Systems Basics: Roots of the Systems Movement

(And Branches)

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International Society for the Systems Sciences
San Jose, California; July 16, 2012
Historical Context

- Late 19th/Early 20th Century Developments
- Industrial Revolution
- World War
- Information Technology
- Management Science
- Behavioral Sciences
- Theoretical Biology
Branches on the Systems Tree

As envisioned by Ludwig von Bertalanffy
“Father of General System Theory”

• Systems Technology
• Systems Science
• Systems Philosophy
What about Systems Practice?
Another Perspective

<table>
<thead>
<tr>
<th>Science</th>
<th>Humanities</th>
<th>Design</th>
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<tbody>
<tr>
<td>Natural World</td>
<td>Human Experience</td>
<td>Man-Made World</td>
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<tr>
<td>Objectivity</td>
<td>Subjectivity</td>
<td>Practicality</td>
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<tr>
<td>Rationality</td>
<td>Ethical Considerations</td>
<td>Innovation Synthesis</td>
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<tr>
<td>Analysis</td>
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From Cross, 2001; Laszlo, 2007; Singer, 2012
19th Century Roots

Physical Science:
Thermodynamics - closed systems, entropy

Biological Science:
Claude Bernard - milieu intérieur
(homeostasis)

Philosophy:
Charles Sanders Peirce - logic, semiotics, pragmatism

1886 - logical operations/electrical switching circuits
basis of digital computers

William James - physiology, psychology, pragmatism
Early 20th Century

Physical Science/Mathematics/Technology
Albert Einstein – theory of relativity
Alan Turing – theory of computing, 1930s
   Formal algorithms; Turing Machine

Biological Science:
Lawrence Henderson, *The Fitness of the Environment*, 1913

Philosophy:
Henri Bergson, *Creative Evolution*, 1907
Metaphors of Organization in Living Systems

Mechanistic – 18th c.
Reductionist, deterministic, predictable
La Mettrie, *L’homme Machine*
Smith, *Wealth of Nations*

Organismic – 19th c.
Emergent properties of biological organisms
Spencer, society as an organism
Clements, organismic model in ecology
Organismic Biology
Three Schools of Thought

France/USA: Bernard, Cannon, Henderson
Focus on homeostasis

England: The Theoretical Biology Group
Mathematical orientation

Germany: Kohler, Weiss, Bertalanffy
Thermodynamics, open systems
Emergence of Systems Metaphor

Characteristics:
✧ emergence, holism, complexity, hierarchy
✧ relationship between system and environment
✧ creativity, innovation, adaptability

Examples:
✧ Bertalanffy, theoretical biology, 1940
✧ Tansley, ecosystem concept, 1935
✧ Parsons, social system theory, 1950s
✧ Miller, living system theory, 1970s
What is a System?

“A set of two or more interrelated elements with the following properties:

1. Each element has an effect on the functioning of the whole.
2. Each element is affected by at least one other element in the system.
3. All possible subgroups of elements also have the first two properties.

From Ackoff, *Creating the Corporate Future*  
With thanks to Alexander & Kathia Laszlo
Systems Science & Philosophy: Some Key Themes

From Martin Ruzek, Universities Space Research Association
Systems Science

• Response to Limitations of Mechanistic Science

• Emphasis on Relationship Between Component Parts of a System

• Consideration of Context or Larger Environment

• More Holistic and Humanistic Approach to Knowledge and Practice

• Unity of Science
Systems Philosophy

Reorientation in Worldview

Holistic, Ecological, Integrative

Emphasize Organized Nature of Reality

“Possibly the model of the world as a great organization can help to reinforce the sense of reverence for the living which we have almost lost.”

-- Ludwig von Bertalanffy
Systems Ontology

Emphasize Organization, Interaction, Interdependence, and Relationship

Shift from Mechanistic to Organic Conception of Nature

Shift from Atomistic & Dualistic Orientation to Networks, Patterns, and Processes of Relationship
Systems Epistemology

Dynamic and Dialectical Nature of Knowledge

Importance of Perception, Interpretation, and Creation of Meaning

Involvement of Observer in Process of Observation

Importance of Multiple Perspectives

“No Experts in the Systems Approach”
Knowledge as Active Process

Dialectical, Pluralistic, and Participatory

"Apart from inquiry, apart from the praxis, individuals cannot be truly human.

Knowledge emerges only through invention and reinvention, through the restless impatient continuing, hopeful inquiry human beings pursue in the world, with the world and with each other."

