Four Types of R&D

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A Brief History of R&D

- Since the mid-1960s the "Research and Development – R&D" outlook has become the dominant approach for technology development and investments in the scientific infrastructures.
- Since the mid-1990s shortcomings and limitations of this linear model have gained attention. Yet, due to lack of alternative models for innovation, the linear R&D has been able to continue to act like a default model for innovation.
- This presentation reviews the role of R&D in four outlooks:

  1) R&D as a Set of Activities
  2) R&D as a Paradigm of Innovation
  3) R&D as a Counterpart for Design and Development (D+D)
  4) R&D as a Source of Idea

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1. R&D as a Set of Activities

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Research and Development – R&D: A Brief Review

The R&D model makes a linear and one-way outlook between three consecutive stages:
Basic Research, Applied Research and Development Research.

The Triple Helix Model for technology development (Academy, Business and Government) is also based on the R&D outlook toward innovation.

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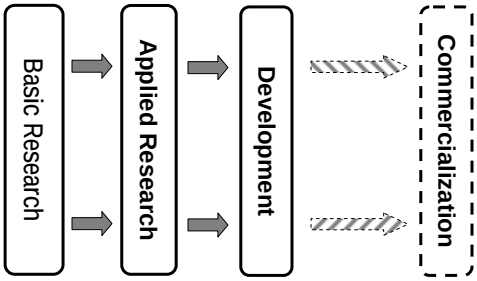
R&D as a Set of Activities



R&D is a method of investigation where it is assumed new scientific knowledge is discovered due to a series of linear and sequential stages that consists of Basic Research, Applied Research and Development

The R&D model assumes that science has a monopoly over knowledge, technology is an outcome of science, and economic development is due to technology development. The R&D model confines innovation to technology and then technology to R&D.

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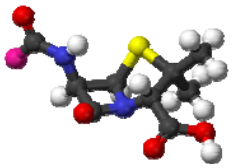
Examples of R&D Based Products



Penicillin

A Bomb

Nuclear Power Plants

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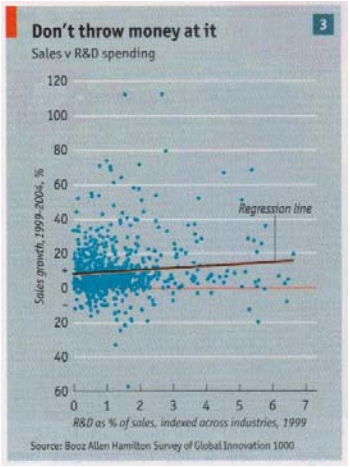
"R&D Spending" Versus "Sales and Profit"



The Economist, January 21-27, 2006

Money Is Not Everything concludes:

"There is no discernable relationship between R&D spending levels and nearly all measures of business success including sales, growth, gross profit, operating profit, enterprise profit, market capitalization, or total shareholder return." …

"No relationship exists between the number of patents issued to an organization and its business results."

Money Is Not Everything. 2005.

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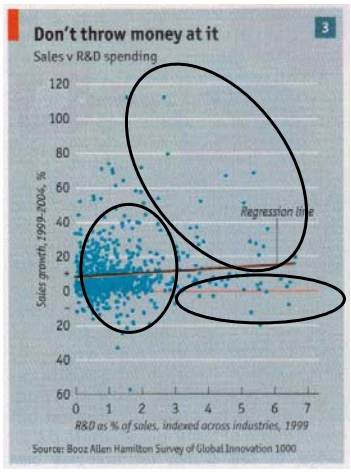
Interpreting Previous Diagram



- Previous diagram – sufficiently insightful – could be interpreted in the context of more than one cluster.
- While the conclusion – lack of discernable relationship between R&D spending levels and all measures of business – may hold for the overall businesses that were studied, the diagram may actually show more than one pattern.
- If we regroup those cases into clusters, we may find unexplored patterns.
- We do not need to abandon R&D, rather, we may look at in a new context!

