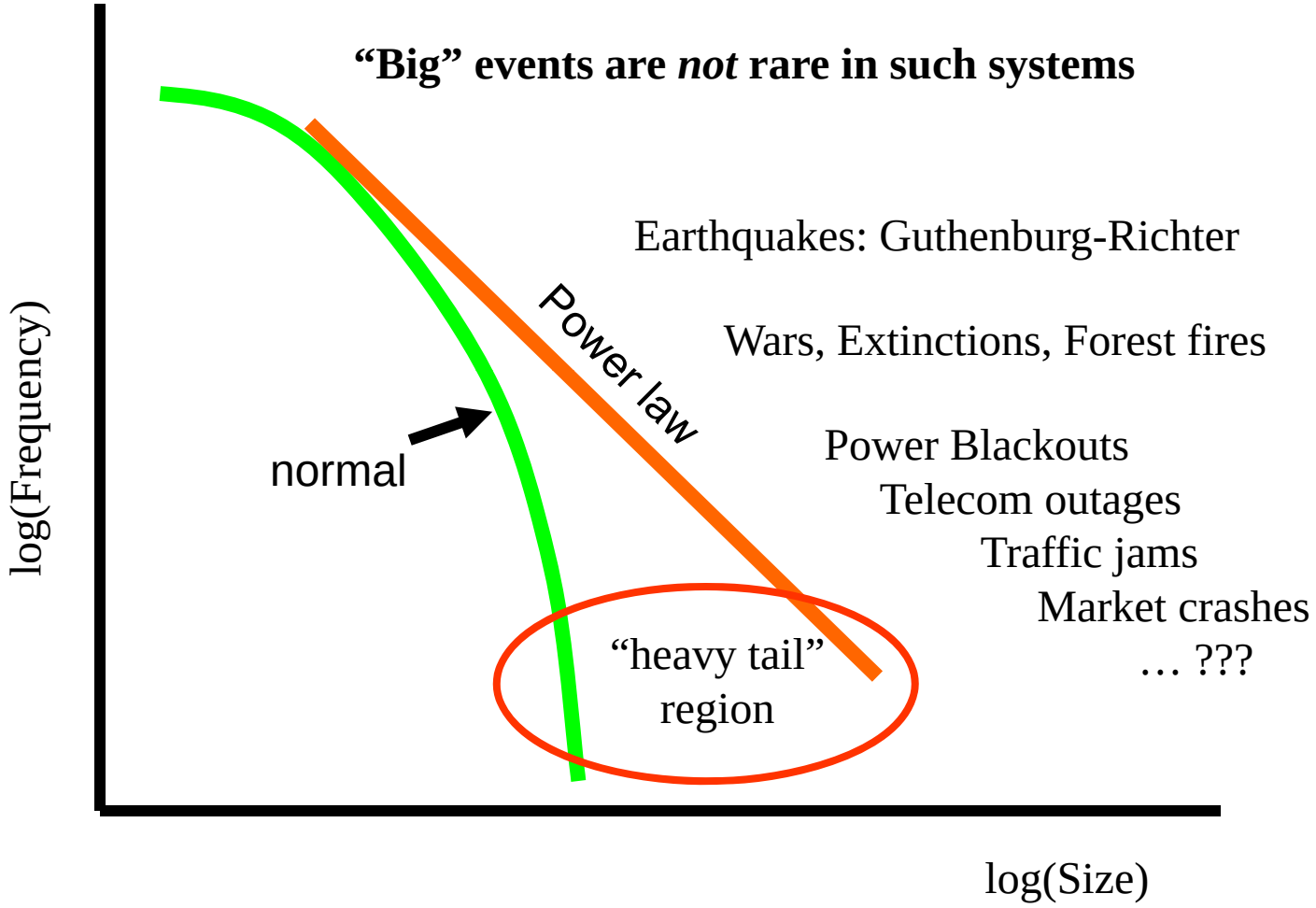
A set of systems whose function cannot be replicated by a single entity

