CENTER FOR COMPLEX SYSTEMS & ENTERPRISES

STEVENS INSTITUTE of TECHNOLOGY
THE INNOVATION UNIVERSITY

MODELING COMPLEX SOCIO-TECHNICAL ENTERPRISES

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Overview

- Complex Socio-Technical Systems
- Overall Methodology
- Thinking in Terms of Phenomena
- Abstraction, Aggregation & Representation
- Methodological Support
- Value of Immersion
- Example of Urban Resilience
- Summary

Complex Socio-Technical Systems

- Complex Public-Private Systems Laced with Behavioral and Social Phenomena in the Context of Physical and Organizational Systems, Both Natural and Designed
- Examples Being Pursued
  - Healthcare Delivery Systems
  - Sustainable Energy Networks
  - Financial Trading Systems
  - Coastal Urban Systems

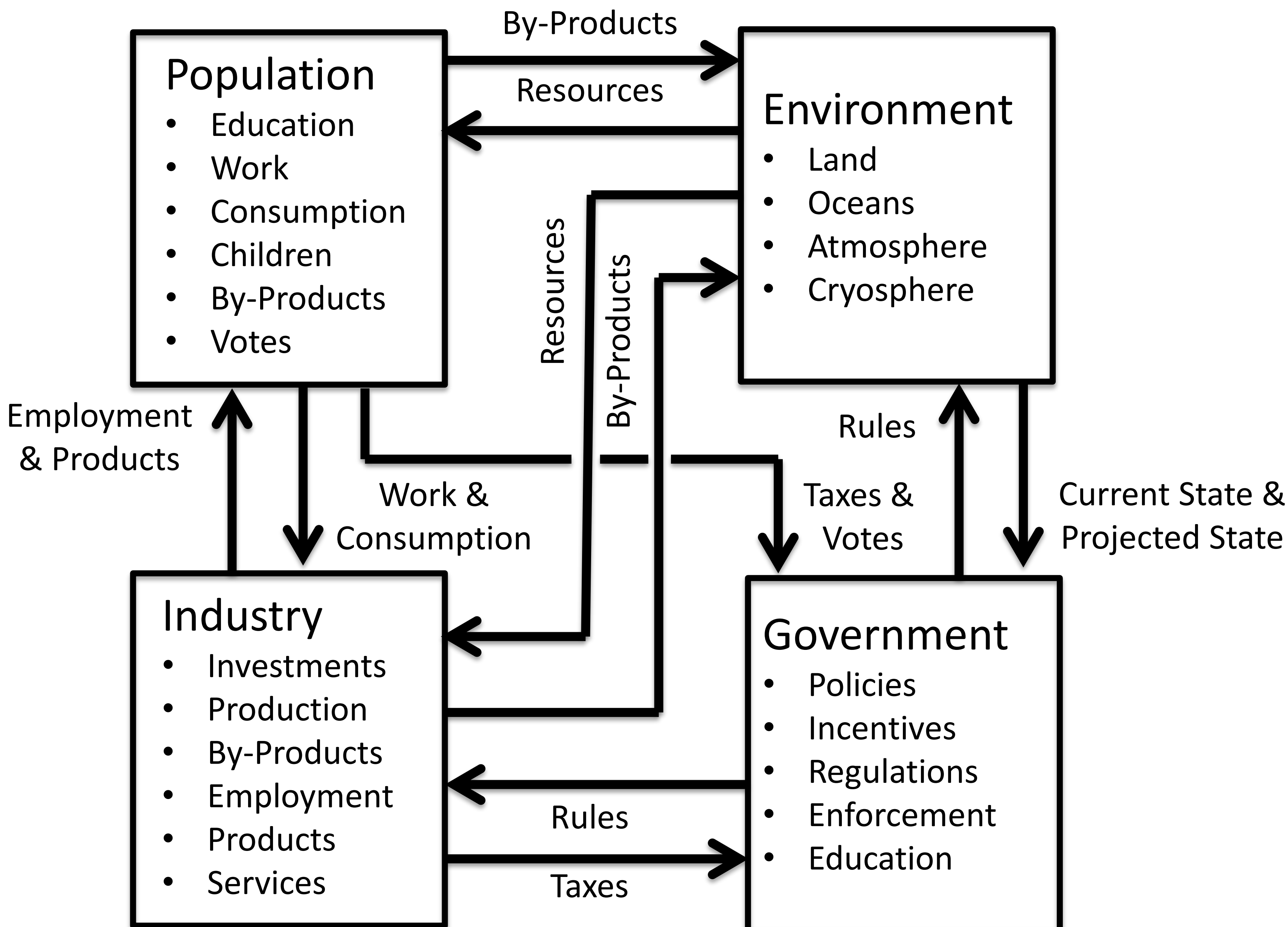
Overall Methodology

1. Decide on the Central Questions of Interest
2. Define Key Phenomena Underlying These Questions
3. Develop One or More Visualizations of Relationships Among Phenomena
4. Determine Key Tradeoffs That Appear to Warrant Deeper Exploration
5. Identify Alternative Representations of These Phenomena
6. Assess the Ability to Connect Alternative Representations
7. Determine a Consistent Set of Assumptions
8. Identify Data Sets to Support Parameterization
9. Program and Verify Computational Instantiations
10. Validate Model Predictions, at Least Against Baseline Data

Thinking in Terms of Phenomena

- Rule Setting
  - Incentives – Behaviors Rewarded
  - Inhibitions – Behaviors Penalized
- Resource Allocation
  - Money, Time, Capacities
  - Attention -- Displays, Signals, Routes,
- State Transitions
  - Position, Velocity, Acceleration
  - Solid, Liquid, Gas
  - Incidence, Progression, Queues
- Flow of Resources
  - People, Materials, Vehicles
  - Energy, Information
  - Laminar, Turbulent, Congested
- Task Performance
  - Execution, Monitoring, Control
  - Detection, Diagnosis, Compensation

Earth as a System



Abstraction Hierarchy

(After Rasmussen)

- Functional Purpose
  - Objectives, constraints
- Abstract Purpose
  - Causal structure, mass, energy information flow
- Generalized Functions
  - Processes, feedback loops, heat & mass transfer
- Physical Functions
  - Electrical, mechanical, chemical processes
- Physical Form
  - Appearance, anatomy, location

