

# Engineering Systems PhD Program

## Overview and Orientation

September 1, 2011

Professor Olivier de Weck

[deweck@mit.edu](mailto:deweck@mit.edu)

ESD Graduate Education Officer

- Program History
- Motivation and Goals
- Program Structure
  - Class Requirements
  - Research and Thesis
  - Timeline
- What comes after?
- Q&A

- 1991 Technology, Management and Policy Program (TMP) PhD is founded
- 2002 ESD PhD Program established
  - Incorporates TMP
  - Initial Pilot Group of 4 Students
- 2004 First ESD PhD Graduates
- 2008 **Revision of ESD PhD Program**
  - Basis for current structure and rules
- 2011 100<sup>th</sup> ESD (incl. TMP) student graduated

# 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



YOUR PROFILE | TO ORDER | CONTACT US

BROWSE BOOKS | BROWSE JOURNALS | BROWSE DIGITAL

SEARCH:

## Series - Engineering Systems

Engineering Systems is an emerging field that is at the intersection of engineering, management, and the social sciences. It draws on work in the following fields as well as others:

- Technology and Policy
- Systems Engineering
- System and Decision Analysis, Operations Research
- Engineering Management, Innovation, Entrepreneurship
- Manufacturing, Product Development, Industrial Engineering

The Engineering Systems Series will reflect the dynamism of this emerging field and is intended to provide a unique and effective venue for publication of textbooks and scholarly works that push forward research and education in Engineering Systems.

### Publications 1 - 3 of 3

Sort by Publication Date (2012-1936) ▾



#### Engineering Systems

##### Meeting Human Needs in a Complex Technological World

Olivier L. de Weck, Daniel Roos and Christopher L. Magee

An overview of engineering systems that describes the new challenges posed for twenty-first-century engineers by today's highly complex sociotechnical systems.

Cloth / January 2012

Price \$30.00 | NOT YET AVAILABLE FOR ORDERING



#### Engineering a Safer World

##### Systems Thinking Applied to Safety

Nancy G. Leveson

A new approach to safety, based on systems thinking, that is more effective, less costly, and easier to use than current techniques.

Cloth / December 2011

Price \$45.00 | NOT YET AVAILABLE FOR ORDERING



#### Flexibility in Engineering Design

Richard de Neufville and Stefan Scholtes

A guide to using the power of design flexibility to improve the performance of complex technological projects, for designers, managers, users, and analysts.

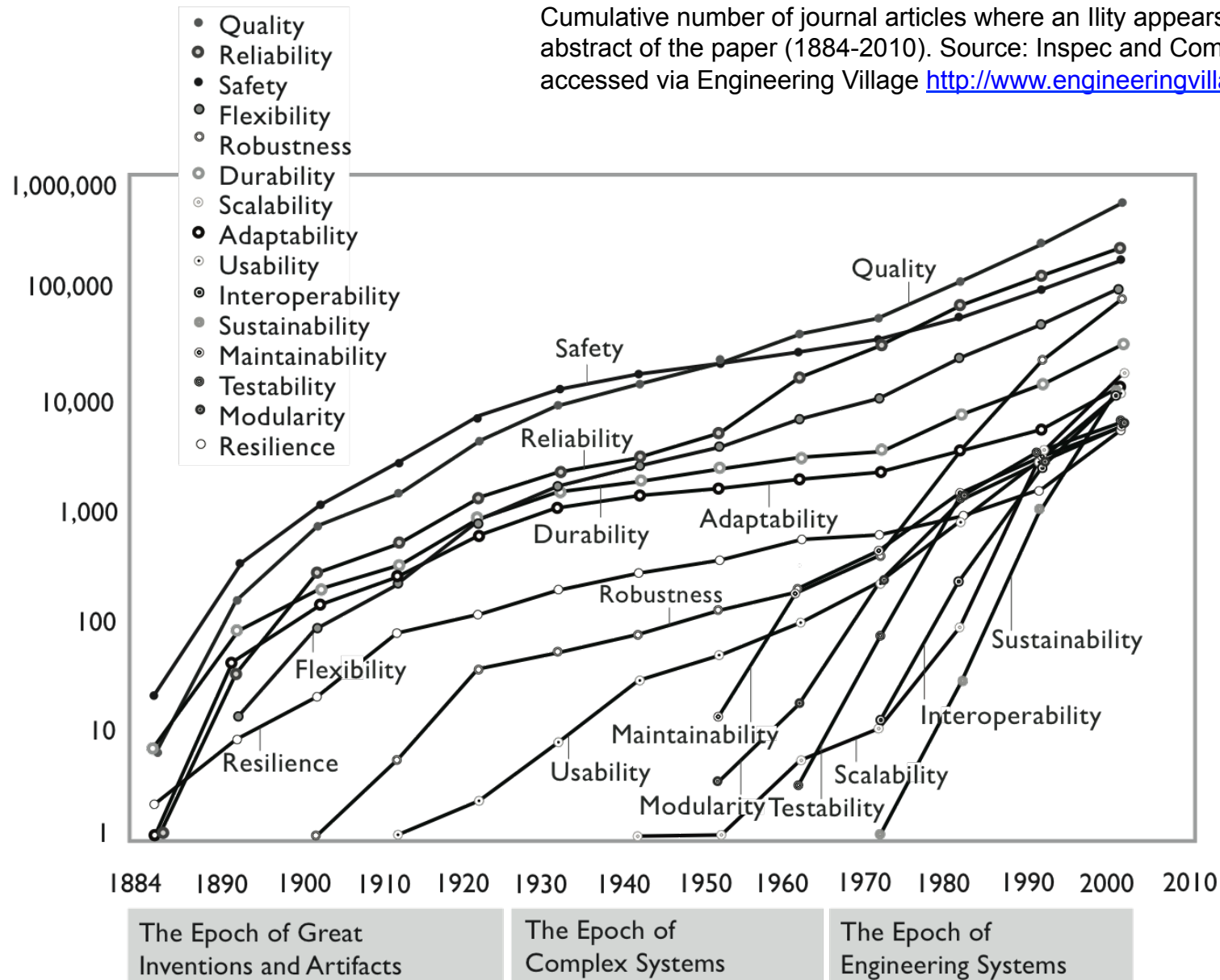
Cloth / September 2011

Price \$35.00 | ADD TO CART

# Cumulative Research in Ilities over Time

Cumulative number of journal articles where an Ility appears in the title or abstract of the paper (1884-2010). Source: Inspec and Compendex, accessed via Engineering Village <http://www.engineeringvillage.com>

Fig. 4-2



to the middle class?

