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# Four Decades of Systems Science Teaching and Research at PSU

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# Four Decades of Systems Science Teaching and Research in the USA at Portland State University

**Systems Science Seminar, 10/10/14**
**Wayne Wakeland, PhD**
**Professor and SySc Program Chair**

# Systems Science

- The study of general principles that govern systems of widely differing types

- Use of systems ideas and methods in interdisciplinary / transdisciplinary research and for socio-technical system design and management

# Some History

- 1956
  - International Society for the Systems Sciences founded
  - System dynamics established as a new field
- 1967
  - First Hawaii International Conference on Systems Sciences
- 1970
  - International Journal of Systems Science
- 1976
  - First System Dynamics conference

# Growing Recognition

- Interdisciplinary approaches are needed to solve complex problems

- Understanding complex systems is central to advances in science, engineering, real-world problem solving, and interdisciplinary research

# Example Systems-Oriented Research Institutes

| Name | Focus | Founded | Location |
|------|-------|---------|----------|
| **International Institute for Applied Systems Analysis** | Policy-oriented global problems | 1972 | Vienna, Austria |
| **Santa Fe Institute** | Complex adaptive systems | 1984 | Santa Fe, NM, USA |
| **New England Complex Systems Institute** | Complex systems | 1996 | Cambridge, MA, USA |
| **Max Plank Institute for Dynamics and Self Organization** | Complex, self-organizing systems | 2003 | Gottingen, Germany |
| **ARC Centre for Complex Systems** | Complex systems | 2004 | Australia |

# Systems Science PhD Program

- Launched in 1970
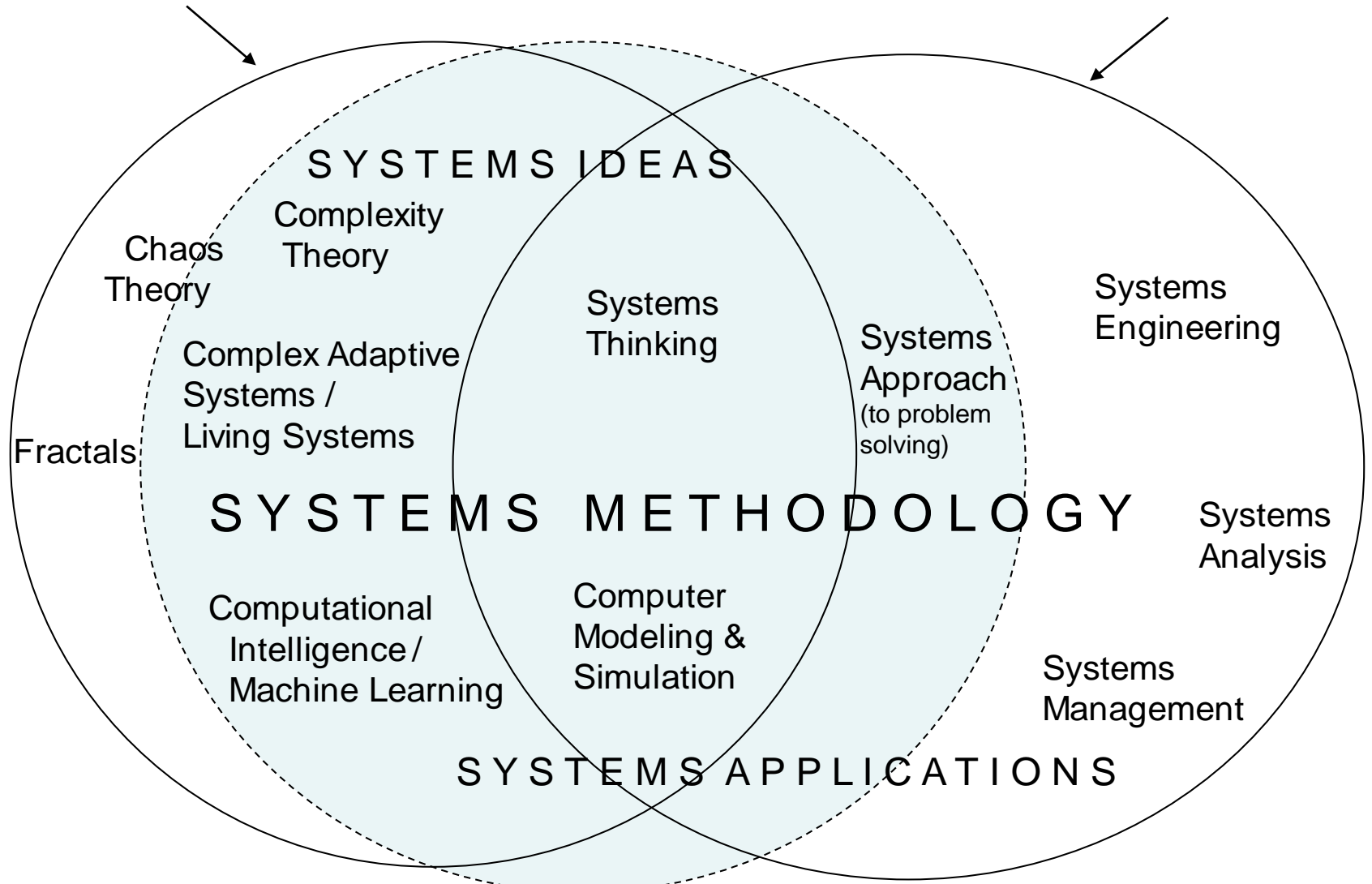  - One of PSU's first three doctoral programs
  - Along with environmental studies and urban studies
- Focal point for integrative, systems-oriented teaching and research
- Reported to the Dean of Graduate Studies
- Early people…
  - Lendaris in '69 to help create and launch
  - Linstone in '70 as first director
  - Wakeland matriculated in '73, graduated in '77 (#6)
  - Zwick joined core Faculty in '76

