

Vacuum Science & Technology Time Line, 1500–1799

Time Line Color Code Key

- Related scientific developments
- Vacuum devices
- Radio & electronics
- Historical events
- Vacuum gauges
- Vacuum pumps
- Captions
- Vacuum device manufacturing

Hero of Alexandria writes *Pneumatics* summarizing what is then known about syphons, pumps, etc. ~150 B.C.E.

Johannes van Helmont defines "gas" (Flemish = chaos) to mean an air-like substance 1620

Hero's *Pneumatics* translated to Italian by Aleotti 1547

Ferdinand II, Grand Duke of Tuscany, invents liquid-in-glass thermometer 1641



Evangelista Torricelli mercury barometer 1643



Rene Descartes (1596-1650) in his *Principia Philosophiae* suggests that a vacuum cannot exist 1644



Evangelista Torricelli (1608-1647) Substitutes mercury for water in overhead water pump 1644



Otto von Guericke Magdeburg hemisphere demonstration 1654



Otto von Guericke (1602-1686) Water barometer 1654

Experiments by Richard Townley (1628-1707) and Henry Power (1623-1668) establish PV law for expansion (later called Boyle's Law or Marriotte's Law) 1660

In response to Boyle's ideas, Franciscu Linus (1595-1675) suggest the properties of a vacuum is due to invisible thread-like "funiculus" that strive to hold nearby objects together 1660



Mayow Apparatus ca. 1669 John Mayow (1641-1679) suggests that air may be made up of two different gases 1674

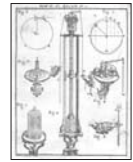


Otto von Guericke's air pump 1672



Otto von Guericke publishes treatise on vacuum experiments 1672

Jakob Hermann (1678-1733) postulates that pressure is proportional to density and to the square of the average velocity of the particles in motion 1716



Jean Antoine Nollet Falling bodies in a vacuum experiment 1743

George Erms Stahl introduces idea of phlogiston as the agent of burning and rusting 1697

Phlogiston theory abandoned 1791

1500 1600

1650

1700

1725

1750

1775

1799

Santorre Santorri (1561-1636) and Galileo independently invent thermoscope for measuring temperature ~1612



Galileo Galilei (1564-1642) measures limit of overhead water pump 1638

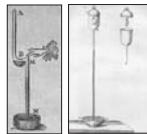
Gasparo Berti first vacuum produced (in water barometer) ~1640



Galileo Galilei's Syphon Experiment 1638



Blaise Pascal (1623-1662) Puy de Dôme Experiment- Florin Perrier showed that the height of the column in mercury barometer decreased with altitude, confirming a prediction of his brother-in-law, 1648



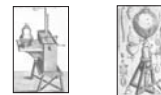
Gilles Personne de Roberval (1602-1675) Void within a void experiment Expanding bladder experiment 1648



Robert Boyle (1627-1691) studies mercury barometer ~1660



Boyle's bell in a vacuum 1660



Robert Boyle publishes *New Experiments Physio-Mechanical, touching the Spring of Air, and its Effects* 1660

Robert Boyle states Boyle's Law for compression of gases 1661

Jean Picard observes "barometric light," a glow discharge induced by static electricity when a mercury barometer is shaken 1675

Edmé Mariotte in France (~1620-1684) independently publishes relation between pressure and volume in *On the Nature of Air* 1676

Francis Hauksbee shows that sound is not transmitted in a vacuum 1705

Daniel Gabriel Fahrenheit Germany, invents mercury thermometer standardized with ice and boiling water 1714

