Basic Science, Society and Technological Applications

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Technological innovations modify deeply and continuously our way of living.

This process is driven by the knowledge acquired through fundamental research.

The historical evolution of the interplay of basic science, technology and society will be discussed with the help of some examples.

Part 1

Introduction

1.1 Definitions and Mechanisms

1.2 The linear chain

1.3 Basic research, why?

1.4 Conflicting views

1.5 A major change:
causes and consequences

1.1 Definitions and Mechanisms

We adopt the following definitions

1) **Basic research**: Study of natural laws, aimed at extending human knowledge (→ Discovery)

2) **Applied research**: Study of the means to make use of known natural laws for practical purposes (→ Invention)

3) **Development**: Study of cost effective solutions for industrial production (→ Industrial know-how, Patents)

Under the label R&D usually points 2 and 3 are considered

Other possible definition such as
Basic research: Curiosity driven, without a practical purpose
may be very detrimental to the image of the scientific activity

1.2 The linear chain

a) Basic research:

↓

b) Applied research:

↓

c) Development

↓

d) Industrial production

The above sequence provides an appropriate (oversimplified) description of the evolution in many cases, but not always

Examples of anti-linear chains exist (steam engine, thermodynamics)

1.3 Basic Research, why?

Basic Research **extends human knowledge** and represents a major cultural component of our civilisation

but also provides

a **powerful training** for other activities

and is

an agent of **economic utility** (≡ increased industrial turnover + cost saving).

Newly acquired knowledge, without exceptions, has found applications in our daily life.

Prof. Casimir,

Symposium on Technology and World Trade , 1966

I have heard statements that the role of academic research in innovation is slight. It is about the most blatant piece of nonsense it has been my fortune to stumble upon.

Certainly, one might speculate idly whether transistors might have been discovered by people who had not been trained in and had not contributed to wave mechanics or the quantum theory of solids. It so happened that the inventors of transistors were versed in and contributed to the quantum theory of solids.

One might ask whether basic circuits in computers might have been found by people who wanted to build computers. As it happens, they were discovered in the thirties by physicists dealing with the counting of nuclear particles because they were interested in nuclear physics.

One might ask whether there would be nuclear power because people wanted new power sources or whether the urge to have new power would have led to the discovery of the nucleus. Perhaps - only it didn't happen that way.

One might ask whether an electronic industry could exist without the previous discovery of electrons by people like Thomson and H.A. Lorentz. Again it didn't happen that way.

One might ask even whether induction coils in motor cars might have been made by enterprises which wanted to make motor transport and whether then they would have stumbled on the laws of induction. But the laws of induction had been found by Faraday many decades before that.

Or whether, in an urge to provide better communication, one might have found electromagnetic waves. They weren't found that way. They were found by Hertz who emphasised the beauty of physics and who based his work on the theoretical considerations of Maxwell. I think there is hardly any example of twentieth century innovation which is not indebted in this way to basic scientific thought.

What the Global Positioning System Tells Us about Relativity

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1. What is the GPS?

The Global Positioning System (GPS) consists of a network of 24 satellites in roughly 12-hour orbits, each carrying atomic clocks on board. The orbital radius of the satellites is about four Earth-radii (26,600 km). The orbits are nearly circular, with a typical eccentricity of less than 1%. Orbital inclination to the Earth's equator is typically 55 degrees. The satellites have orbital speeds of about 3.9 km/s in a frame centered on the Earth and not rotating with respect to the distant stars. Nominally, the satellites occupy one of six equally spaced orbital planes. Four of them occupy each plane, spread at roughly 90-degree intervals around the Earth in that plane. The precise orbital periods of the satellites are close to 11 hours and 58 minutes so that the ground tracks of the satellites repeat day after day, because the Earth makes one rotation with respect to the stars about every 23 hours and 56 minutes. (Four extra minutes are required for a point on the Earth to return to a position directly under the Sun because the Sun advances about one degree per day with respect to the stars.)

The on-board atomic clocks are good to about 1 nanosecond (ns) in epoch, and about 1 ns/day in rate. Since the speed of light is about one foot per nanosecond, the system is capable of amazing accuracy in locating anything on Earth or in the near-Earth environment. For example, if the satellite clocks are fully synchronized with ground atomic clocks, and we know the time when a signal is sent from a satellite, then the time delay for that signal to reach a ground receiver immediately reveals the distance (to a potential accuracy of about one foot) between satellite and ground receiver. By using four satellites to triangulate and determine clock corrections, the position of a receiver at an unknown location can be determined with comparable precision.

