The Case for Reform of Engineering Education*

A presentation at

"Reforming Electric Energy Systems Curriculum"

*** With Electrical Engineering as the principal test case**

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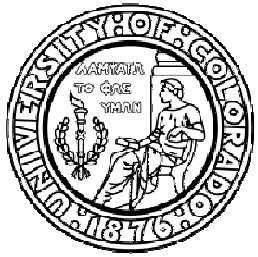

Moshe Kam
2010 IEEE President Elect

ECE Department
Drexel University

Michael Lightner
2006 IEEE President & CEO

ECEE Department
University of Colorado at Boulder

Outline

- The last time we reformed EE education…
- The fundamentals may be shifting
- The profession is changing
  - Geographically
  - In relation with other disciplines
  - In terms of products and services
  - In the nature of the workplace
- The economic and demographic problems of the profession have not been solved

EE education in the US: the first 50 years in a glance

- Early EE departments were established in the last 20 years of the 19th century
  - Most grew out of Physics departments
  - Curricula focused on AC and DC circuits and power distribution
  - B.Sc. Degree was the norm
    - Plus hands-on training in industry
  - After World war I communication options appear
  - Little academic research
    - In 1925 only one MIT EE faculty member had a Ph.D.
    - Half of the faculty had a B.Sc degree + practical experience

Terman 1976

The Impact of World War II

- The rise of new technology found the field unprepared
  - Most “EE work” was performed by scientists from other disciplines, especially physics
  - Radar, microwaves, control systems, guided missiles, proximity fuses
- The case was reform was clear

Terman 1976

The First Reform (1945-1955)

- Overhaul of textbooks and courses
  - A new book shelf
- Focus on the fundamentals
  - Mathematics and Physics
  - Introducing Physics-based Calculus as the basic first step of the EE curriculum
- De-emphasis of classes on "engineering practice"
  - Drafting, surveying, practicum

Impetus for reform: new technology

Terman 1976

The First Reform (1945-1955)

- Large expansion of graduate programs
  - Beginning of federal funding of academic EE research
- Emergence of new requirements and expectations from EE faculty members
  - At least an M.S. degree
  - In many institutions – demonstration of ability to conduct independent research
    - Educate new Ph.D. students
    - Obtain external support for research
- Painful transition in many institutions

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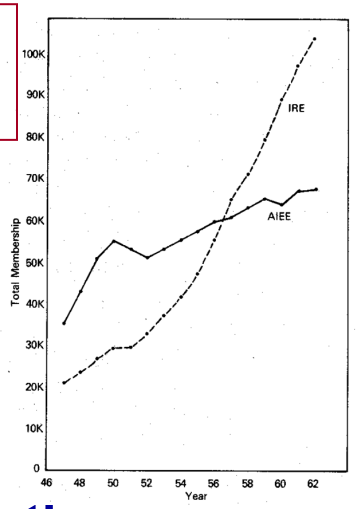
Late reaction: the merger between AIEE and IRE



AIEE

- Established 1884
- An American Organization
- Representing the establishment
- Rooted in Power Engineering and telephony
- First computers working group
  - Now the Computer Society

IRE

- Established 1912
- An international Organization
- Open to students, young professionals
- Quick to adopt advances in radar, radio, TV, electronics, computers
- Proceedings of the Institute of Radio Engineers (January 1913)

1963: Merger of AIEE and IRE to create IEEE

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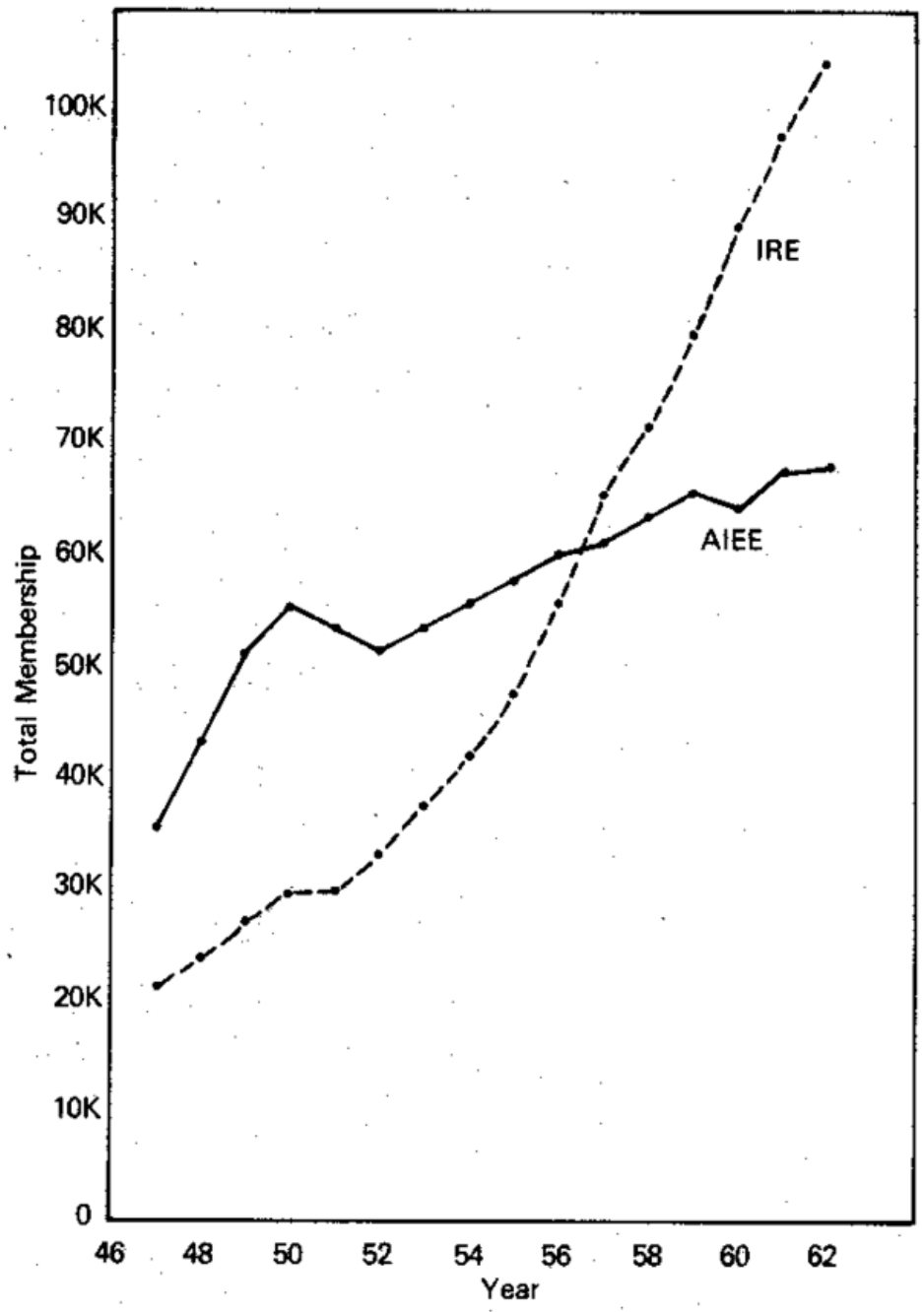

