A Historical Approach to R+D+E in Telecommunications

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***Abstract* — This paper provides a historical perspective of the Research activities carried out in Telecommunications in the US and Europe. It describes the three phases that embody innovation in Telecom and explains the "triangular models" of the Bell System and ITT that enabled the funding of huge RDE expenses. The output of these efforts is reviewed in terms of products and the prestige attained by Corporations with the award of Nobel Laureates. The divestiture of Ma Bell and the selling out of ITT Telecom to Alcatel is revisited. These events brought about the collapse of the "triangular models" and weakened the research muscle of both companies.**

***Index Terms* — ATT, Fiber, History, ITT, Nobel Laureates, Research, Telecommunications.**

I. INTRODUCTION

This paper is aimed at providing a historical perspective of the Research, Development and Engineering (RDE) activities carried out in the field of Telecommunications along the XX century mostly in the US and Europe.

A point of interest could be to try to answer the question of why research is so important to Corporations.

a) Firstly it allows companies to be in the front line of advanced technology.
b) Research also provides them with competitive advantage in the open markets.
c) At the same time, innovation ensures companies the continuity of their businesses throughout time.
d) Finally the prestige of Corporations is enhanced if their core business is supported by a wise and sound development team.

If these arguments are momentous for Societies, the question now could be put to individuals. What drives Scientists to be involved in research activities?

a) No doubt an inquiring mind or plain curiosity is the first motivation. Intelligent persons only find true satisfaction looking for solutions to the intricate problems posed by research and development.
b) The search for the truth is also a potent compelling force pushing people beyond the limits of their mental and physical aptitudes.
c) Notoriety has also played an important role in urging scientists to move forward the limits of the actual edge of knowledge.
d) Finally moral or material rewarding can also be quoted as a significant motivational force.

As we are about to see in this paper, when the common interests of companies and individuals can be mutually satisfied and the appropriate resources generously allocated, the results obtained can certainly be staggering.

Research activities in Telecommunications have some particular and unique features that are important to grasp in order to understand the strategies carried out by both Governments and Private Corporations to fully master these technologies. At the same time the strategic character of Telecommunication Services make them particularly important in times of war. This explains the additional efforts made by Governments to finance research activities in this field just before and during times of conflict.

But what are those particular features mentioned before?

- The scientific bases which support most of the present Telecom technologies are relatively new. Maxwell equations, Quantum Mechanics, Relativity Theory, Solid State Physics, Advanced Materials, Micro-mechanics, etc. That a scientific subject is recent in time is tantamount to saying that it has an intrinsic difficulty so that humans have required thousands of years to refine it. This complexity is, in turn, later transferred to the technologies that derive from it.
- As a consequence the human resources needed to master these sciences and technologies must be highly qualified and specialized.
- Evolution of Telecom technologies is very rapid which is what makes it difficult to keep pace with them. Continuous updating is then necessary.
- Consequently the financial resources required by Corporations to maintain a first line position and steadily roll out new products to the market are huge.
- As a result a critical mass is often needed to put together the required resources (human and financial) to succeed. (A typical case in point is Cooperation among Government, Universities and Corporations).

II. XX CENTURY PANORAMA OF THE TELECOMMUNICATION SECTOR IN THE IN USA AND EU

Around 1910, the American Telecommunications operator ATT and the recently created American company ITT, signed a secret memorandum of agreement by which they committed to respect each others territories of business operation. ATT restricted itself to the American territory and ITT settled to operate in the rest of the world.

In the USA the Bell System was made up of three different entities, each one being the vertex of a "triangular model", with a well defined function. ATT to operate the network

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and provide Telecom services, WECO (Western Electric) responsible for equipment manufacturing, and the Bell Laboratories to perform research activities.

