PREPTalks

New perspectives for emergency managers

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IAEM International Association of Emergency Managers

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Using Complex Adaptive Systems Thinking to Understand Community Interdependencies

Dr. Charles "Chick" Macal

Agenda

Agenda
Introductions (5 minutes)
Watch the PrepTalks (20 minutes)
Discussion (30 minutes)

Introduction

- Dr. Charles “Chick” Macal is the Chief Scientist of Argonne National Laboratory’s Resilient Infrastructure Initiative, where he leads a team of interdisciplinary researchers developing new computational models and simulations for infrastructure interdependency analysis, planning, and resilience.
- Dr. Macal is recognized globally as a leader in the field of agent-based modeling and simulation, focusing on the social and behavioral components of socio-technical systems.

Watch the PrepTalk

https://www.fema.gov/blog/preptalks-dr-macal-using-complex-adaptive-systems-thinking

Topics

- Understanding Complex Adaptive Systems and Systems Thinking
- Case Study: Ebola Outbreak
- Case Study: Critical Infrastructure Interdependencies

Topic 1: Understanding Complex Adaptive Systems and Systems Thinking

- Describe and discuss these terms used by systems thinkers:
- Tipping Point, Turning Point
- Non-linear, Phase Change, Sea Change
- Feedback, Blowback
- Domino Effect, Cascades
- Emergence, Collective/Distributed Intelligence, Swarm Behavior
- Small World, Six Degrees of Separation, “Kevin Bacon” Game
- Top Down vs. Bottom Up

> “We need more systems thinking and we need more systems doing in this entire field of emergency preparedness.”
>
> – Dr. Chick Macal

Topic 1: Understanding Complex Adaptive Systems and Systems Thinking

Visualization Techniques - Complex adaptive systems can be visualized based on the amount of time available, type of data, and overall goals of the analysis.

1. **Network Analysis:** Draw a picture of the important decision-making organizations, how they are connected, and how information is exchanged between them. Network Analysis include nodes, links, and flow.
2. **Causal Modeling / System Dynamics:** Look at the factors that are responsible in a system for producing its behavior, step-by-step.
3. **Optimization:** Capture the objectives, constraints, and resources and how they work together in an inter-woven framework.
4. **Agent-based modelling:** A bottom-up approach that models individual actions within a population and their decision-making behaviors.

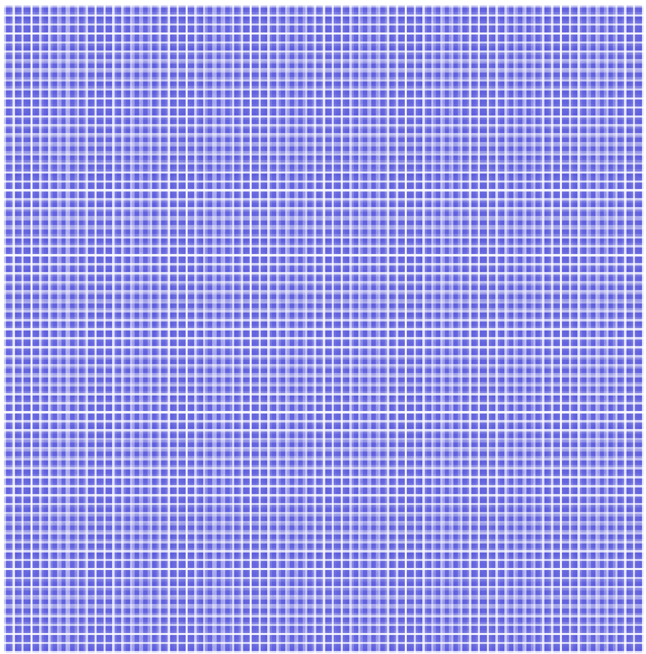
Topic 1: Understanding Complex Adaptive Systems and Systems Thinking

- Are you a systems thinker? Systems thinking requires a shift from seeing individual elements with a linear cause and effect to seeing an entire system with interrelated nodes, links, and flows.
- Conduct a network analysis. Doing a network analysis exercise has immediate value because participants quickly identify gaps. Often these gaps involve realizations that decision makers don’t have important relationships with key stakeholders, or won’t have timely access to critical information, or don’t have adequate resources.
    - What are the requirements of the system; what is it supposed to do? Consider the stakeholders (nodes) in the system, the people who will be making the decisions. What processes will they follow to arrive at those decisions?
    - What is flowing through the system – is it information? Money? Energy? A complex adaptive system always has a flow; that’s one of the principles. The flow gives the system life; it animates the system.
    - What are the measures or metrics of what the system is supposed to do? How will you know how well the system is functions?
    - What are the resources that are needed to allow the system to move forward?
- Catalog past decisions and actions. Jurisdictions should record the reoccurring issues that arise during disasters in their community and document how these problems were addressed. This will help communities become learning organizations, building on past experiences.