In 1963 the IRE and AIEE form the IEEE

In 1962 the first Computer Science program is established

Differentiation and Compartmentalization
1975-1985

- **Many EE programs develop "tracks"**
  - **Often available only in the Senior year**
  - **"Signal processing" "Power and Control" "Biomedical Devices" "Computers" "Antennas and Propagation"**
- **Computer Engineering programs proliferate**
  - **The emergence of the ECE department**
- **'Secession' of Computer Science is complete**
- **New programs emerge in Biomedical Engineering**

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Serov 1997

The impetus for the second reform attempt… (1990-2003)

- Desire to use emerging technology to improve instruction
  - Personal computer, digital communication and networking
- The sense that the pendulum has swung too much toward Engineering Science
- High attrition rate of students in the early years
  - Attributed to the abstract nature of preparatory classes
- Graduates perceived to be deficient in communication and presentation skills

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Serov 1997

The impetus for the second reform attempt… (1990-2003)

- Graduates perceived to be unable to take into consideration economic, social, and ethical considerations; can't work in teams
- Increased economic gap between engineering and practitioners of the 'professions'
- Continued failure to attract minorities and women to engineering
- A plethora of new proposals for better pedagogical approaches for engineering

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General Outline of the Second Reform Attempt

- Started with the 1988 NSF-funded E4 experiment at Drexel University
- Continued by establishment of NSF coalitions of schools, which operated 1992-2002
  - Gateway, SUCCEED
- The coalitions developed new curricular materials, ideas and structures
  - Implementation and scaling proved difficult
  - Adoption of coalition-created instructional material and methods outside home institutions was limited

Impetus for a Third Reform Attempt

- **The fundamentals may be shifting**
  - **Modern computing is not integrated properly in engineering education**

- **The profession is changing**
  - **Geographically**
  - **In relation with other disciplines**
  - **In terms of products and services**
  - **In the nature of the workplace**

- **The economic and demographic problems of the profession have not been solved**

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Impetus for a Third Reform Attempt

The Fundamentals may be shifting

Modern computing is not integrated properly in engineering education

Computing is Changing the Nature of Engineering Work

- The use of computing tools has pervaded almost all areas of engineering
  - Look under the hood of your car
  - Look under the hood of your Spectrum Analyzer
- Engineering education did not yet catch up
  - For us it is still “computer aided design”
  - For industry this is the only design that there is
- We continue to teach many subjects as if symbolic computation and computers do not exist

Favorite Examples

- We continue to teach again and again how to find, guess and synthesize integrating factors
- We still teach students how to use approximations and rules of thumb most of which will never ever be used
  - Think about Bode Plots and Root Locus Methods
- Fundamentals of software writing and software testing are often left for self exploration
  - And yet these are huge gaps for engineers on the job

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One Possible Reaction:
Keep Computing to the Computer Scientists!

One Possible Reaction:
Keep Computing to the Computer Scientists!

This view neglects the fact that for engineers proficiency in computing is no less fundamental nowadays when compared with proficiency in Physics-Based Calculus

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A More Reasoned Approach

- The role of computing in the education of engineers need to be re-thought
- Computing skills can no longer be add-ons and nice-to-haves
- As analytical skill needed by engineers, computing may have become as least as fundamental as Calculus

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IEEE has a role to play…

A More Reasoned Approach

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Impetus for a Third Reform Attempt

The Profession is Changing…

Geographically

Our Profession is Changing Geographically

- Science and engineering education is expanding into new geographical areas
- Some engineering work has migrated from its former US and West European centers to other countries and regions
- Manufacturing, Design, Research and Development are performed in many countries that had no Hi-tech industry even 20 years ago

