The Future

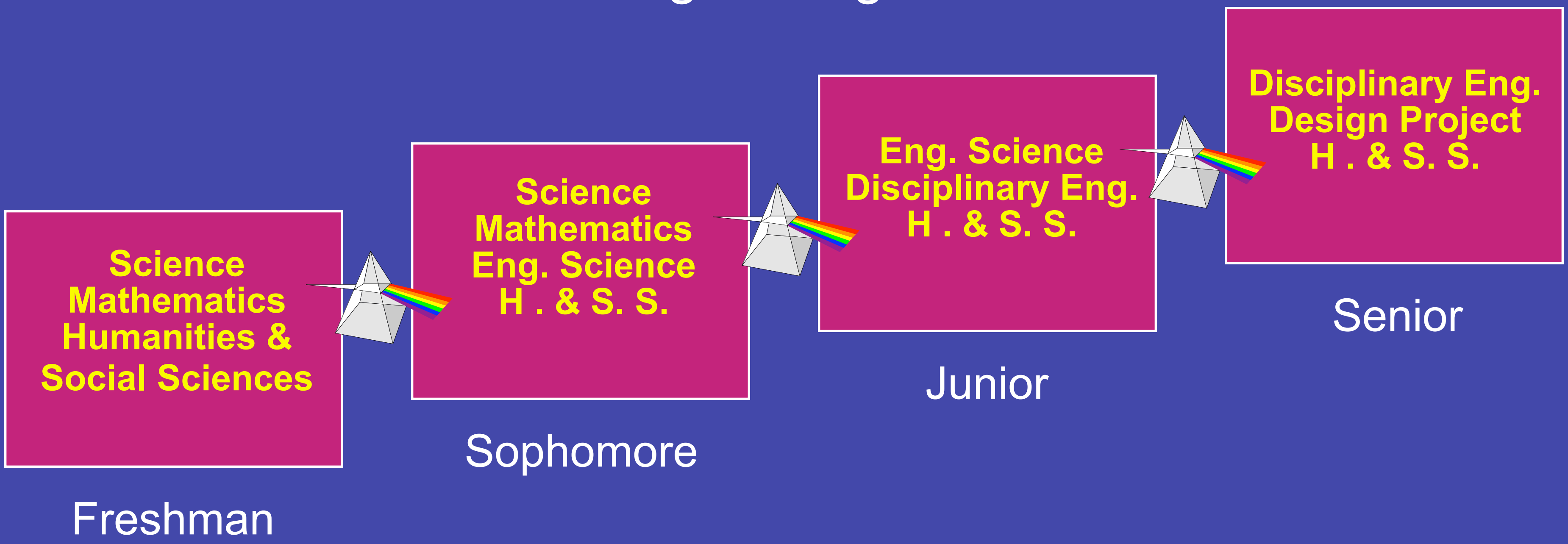
Engineering Education
for the 21st Century

Traditional Engineering Education

- Highly sequential, a pyramid of prerequisites
- Highly specialized within majors
- Little flexibility (few free electives)
- Stress scientific analysis rather than design and synthesis
- Too much technical content at the expense of a broader, liberal education