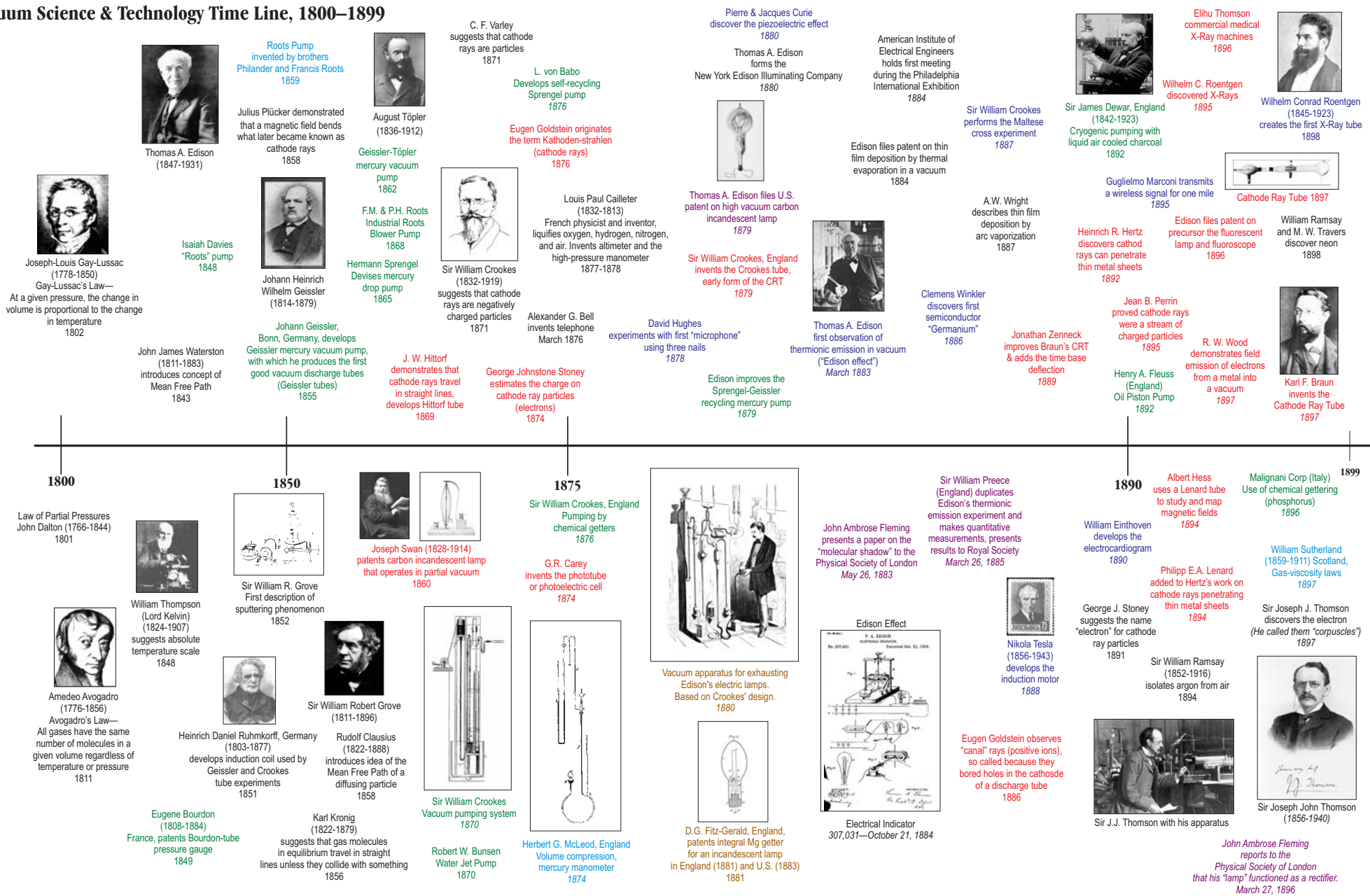


Daniel Bernoulli (1700-1782) writes "Hydrodynamica" -includes concept of gas viscosity 1733-1738

