



# Engineering Solutions in an Interdependent World: The CASoS Roadmap

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*An **invitation** to our Roadmap. We hope that it will  
motivate you to read our report.*



## First, A Story

To illustrate

- What a **CASoS** is
- Defining **problems** wrt CASoS
- Engineering **solutions** using a generic component based approach to modeling
- Using CASoS principles to **influence policy** (get the solution used within the CASoS)

*Pandemic Influenza: Halloween 2005*

## The Situation

Two years ago on Halloween NISAC got a call from DHS. Public health officials worldwide were afraid that the H5NI “avian flu” virus would jump species and become a pandemic like the one in 1918 that killed 50M people worldwide.

DHS wanted NISAC to put together a briefing package to prepare DHS Sec Chertoff for a White House table top exercise the second week of December.



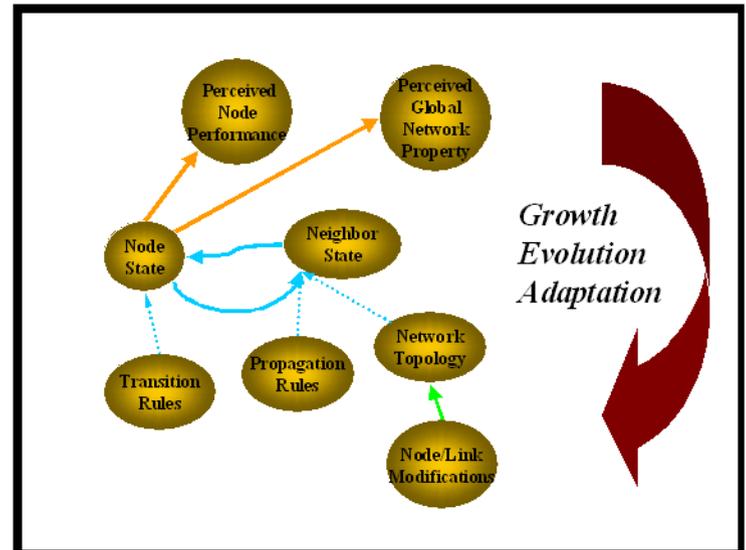
*Chickens being burned in Hanoi*

# Our Generic Approach from CAS

## Take any system and Abstract as:

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

*“Caricatures of reality” that embody well defined assumptions*





## Our Applications at the time...

- We were applying the approach to **power grids**, to the movement of funds from bank to bank within the FED's **Fedwire** system (2+\$T a day), to the contagious transfer of ideas and action in settings of **civil disobedience**.
- In these systems we see **cascades** of activity, **emergence** of **power-laws** for distribution of event sizes vs event frequency, **fractals**, all the hallmarks of CAS
- In context of these systems, we were interested in questions that had to do with **keeping a system from cascading** and if it did, defining the right **corrective action** to take that would dissipate the cascade.