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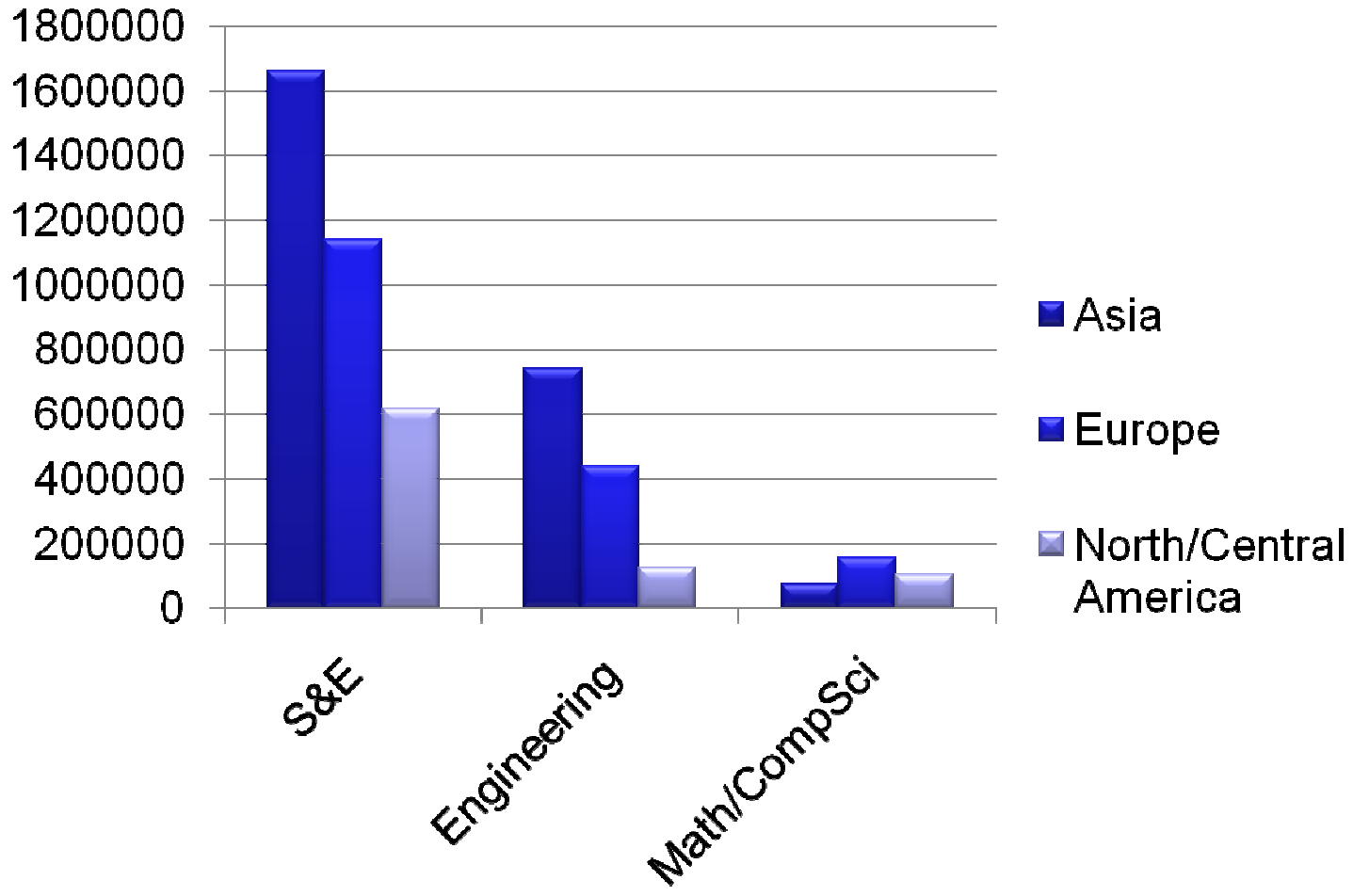
First University Degrees in Selected Areas



http://www.nsf.gov/statistics/seind08/c2/c2s5.htm

Science and Engineering Indicators 2008 (US NSF)

S&E degree as fraction of the total number of degrees granted

- In the United States, S&E degrees are about one-third of U.S. bachelor's degrees

- In several countries more than half of first university degrees were in S&E
  - Japan (63%), China (56%), Singapore (59%), Laos (57%), Thailand (69%)

Science and Engineering Indicators 2008 (US NSF)

Degrees in Engineering

- In the United States, about 5% of all bachelor's degrees are in engineering
- In most of Asia, 20% of the degrees are in engineering
  - In China, the number of first university degrees in engineering more than doubled between 2000 and 2004 and quadrupled over the past two decades
- In many other countries worldwide, more than 10% of the degrees are in engineering

Science and Engineering Indicators 2008 (US NSF)

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Recent Developments in Higher Education in China

- Major education reform efforts in China began in the late 1990s

- These efforts focused on…
  - consolidating and strengthening higher education institutions
  - expanding disciplines offered
  - increasing funding
  - improving teaching

Science and Engineering Indicators 2008 (US NSF)

China

Enrollment increases in China Colleges and Universities

- Enrollment in higher education in China increased sharply
- Undergraduate enrollment in colleges and universities increased from 0.3 million in 1998 to 13.3 million in 2004
  - 4-year degrees increased from 405,000 to 1.2 million
- Although enrollment and degree production increased exponentially, the per capita rate of college attendance remains low

Science and Engineering Indicators 2008 (US NSF)

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Current Reform Efforts in China

- Improving quality of instruction
- Slowing the growth in college enrollment to 5% per year
- Targeting advanced education

- The increased growth in enrollment is largely outside of S&E
  - In 1994, 46% of earned degrees were in engineering
  - By 2004, 37% were in engineering

Science and Engineering Indicators 2008 (US NSF)