# Evolution

- In the mid-1980s, departmental options created
  - 9 participating departments
    - Most popular: ETM, Psychology, School of Bus. Admin.
- In early 2000s, ETM & Psych created standalone PhD programs
- SySc transitioned to a stand-alone program
  - Added graduate certificates
  - Added SySc MS degree
  - Added "multi-disciplinary" track
  - Sought to complement not compete with departments
- In 2010, began to create an undergraduate presence

**Systems Research**

**Systems Practice**

SYSTEMS IDEAS

Chaos
Theory

Complexity
Theory

Systems
Thinking

Systems
Approach
(to problem
solving)

Systems
Engineering

Complex Adaptive
Systems /
Living Systems

Fractals

SYSTEMS METHODOLOGY

Systems
Analysis

Computational
Intelligence /
Machine Learning

Computer
Modeling &
Simulation

Systems
Management

SYSTEMS APPLICATIONS

**PSU Systems Science Program**

# Graduate Curriculum

| Level | Name | Role | When? | Notes |
|---|---|---|---|---|
| Grad | Systems Theory | Core | 70's | |
| Both | Systems Approach (renamed Holistic Strategies for Problem Solving) | Core | 70's | added UG section recently |
| Grad | System Dynamics | Core Methods | 80's | |
| Both | Game Theory | Elective | 80's | Added UG section recently |
| Grad | Artificial Life | Elective | 80's | |
| Grad | AI: Neural Networks | Methods | 80's | Instructor retired; needs revamping |
| Grad | Discrete System Simulation | Methods | 80's | |
| Grad | Quantitative Methods of Systems Science | Core Methods | 90's | Major revision planned to incr. relevance to environ. scientists |
| Both | Systems Philosophy | Elective | 90's | Added UG section recently |
| Grad | Discrete Multivariate Models | Core Methods | 90's | |
| Grad | Business Process Modeling & Simulation | Methods | 90's | Outreach: business |
| Grad | Manufacturing System Simulation | Methods | 90's | Outreach: engineering & technology management |
| Grad | Agent Based Simulation | Methods | 2002 | Outreach: social science, computer science |
| Both | Systems Ideas and Sustainability | Elective | 2009 | Added UG section recently |
| Grad | System Sustainability and Organizational Resilience | Elective | 2011 | Outreach: public policy |
| Both | Systems Thinking for Business | Elective | 2013 | +UG Outreach: business |
| Both | Data Mining with Information Theory | Elective | 2013 | +UG Outreach: computer science, social science, biomedicine |