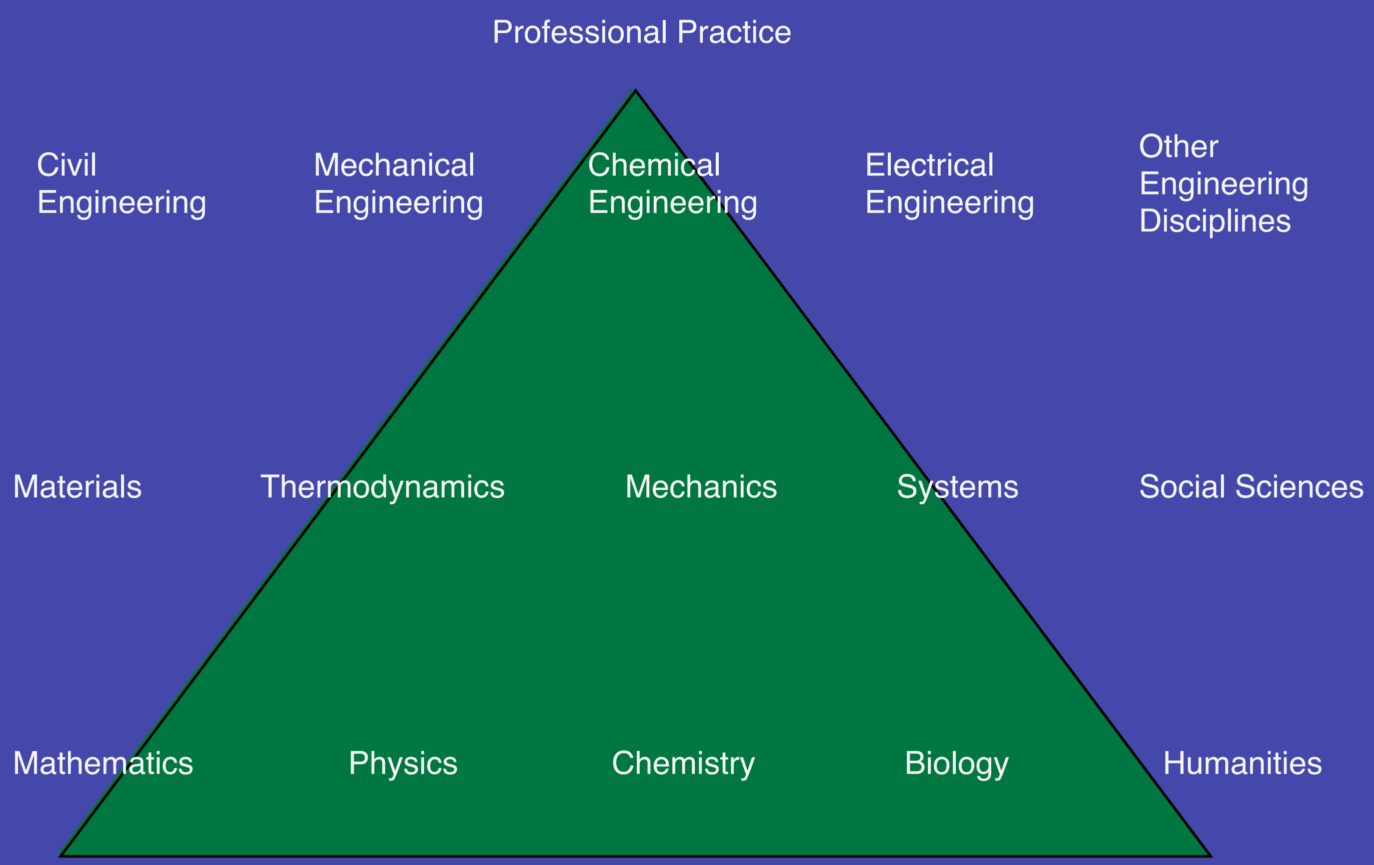
Traditional Undergraduate Curriculum

Passing Through Filters



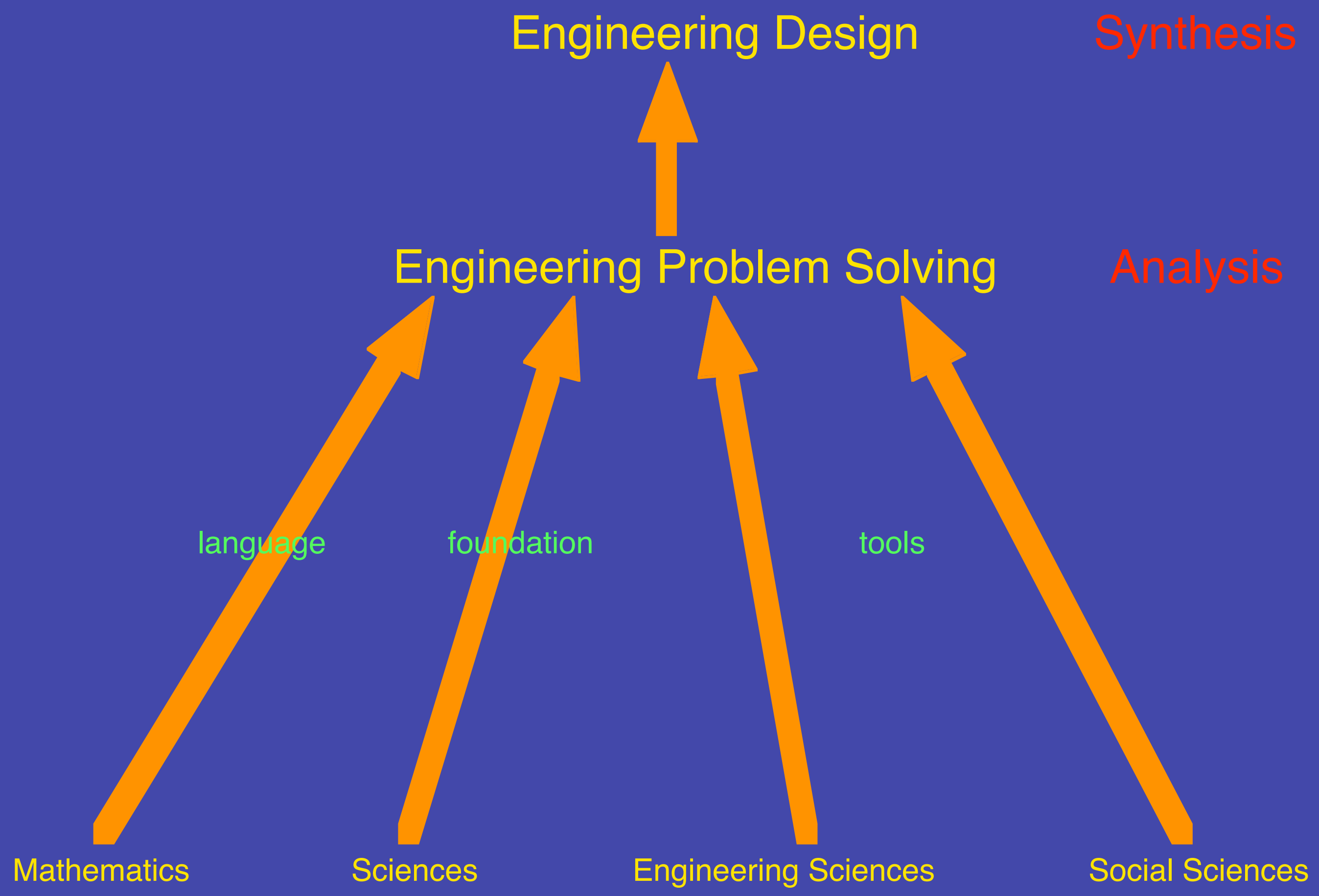
Bordogna, NSF

An Engineering Education



The Education Pyramid

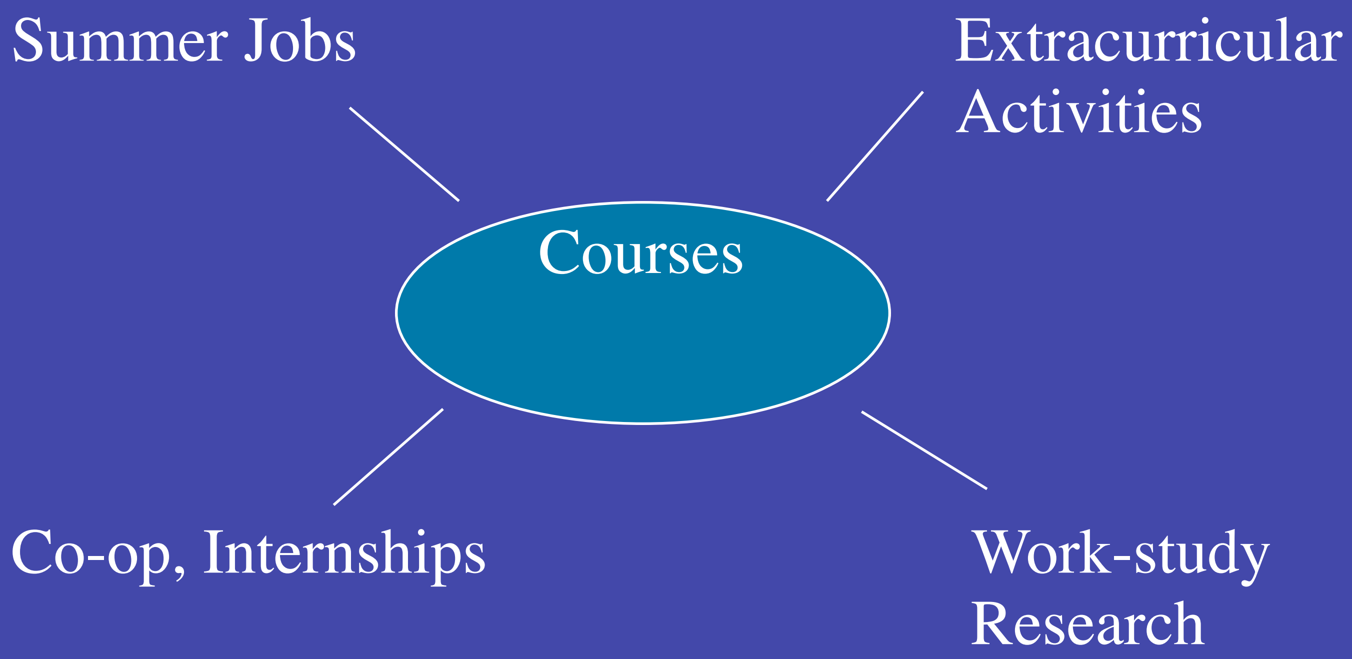
The Engineering Curriculum



What do employers want?

- Graduates who can communicate well.
- Graduates who can appreciate diversity.
- Graduates who are committed to a lifetime of learning.
- Graduates who not only can tolerate change but can drive change.

Look at entire college experience



Some Observations about Education

Peter Drucker: "We will redefine what it means to be an educated person. Traditionally an educated person was someone who had a prescribed stock of formal knowledge. Increasingly, an educated person will be someone who has learned how to learn, and who continues learning throughout his or her lifetime."

Ancient Chinese proverb:

I hear, and I forget.

I see, and I remember.

I do, and I understand!