CASoS Engineering Aspirations

From an engineering perspective, *Aspirations* fall into a set of clearly identified categories:

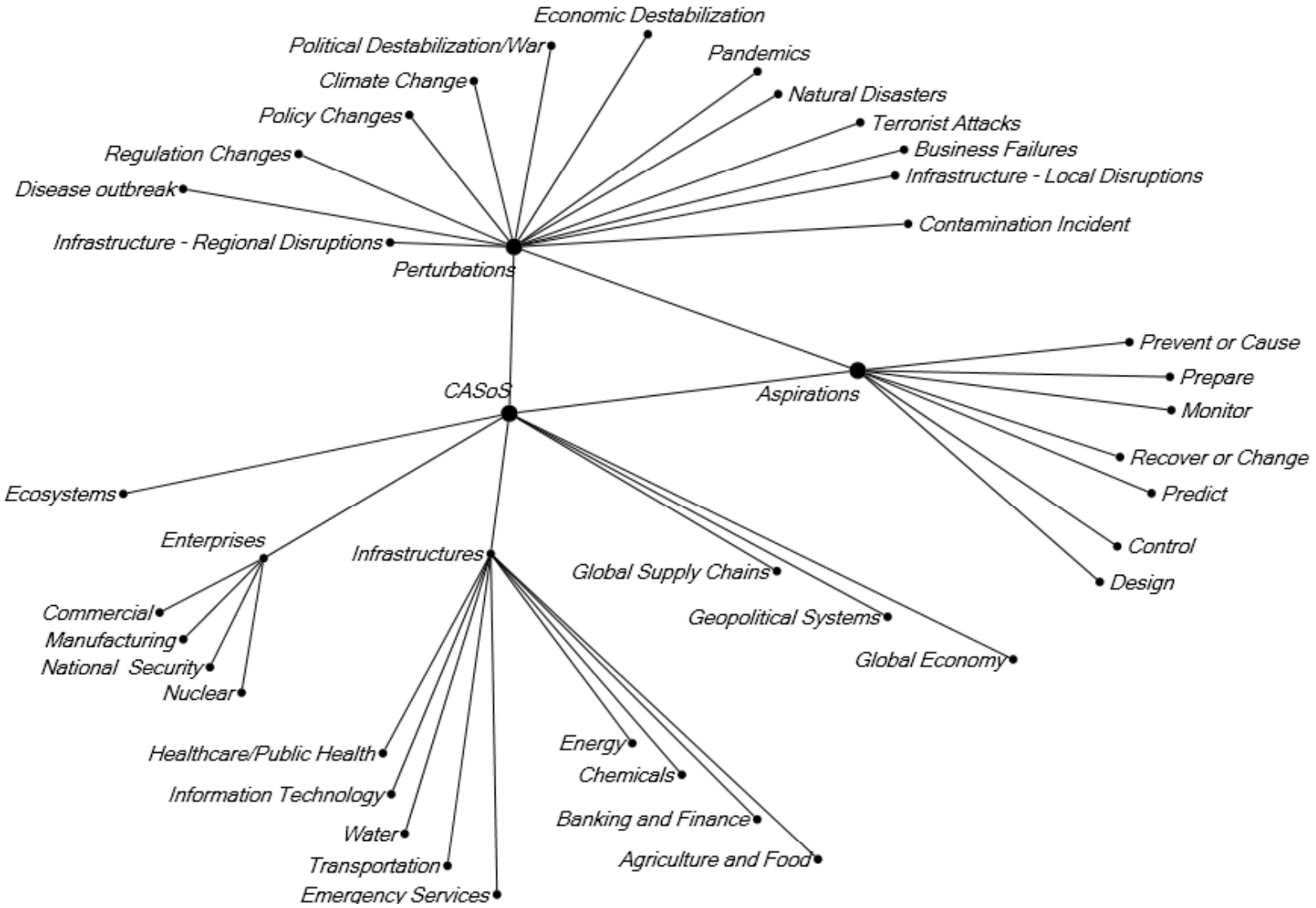
- **Predict** the evolution of the system and, in particular, the results of events (*e.g.,* perturbations of a variety of qualities and quantities) with direct and consequential changes in system health.
- **Prevent or Cause** an event to occur.
- **Prepare** elements of the system for impending events (*e.g.*, minimize/maximize influence).
- **Monitor** important aspects of a system to record the response of the system to events.
- **Recover or Change** in response to events.
- **Control** system behavior to avoid or steer the system towards specified regimes through the design of appropriate incentives and feedback.
- **Design** a CASoS.

