

I am indeed very happy to be here to-day at the inauguration of the workshop on "Instrumentation, Control and Guidance"

Instrumentation is not only the heart of all scientific and technological endeavours, but also the hub of modern civilization. It is said that the extent of modernization of a country can be gauged by the type of instrumentation that is in general use in that country.

It so happens that in my long research career in the field of cosmic rays and high energy astronomy I was quite deeply involved along with my colleagues in the design, fabrication and deployment of a variety of instruments. This was quite a challenge that in the late 40's when I began my career, the indigenous industry was very backward and all instrumentation had to be fabricated in-house with mostly raw surplus components since import was just impossible due to the severe shortage of foreign exchange, and also would take an inordinately long time. I must say however, that all this helped us in developing and fostering the attitude of self-reliance.

Before I come to modern instrumentation, I think it would be highly instructive and informative to familiarize ourselves with the historic development of technology itself. Though we do not want to reinvent the wheel, let us begin with the Potter's wheel.

Year <del>Date</del>	Instrument / device / material.	(Country)	Discover. / Inventor.
6500 B.C.	• Potters wheel	• Asia Minor.	-
3300 B.C.	• Wheel	• Sumerians	-
2900 B.C.	• Pyramid Gizeg.	• Egypt.	-
2500 B.C.	• Ship	• Egypt, Phoenicia	-
1500 B.C.	• Lathe	• Greece Greece	-
⋮			
200 B.C.	• Lever, Pulley	• Greece Greece	Archimedes
⋮			
600 A.D.	• Wind mill	• Iran	-
700 A.D.	• Porcelain	• China	-
725	• Mechanical clock	• China	-
800	• Compass	• Iran	-
800	• Gun Powder	• China	-
1285	• Spectacles	• Italy	-
1454	• Printing Machine	• China	-
1455	• Metal Types for Printing	• Germany	Gutenberg
1500	• Main Spring watch	• Germany	-
1590	• Microscope	• Netherlands	Hans, Janssen.
<u>17th. Century</u>			
1609	• Telescope (Reflecting)	Italy	Galileo
1643	• Mercury Barometer	Italy	Toricelli
1656	• Pendulum clock	Netherlands	Huygens
<u>18th. Century</u>			
1769	• Steam Engine	Scotland	James Watt
1769 <del>1260</del>	• Steam Driven Car	France	Cugnot
1770	• Spinning Jenny	Britain	Hargreaves

1778

• Flush Toilet

Britain

Brahmah

1792

• Gas Lighting

Scotland

Murdock

1793

• Cotton Gin

U.S.A.

Whitney

1793

• Telegraph  
(Visual Semaphore)

France

Chappe

19th Century

1804

Steam Locomotive

Wales

Trevithick

1807

Steam Ship

USA

Foulton

1809

Arc Lamp

England

Davy

1810

Gyroscope

Germany

Bohnenberger

1814

Spectroscope

Germany

Fraunhofer

1816

Bi Cycle

Germany

Sauerbronn

1824

Cement

England

Aspdin

1824

Electromagnet

U.S.A.

Henry

1825

Rail Road

England

Stephenson

1826

Crude Camera

France

Niepse

1832

Electric Generator

France

Pixil

1832

Electric Telegraph

~~France~~ U.S.A.

Morse

1835

Revolver

U.S.A.

Colt

1839

Photography

~~Eng~~ England

Talbot

1841	Sewing Machine	France	Thimonnier
1844	Safety Match	Sweden	Pasch
1851	Ice making machine	USA	Gorrie
1852	Elevator	USA	Otis
1852	Kerosine	Canada	Gesner
1856	Steel production	England	Bessemer
1859	Oil Wells (modern)	USA	Drake
1860	Internal Combustion Engine	France	Lenoir
1867	Type writer	USA	Sholes, Glidden
1867	Dynamite	Sweden	Nobel
1875	Telephone	USA	Bell
1877	Phonograph	USA	Edison
1878	Cathode Ray Tube	Britain	Crookes
1879	Incandescent lamp	USA	Edison
1884	Transformer	Hungary	Blathy
1884	Rayon	France	Chardonnet
1884	Fountain Pen	USA	Waterman
1885	Automobile (gasoline powered)	Germany	Benz.

