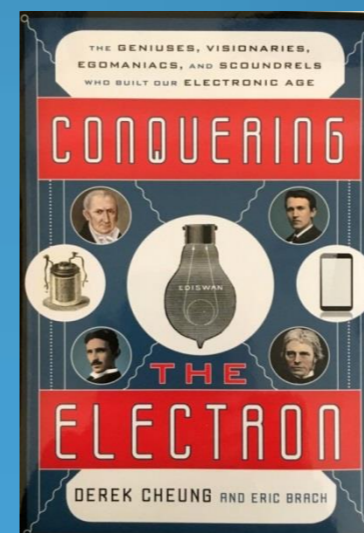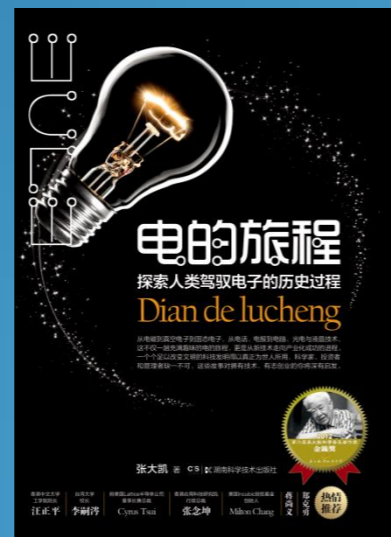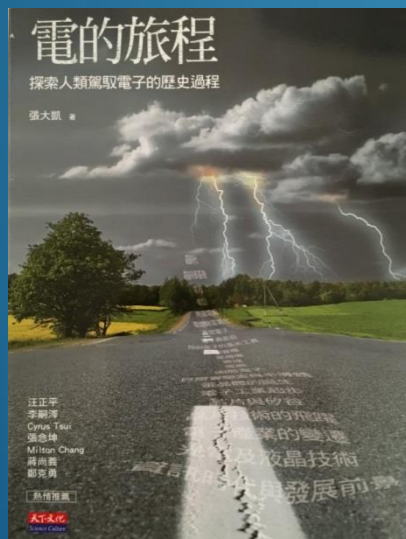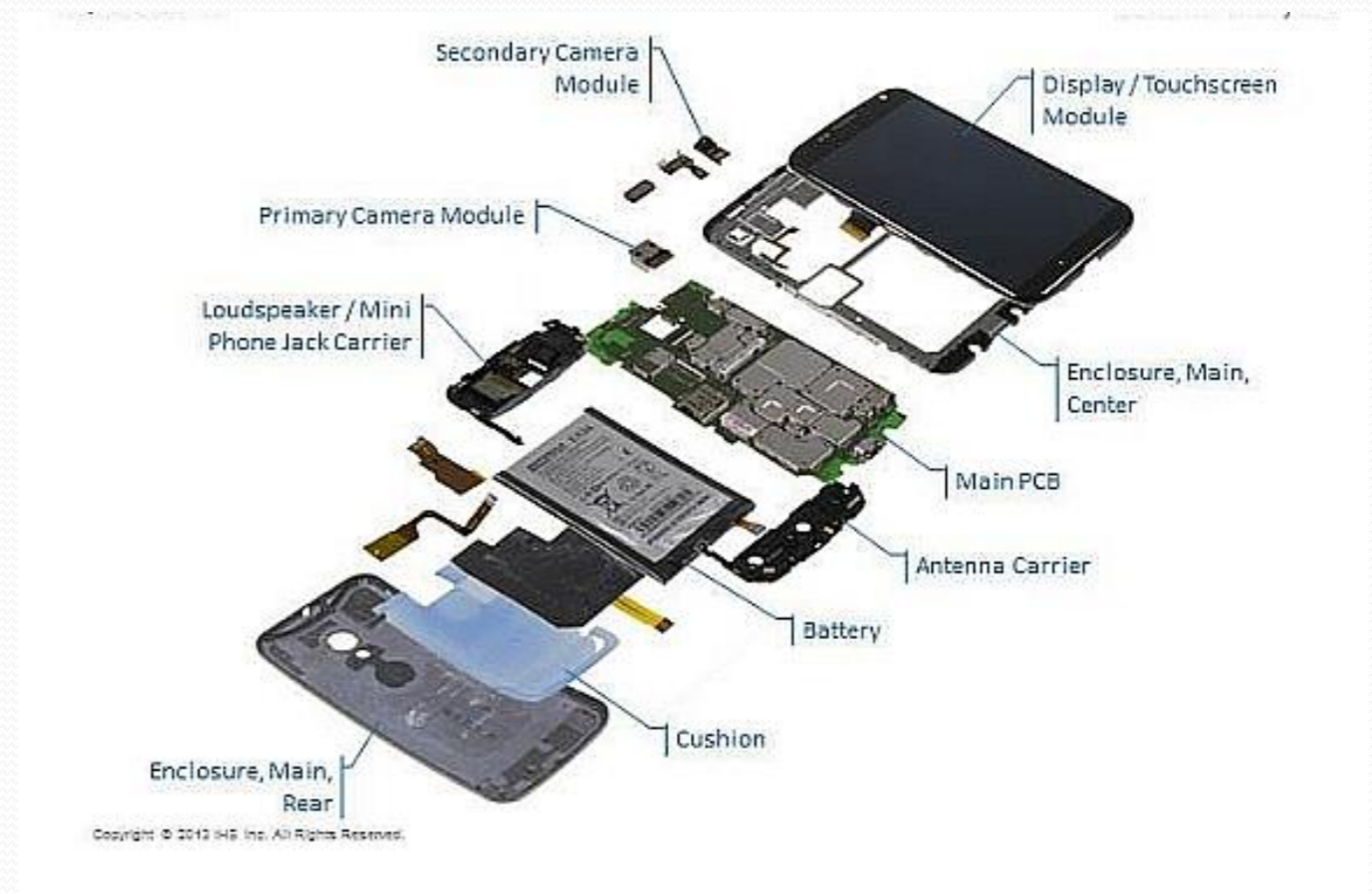# *Impactful Innovation & Invention*: 創新- 發明

