

Engineering Systems Overview

Grappling with Intertwined Technological and Social Complexity

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Industrial Revolution

Timeline

World Population

18th Century

0.7 Billion

19th Century

1 Billion

20th Century

2.5 Billion

21st Century

6.5 Billion

22nd Century ?

10+ Billion?

Other “spines”

Aircraft (1903)

Airports

Air Transport

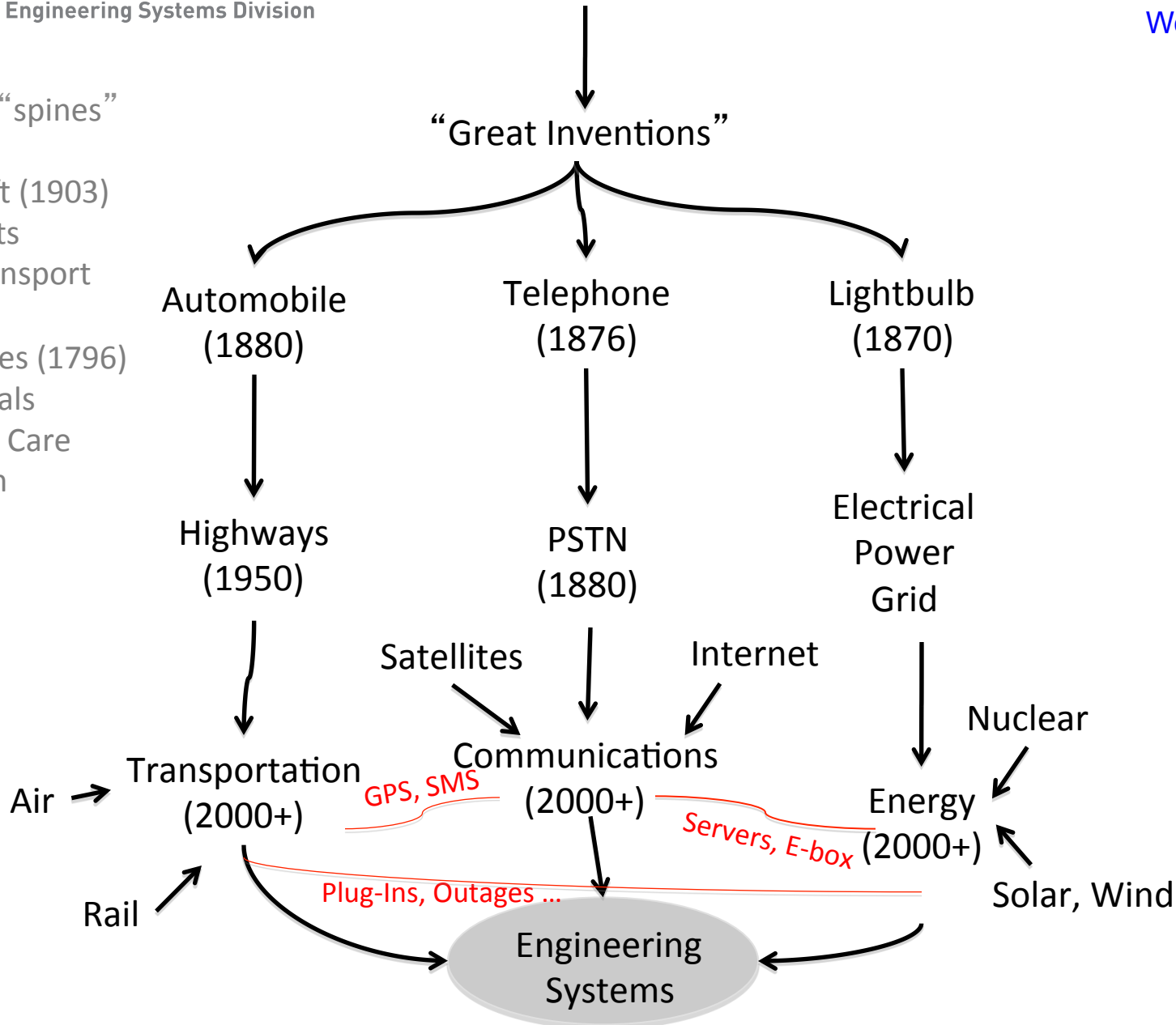
Vaccines (1796)

Hospitals

Health Care

System

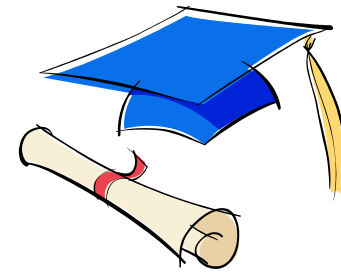
Etc...