The important revenues obtained from operations by ATT were generously re-invested in research in the Bell Labs, which developed new products that were subsequently manufactured by WECO and installed by ATT. These were the years of great innovations: the transistor, submarine telephone cables, communication satellites, solar batteries,…

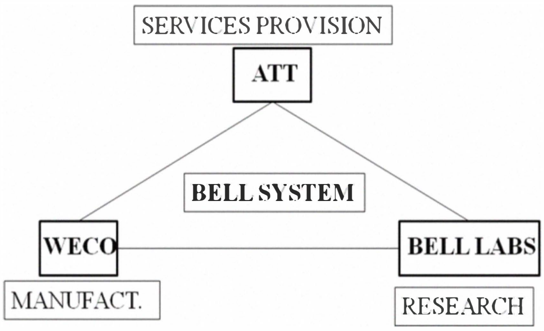


Fig 1 Triangular model of the Bell System in the USA

ITT in turn replicated the "triangular model" mainly in Europe. In Spain for instance ITT provided Telecom services from 1912 up to 1946, when the company was nationalized by General Franco to create CTNE (Telefónica). Manufacturing activities were carried out in many subsidiary companies all over Europe: STC (Standard Telephone and Cables) in the UK; SEL (Standard Electric Lorenz) in Germany; FACE in Italy; SESA (Standard Eléctrica) in Spain; BTM (Bell Telephone Manufacturing) in Belgium; STK in Norway; IKO in Sweden, etc. As far as research is concerned, ITT had two important centres: STL (Standard Telecommunication Laboratories) in the UK and ITT-LS in Spain.

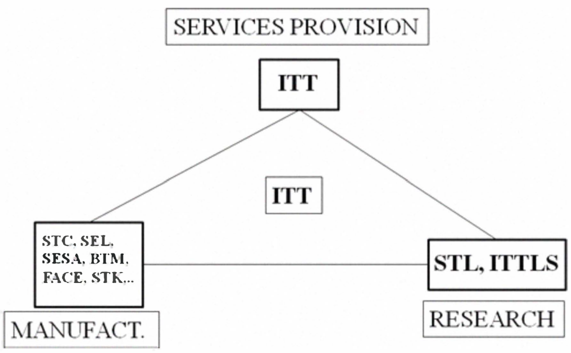


Fig 2 Triangular model of ITT Telecom in Europe

The financial robustness of these models provided a solid base upon which a fruitful and successful research environment was formed.

The following figure is an schematic view of the distribution of revenues and expenses (not to scale) of the triangular model. The vast resources required to support the RDE activities were siphoned out from services provision.

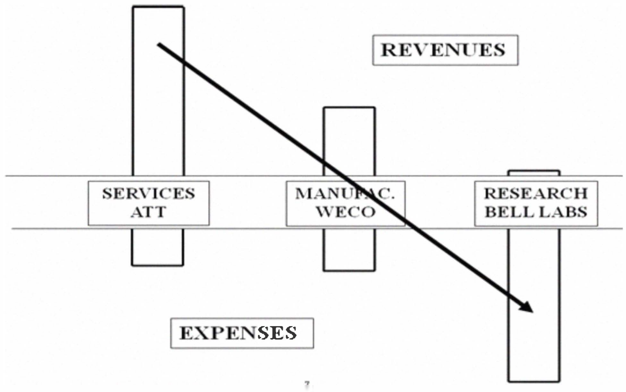


Fig 3 Revenues and expenses in the triangular models (not to scale)

III. PHASES OF INNOVATION ACTIVITY IN THE TRIANGULAR MODELS

At this point it is convenient to recall the three phases that have traditionally encompassed innovation activities.

a) RESEARCH (R). This task is reserved to those activities aimed at advancing the basic knowledge of scientific matters that will eventually form the support for further technological developments. This part of the innovation process requires huge amounts of human and financial resources which are generally only available to important research centres of big Corporations, Governments or first rate Universities. Typically this is a long term activity. The results of these endeavours are significant leaps in human knowledge which are sometimes rewarded by prestigious awards such as the Nobel Laureate.

b) DEVELOPMENT (D). This activity is aimed at obtaining technological innovations which are later used to develop prototypes with functionalities and applications different to those of already existing products. The financial resources required are also significant, and a basic requisite is the existence of an important industrial fabric on which the production and testing of the experimental models is carried out. Apart from the prototypes themselves an additional bonus of this activity is the numerous patents filed along the process.

c) ENGINEERING (E). This last stage of the innovation process includes those activities required to put into industrial production those prototypes developed before with levels of quality, cost and functionality that make them competitive in the open market. These engineering activities are normally carried out in the same plants where the products are regularly manufactured.