A 21st Century World

Information Explosion

Global Economy

Cognitive Revolution

International Competition

Diverse Workforce

Finite Resources

Defense Reinvestment

Environmental Sustainability

Shared Wealth

Dual Use

Demographic Shifts

Meeting the Challenge

Next Generation Engineering Career Paths

- **Sustainable development: avoiding environmental harm; energy / materials efficiency**
- **Life cycle / infrastructure creation and renewal**
- **Micro / nanotechnology / microelectromechanical systems**
- **Mega systems**
- **Smart systems**
- **Multimedia and computer-communications**
- **Living systems engineering**
- **Process quality / control**
- **Management of technological innovation**
- **Enterprise transformation**
- **. . . ?**

Next Generation Engineering Skill Set

- Systems integration; synthesis
- Engineering science; analysis
- Problem formulation as well as problem solving
- Engineering design
- Ability to realize products
- Facility with intelligent technology to enhance creative opportunity
- Ability to manage complexity and uncertainty
- Teamwork; sensitivity in interpersonal relationships
- Language and multi-cultural understanding
- Ability to advocate and influence
- Entrepreneurship; management skills; decision making
- Knowledge integration, education and mentoring

Next Generation “Core” Curriculum*

- conservation laws
- biochemistry
- scalar wave equation
- genetics
- dynamical systems
- evolution
- cell biology
- physical forces
- geochemistry
- atmospheric chemistry
- quantum mechanics
- discrete mathematics
- logic and probability
- chemical bonding
- information theory
- electrical circuits
- statistical mechanics
- thermodynamics
- chemical equilibrium
- condensed matter
- systems engineering
- complexity
- collective properties
- chaotic systems
- neurobiology

*Caltech

More fundamentally…

Less emphasis on “reductionist” science (e.g., physics)
More emphasis on “information -rich” sciences (e.g., biology)

Less emphasis on technical material
More emphasis on humanities, arts, and social sciences

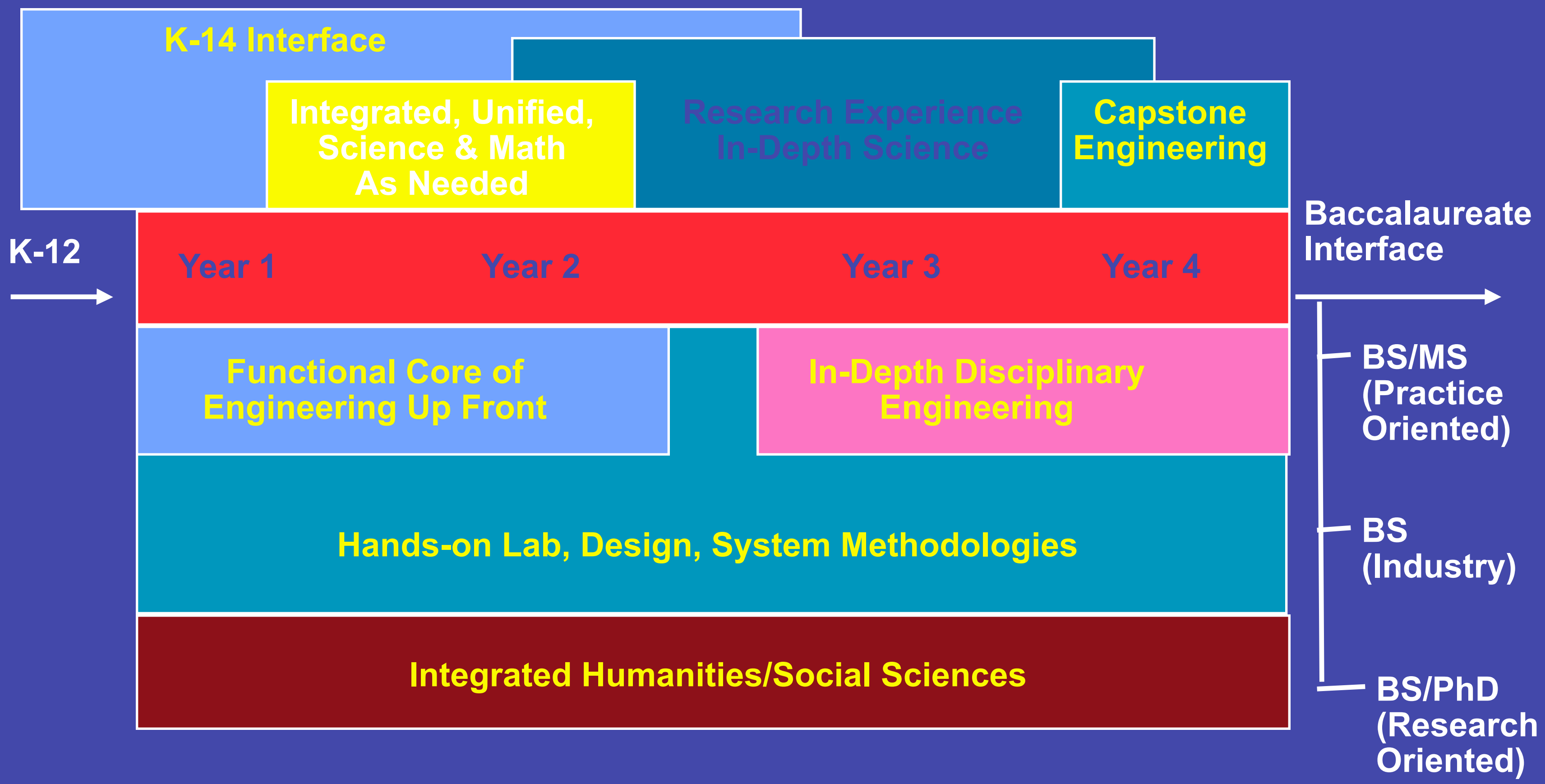
Less emphasis on analysis
More emphasis on synthesis