Excerpts from the Big-E Report

- The creation of ESD in 1998 was preceded by a multi-decadal conversation at MIT about creating a new academic unit
- T.W. Eager (chair), D.A. Lauffenburger, T.L. Magnanti, E.M. Murman, D. Roos, “Final Report of the Committee on Hiring and Promotion of Faculty interested in Big E Engineering”, *MIT School of Engineering, September 15, 1996*
 - ... *we propose that the School of Engineering create a Division of Engineering Systems that cuts across the eight Engineering Departments* ...
 - ... stronger emphasis on *integrative role of engineering* ...
 - *Big E Engineering* includes a number of different multidisciplinary activities such as engineering systems, policy, engineering management and the like
 - Big E is closely coupled with *large scale systems*
 - ... the *social, political, economic and institutional aspects of system design* are as important as the technical aspects.

ESD Degree Programs



- **LFM (now LGO)** – manufacturing; global operations



- **MLOG (now SCM)** – logistics and supply chain management



- **SDM** – system design and management



- **TPP** – technology and policy

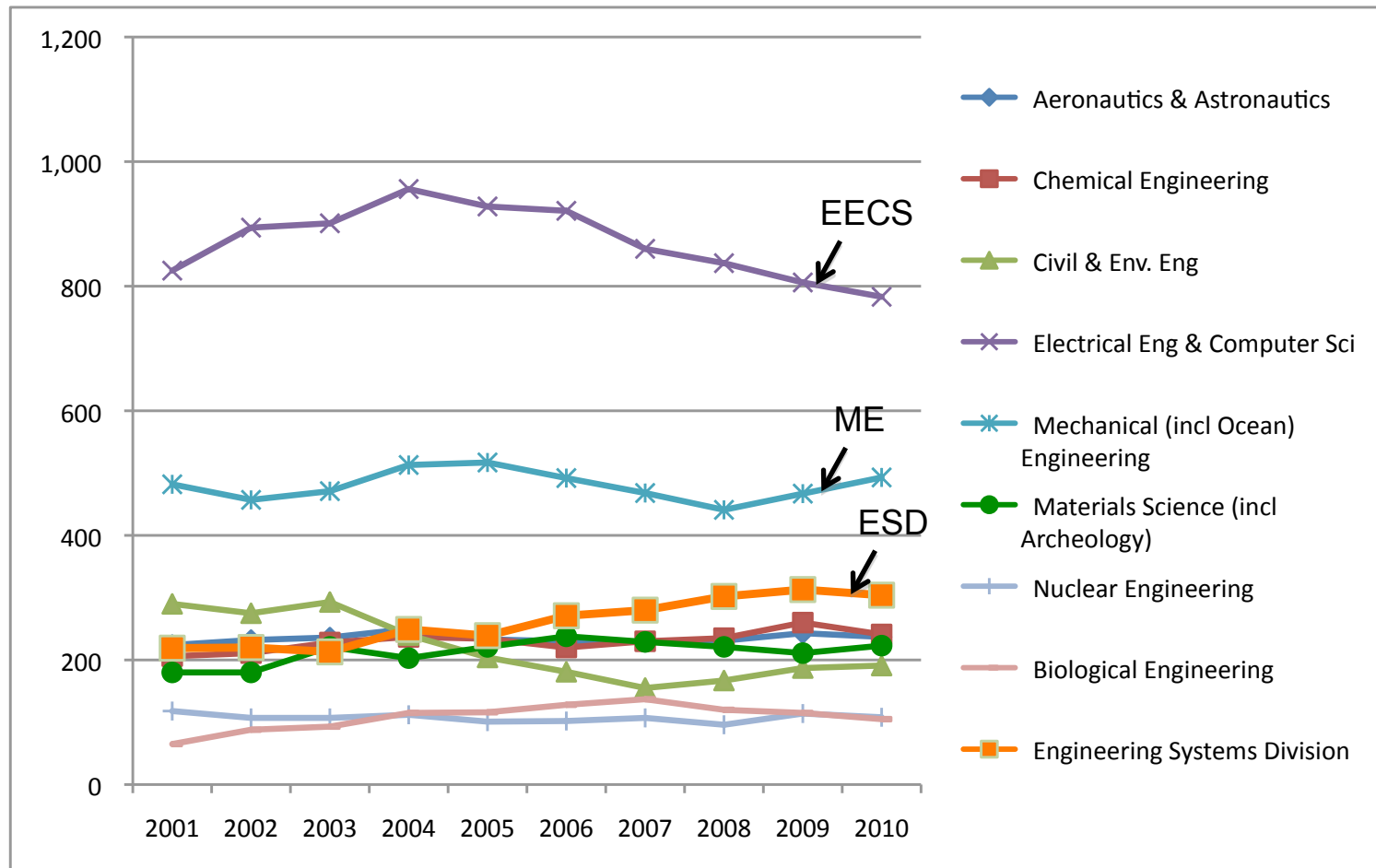


- **ESD PhD and SM** – Engineering Systems

Common denominators:

- Broad beyond classical engineering education
- Cross industry
- Dealing with the extended enterprise (including the government)
- Involves many traditional management and social science issues/concerns
- Specific leadership education
- Close to the corporate/government world
- International experience/outlook

ESD has the 3rd largest graduate program at MIT (after EECS and ME)

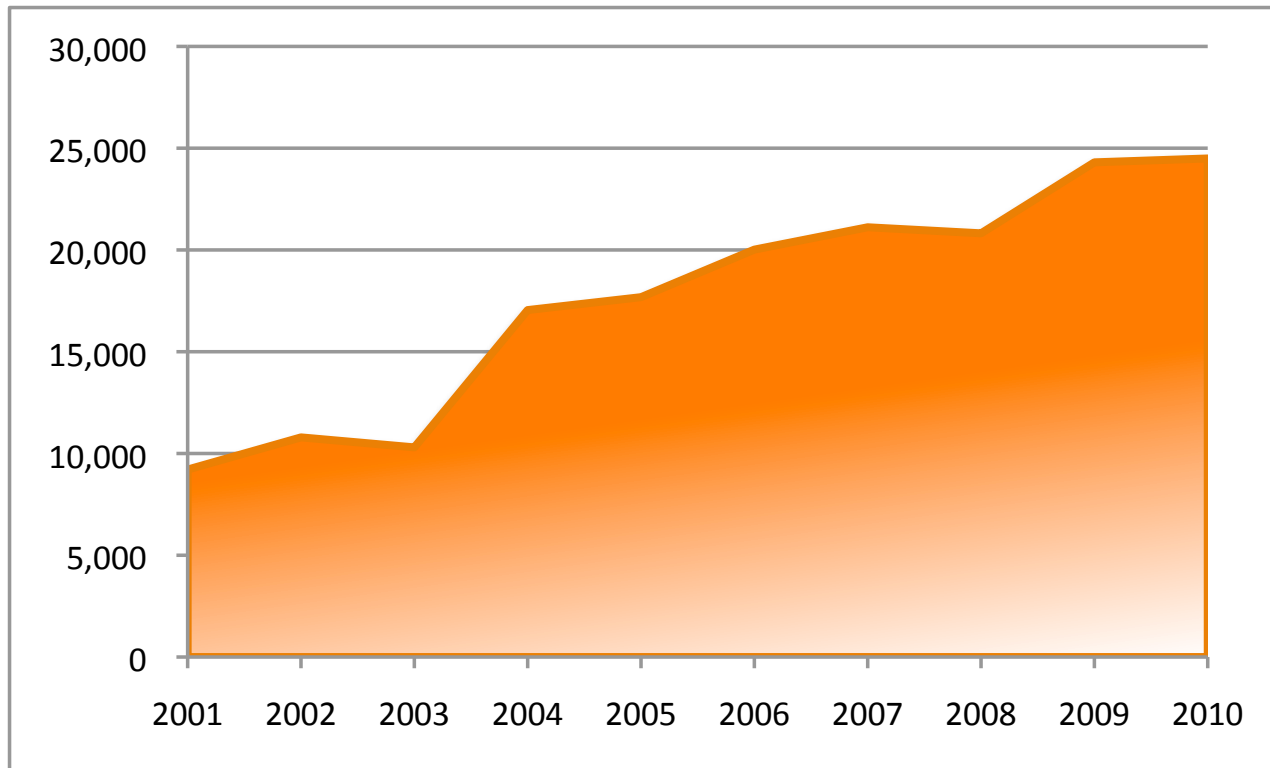


Note: The number of ESD graduate students here does not include all LFM students, ESD internal count: 440

Source: Office of the Provost

Demand for ESD classes has more than doubled since 2001

Total number of ESD Credit Units taken by MIT students



Year

Source: Office of the Provost

What is/are *Engineering Systems*?

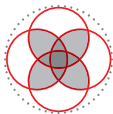
A Class of Systems

Engineering systems are characterized by a **high degree of technical and social complexity** and they aim at fulfilling important functions in society.

Emerging Field of Research

Engineering systems research is **problem-oriented**, developing and employing multiple methodologies, and balances quantitative and qualitative arguments.