# Undergraduate Curriculum

| Title | When |
|---|---|
| Complexity in Science and Technology (from CS) | 2009 |
| Models in Science (Fletcher) | 2010 |
| Indigenous and Systems Perspectives on Sustainability (Hall) | 2011 |
| Intro to Agent Based Modeling (Sotnik) | 2012 |
| Modeling Social-ecological Systems (Sotnik) | 2012 |
| Networks in Society (Straus, Echt) | 2013 |
| Decision-Making in Complex Environments (Venkatachalapathy*) | 2013 |

* also developed a prototype course "Darwinian Thought in Society"

Reconstructability Analysis: lattice of models of four variables
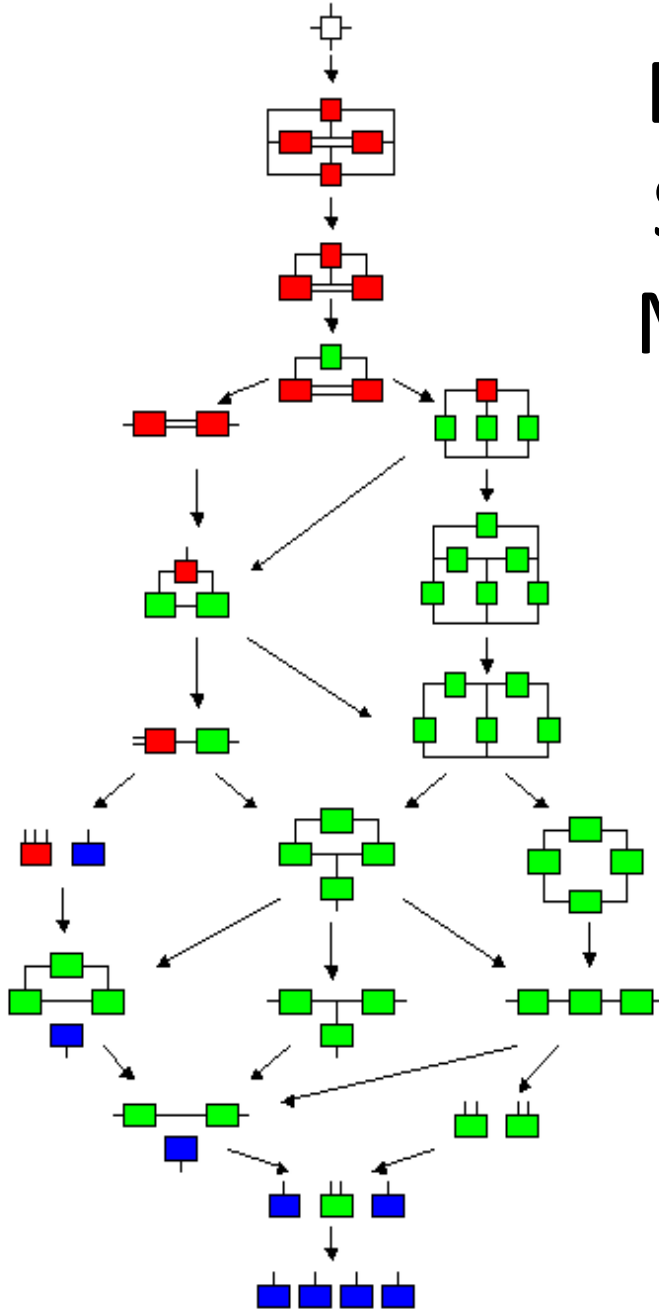
Example Systems Methods

