Defining & Evaluating Threats and Designing Mitigation Strategies for VA Healthcare

Robert Glass, Thomas Moore, Walter Beyeler, Arlo Ames, Louise Maffitt, Patrick Finley
Sandia National Laboratories

Ronald Norby
Veterans Health Administration
10N/VISN 22

Victoria Davey
Veterans Health Administration
Office of Public Health and Environmental Hazards

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The Problem

- VA has had substantial experience facing both natural and man-made threats
  - Earthquakes
  - Hurricanes
  - Severe Acute Respiratory Syndrome (SARS)
  - Avian influenza/ H1N1 influenza
  - Acts of terrorism
- Many questions and concerns based on these events
  - What if we had done things differently?
  - How could we better prepare?
  - If 'X' happens, what approaches lead us to '$Y_1 + Y_2 + Y_3$' (the outcomes we want)?

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Computational Modeling as an Approach to consider a multitude "what if's"

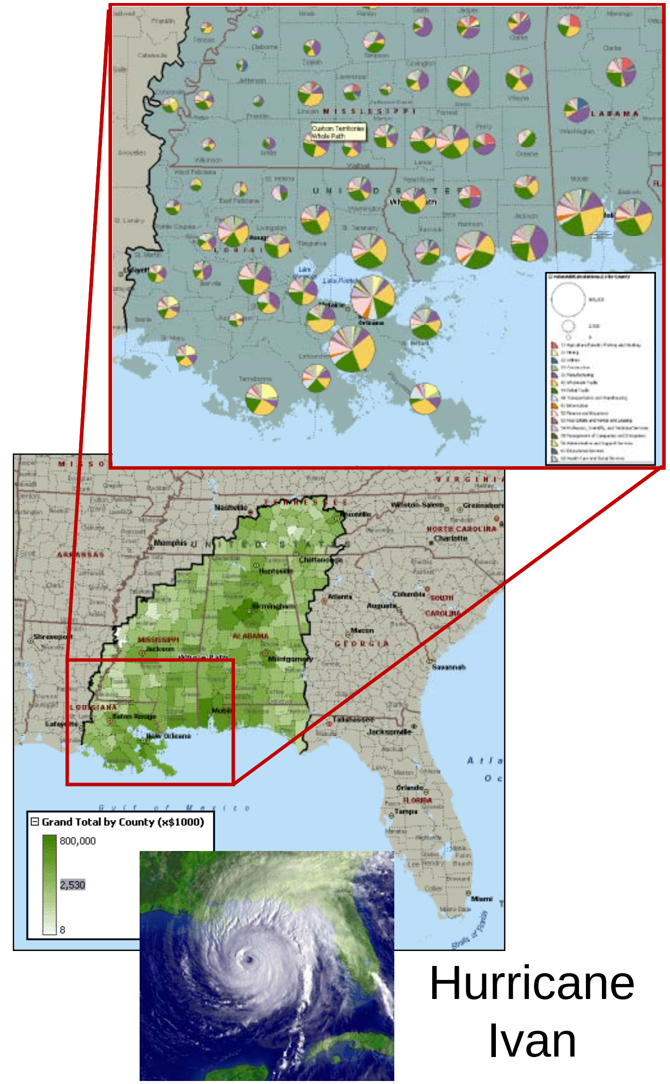
- We will use advanced computational models of real-world threats and potential disasters in order to provide options for policy, interventions, actions.
- A 5-year project
  - model the complex system of VA health care within communities
  - simulate various natural or manmade threats (H1N1 influenza, an earthquake)
  - select key aspects that might be averted, mitigated, improved
  - simulate, re-define, re-simulate, apply in exercises, evaluate, prepare, use

National Infrastructure Simulation and Analysis Center

NISAC

Analyses:

- Damage areas, severity, duration, restoration maps
- Projected economic damage
  - Sectors, dollars
  - Direct, indirect, insured, uninsured
  - Economic restoration costs
- Affected population
- Affected critical infrastructures
- Propagating supply chain effects



Hurricane Ivan

Los Alamos

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NISAC

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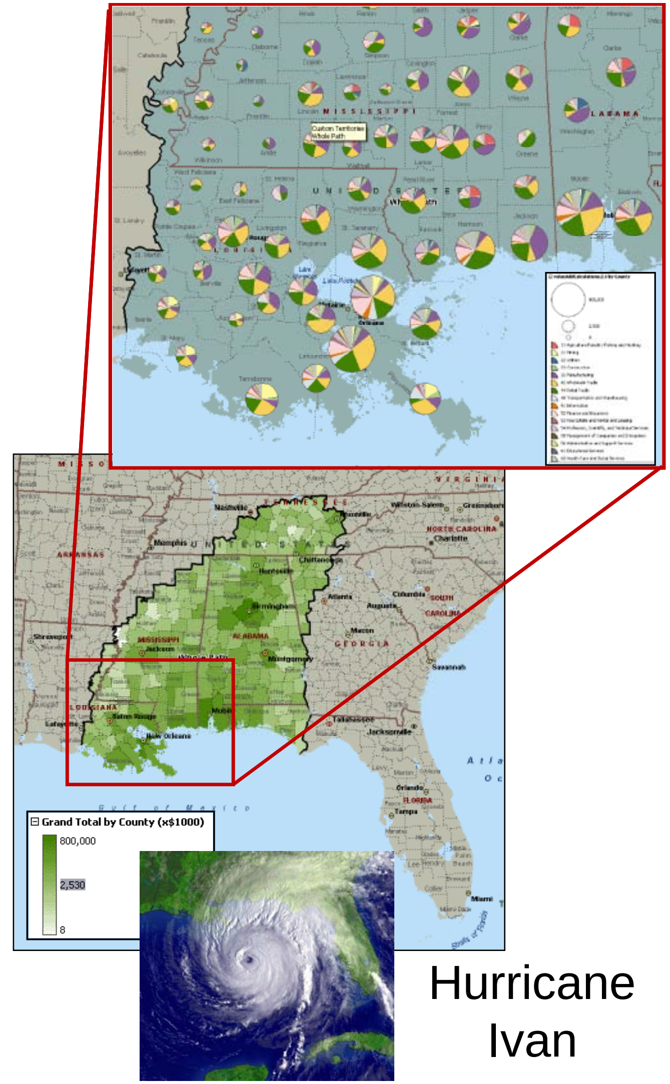

Hurricane Ivan

Focus of research:

- **Comprehensive evaluation of Threats**
- **Design of Robust Mitigation**
- **Evolving Resilience**

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2002: Advanced Methods and Techniques Investigations (AMTI)

Critical Infrastructures:

- Are ***Complex***: composed of many parts whose interaction via local rules yields ***emergent structure* (*networks*) *and behavior* (*cascades*)** at larger scales
- ***Grow and adapt*** in response to local-to-global ***policy***
- ***Contain people***
- Are interdependent "***systems of systems***"

http://www.sandia.gov/nisac/amti.html

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Critical infrastructures are -