Lessons from
History of Electronics Technology

Derek Cheung 張大凱
derektcheung@gmail.com
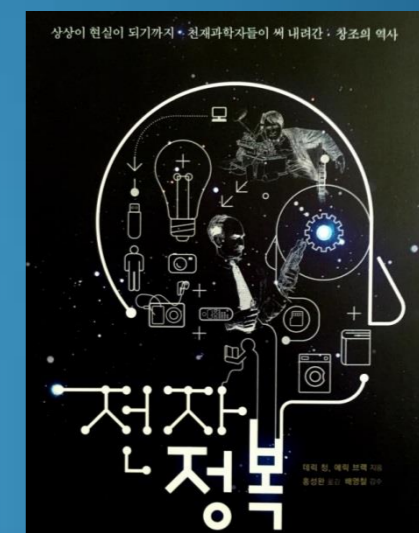
The Smart Phone Phenomena

200+ Years of Cumulative Innovation & Invention (Innovention)

Volta's battery (1800)

I) Electromagnetics (1800~1900)

Battery, Electromagnet, EM theory

Telegraph, Telephone, Wireless Telegraph

Motor, Generator, Transformer

Tram, subway, elevator, pump, lighting, refrigerator

II) Vacuum Electronics (1900~1950)

Electron beam, Vacuum Triode

X-Ray, Radio, Television, Radar, Computer

III) Semiconductor Electronics (1950~ Present)

Transistor, Silicon chips, LCD, Fiber-Optics

Building blocks of Information Age

Smartphone (2007)
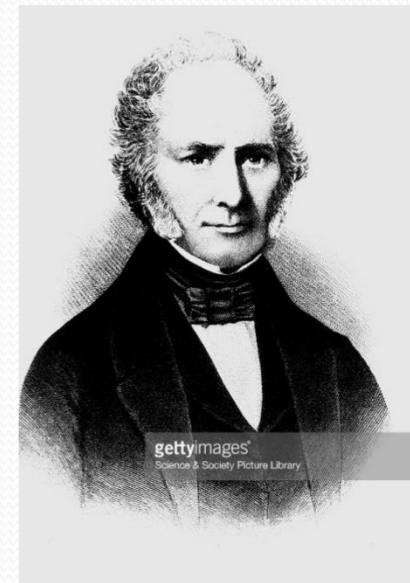
How Did It All Get Started?

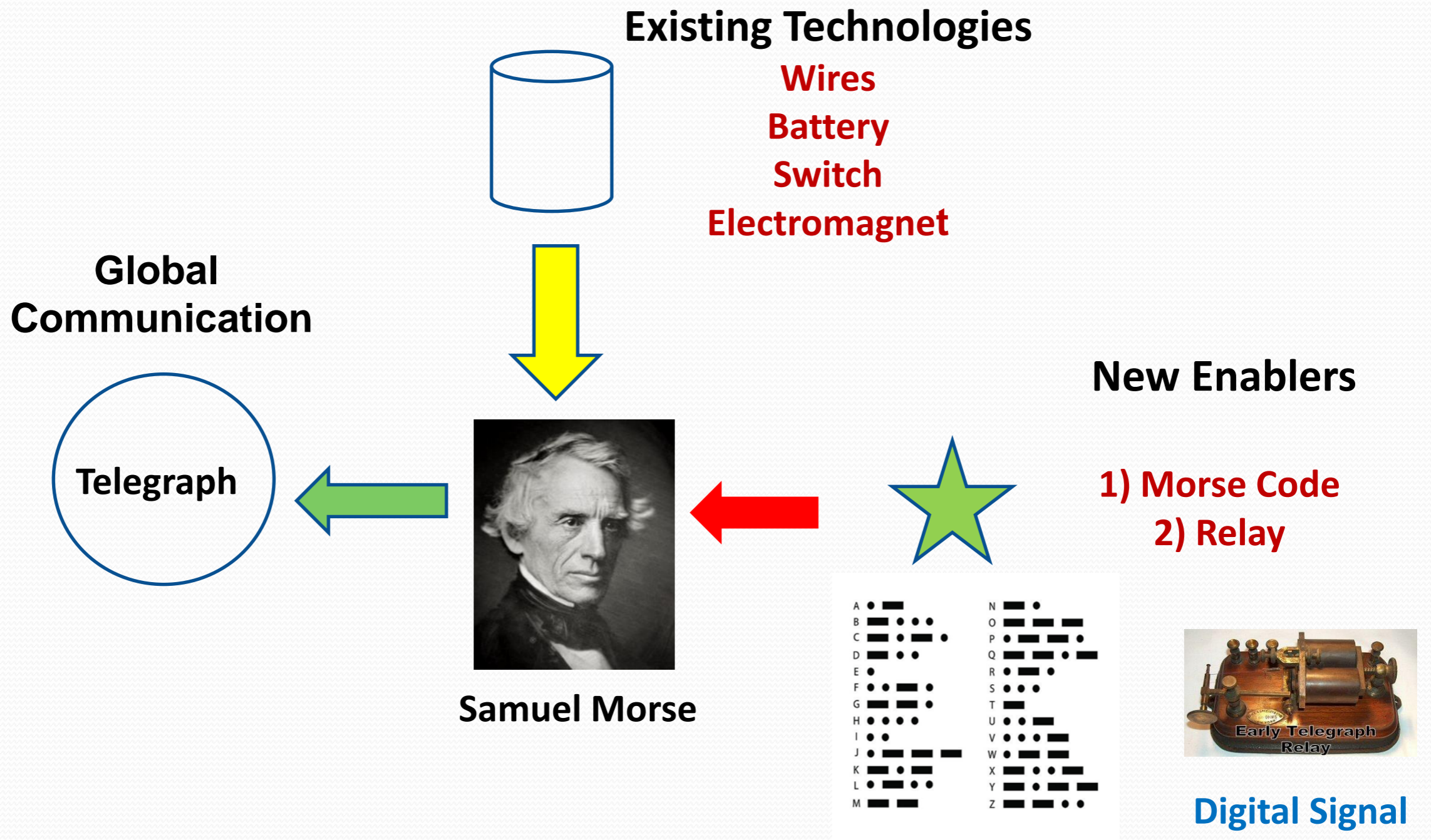Volta (1800)