EMERGENT BEHAVIOR: Complex

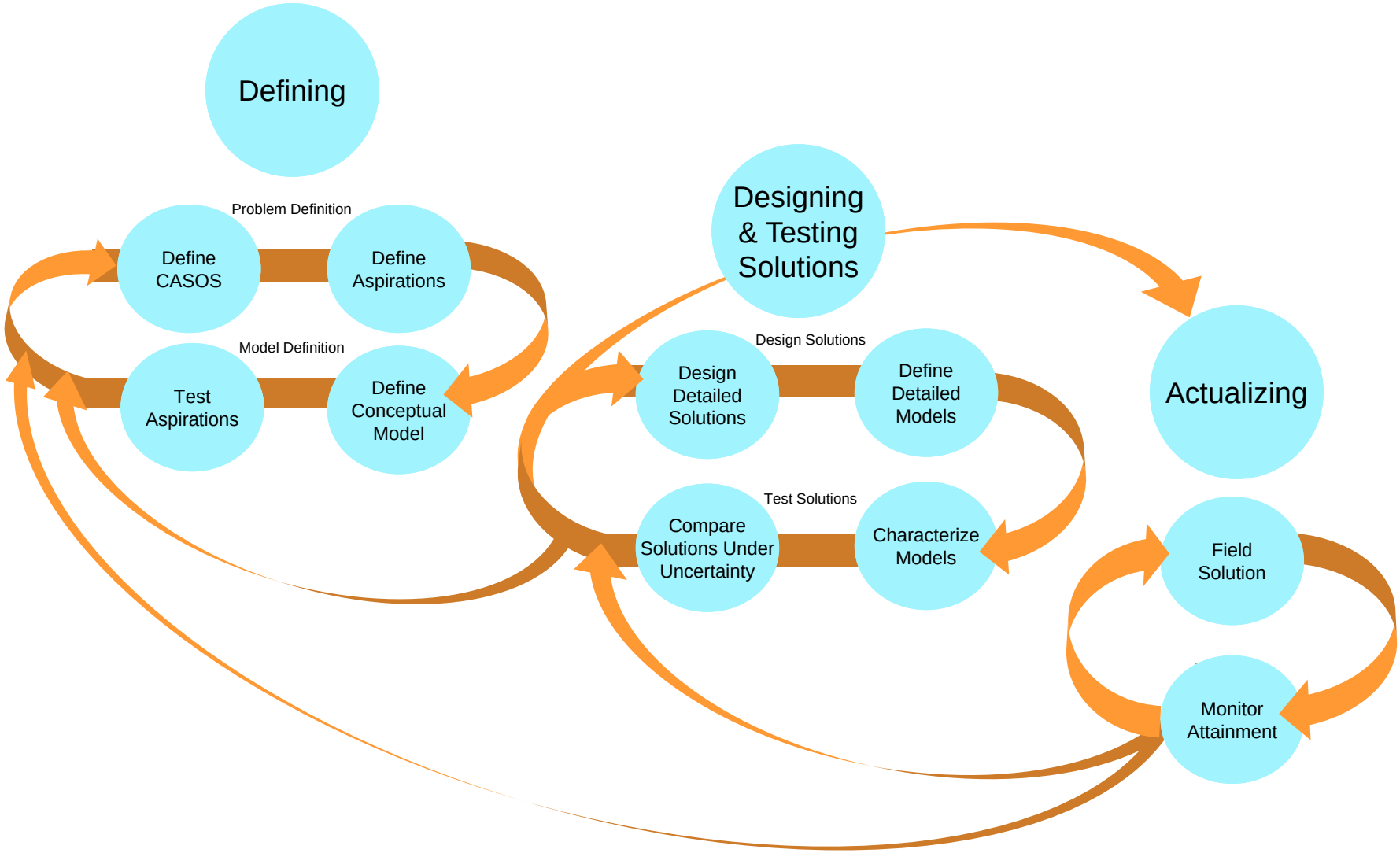


Cascades with power-laws & "heavy tails"

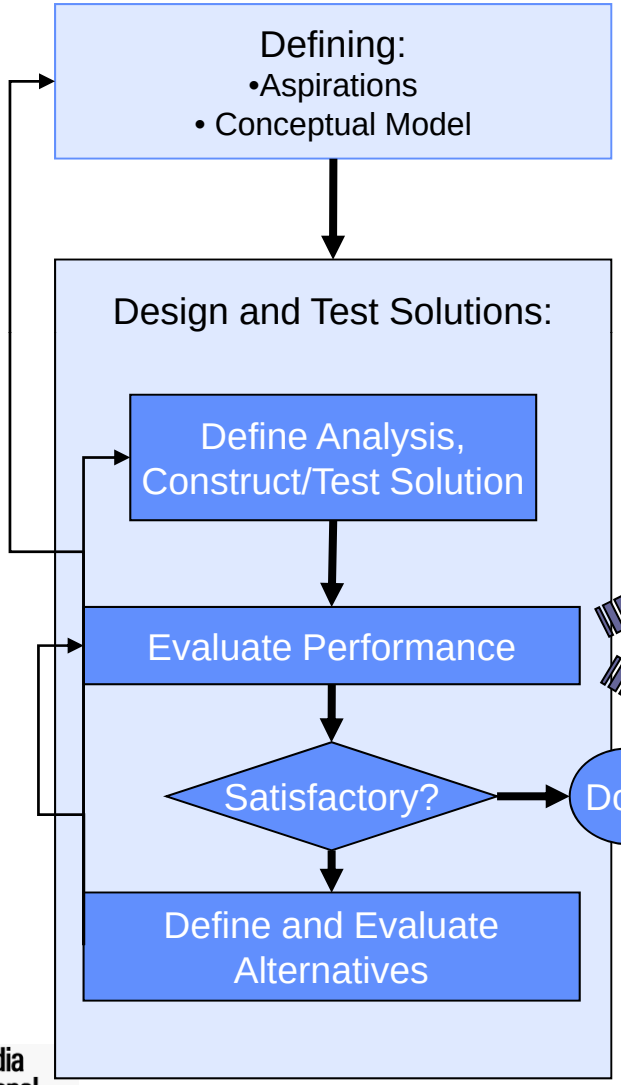
What Problems?



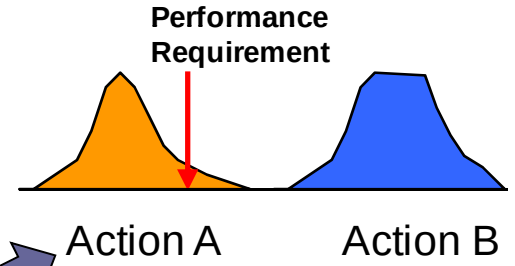
CASoS Engineering Framework Components



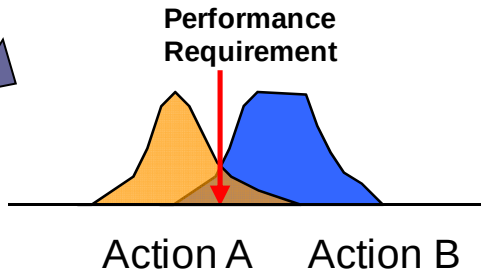
CASoS Engineering: An Iterative Process that Uses Uncertainty



