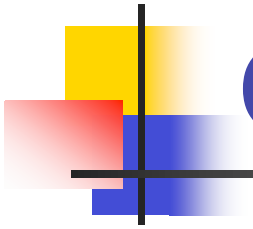
Systems Perspectives

William B. Rouse

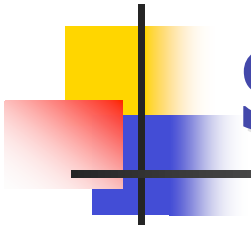
School of Industrial & Systems Engineering

Georgia Institute of Technology



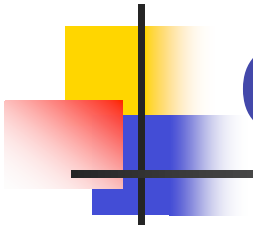
Overview

- Definitions
- Views of Systems
- Contrasting Views
- Spanning Issues
- Systems Research
- Systems Portfolio



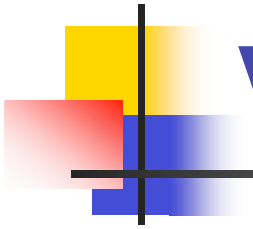
System

System: A group or combination of interrelated, interdependent, or interacting elements that form a collective entity. Elements may include physical, behavioral, or symbolic entities. Elements may interact physically, mathematically, and/or by exchange of information. Systems tend to have purposes, although in some cases the observer ascribes such purposes.



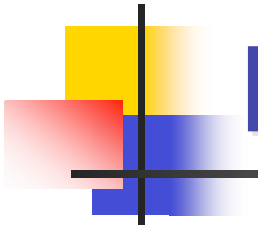
Complex System

Complex System: A system whose perceived complicated behaviors can be attributed to one or more of the following characteristics: large numbers of elements, large numbers of relationships among elements, nonlinear and discontinuous relationships, and uncertain characteristics of elements and relationships. Complexity is perceived because apparent complexity can decrease with learning.



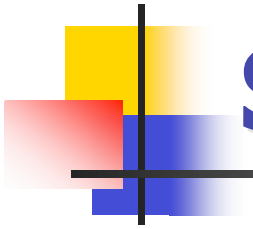
Views of Systems

- Hierarchical Mappings
- Uncertain State Equations
- Discontinuous, Nonlinear Mechanisms
- Autonomous Agents



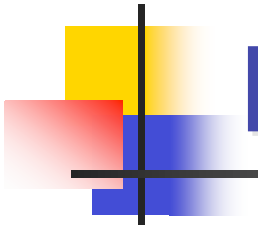
Hierarchical Mappings

- Systems engineering = Processes for designing, developing, deploying, and sustaining complex systems
- Hierarchical decomposition of a very complicated design task into component tasks
- Management of the execution of these tasks and integration of task outcomes
- Complexity typically due to large numbers of interacting elements
- A large number of reasonably straightforward tasks whose outcomes will flow together to create a successful complex system
- Appropriate resolution of multi-attribute tradeoffs across multiple stakeholders
- Complexity managed by dividing and conquering it



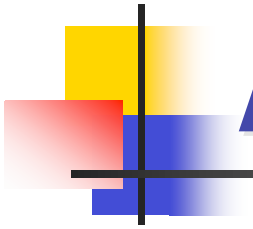
State Equations

- Systems engineering = Design of mechanisms whereby the “state” evolves affecting system response and stability
- Central design issue is nature of appropriate feedback mechanisms for controlling system state
- Observability and controllability are key constructs; optimization of control often an overriding goal
- Inabilities to fully specify state-transition mechanisms & uncertainties limit formulation to constrained optimality.
- Formal depiction and manipulation of mechanisms underlying complex behaviors seldom “scale up”
- Complexity due to large numbers of state variables and significant levels of uncertainty
- Pursuit of optimal control solutions often made possible by assumptions of linearity