Synchronisation of Clock-Stations and the Sagnac Effect

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It is shown that the Sagnac correction, as applied to time comparisons upon the Earth, does not derive from the normal Relativistic corrections. It is proposed that the reason given for the application of the Sagnac correction, and the circumstances appropriate to its application, require amendment.
Key words:: Clock synchronisation; Sagnac effect; Relativistic corrections.

Standards for the synchronisation of clock-stations upon the Earth are to be found in the 1990 publication of the CCIR (International Radio Consultative Committee: International Telecommunication Union) [1]. Similar rules are in the 1980 publication of the CCDS (*Comité Consultatif Pour la Définition de la Seconde: Bureau International des Poids et Mesures*) [2]. Two methods are used to synchronise clocks at different clock stations. The first method is physically to transport a clock from one site to the other, and thereby to compare the times recorded at the two clock stations. The second method is to send an electromagnetic signal, from one site to the other.

Three corrections to be applied, as listed in the above publications, are as follows:-

(a) to take account of the Special Relativistic velocity effect, caused by carrying a portable clock at speed aboard an aeroplane, from one site to the other.

(b) under General Relativity, to allow for height above sea level.

(c) a correction described as being for the *rotation of the earth*.

Correction (a) is quantified as $v^2/2c^2$. This is the slowing of time as calculated under the Special Theory of Relativity. A clock transported from one site to another will have such a correction applied, because of the ground speed v of the aeroplane; c is the velocity of light. Correction (b) is quantified as $g(\phi)h/c^2$ where g is the total acceleration at sea level (gravitational cum centrifugal) at a latitude of ϕ, and h is the height over sea level.Correction (c) is

1.4 Conflicting views

Scientists tend to privilege "science for science", while politicians and economists are mainly confronted with the practical consequences of science.

Cultural conflict.

Scientists accuse Politicians of being "short-sighted".

Politicians accuse Scientists of being "arrogant".

Are these views

CONTRADICTORY

or

COMPLEMENTARY?

Why the conflict is particularly acute now?

1.5 A major change: Causes and consequences

Possible causes (non hierarchical, non exhaustive, provocative list)

1) Size of required investments
2) Time scale
3) Lack of major "breakthroughs"

4) Environment concern
5) Decline of rationalism
6) End of "cold war"

7) Economy globalisation
8) Transition from Industrial to Financial Society

1. USABLE KNOWLEDGE

example	time to application
X-rays	**0.2 years**
nuclear fission	**3 years**
antiproton[(1)]	**> 50 years**
μ-induced fusion[(2)]	**∞ (?)**

(1) antiproton **18th May 1999 - NASA Marshall Space Flight Center in Huntville :**

"We are experimenting with laser propulsion and antimatter as viable options for space travels".

(2) μ-induced fission **L. Alvarez:**

"For a few days we thought we had solved all the fuel problems of mankind for the rest of time".

1. 2 Energy Production linked to Physics beyond the SM

"Monopole catalysed proton decay"

"Non-topological stable solutions with a global baryon number"

"Long-lived charged particles which could catalyse fusion"

EXPLOITING ZERO-POINT ENERGY

Energy fills empty space, but is there a lot to be tapped, as some propound? Probably not

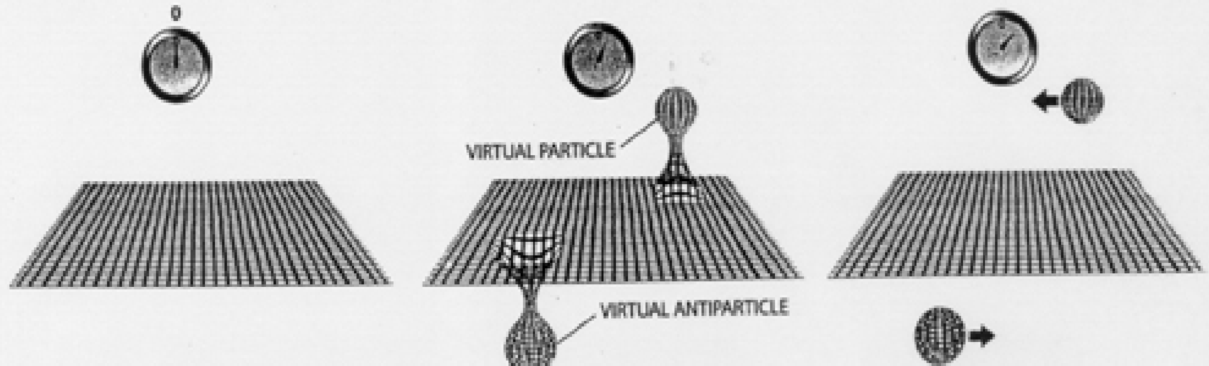
by Philip Yam, *staff writer*

Something for nothing. That's the reason for the gurgling water, ultrasonic transducers, heat-measuring calorimeters, data-plotting software and other technological trappings—some seemingly of the backyard variety—inside the Institute for Advanced Studies in Austin, Tex. One would not confuse this laboratory with the similarly named but far more renowned one in Princeton, N.J., where Albert Einstein and other physicists have probed fundamental secrets of space and time. The one in Austin is more modestly appointed, but its goals are no less revolutionary. The researchers here test machinery that, inventors assert, can extract energy from empty space.