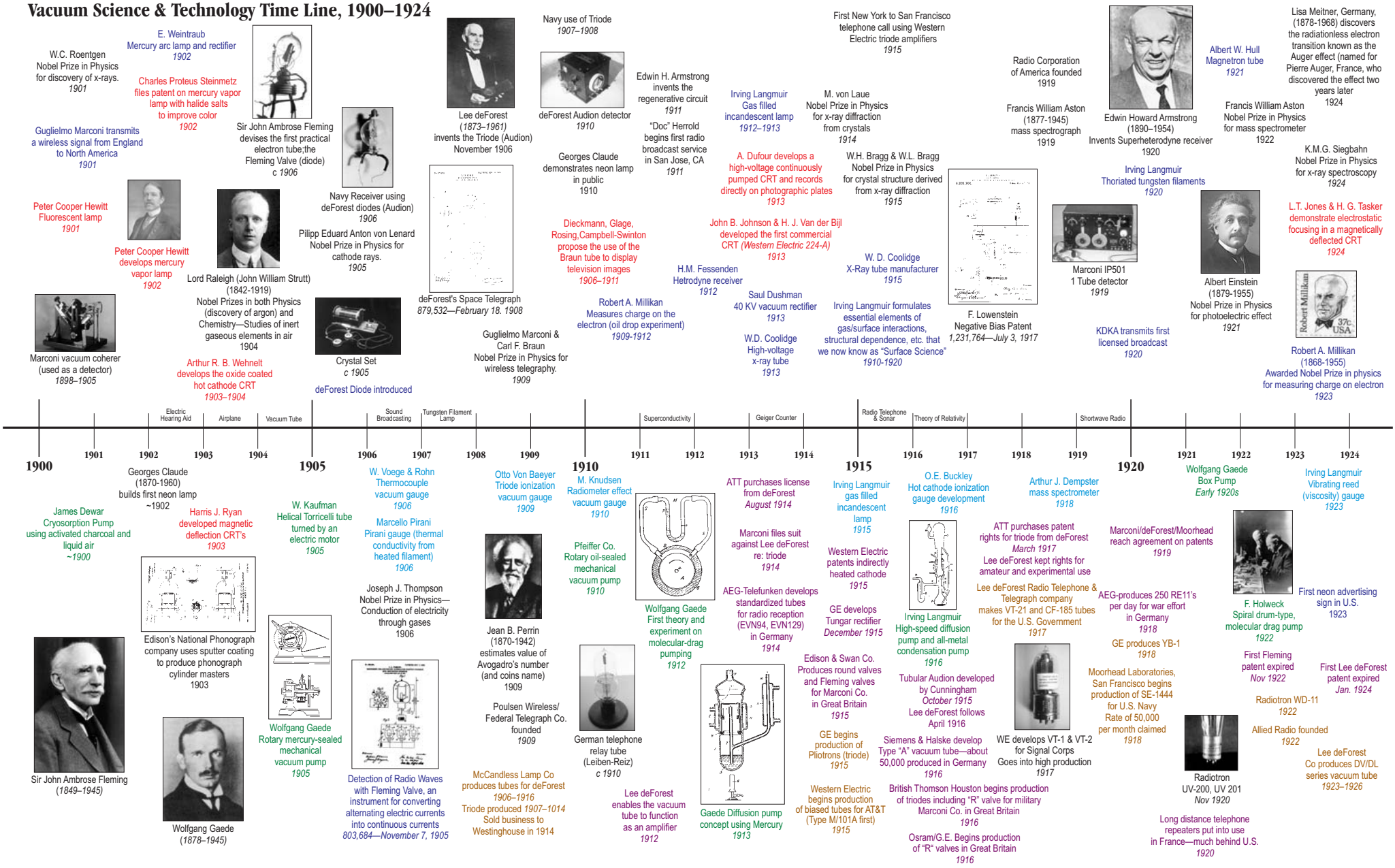
Daniel Bernoulli (1700-1782) First truly statistical treatment of kinetic theory of gasses 1728-1733

Charles Law— Jacques-Alexandre Charles establishes that for a given temperature change, different gases expand the same amount 1787