Domains



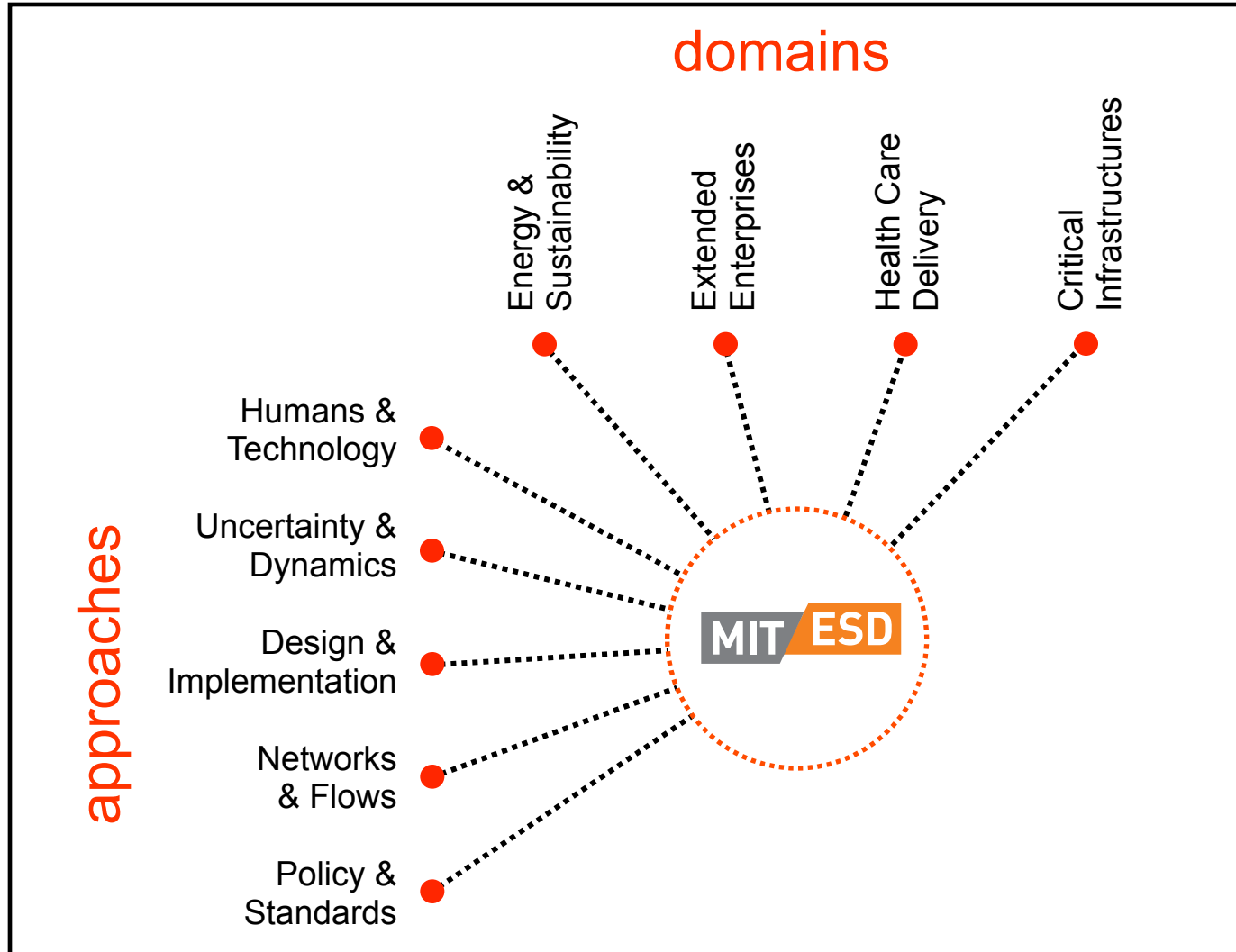
- ❑ Extended Enterprises
- ❑ Critical Infrastructures
- ❑ Energy and Sustainability
- ❑ Health Care Delivery