IIII. NOBEL LAUREATES IN PHYSICS WHOSE DISCOVERIES HAVE BEEN INFLUENTIAL IN TELECOMMUNICATIONS

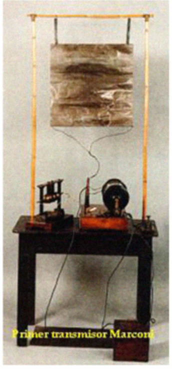
As has been mentioned before a coveted recompense to the research activity of any Scientist is to get nominated as a Nobel Laureate. This reward is not only prestigious for the individual itself but also for the Organization who has supported and encouraged his investigations.

Telecommunication is mainly a technological discipline and, as it is well known, the Swedish Academy do not bestow the Nobel recognition to technological discoveries but to Scientific breakthroughs in the form of Nobel prizes of Physics.

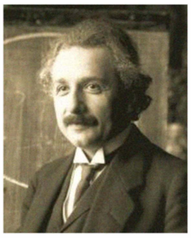
However, throughout the history of Telecommunications some Nobel awards were granted to Scientists whose discoveries later found direct application in the Telecom technologies. As a matter of fact many of these findings were made in the laboratories of the two Companies who have been the most important players in the Telecom sector along the XX century, namely ATT and ITT.

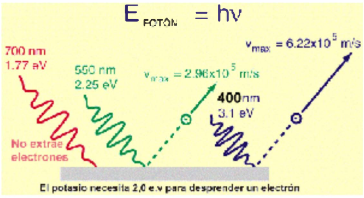
These are some of the most important Nobel Laureates

1909 - Guglielmo Marconi and Ferdinand Braun for their development of wireless telegraphy.



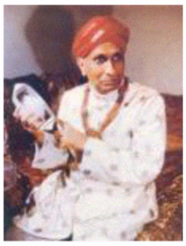
1921 - Albert Einstein for his contributions to theoretical Physics, particularly for his interpretation of the photoelectric effect.

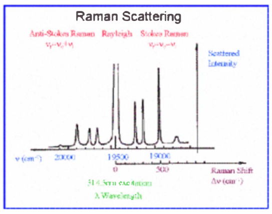




$$hf = hf_0 + \frac{1}{2} m v_m^{2}$$

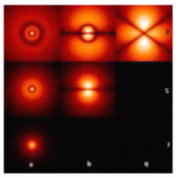
1930 - Chandrasekhara Venkata Raman for his investigations about diffraction of light and the discovery of the effect that bears his name (Raman effect)





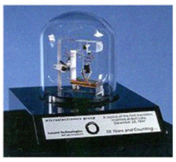
$$\frac{N_1}{N_0} = \frac{g_1}{g_0} e^{-\frac{\Delta E_v}{kT}}$$

1937 - Clinton Davisson (Bell Labs) for his discovery about the wave nature of matter



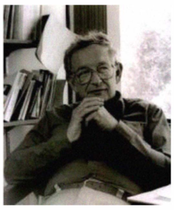
$$\lambda = \frac{h}{p} = \frac{h}{m \cdot v}$$

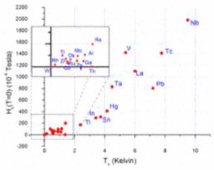
1956 - John Bardeen, Walter Brattain y William Shockley (Bell Labs) for their invention of the transistor.