Our Profession is Changing Geographically

- S&E and engineering education are expanding into new geographical areas

- Some engineering work has migrated from its former US and West European centers to other countries and regions

- Manufacturing, Design, Research and Development are performed in many countries that had no Hi-tech industry even 20 years ago

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One Possible Reaction: "Keep the Invaders Out"

A More Reasoned Approach…

- Educate future engineers to work in a transnational environment
  - E.g., encourage “a semester abroad”
  - Introduce study on pertinent international trends into the curriculum
    - Including education in business and law
- Provide resources to engineers to understand industrial and economical trends that affect the profession
- Develop a global system of credential and accreditation recognition

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IEEE has a role to play…

A More Reasoned Approach…

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Impetus for a Third Reform Attempt

The Profession is Changing…

The Rise of the Service Economy

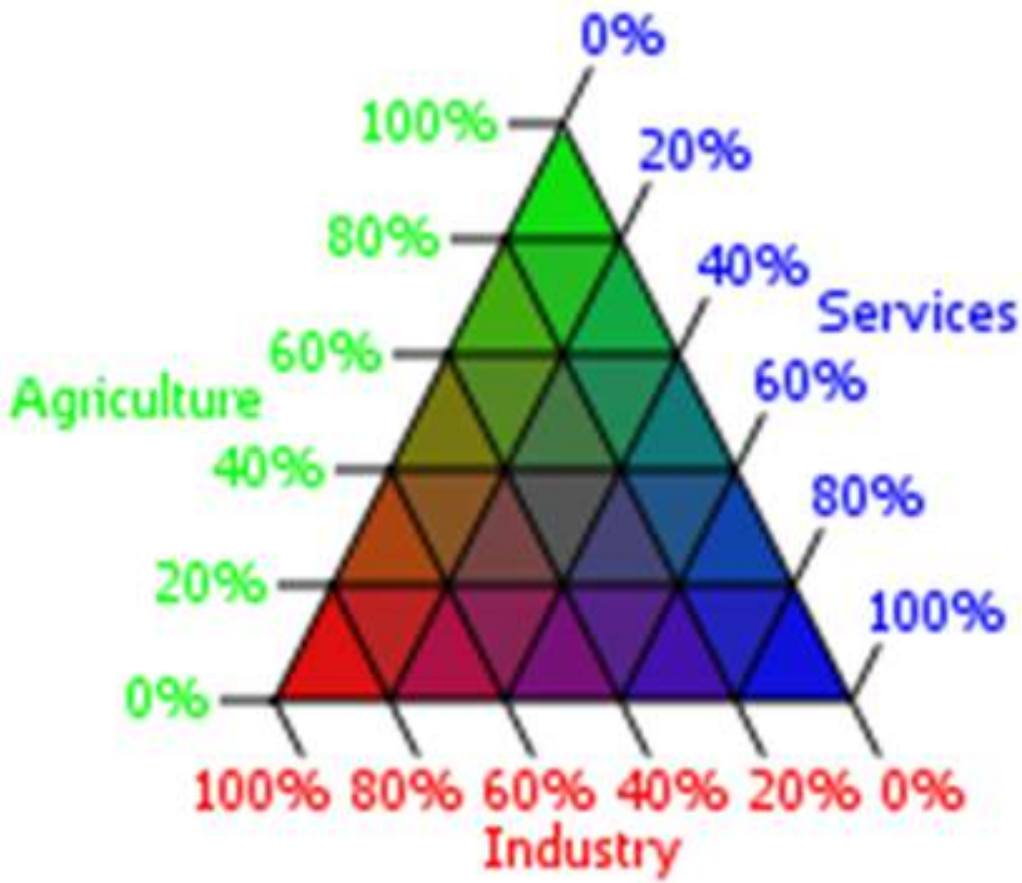
The Role of Service Economy is Increasing

- Increased importance of the service sector in industrialized economies
- Look at the Fortune 500
  - …more service companies
  - …fewer manufacturers
- The old dichotomy between product and service has been replaced by a service-product continuum

“Servitization of products”

- Products today have a higher service component than in previous decades
- Virtually every product today has a service component to it
- Many products are being transformed into services

