Complex Multidisciplinary R&D

Engaging With Big Science Problems

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• Systems Ethnography and Qualitative Modeling

• Ph.D. in Rhetoric—Rhetoric is the world’s second oldest method for deciding questions of qualitative uncertainty (The first oldest is the stone axe).

• Research Interests—Interdisciplinary decision making, How scientists use language to do science
Engaging With Big Science Problems

- Big Science—How is it different?
- Thinking about complex problems
- How we get our arms around big problems—Ethnographic methods as a way to begin quantification
- What are ethnographic methods and how are they useful?
The Scientific Method

- Linear progression through the steps
- Variables minimized and isolated
- Simple logic
- Traditional data
- This is the realm of the testable
Today’s Science is Different

• Problems More Complex
• Multi- & Interdisciplinary Work
• Technology Driving Expectations (which is good and bad)
• Science Drives at Decision Making
• Example: Genomics and Proteomics
Technology Push or Pull

Traditional Scientific Process

- New Idea/theory
  - Or
- New Question/Problem
  - Development of New Methodologies to Address a Question/Problem or Test a Theory/idea
  - Answers/Proof
  - Ability to Ask Tougher Questions

New Technology Can Emerge as a By-Product (means) of the Methodology
"What do we have to build to answer this question/test this theory?"

New Technology Can Emerge as Product (end) of Answered Question/Tested Theory

Technology-Driven Scientific Process

- New Technology
  - Ability to Ask Tougher Questions Plus Expectations that Tougher Questions Will be Answered
  - Identification of Previously Intractible Problems
  - Development of New Methodologies to Address These Problems
  - Development of Theories to Explain Results
Broader Decision Frame for Science

Decision Context and Objectives

Iterative Problem Refinement

Problem Definition

Qualitative Models

Qualitative Quantitative Mapping

Stat/Math Models

Data Sources

Community of Practice/Multiple Disciplines

Decision Making
What Is a “Problem”?

- Discrepancy between belief and experience (ought vs. is)
- Shifted decision frame
- Problem perceptions are local
- Exigency (relevance) must be communicated/argued to larger context
- Problems have to be rigorously and collaboratively defined
Smallpox Decision Frame

• Smallpox as Endemic Disease: eradication strategy, SIR models, effect on 3rd world population, homogeneous population modeling, public health issue, decision frame is established and static.

• Smallpox as Bioterrorist Weapon: prevention & response strategy? models? effect on modern urban population? heterogeneous population modeling, interdisciplinary issue, decision frame is new and dynamic.
What the Customer Needed to Know

Customer: MG Bruce Lawlor of the U.S. National Guard/Office of Homeland Security

Question: In the event of a bioterrorist attack,
• What response would be most effective?
• What personnel should be deployed?
• What functions would they need to perform?
• What materiel would they need to do their jobs?
• Where should they go?
Joining Different Perspectives

TranSims

- Exposed
  - Infection
  - No Infection
    - Develops to Clinical Case
      - Manifestation of Disease: A, B, C, D, E
      - Course of Disease
        - Recover
        - Die
    - Does Not Develop

- Victim Characteristics
- Contagiousness
What is a Complex Problem?

What do we mean by Complex?

• Not just Big?
• Not just Lots of Parts?
• Not just Multi-Faceted?
• Not just Logistically/Computationally Difficult
What is a Complex Problem?

What do we mean by Complex?

• Interdisciplinary: No single discipline has commanding authority over the “problem”
• Testing is expensive/impossible.
• Data sources are heterogeneous, nontraditional, and distributed
• Decision Frame is ill-defined
• Everyone working on small local piece of problem that needs to be integrated with the collective whole
• Examples: bioterrorism, global warming, national missile defense
“Multi-” vs. “Inter-” Disciplinary

• Multi-Disciplinary = People from different disciplines coming together to each do a separate part of a problem.

• Inter-Disciplinary = People from different disciplines having to integrate and synthesize their knowledge, understanding, skills, to solve a problem.

• Usually no tools or framework exists to facilitate Interdisciplinary work
“It will be necessary to carry out research in new ways. Some of the things that we must consider include how large research problems are articulated, how research teams are organized to address those problems, and how the results of these activities are propagated and evaluated.”
Socio-Technical Dimensions

• Complexity stems from interface of social/cultural/technical dimensions
• Problem is more than physical parts
• Problem context is highly relevant to performance
• System/Problem spans disciplines, organizations, status levels, and physical locations
• Examples: Stem Cells, National Missile Defense, Global Warming, Bioterrorism
The Approach

• Elicit experts knowledge on features and relationships—model structure
• Create basic graphical representations of that model structure and iterate them with the experts
• Evolve the graphical representations to a series of more formal logic-based representations
• Migrate the qualitative model to a quantitative model in collaboration with statisticians, mathematicians, scientists, engineers, economists, etc.
Modeling Smallpox as a Bioterrorist Agent

Plan A: Draw on concrete facts and valid test data that are well established in the scientific literature, and that answer the questions you need answered.