*Pandemic? No Vaccine, No antiviral.*

*What could we do to avert the carnage?*

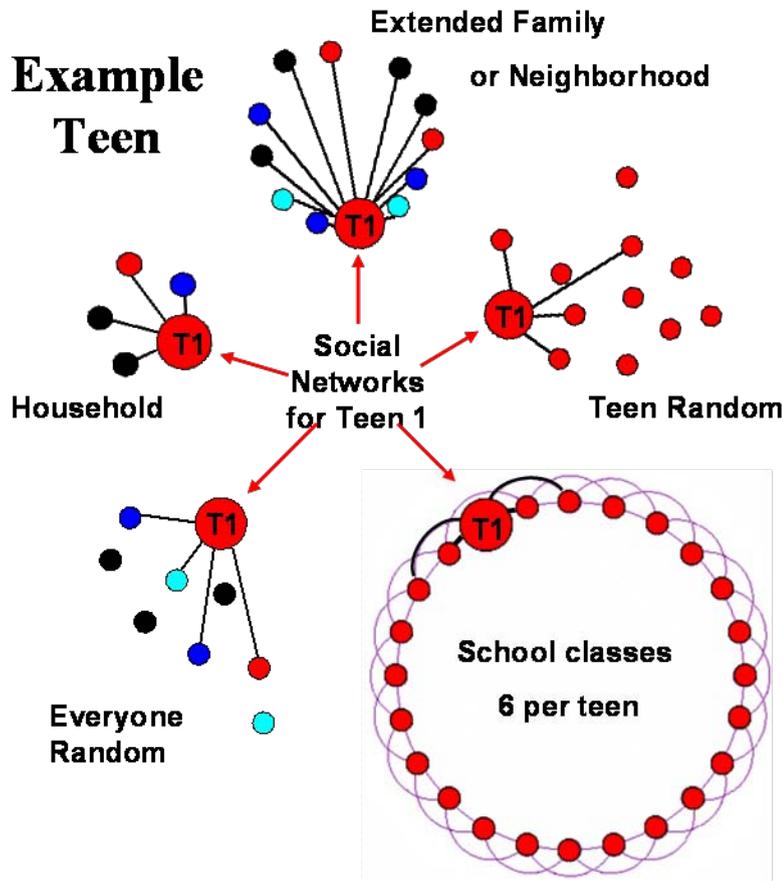


## By Analogy with other CAS systems

- **Forest fire:** You can *build fire breaks* based on where people throw cigarettes... or you can *thin the forest* so no that matter where a cigarette is thrown, a percolating fire (like an epidemic) will not burn.
- **Power grid blackout:** it's a cascade. But it runs on the interactions among people, the social network, instead of the wires of a power-grid.
- Could we target the social network and thin it?
- Could we thin it intelligently so as to minimize impact and keep the economy rolling?

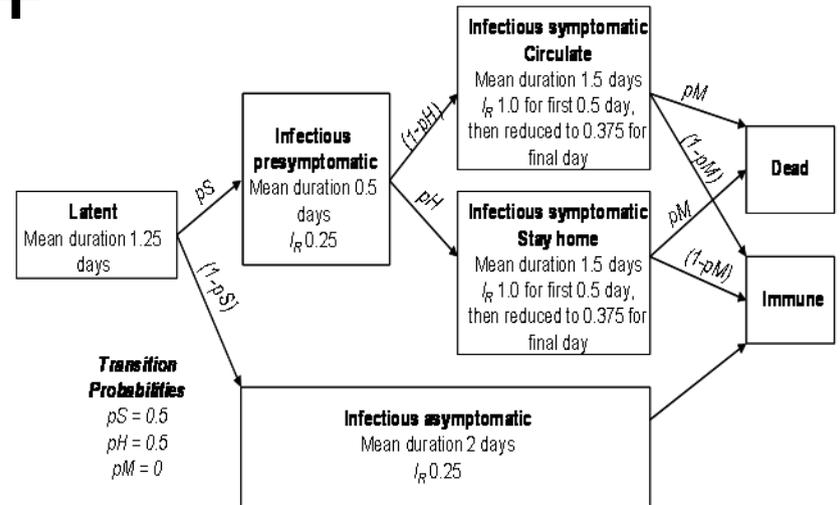
*PROBLEM DEFINITION: stop an epidemic  
with the least social burden*