Complex

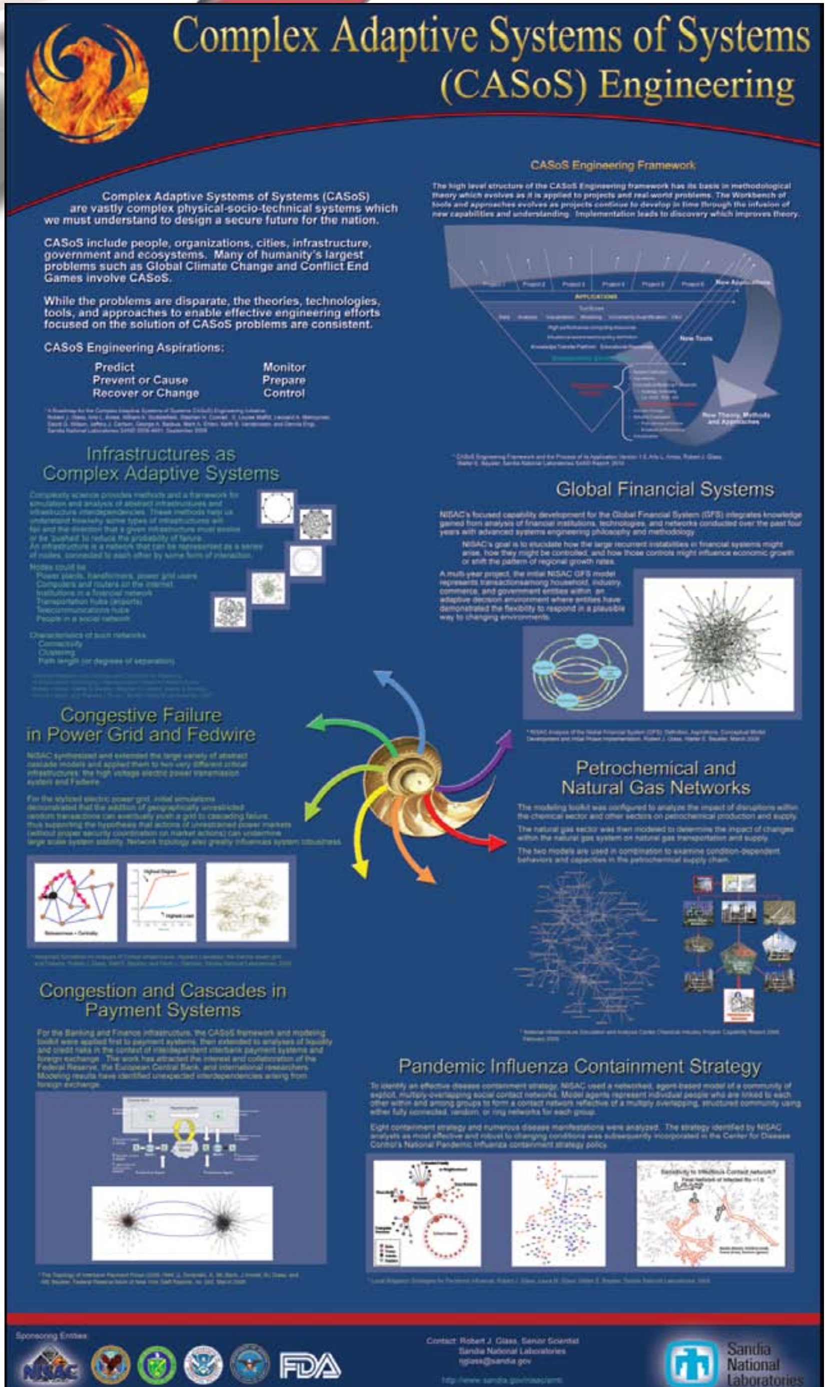
Adaptive

Systems of Systems

or *CASoS*

http://www.sandia.gov/nisac/amti.html

Examples



Complex Adaptive Systems of Systems (CASoS) Engineering
CASoS Engineering Framework
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
Prevent or Cause
Recover or Change
Monitor
Prepare
Control
Infrastructures as Complex Adaptive Systems
Global Financial Systems
Congestive Failure in Power Grid and Fedwire
Petrochemical and Natural Gas Networks
Congestion and Cascades in Payment Systems
Pandemic Influenza Containment Strategy
FDA
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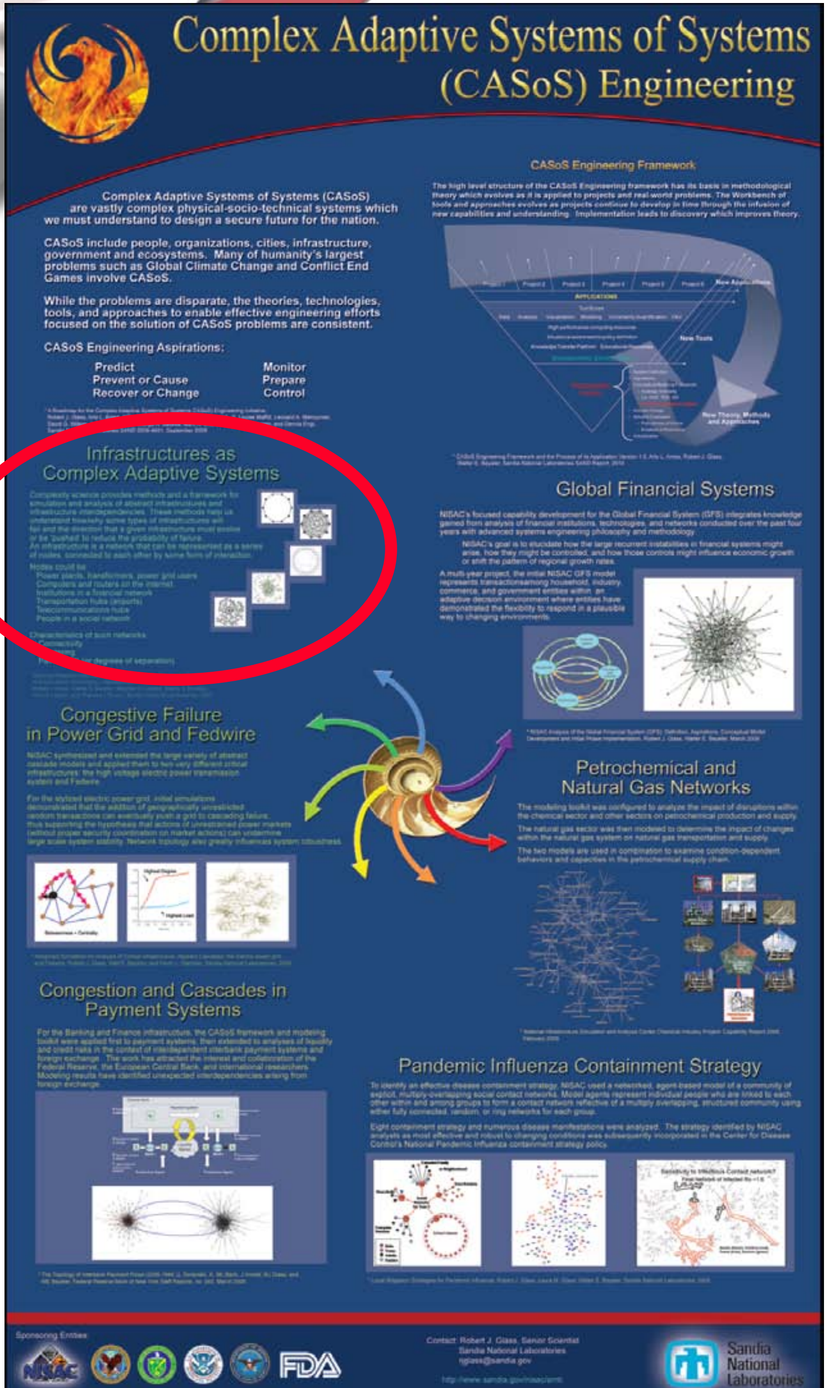
Examples