Approaches

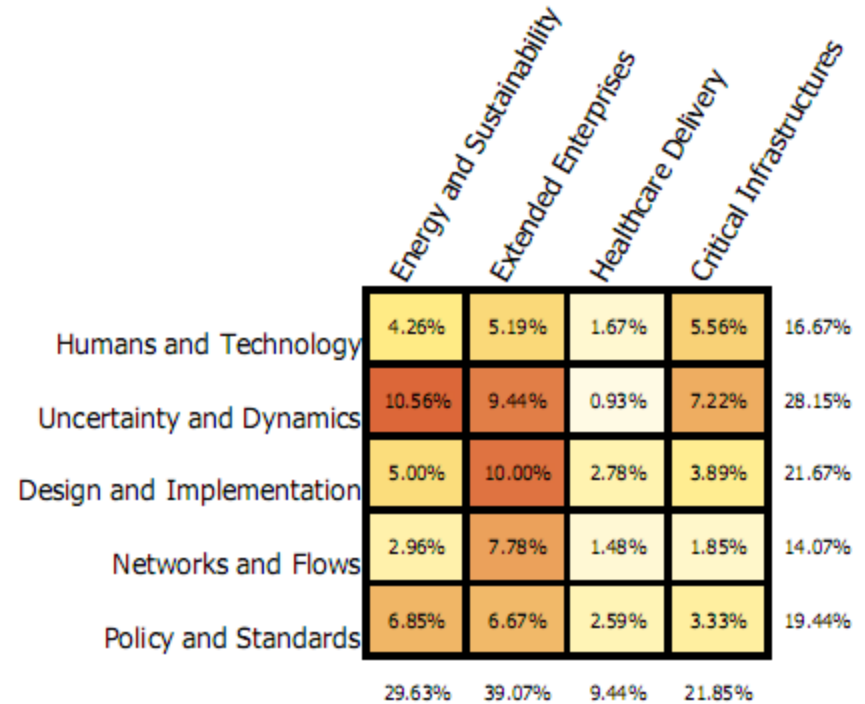
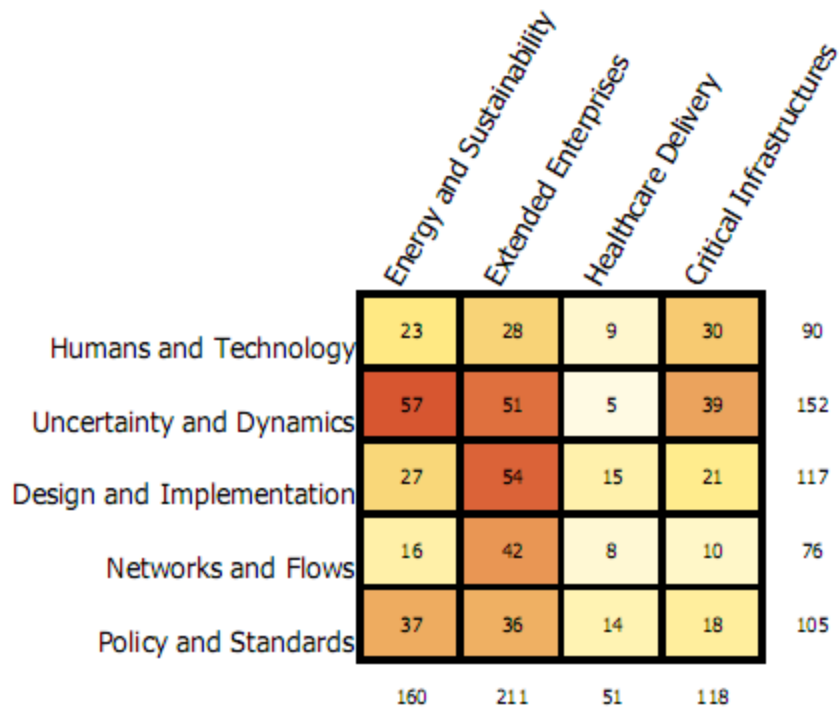


- ❑ Humans and Technology
- ❑ Uncertainty and Dynamics
- ❑ Design and Implementation
- ❑ Networks and Flows
- ❑ Policy and Standards

ESD Approaches and Domains



What do ESD PhD students work on (as of Feb 2009)?