# Influenza Model



## Disease manifestation

+



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

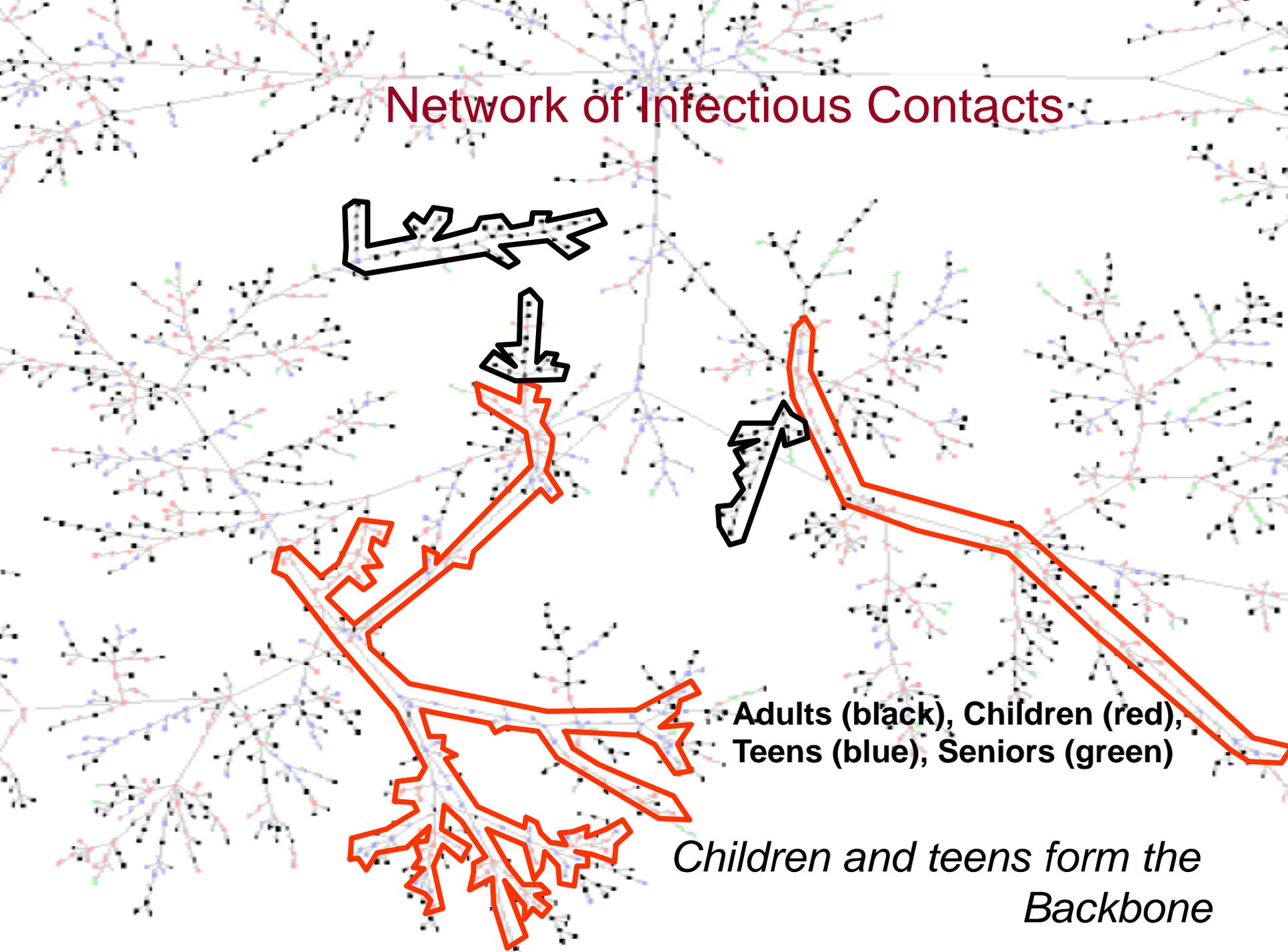
# Simulation

6 of 10 seeds  
developed secondary  
infections

1 of 10 seeds created the epidemic

We ran the model and it hit the numbers from past pandemics without calibration (those of other's required this calibration). We had the right node and link behavior, the right network, we had the right "physics".