Consilience

"Most of the issues that vex humanity daily cannot be solved without integrating knowledge from the natural science with that of the social sciences and humanities. Only fluency across the boundaries will provide a clear view of the world as it really is, not as seen through the lens of ideologies and religious dogmas or commanded by myopic response to immediate needs."

E. O. Wilson

Holistic Engineering Curriculum



Components of a Holistic Baccalaureate Education

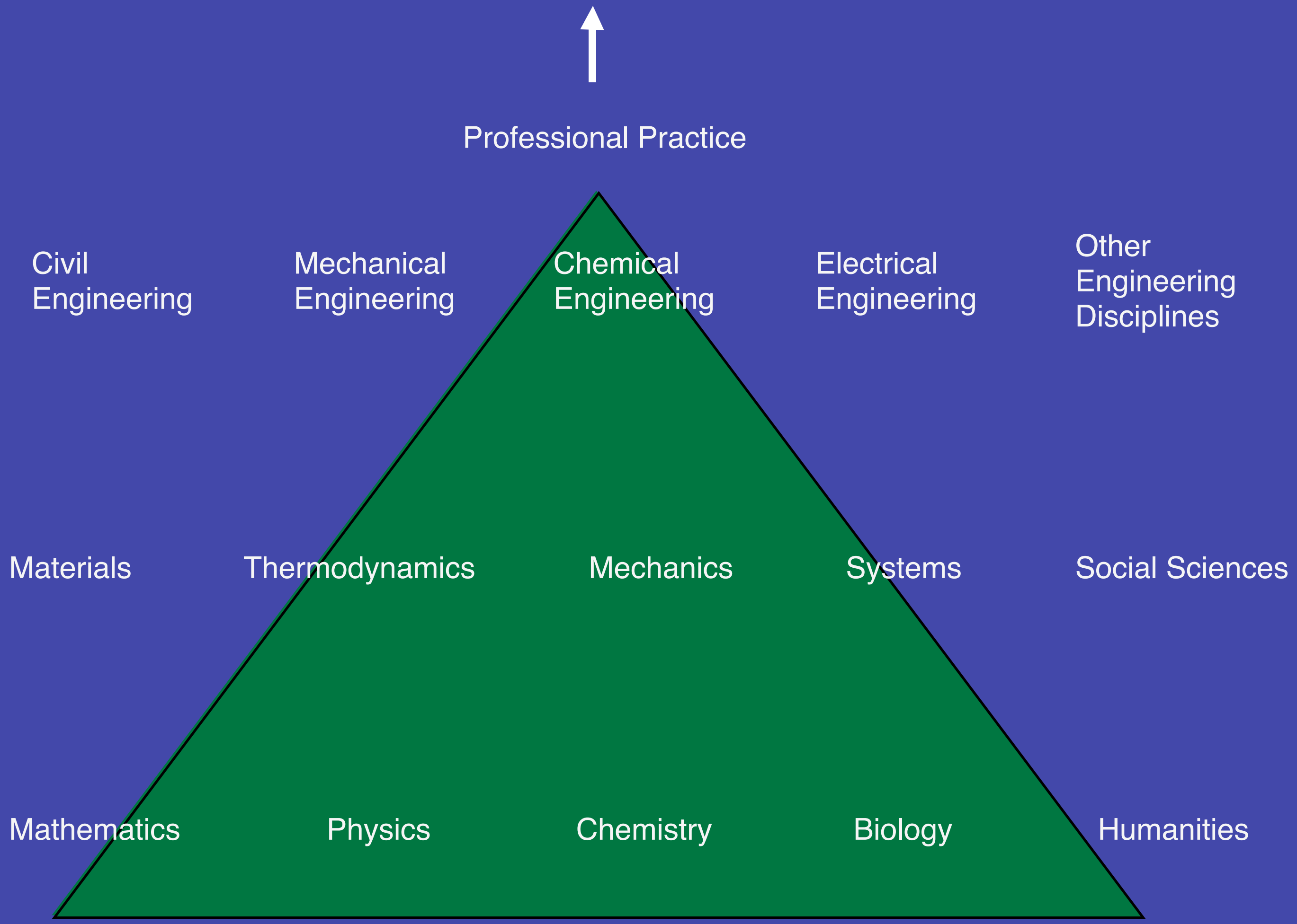
Vertical (In-depth) Thinking	Lateral (Functional) Thinking
Abstract Learning	Experiential Learning
Reductionism - Fractionization	Integration - Connecting the Parts
Develop Order	Correlate Chaos
Understand Certainty	Handle Ambiguity
Analysis	Synthesis
Research	Design / Process / Manufacture
Solve Problems	Formulate Problems
Develop Ideas	Implement Ideas
Independence	Teamwork
Technological - Scientific Base	Societal Context / Ethics
Engineering Science	Functional Core of Engineering