Voltage (Volt)

Ampere (1820)
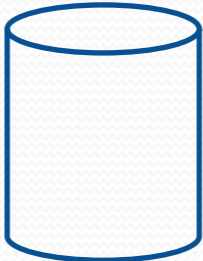
Current (Amp)

Sturgeon (1825)

Electromagnet

First Major Application: **Telegraph (1844)**
The Victorian Internet

Existing Technologies

Wires
Battery
Switch
Electromagnet

Global Communication

Telegraph

Samuel Morse

New Enablers

1) Morse Code
2) Relay

Early Telegraph Relay

Digital Signal

The Innovention Model

Building Blocks

Existing Technologies

Market / Application

New Enablers

Product & Service

Invent

Features Performance Cost

Creative Master Mind

Innovate

Definition

❖ **Innovate 創新**

    ❖ **Do things in a new way that creates more value**

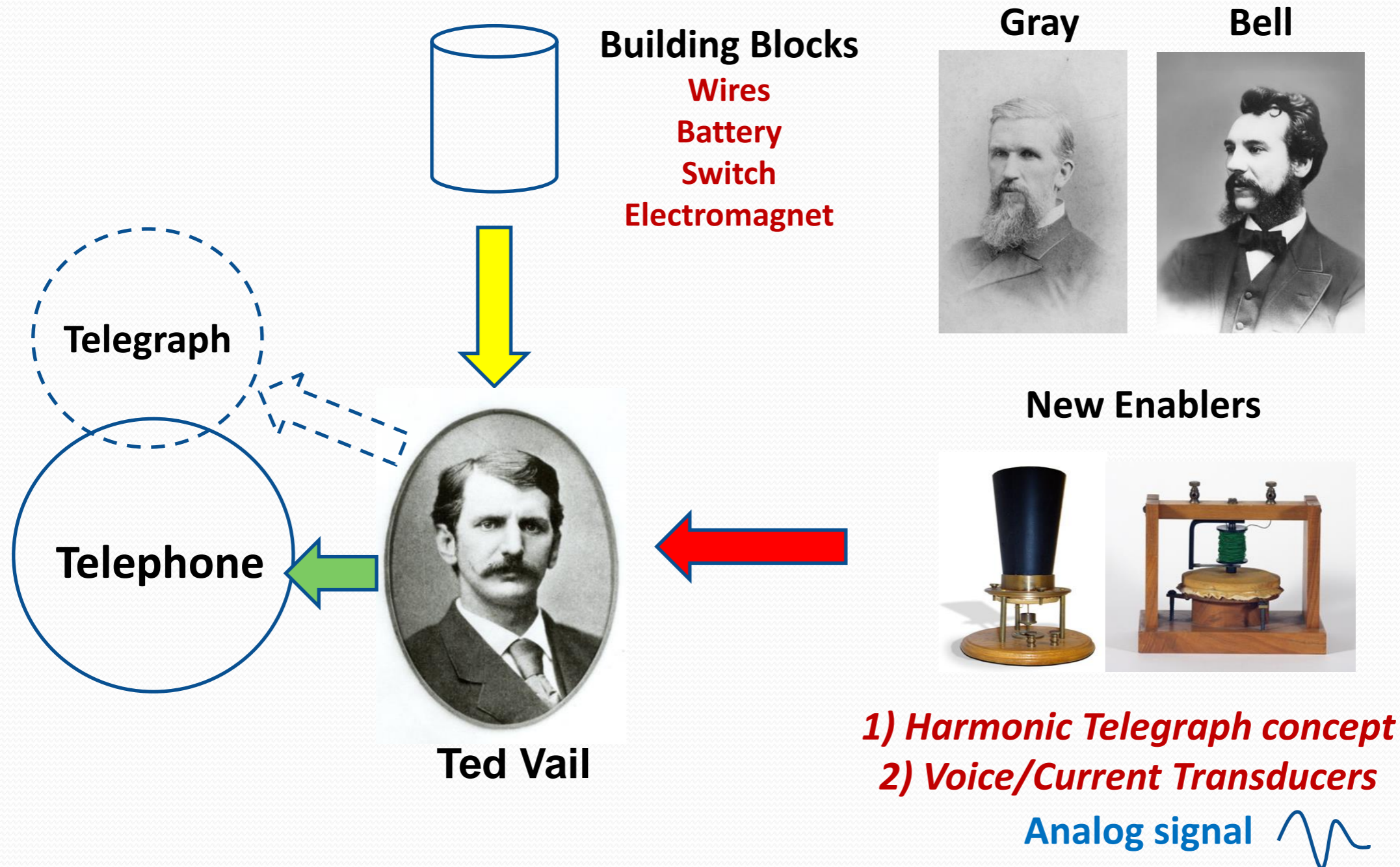   ❖ Stimulated by **new elements** in the process

❖ **Invent 發明**

    ❖ **Discover or Create something new for the first time**

❖ **Innovention: 創發**

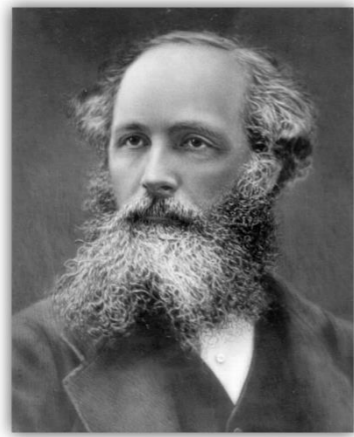   ❖ **Combine the two actions together**

The Innovention of **Telephone** (1876)
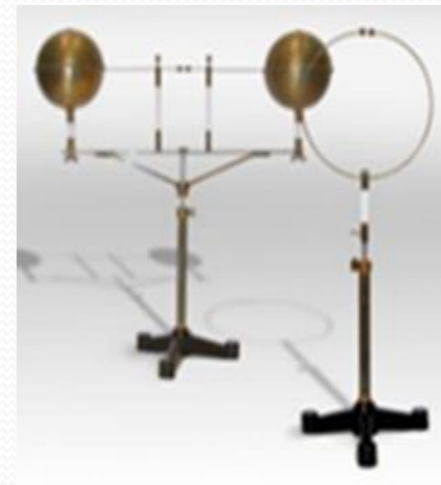## "Pivot" in Technology-Business Development Process

Building Blocks
Wires
Battery
Switch
Electromagnet

Gray

Bell

Telegraph

Telephone

Ted Vail

New Enablers

1) Harmonic Telegraph concept
2) Voice/Current Transducers

Analog signal

Scientific Breakthroughs in Electromagnetic Waves (1879-1888)
Geniuses at work!