1886	Aluminium (From Bauxite)	USA	Hall
1888	Pneumatic Rubber Tyres	Britain	Dunlop
1888	Electric Fan	USA	Wheeler
1888	A.c. Motor	USA	Tesla
1889	Motion Picture Projector	USA	Edison
1895	Radio Transmission Across Atlantic	Italy	Marconi
1895	Safety Razor	USA	Gillette
1898	Submarine	USA	Holland

20th. Century.

1902	Air Conditioner	USA	Carrier
1903	Air Plane	USA	Knight Brothers
1903	Electro Cardiograph	Netherlands	Einthoven
1904	Vacuum Diode	England	Fleming
1905	off-Set Printing	USA	Rubel
1906	Vacuum Triode	USA	Lee de Forest
1909	Bakelite (Plastic)	USA	Ba <sup>c</sup> keland
1913	Stainless Steel	England	Brearley
1915	Neon Lamp	France	claud
1919	Mass Spectrograph	Britain	Ashton.

1920	Rocket (Liquid Fuel)	USA USSR Germany	Goddard Tsiolkorsky Oberth.
1922	Radar	USA	Taylor, Young
1923	Television	USA	Zworykin
1930	Cyclotron	USA	Lawrence
<del>1931</del>	<del>Radio Telescope</del>		
1930	Analog Computer	USA	Vannevar Bush
1931	Radio Telescope	USA	Jansky
1933	Electron Microscope	Germany	Ruska
1935	Nylon	USA	Carothers
1937	Xerography (Electrostatic Printing)	USA	Carlson
1939	Jet Plane	Germany	Heinkel
1945	Digital Computer (IBM)	USA	Aiken
1945	Atom Bomb	USA	International Team.
1947	Transistor	USA	Bardeen, Shockley, Brittain.
<del>1948</del>	<del>Holography</del>	<del>England</del>	
1947	Polaroid Camera	USA	Land
1948	Holography	England	Gabor
1957	Laser	USA	Gould
<del>1971</del>	<del>Micro-Computer</del>		

1971

Micro Computer  
(Silicon chip)

Tomography

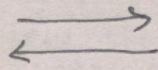
USA

Cochrane, Boone

1890-1990

In the last 100 years there has been a close coupling between the developments in physical sciences and major technologies.

Discoveries in  
Physical Sciences.



Technological  
Developments

Electron, Proton

Electromagnetic  
waves

X-rays

Radioactivity

Relativity

Quantum Mechanics

Anti-particles.

Photo-electric effect.

Nucleus, Neutron,

Fundamental Particles

Maser, Laser

~~Low~~ Temperatures.

Superconductivity

Transistor.

Nuclear Magnetic  
Resonance

Electronics Valves

Radio, TV, Radar, ... VCR.

X-ray Machines.

Particle Accelerators

Atom Bomb. Hydrogen Bomb.

Nuclear Reactors

Refrigerator

Superconducting Magnets

Computers

Lasers

Tomography

Space Technology,

Radio Telescopes.

Space Astronomics

Hubble Telescope

~~SETI~~ Satellite Communication

SETI (Search for Extra-  
terrestrial Intelligence)

(Continued)

Modern Instrumentation can be classified under

(i) Mechanical, (ii) Electrical, (iii) Electro-Mechanical, (iv) Electronic, (v) Optical, (vi) Acoustic both combinations like Opto-electronics, electro-acoustics, etc.

The early motivation for instrument development came from requirements of navigation, Survey, Meteorology, and Scientific Research. In more recent times the motivation is for the requirements of Society - Communications, Power, Energy, Defence, Medicine, Medical and so on and from the demands of developments in the field of atomic energy, Space and more recently in the industrial process control. Requirements of our Scientific Research has been the more dominant motivation for development of more and more sophisticated instrumentation.

The chief criteria that go into instrument design nowadays are dependant on ~~requirements~~ like whether the instruments are for (i) manual operation (ii) automatic (iii) semi-automatic (iv) remote, (v) onboard, (vi) computer based processing, (vii) emergency, etc. operations.