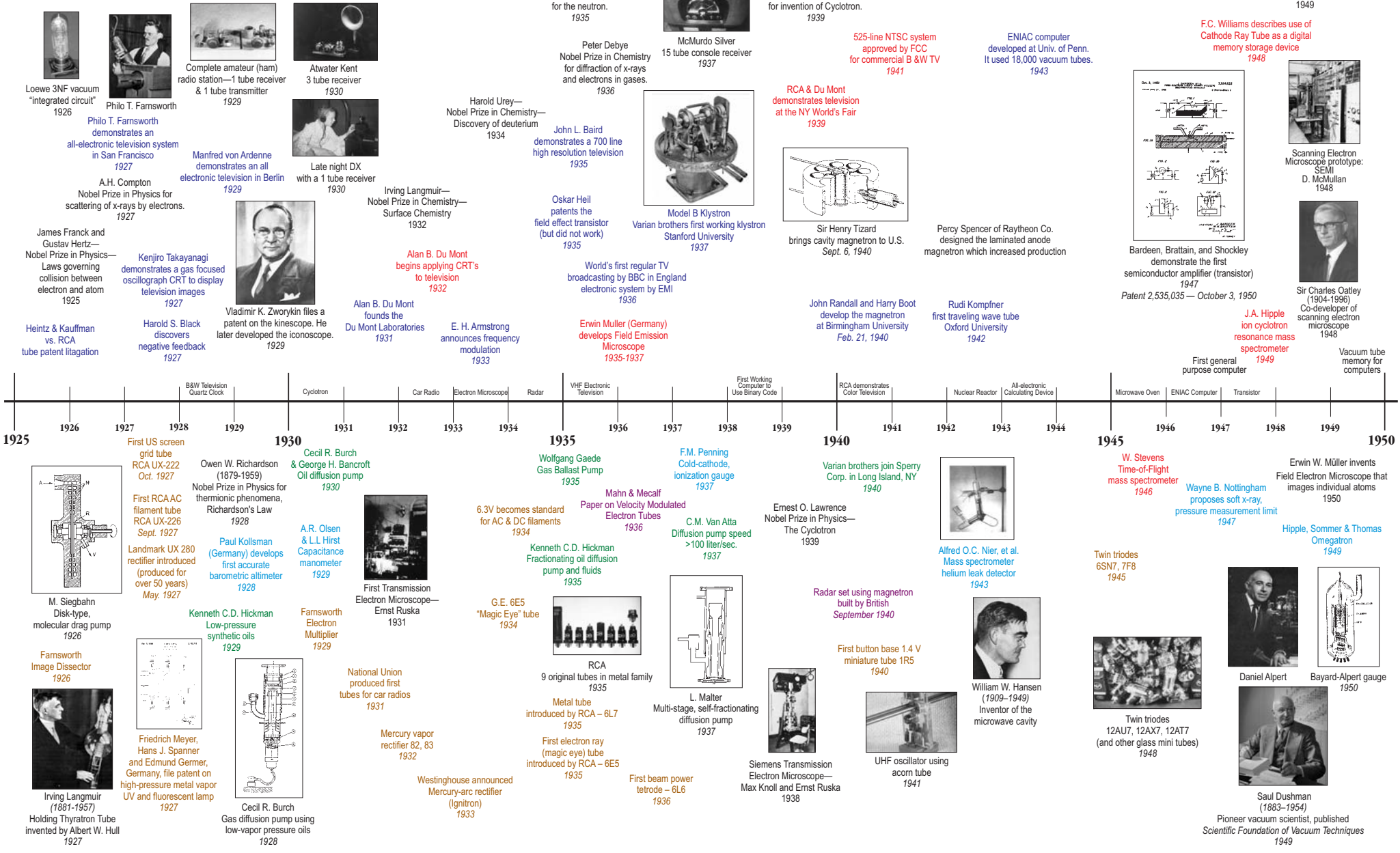
Vacuum Science & Technology Time Line, 1800–1899



Vacuum Science & Technology Time Line, 1900–1924



Vacuum Science & Technology Time Line, 1925–1950



Loewe 3NF vacuum "integrated circuit" 1926

Philo T. Farnsworth demonstrates an all-electronic television system in San Francisco 1927

A.H. Compton Nobel Prize in Physics for scattering of x-rays by electrons. 1927

James Franck and Gustav Hertz— Nobel Prize in Physics— Laws governing collision between electron and atom 1925

Heintz & Kauffman vs. RCA tube patent litigation

M. Siegbahn Disk-type, molecular drag pump 1926

Farnsworth Image Dissector 1926

Irving Langmuir (1881-1957) Holding Thyatron Tube invented by Albert W. Hull 1927

Complete amateur (ham) radio station—1 tube receiver & 1 tube transmitter 1929

Manfred von Ardenne demonstrates an all electronic television in Berlin 1929

Kenjiro Takayanagi demonstrates a gas focused oscillograph CRT to display television images 1927

Harold S. Black discovers negative feedback 1927

Friedrich Meyer, Hans J. Spanner and Edmund Germer, Germany, file patent on high-pressure metal vapor UV and fluorescent lamp 1927

Kenneth C.D. Hickman Low-pressure synthetic oils 1929

National Union produced first tubes for car radios 1931

Cecil R. Burch Gas diffusion pump using low-vapor pressure oils 1928

Atwater Kent 3 tube receiver 1930

Late night DX with a 1 tube receiver 1930

Vladimir K. Zworykin files a patent on the kinescope. He later developed the iconoscope. 1929