- General infrastructures



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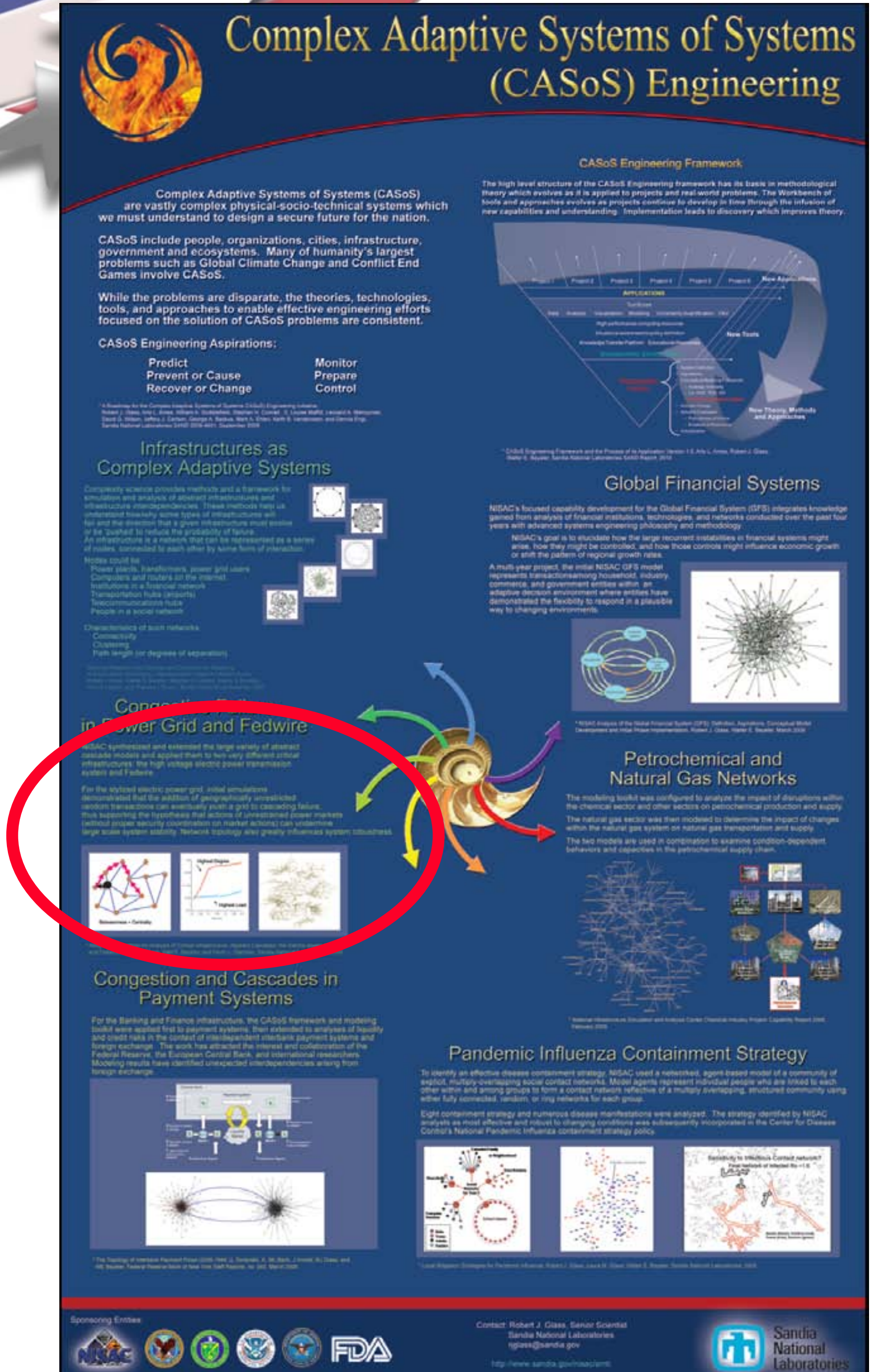
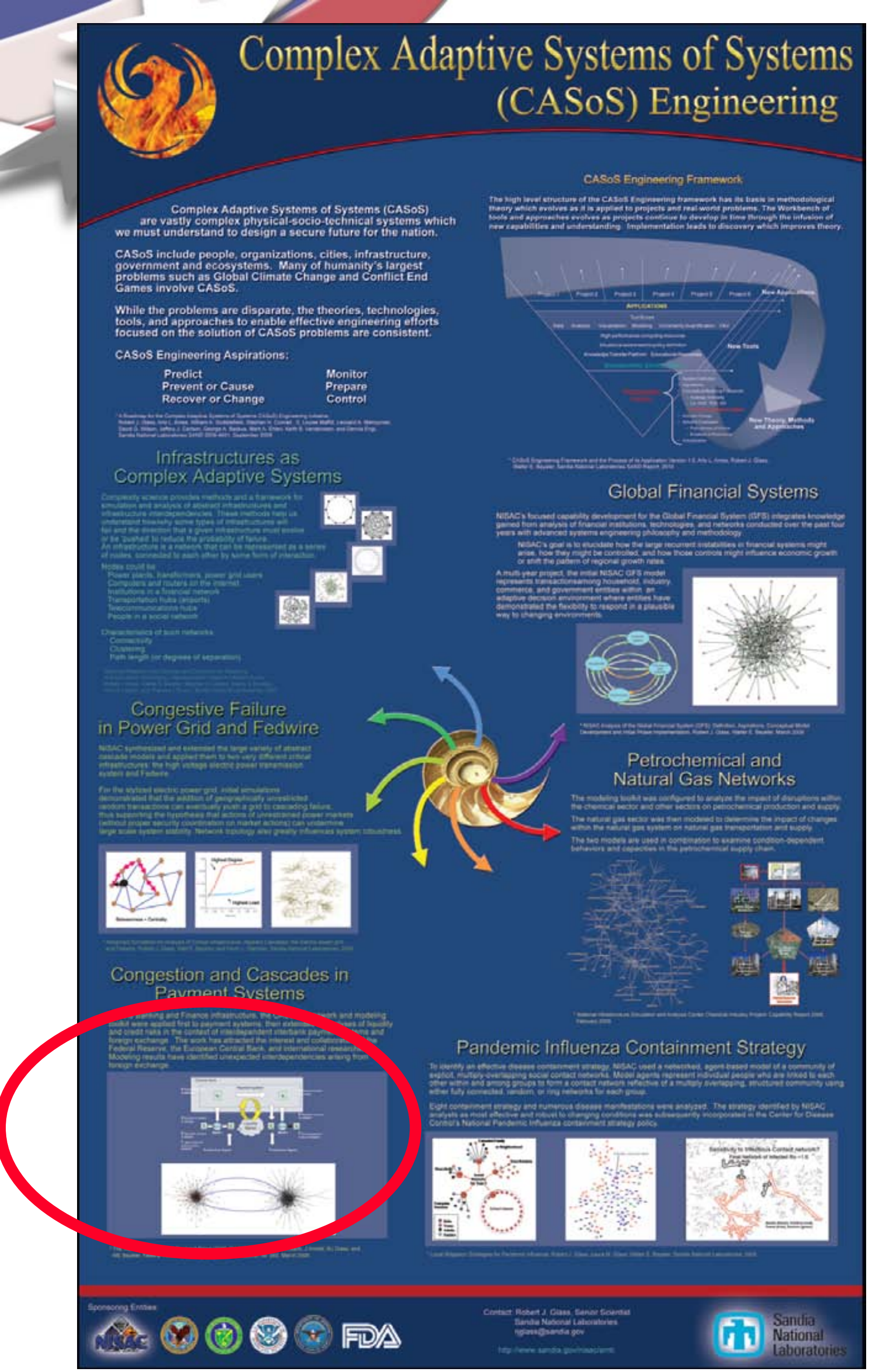


Examples

- General infrastructures
- Congestive Failure
  - Power Grids
  - Payment systems (Fedwire: financial transfer system)



Examples

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  - Payment systems (Fedwire: financial transfer system)
- Coupled payment systems (Fedwire: FX market: Target)

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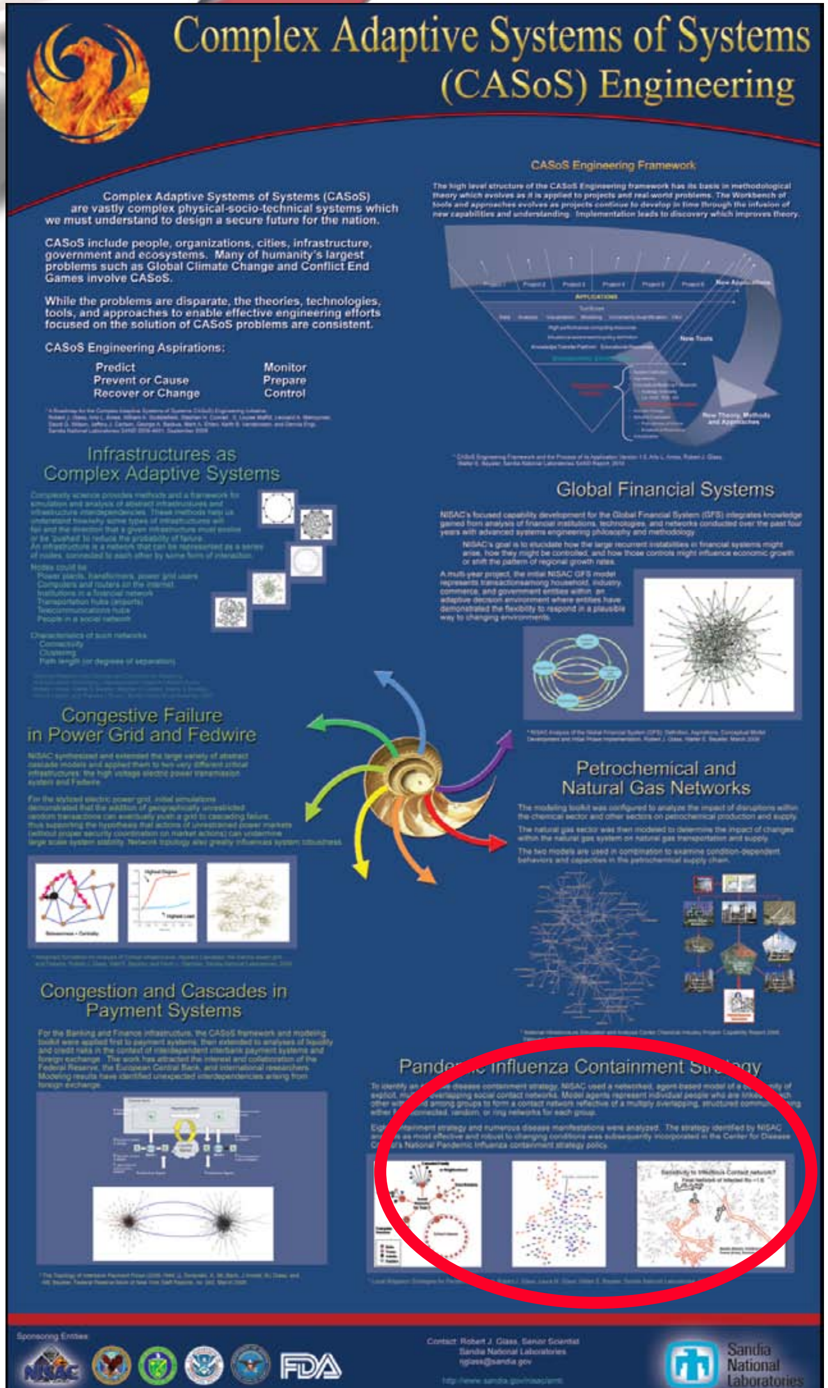