Artificial Neural Network: model with one hidden layer
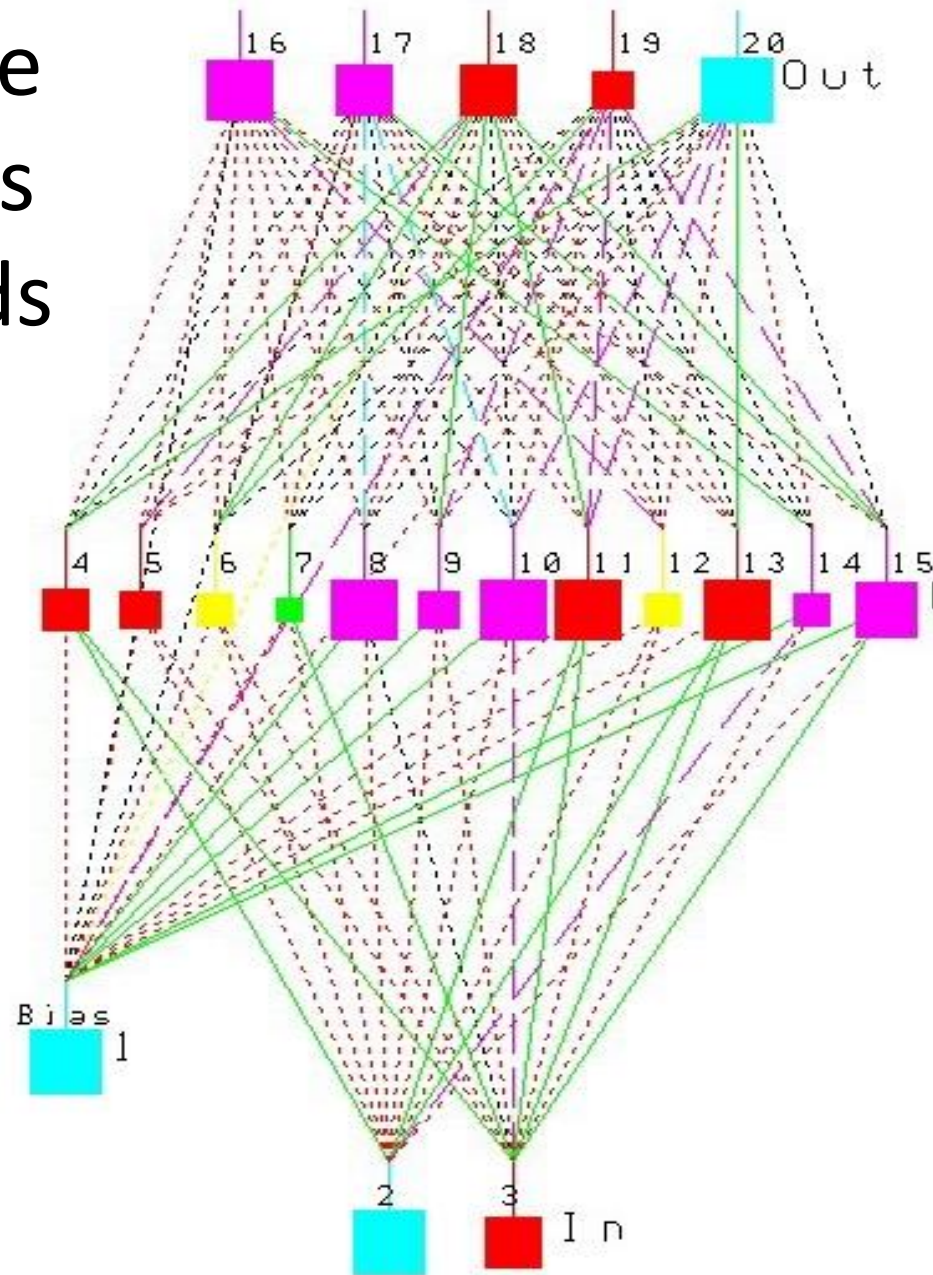
# Other Systems Science Programs vs. PSU's