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$

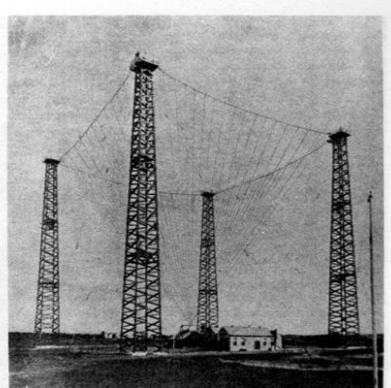**J. C. Maxwell**
(1873)

H. Hertz
(1888)

Electromagnetic Wave

Radio   Microwave   T-rays   Infrared   Visible   UV   X-rays

10^8 10^9 10^{10} 10^{11} 10^{12} 10^{13} 10^{14} 10^{15} 10^{16} 10^{17}
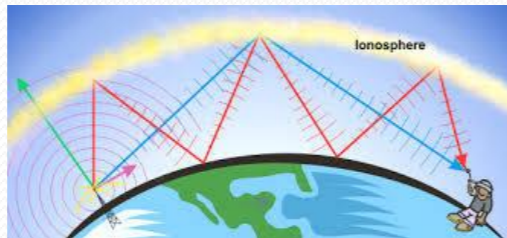
Frequency (Hz)
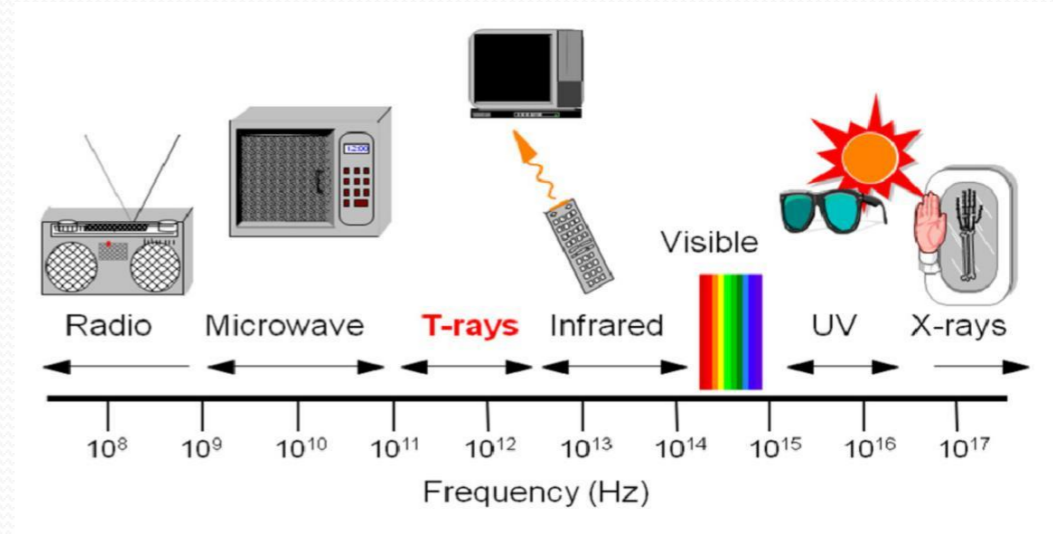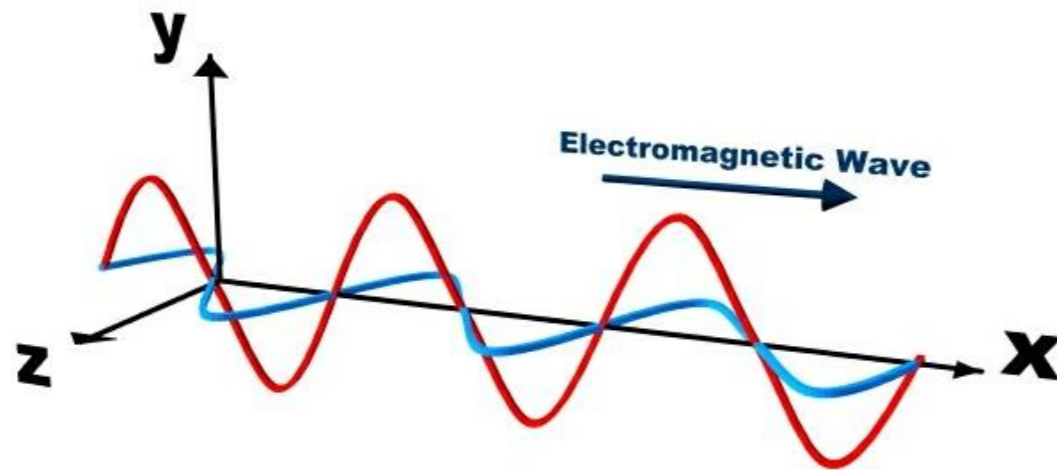
The Innovention of **Wireless Telegraphy** (1896)
Science gets down to business