Examples

- General infrastructures
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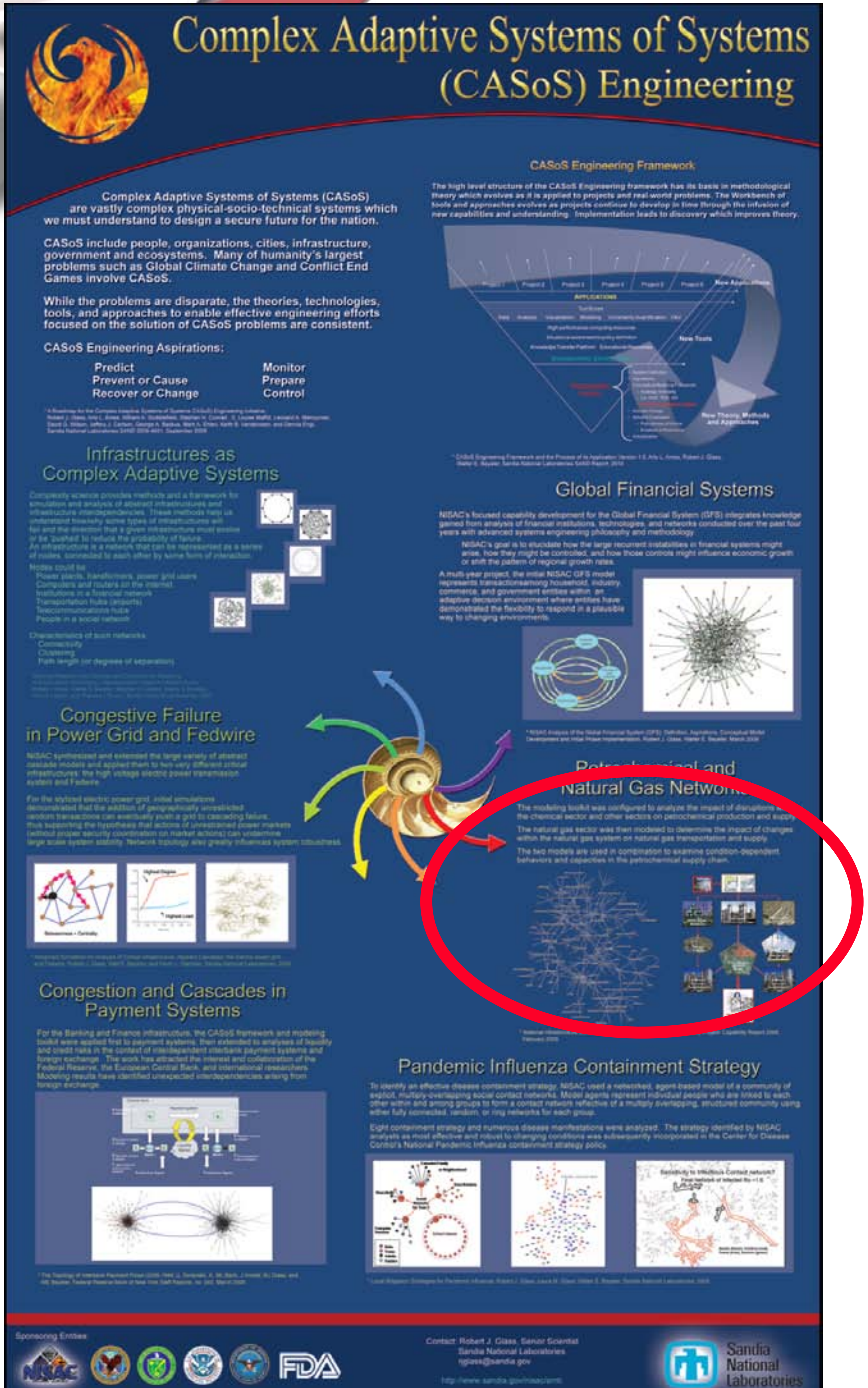

Examples

- General infrastructures
- Congestive Failure
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- Pandemics
- Petrochemicals and Natural gas networks

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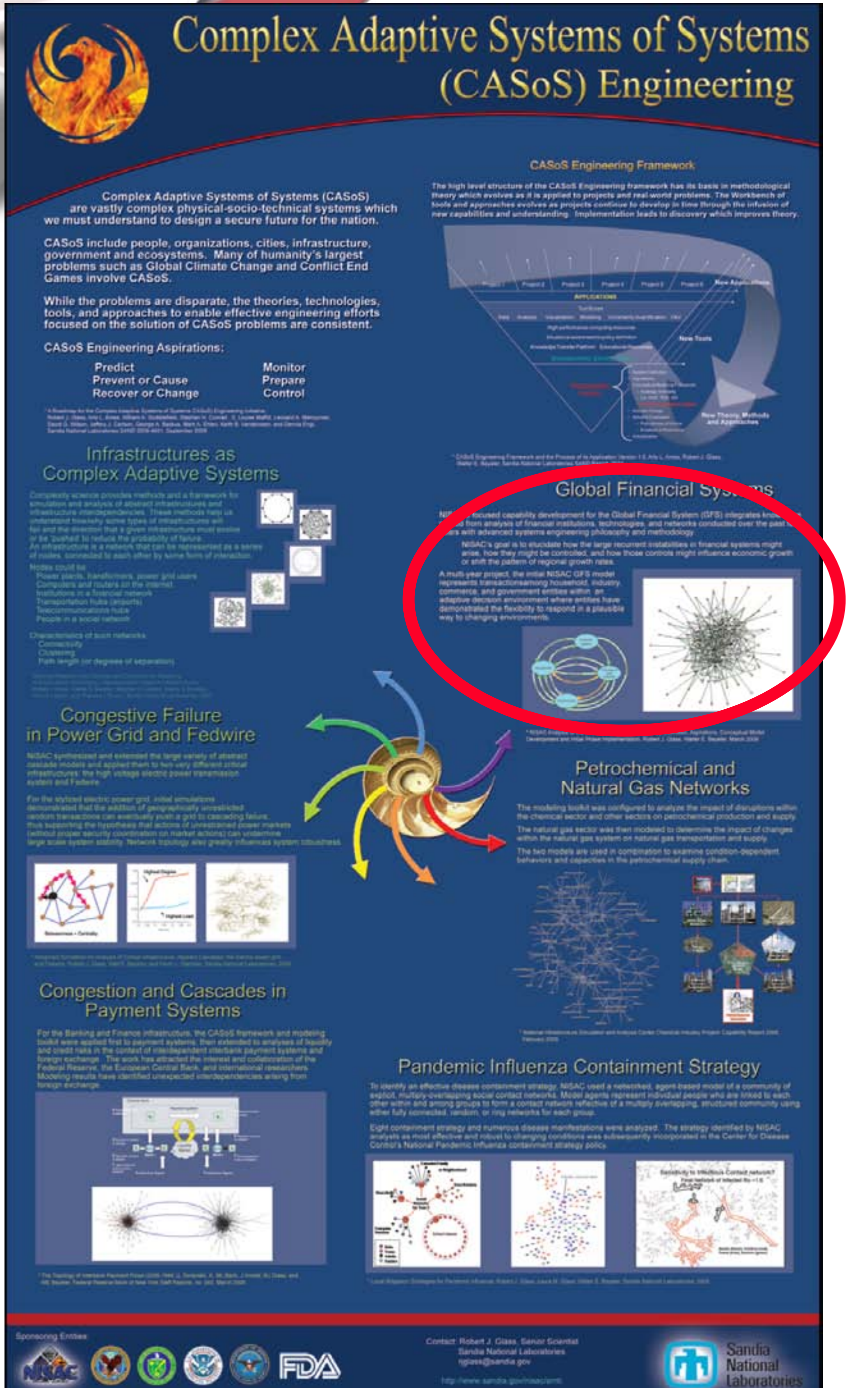

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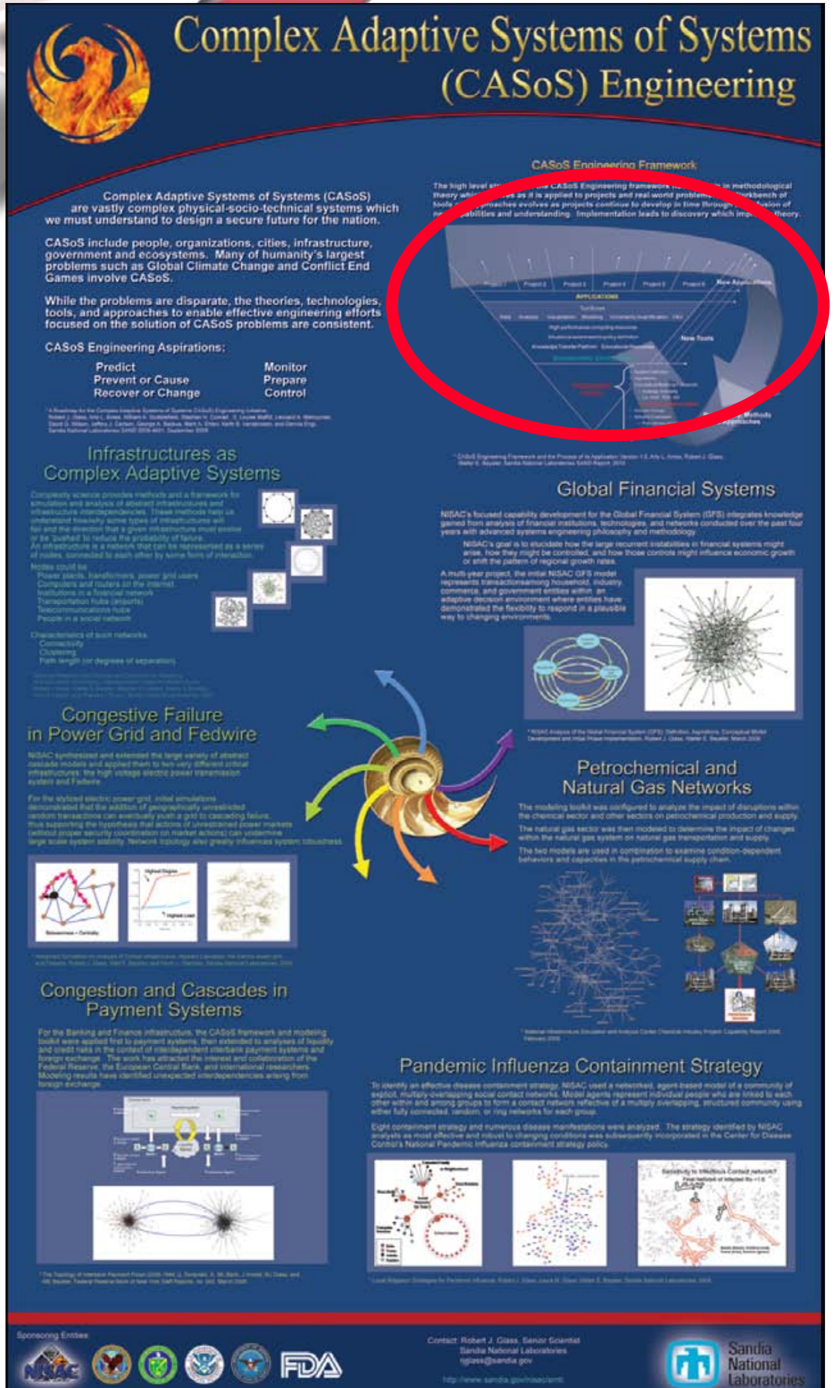