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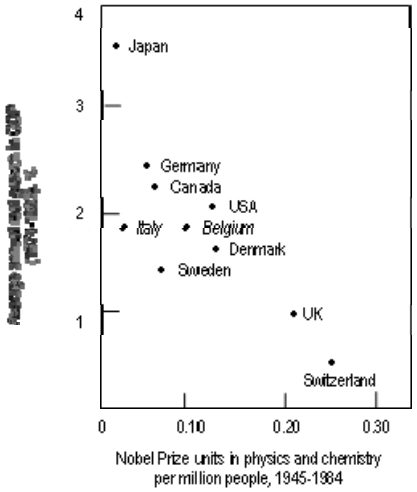
Growth in gross domestic product and Nobel Prize winning in physics and chemistry



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2. R&D as a Paradigm of Innovation

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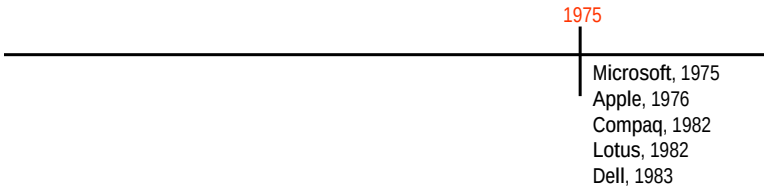
A Paradigm Shift Around 1975?



A new context for R&D appeared from another study.

In my studies about innovation and entrepreneurship, and commercialization of new technologies, I noticed that around 1975, a major change happened. In the mid-1970s and later, new companies emerged such as: Microsoft, Apple, Dell, Compaq and Lotus Software. The founders of these companies did not have strong scientific background. Indeed the founders of Microsoft, Apple, CNN and Dell all were college dropouts. This was a very different pattern compared with the founders of previous successful ventures, that were dominant in the years before 1975.

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A New Outlook for Innovation and Entrepreneurship

- This presentation looks for a new context for innovation that looks at R&D as a source of innovation, rather than the source of innovation.
- The new outlook for innovation concentrates on the "Confluence of Innovation and Entrepreneurship."
- The unit of analysis is ventures (new businesses) that were able successfully to commercialize a new technology and become large enterprises.
- The following chart covers major new ventures in each time period that are consistent with the above description:

1) They were new ventures,
2) They commercialized a new technology, and
3) They were able to grow from small size and became large enterprises.

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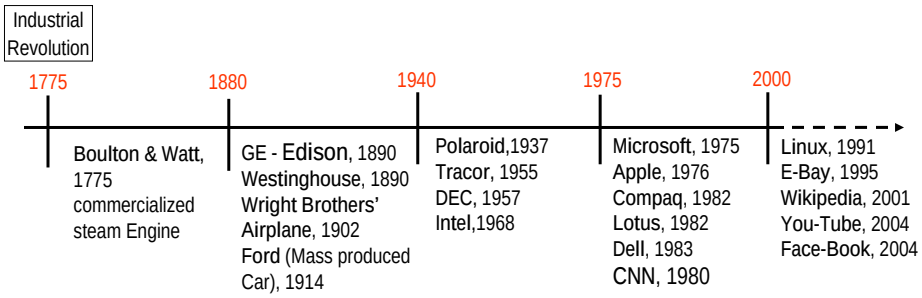
Paradigms of Innovation



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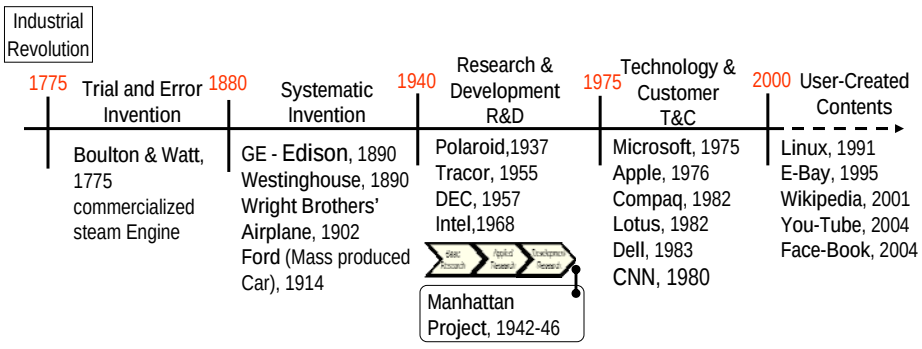
Paradigms of Innovation