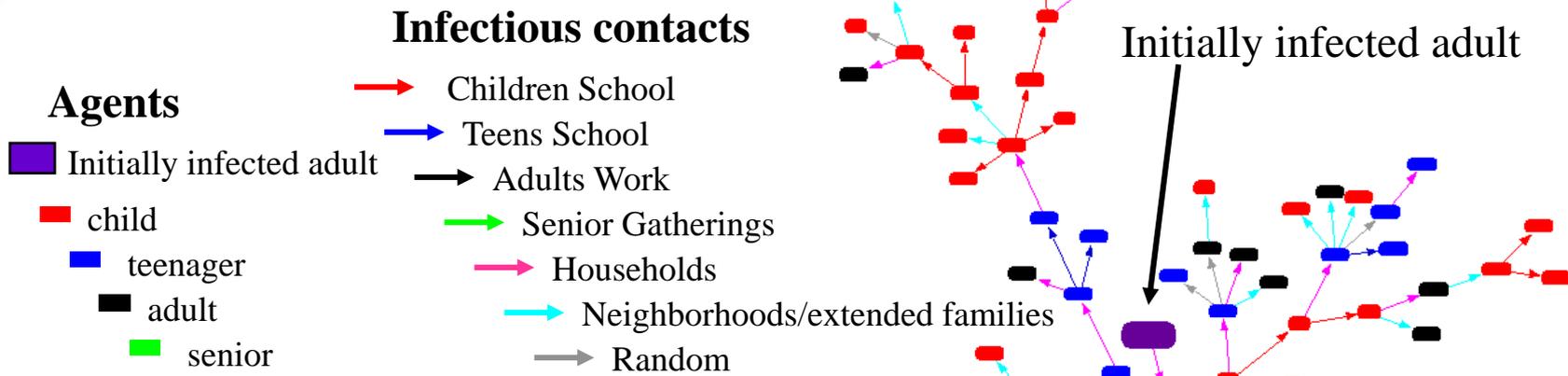
# Network of Infectious Contacts



**Adults (black), Children (red),  
Teens (blue), Seniors (green)**

*Children and teens form the  
Backbone*

# Initial Growth of Epidemic



Tracing the spread of the disease: From the initial seed, two household contacts (light purple arrows) brings influenza to the *High School* (blue arrows) where it spreads like wildfire.

**PROBLEM SOLUTION: Close the schools  
AND keep the kids and teens at home**



## The Clouds Thicken...

- Sec Chertoff briefed, open release SAND report written.
- White House table top: everyone several steps behind our thinking, such as closing borders, etc. Closing borders = building fire breaks. *They don't solve the problem.*
- Big names in epidemiology modeling the movement of the disease across the US with massive models at LANL and in Great Britain (published rapidly in Science and Nature) suggested there was little that could be done. The pandemic would wash over the US without antivirals. *But their tools were not built to consider the intricacies of the underlying social network on which the pandemic would spread in a local community.*



## Getting our results used...

- We needed to **INFLUENCE PUBLIC POLICY** and quickly.
- We used the *informal social-influence network* instead of the command and control hierarchy to get our work to the critical nodes with control.
- We sent our SAND report to a friend at the VA who sent it to his colleague who was the VA's rep on the Homeland Security Council (HSC) Pandemic Implementation Plan Writing Team, who sent it to the team lead who sent it to the Senior Director for Biodefense Policy, HSC.
- Glass got on a plane and after a 4 hour presentation/interrogation/brain storming session, he had *changed the course of public policy*.
- We had started another kind of cascade. The story goes on and illustrates other critical features such as collaboration, reaction, adaptation, consensus building... and the continuous use of *CASoS principles to affect system behavior*, but this is enough for our illustration today.



## The main points

- We were dealing with a large complex adaptive system, a CASoS: a global pandemic raging across the human population within a highly connected world (social, economic, political)
- By similarity with other such systems, their problems, their solutions, we defined **THE CRITICAL PROBLEM** for the pandemic (*currently an art*), applied a **GENERIC APPROACH** for simulation and analysis, and came up with a **ROBUST SOLUTION** that would work with minimal social and economic burden independent of what decisions were made outside the local community (e.g., politics, borders, travel restrictions).
- Through recognition that the **GOVERNMENT** and its dealing with global pandemic preparation was a CASoS, we then used CASoS concepts (social net, influence net, people) to **INFLUENCE PUBLIC POLICY** in short time. These concepts continued to be used by the HSC folks over the past 1.5 years to implement the policy that we identified. And work continues.



So...

- We have prototype theory, practice, and examples for solving CASoS related problems, *independent of domain*, that is focused on applications
- We know that we can expand to new applications, and we can do it better, but we will have to “do the science”

*Questions:*

- Can we do it generically?
- Can we do it across Sandia in a way that increases leverage and impact?
- Can we become the “go to” place for the problems of today and the future?