The special environmental requirements that get imposed are of the type: very high temperature, very low temperature, varying temperature cycles, low pressure, high humidity, high radiation, high background noise, hostile man-made

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The instrument designer has to also take into account the required (i) sensitivity, (ii) range, (iii) whether analog or digital or hybrid, (iv) whether based on Fuzzy logic, and also the limitations on (i) weight, (ii) volume, (iii) power available. These become important considerations in the instruments that go on space vehicles - balloons, rockets and satellites.

Perhaps, I should tell you at this juncture a story about miniaturisation:

The famous physicist and Nobel Laureate, Richard Feynman of the California Institute of Technology sometime in the early 60's, threw a challenge that he would reward a 1000 dollars to any one who made a motor whose ~~the~~ axis rotation can be seen only under a powerful microscope. Well some one met the challenge and got the reward. If you go to CIT, you can see the motor ~~in~~ with its axis rotating through a microscope in the display window.

I am sure as part of the course you have learnt many aspects of instrumentation, control and guidance from the experts.

The message that I want to leave you with is that despite our remarkable achievements in high technologies - atomic energy, space, communications etc, which have required high level instrumentation, the country's performance in the indigenous development of

Components and materials has not been good enough. We still import lots of the critical components. Also our performance in the development of highly original instrumentation has also been very poor. I do hope that that we failed to do in the past century, we be more than compensated in the coming century in this vital field of national importance.

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Inaugural address delivered at the Short Term Course on Instrumentation, Control and Guidance at Hassan on 4th March '96 by Professor B.V. Sreekantan, National Institute of Advanced Studies, Bangalore.

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/INVENTOR
6500 B.C.	* POTTERS WHEEL	* ASIA MINOR	-
3300 B.C.	* WHEEL	* SUMMERIA	-
2900 B.C.	* PYRAMID GIZEY	* EGYPT	-
2500 B.C.	* SHIP	* EGYPT, PHONECIA	-
1500 B.C.	* LATHE	* GREECE	
200 B.C.	* LEVER, PULLEY	* GREECE	ARCHIMEDES
600 A.D.	* WIND MILL	* IRAN	
700 A.D.	* POCELAIN	* CHINA	
725 A.D.	* MECHANICAL CLOCK	* CHINA	
800	* COMPASS	* IRAN	
800	* GUN POWDER	* CHINA	
1285	* SPECTACLES	* ITALY	
1454	* PRINTING MACHINE	* CHINA	
1455	* METAL TYPES FOR PRINTING	* GERMANY	GUTENBERG
1500	* MAINSPRING WATCH	* GERMANY	
1590	* MICROSCOPE	* NETHERLANDS	HANS, JANSSEN

17TH CENTURY:

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/INVENTOR
1609	* TELESCOPE (REFLECTING)	* ITALY	GALILEO
1643	* MERCURY BAROMETER	* ITALY	TORICELLI
1656	* PENDULUM CLOCK	* NETHERLANDS	HUYGENS

18TH CENTURY:

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/ INVENTOR
1769	* STEAM ENGINE	* SCOTLAND	JAMES WATT
1769	* STEAM DRIVEN CAR	* FRANCE	CUGNOT
1770	* SPINNING JENNY	* BRITAIN	HARGREAVES
1778	* FLUSH TOILET	* BRITAIN	BRAHMAH
1792	* GAS LIGHTING	* SCOTLAND	MURDOCK
1793	* COTTON GIN	* U.S.A	WHITNEY
1793	* TELEGRAPH (VISUAL SEMAPHORE)	* FRANCE	CHAPPE

19TH CENTURY:

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/ INVENTOR
1804	* STEAM LOCOMOTIVE	* WALES	TREVITHICK
1807	* STEAM SHIP	* U.S.A	FOULTON
1809	* ARC LAMP	* ENGLAND	DAVY
1810	* GYROSCOPE	* GERMANY	BOHNENBERGER
1814	* SPECTROSCOPE	* GERMANY	FRAUNHOFER
1816	* BI-CYCLE	* GERMANY	SAUERBRONN
1824	* CEMENT	* ENGLAND	ASPDIN
1824	* ELECTROMAGNET	* U.S.A	HENRY
1825	* RAIL ROAD	* ENGLAND	STEPHENSON
1826	* CRUDE CAMERA	* FRANCE	NIEPSE