Challenges for 21st Century Academe

Educate students to:

- See the world whole; sense the coupling among seemingly disparate fields of endeavor
- Perform synthesis in balance with analysis
- Build connections between the world of learning and the world beyond
- Innovate

An Engineering Career



The Education Pyramid

A broader perspective

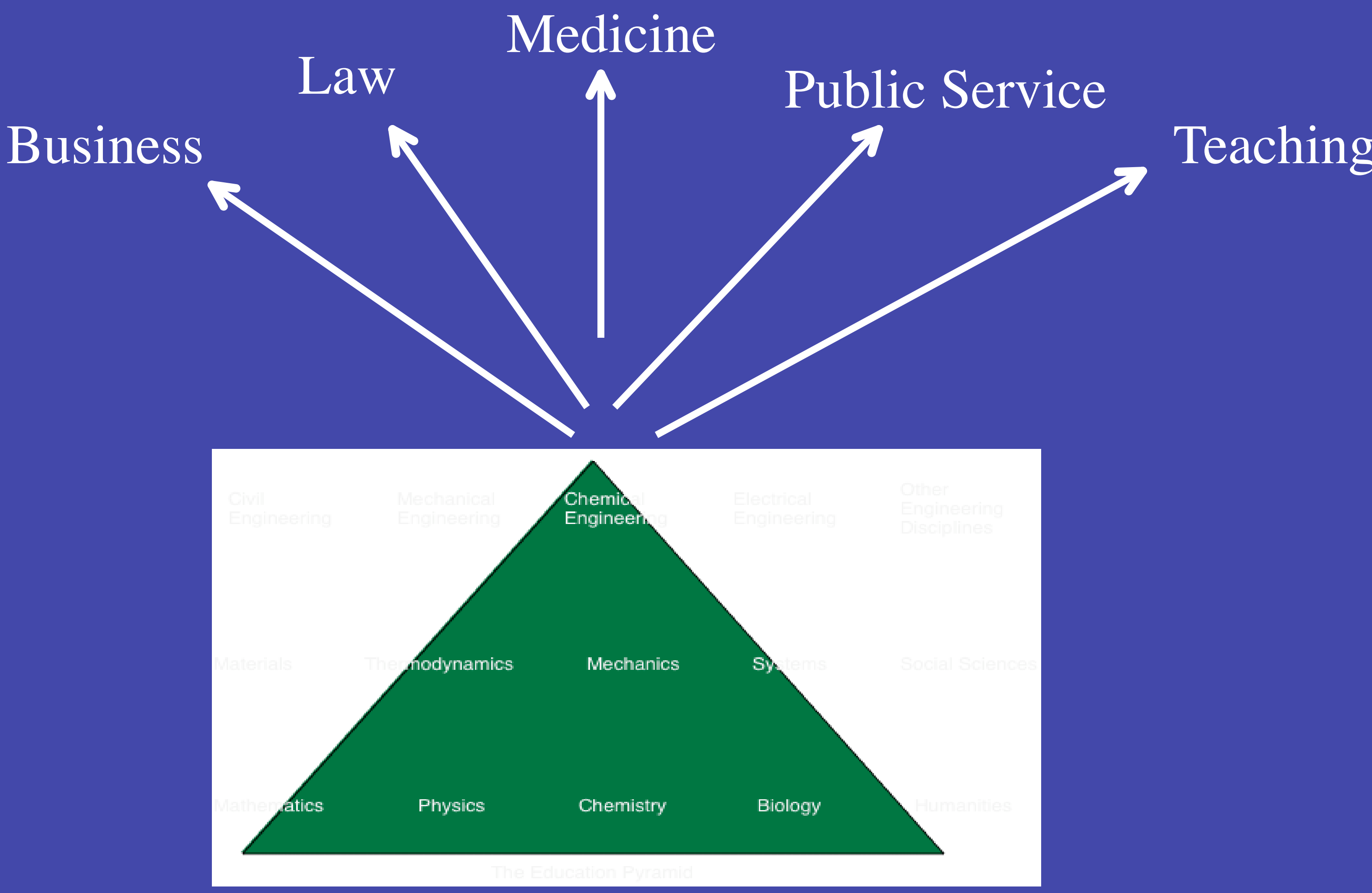
Engineering educators should be challenged to devise an engineering-based “liberal education” for students of the next century.

Engineering principles and modes of thought should be the centerpiece of what the liberally educated person should be expected to know in the world of the future.