Colour Key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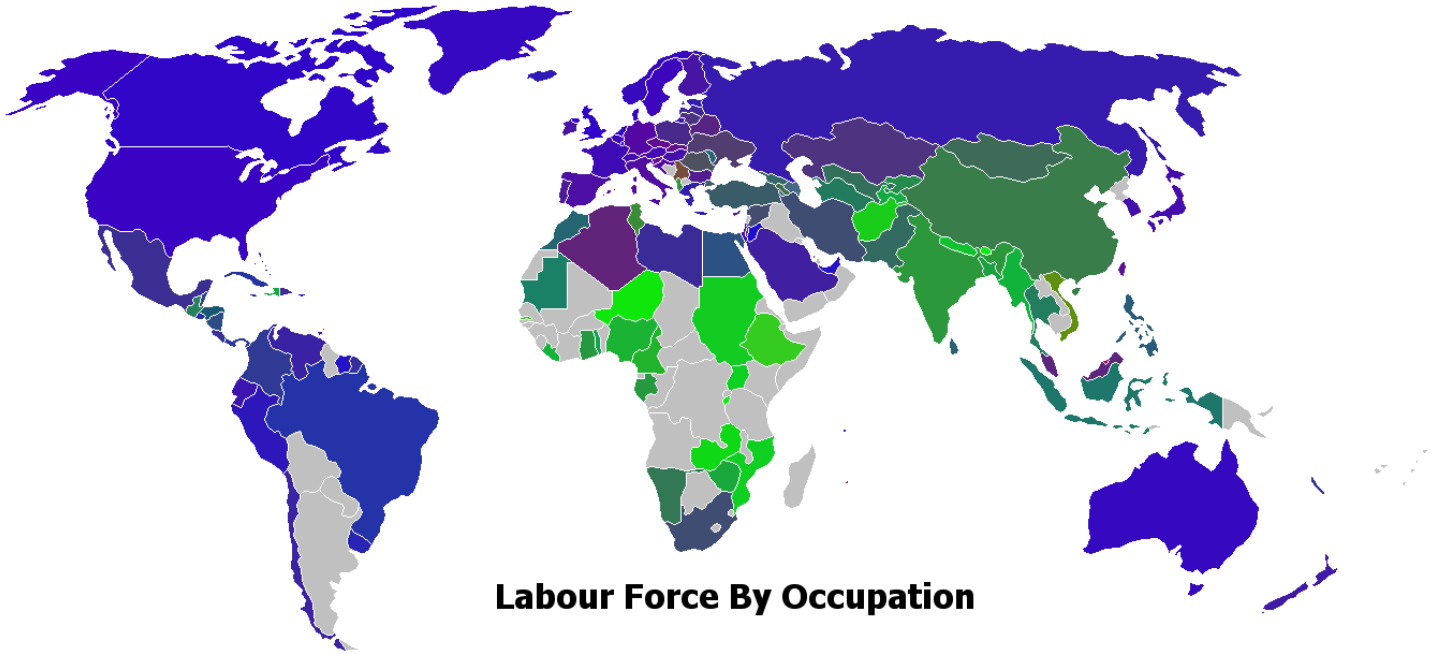
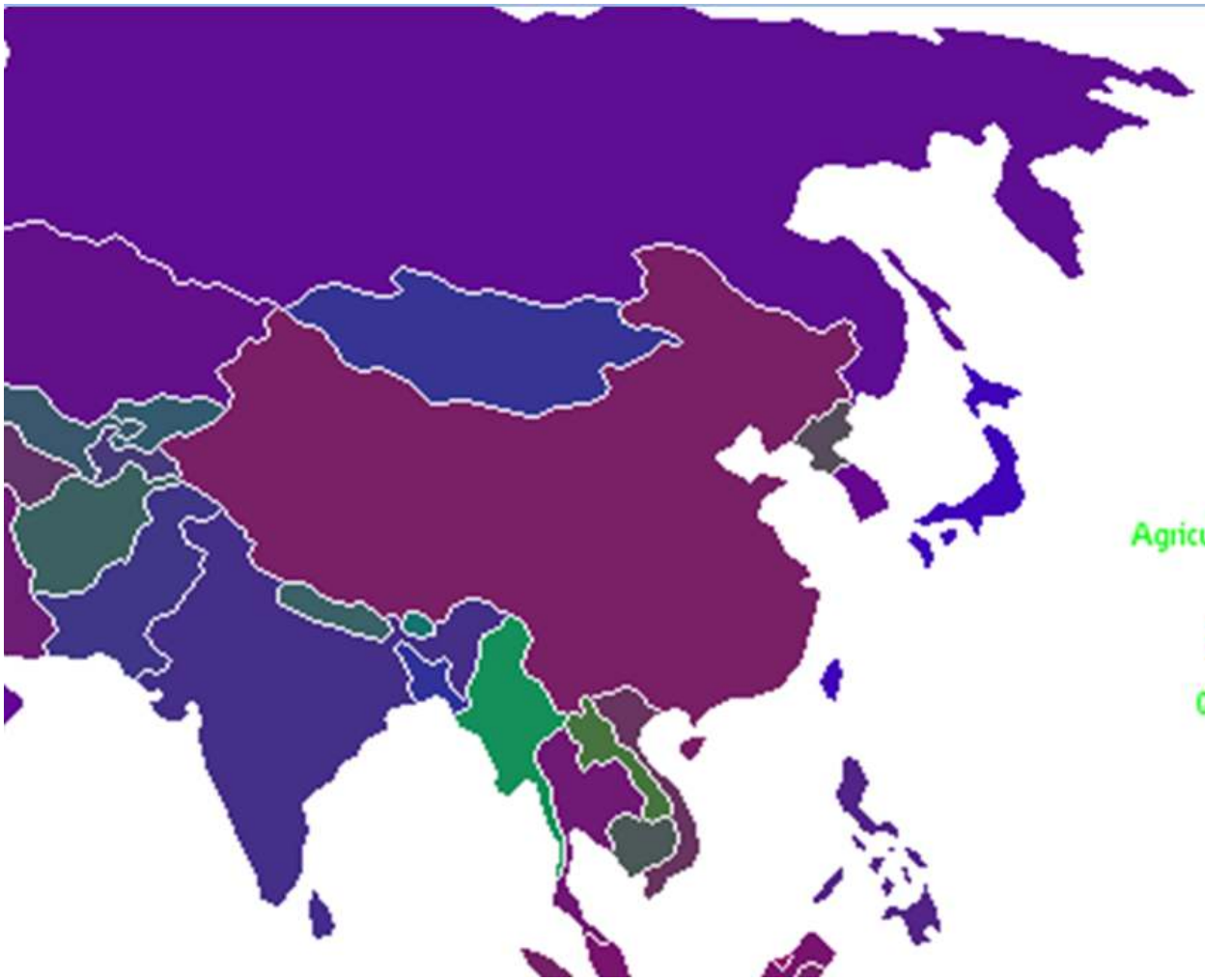
GDP Composition By Sector