Building Blocks
(Fleming Valve)
Morse Code
Kite Antenna

Shrewd market focus

New Enablers

Wireless Telegraphy

Marconi

Maxwell

$$\nabla \cdot \vec{E} = \frac{\rho}{\varepsilon_0}$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$
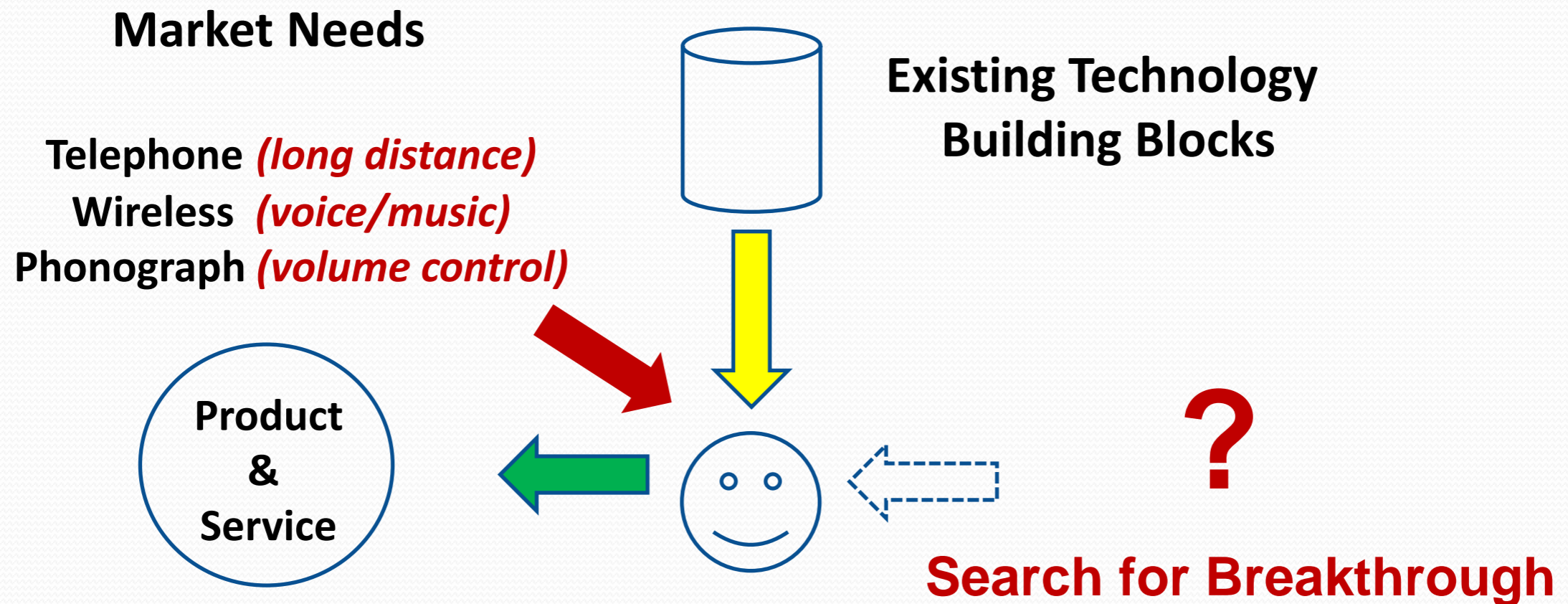
$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{B} = \mu_0 \vec{J} + \mu_0 \varepsilon_0 \frac{\partial \vec{E}}{\partial t}$$
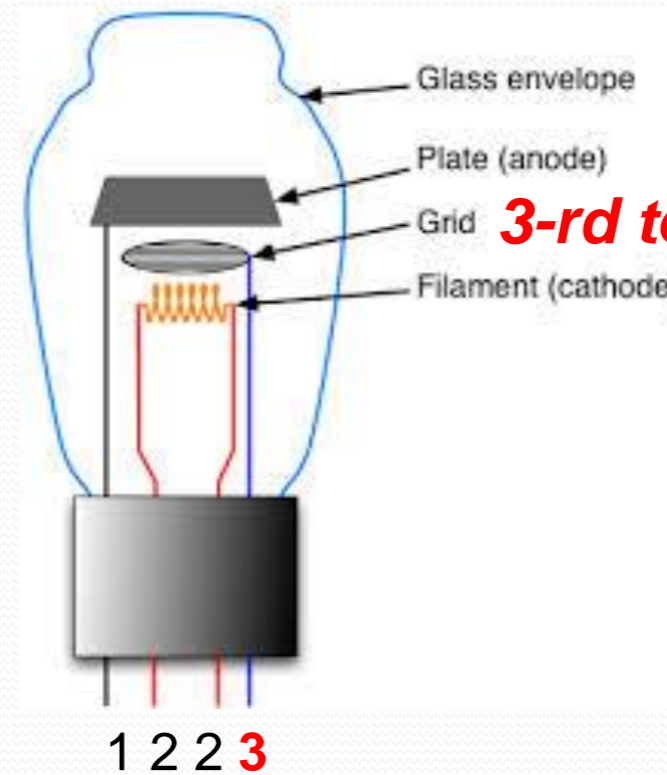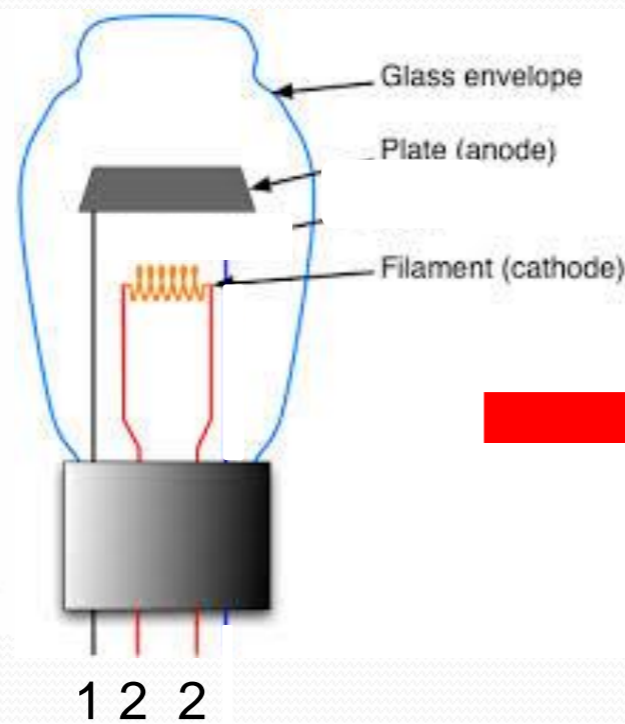
Herz

Technical Bottlenecks @ start of 20th Century

Market Needs

Existing Technology Building Blocks

Telephone *(long distance)*
Wireless *(voice/music)*
Phonograph *(volume control)*

Product & Service

?