-- Paulo Friere
Ethics of Systemic Practice

From Control to Collaboration

From Competition to Interdependence

From Hierarchical to Participatory Decision-Making Processes

From Objectivity to Subjectivity and Reflexive Self-Awareness
Schools of Thought
Within the Systems Movement

Cybernetics

General System Theory

System Dynamics

Complexity & Chaos Theory
Foundations of Cybernetics I

Information & Communication

Leo Szilard, information distinct from matter/energy, 1929

Shannon and Weaver, mathematical theory of information, 1949

Von Neumann, 1946 architecture of computers
Foundations of Cybernetics II

Rosenblueth, Wiener and Bigelow, “Behavior, Purpose and Teleology,” 1943

“All purposive behavior may be considered to require negative feedback”

McCulloch and Pitts, neural networks, 1943
Macy Conferences, 1946-1953

Brought together researchers from computer science, neurophysiology, and the social sciences

Inspired developments in artificial intelligence and cognitive science

Other Participants:
Wiener, Bateson, Mead, Lewin, Gerard
It is the thesis of this book that society can only be understood through a study of the messages and communication facilities which belong to it; and that in the future development of these messages and communication facilities, messages between man and machines, between machines and man, and between machine and machine, are destined to play an every-increasing part.
Further Development

Ashby, *Design for a Brain*, 1954

Law of requisite variety: the available control variety must be equal to or greater than the disturbance variety for control to be possible.

Beer, *Cybernetics and Management*, 1959

*The Brain of the Firm*, 1972

Cybernetics: the science of effective organization

Cybernetics studies the flow of information round a system, and the way in which this information is used by the system as a means of controlling itself.
Second Order Cybernetics

Bateson, *Steps to an Ecology of Mind*, 1972
*Mind and Nature*, 1979

“Cybernetics is the study of form and pattern”

Von Foerster, *Cybernetics of Cybernetics*, 1974

Observer
Integral
Part of
System
Being
Observed

From Learning Space, Open University, UK
System Dynamics


System Dynamics:
Grounded in electrical engineering
Modeled on electrical circuitry

Forrester, *Industrial Dynamics*, 1961
Positive and Negative Feedback Loops: Balancing and Reinforcing

From Fiksel, “Sustainability & Resilience,” 2006
System Dynamics Contributions

Thinking dynamically

From events and decisions to patterns of behavior over time

Thinking in circular causal (feedback) patterns

Self-reinforcing and self-balancing processes

Communicating complex nonlinear system structure

Thinking in terms of stocks and flows

Modeling and simulation

Articulating complexity of interdependencies in system

Allowing for experiment and reflection

From Richardson, *Feedback Thought in Social Science and Systems Theory*
Six Traditions Contributing to the Evolution of Feedback Thought

- Biology: math models
- Econometrics
- Engineering
- Social Sciences
- Biology: homeostasis
- Logic

Two Threads of Feedback Thought

System dynamics evolves from the servomechanisms thread

From Richardson, *Feedback Thought*
## Two Strands of Feedback Thought

<table>
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<tr>
<th>Servomechanism</th>
<th>Cybernetics</th>
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<tbody>
<tr>
<td>Control Engineering</td>
<td>Communications Engineering</td>
</tr>
<tr>
<td>Role of Feedback in Dynamic Behavior</td>
<td>Role of Feedback in Communication and Control</td>
</tr>
<tr>
<td>Emphasize Structure of Internal Processes</td>
<td>Emphasize Behavior: Black Box</td>
</tr>
<tr>
<td>Endogenous: Source of Behavior Inside</td>
<td>Exogenous: Subject to External Forces</td>
</tr>
<tr>
<td>Feedback as Intrinsic Part of Real System Not Just</td>
<td>Feedback as Transmission of Information: Message Loops Related to Self-Reference</td>
</tr>
<tr>
<td>Mechanism of Control</td>
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General System Theory

Bertalanffy introduced the term in a seminar at the University of Chicago in 1939

*Robots, Men and Minds*, 1967


- Inadequacy of classical physics for explanations in biology, psychology and sociology
- Open systems – dynamic steady state, not equilibrium
- Living systems as self-organizing systems
- Isomorphisms: universal principles applying to systems in general
University of Chicago
Behavioral Science Committee

Ralph Gerard
Neurophysiology
Macy Conferences
“Grandfather of Prozac”

James Grier Miller
Behavioral Science
Living Systems, 1978

Anatol Rapoport
Mathematical Biology
Neural Networks
Game Theory, Semantics
Peace Research
Living Systems Theory

7 levels of living systems:
cell, organ, organism, group, organization, community, society, supranational system

Subsystems that process both matter/energy & information:
reproducer, boundary

Subsystems that process matter/energy:
ingestor, distributor, converter, producer, storage, extruder, motor, supporter

Subsystems that process information:
input transducer, internal transducer, channel & net, timer, decoder, associator, memory, decider, encoder, output transducer
“Imagine a place where great minds of every generation come to reflect on the critical problems of our time. A place where rising stars and distinguished scholars from many fields collaborate in unexpected ways. A place where innovative thinkers step outside the boundaries, challenge old assumptions, and seek answers to questions that will change the world in which we live.”
Kenneth Boulding

Ecological Economics
Importance of Dialogue in Decision Making
Peace and Conflict Studies