Alan B. Du Mont founds the Du Mont Laboratories 1931

Cecil R. Burch & George H. Bancroft Oil diffusion pump 1930

Paul Kollsman (Germany) develops first accurate barometric altimeter 1928

Westinghouse announced Mercury-arc rectifier (Ignitron) 1933

Ernst Ruska First Transmission Electron Microscope 1931

Harold Urey— Nobel Prize in Chemistry— Discovery of deuterium 1934

John L. Baird demonstrates a 700 line high resolution television 1935

John H. Langmuir— Nobel Prize in Chemistry— Surface Chemistry 1932

Alan B. Du Mont begins applying CRT's to television 1932

A.R. Olsen & L.L. Hirst Capacitance manometer 1929

Ernest O. Lawrence Nobel Prize in Physics for invention of Cyclotron. 1935

Mercury vapor rectifier 82, 83 1932

John H. Langmuir— Nobel Prize in Chemistry— Surface Chemistry 1932

Peter Debye Nobel Prize in Chemistry for diffraction of x-rays and electrons in gases. 1936

Oskar Heil patents the field effect transistor (but did not work) 1935

World's first regular TV broadcasting by BBC in England electronic system by EMI 1936

Erwin Muller (Germany) develops Field Emission Microscope 1935-1937

Wolfgang Gaede Gas Ballast Pump 1935

Mahn & Mealf Paper on Velocity Modulated Electron Tubes 1936

Ernest O. Lawrence Nobel Prize in Physics— The Cyclotron 1939

Ernest O. Lawrence Nobel Prize in Physics for invention of Cyclotron. 1935

McMurdo Silver 15 tube console receiver 1937

Model B Klystron Varian brothers first working klystron Stanford University 1937

Ernest O. Lawrence Nobel Prize in Physics— The Cyclotron 1939

Ernest O. Lawrence Nobel Prize in Physics— The Cyclotron 1939

C.M. Van Atta Diffusion pump speed >100 liter/sec. 1937

L. Maltor Multi-stage, self-fractionating diffusion pump 1937

Siemens Transmission Electron Microscope— Max Knoll and Ernst Ruska 1938

Ernest O. Lawrence Nobel Prize in Physics— The Cyclotron 1939

525-line NTSC system approved by FCC for commercial B & W TV 1941

RCA & Du Mont demonstrates television at the NY World's Fair 1939

Sir Henry Tizard brings cavity magnetron to U.S. Sept. 6, 1940

RCA demonstrates Color Television 1941

Ernest O. Lawrence Nobel Prize in Physics— The Cyclotron 1939

Alfred O.C. Nier, et al. Mass spectrometer helium leak detector 1943

William W. Hansen (1909–1949) Inventor of the microwave cavity

Siemens Transmission Electron Microscope— Max Knoll and Ernst Ruska 1938

ENIAC computer developed at Univ. of Penn. It used 18,000 vacuum tubes. 1943

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Siemens Transmission Electron Microscope— Max Knoll and Ernst Ruska 1938

Bardeen, Brattain, and Shockley demonstrate the first semiconductor amplifier (transistor) 1947

John Randall and Harry Boot develop the magnetron at Birmingham University Feb. 21, 1940

Rudi Kompfner first traveling wave tube Oxford University 1942

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F.C. Williams describes use of Cathode Ray Tube as a digital memory storage device 1948

Scanning Electron Microscope prototype: SEMI D. McMullan 1948

Sir Charles Oatley (1904-1996) Co-developer of scanning electron microscope 1948

J.A. Hipple ion cyclotron resonance mass spectrometer 1949

Erwin W. Müller invents Field Electron Microscope that images individual atoms 1950

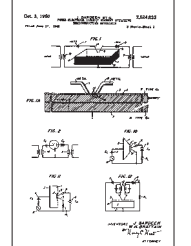
Hipple, Sommer & Thomas Omegatron 1949

Daniel Alpert Bayard-Alpert gauge 1950

Saul Dushman (1883–1954) Pioneer vacuum scientist, published Scientific Foundation of Vacuum Techniques 1949

Scientific Foundation of Vacuum Techniques published by Saul Dushman 1949

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Patent 2,535,035 — October 3, 1950