**MANAGE** global manufacturing and supply chains?

**ENSURE** the safety of complex systems?

**WORK** toward energy security?

**CONTAIN** communicable diseases?

**MAKE** health care affordable and available?

## None of these has a purely technical solution.

Addressing these challenges involves technology, processes, and policies. Join the students and faculty of MIT's **Engineering Systems** Division in their quest to find solutions to these and other important, real-life challenges. ESD **PhD** students use integrated engineering, management, and social sciences approaches to tackle complex, socio-technical challenges.

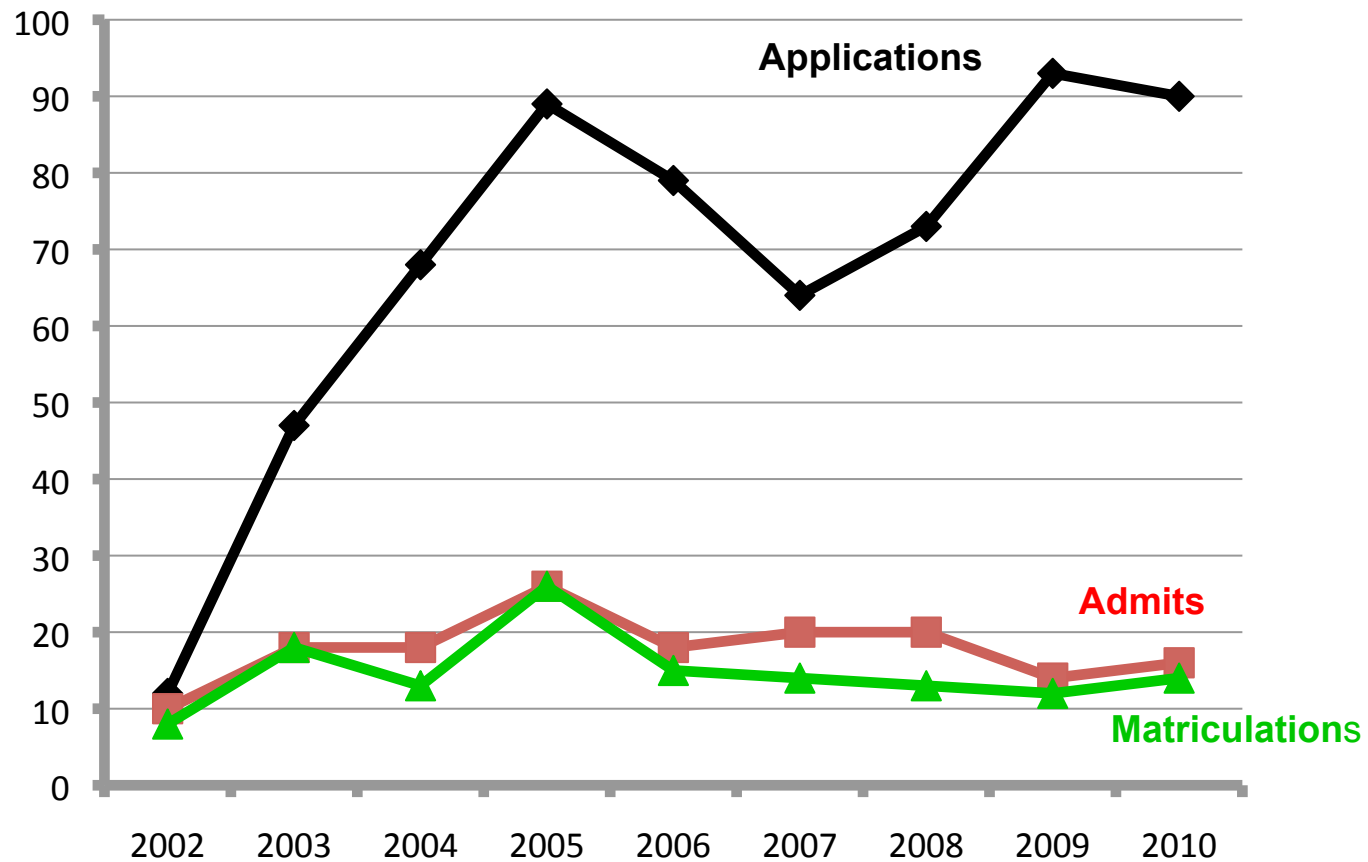
For more information, visit <http://esd.mit.edu/phd> or write to [esdgrad@mit.edu](mailto:esdgrad@mit.edu)