- Dozens of systems science programs created in 60's and 70's
  - Few remain
- Binghamton University (SUNY) Systems Science PhD Program has been closely linked with industrial engineering and automation for the past decade
- Washington University Systems Science PhD Program is housed in Electrical and Systems Engineering
- University of Ottawa has a Systems Science MS degree
- Systems-oriented programs in Europe and Australasia mostly focus on systems engineering or mathematical complex systems
- Like the above, PSU's program has connections with engineering, computer science, and mathematics
  - And also features practitioner focused with applications in biomedicine, health policy, and environmental sustainability
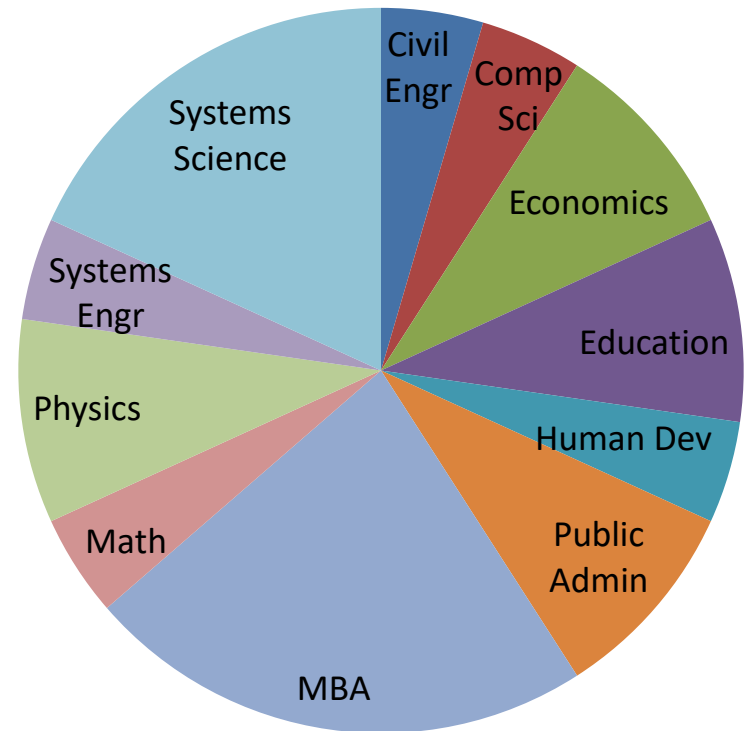
# Student Population

- From 10-20 in early years to over 100 at the peak of the period when the departmental options fluro

- Core remained small (10-15) for decades; has grown recently to ~50 (30 doctoral and 20 MS students)