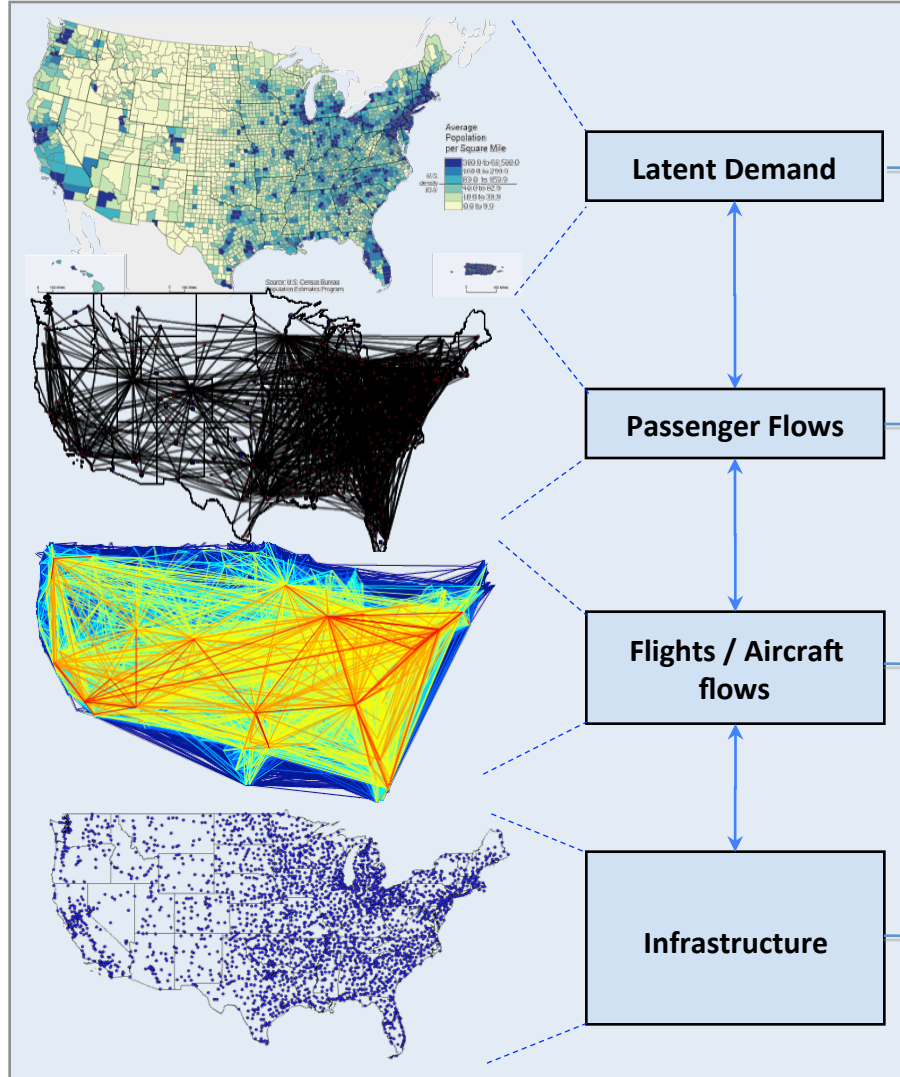


Source: Sid Rupani and Erica Gralla

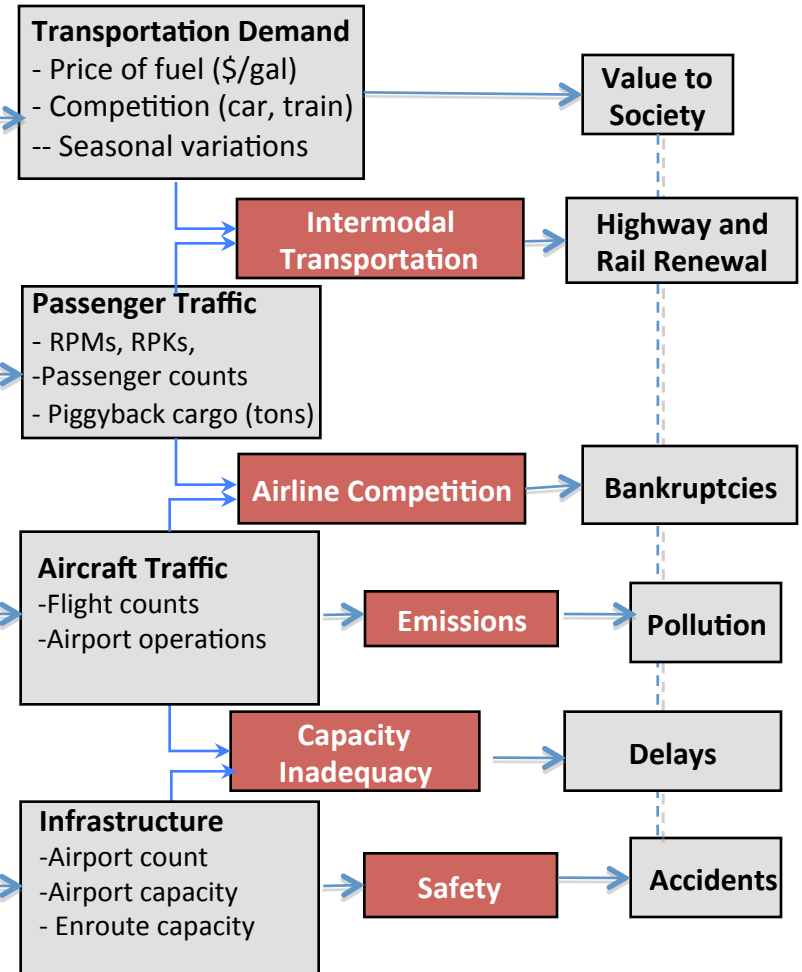
Air Transportation

A typical Engineering System