Massachusetts Institute of Technology  
Engineering Systems Division



## ESD PhD Admissions

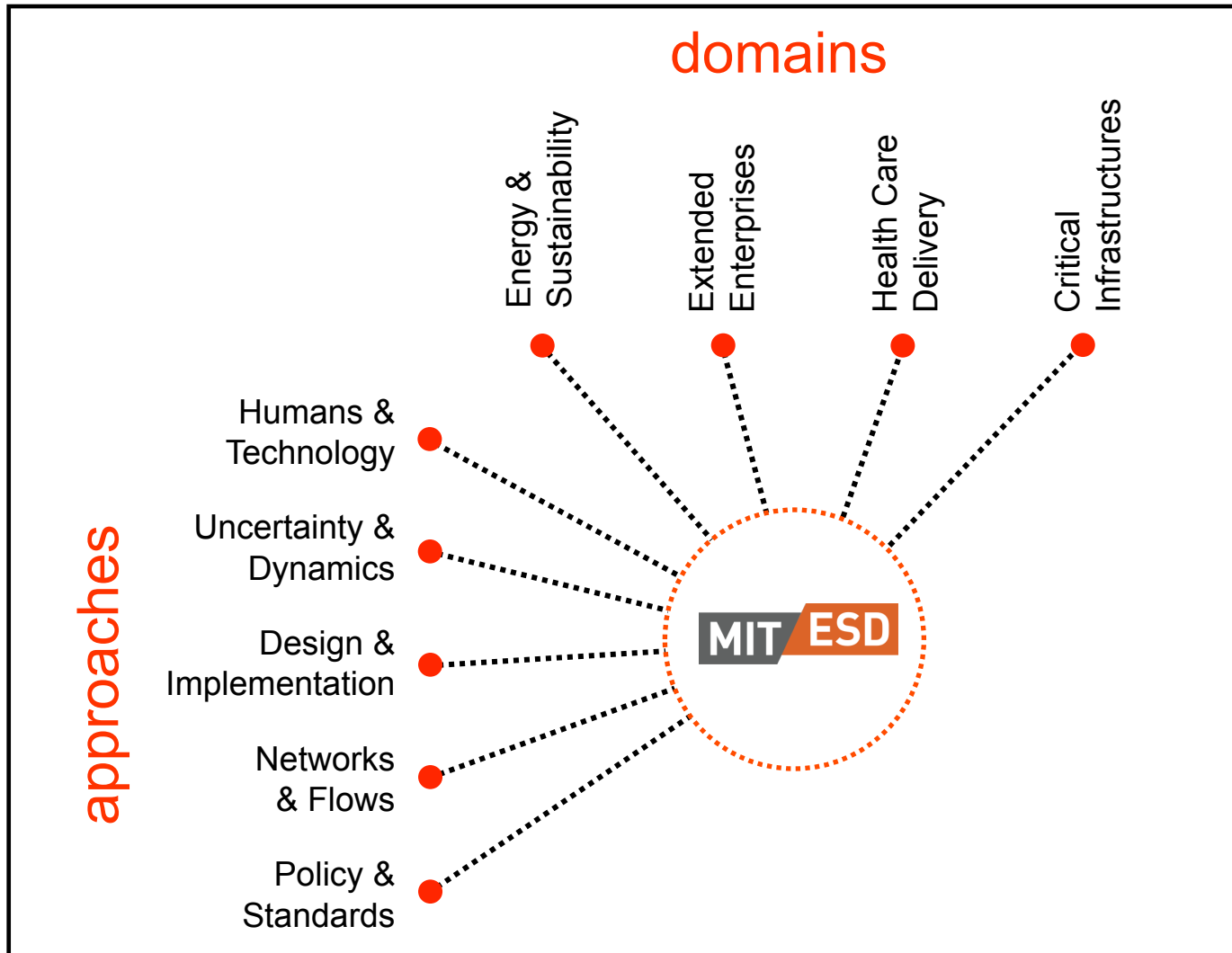


Admissions rate to ESD PhD program is about 20% (1/5 applicants)  
In 2010 we admitted SB-only candidates for the first time

**You are part of a very select group !**



# ESD Approaches and Domains



# ESD Doctoral Academic Footprint

- Self-reported Academic Footprint (ESS survey ca. 2009)
  - 54/56 current ESD PhD students responded (96%)

**Extended Enterprises**  
Is the most heavily researched domain

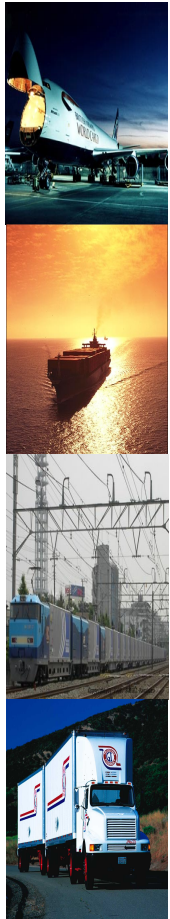
**Health Care Delivery** is <10% and is the youngest area

Many PhD students are investigating **Uncertainty and Dynamics**

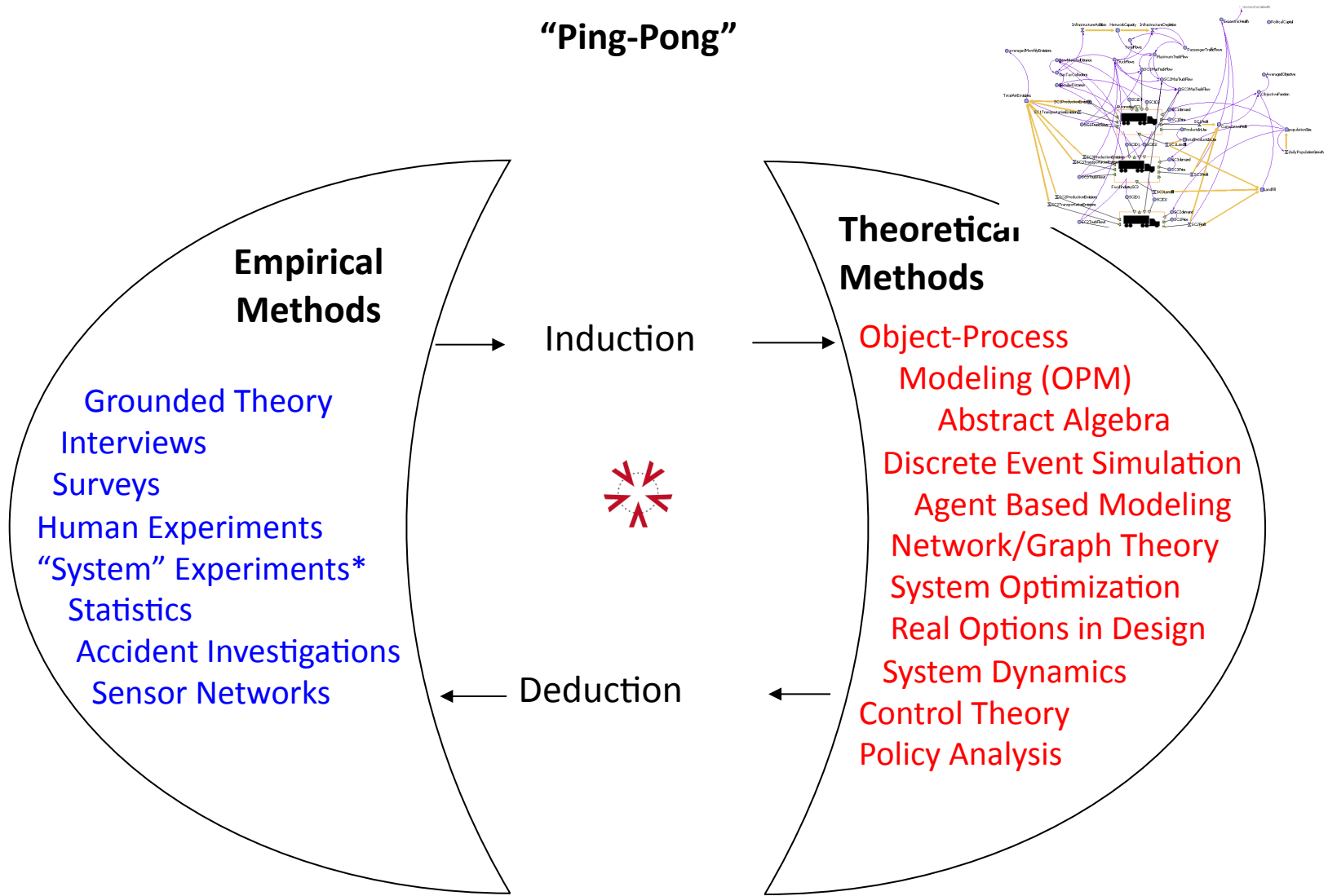
	<i>Energy and Sustainability</i>	<i>Extended Enterprises</i>	<i>Healthcare Delivery</i>	<i>Critical Infrastructures</i>	
Humans and Technology	4.26%	5.19%	1.67%	5.56%	16.67%
Uncertainty and Dynamics	10.56%	9.44%	0.93%	7.22%	28.15%
Design and Implementation	5.00%	10.00%	2.78%	3.89%	21.67%
Networks and Flows	2.96%	7.78%	1.48%	1.85%	14.07%
Policy and Standards	6.85%	6.67%	2.59%	3.33%	19.44%
	29.63%	39.07%	9.44%	21.85%	