Bachelor's Degrees
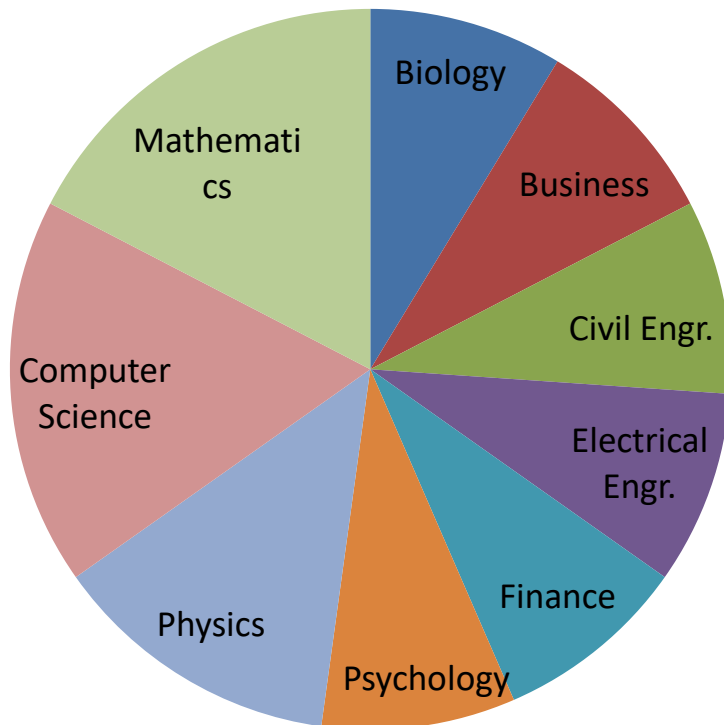
Master's Degrees

# Annual Graduation Rates, Avg. Student Credit Hours

|  | 1972–79 | 1980–89 | 1990–99 | 2000–09 | 2010–13 |
|---|---|---|---|---|---|
| **Departmental Ph.D. Graduates** | 0 | 0.7 | 2.7 | 6.2 | 3.0 |
| **SySc Core Ph.D. Graduates** | 1.1 | 2.0 | 2.6 | 1.3 | 1.3 |
| **SySc MS Graduates** | 0 | 0 | 0 | 2.8 | 6 |
| **Graduate Student Credit Hours** | n/a | n/a | n/a | 900 | 865 |
| **Undergraduate Student Credit Hours** | 0 | 0 | 0 | 156 | 480 |

# Recent Externally Funded Research

| Project Period | Brief Project Description | Researcher | Role | Funding Source | Amt. |
|---|---|---|---|---|---|
| 1999–2002 | Adaptive Critics for Controller Design | Lendaris | PI | NSF | $300K |
| 2002–2003 | State Space Designs for Aircraft Control | Lendaris | PI | NASA | $57K |
| 2003–2006 | Surface Design for Controllers | Lendaris | PI | NSF | $218K |
| 2003–2006 | Modeling Intracranial Pressure Dynamics in Pediatric Traumatic Brain Injury | Wakeland | co-PI | Thrasher Research Fund | $320K |
| 2003–2006 | Optimizing IV & V Costs and Benefits using Simulation | Wakeland | co-PI | NASA | $624K |
| 2008 | Occam Improvement | Zwick | PI | Wells Fargo | $30K |
| 2009–2011 | SD Model for Reducing Risks of Prescription Drug Abuse and Diversion | Wakeland | PI | Purdue Pharma, L.P. | $198K |
| 2011–2014 | System Dynamics of Prescription Opioid Misuse | Wakeland | PI | NIH/NIDA | $360K |
| 2014-2017 | Dynamic Model of Concussion Recovery | Wakeland Zwick | PI co-PI | Brain Trauma Found. | $544K |

# From Dissertation Titles 1972 to 1993

# From Dissertation Titles 1994 to 2003

# From Dissertation Titles 2004 to 2013

# Placement of SySc Grads

- Generalist skills are apparently valued by employers
  - To complement the specific skills they are seeking
- Some grads are faculty members at PSU and other universities
- Others have started consulting or software development firms
- Many work in governmental agencies
  - E.g., BPA, VA, National Labs
- Others work as researchers at public and private enterprises
  - Healthcare, high technology, energy consulting, etc.
- Some teach or serve as administrators in K-12 or community colleges
- SySc grads often create their own roles

# The Future…

- The evolution continues:  SySc is now part of PSU's School of the Environment within the College of Liberal Arts and Sciences
- Research may shift over time towards environmental concerns and sustainability-related topics
  - But not to the exclusion of systems methods development, biomedicine, health policy, energy systems, etc.
- Being located in a highly interdisciplinary environmental school rather than a specific department  seems likely to bode well for SySc
  - In part because SySc methods can contribute quantitative analysis capabilities for environmental studies, env. science, and env. management students