Scanning Electron Microscope prototype: SEMI D. McMullan 1948



Sir Charles Oatley (1904-1996) Co-developer of scanning electron microscope 1948

J.A. Hipple ion cyclotron resonance mass spectrometer 1949

First general purpose computer

Vacuum tube memory for computers

W. Stevens Time-of-Flight mass spectrometer 1946

Wayne B. Nottingham proposes soft x-ray, pressure measurement limit 1947

Hipple, Sommer & Thomas Omegatron 1949



Twin triodes 6SN7, 7F8 1945

Radar set using magnetron built by British September 1940



First button base 1.4 V miniature tube 1R5 1940



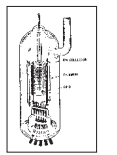
Twin triodes 12AU7, 12AX7, 12AT7 (and other glass mini tubes) 1948



UHF oscillator using acorn tube 1941



Saul Dushman (1883–1954) Pioneer vacuum scientist, published Scientific Foundation of Vacuum Techniques 1949



Bayard-Alpert gauge 1950

Vacuum Science & Technology Time Line, 1951–1975

1951

- Erwin Muller describes Field Ion Microscope 1951
- Magnetically focused electron beam gun—Leslie Holland 1951
- RCA demonstrated the shadow mask color TV tube 1950
- British & Japanese begin using traveling wave tubes for radio relay systems 1951

1952

- American Vacuum Society became incorporated October 19, 1953
- Committee on Vacuum Techniques (later the AVS) holds its first symposium 1953
- Ring Getter with U-shaped cross section (used in vacuum tubes) 1952
- M-type Carcinotrons (voltage tuned microwave oscillators) developed 1952

1953

- William Shockley celebrates Nobel Prize 1956
- Erwin W. Müller invents Field Ion Microscope images individual atoms 1956
- Wolfgang Paul Quadrupole Mass Filter 1953
- R.G. Herb Getter-Ion pump 1953

1954

- Vacuum Deposition of Thin Films by Leslie Holland published 1956
- First silicon transistor Texas Instruments 1954
- A.M. Gurewitsch & W. F. Westendorf Single cell sputter ion pump 1954

1955

- W. Becker Multi-stage turbine (turbomolecular) pump concept 1955
- R. Herb Orbitron pump with electron-impact Ti sublimation 1955
- Leybold Company Roots vacuum pump mfg. 1955

1956

- William Shockley, John Bardeen, and Walter H. Brattain Nobel Prize in Physics for discovery of transistor effect 1956
- W. Becker Multi-stage turbine (turbomolecular) pump concept 1955

1957

- Nixie Display Tubes 1957
- Society of Vacuum Coaters (SVC) holds first Symposium 1957
- Willi Becker Turbomolecular Pump 1958
- Lewis D. Hall, R.L. Jepsen & J.C. Helmer Vacion (sputter-ion) pump based on Penning discharge—all electronic pump 1957

1958

- International Organization of Vacuum Science and Technology founded (IOVST) 1958
- Elmer Fridrich and Emmett Wily file patent on tungsten-halogen lamp 1958
- Mars Habianian Axial flow, automotive (thin-bladed) supercharger at high vacuum Showed air compressors make good vacuum pumps, confounding existing theory 1957

1959

- IBM 7090 computer first transistor computer, 1959
- Ali Javan invents helium-neon gas laser 1960
- Mars Habianian Axial flow, automotive (thin-bladed) supercharger at high vacuum Showed air compressors make good vacuum pumps, confounding existing theory 1957

1960

- IBM 709 computer last major vacuum tube computer, used magnetic core memory 1958
- IC Patents filed
- First man (USSR) in space
- J.Peter Hobson and Paul A. Redhead UHV inverted magnetron, cold-cathode gauge 1958
- Jesse W. Beams Spinning-rotor gauge (viscosity) 1960
- 2000 ft³ space chamber U.S. Air Force 1960
- First practical capacitance manometer MKS Instruments 1961
- James M. Lafferty Hot-cathode magnetron, ionization gage 1961
- William R. Wheeler UHV (CF) metal-gasket captured step-seal 1961

1961

- Integrated circuit Fairchild Semiconductor 1962
- Robert Noyce Integrated circuit patent 2,981,877 April 25, 1961
- Elmer Fridrich and Emmett Wily file patent on tungsten-halogen lamp 1958
- Ali Javan invents helium-neon gas laser 1960
- IBM 709 computer last major vacuum tube computer, used magnetic core memory 1958
- Ross Aiken CRT for aircraft and 14" Thin CRT tube 1960
- James M. Lafferty Hot-cathode magnetron, ionization gage 1961
- C.H. Kruger & A.H. Shapiro Statistical theory of turbo-molecular pumping 1961
- William R. Wheeler UHV (CF) metal-gasket captured step-seal 1961