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/ INVENTOR
1832	* ELECTRIC GENERATOR	* FRANCE	PIXIL
1832	* ELECTRIC TELEGRAPH	* U.S.A	MORSE
1835	* REVOLVER	* U.S.A	COLT
1839	* PHOTOGRAPHY	* ENGLAND	TALBOT
1841	* SEWING MACHINE	* FRANCE	THIMONIER
1844	* SAFETY MATCH	* SWEDEN	PASCH
1851	* ICE MAKING M/C	* U.S.A	GORRIE
1852	* ELEVATOR	* U.S.A	OTIS
1852	* Kerosine	* CANADA	GESNER
1856	* STEEL PRODUCTION	* ENGLAND	BESSEMER
1859	* OIL WELLS(MODERN)	* U.S.A	DRAKE
1860	* INTERNAL COMBUS- TIBLE ENGINE	* FRANCE	LENOIR
1867	* TYPE WRITER	* U.S.A	SHOLES, GLIDDEN
1867	* DYNAMITE	* SWEDEN	NOBEL
1875	* TELEPHONE	* U.S.A	BELL
1877	* PHONOGRAPH	* U.S.A	EDISON
1878	* CATHODE RAY TUBE	* BRITAIN	CROOKES
1879	* INCANDESCENT LAMP	* U.S.A	EDISON
1884	* TRANSFORMER	* HUNGARY	BLATHY
1884	* RAYON	* FRANCE	CHARDONNET
1884	* FOUNTAIN PEN	* U.S.A	WATERMAN
1885	* AUTOMOBILE (GASOLINE POWERED)	* GERMANY	BENZ

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/INVENTOR
1886	* ALUMINIUM (FROM BAUXITE)	* U.S.A	HALL
1888	* PNEUMATIC RUBBER TYRES	* BRITAIN	DUNLOP
1888	* ELECTRIC FAN	* U.S.A	WHEELER
1888	* A.C. MOTOR	* U.S.A	TESLA
1889	* MOTION PICTURE PROJECTOR	* U.S.A	EDISON
1895	* RADIO TRANSMISSION ACROSS ATLANTIC	* ITALY	MARCONI
1895	* SAFETY RAZOR	* U.S.A	GILLETTE
1898	* SUBMARINE	* U.S.A	HOLLAND

20TH CENTURY:

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/INVENTOR
1902	* AIR CONDITIONER	* U.S.A	CARRIER
1903	* AIR PLANE	* U.S.A	WRIGHT BROTHERS
1903	* ELECTROCARDIOGRAPH	* NETHERLANDS	EINTHOVEN
1904	* VACUUM DIODE	* ENGLAND	FLEMING
1905	* OFF-SET PRINTING	* U.S.A	RUBEL
1906	* VACUUM TRIODE	* U.S.A	LEE DE FOREST
1909	* BAKELITE (PLASTIC)	* U.S.A	BACKLAND
1913	* STAINLESS STEEL	* ENGLAND	BREARLEY
1915	* NEON LAMP	* FRANCE	CLAUDE

YEAR	INSTRUMENT/DEVICE MATERIAL	COUNTRY	DISCOVER/ INVENTOR
1919	* MASS SPECTROGRAPH	* BRITAIN	ASHTON
1920	* ROCKET (LIQUID FUEL)	* U.S.A * U.S.S.R * GERMANY	GODDARD TSIOKORSKY OBERTH
1922	* RADAR	* U.S.A	TAYLOR, YOUNG
1923	* TELEVISION	* U.S.A	ZWORYKIN
1930	* CYCLOTRON	* U.S.A	LAWRENCE
1930	* ANALOG COMPUTER	* U.S.A	VANNEVAR BUSH
1931	* RADIO TELESCOPE	* U.S.A	JANSKY
1933	* ELECTRON MICROSCOPE	* GERMANY	RUSKA
1935	* NYLON	* U.S.A	CARROTHERS
1937	* XEROGRAPHY (ELECTROSTATIC PRINTING)	* U.S.A	CARLSON
1939	* JET PLANE	* GERMANY	HEINKEL
1945	* DIGITAL COMPUTER (IBM)	* U.S.A	AIKEN
1945	* ATOM BOMB	* U.S.A	INTERNATIONAL TEAM
1947	* TRANSISTOR	* U.S.A	BARDEEN, SHOCKLEY BRITAIN
1947	* POLAROID CAMERA	* U.S.A	LAND
1948	* HOLOGRAPHY	* ENGLAND	GABOR
1957	* LASER	* U.S.A	GOULD
1971	* MICROCOMPUTER (SILICON CHIP)	* U.S.A.	COCHRANE, BOONE
	* TOMOGRAPHY		

