The Golden Fleece: how the most powerful (and lucrative!) ideas come from seemingly impractical pursuits

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http://en.wikipedia.org/wiki/Golden_Fleece

Outline

- The Golden Fleece in mythology & politics
- POV
- Innovation & power in the 21st century
- The research/innovation spectrum
- Case studies
  - » Why is the sky blue?
  - » What is stuff made from?
  - » Why does math matter?

Golden Fleece in mythology and politics

- The Golden Fleece came from a magical ram in Greek mythology (several versions of the myth exist) and was a symbol of kingly power sought by Jason and the Argonauts. (http://en.wikipedia.org/wiki/Golden_Fleece)
- The Golden Fleece Awards were established in 1975 by William Proxmire, former U.S. Senator from Wisconsin, and issued until 1988. Awardees were chosen based on how well their impractical use of public funds was deemed to "fleece" the taxpayer. (http://en.wikipedia.org/wiki/Golden_Fleece_Award)
- I chose the title to highlight how the definition of a powerful and practical scientific research mission depends a lot on the long-or short-term perspective of the viewer.
- This definition is central to discussions of scientific merit, national science policy and economic and business strategies, where short term practicality tends to dominate discussions.

A professional scientist’s point of view is different from the “school” view

School World

STEM = Science

+ Technology

+ Engineering

+ Mathematics

Reductive

Linear

Science World

Science

Mathematics

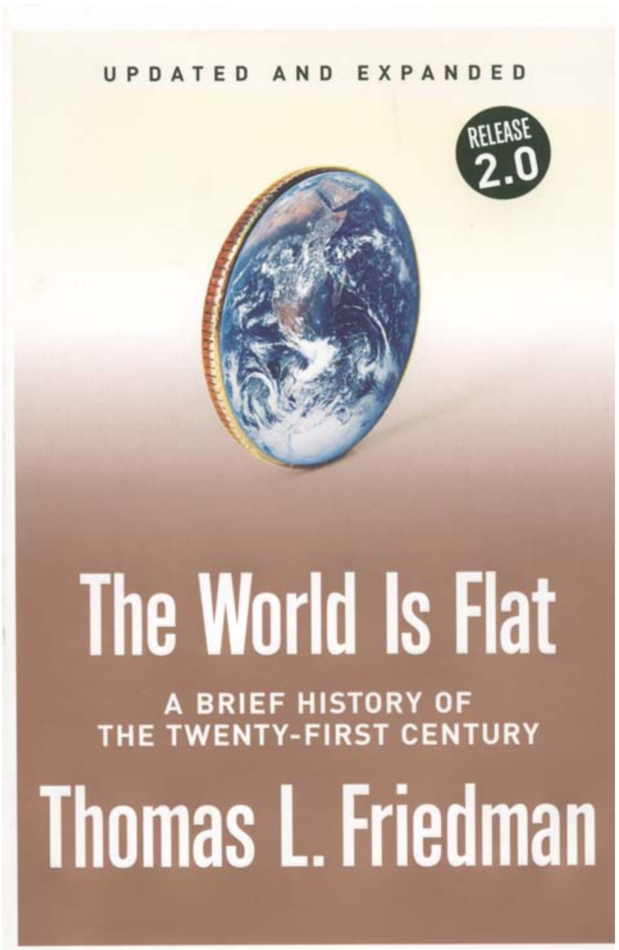
Technology

Engineering

Integrative

Spiral

New Paradigm for the World Economy