Search for Breakthrough
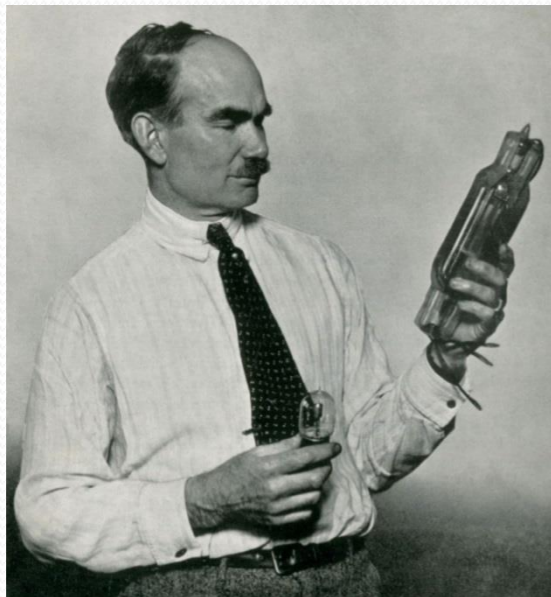
The Solution is Here Already! Vacuum Triode (1906)
Great invention sometimes comes from serendipity

1

3

2

Anode

Glass envelope

Plate (anode)

Grid — *3-rd terminal, Grid*

Filament (cathode)

Cathode

Glass envelope

Plate (anode)

Filament (cathode)

1 2 2

1 2 2 **3**
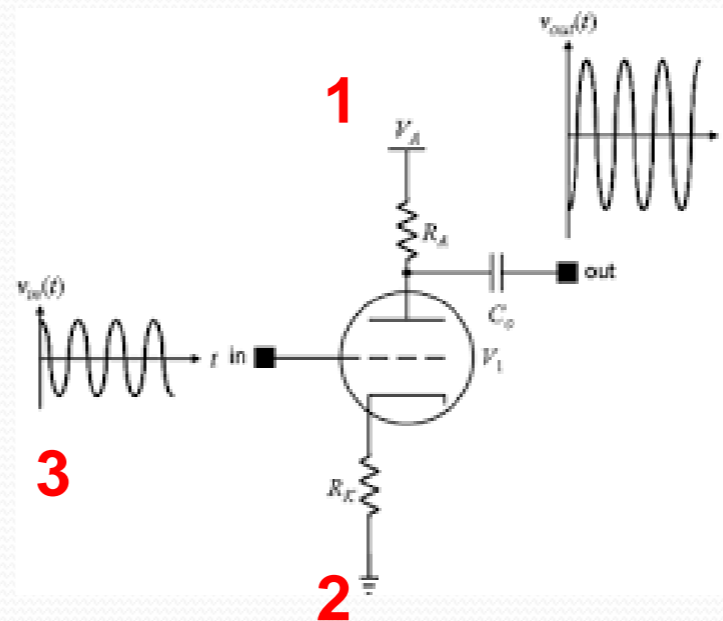
- Amplifier
- Switch

Triode Enabled Explosion of New Applications
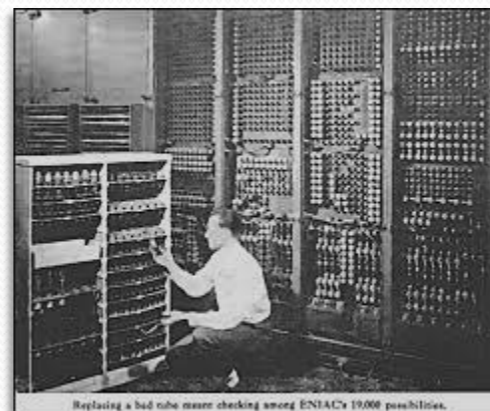## *A True Breakthrough*

NYC-SF Long distance Phone Line 1914

Radio 1915

Television 1927

Mass Produced by AT&T
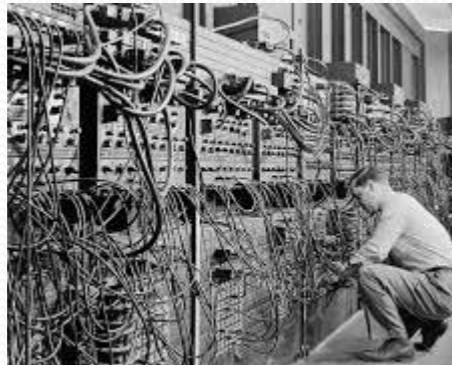
Radar & Radio Navigation 1939

Computer 1946

"First" Digital Computer: **ENIAC** (1946)
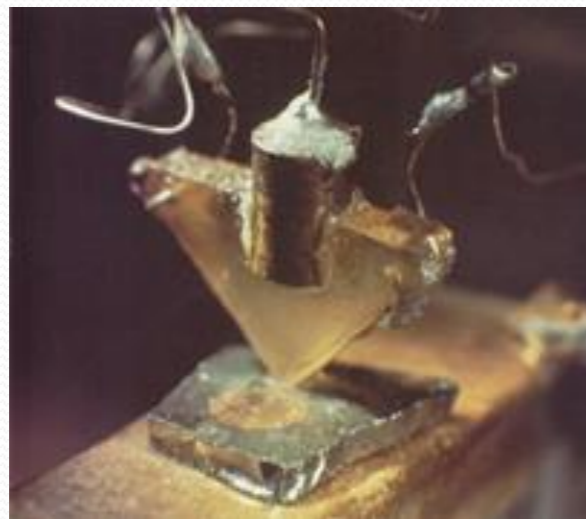