$$J_p(Base) = \frac{qD_p p_{bo}}{W}\left[e^{\frac{V_{EB}}{V_T}}\right]$$

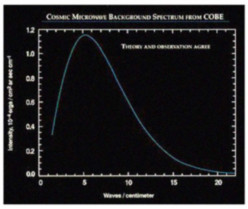
1977 - Phillip Anderson (Bell Labs) for his works on the electronic structure of disorderly magnetic systems





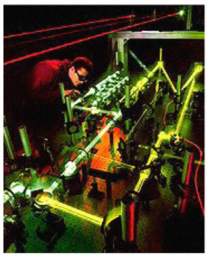
$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t} = 0 \rightarrow \vec{B}(t) = constante$$

1978 - Arno Penzias and Robert Wilson (Bell Labs) for their discovery of the microwave cosmic radiation background of the Big Bang



$$E(\nu,T) = \pi \cdot I(\nu,T) = \frac{2\pi h\nu^3}{c^2}\frac{1}{\exp(h\nu/kT)-1}$$

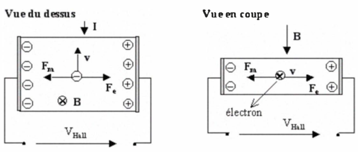
1981 - Arthur Leonard Schawlow (Bell Labs) for his contribution to the development of the laser source.



$$\Delta E = h \cdot \nu$$

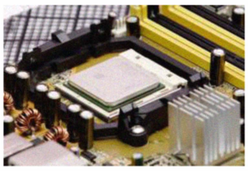
1997 - Steven Chu (Bell Labs) for his discovery of a method to cool and trap atoms using lasers.

1998 - Horst Stormer, Robert Laughlin (Bell Labs) and Daniel Tsui for their discovery of the quantum Hall effect

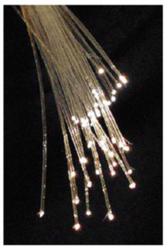


$$F_e = F_m \Rightarrow q \cdot E = q \cdot v \cdot B \Rightarrow E = v \cdot B \Rightarrow V_H/d = v \cdot B \Rightarrow V_H = v \cdot B \cdot d$$

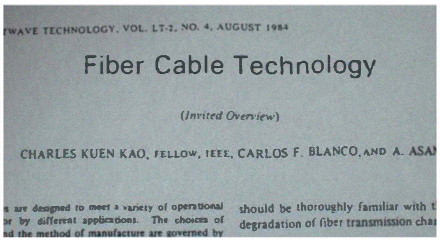
2000 - Herbert Kroemer, Zhores Ivanovich Alferov, for their development of high velocity semiconductor hetero-structures in electronics and opto-electronic



2009 - Charles K. Kao (STL-ITT) for his advances in the transmission of light in optical fibre cables



$$T^2\left[T+\delta(t-t_n)\,SE - T_m + \frac{a}{24}\frac{W_H^2}{T_m^2}SE\right] = \frac{a^2W^2}{24}SE \quad (5)$$



WAVE TECHNOLOGY, VOL. LT-2, NO. 4, AUGUST 1984

Fiber Cable Technology

(Invited Overview)

CHARLES KUEN KAO, FELLOW, IEEE, CARLOS F. BLANCO, AND A. ASA

s are designed to meet a variety of operational ... by different applications. The choices of ... d the method of manufacture are governed by

should be thoroughly familiar with t ... degradation of fiber transmission cha

Fig 4 First page of the paper jointly published in 1984 in the IEEE by The Nobel Laureate Dr. C. K. Kao and the author of this paper on fibre technology, in which the above equation is obtained.

Functions of Telecommunication networks today are split up in a series of seven layers known as the OSI pile of standards. According to what we have been saying so far, most of the basic research activities should be grouped in what is commonly known as the physical layer.