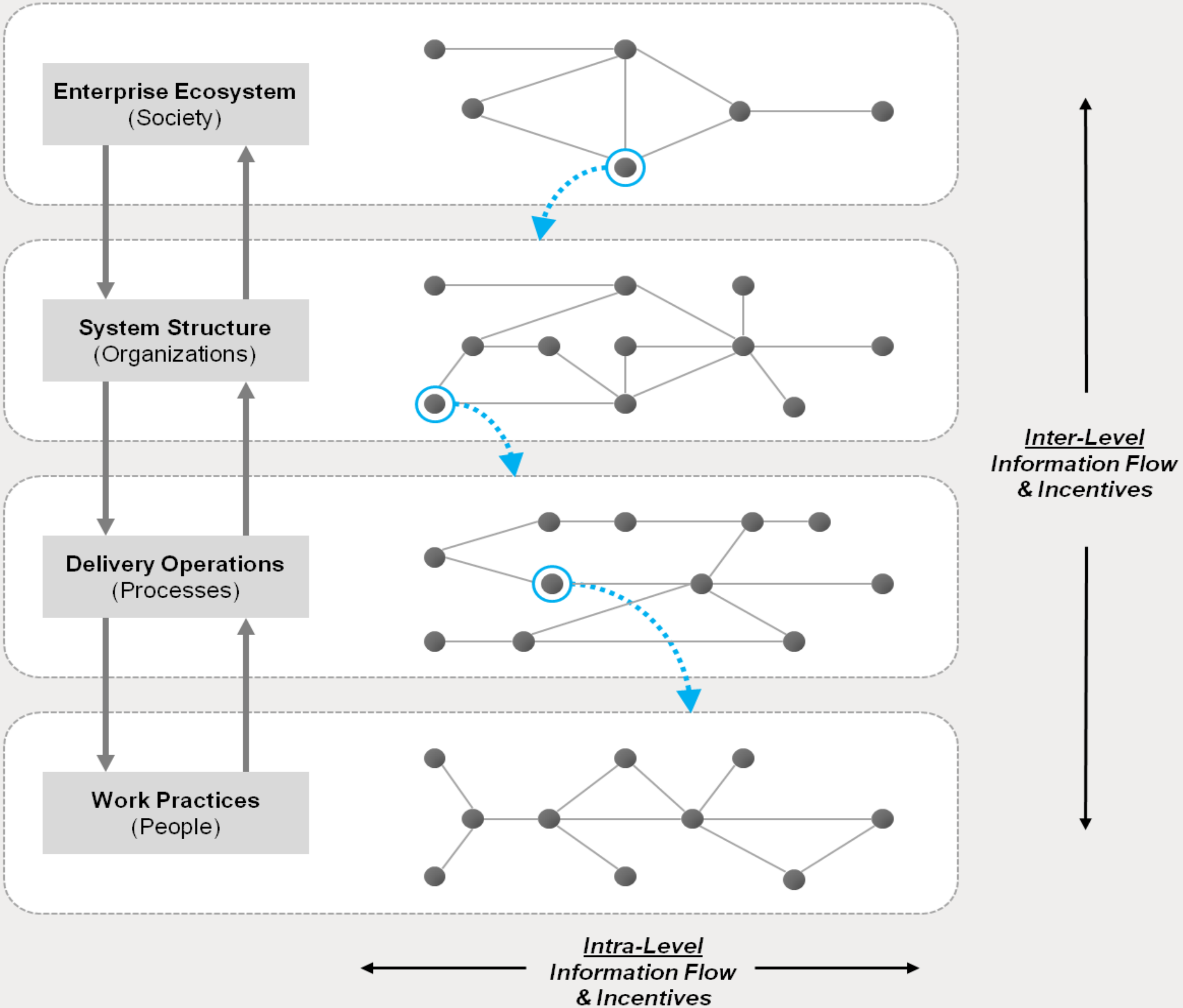
Aggregation Hierarchy

- Systems of Systems
- Systems
- Subsystems
- Assemblies
- Components
- Parts

- All People
- All Patients
- Populations of Patients
- Cohorts of Patients
- Individual Patients

Abstraction & Aggregation

	Level of Aggregation	
Level of Abstraction	Highly Disaggregated	Highly Aggregated
Ecosystem	Each regulator Each payer	Government All payers
Organizations	Each provider Each clinician practice	All providers All clinician practices
Processes	Each operating room Each imaging capability	Operating room capacity Imaging capacity
People	Individual clinicians Individual patients	All clinicians in a specialty Cohorts of similar patients


Enterprise Ecosystem
(Society)
System Structure
(Organizations)
Delivery Operations
(Processes)
Work Practices
(People)
Inter-Level
Information Flow
& Incentives
Intra-Level
Information Flow
& Incentives

Representations

Level	Phenomena	Models
Ecosystem	GDP, Supply/Demand, Policy	Macroeconomic
	Economic Cycles	System Dynamics
	Intra-Firm Relations, Competition	Network Models
Organizations	Profit Maximization	Microeconomic
	Competition	Game Theory
	Investment	DCF, Options
Processes	People, Material Flow	Discrete-Event Models
	Process Efficiency	Learning Models
	Workflow	Network Models
People	Consumer Behavior	Agent-Based Models
	Risk Aversion	Utility Models
	Perception Progression	Markov, Bayes Models

Methodological Support

- An interactive environment that supports the set of nominal steps outlined above.
  - Steps are “nominal” in that users are not required to follow them.
  - Advice is provided in terms of explanations of each step and recommendations for methods and tools that might be of use.
- Compilations of physical, organizational, economic and political phenomena are available
  - Includes standard representations of these phenomena, in terms of equations, curves, surfaces, etc.
  - Advice is provided in terms of variable definitions, units of measure, etc., as well typical approximations, corrections, etc.
  - Advice is provided on how to meaningfully connect different representations of phenomena.

Support – Cont.

- Visualization tools are available, including block diagrams, IDEF, influence diagrams, and systemograms.
- Software tools for computational representations are recommended
  - Emphasis is on commercial off-the-shelf platforms that allow input from and export to, for example, Microsoft Excel and Matlab.
  - Examples include AnyLogic, NetLogo, Repast, Simio, Stella, and Vensim.
- Support is not embodied in a monolithic software application.
- Framework operates as fairly slim application that assumes users have access to rich and varied toolsets elsewhere on their desktops.
  - Support provides structured guidance on how to best use this toolset.
- Model development occurs within the confines of one or more desktops or laptops.
- Capabilities to export interactive visualizations to much more immersive simulation settings.