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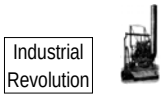
Paradigms of Innovation





Industrial Revolution

1775 Trial and Error Invention
- Boulton & Watt, 1775 commercialized steam Engine

1880 Systematic Invention
- GE - Edison, 1890
- Westinghouse, 1890
- Wright Brothers' Airplane, 1902
- Ford (Mass produced Car), 1914

1940 Research & Development R&D
- Polaroid,1937
- Tracor, 1955
- DEC, 1957
- Intel,1968
- Manhattan Project, 1942-46

1975 Technology & Customer T&C
- Microsoft, 1975
- Apple, 1976
- Compaq, 1982
- Lotus, 1982
- Dell, 1983
- CNN, 1980

2000 User-Created Contents
- Linux, 1991
- E-Bay, 1995
- Wikipedia, 2001
- You-Tube, 2004
- Face-Book, 2004

- Paradigms of Innovation are NOT mutually exclusive! During the same time span, different types of industries may follow different paradigms of innovation.
- Previous paradigms may be influenced by more recent paradigms.

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Five Main Paradigms of Innovation

1. Trial and Error (Semi-Systematic) Invention: Represented by the steam engine.
2. Systematic invention: Represented by the light bulb and electricity.
3. Research and Development - R&D: Represented by the A-bomb, rockets and main-frame computers.
4. Technology and Market Development – T&C: Represented by personal computers.
5. User-Created Contents: Represented by Linux, Wikipedia, You-Tube and Face-book.

- Research and Development – R&D is one of the five main Paradigms of Innovation, since the start of the Industrial Revolution. There are at least four other paradigms of innovation.
- Paradigms of Innovation are NOT mutually exclusive! During the same time span, different types of industries may follow different paradigms of innovation.
- Previous paradigms may be influenced by more recent paradigms.

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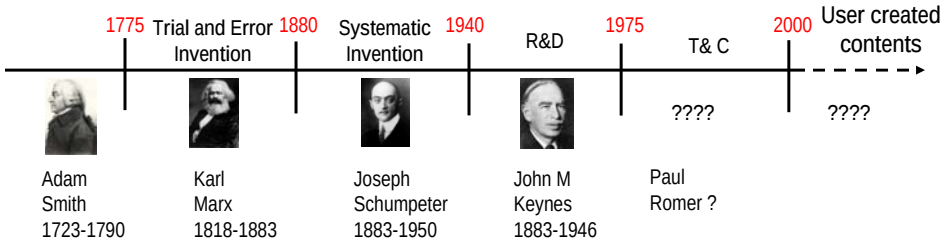
Potential Future Theoretical Studies Related to Paradigms of Innovation?



The first three of prominent economists reviewed the characteristics of the first three paradigms of innovation. Each of them, however, considered the paradigm that they studied as the default pattern of technology development.

John Maynard Keynes was instrumental in the development of the R&D-based paradigm, but he actually did not study the R&D paradigm.

It seems no major economist has elaborated yet the theoretical basis of the two recent paradigms of innovation! Will someone do?

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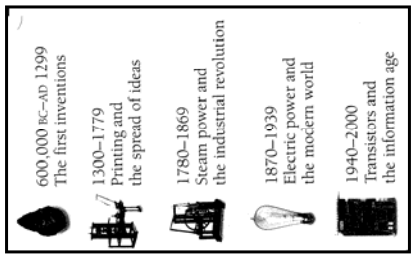
Technology/Artifact Development Timeline



Looking for a time-line for technology/artifact development is not new. Timeline of Inventions (copied form *Smithsonian Timeline of Inventions)* depicts the different time lines from 600,000 BC to 2000 and the tools that symbolize each era. This classification bundles the 1940-2000 period in one group, labeled .