We should develop and promote a new kind of engineering education as a primary option for a “liberal education” for the 21st Century.

We will produce many more leaders–in politics, finance, industry, law–with an education attuned to the issues and challenges of the century, most of which have dominant technical themes.

Alternative Careers



The Future of the College of Engineering

Some questions and observations…

First, some questions:

- Is the current instructional, research, and service load on the Engineering faculty realistic? Or is there a danger of faculty "burnout"?
- Is the priority of the College within the University adequate? (Within the state? Within the nation? Globally?)
- Is the College adequately exploiting all of its revenue opportunities (e.g., tuition?…state support?…consulting activities?…equity interests?)
- Has there been adequate cost containment in nonacademic areas (e.g., administrative staffing)? What do "best practices" comparisons suggest?

More questions:

- Does the present intellectual organization of the College make sense? (E.g., fewer departments, more matrix structures?)
- Do you need to modify learning paradigms? (E.g., faculty shifting from “teaching” to “designing” learning experiences?)
- Do you need to restructure research activities? (E.g., being more selective in seeking sponsored research, shifting from single investigator to team research?)
- Is the faculty culture optimum? (e.g., encouraging risk-taking, teamwork, communication, and accountability?)

Still more questions:

- Does the College need to form more strategic alliances?
  - With the top engineering schools?
  - With key industry?
  - With national laboratories?
- What are the goals of the College?
  - In 10 years?
  - In 20 years?
  - When it celebrates its 200th anniversary?

Possible Futures?

College of Science and Engineering

A "college" with broader UG and graduate programs in the physical sciences and engineering?

Or a "professional school" at the graduate level?

?

School of Engineering

College of Science and Technology

- Elements:
  - Engineering
  - Physical Sciences (Physics, Chemistry, Earth Systems, …)
- Redesign undergraduate degree into a “liberal education for a knowledge society”
- Shift more formal education in technology (e.g., “engineering degrees”) to graduate level, along with M.S. and Ph.D. in physical sciences

School of Engineering

- All degrees at the graduate level (with the M.S.E. as the first professional degree)
- Add more “practitioner” faculty to the current cadre of “engineering scientists”
- Work with the University to define a broader undergraduate degree in “science and technology” (much like the pre-med and pre-law degree programs)

A Final Observation

- Today the College enjoys
  - An outstanding faculty…
  - Some of the best facilities in the nation…
  - One of the best computing environments…
  - Some highly novel programs…
  - And is a part of one of the greatest universities in the world…
- It has extraordinary opportunity!

But, to take advantage of this:

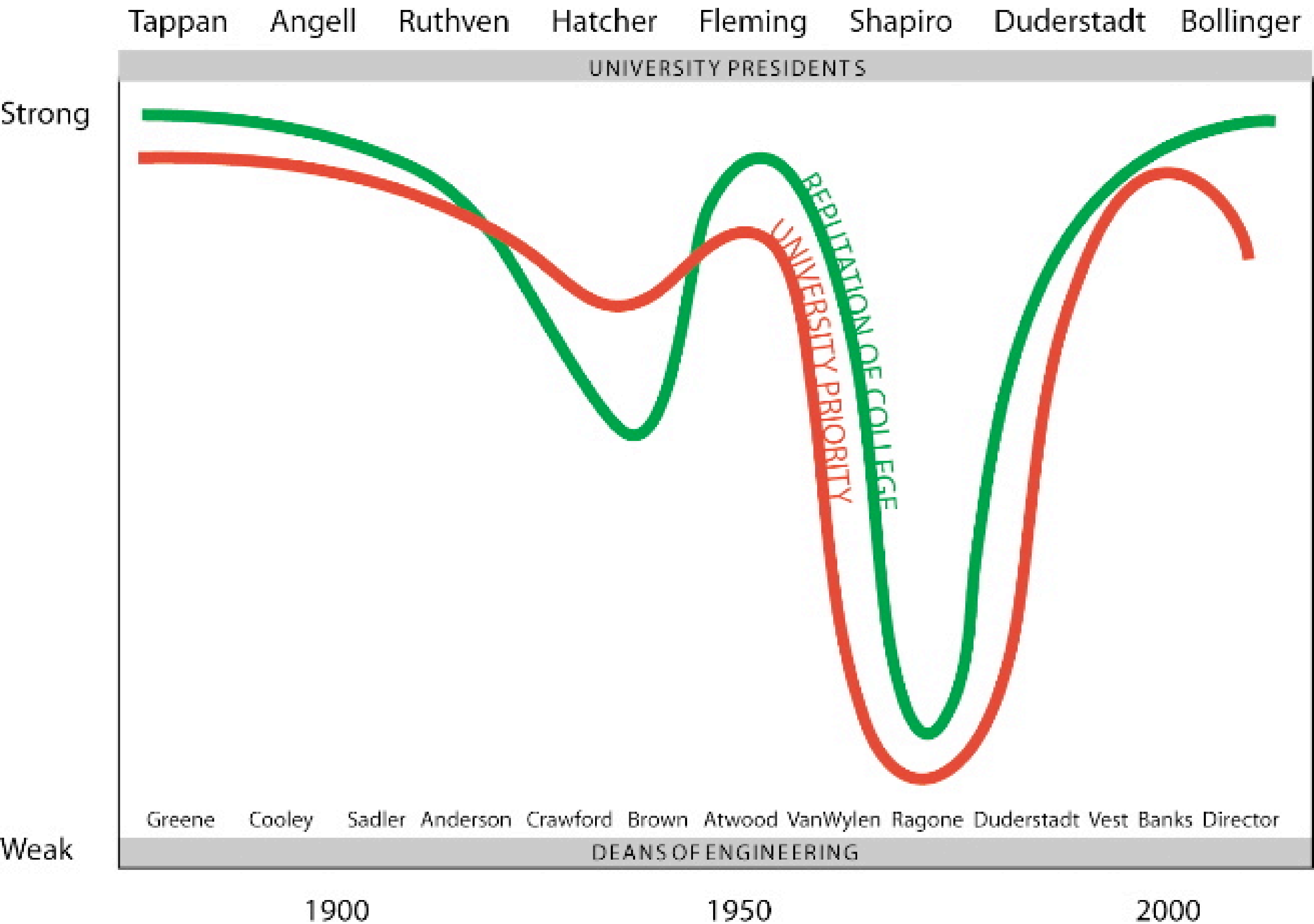
- The College is going to have to change its basic paradigms:
  - For teaching (rather "learning")…
  - For scholarship…
  - For service…
  - For financing its activities…
  - For its intellectual organization…
  - For achieving leadership…
- Change must become its "strategic intent"!