Nonlinear Mechanisms

- Simple underlying phenomena yield complex behaviors for systems with very few elements, perhaps even just one element with particular interaction terms
- Nonlinear and/or discontinuous nature of the elements lead to behaviors labeled as catastrophes, chaos, etc.
- Systems that appear simple can produce very complex behaviors; complex phenomena may be attributable to simple mechanisms.
- Complexity due to departures from our expectations of continuous, linear phenomena
- Understand complexity by exploring underlying mechanisms which may lead to design solutions.
- Formal systems approaches tend to flounder when addressing fairly small numbers of nonlinear mechanisms

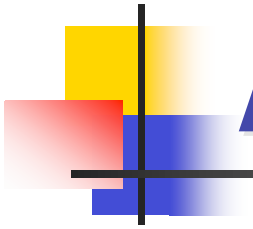


Autonomous Agents

- Composition of large numbers of simple behaviors into overall system behaviors that exhibit hallmark characteristics of complex systems
- Simple behaviors created by autonomous “agents” acting independently in pursuit of their individual goals
- Reactions of agents to each other’s behaviors result in emergent phenomena that could not have been predicted by dissecting individual agents.
- Understanding the nature of incentives, motivations, and prohibitions that will influence individual agents to contribute to creating desirable collective behaviors
- Understanding and managing complexity are experimental rather than axiomatic undertakings
- Many things can be demonstrated but few can be proven

Contrasting Views

No.	View	Approach	Focus
1	Hierarchical Mappings	Design decomposition	Engineering solutions
2	State Equations	Axiomatic derivation	Control performance
3	Nonlinear Mechanisms	Behavior demonstration	Basis of complexity
4	Autonomous agents	Empirical assessment	Emergent behaviors

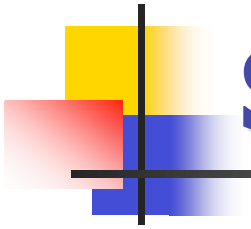


An Example

- Effects of turbulent flow on aerodynamic behavior and vehicle performance in high-density traffic
  - View No. 1 for designing the vehicle
  - View No. 2 to explore vehicle dynamics
  - View No. 3 to model the turbulence
  - View No. 4 to understand traffic effects
- Problem, e.g., poor vehicle handling qualities vs. traffic congestion problems