The above outlook at technology development covers only the hardware confines technologies.

Jeffry Moor's prediction that the capacity of micro-processors increases two folds every 18 months is along this view of technology timeline.

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Economic Waves

Economics of Industrial Innovation (1997) by C. Freeman and L. Soete

Cycle number, Approx. Timing.	First Wave, 1780s - 1840,	Second Wave 1840s – 1890s	Third Wave 1890s – 1940s	Fourth Wave 1940s – 1990s	Fifth Wave 1990s – ?
Kondratieff Waves	Industrial revolution, factory production	Age of steam power and railways	Age of electricity and steel	Age of mass production of automobiles and synthetic materials	Age of microelectronics and computer networks.
Science, Technology, Education, and Training	Apprenticeship, learning by doing, dissenting academies, scientific societies	Professional mechanical and civil engineers, institute of technology, mass primary education	Industrial R&D labs, chemicals and electrical, national laboratories, standards laboratories	Large-scale industrial and government R&D, mass higher education	Data networks, R&D global networks, lifetime education and training
Transport Communication	Canal, carriage roads	Railways (Iron) telegraph	Railways (Steel), telephone	Motor highways, radio and TV, airlines	Information highways, digital networks
Energy Systems	Water power	Steam power	Electricity	Oil	Gas/oil
Cheap Key Factors	Cotton	Coal, iron	Steel	Oil, plastics	Microelectronics

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3. R&D as a Counterpart for Design and Development (D+D)

A familiarity with Design and Development (D+D) provides a better understanding about R&D

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Design versus Science

- To have a better understanding of Design we first my look at Science.
- Science is systematic investigation to have a better understanding of an existing phenomenon.
- Design is about systematic thinking about, before or as part of, an action to make a new phenomenon.
- Science pursues and applies analytic methodologies, as the goal is to figure out the structure of an existing phenomenon.
- Design follows synthetic (non-analytic) and integrative approaches, as the goal is to integrate a new thing.

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R&D versus D+D (Design and Development)

- Three examples serve to underline the main difference between R&D versus D+D: Atomic Bomb, Airplane and Light Bulb.
- The A-Bomb probably is the best example of an R&D invention. Basic Research was done Albert Einstein, who had no clue about it final application.
- The invention (design) of Aircraft is good example of D+D. The Wright brothers, from day one knew the final goal, a heavier than air aircraft and they did everything to get it.
- The invention of the Light bulb by Edison is another example of a D+D case. The idea was to make a electric-base light source (bulb) that can compete with gas-base light source.
- D+D always starts with a product in mind and going back to get it.
- The invention of the Marine Chronometer to solve the Longitude problem is likely another important and less studied case of D+D.

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Example of Products Based on Designed and Development

Airplane and Light Bulb were two inventions based on D+D rather than R&D. The Wright Brothers, and Edison were not scientists.

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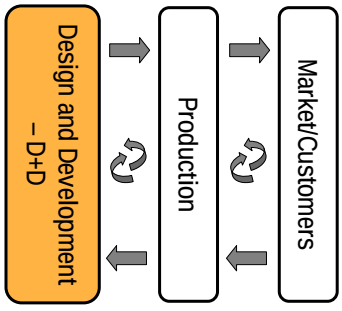
D+D Model

Design and Development – D+D
is one of the key aspects of Technology Innovation/Development



D+D aims at Production, and intends at satisfy Market/Customer needs.

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The Combined Model of R&D and D+D

The combined model of D+D plus R&D is more practical and comprehensive than the R&D model for the following reasons:

- The combined model already includes the R&D model, but the other way is not applicable.
- The D+D model provides a non-linear outlook that cover both Forward Design and Reverse Design. While the R&D model is linear model that goes from Research to Development.
- The D+D model embraces an integrative methodology, which is non-linear but it already includes linear methods which is consistent with the R&D.