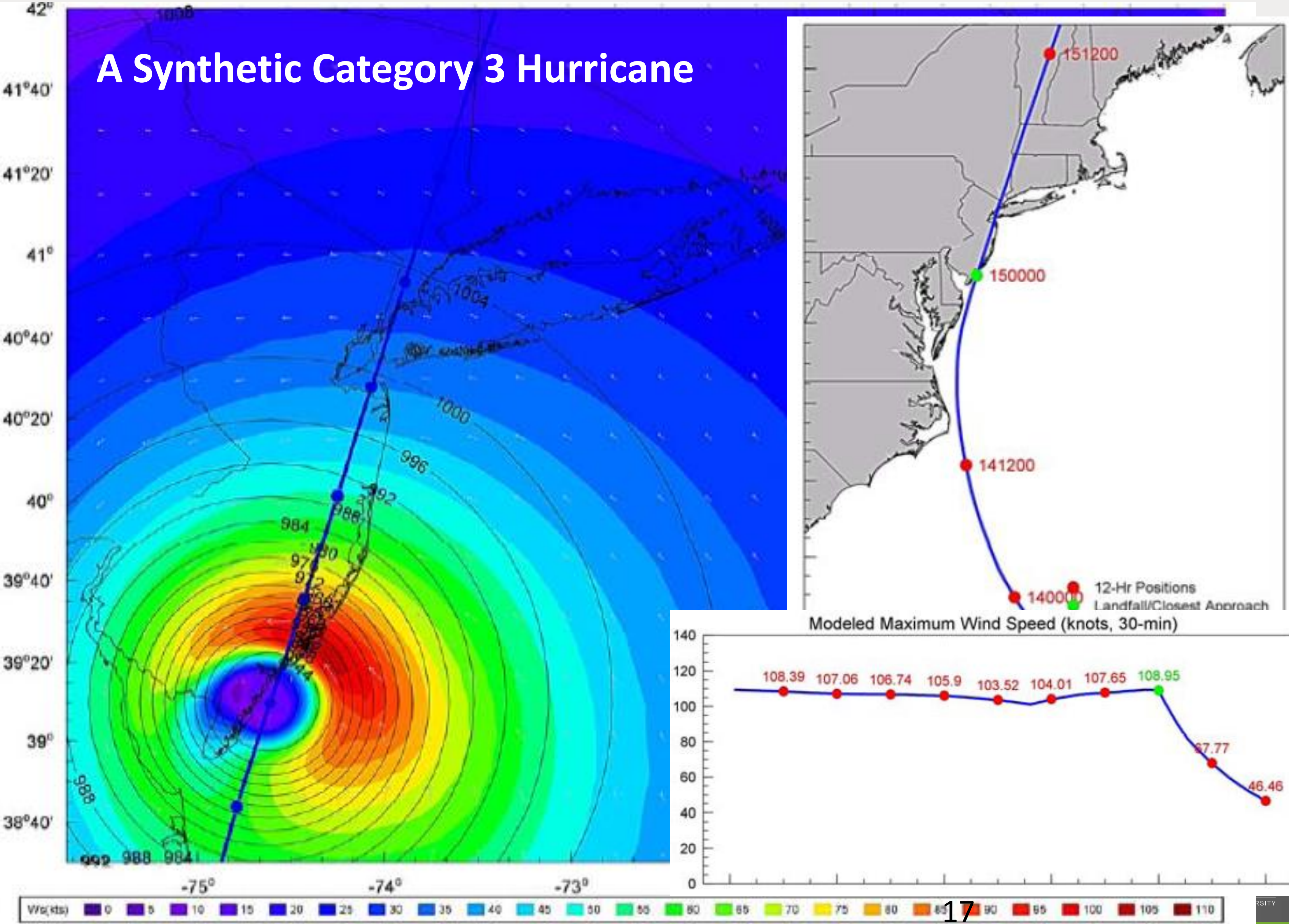
Value of Immersion

- Many of the phenomena in our critical public-private systems are very complex and becoming more so.
- Many of the key stakeholders in these systems are not technically sophisticated yet they have enormous influence on outcomes.
- These stakeholders can be engaged and influenced by being immersed in the complexity of their domain.
- The ***Immersion Lab*** attracts key stakeholders and sponsors – many report that they did not realize what they experienced was possible.

Virtual Antarctica

New York City & Long Island

A Synthetic Category 3 Hurricane



Mantoloking, NJ

Hoboken, NJ

Research Questions

- Where will the water be?
  - What streets? What depth? When?
- How will the urban infrastructure react?
  - Transportation, energy, food, water, etc.?
- What will be people's perceptions, expectations, and intentions?
  - Government decision makers
  - Industry decision makers
  - Population in general

People's Questions

- At First
  - What is happening?
  - What is likely to happen?
  - What do others think?
- Somewhat Later
  - Will we have power, transportation?
  - Will we have food and water?
  - What do others think?
- Further On
  - Where should we go?
  - How can we get there?
  - What are others doing?

Fundamental Issues

- Creating valid and useful combinations of
  - Partial differential equation models of water flow
  - Network models of urban infrastructures
  - Agent-based models of population response
- Accounting for information sharing among members of the population
- Incorporating real-time sensing, including tweets, to update predictions as situations evolve
- Creating immersive decision support systems for government and industry decision makers

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