Topic 2: Case Study: Ebola Outbreak

Modeling Potential Interventions

Without intervention:
1.8 million potentially infected



With optimal intervention:
370 infected

Within 1 month from start of outbreak, **90% contacts identified and isolated**

Within 6 months from start of outbreak, able to **hospitalize 90% of all infected individuals**

Additional intervention implemented that aims to **reduce transmission in the community** over the first 6 months

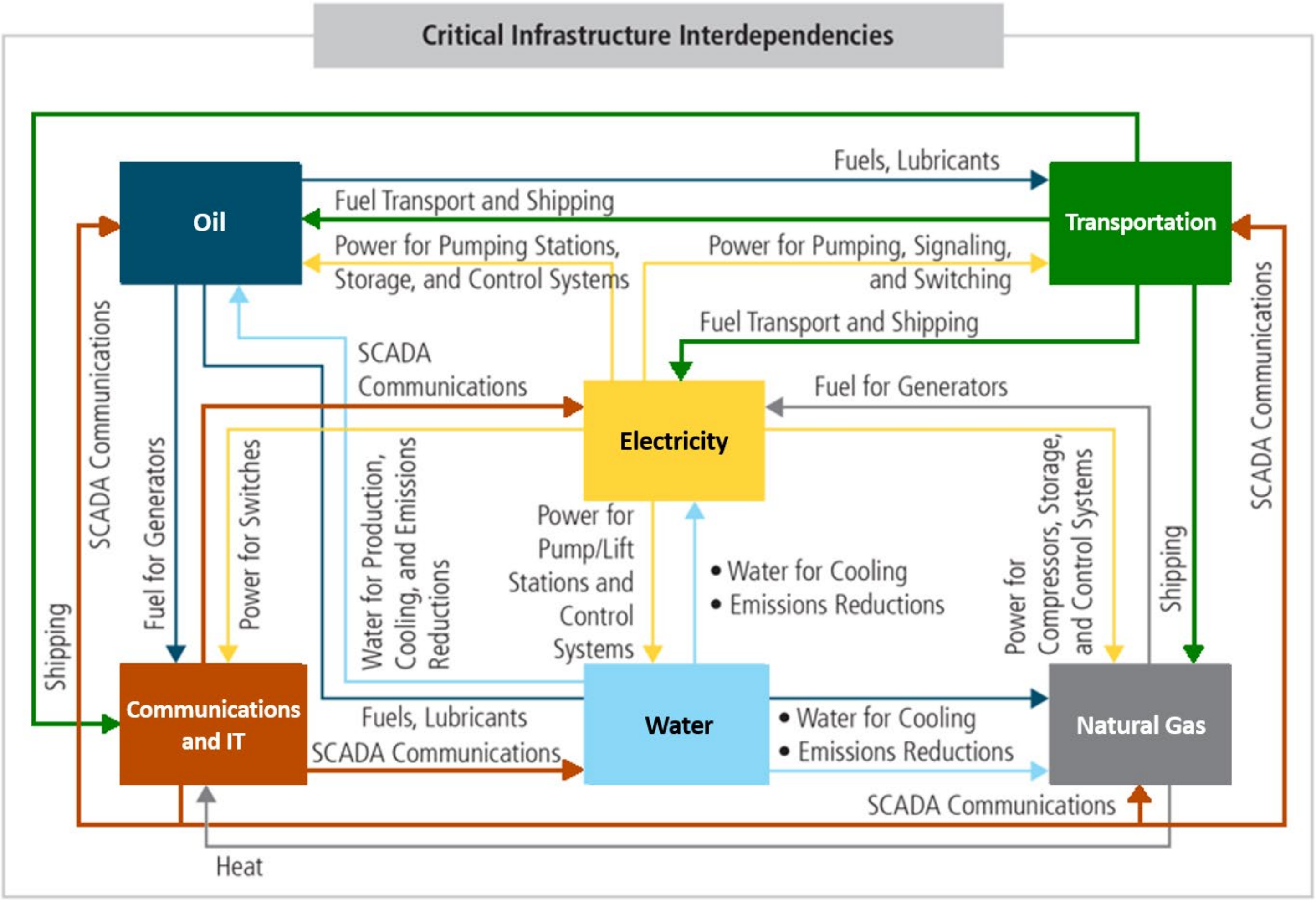
Argonne

Topic 2: Case Study: Ebola Outbreak

- **Build the Model** - analysts used agent-based modeling to display the social contacts of individuals (agents) throughout their day under thousands of different scenarios
- **Identify Optimal Interventions** - analysts were able to identify interventions that reduced the potential number of people affected in Chicago from millions to hundreds
- **Other Outcomes** - allowed the researchers to determine the existing capacity of care for potential Ebola patients, based on resources, space, and health care personnel.

- Think about where surgically timed and placed interventions could affect the entire system more effectively, including injections of information and resources.
- Assess interventions from a systems perspective. Small interventions can have big effects.
- Consider the whole system when making decisions to ensure that interventions benefit the system and move the system to a more desirable or more useful state.

Topic 3: Case Study: Critical Infrastructure Interdependencies



Topic 3: Case Study: Critical Infrastructure Interdependencies

Critical infrastructures, including oil, transportation, electricity, communications, water, and natural gas, are a complex adaptive system with many interdependencies.

Consider these two examples:

1. Natural gas is an important source of fuel for power generation and the natural gas system often relies on electric power to continue operating.
2. Electric power systems supply electricity for water pumps, which are necessary to bring water to a community, and water is also needed to cool electric power plants.

- Can you identify multiple systems in which you operate? Consider infrastructure and lifeline systems.
- What critical infrastructure interdependencies exist in your community? Use a network analysis or other visualization technique to map the interdependencies and identify the nodes, links, and flows to make sure you are ready to support response and recovery of these infrastructure systems after a disaster.

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