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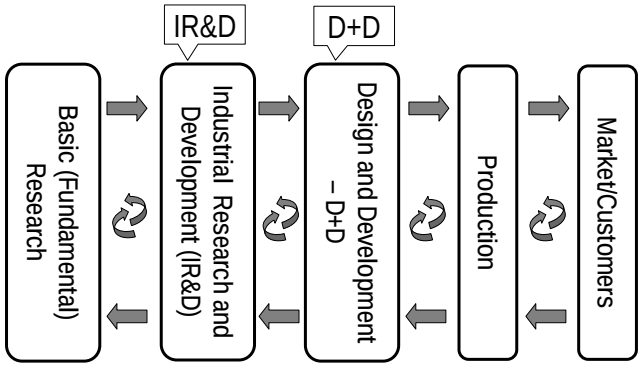
The Combined Model of IR&D and D+D



The new model combines Basic Research, Industrial Research and Development (IR&D) and D+D (Design and Development).

D+D is one of the key aspects of Technology Innovation/Development and it is not the same or inferior to R&D.

D+D often acts like a link between successful R&D and Production to satisfy Market/Customer needs.

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Forward and Reverse Design

- Design and Development (D&D) embraces both **Forward Design** and **Reverse Design**.
- **Forward Design** includes the forward flow of information that initiates from Design and Development to provide information needed for Production which leads to new products for the Market. Example: developing a new idea and take it from design to the market.
- **Reverse Design** involves the activities to legally make a product similar or superior to one already available on the market. Example: taking an existing product in the market and then re-design it.
- Forward and Reverse Design actually work hand in hand with each other. Reverse Design is often complementary to Forward Design that including activities from D&D to production and then marketplace.

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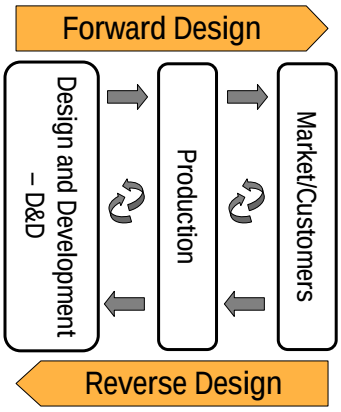
Forward versus Reverse Design

Forward Design: From D&D to Product.
Reverse Design: From an existing Product to D&D and back to Product, to improve it.



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Forward and Reverse Designs Are Further Reviewed in Separate Sets of Slides

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4. R&D as a Source of Idea

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Inception: The Origin of Business Ideas -1

Each new business ideas has a distinctive patterns of development form its inception (origin). New business ideas may originate form many sources, which can be classified into 12 overlapping groups:

Technology Push

1. Research and Development (R&D)
2. Invention and Patent
3. Design and Development (D+D) – Forward Design
4. Reverse Design: Reverse Engineering and Benchmarking (Copying, Imitation and Adaptation)

Mark Pull

5. Extensive Market Research to explore business opportunities: Societal changes, Demographic changes, etc.
6. Feedbacks: from customers, employees, suppliers, etc. to uncover unarticulated needs

7. Previous Experience: Work, Education and Hobby of the Entrepreneurs.

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Inception: The Origin of Business Ideas - 2

8. Creativity (Individual, Group and Organizational): such as lateral thinking, mind mapping, metaphors, and brain storming.
9. Symbiotic Ideas: Combining two or more existing ideas for a new application
10. Innovation Inspired by Nature (Biomimetics, Biomimicry): new business ideas based on observing natural phenomena. Example: Kook-and-loop fasteners (Velcro).
11. New regulations: Example Child safety regulations and Child's Car Seat
12. Eureka and Serendipity: New business ideas due to unexpended events!

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The Technology Push Sources of Ideas

Technology Push

1. **Research and Development** (R&D)
2. **Invention and Patent**
3. **Design and Development** (D+D) – Forward Design
4. **Reverse Design**: Reverse Engineering and Benchmarking (Copying, Imitation and Adaptation)

Note the relationship between the Technology-push sources of ideas and the R&D and D+D models that we discussed before.

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