Decision to refine the model can be evaluated using uncertainty, on the same basis as other actions

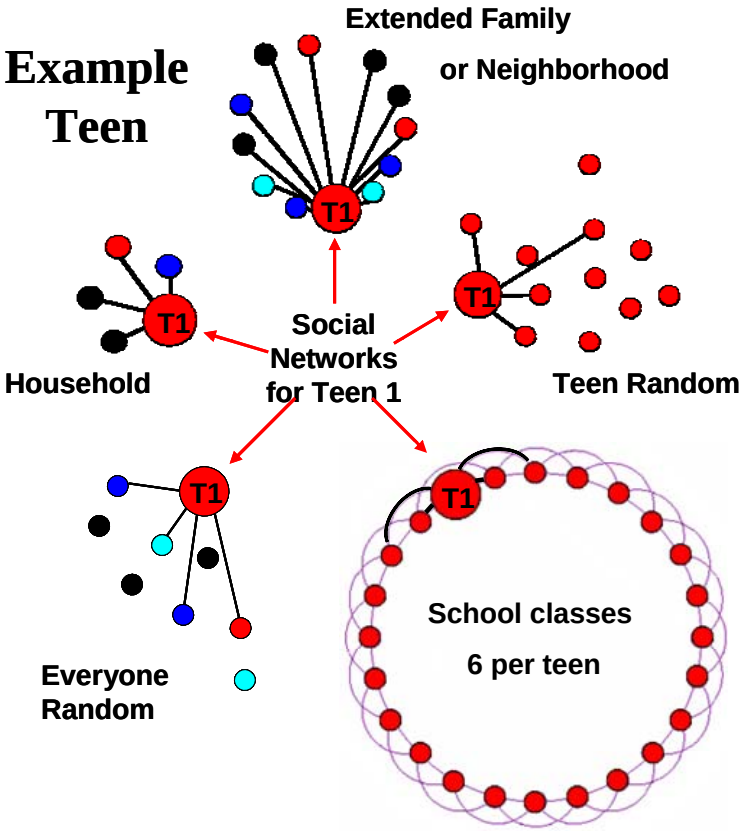


Model uncertainty permits distinctions



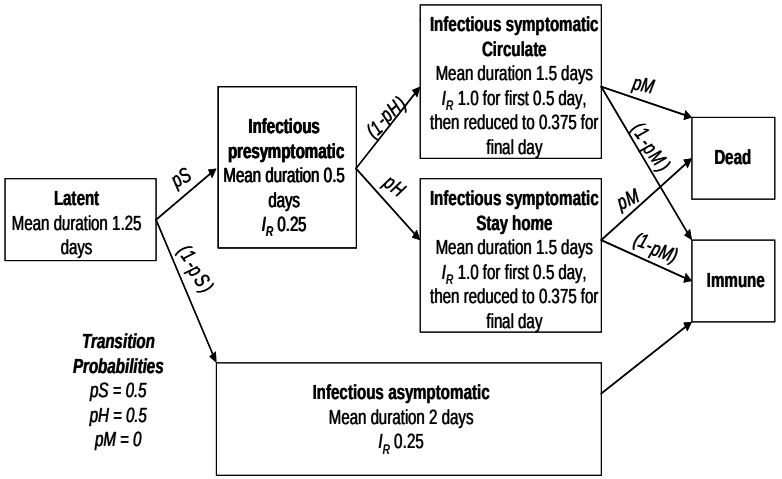
Model uncertainty obscures important distinctions, and reducing uncertainty has value