*Overall the ESD intellectual framework worked for most*

# Example Research Methods in Engineering Systems



## “Ping-Pong”



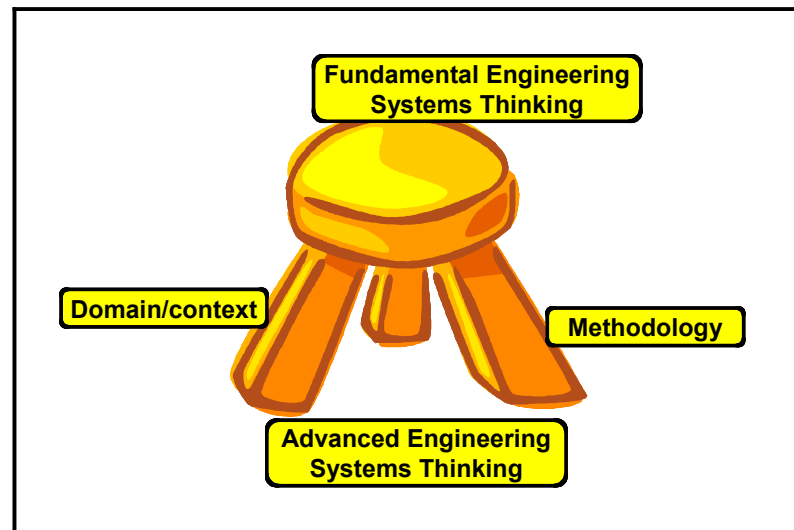
\* e.g. “Green Islands” project in the Azores (MIT Portugal Program)

## ESD PhD Program Structure

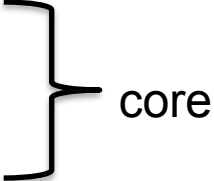
You will hear

 $\top$ -shaped     $\Pi$ -shaped     $\mathbb{T}$ -shaped

- ESD PhD Program Structure:



- A doctoral student in ESD should be able to build on ***fundamental and advanced engineering systems thinking knowledge*** to frame large scale complex problems in one or more ***domains/contexts of interest***, apply an ***established methodology***, or a combination of methodologies; uncover the principles and articulate the properties underlying such systems, thereby adding to the developing knowledge of engineering systems.

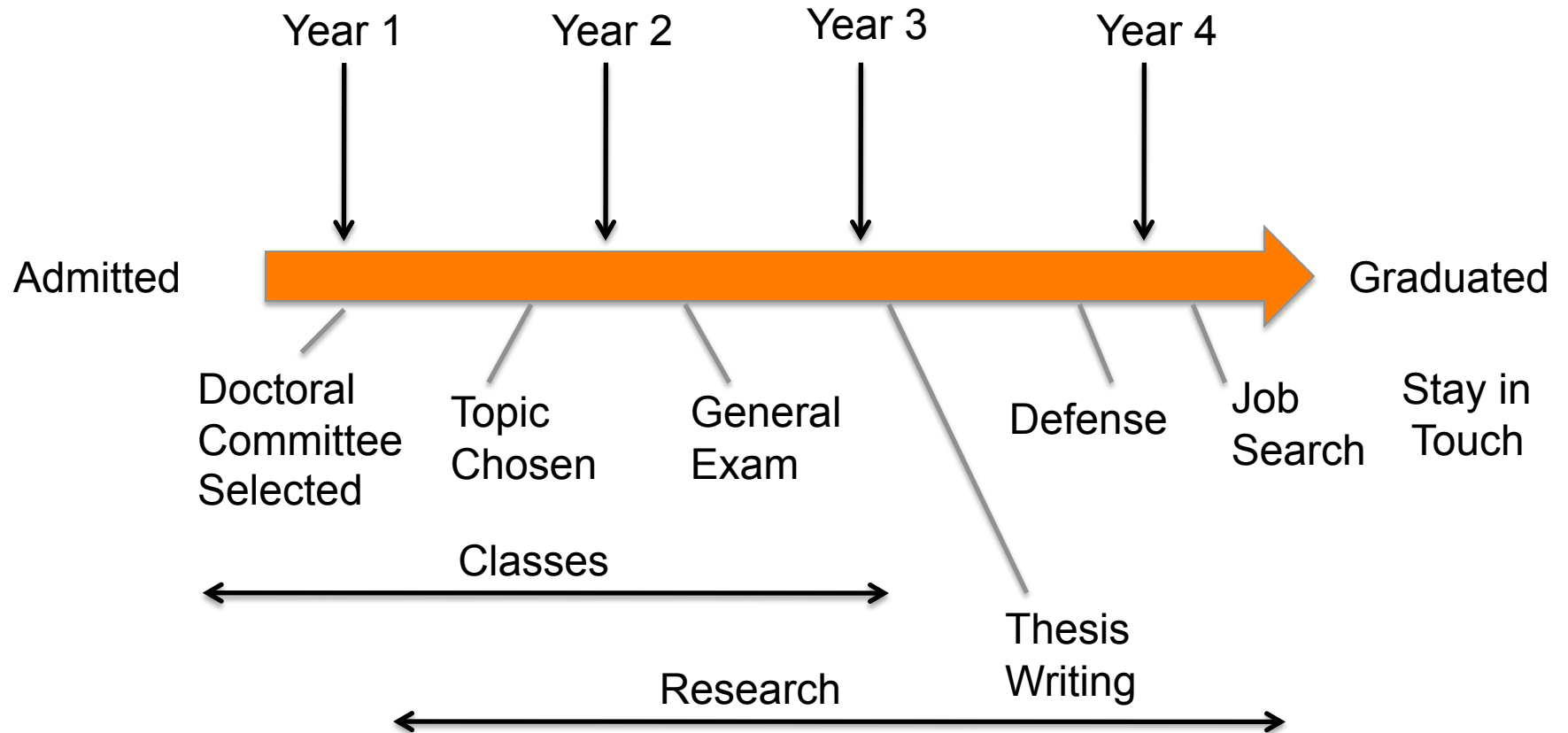
- **Fundamental Engineering Systems Thinking**
    - ESD PhD seminar (**ESD.83**)
    - Models, Data, Inference for Socio-technical Systems (**ESD.86**)
    - Social Science Concepts and Methods (**ESD.87**)
  - **Depth in Methodology – 3 subjects**
    - Control Theory
    - Economics
    - Operations Research
    - Systems Engineering
    - Finance
    - Systems Dynamics
  - **Depth in Domain/Context knowledge – 3 subjects**
    - Energy and Environment
    - Critical infrastructures
    - Healthcare
    - Extended Enterprises
    - Urban planning, Air Transportation etc...
  - **Applied/Advanced ES thinking**
    - Safety
    - Networks and flows
    - Human-Technology engineering (man-machine interfaces)
  - **Electives**
- 
- Total: 150 units+