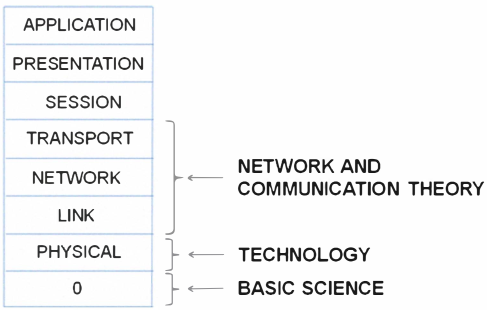


Fig 5 The conventional OSI layer model

However, in the history of Telecommunications, many other Scientists and Engineers have also searched in other functions of the Telecom network which are located above the bottom layer. These functions are grouped today in what we know as Link, Network and Transport layers. In the past these investigations were carried out in what was known as Network and Communication Theory.

The following are some of the Scientists who contributed to the development of the Telecommunication networks as we know them the today.

TELEPHONE TRAFFIC THEORY

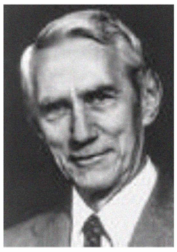
Agner Krarup Erlang

$$P_B = \frac{\frac{A^N}{N!}}{\sum_{n=0}^{n=N} \frac{A^n}{n!}}$$

$$P_C = \frac{\frac{(\rho N)^N}{N!}\frac{1}{1-\rho}}{\sum_{n=0}^{n=N-1}\frac{(\rho N)^n}{n!} + \frac{(\rho N)^N}{N!}\frac{1}{1-\rho}}$$

INFORMATION THEORY

Claude Sannon (Bell Labs)



$$C = B \times \log_2\left(1 + \frac{S}{N}\right)$$

NOISE AND STABILITY THEORY

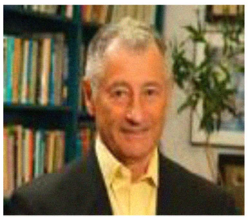
Harry Nyquist (Bell Labs)

$$P = \bar{v}_n^2/R = 4k_B T\Delta f$$

$$C = 2 \times B$$

PACKET SWITCHING THEORY (ARPANET-INTERNET)

Leonard Kleinrock



$$P(\text{delay}) = \frac{\frac{(\rho N)^N}{N!}\frac{\rho^{L+1}-1}{\rho-1}}{\sum_{n=0}^{n=N-1}\frac{(\rho N)^n}{n!} + \frac{(\rho N)^N}{N!}\frac{\rho^{L+1}-1}{\rho-1}}$$

WORLD WIDE WEB (WWW)

Tim Berners-Lee

- **HTML (HyperText Markup Language)**
- **HTTP (HyperText Transfer Protocol)**
- **URL (Uniform Resource Locator).**

As a summary these are the 12 most important achievements in Telecom in the Bell System and ITT as a result of their massive RDE activity

1. Pulse Code Modulation (PCM) (ITT)
2. Data Transmission networks (Bell Labs)
3. Transistor (Bell Labs)
4. Cellular Telephony (Bell Labs)
5. Solar Cells (Bell Labs)
6. Laser (Bell Labs)
7. Optical Fibre (ITT)
8. Digital Transmission and Switching (Bell Labs)
9. Communication Satellite (Bell Labs)
10. Touch Tone telephone (Bell Labs)
11. UNIX Operating System and C Language (Bell Labs)
12. Signal Digital Processor (Bell Labs)

All in all, 7 Nobel Awards and 12 Researchers, plus thousands of patents.

V. DIVESTITURE OF THE BELL SYSTEM AND SELL OUT OF ITT

In 1984 an event took place that was to shake the foundations of the Telecom business in an irreversible way. American Judge Harold Green in base to antitrust legislation took the decision to divest the Bell System into seven regional Bell Operating Companies (RBOC), leaving it to ATT to provide long distance services and to RBOC to provide local services.

The Bell triangular model was torn down and the Bell Labs and Western Electric were forced to team up to support the huge expenses of research activities. They formed Lucent Technologies and, since then, no new Nobel Laureates have been awarded to them.