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- Pandemics
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- Global Financial Systems
- … Combining understanding across all CASoS application domains

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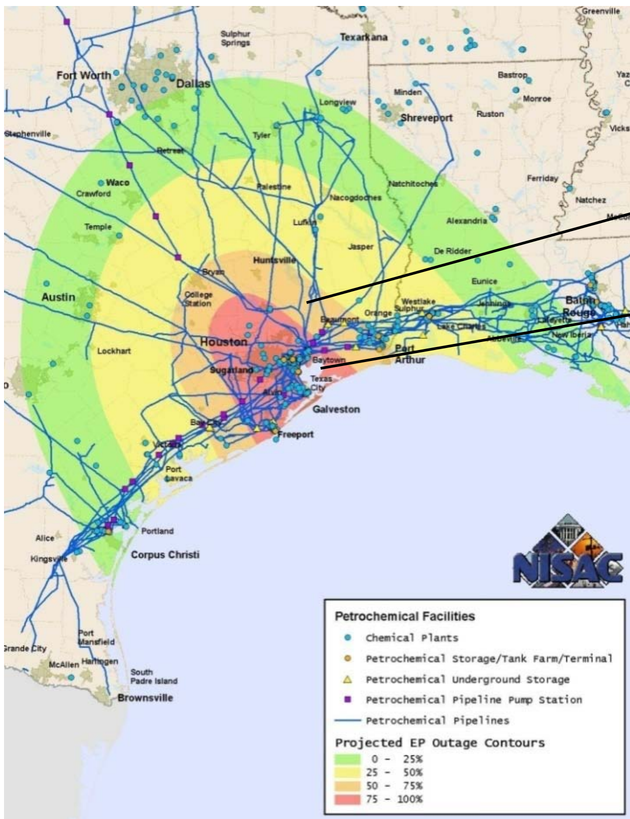
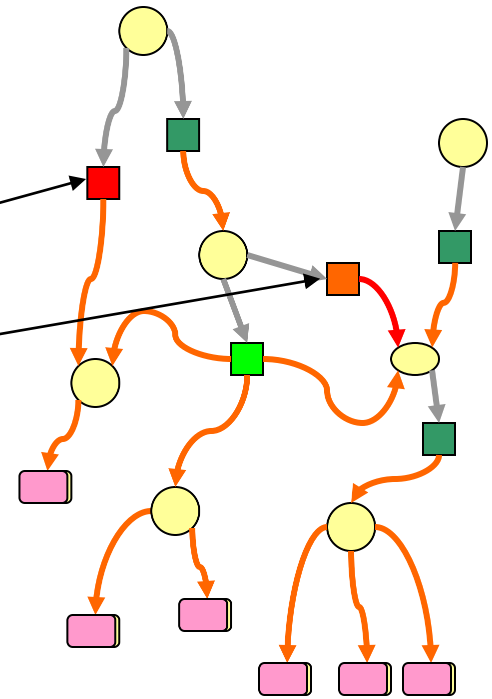
In a CASoS such as the VHA…

Everything is connected
skilled workers-utilities-transportation-structures-supplies-emergency services

In a threat like a hurricane, if components are disrupted…

Reduced health care capacity

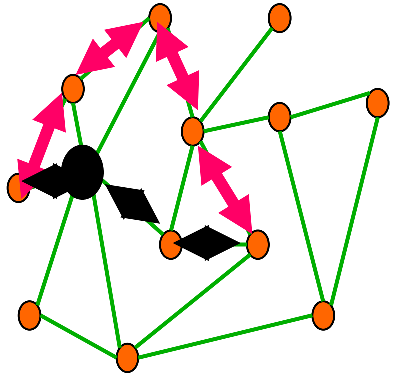




Increased morbidity
Decreased preventive services
Diminished health status

Modeling Threats to VA Health Care System

- What are the threats?
- How important is each system component?
- How can threats be prevented or mitigated?



Define

- Complex system of systems (e.g. VA health care)
- Apply appropriate methods and theories (e.g. analogy, percolation theory, game theory, network theory…)
- Create computational model and populate with required data to address problem (e.g. population, # clinics, personnel, beds, ventilators, supply chains, trucks, etc)

Design and Test Solutions

- Determine feasible, real-world options for mitigation (helicopters vs. trucks)
- Discover how robust these options are to uncertainties in assumptions (e.g. weather, who comes to work), and
- Establish critical enablers that increase system resilience (e.g. nothing works without water)

Implement Solutions within the Real World

Elicitation of VISN 22

Began the process of:

- Learning about people and their roles under normal and stressed conditions within a VISN (including veterans for whom the system cares)
- Understanding roles and interrelationships within individual facilities
- Understanding interrelationships between facilities within a VISN and with other non VHA facilities in the surrounding community or region
- Understanding the interrelationships between individual VISNs and national VHA and VA administration
- Identifying data to inform models at both small scale high-resolution (individual hospital-community) and large scale low-resolution (facilities within regions and the nation)
- Identifying surprises – surprising scarce resources, surprising interactions, surprising reliances

Perceived Threats VISN 22

Summary of Categories

- Physical Security
- Unpredictable human behavior
- Infrastructure
- Too much demand to meet
- Disasters
- Diseases
- Staffing
- Patients
- Community Relationships
- Organizational Issues
- Disaster Preparedness
- Distractions

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Conclusions:

- Threats perceived as Local
- Thus our concern is raised to the system level or ***Systemic Risk***
  - Response to national disasters
  - Normal operations weighted down by mandates

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… **Moving to Conceptual Modeling**