1962

- High-power traveling wave tube 1962
- Richard E. Honig publishes "Vapor Pressure Data for the Solid and Liquid Elements" - Data and charts for 79 elements in RCA Review (Updated in 1969 by Honig and Dean A. Kramer) 1962
- IOVST becomes International Union for Vacuum Science, Techniques, and Applications (IUVSTA) 1962
- First AVS Chapter founded-Pacific Northwest 1962
- Radio-frequency sputter deposition—G.S. Anderson et al. 1962
- Cambridge Instrument Company (England)-Stereoscan Scanning Electron Microscope prototype 1965
- First commercial monopole residual gas analyzer General Electric 1964
- W.M. Brubaker, P. Michael Uthe, & Robert Finnigan First commercial quadrupole mass spectrometer residual gas analyzer 1964
- J.C. Helmer & W.H. Hayward Bent-beam (Helmer) gauge 1966
- Association of Vacuum Equipment Manufacturers (AVEM) founded 1969
- W. Steckelmacher and B. Fletcher develop convection thermal conductivity vacuum gauge that measures up to one atmosphere 1971

1963

- Gilbert Reiling (U.S.) files patent on modern metal-halogen incandescent lamp 1961
- First JVST, Vol. 1, No. 1, Sept./Oct. 1964
- W.M. Brubaker, P. Michael Uthe, & Robert Finnigan First commercial quadrupole mass spectrometer residual gas analyzer 1964
- J.C. Helmer & W.H. Hayward Bent-beam (Helmer) gauge 1966

1964

- SLAC Linear Accelerator invented by William Hansen, developed by Edward Ginzton (pictured), and completed under the direction of Dr. Wolfgang Panofsky 1966
- J. English, B. Fletcher and W. Steckelmacher develop wide-range Pirani vacuum gauge 1964
- Charles W. Hanks—270" bent-beam electron-beam gun evaporation source 1968
- A.Y. Cho, et al.—Molecular-beam epitaxy 1968
- The Physical Basis of Ultra-high Vacuum by Paul A. Redhead, J.P. Hobson and E.V. Kornelson published 1968
- K.H. Mirgel Vertical uni-directional turbomolecular pump 1969
- Peter Clarke—Cylindrical and conical magnetron sputter deposition sources 1971
- John Chapin—Planar Magnetron sputter deposition source 1974

1965

- Integrated circuit patent Jack S. Kilby 3,138,744 June 23, 1964
- PA. Redhead Extractor gauge 1966
- Cambridge Instrument Company (England)-Stereoscan Scanning Electron Microscope prototype 1965
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- K.H. Mirgel Vertical uni-directional turbomolecular pump 1969
- Peter Clarke—Cylindrical and conical magnetron sputter deposition sources 1971
- John Chapin—Planar Magnetron sputter deposition source 1974

1970

- Commercial scanning electron microscope—Cambridge Instruments, U. K. 1970
- Peter Clarke—Cylindrical and conical magnetron sputter deposition sources 1971
- K.H. Mirgel Vertical uni-directional turbomolecular pump 1969
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1971

- Peter Clarke—Cylindrical and conical magnetron sputter deposition sources 1971
- K.H. Mirgel Vertical uni-directional turbomolecular pump 1969
- John Chapin—Planar Magnetron sputter deposition source 1974

1972

- J.K. Fremery spinning rotor vacuum gauge at Jülich 1972
- NASA Cryo-pumps for Space Simulation and semiconductor fabrication 1975

1973

- NASA Cryo-pumps for Space Simulation and semiconductor fabrication 1975

1974

- John Chapin—Planar Magnetron sputter deposition source 1974
- First oil-free piston vacuum pump 1974

1975

- NASA Cryo-pumps for Space Simulation and semiconductor fabrication 1975
- Zenith shuts down Lansdale, PA unit 1975

Vacuum Science & Technology Time Line, 1976–2003

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- Historical events
- Vacuum gauges
- Vacuum pumps
- Captions
- Vacuum device manufacturing