Labour Force By Occupation



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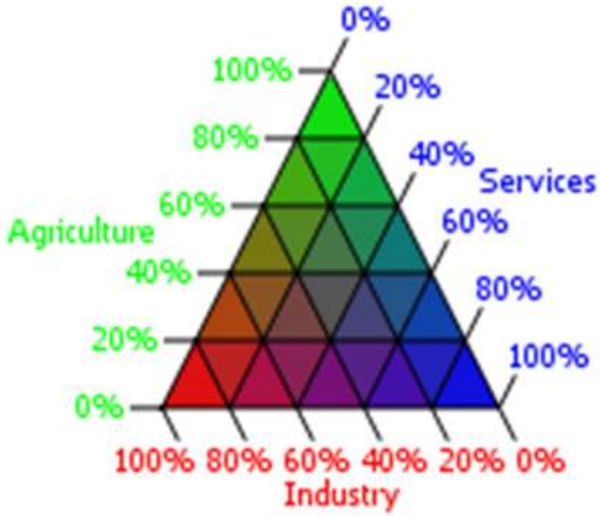

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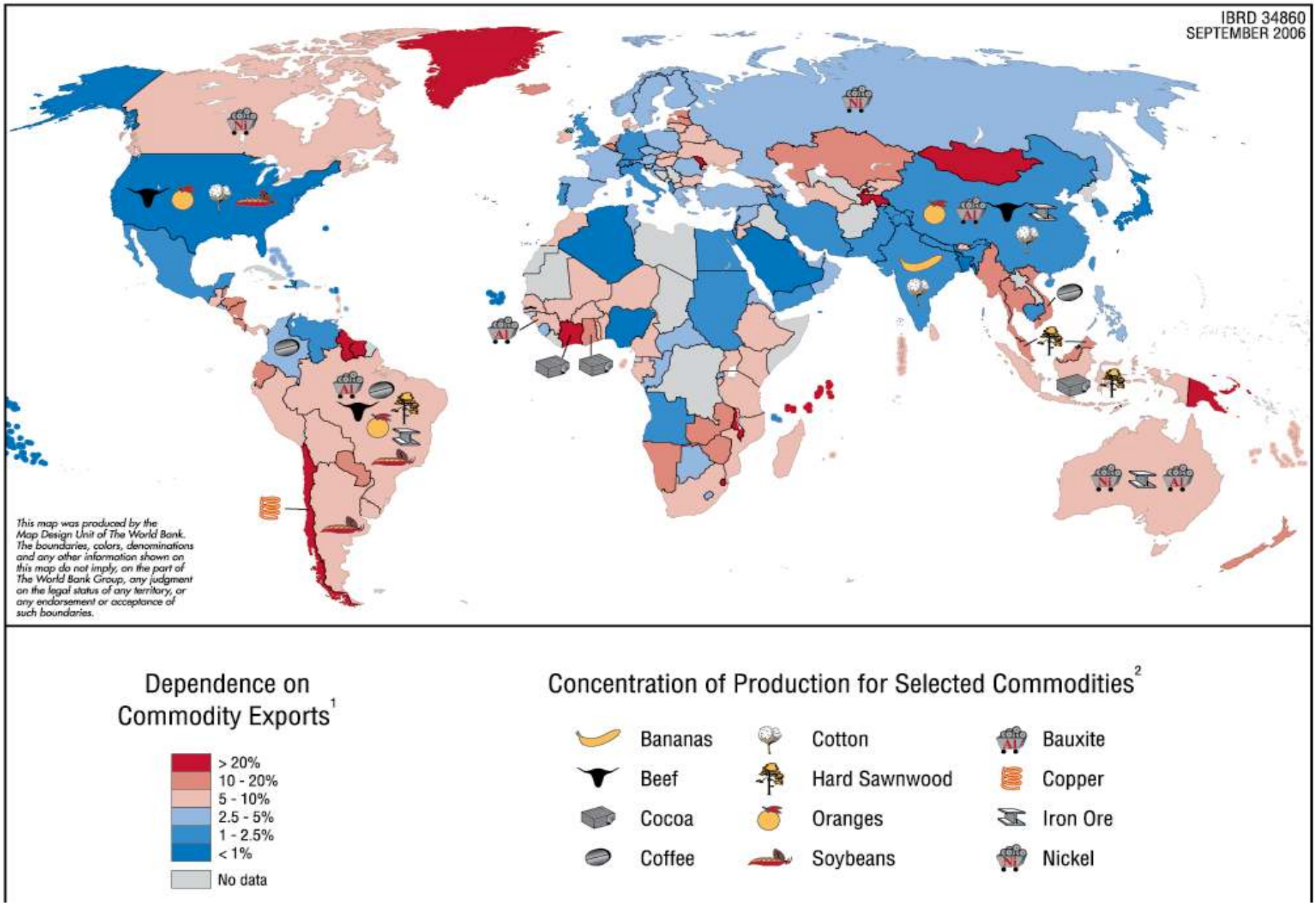
Note: Map colours are more finely graded than key colours