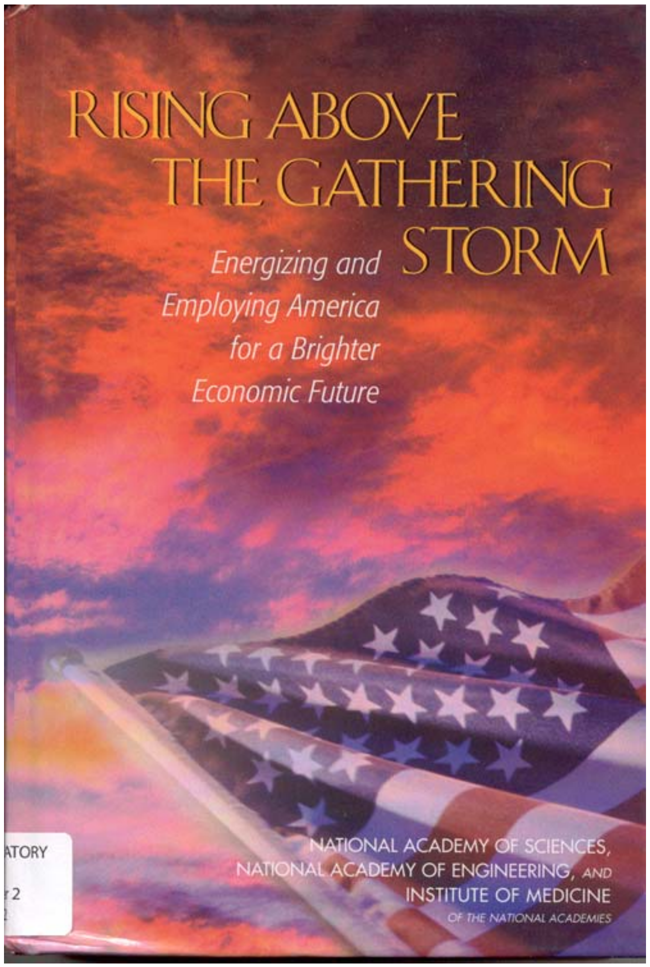


Globalization 1.0, ca. 1500-1800:
"Where does my country fit into global competition?"

Globalization 2.0, ca. 1800-1990:
"Where does my company fit into global competition?"

Globalization 3.0, since 1990:
"Where do I (we) fit into global competition?"

Professional Science and Science Education Issues Overlap



"Without high-quality, knowledge intensive jobs and the innovative enterprises that lead to discovery and new technology, our economy will suffer and our people will face a lower standard of living." – Executive Summary

Innovation is …

- Increasingly rapid in diffusing across society
  - » Automobile - 55 years to spread to 25% of population
  - » Telephone - 35 years
  - » Radio - 22 years
  - » PC - 16 years
  - » Cell phone - 13 years
  - » World Wide Web - 7 years
  - » Current innovation to market time in electronics industry is 18 months
- Increasingly multidisciplinary and technologically complex (subjects don't matter; integration across disciplines is key)
- Collaborative and diverse
- Global

Recommendations from *Rising Above the Gathering Storm*

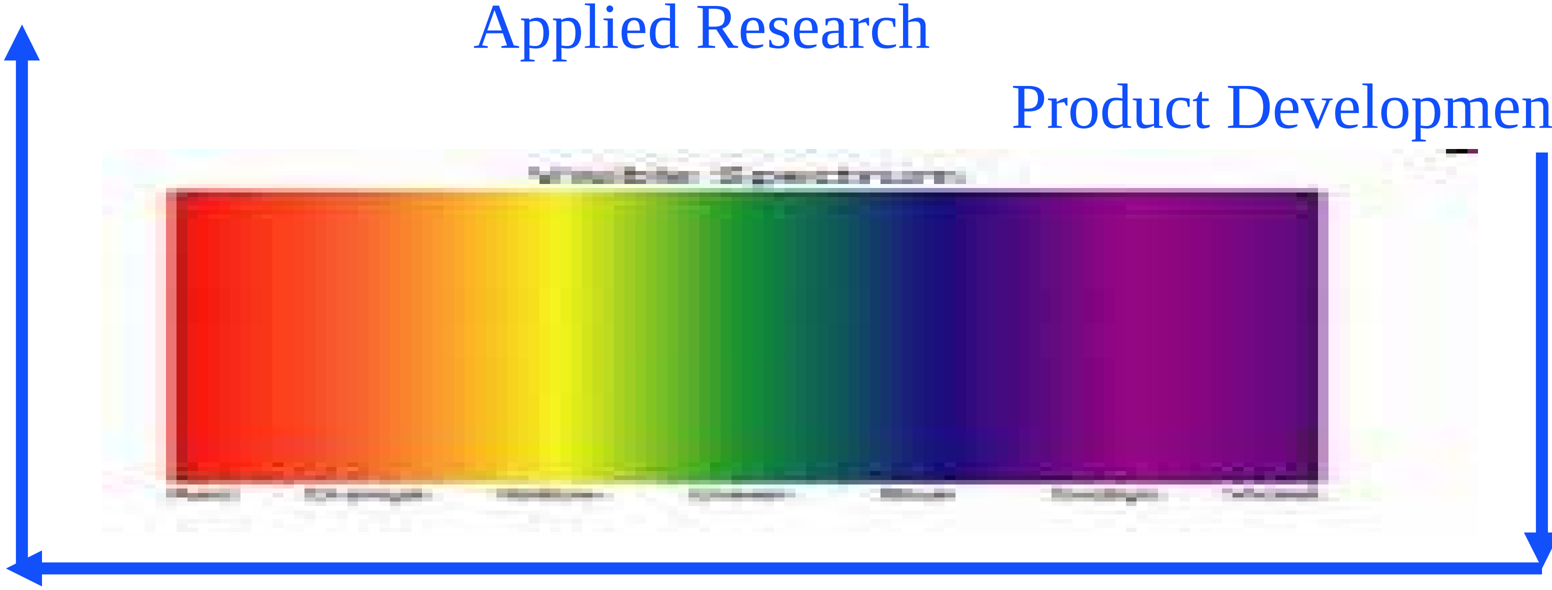
- Increase America's talent pool by vastly improving K-12 math and science education
- Sustain and strengthen the nation's commitment to long-term basic research
- Develop, recruit and retain top students, scientists and engineers from both the US and abroad
- Ensure that the US is the premier place in the world for innovation

The research/innovation spectrum and cycle

Basic Research

Applied Research

Product Development



Like a rainbow, this spectrum has no sharp boundaries between colors.