Spatial Decomposition



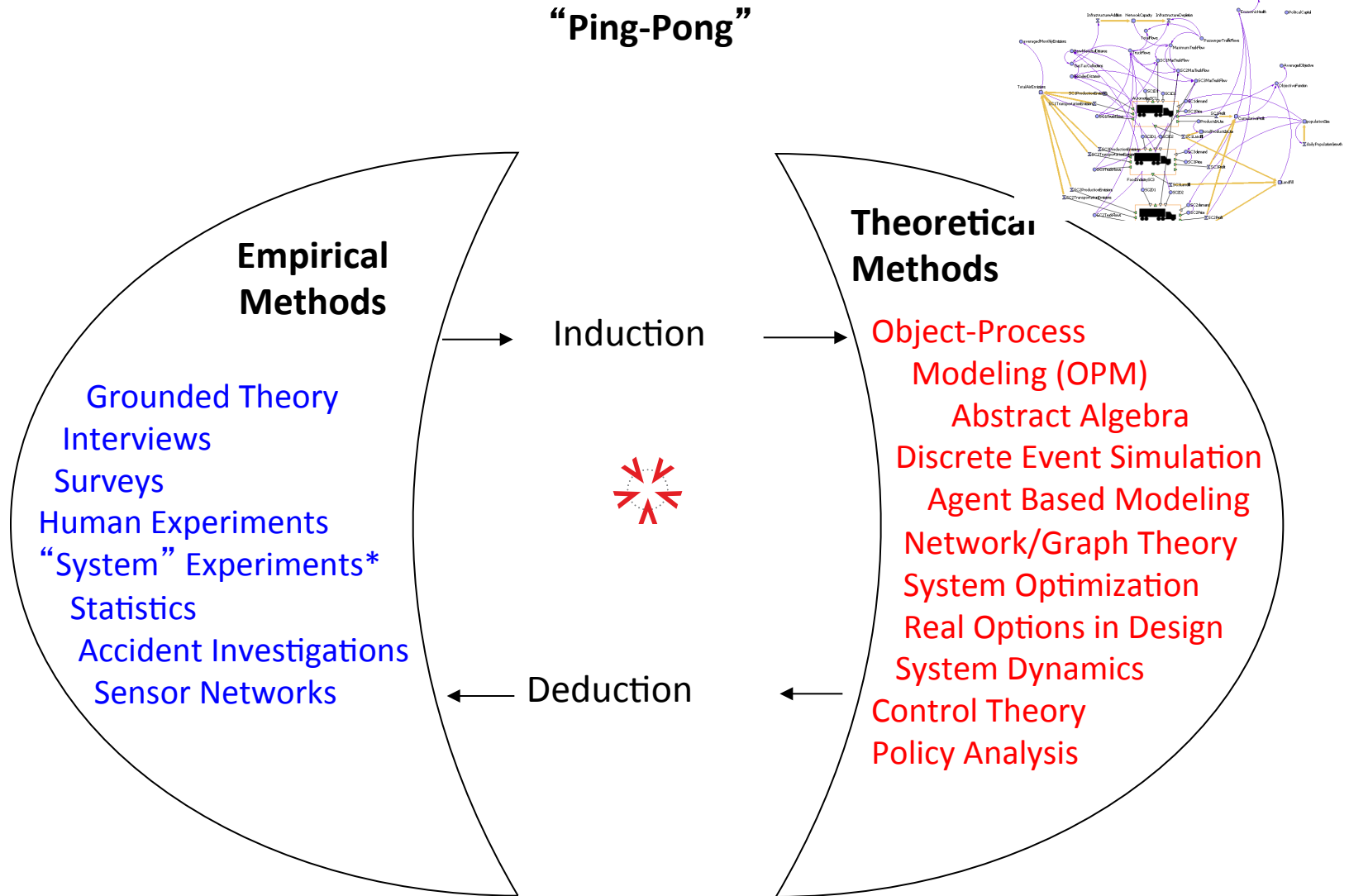
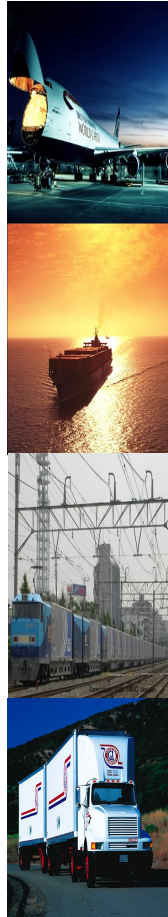
System Performance and Other Issues