Claims for perpetual-motion machines and other free-energy devices still persist, of course, even though they inevitably turn out to violate at least one law of thermodynamics. Energy in the vacuum, though, is very much real. According to modern physics, a vacuum isn't a pocket of nothingness. It churns with unseen activity even at absolute zero, the temperature defined as the point at which all molecular motion ceases.

Exactly how much "zero-point energy" resides in the vacuum is unknown. Some cosmologists have speculated that at the beginning of the universe, when conditions everywhere were more like those inside a black hole, vacuum energy was high and may have even triggered the big bang. Today the energy level should be lower. But to a few optimists, a rich supply still awaits if only we knew how to tap into it. These maverick proponents have postulated that the zero-point energy could explain "cold fusion," inertia and other phenomena and might someday serve as part of a "negative mass" system for propelling spacecraft. In an interview taped for PBS's *Scientific American Frontiers,* which aired in November, Harold E. Puthoff, the director of the Institute for Advanced Studies, observed: "For the chauvinists in the field like ourselves, we think the 21st century could be the zero-point-energy age."

That conceit is not shared by the majority of physicists; some even regard such optimism as pseudoscience that could leech funds from legitimate research. The conventional view is that the energy in the vacuum is minuscule. In fact, were it infinite, the nature of the universe would be vastly different: you would not be able to see in a straight line beyond a few kilometers. "The vacuum has some mystique about it," remarks Peter W. Milonni, a physicist at Los Alamos National Laboratory who wrote a text on the subject in 1994 called *The Quantum Vacuum.* "One has to be really careful about taking the concept too naively." Steve K. Lamoreaux, also at Los Alamos, is harsher: "The zero-point-energy community is more successful at advertising and self-promotion than they are at carrying out bona fide scientific research."



ILLUSTRATIONS BY MICHAEL GOODMAN

Consequences

- Scientists freedom is under control
- Governmental agencies inject founds to catalyse collaboration between Research Institutes and Industry
- Self financing is strongly advocated
- A major cultural change is under way

Part 2

Technology transfer

The real problem

The transfer of technology relies on two equally important, mutually enhancing, ingredients
- an adequate scientific culture
- a "receptive" Industry

Both the ingredients exist in Europe at a much lower level in comparison with U.S.A. and Japan. Traditionally European Scientists are "civil servants" rather than "entrepreneurs".

Hi-Tech Industry is practically non existing in Italy and marginal in Europe.

With a few exceptions, the products developed by HEP have small or no external markets, but the HEP culture could be extremely valuable to provide solutions to large market problems.

SCIENCE AND INDUSTRY SHOULD BETTER KNOW EACH OTHER

2. 1 Students

- **In the USA and in Europe students have different attitudes towards creating their own company**

University of San Diego	**92 % want it**
Switzerland	**8% want it**

- **States supporting technological theses at CERN**

  Austria, France, Israel, Italy, Japan, Spain, Sweden

- **300 PhD experimental theses/year based on CERN data (Ch. Llewellyn Smith)**

  A large fraction goes to industry - DELPHI enquiry

- We must begin with the *sine qua non* that we are going to retain the rigor and the scientific basis that underlies engineering education and practice. Having said this, I believe it is time that we anchor ourselves somewhat more firmly with industry. "Anchor" may not be the right term, because we are hooking onto something that is moving in new directions very rapidly. Still, we do need to maintain much closer contact with industry as it is evolving.
- We have to de-emphasize narrow disciplinary approaches, particularly in the structure of our curricula and in the way we help students learn to think. We need to pay more attention to the context in which engineering is practiced. This sounds simple, but we are finding it very challenging. We need to give students more hands-on engineering experience, or grounding in how to "design-build-operate," as we like to call it.
- We need to educate students to work better in teams. Do not misunderstand: Ultimately, the most important strength we have is individuals and their capacity for innovation. However, every organization that I know about accomplishes most of its work in teams because of the complexity of today's tasks. Indeed, many teams in business and engineering today are in fact world-wide electronic communities, linked by a variety of telecommunications channels.
- We need to become more adept at preparing our students for living and working in an international environment. Globalization is not something that is coming, it is something that has already happened. Academic institutions are behind the curve somewhat in bringing this reality into our educational programs. My guess is that the key is going to be engagement - engagement by U.S. universities with organizations, governments, and industries operating in other countries. We tend to work best and learn the most when we're actively engaged in partnerships of one sort or another.
- We have to continue developing and utilizing information technologies in education, no matter how rapidly they advance. At MIT and elsewhere, books are published and courses taught on the World Wide Web. Nonetheless, I continue to believe that we have just scratched the surface of what the new technologies make available to us in education and learning. This is a time for experimenting. It is a time for networking among U.S. universities to learn which new approaches to learning are working well and which are not.