*The CASoS Roadmap*



## Can we do it generically?

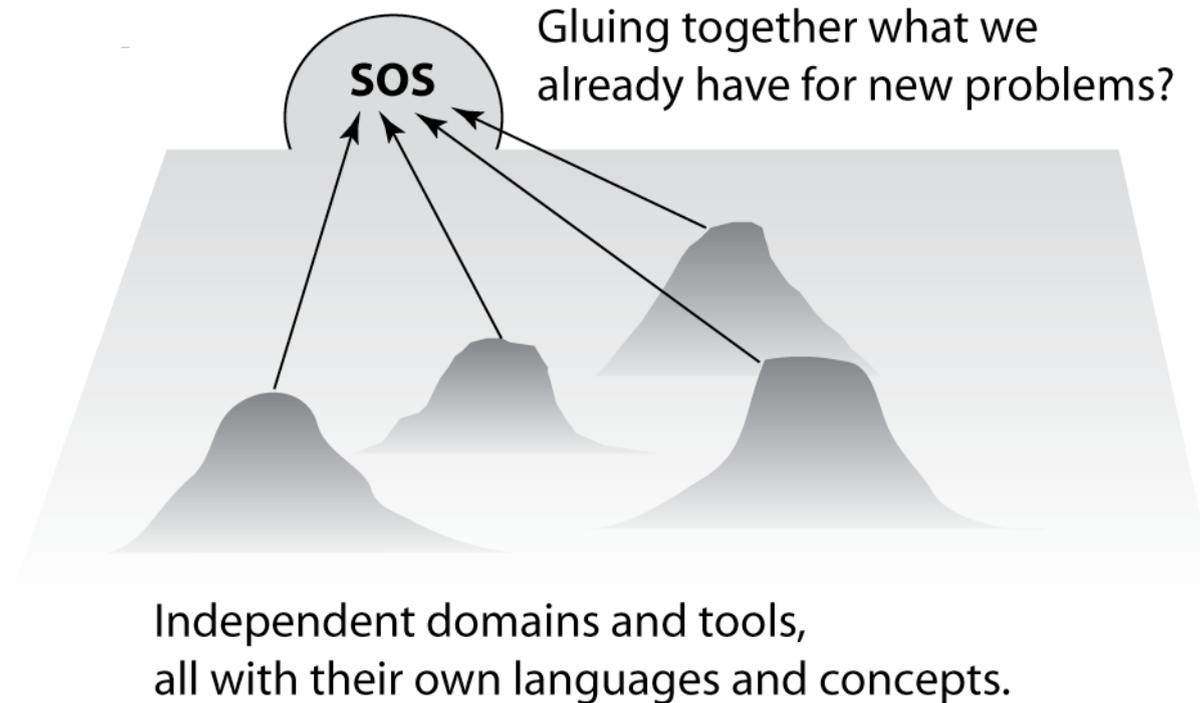
- CASoS are similar
- The engineering problems of CASoS are similar
- The questions for each problem are similar and of are of three classes:
  - What Decision?
  - Is the Decision Robust?
  - How can we Evolve towards Resilience?

*We believe the answer is YES*

*But we need to fund and do the science*



Can we do it across Sandia in a way that  
increases leverage and impact?



*Maybe, but we would have to move from the Current  
Stove Piped Structure to...*

# An Integrated Structure: CASoS Science and Engineering Initiative

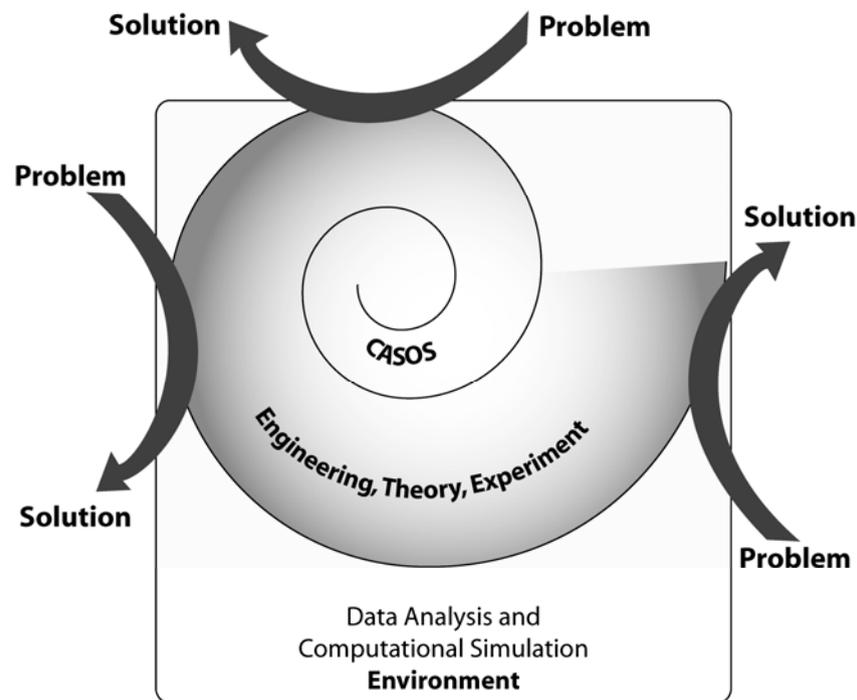
**Theory:** generic, applicable to the seemingly disparate problems that share the deep structure of CASoS.