Components of the innovation cycle

- Basic research works at the frontier of human imagination and knowledge to invent the future (new, transformative ideas); any practical applications are hard to identify.
- Applied Research explores the new ideas coming from basic research with intent to harness them for some practical application; specificity may vary.
- Product development forges the output of applied research into desirable products that will be purchased and used.
- New products expand the capabilities to probe the frontier of human imagination and knowledge

Case study 1: Why is the sky blue? (The long-term view.)

- Basic research attempted to understand the origins of color and the interaction between light and matter.
- Outcomes:
  - » General Theory of Relativity
  - » Quantum Mechanics
  - » Cosmology
  - » Understanding of the structure of matter
  - » Understanding of the nature of conduction of electricity by materials
  - » Understanding of the nature of the chemical bond
  - » Understanding of the duality of energy and matter

Case study 1 continued…

- Applied research outcomes
  - » Invention of transistors, lasers, superconductors, modern chemistry, nuclear energy/weapons, are a few prominent examples
- Product development outcomes
  - » The products in most any movie depicting the latter half of the 20th century.
  - » A few specific examples: most drugs, most medical technologies, computers, the internet, modern surveying, global positioning system, CD and DVD technology, precision surgical tools, solar power industry, Energy Northwest, fluorescent and LED lighting products.

A specific thread in case study 1

- Basic research sought to understand how matter absorbs, scatters and emits light
- Applied research used this understanding to develop efficient fluorescent lighting by running electrical discharges through gases to produce copious amounts of UV and the phosphorescent coatings to convert UV to visible light.
- Product development figures out how to make cheaply 4-ft-long T12 lamps and ballasts or “pin- and form-compatible” replacements for the standard incandescent bulb (the CFL bulb).

Case study 2: What is stuff made from? (Highlighting non-obvious applications)

- Basic research on the atomic/subatomic scale: what are the fundamental building blocks of nature?
- A few outcomes
  - » Discovery of the proton
  - » Discovery of the neutron
  - » Discovery of antimatter (positron is first discovered antimatter)
- Practical outcomes in a single field (medicine):
  - » MRI technology developed from understanding the behavior of the proton
  - » The field of genomics resulted from unraveling the structure of DNA using neutron diffraction
  - » Most of what we know about how the brain processes and thinks has come from analyzing the metabolism of sugar using positron emission tomography (PET) scans.
  - » Nuclear medicine (both diagnostic and theraputic procedures)

Case 2 continued: how non-obvious can the applications of basic research be?

- Basic research in nuclear physics was not seen to have much practical application prior to 1938, when Lise Meitner and Otto Frisch described the process of nuclear fission as a way to convert matter to energy.
- The first controlled release of nuclear energy in a reactor at the University of Chicago occurred by 1942.
- The Manhattan Project conducted the Trinity test in1945.

Case 3: "Why does math matter?"

- Larry Page & Sergey Brin, co-founders of Google
- Age: mid-30s
- Net Worth: ~ $18B/ea
- Discipline: computer science
- Creation: mathematical algorithm behind most efficient internet search engines

Google ranks 213th on Forbes 2000 list of the world's largest companies; ranks 33rd in market value ahead of all auto manufacturers, except Toyota; ahead of Boeing, Caterpillar, Dow Chemical, Duke Energy, Florida Power & Light, Monsanto, PepsiCo, …

Math matters because it is the science of patterns and order

- Basic research example: *Game theory* “begun” by John von Neuman and Oskar Morgenstern
  - » *Describes the interactions of individuals and networks*
  - » *Immense implications for economics (8 Nobel Laureates in economics), biology, sociology, military, diplomatic and anti-terrorism strategies*
- Basic research example: *Fractal Geometry* “begun” by Benoit Mandelbrot
  - » *Describes the order underlying the apparent randomness of coastlines, mountains, tree branches, blood vessels and other forms in nature*
  - » *Applications to physiology, computer-generated movies, cell phone antennae, ecology, technical analysis of markets, etc.*

In summary…

- Vertical, industrial-age models of economics, management, science, education and technology development are "*so 20th century*"; innovation depends on creative, diverse thinking across a range of disciplines
- The President and Congress recognize that America's future role as a world power and the standard of living of its people hinge more on success in professional science and science education than any other single factor; innovation will have national and global implications
- Innovation depends on three styles of scientific enterprise: basic research, applied research and product development
- Which style suits a person is a matter of personality; all three need to be strong for us to remain globally competitive