- **US Army funded project at Univ. Pennsylvania**

  - Digital switching & Boolean Algebra
  - **17,468 triodes**
  - 160 KW power
  - > 60,000 pounds
  - > 5,000 op/sec (1,000 x faster, scalable)
  - MTF ~ 36 seconds

The Holy Grail: **Transistor** (1947)
Ultimate building block for everything "electronic"

- AT&T Bell Labs
- > 10 years (1937-1948) of intense R&D
- Brilliant individuals
- Multidisciplinary teams
- Triumph for physics & chemistry

Kelly   Shockley   Brattain   Bardeen   Teal   Pfann
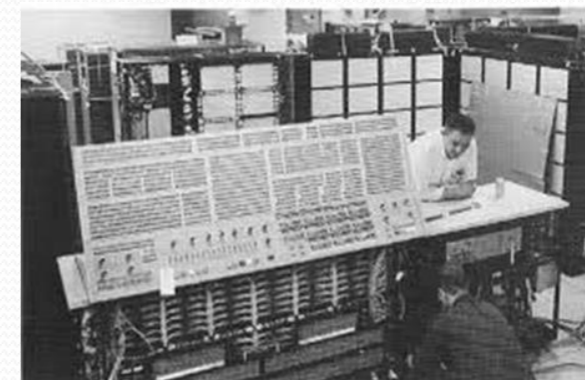
The Transistor Revolution (1954 -)
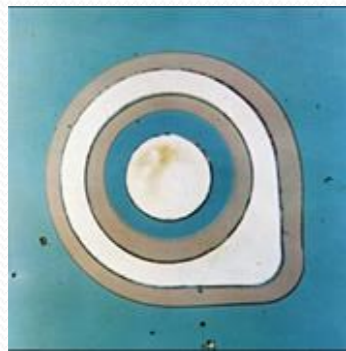## *Beginning of the Electronic Era*

- Start of a new, global industry
  - Licensing by AT&T
  - Birth of Silicon Valley
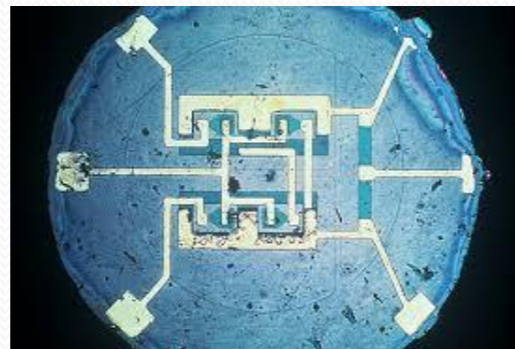- New generations of products
  - Military – Industrial - Consumer

Magical Evolution: Integrated Circuit (IC) (1960 -)
Aggregate many Transistors on a single Chip
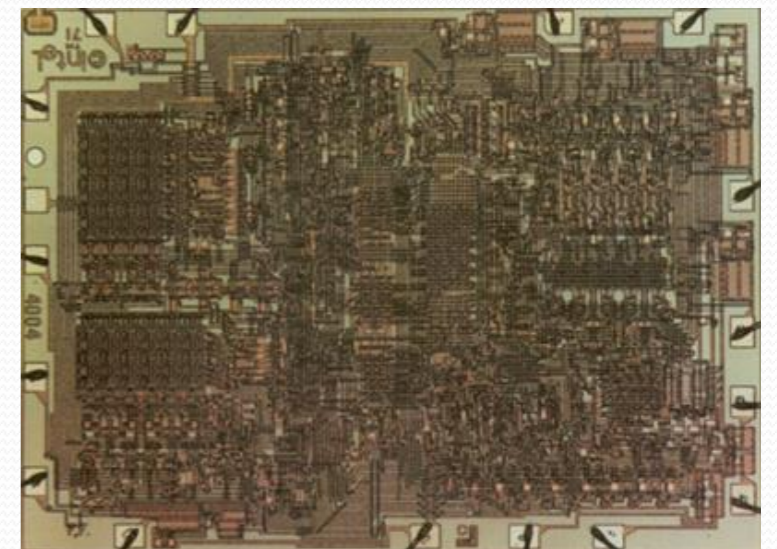