Application of Networked Agent Method to Influenza



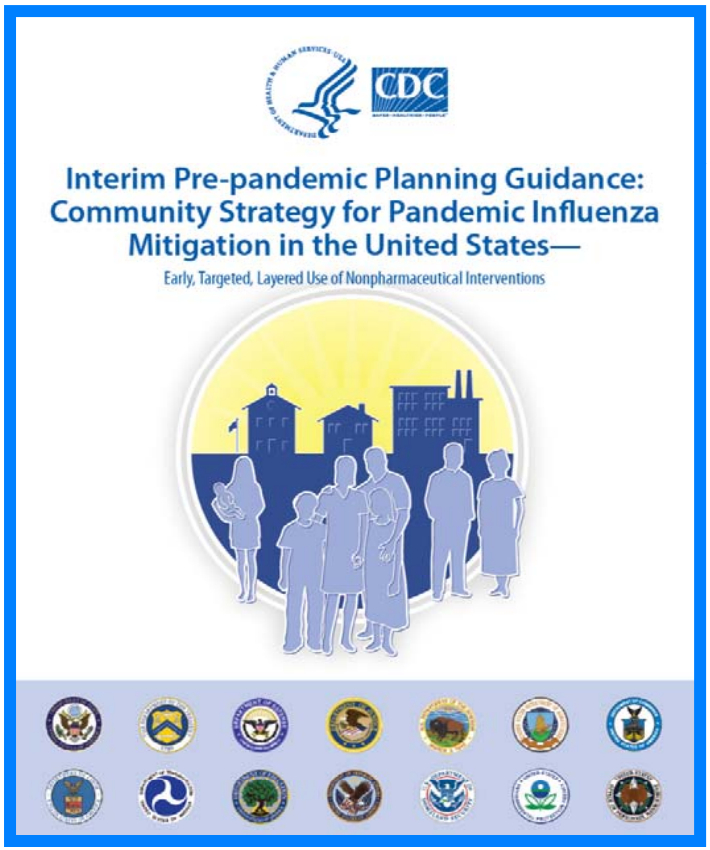
Stylized Social Network
(nodes, links, frequency of interaction)

Disease manifestation
(node and link behavior)



Worked with the White House to formulate Public Policy

Pandemic Planning is an early example of applying the CASoS Engineering process



For Details see:

Local Mitigation Strategies for Pandemic Influenza, RJ Glass, LM Glass, and WE Beyeler, SAND-2005-7955J (Dec, 2005).

***Targeted Social Distancing Design for Pandemic Influenza*,** RJ Glass, LM Glass, WE Beyeler, and HJ Min, *Emerging Infectious Diseases* November, 2006.

Design of Community Containment for Pandemic Influenza with Loki-Infect, RJ Glass, HJ Min WE Beyeler, and LM Glass, SAND-2007-1184P (Jan, 2007).

Social contact networks for the spread of pandemic influenza in children and teenagers, LM Glass, RJ Glass, *BMC Public Health*, February, 2008.

Rescinding Community Mitigation Strategies in an Influenza Pandemic, VJ Davey and RJ Glass, *Emerging Infectious Diseases*, March, 2008.

Effective, Robust Design of Community Mitigation for Pandemic Influenza: A Systematic Examination of Proposed U.S. Guidance, VJ Davey, RJ Glass, HJ Min, WE Beyeler and LM Glass, PLoSOne, July, 2008.