Some Lessons Learned

As dean, provost, and president…

First get commitment from the top!

- The highest priority is establishing the College of Engineering as a high priority of the University.
- When the visibility of the College on “State Street” has been high, the College has thrived.
- But until this is accomplished, the rest of the agenda is simply not possible.


Tappan
Angell
Ruthven
Hatcher
Fleming
Shapiro
Duderstadt
Bollinger
UNIVERSITY PRESIDENTS
Strong
REPUTATION OF COLLEGE
UNIVERSITY PRIORITY
Greene
Cooley
Sadler
Anderson
Crawford
Brown
Atwood
VanWylen
Ragone
Duderstadt
Vest
Banks
Director
Weak
DEANS OF ENGINEERING
1900
1950
2000

Consistency and Persistence

- Like contemporary politicians, you have to “stay on message”!
- Although it can sometimes seem like beating your head against a brick wall, consistency and persistence are everything.

Speed and timing are everything!

- It is important to realize how rapidly windows of opportunity open and close.
- Looking back today, the 1980s blitzkrieg to rebuild the College is hard to imagine (four years to complete the North Campus move, triple the budget, double salaries, build CAEN, hire 120 faculty, etc.).
- Yet the ability to act rapidly, accelerate, and build momentum was key to our success.

The Importance of a Clear Strategy

- Importance of strategies that view constraints as opportunities, striving to actually modify the planning environment.
- We used an opportunistic planning approach (“logical incrementalism”).
- Although some viewed it as “fire, ready, aim”, it certainly was more effective that “ready, aim…aim…aim…” that is typical of universities.

Always bet on your best people!

- Universities are intensely people-dependent enterprises.
- The key to success is simple: attract the very best people, provide them with the support, encouragement, and opportunity to push to the limits of their abilities and dreams; and then get our of their way!
- If you are going to place a big bet on the future, make certain you place it on your best people and your best programs.

Thinking outside the box

- In order to break a logjam of indecision, it is sometimes necessary to think outside of the box (e.g., offering to loan the provost $2 million to get the North Campus move started, the use of a special student fee to build CAEN, getting permission for the deans to go to Lansing to lobby for new capital facilities…)

The importance of teamwork

- Engineers are most comfortable working closely as teams.
- Our “deans team” shared all responsibilities and assignments among ourselves, with the department chairs, the College executive committee, and with key staff.
- Academic leadership is NEVER effective from far behind the front lines. You have lead the troops into battle as one of the team!

The importance of experience

- Although our “deans’ team” may have been inexperienced in administration, we did bring to the dean’s office extensive experience on working both within the College, the University, the state, and on the national level.
- One should never underestimate the importance of relationships with key University leaders (e.g., president, provost, VPs) and staff (Plant, State Relations, Development)

The final and most important lesson

The College of Engineering tends to thrive when it is at the center of University activities. It invariably suffers when it attempts to go it alone, to follow its own agenda, to decouple from the University leadership.

One must never forget that the College of Engineering draws its strength and its reputation from the University of Michigan. It is a great engineering school because it is an integral part of a great university!!!


NECESSARY TO
OF MANKIND SCHOOLS AND
SHALL FOREVER BE ENCOURAGED