Ingrid Ten Have considers herself "an example of technology transfer through people"

- At CERN (as NIKHEF PhD student and Glasgow post-doc) 1985–94
- Now Product Manager, NMR imaging techniques, Philips Medical Systems, Holland
- Considers "absolutely" that working in high energy physics was a good school for other scientific sectors

"As a physicist I understand a lot about MRI, superconducting magnets, Information Technology (DAQ, data processing, data quality, expert systems, networking, etc.). Semiconductor developments, Fourier transforms. I use all of these in my current jobs. For Philips it is very valuable that I can listen to "complicated" issues and say I understand. It means I get into discussions about e.g. speeding up the DAQ in our systems, where people tell me this is not possible. I can then go back to what I learnt in the CERN trigger systems and tell them how to do it."

I. ten Have's own summary of "elements from her CERN working experience that are extremely useful in my current position":

Technology transfer

- NMR is based on manipulation of particle spin
- The NMR technique like many CERN experiments uses superconducting magnets
- Information Technology plays a central role in NMR imaging and has elements similar to CERN experiments such as:
  - Fast data acquisition
  - Data processing
  - Data quality
  - Networking, etc.
- X-ray imaging uses semiconductor technology for detector arrays

Scientific Methodology

- Analytic thinking
  - Working with abstractions
  - Modeling
  - Systematic approach
- PhD, which in industry is interpreted as that the individual has produced a substantial, original contribution to knowledge
- Experience with designing and carrying out a project

International working experience

- Experiment being built across the globe and assembled with high precision fit at CERN
- Working in international teams
- Cross-cultural management
- Expatriate life

After working at CERN for a number of years the word *impossible* is no longer part of your vocabulary: ~~IM~~POSSIBLE

Targets of new Policies:

Missing entrepreneurial attitude

Itellectual Property Right (IPR) culture

Questions:

How to protect IPR without hampering the discussion of new ideas within a world-wide scientific collaboration ?

How to enhance the exchange of technology and know-how internationally ?

How to ensure the exploitation of inventions and ideas ?

How to ensure that European industries benefit from the investment in European science ?

TECHNOLOGY TRANSFER

Patenting and copyrighting

- **A cultural problem for academia and HEP**
  - Publish in conferences and scientific journals
  - Lack of literacy in technology watch
- **Mirror situation in Industry**
  - Patent first
  - Technology watch essential
  - "Could not care less with publishing"
- **PROS**
  - Patenting is a swift way of simultaneously disseminating and publishing technology
  - 90% of technology documented through patents
  - Well organised and cheap access to know-how
- **CONS**
  - It costs (see next transparency)
  - Confidentiality may impair swift dissemination
  - Basic science community rejective

TECHNOLOGY TRANSFER

Filing a patent

- **Patent filed following appropriate wording by a patent agent**
- **Confidentiality**
    - First to file in most countries
        - Additional 12 month confidentiality recommended when related patents need be filed in which case they are retroactively dated
    - First to invent within the last 12 months in the USA
- **Patent granted up to 4 years after filing**
- **Protection: 20 years**
- **Costs**
    - Search for prior art: 1 KEuro
    - Filing: 1-2 KEuro
    - Total: 10-100 KEuro depending on the scope (# of countries)

TECHNOLOGY TRANSFER

Marketing: the real problem

- **For 1 Euro spent in the demonstrator+patent**
  - 10 Euros to be spent to have a working prototype
  - 100 Euros to be spent to have the product on the market
  - Some exceptions eg: biology
- **Less than 3% of patents turn out to be cost neutral and**
  - Less than 1% are really successful (but in general outstandingly successful !)
- **Time a key feature**
- **Exclusivity can be required to warrant minimum income**
- **THEREFORE A TT POLICY COSTS (staff and money)**

Final conclusions (personal!)

- TT is an irreversible reality

- Basic Research must adopt it to survive

- A major cultural change is required

  - Ranking of activities by content must be de-emphasized

  - TT should be considered as a way to protect basic research rather than a dangerous competitor for the sharing of available resources

  - Industry needs should be seriously considered

  - The potential values of inventions should be correctly evaluated