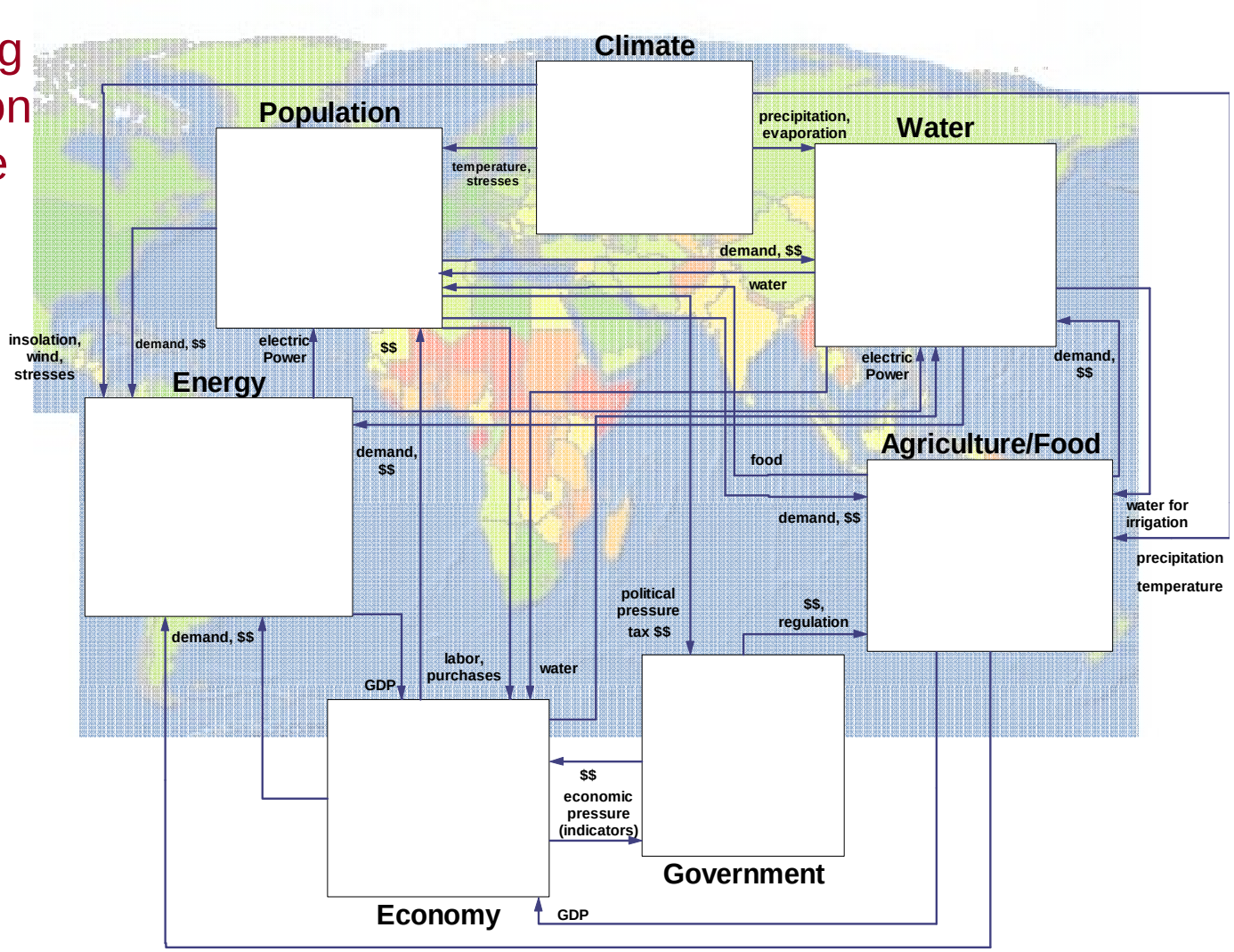
Pandemic Influenza and Complex Adaptive System of Systems (CASoS) Engineering, Glass, R.J., Proceedings of the 2009 International System Dynamics Conference, Albuquerque, New Mexico, July, 2009.

Health Outcomes and Costs of Community Mitigation Strategies for an Influenza Pandemic in the U.S, Perlroth, Daniella J., Robert J. Glass, Victoria J. Davey, Alan M. Garber, Douglas K. Owens, Clinical Infectious Diseases, January, 2010.

CASoS Engineering Example- Adaptation to Climate Change Impacts

Goal/Aspiration: Identify key uncertainties and dynamics in order to design and develop a CASoS engineering approach for reducing climate risks

Method: risk analysis approach that accounts for the full range of potential outcomes by explicitly including uncertainty, design validation strategy and identify modeling needs. Interacting nation state transaction modeling



To see our work on CASoS Engineering please visit:

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