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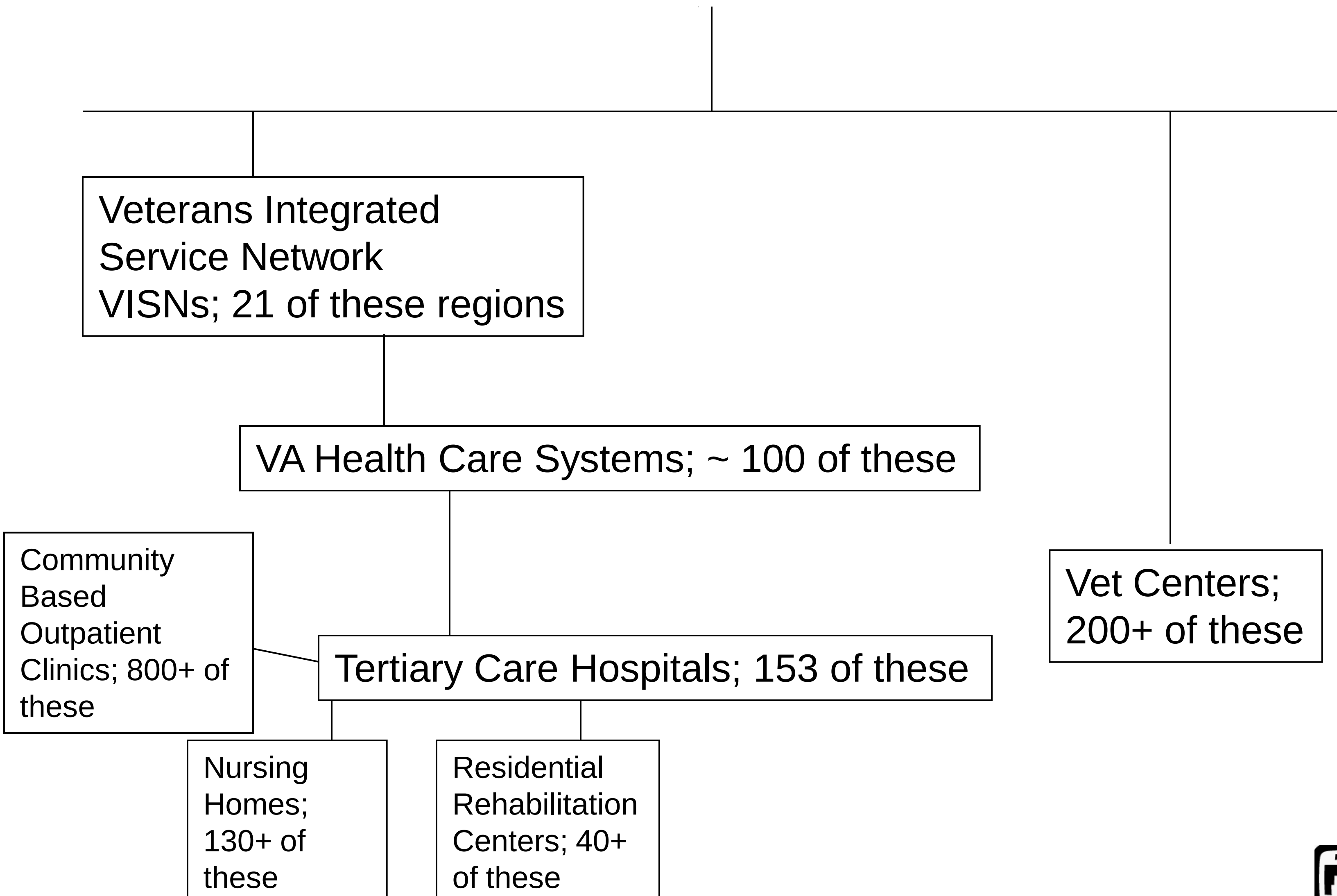
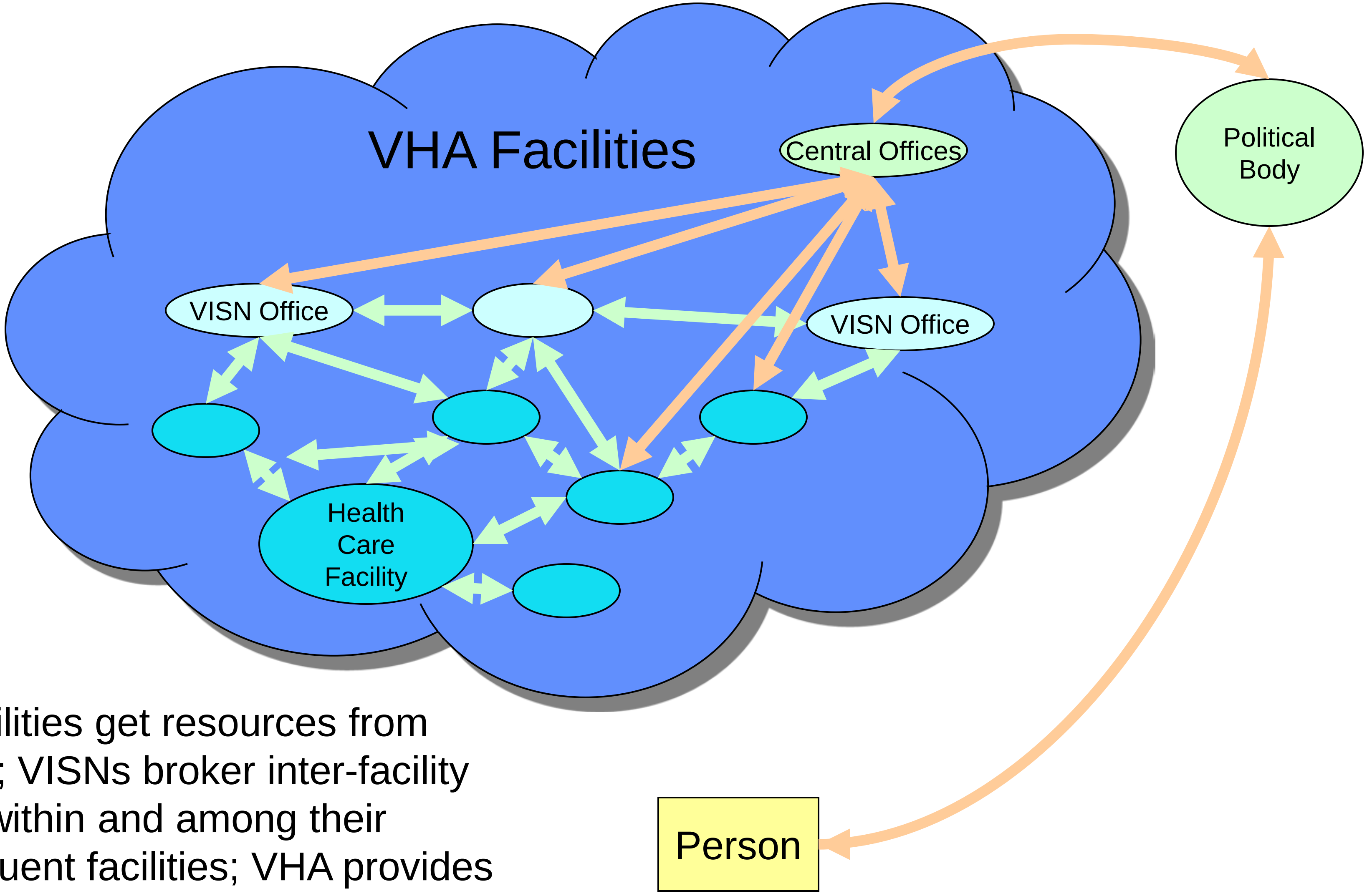


Political/Funding pathways



VA facilities get resources from VISNs; VISNs broker inter-facility flows within and among their constituent facilities; VHA provides funding, resources, information, and obtains status information

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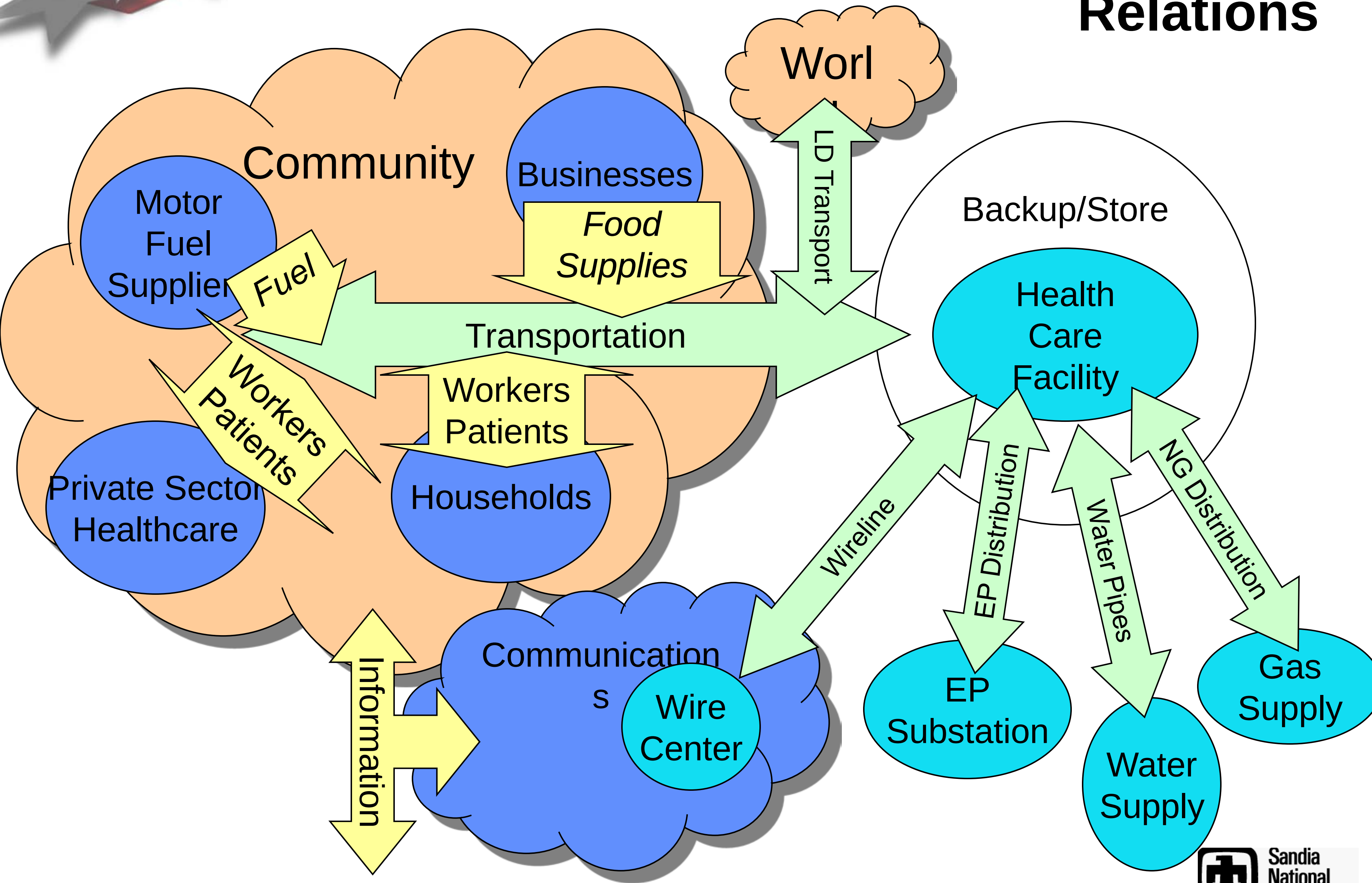
Major Entity Types, Aggregations, and Relations