## ESD PhD Overall Requirements

Fundamental Engineering Systems Thinking	3 Subjects
Domains/Contexts	3 Subjects (or equivalent)
Methodology	3 Subjects
Advanced Engineering Systems Thinking	1-2 Subjects
Additional Electives	2-3 Subjects

- This is in the range of 12-13 subjects, 150 units beyond the SB in accord with MIT practice. Often some subjects taken in SM programs at MIT or elsewhere can be applied toward the 150-unit requirement. We note these are minimum requirements. Students may choose to take more units or may be asked by their committee to do so.

# Notional Doctoral Timeline



Average Duration: 4 Years (8 semesters)



# Doctoral Committee

- Choice of main advisor and committee is critical
- Role of the committee is to advise, critique, challenge, advocate for you ....
- Chair must be ESD Faculty Member
- Minimum 2 MIT Faculty Members
- Typically 3 Committee Members
- Maximum 5 Members

## Example:

- Please join us for the dissertation defense of Valerie Karplus.
- Date: Wednesday, February 23, 2011 Time: 1:30PM Room: E19-319
- Title: Climate and Energy Policy for U.S. Passenger Vehicles: A Technology-Rich Economic Modeling and Policy Analysis
- Committee: M. Webster (chair), J. Heywood, H. Jacoby, K. Oye, J. Reilly

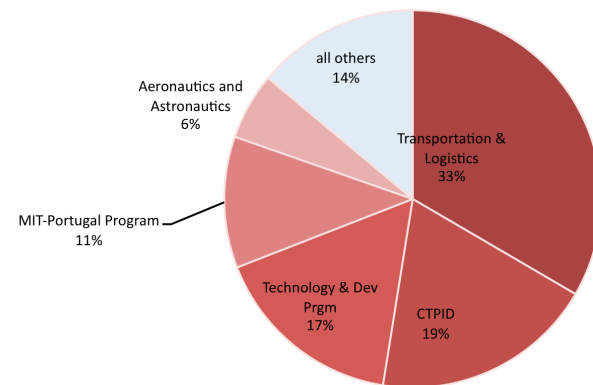
# ESD Research: Centers and Programs

## Where will my research funding (RA/TA) come from ?

- ESD-affiliated Centers
  - Center for Transportation and Logistics (CTL)
  - Center for Technology, Policy and Industrial Development (CTPID)
  - Center for Biomedical Innovation (CBI)
  - Center for Engineering Systems Fundamentals (CESF)
  - Lean Advancement Initiative (LAI)\*
- Programs
  - MIT Portugal Program (MPP)
  - MASDAR Institute (Abu Dhabi)
  - CCES at KACST and MIT (Saudi Arabia)

### Notes:

- Not all research in ESD is book-kept in ESD (\*)
- Only 50% of dual faculty research credited to ESD