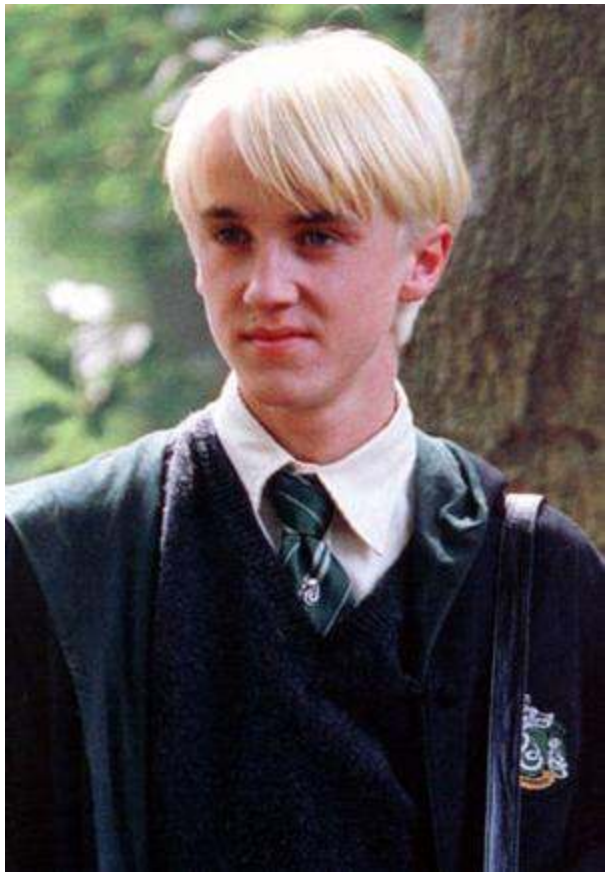
Figure 5.1. Dependence on Exports of Nonfuel Commodities and Geographical Concentration of Production

Many developing countries and emerging markets continue to be highly dependent on exports of nonfuel commodities (these countries are marked in red). Production of some commodities is highly geographically concentrated, potentially making world prices sensitive to country-specific events.



One Possible Reaction:
This is Beneath Us…

Service is NOT Engineering



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A More Reasoned Approach

- Recognize that the Service Economy is here to stay
- Find ways to integrate the Service Economy in the Engineering curriculum
- Re-examine interdisciplinary work in Commerce and Engineering
  - This may be the right time for another look

IEEE has a role to play…

A More Reasoned Approach

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Impetus for a Third Reform Attempt

The Profession is Changing…

with respect to other disciplines

Our Profession is Expanding Beyond Traditional EE and CE Departments

Here are a few courses taught by the Mechanical Engineering Department in Lehigh University:

- Control Systems
- Digital Control
- Control Systems Laboratory
- Mechatronics
- Mechatronics Laboratory
- Nuclear Reactor Engineering
- Mechanical Engineering Laboratory
  - Introduction to elementary instrumentation. Introduction to digital data acquisition.
  - Including use of transducers, advanced instrumentation, and data acquisition.

Kidnapping of the Leukipp's Daughters

Our Profession is Expanding Beyond Traditional EE and CE Departments

Here are a few courses taught by the Biomedical Engineering Department in Georgia Tech:

- Introduction to Signal Processing
- Biomedical Systems and Modeling
- Computing for Engineers
- Biomedical Instrumentation
- Introduction to Medical Image Processing

- Biomedical Systems and Modeling
  - Systems and Modeling
  - Linear-Systems Analysis in the Time Domain
  - Linear-Systems Analysis in the Laplace Domain
  - Linear-Systems Analysis in the Frequency Domain
  - Control Systems Design and Analysis

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One Possible Reaction: Fight the Impostors

A More Reasoned Approach…

- Develop bridges between disciplines
  - Minors, Joint Degrees, Joint Projects
- Educate young engineers to work in teams and across disciplinary barriers
- Prepare young engineers to work at the intersection of electrical engineering, computer engineering, computer science and the life sciences.

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IEEE has a role to play…

A More Reasoned Approach…

- **Develop bridges between disciplines**
  - **Minors, Joint Degrees, Joint Projects**
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Impetus for a Third Reform Attempt

The Profession is Changing…

…it is not the same workplace

The Nature of the Engineering Workplace is Changing

- Long term tenures of engineers in one job in a single company are becoming less common
- Even when unemployment rates remain low, turnover is higher
- The arsenal of skills required of engineers continue to change rapidly
  - Advances in computing necessitate almost-continuous re-training

One Possible Reaction: We Need Better Protection

IEEE has a role to play…

A More Reasoned Approach

- **We need to "arm" new engineers with methodology that would increase their performance in the new labor marketplace**
  - **"Yourself as a business"**
- **Professional associations should develop services that replace the traditional service provided by the "home company"**
- **Continuing education should become the norm**

The Case for Curricular Reform

- **The fundamentals may be shifting**
  - **The impact of modern computing is not yet integrated in engineering education**