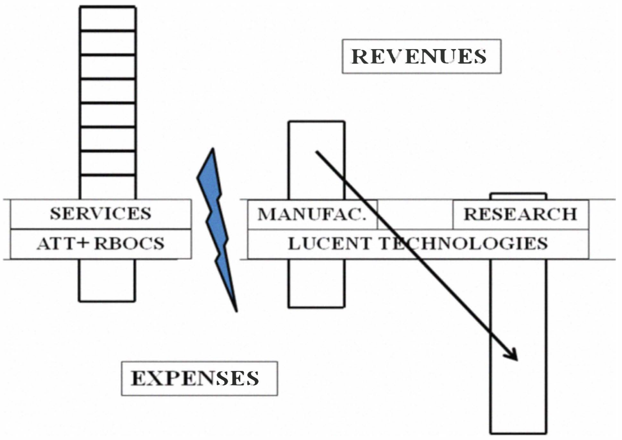


Fig 6 The divestiture of the Bell System and its impact on research funding

Just prior to the divestiture decision of Judge Green in 1984, ATT and ITT decided to revoke their non intrusion agreement, trying to expand their markets beyond the borders initially agreed. In particular, ITT was eager to enter the American market, as their sales in Europe had been dwindling since the early 70`s.

But for ITT to enter the American market was not immediate. It had to adapt its S-12 switching exchanges to the stringent US specifications. What initially was not considered as a particularly troubling matter, in the end resulted in a formidable task that swallowed huge amount of resources. In 1986 ITT, exhausted by the effort, and perhaps foreseeing the uncertain times forecast for the Telecom sector, gave up and decided to sell out its Telecom activities to Alcatel.

The triangular model of ITT was also dismantled and its research activities were reduced accordingly.

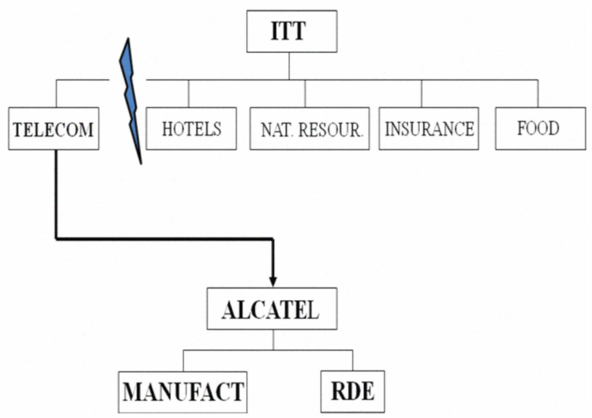


Fig 7 The sell out of ITT Telecom to Alcatel

Once these models were taken apart the resources required to support the much needed research activities were to be borne by the manufacturing branches of the businesses. As it became clear almost from the beginning, this inflow of funds was not comparable to the one provided by the services provision branch. The net result was a reduction of the research muscle of both Corporations.

Only recently we have witnessed the merge of Alcatel and Lucent in an effort to adapt and keep up with the innovation required to maintain their leadership in the markets.

The expansion of Telecom networks today to transport massive amounts of information, mainly due to Internet Applications (Google, Face Book, You Tube,....), is forcing Telecom Operators to continually upgrade their networks with more powerful storage, transport and switching facilities. However the real benefits of these applications do not revert to the network Operators or Equipment manufacturers but are mostly collected by the Internet Applications Developers (IAD) who take advantage of highly developed networks on which their applications actually run. At the same time it is in the interest of these IAD's to dispose of the most advanced and capable networks. But Equipment Manufacturers and Network Operators could not find sufficient incentives to develop them and the very advanced products required in future networks, if their participation on the revenues was to be maintained at the present levels. Perhaps it could be time to return to the old "triangular models" in which the third vertex could be efficiently played by the Internet Applications Developers.

VI. Conclusion

The models set up at the turn of the XX century by the Bell System and ITT to provide the important inflows of funds required to support advanced Research and Development produced significant breakthroughs in the Telecommunication Industry. When these models were dismantled in the fourth quarter of the century, the net result was a debilitation of the research force.

If this research effort is to be continued today to bring forth the powerful networks of the future, it could be worth considering revitalising the old models with new players, adapted to the present circumstances.

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