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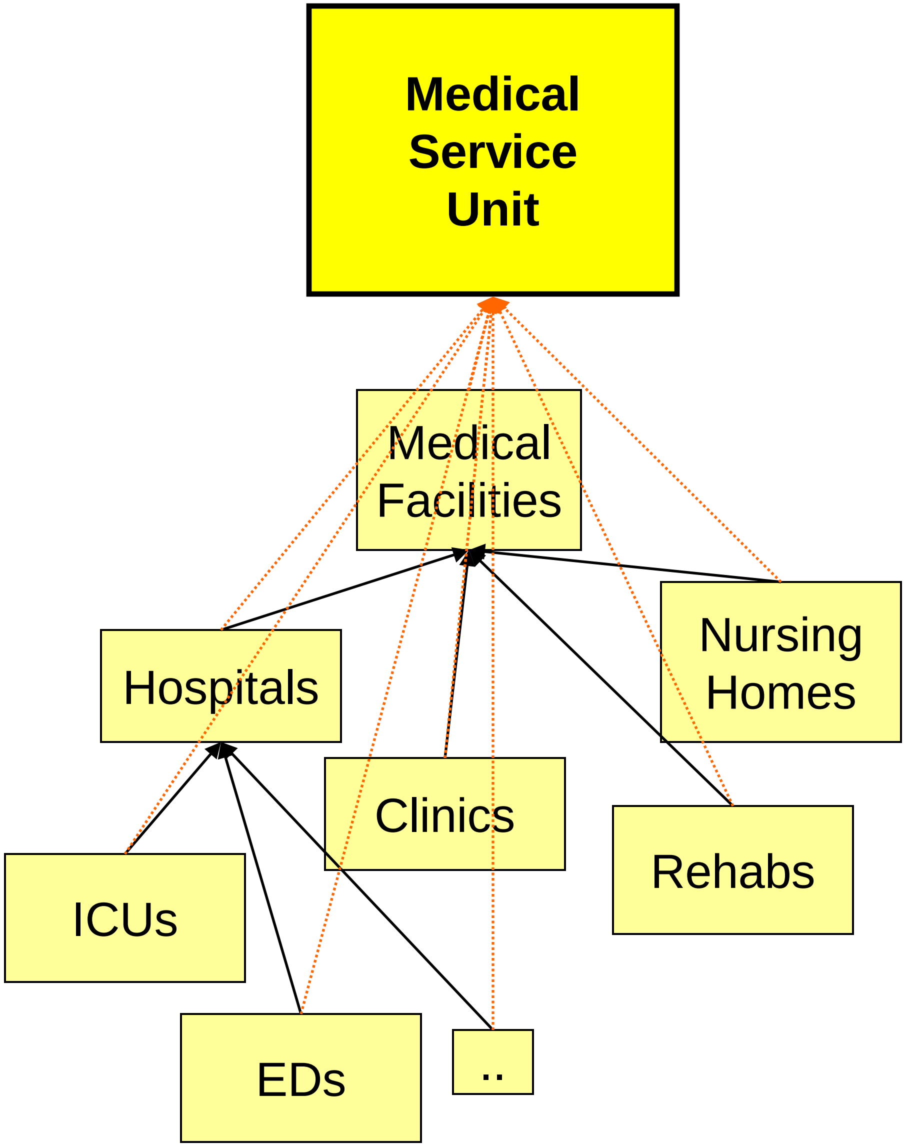
Fundamental building block for Health Care Facilities



We've defined a **Medical Service Unit** (MSU) as a generic model for any location where some kind of medical service is provided. It can be applied at a large scale (to represent an entire hospital for example) or at a small scale (to represent an individual ICU station), and ***may be nested***

Basic Medical Service Unit - States

A Medical Service Unit (MSU) is a location at which workers (of one or more types) service patients (having one or more kinds of conditions). MSU's capture the basic processes common to many facilities at many scales. Complex facilities (hospitals) can be represented as an MSU or as a complex collection of interacting MSUs.

- Worker
  - Load
  - Mood

- Medical Service Unit
  - Workers' States
  - Patients' States
  - Wastewater State
  - Communications State
  - Power State
  - Water State
  - NG State
  - Supplies State
  - Equipment State
  - Diversion State

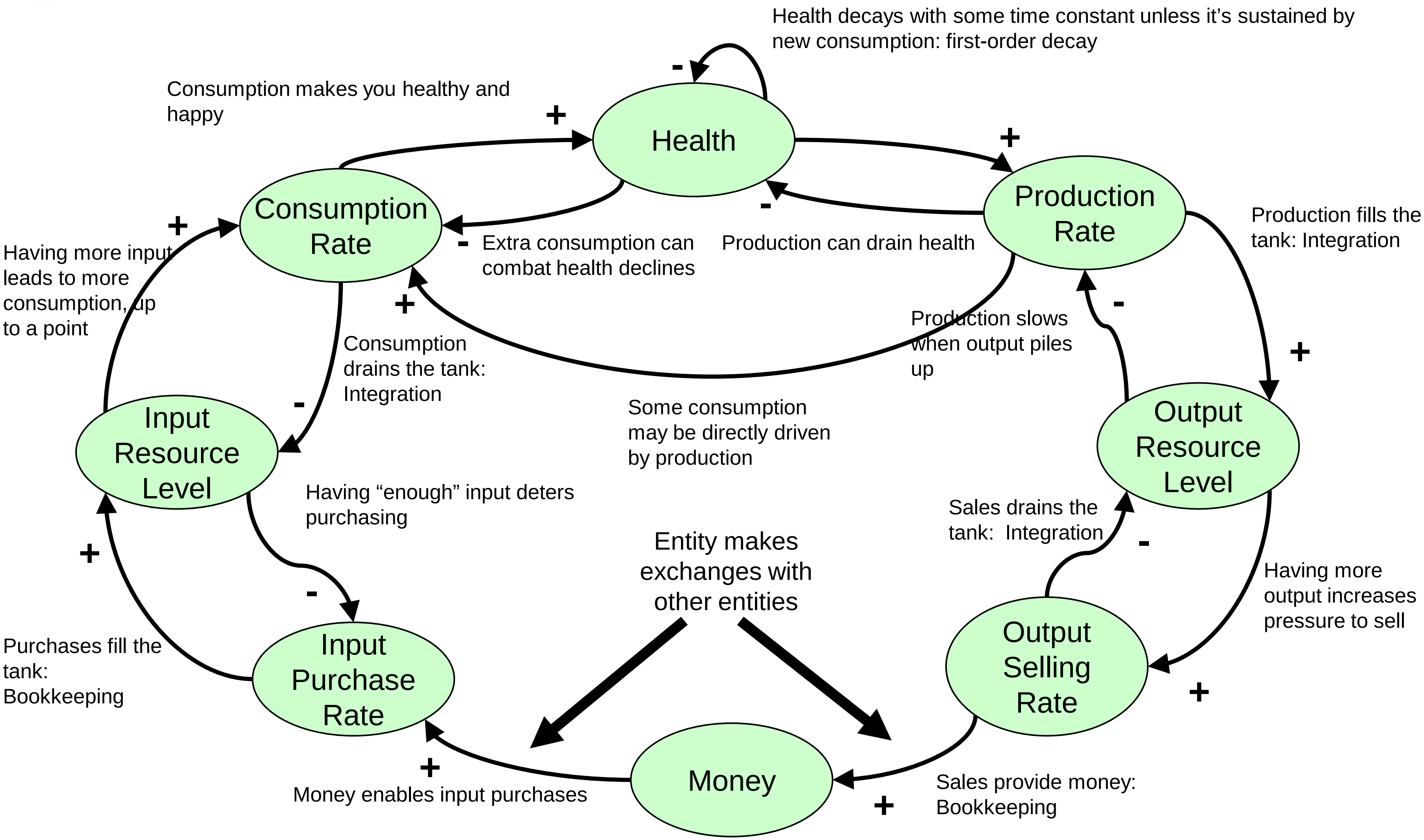
An MSU's infrastructure states may be defined by an embedding MSU (for example a ward's power state is determined by the hospital's power state)

The MSU may explicitly keep the set of Workers and Patients, or may count the number in each state.

The diversion state, which may be a simple function of other states, indicates whether the MSU is accepting new patients and/or is attempting to relocate existing patients

- Patient
  - Treatment State
  - Mood

Modeling a Generic Entity



NEXT STEPS

- In process of creating generic computational entity (mathematics and computational solution)
- Specialize general entity for: MSU, patients and medical staff
- Link MSUs into a network to represent several scales within the VA: a hospital, a VISN, the national system
- Operate stylized systems under normal conditions and allow individual entities to adjust, compare to expectations from the real world
- Consider robustness of system to perturbations of a variety of types and a range of sizes, find those that are problematic at the scale of interest (focus is on entire system)
- Consider tradeoffs between a set of strategies that could be implemented to mitigate the severity of perturbations
- AND… re-define, re-simulate, use to define critical research, apply in exercises, test and evaluate, prepare, use