- **The profession is changing**
  - **Geographically**
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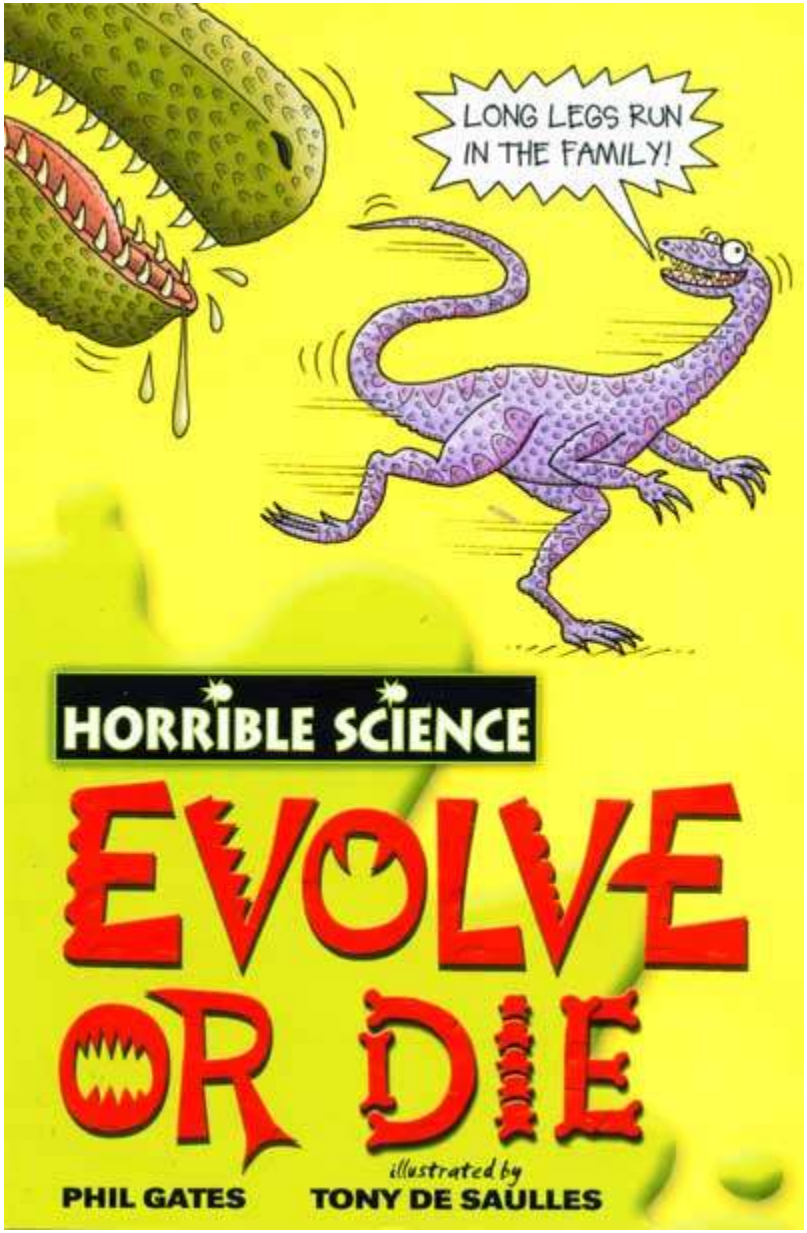
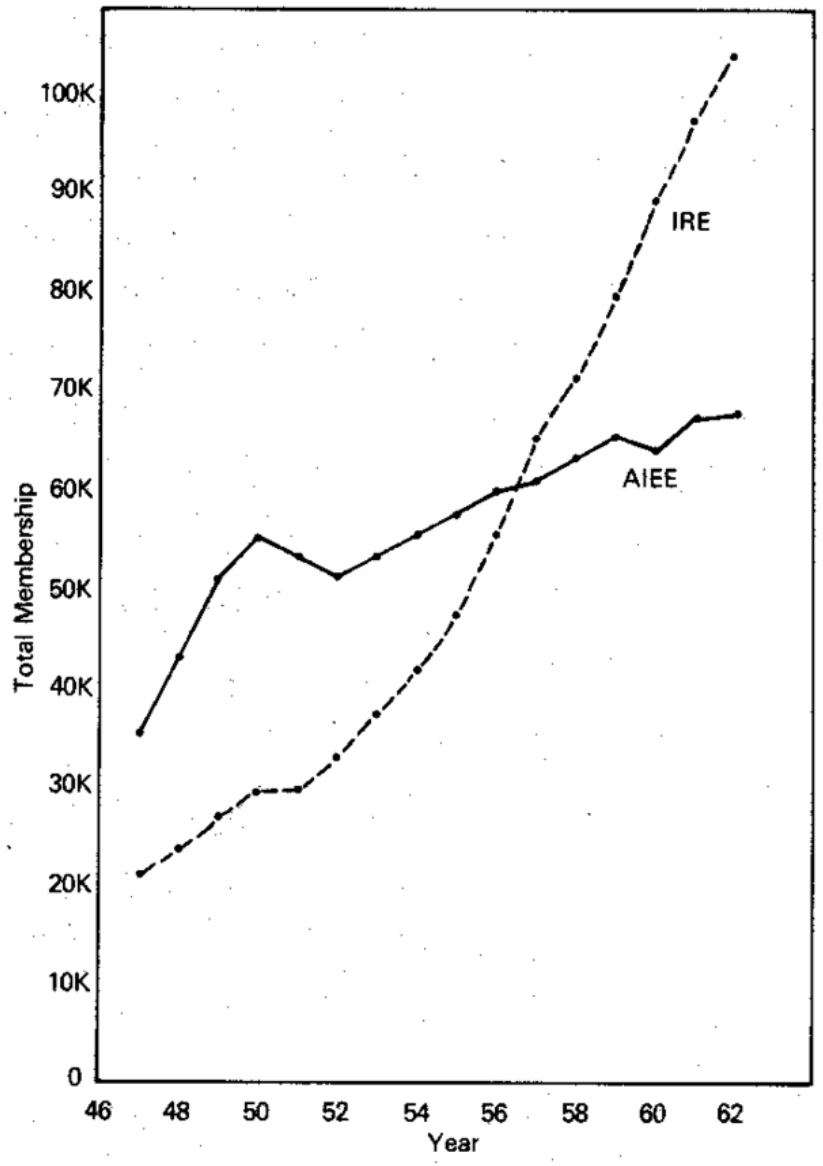

LONG LEGS RUN IN THE FAMILY!
HORRIBLE SCIENCE
EVOLVE OR DIE
illustrated by
PHIL GATES
TONY DE SAULLES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