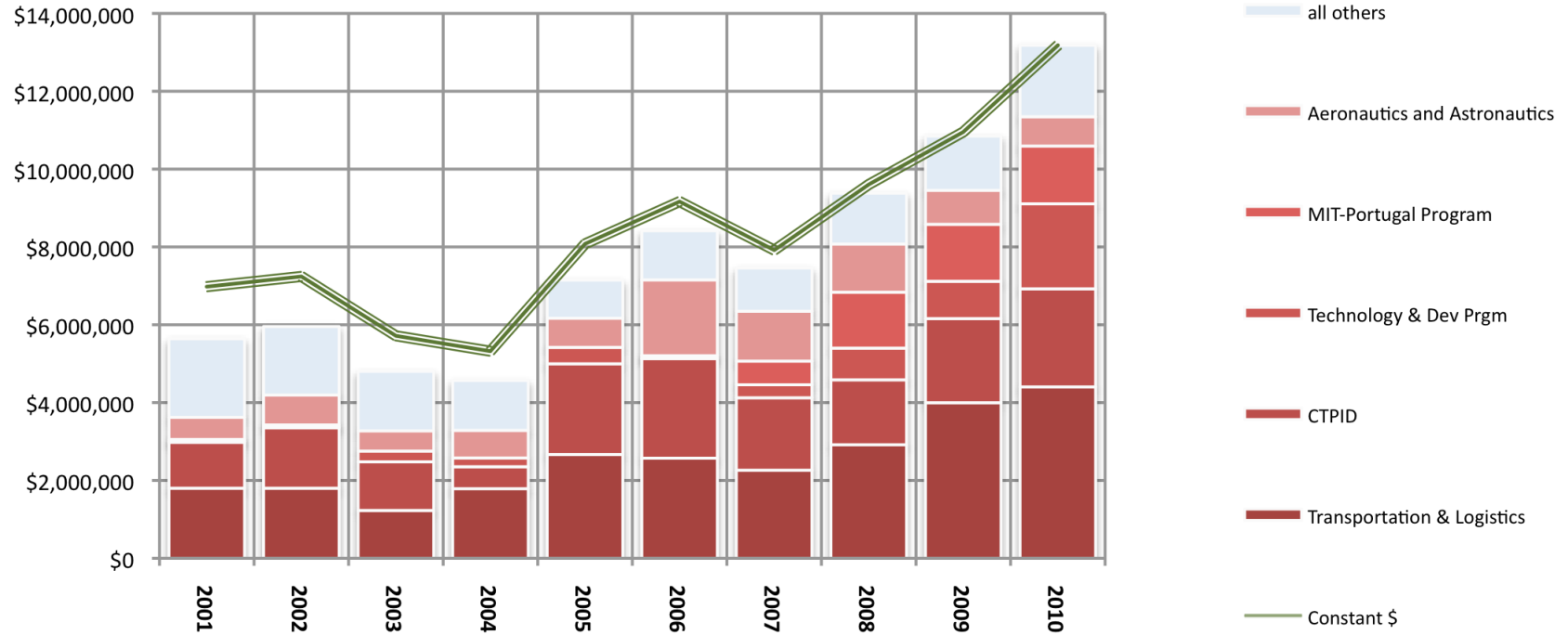


\* Joint with Department of Aeronautics and Astronautics

+ fellowships, + other MIT

# Sponsored Research in ESD

By where performed

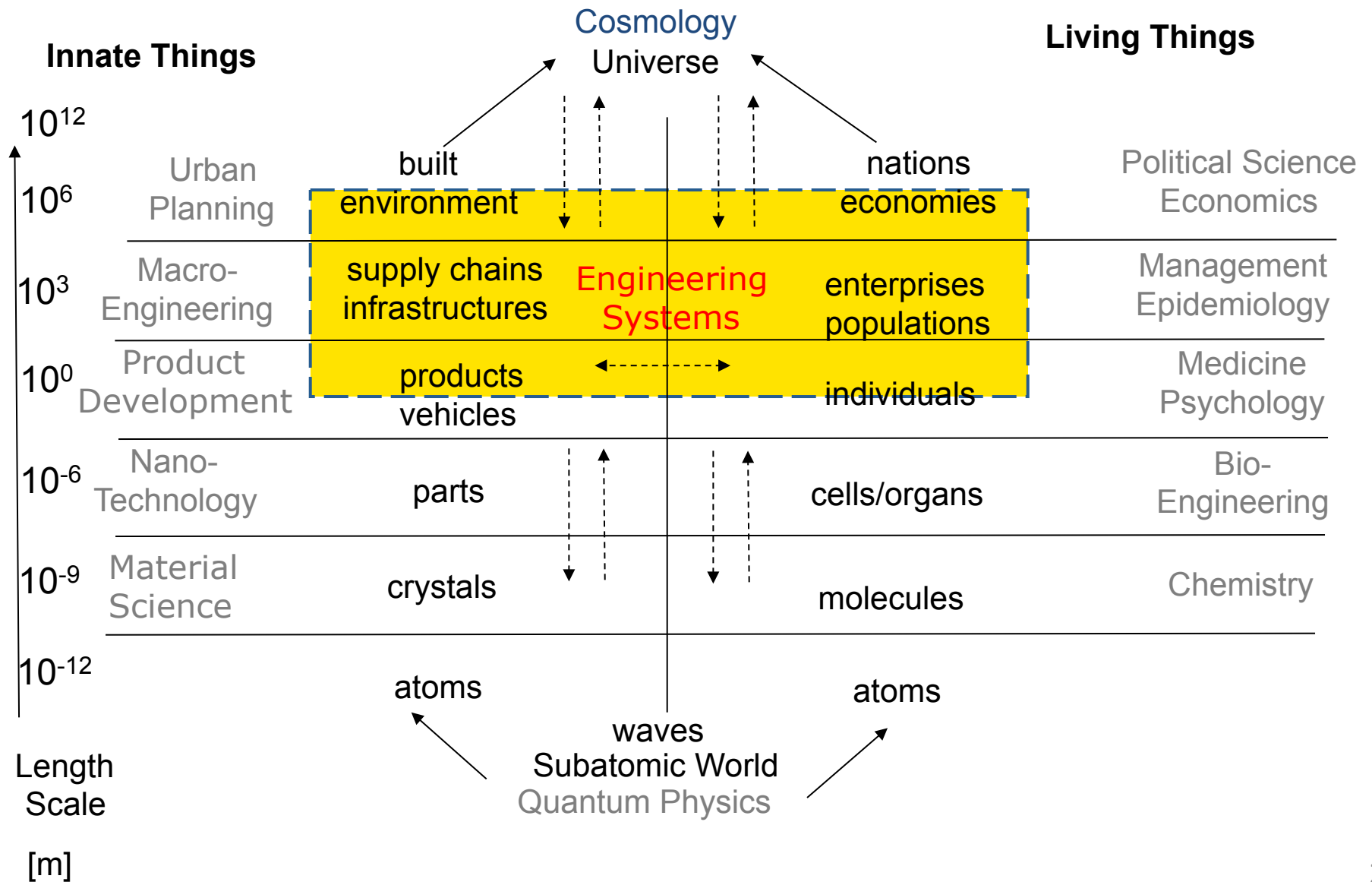


Research support in ESD has grown significantly since 2007

# How do I choose a topic?

- Needs to represent a novel contribution to science (address a current gap)
  - Read, read, read to make sure this is indeed true
- Based on real-world problem (CCI)
- Multidisciplinary and socio-technical in nature
- Data / Stakeholders are available
- Solvable in ~ 2-4 years
- You have to be passionate about it

# Levels of Abstraction



## Some Ph.D. Topics from AY 2010/2011

- A **Decision Analysis** Framework for the **U.S. Nuclear Fuel Cycle** (**Pierpoint**)
- The MQ-9 Reaper Remotely **Piloted Aircraft**: **Humans and Machines** in **Action** (**Cullen**)
- Using **Information Technology** to Exchange Health Information among **Healthcare Providers**: **Measuring Usage and Understanding Value** (**Rudin**)
- **Costing** Commonality: Evaluating the Impact of **Platform** Divergence on Internal Investment Returns (**Cameron**)
- Towards High Performing **Hospital Enterprise Architectures**: **Elevating Hospitals** to Lean Enterprise Thinking (**Fradinho**)
- The **Energy Box**: Comparing Locally Automated **Control Strategies** of **Residential Electricity Consumption** under Uncertainty (**Livengood**)
- Leveraging **Social Information Systems**: Using Blogs to Inform Technology **Strategy Decisions** (**Seshasai**)
- **Innovation** Pathways in **Technology** Intensive **Government Organizations**: Insights from NASA (**Szajnfarter**)