Plan B: Systems Ethnography & Qualitative Modeling
• Cull the useful data and information from the scientific literature
• Understand what this data and information tells you and what it doesn’t
• Seek Advisor Experts who can synthesize from the existing information to the needed information
• Iterate your models and parameter values with the experts until there is consensus.
Parameterizing the Model

Transmission Model
Is 6’ contact distance reasonable? Is exposure possible outside that circle? Is degree of exposure a factor? Is there just a requisite dose of smallpox for infection? Or does heavier exposure mean quicker/more severe/deadlier infection? Assume a person with standard smallpox at the peak of their contagiousness. An uninfected person enters their 6.5’ contact circle. What would be the minimum time needed for infection? What would be the average time? What would be the maximum time? How would these estimates differ for a person with standard smallpox at the least contagious time in their rash stage? How would these numbers differ for a person with hemorrhagic smallpox? Do we need to make a “late” – “early” hemorrhagic distinction? Are these reasonable ranges for the length disease stages? How would Hemorrhagic differ? When is death likely to occur? Ordinary smallpox: “10th to 16th day of illness”? Hemorrhagic: “5th or 6th day of rash”? Does infectiousness correspond roughly with rash stage? How does infectiousness vary over that stage? What important transmission factors are we missing? What accounts for the temperature fluctuations during course of disease? How do you quantify the “infectivity” in the consensus chart.

Disease Model
Are there natural age groupings we should use based upon how smallpox affects different age populations? Are people of different ages more/less susceptible? More/less likely to get ordinary or hemorrhagic? More/less likely to get infected but not develop smallpox? More/less likely to die? Are there differences between men and women: susceptibility, ordinary/hemorrhagic, infected but never sick, fatality? Are there differences for pregnant women: susceptibility, ordinary/hemorrhagic, infected but never sick, fatality? Are there differences for immunosuppressed people: susceptibility, ordinary/hemorrhagic, infected but never sick, fatality?

Outbreak Response Questions
With the type of contact tracing efforts outlined in the “CDC Interim Smallpox Response Plan and Guidelines” what percentage of actual contacts do you estimate workers will be able to locate? How many person hours are involved in contact identification and tracing? Identifying and surveilling “populations at risk”? How many days after an initial smallpox release do you think CDC will be on the ground starting contact tracing and vaccination? (time to detection + time to confirmation + time to mobilization + ? )? What percentage of vaccinations don’t “take”? How would the current vaccination profile in the U.S. affect mortality, morbidity, etc.? Why does post exposure vaccination reduce mortality? What is the mechanism?
The Ethnographic Perspective

- Thick Description—textual/discursive ordering of experience
- Participant observation—immersion
- Insiders, informants, advisor experts
- Qualitative not quantitative
- Understanding a culture in its own terms
- Iterating results with the subjects/participants
- Self-reflexive, self-conscious about cultural bias and perspective.
Qualitative Research Tools

Interview, Focused Discussion, Background Research, Teach Back, Construct Elicitation, Sorting Tasks, Laddering, Critiquing, Protocols, Role Playing, Simulations

Attempting to identify patterns and formalize tacit knowledge within and across the problem community.

References: Dan Diaper, *Knowledge Elicitation Principles, Techniques and Applications*
Nancy J. Cooke, *Varieties of Knowledge Elicitation Techniques*
Basic Graphical Methods

- Scratch Nets, Knowledge Maps
- A tool to spin up, cross boundaries, gain understanding, formalize tacit knowledge.
Example: Diagraming Expertise

Questions:
• What is the problem?
• What disciplinary communities are involved?
• What can I read as background material?
• What are the existing representations?
• What are the implied/tacit connections between existing representations?
• What are the important features of this problem?
• What are the relationships between features?
• Iterate: What’s missing? What’s wrong?
Value Added

• Need a way to learn, understand, and communicate about
  – the big picture and its parts
  – the relevance of you and your research
• Big, complex, interdisciplinary science isn’t your grandfather’s science
• Scratch nets and knowledge maps are good building blocks
References