8086 industry standard
16-bit microprocessor.
It had 29,000 transistors
and a clock speed of 4.77 Mhz
(4-inch wafers)
June 1978

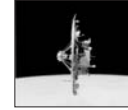
6-inch wafers
fabricated successfully
December 1983



Gerd Binnig & Heinrich Rohrer
Nobel Prize in Physics for
scanning tunneling microscope
1986

Hans Georg Dehmelt
Nobel Prize in Physics
for use of Penning Trap
to study charged particles
1989

First 8 inch semiconductor
wafers produced
April 1992



Molecular beam
epitaxy experiments
in space (NASA)
1995



Jack St. Clair Kilby
(1923-)
Nobel Prize in Physics—
Integrated Circuit
2000



Steve Jobs & Steve Wozniak
Found Apple Computer
April 1976



Hard disk drive for PC
(Seagate & Shugart)
1980

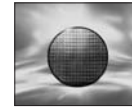
Court breaks up AT&T
clearing the way for
competition in
long distance
1984



Ernst August Friedrich Ruska
(1906-1988)
Nobel Prize for transmission
electron microscope
1986

Wolfgang Paul
Nobel Prize in Physics
for Paul Trap for
charged particles
1989

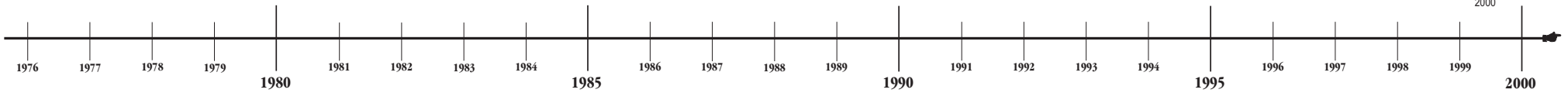
1.2 million-transistor
Intel 80486™ processor
It runs at 25 Mhz
April 1989



Intel introduces
Pentium™ processor
(8-inch wafers)
March 1993



Zhores I. Alferof (1930-)
and Herbert Kroemer (1928-)
Nobel Prize in Physics—
Heterojunction transistor,
solid state laser
2000



Viking I & II
land on Mars
1976

Large non-evaporable
getter panel
1976

RCA closes Harrison, NJ
receiving tube plant
Sylvania takes over
Nuvistor line
April 30, 1976

Paul C. Arnold
Daniel G. Bills -
First commercial
convection Pirani gauge
1977



Vacuum tube production
ends for all practical purposes
in most Western European
Countries and the US.
1977

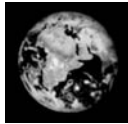
Osaka Vacuum Ltd.
Compound Molecular Pump
1980

WE 215A vacuum tube
manufacture shutdown 1981
1919–1981

K.M. Siegbahn
Nobel Prize in Physics
for high resolution
electron spectroscopy
1981

Nicolaas Bloembergen
and Arthur L. Schawlow
Nobel Prize in Physics
for laser spectroscopy
1981

JVSTA
JVST B
1983



The Earth, in a vacuum,
from space

Edwards introduced
the dry pump for the
semiconductor industry
1985

The last major vacuum tube
production line was shut down
(Raytheon)
1986

1990

First commercial color plasma
television display (21-inch)
1992

First issue of
"The Bell Jar"
vacuum for the amateur
January 1992



150 ft. diameter dish for
radar and communications
Stanford University

First Issue of
Surface Science
Spectra
1992

GLASS VACUUM TUBE MANUFACTURERS AS OF 1997

- China**
Shuguang Electrical Factory No. 1
- France**
Amperex
- Russia**
Reflector Corp, Saratov
Ryazan Plant of Electronics, Ryazan
SRPC Istok, Moscow
Svetlana Electronic Devices, St. Petersburg
Ulyanov, Ulyanovsk
Vokhod, Kaluga
- Slovakia, Czech Republics**
AVVT, Prague
KR Enterprise, Prague
JJ Electronic, Prague
Teslovak, Cadca
- USA**
Fritztronics, Randolph, MA
GE/Sylvania (RCA), Maryland
MU, Oceanside, CA
Richardson Electronics, LaFox, IL
Triton Services ETD, Gaithersburg, MD
Westrex Corporation, Kansas City, MO
- Yugoslavia**
EI Electronic Industries, Nis, Serbia



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