Organizational Revolution, 1953
The Image, 1956
Three Faces of Power, 1989
Boulding’s Nine System Levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Description</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frameworks</td>
<td>Static Structures</td>
<td>Anatomical Relationships</td>
</tr>
<tr>
<td>Clockworks</td>
<td>Simple Dynamic Systems</td>
<td>Predetermined Motions</td>
</tr>
<tr>
<td>Thermostats</td>
<td>Cybernetic Control Mechanisms</td>
<td>Transmission and Interpretation of Information</td>
</tr>
<tr>
<td>Open Systems</td>
<td>Self-Maintaining</td>
<td>Life; Capacity for Learning</td>
</tr>
<tr>
<td>Plants</td>
<td>Growth Systems</td>
<td>Division of Labor, Equifinality</td>
</tr>
<tr>
<td>Animals</td>
<td>Aware Systems</td>
<td>Mobility, Teleology</td>
</tr>
<tr>
<td>Humans</td>
<td>Self-Conscious Systems</td>
<td>Language/symbolism</td>
</tr>
<tr>
<td>Symbolic Systems</td>
<td>Systems of Meaning</td>
<td>Product of Human Consciousness</td>
</tr>
<tr>
<td>Social Systems</td>
<td>Relationships of Power, Exchange and Cooperation</td>
<td>Socially Constructed; Conscious Design</td>
</tr>
</tbody>
</table>
If there's an answer, then its basis
Must lie in Higher Homeostasis,
For evolution will not come
To simple equilibrium.

So Man, as critic and creator
Must regulate his regulator,
And even take a higher station
To regulate his regulation.

From “Human History in a Nutshell”
Complexity/Chaos Theory

Computer simulation ushers in a new kind of science:

Cellular Automata, 1940s
  Von Neumann, Wiener, Rosenblueth

Butterfly Effect, 1972
  Lorenz, weather prediction, 1961

Genetic Algorithms, 1960s

Fractal Geometry
  Mandelbrot set, 1978
Recent Developments

Santa Fe Institute, Founded 1984

- By Murray Gell-Mann, George Cowan and others from Los Alamos Labs
- To study complex adaptive systems, agent-based modeling, network theory, artificial life
- Explore tendency of complex systems to organize themselves into patterns
- "Order at the edge of chaos"
A Few References

Prigogine, *Order Out of Chaos*, 1984
- Self-organizing systems
- Dissipative structures


Systems Technology/Practice

Systems Engineering
Bell Telephone Labs 1940s ➔ DOD/NASA
Design, development, production and operation of large complex physical systems
Includes technical and management processes
NCOSE: 1990/INCOSE: 1995

Systems Analysis
Rand Corporation, Robert McNamara
Feasibility, cost/benefit, improved decision making
Operations Research ➔ Management Science

Roots in mid-19th c. (Charles Babbage)

Emerged as distinct field in WWII:
Early warning radar system (A.P. Rowe)

Mathematical modeling, statistical analysis, optimization under constraints

Human-technology interaction

Russell Ackoff, West Churchman, Stafford Beer
From Hard to Soft Systems

Roots in Action Research, Kurt Lewin, 1944
Tavistock Institute for Human Relations, 1947
University of Lancaster
   E. Mumford, “participative approach” 1960s
   Jenkins, Wilson, Checkland, 1966-1969
Trist & Emery, participatory design workshops, 1970s
Ackoff & Emery, On Purposeful Systems (1972)
Checkland, Systems Thinking, Systems Practice (1981)

Address limitations of systems engineering in situations with divergent perspectives on what constitutes “problem”
Engage stakeholders in interactive inquiry
Getting to Unified Systems Praxis

Systems Science
---System Patterns---
Theory
Systems Praxis
---Praxis Patterns---
Systems Engineering
Action
Systems Intervention

Intervention

Quantitative evaluation

“Hard” Systems Approaches

Continuum

Qualitative evaluation

“Soft” Systems Approaches

From IFSR Team 4: Toward a Common Language for Systems Practice
Structure and Culture as Components of Organization

**Structures**
- Functions/processes
- Work roles
- Responsibilities
- Lines of Authority
- Accountability
- Physical plant

**Culture**
- Organizational Values
- Definition of leadership
- Beliefs about people
- Habits of speech
- Dress norms
- Reward/punishment
- Defensive patterns

From Reckmeyer, A Systems Approach to Leadership
Systems Design

Churchman, Design of Inquiring Systems, 1971

Ackoff, Redesigning the Future, 1974


Banathy, Designing Social Systems in a Changing World, 1996
Critical Systems Theory


Midgley, *Systemic intervention*, 2000
Challenges Confronting the Systems Field

- Meaning and Motivation in a World of Multiple Values
- Empowerment and Emancipation in a World of Inequality

-- Mike Jackson
ISSS, Cancun, Mexico, 2005
Contributions of the Systems Approach

• Overcome Fragmentation of Knowledge
• Strengthen Connections Between Human and Natural Systems
• Nurture Inclusive and Democratic Approaches to Decision Making
• Support Integrated Education and the Cultivation of Skills in Dialogue and Collaboration