What is most striking and disappointing for us is that India does not figure at all in the historical development of technology. Perhaps our interests and efforts were elsewhere - philosophy, mathematics. It is possible that our historical records on technology are poor. This needs to be looked into.

As we come to more recent times, especially in the last hundred years, the technological development is motivated and assisted by science and in turn development of science itself is highly dependent on technology as can be seen from the following:-

Discoveries in Physical Sciences	-----> <-----	Technological Developments
Electron, Proton		Electronics
Electromagnetic waves		Radio, TV, Radar, VCR
x-rays		X-ray mechanics
Radioactivity		Particle Accelerators
Relativity		Atom Bomb, Hydrogen bomb Nuclear Reactors, Refrigerator
Quantum mechanics		Superconducting Magnets
Anti-particles		Computers
Photo-electric effect		Lasers
Nucleus, Neutron		Tomography
Fundamental particles		Space Technology, Radio Telescopes
Maser, Laser		Space Astronomics
Superconductivity		Hubble telescope
Transistor		
Nuclear Magnetic -Resonance		Satellite Communication
		SETI (Search for extra terrestrial intelligence)

Modern Instrumentation can be classified under (i) Mechanical (ii) Electrical (iii) Electro-mechanical (iv) Electronic (v) Optical (vi) Acoustic with combinations like opto-electronics, electro-acoustics, etc.

The early motivation for instrument development came from requirements of navigation, survey, meteorology, and scientific research. In more recent times, the motivation is from the requirements of society in general - Communications, Power, Energy, Defence, Medical and so on and from the demands of developments in the field of atomic energy, space and more recently in the industrial process control and quality assurance. Ofcourse, scientific research has been the most dominant motivation for development of highly sophisticated instrumentation, which later has had spin off to other sectors.

The chief criteria that go into instrument design nowadays are dependant on whether the instruments are for (i) manual (ii) automatic (iii) semi-automatic (iv) remote (v) onboard, (vi) computer based processing (vii) emergency, etc. operations.

The special environmental requirements that get imposed are of the type: very high temperature, very low temperature, varying temperature cycles, low pressure, high humidity, high radiation, high background noise, mostly man-made.

The instrument designer has to also take into account the required (i) sensitivity (ii) range (iii) whether analog or digital or hybrid (iv) whether based on Fuzzy logic and also the limitations on (i) weight (ii) volume (iii) power available. These become important considerations in the instruments that go on space vehicles - balloons, rockets and satellites. Miniaturisation has become a highly competitive art in the field of instrumentation.

Perhaps, I should tell you at this juncture a story about miniaturisation.

The famous physicist and Nobel Laureate, Richard Feynman of the California Institute of Technology, sometime in the early 60's, threw a challenge that he would reward a 1000 dollars to any one who made a motor whose axis rotation can be seen only under a powerful microscope. Well some one met the challenge and got the reward. If you go to CIT, you can see the motor with its axis rotating through a microscope in the display window.

I am sure as part of the course you will learn many aspects of instrumentation, control and guidance from the experts. So I do not want to go into more details.

The message that I want to leave you with is that despite our remarkable achievements in high technologies - atomic energy, space, communications etc. which have required

high level instrumentation, the country's performance in the indigenous development of components and materials has not been good enough. We still import most of the critical components. Also our performance in the development of highly original instrumentation has also been very poor. I do hope that what we failed to do in the past centuries will be more than compensated in the coming century in this vital field of national importance. The competitive spirit that is now enforced on us by the liberalisation of imports and the realisation of the fact that for all the key and strategic components, we have to depend on ourselves, should go a long way in making us more and more self-reliant in all the sectors including components and materials.