Engineering Systems Classification

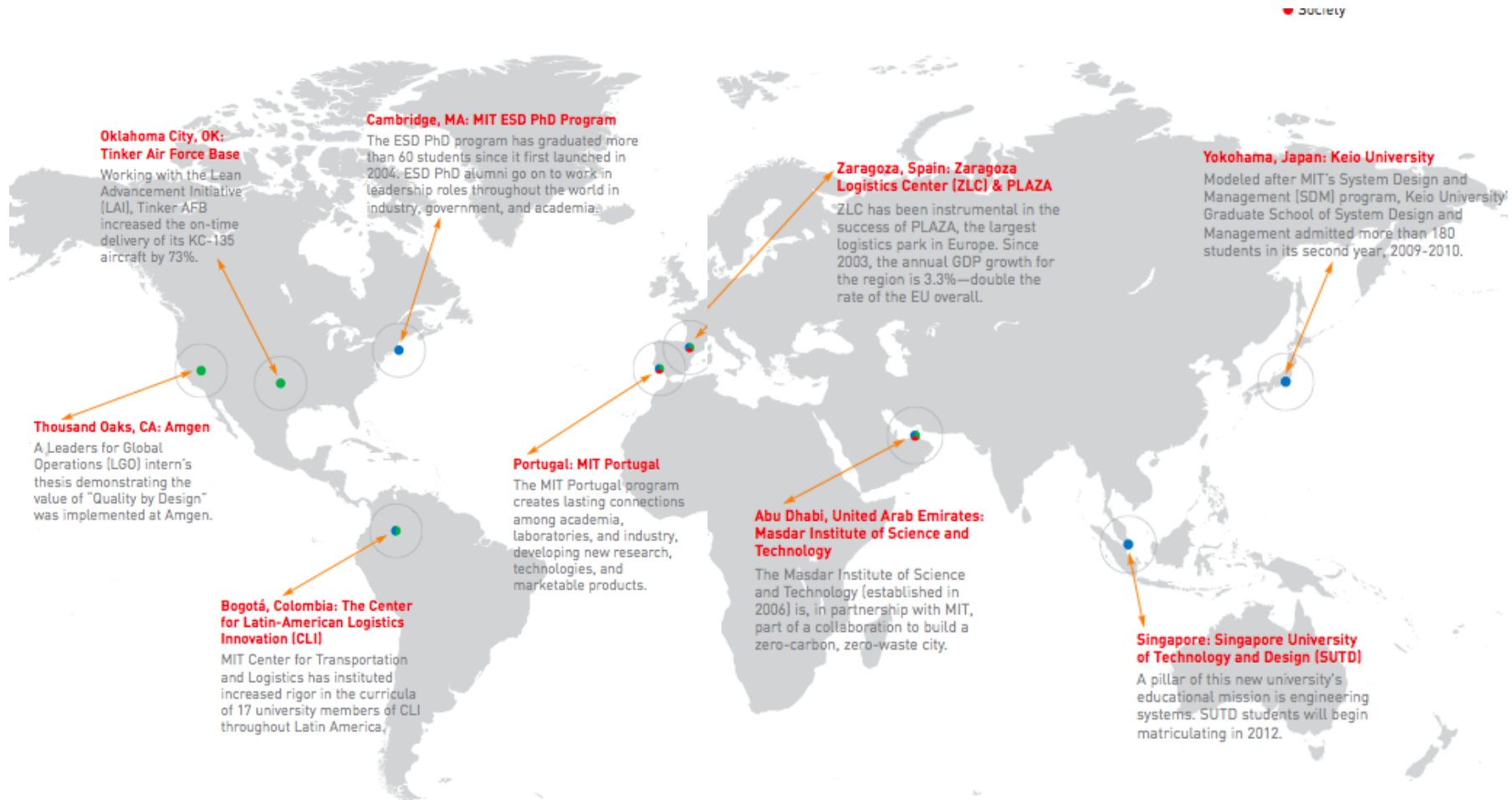
Attributes	Functional Classification					
	Operand Process	Matter	Energy	Information	Money	Humans Animals
Degree of Complexity	Transform Process	Agricultural Production	Wind Power Generation			Mass General Hospital
Branch of Economy	Transport Distribute	Water Management	Smart Electric Grids	Scientific Spacecraft		Air Transport System
Realm of Existence	Store House		Batteries Storage Systems			
Boundary	Exchange Trade			Electronic Medical Records		
Origin	Control Regulate	Climate Change Policy			U.S. Federal Reserve	Senior Driver Certification
Time Dependence						
System States						
Human/Control						
Human Wants						
Ownership						
Functional Type						

adapted from Table 10

Research Methods Overview
Engineering Systems / SDM

* e.g. “Green Islands” project in the Azores (MIT Portugal Program)

ESD Global Footprint



“Imagine the excitement of working on the frontiers of **macroscopic engineering---the domain of larger and larger and more and more complex systems** for energy, the environment, communications, health care, manufacturing, and logistics. Innovation and success here will be essential for meeting the daunting challenges of a world with a burgeoning population, limited resources, and justified demands for a better quality of life and more economic opportunity.”



Charles M. Vest, Nov 2nd, 2007
President National Academy of
Engineering

Questions and Discussion