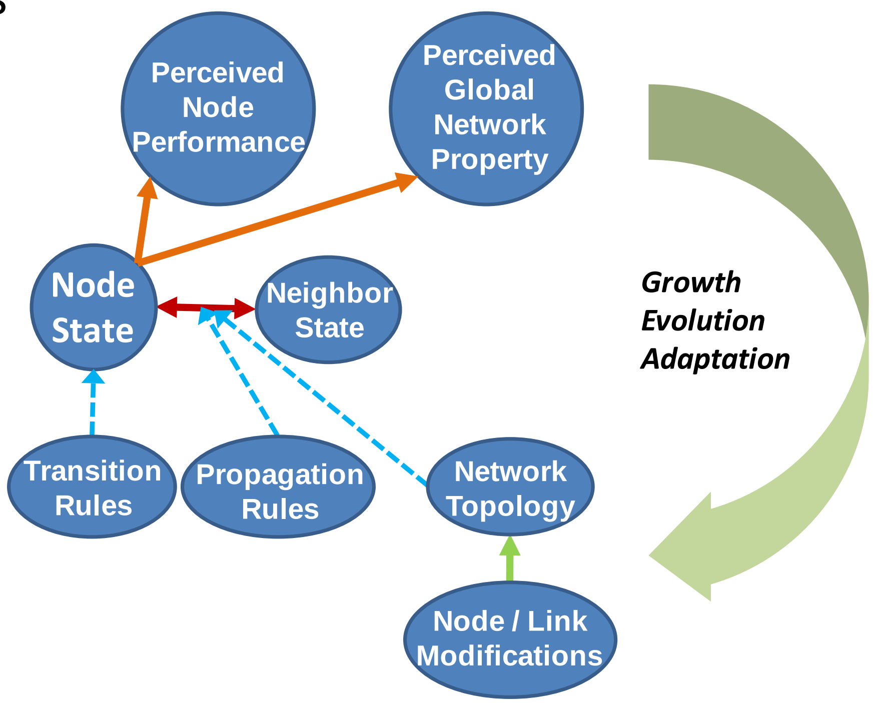
Q&A

Slides in Reserve

Generalized Conceptual Modeling Approach for CASoS Engineering

Take any system and Abstract as:

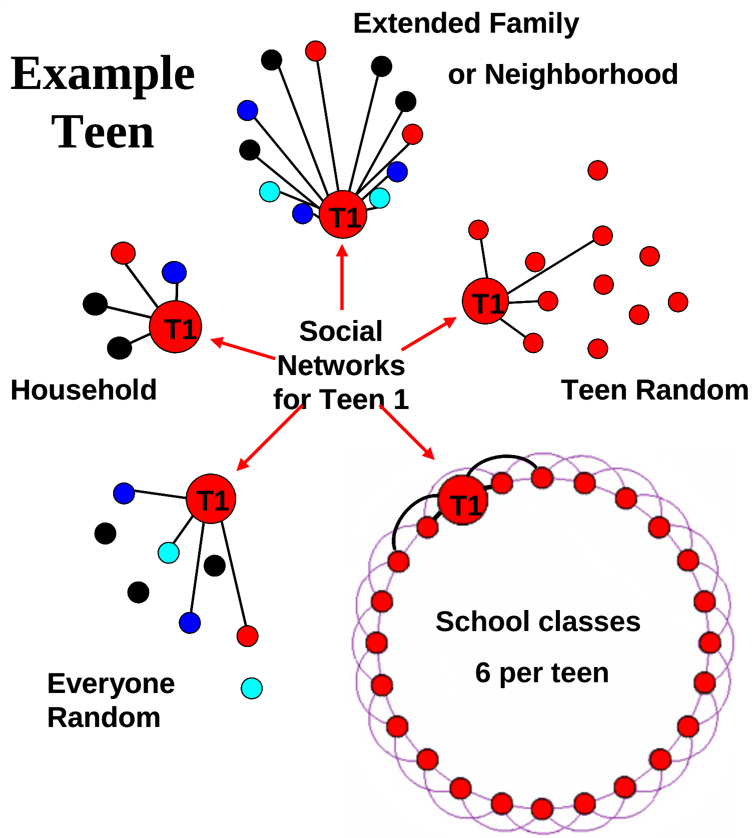
- Nodes (with a variety of "types")
- Links or "connections" to other nodes (with a variety of "modes")
- Local rules for Nodal and Link behavior
- Local Adaptation of Behavioral Rules
- "Global" forcing



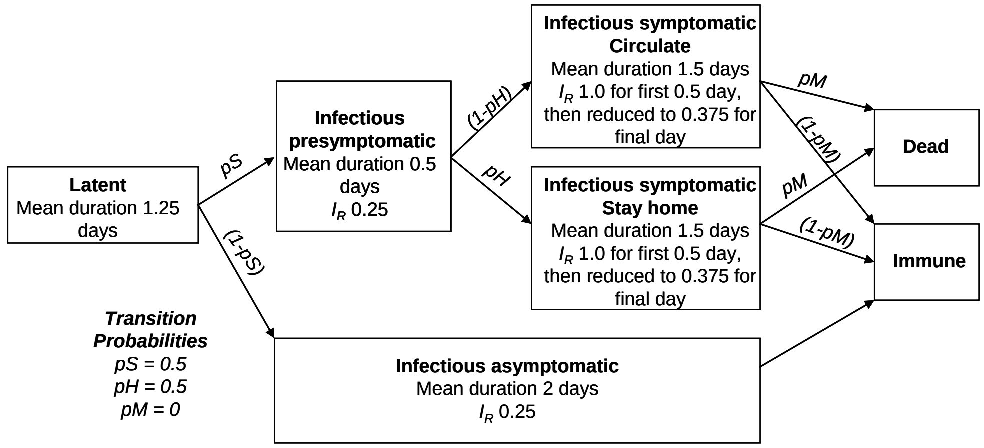
Connect nodes appropriately to form a system (network)

Connect systems appropriately to form a System of Systems

Application: Community Containment for Pandemic Influenza



Social Contact Network



Disease Manifestation

For Details see:

Local Mitigation Strategies for Pandemic Influenza, RJ Glass, LM Glass, an 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.

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.

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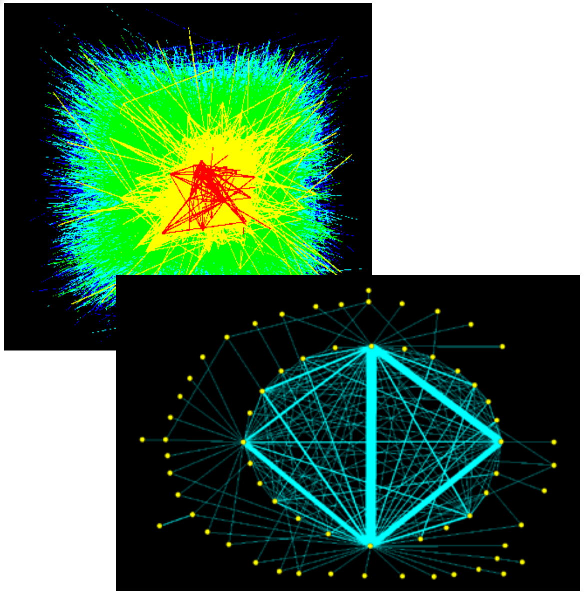
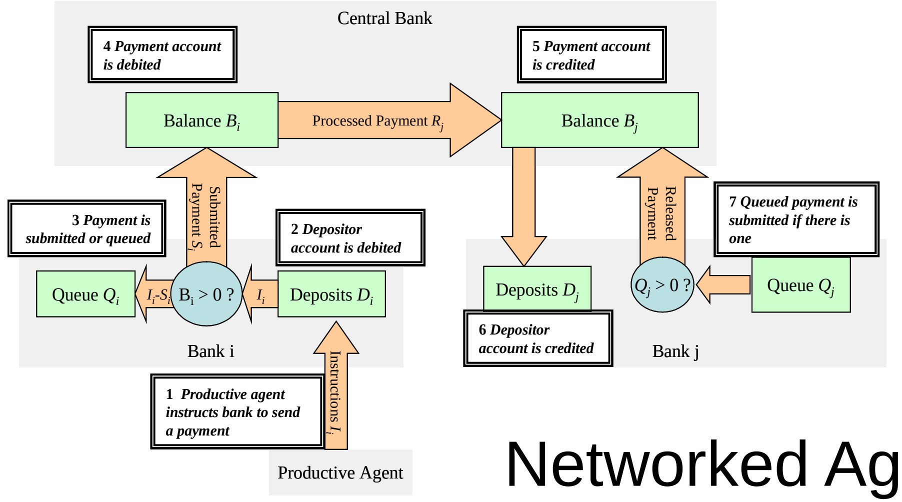
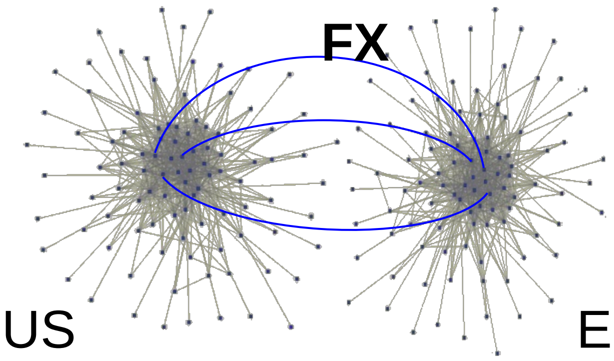
Application: Congestion and Cascades in Payment Systems



Payment system network



Networked Agent Based Model



Global interdependencies

For Details see:

The Topology of Interbank Payment Flows, Soramäki, et al, *PhysicaA,* 1 June 2007; vol.379, no.1, p.317-33.

Congestion and Cascades in Payment Systems, Beyeler, et al, *PhysicaA,* 15 Oct. 2007; v.384, no.2, p.693-718.

Congestion and Cascades in Coupled Payment Systems, Renault, et al, Joint Bank of England/ECB Conference on Payments and monetary and financial stability, Nov, 12-13 2007.

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