Technology

Management

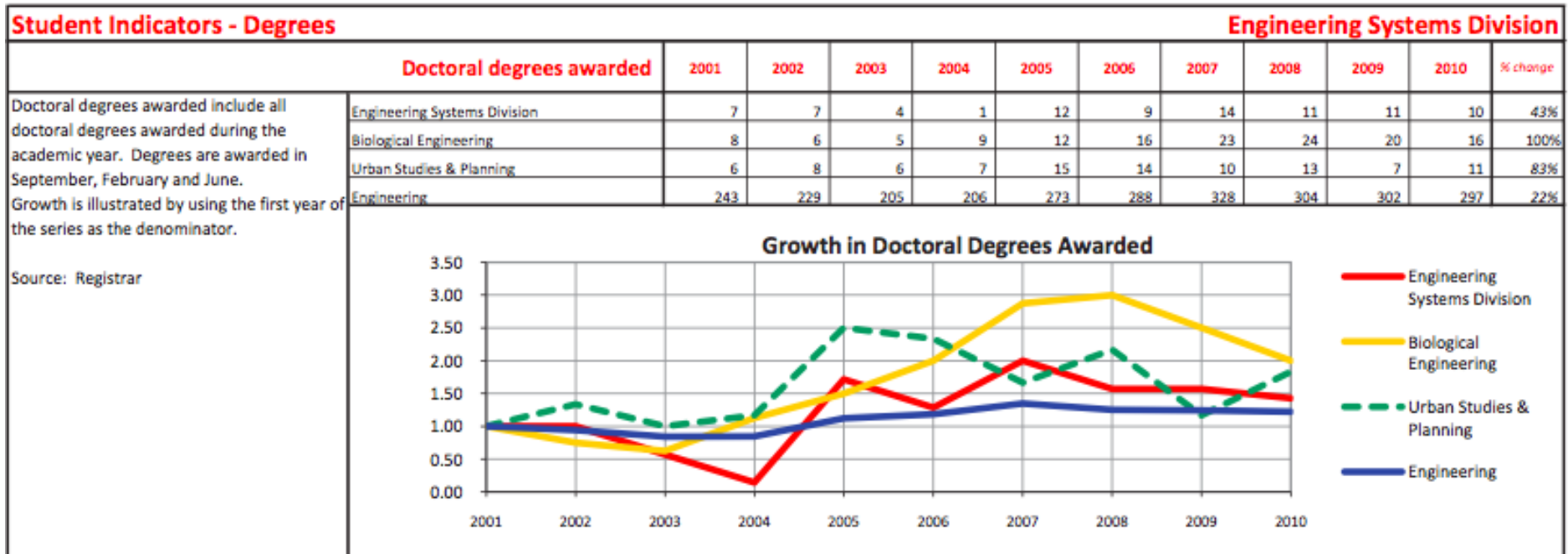
Social Sciences

- The General Exam
  - The second and “main gate” in the PhD program
  - Is the candidate prepared and capable of conducting PhD level research at the level of quality we expect at MIT?
  - **Typically taken after core requirements have been fulfilled, a topic has been chosen and doctoral committee has been formed.**
  - A creature of both the ESD faculty and the student’s committee. The decision on whether the student has passed or failed the general exam is ultimately the province of the ESD faculty-at-large. It tests both the candidate’s knowledge in engineering systems and potential to do PhD-level research.
  - Two written questions (of four) on the general exam build on fundamental engineering systems material. (ESD.83, ESD.86, ESD.87)
  - Two questions are given by the student’s doctoral committee



- Oral
  - The **oral exam**—a student submits a research paper when he or she picks up the written exam. As it is currently, this paper is not a formal thesis proposal, but rather is intended to demonstrate that the candidate has PhD-level research potential.
  - ESD faculty beyond the committee is present at the oral exam.
  - Presentation of 30 minutes
  - Extensive Q&A Session (about 60 minutes)
  - Secret Vote on Pass, Fail or Retake
  - Can attempt the General Exam twice, must pass on 2<sup>nd</sup> try or withdraw from the program