**Experiment:** approaches, systems, and test-beds for both discovery and the testing of theory.

Data analysis and computational simulation **Environment.**

**Applications** for a wide range of customers that pull rather than push the Theory, Experiment and Environment

**Reflexive Management** of the Initiative as a CASoS



Customer problems drive the research engine



## Example CAsoS problems we would like to solve/engineer:

- What do we do about Iraq? Afghanistan? Kurds? Dafur? Sudan?
- What do we do about Iran/Syria/North Korea...?
- CO2 emissions?
- Dependency on foreign oil?
- Katrina like events?
- Sub-Prime Credit Crisis and CDOs? (weaponized financial instruments?)

*The New Problems of National Security*



Can we become the “go to” place for the problems of today and the future?

Only if we have the courage, wisdom, heart, and faith to begin... the CASoS roadmap points a direction.



# Next Steps



## Concurrent Evolution

- Community building
- CASoS workshops
- Integration across groups doing CASoS
- Increase CASoS components in current funding
- New Funding to do New Applications in new CASoS



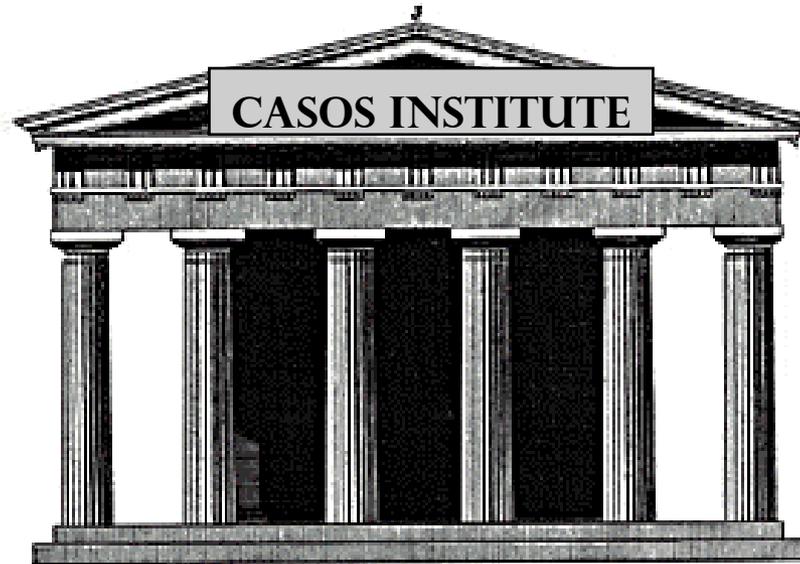
# Sequencing

- Proof of concept: with application collaborators
    - Consider 3 CASoS, categorize actions
    - Pose a series of questions/problems
    - Develop and apply a set of common tools to approach them (Theory, Experiment, Environment)
  - Expansion 1: Robustness of Choice
  - Expansion 2: Evolution of Resiliency
- Grand challenge  
LDRD*
- Additional Expansions (concurrent with Expansion 1):
    - Additional CASoS with application collaborators
    - Additional Categories, Questions/problems
    - Additional detail, higher resolution, larger scales

*V&V is an integral part of all*



# Concurrent Revolution



- Create an internal/external CASoS Engineering Institute
- Create a curriculum in CASoS Engineering through the CASoS engineering institute
- Apply CASoS Engineering principles to management of the Institute (or Sandia itself)



# On the Path for a Big Win?

- A community of shared theory, terminology, methods
  - Elements of CASoS Theory
  - Experiment, measurement, testing
  - Data analysis and Computational Simulation Environment
- Definition of a compelling problem set
  - Problems that defy conventional approaches
- Organization driven by technical vision
  - Fully integrated Science&Engineering&Application
  - Limitless applications and external collaborations
  - Managed as a CASoS
- Significant funding