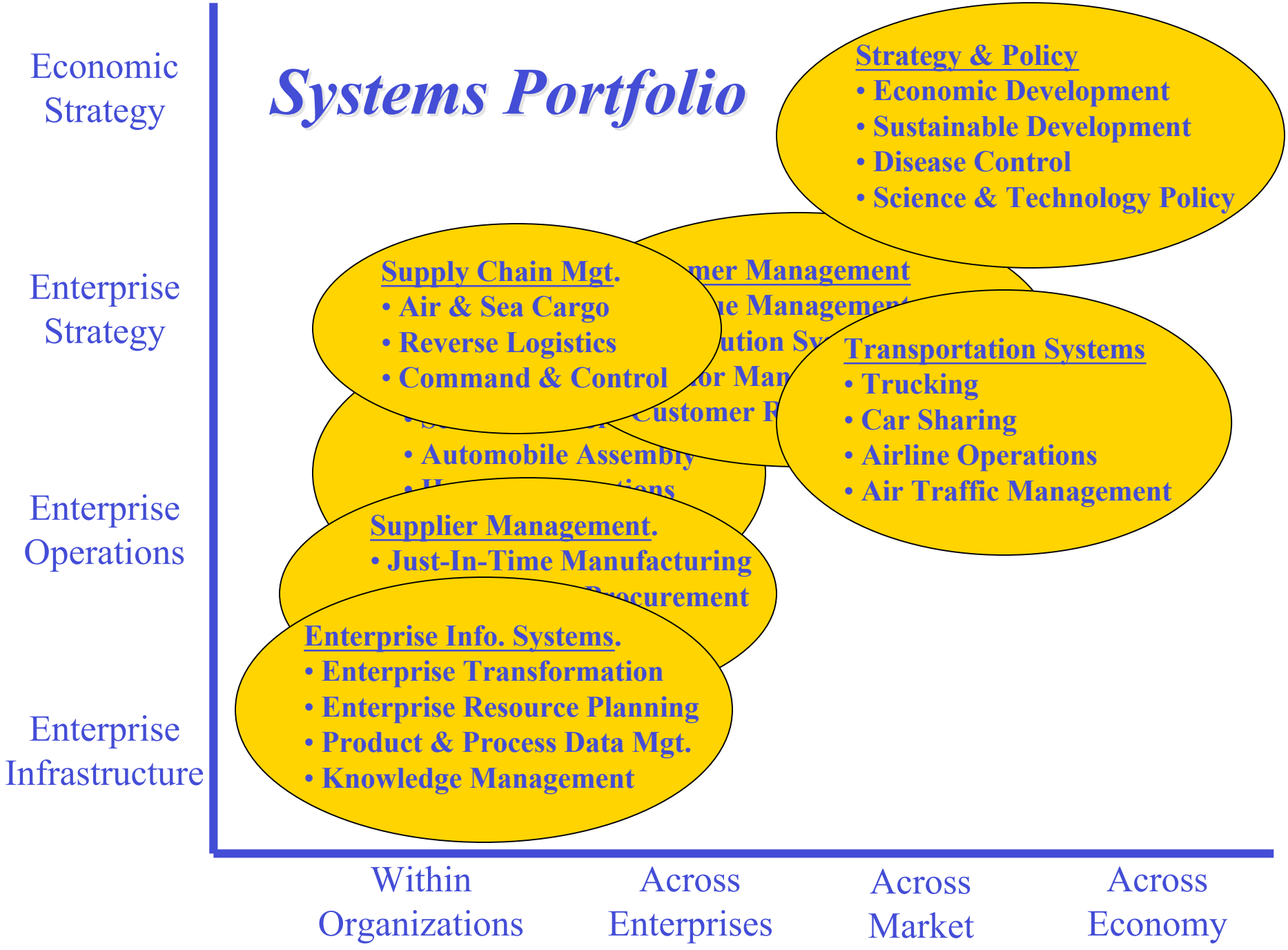
Spanning Issues

	Nature & Flow of Information	Decision Making & Control	Representation of Human Behavior
Hierarchical Mappings	State & Design Information	Decision Making & Decision Support	Human Control, Design & Develop
State Equations	State Information	Prescriptive Control Strategies	In-The-Loop Control
Nonlinear Mechanisms	State Information	Prescriptive Control Strategies	In-The-Loop Control
Autonomous agents	Bottom-Up Communications	Elementary Strategies	Individual Behaviors

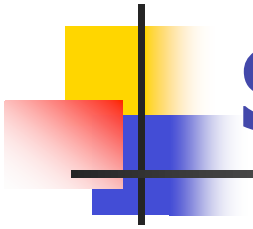


Systems Research

- Exploring, understanding, and designing how views fit together
- Creation of means for translating among representations of views
- Formulation of an “architecture” of knowledge across views


Systems Portfolio
Economic Strategy
Enterprise Strategy
Enterprise Operations
Enterprise Infrastructure
Strategy & Policy
• Economic Development
• Sustainable Development
• Disease Control
• Science & Technology Policy
Supply Chain Mgt.
• Air & Sea Cargo
• Reverse Logistics
• Command & Control
Transportation Systems
• Trucking
• Car Sharing
• Airline Operations
• Air Traffic Management
Supplier Management.
• Just-In-Time Manufacturing
Enterprise Info. Systems.
• Enterprise Transformation
• Enterprise Resource Planning
• Product & Process Data Mgt.
• Knowledge Management
Within Organizations
Across Enterprises
Across Market
Across Economy

Tennenbaum Institute for Enterprise Transformation



Summary

- Definitions
- Views of Systems
- Contrasting Views
- Spanning Issues
- Systems Research
- Systems Portfolio