# Doctoral Degrees Awarded

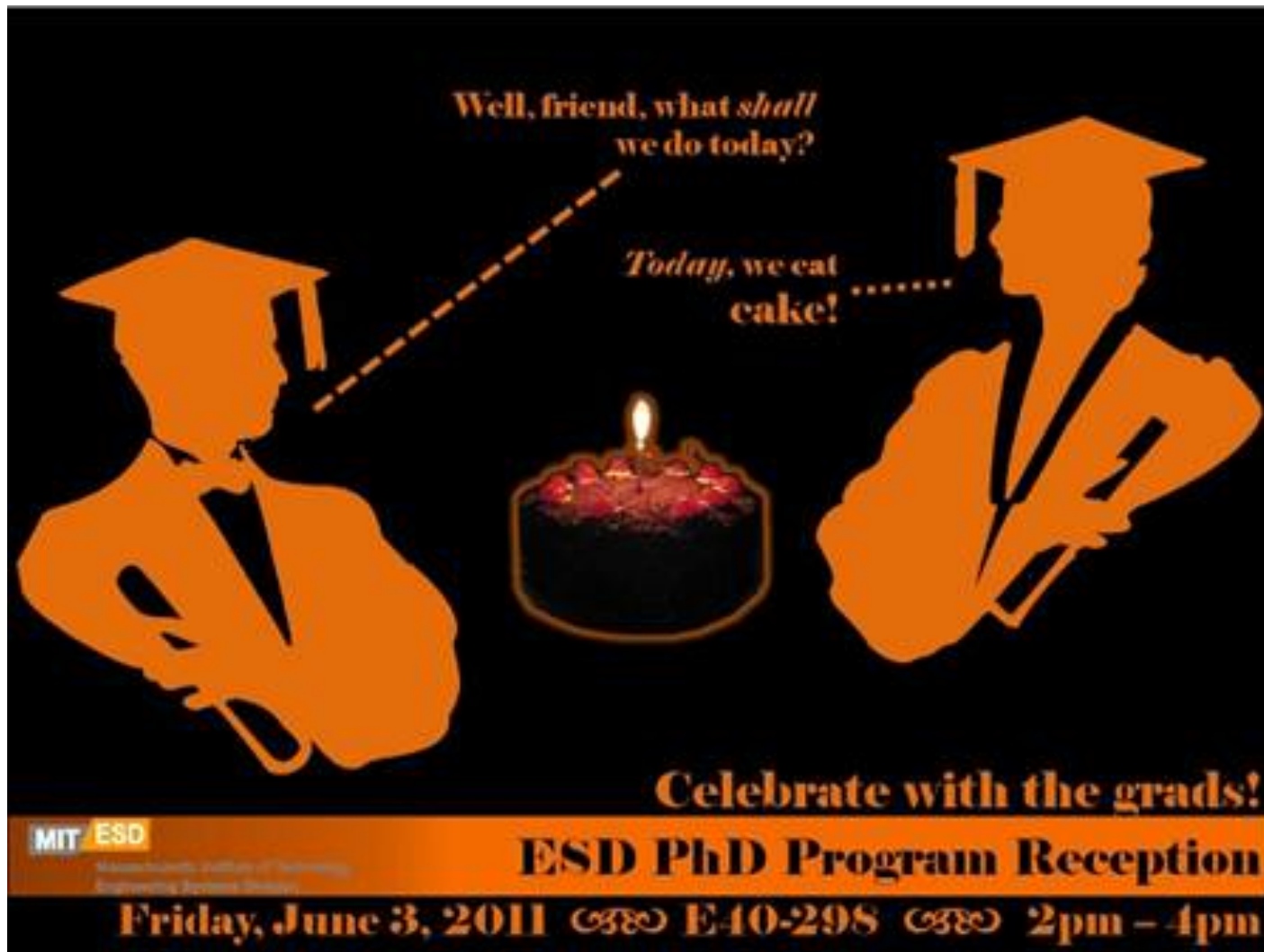


The number of **doctoral degrees awarded is increasing**, especially since 2004 (due to the startup of the new ESD PhD program in 2002)

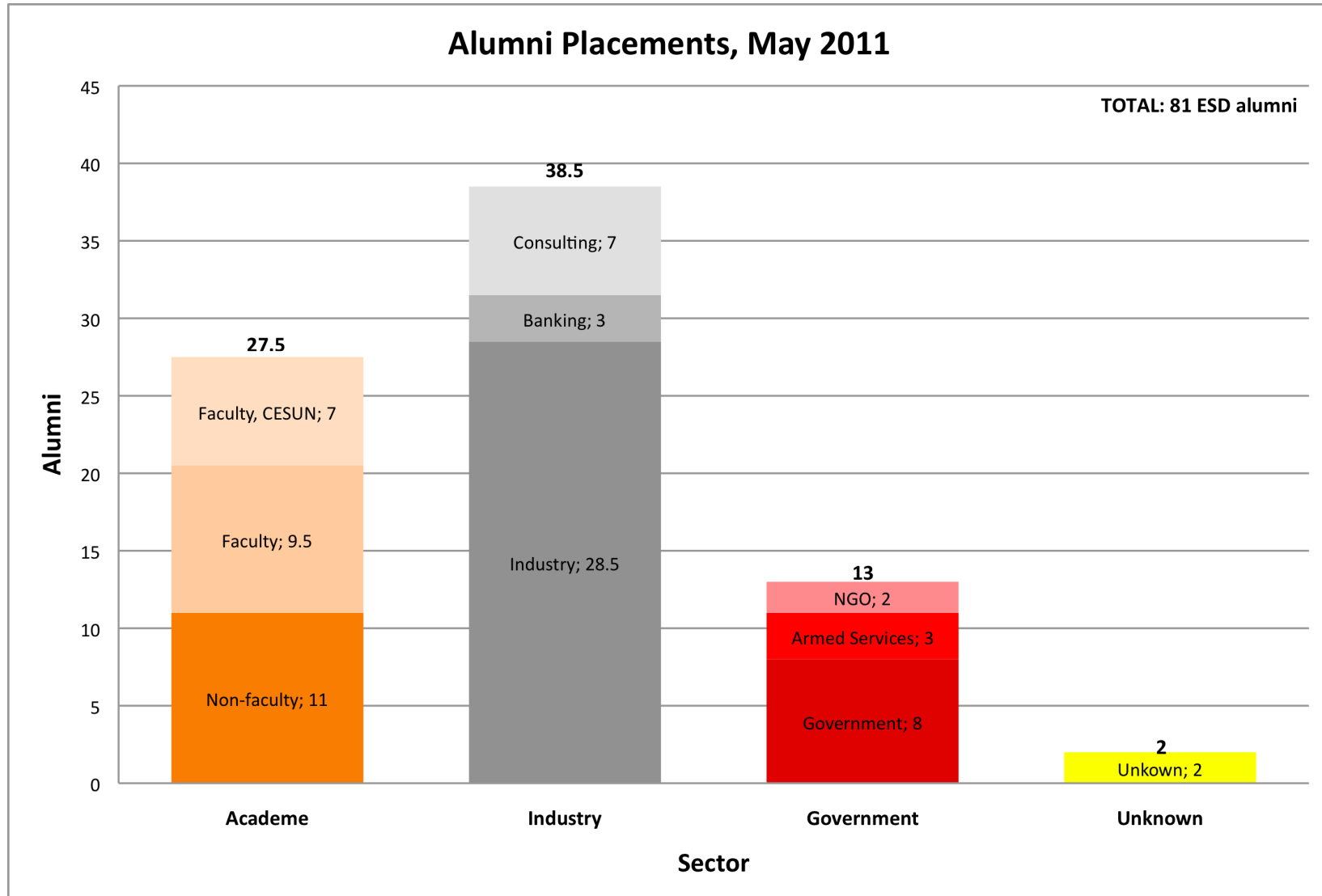
Expect it to stabilize at about **10-15** per year.

The ESD PhD program is now at **steady state**

# So you graduated, now what?



# ESD PhD Alumni Placements [2004 - 2011]



**Recommended to attend September 16, 2011 Alumni Homecoming Event**

# Failure Modes in the PhD Program

- Wait forming a committee until year 2
- Take a job while attempting to complete
- Go on non-resident status for more than 1 semester
- Load up on too many classes (4+ per semester)
- Become a “floater” (especially fellowship students)
- Read little and talk to no one
- Read too much and talk to “too many” people
  
- Good Luck , you have embarked on an exciting and challenging journey !