Planar Transistor 1959

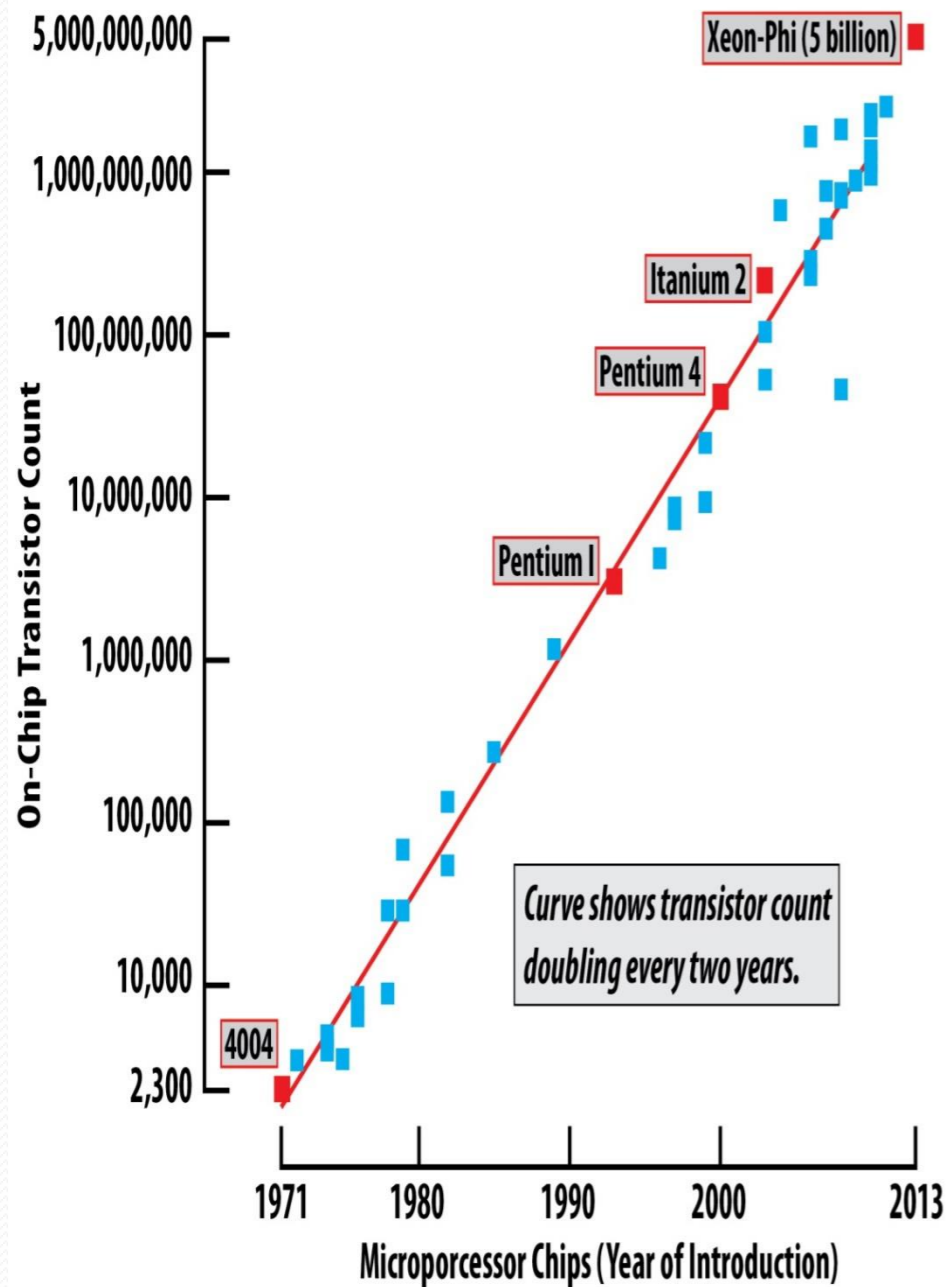**First IC 1960**

First IC In Space 1962

First "Computer-on-a chip" Intel "4004" 1971

**Comparable performance to ENIAC !**

Chip Scaling & Moore's Law
> 50 years of exponential growth

❖ Number of transistors on a chip 2x in every ~18-24 months (from 3 to 6.5billion!)

❖ Enabled other building block technologies

  ❖ LED, LCD, Lasers and Fiber Optics

  ❖ MEMS and other Sensors

  ❖ Mass memory

❖ Integrated "System on a chip"

❖ **A major driving force for economic growth**
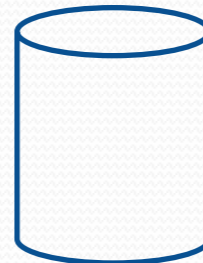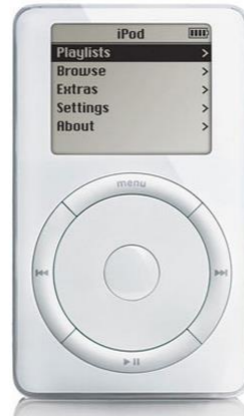
❖ **But it is slowing down......**

Curve shows transistor count doubling every two years.
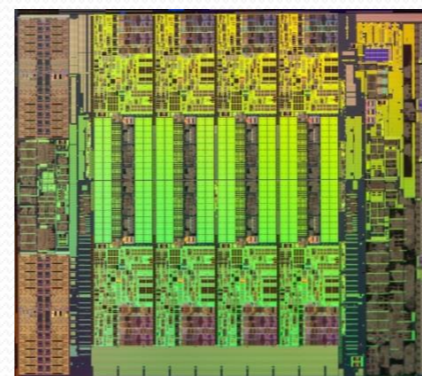
Intel Xenon (2015)
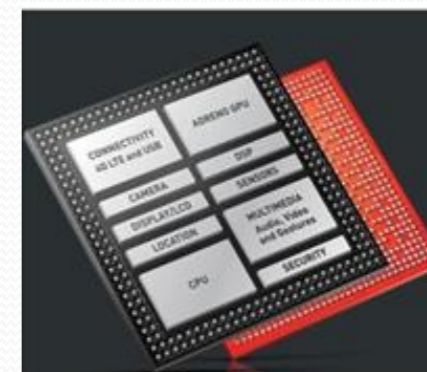
Qualcomm Snapdragon (2016)

Revisit Innovention:
The Apple Examples (Mac, iPod, iPhone)

Building Block Technologies
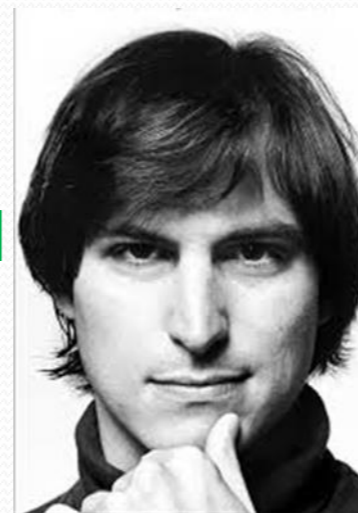**Chips, LCD, LI battery, Mass memory**
System SW, Algorithms, Apps…..

Market

Products

Features
Performance
Cost

Master Mind
(Innovator)

The Enablers
(Many Inventors)

GUI / Mouse (Mac)

1.8" drive+ iTune (iPod)

"Computer" as a phone
Touch Screen (iPhone)

Future Outlook for Smartphones

- Incremental improvement & Commoditized
  - What are the implications?
- Personal gateway to
  - Web – Cloud – Internet of Things (IoT)
  - Big data – Deep learning – Precision information
- Open up new horizon for everything we do
  - Medical/health, energy/environment,…..

Quiz for book prizes

What are these two experiments by Faraday?