INSTRUMENTAL WAYS FOR QUALITY ASSESSMENT OF AGRI-PRODUCE

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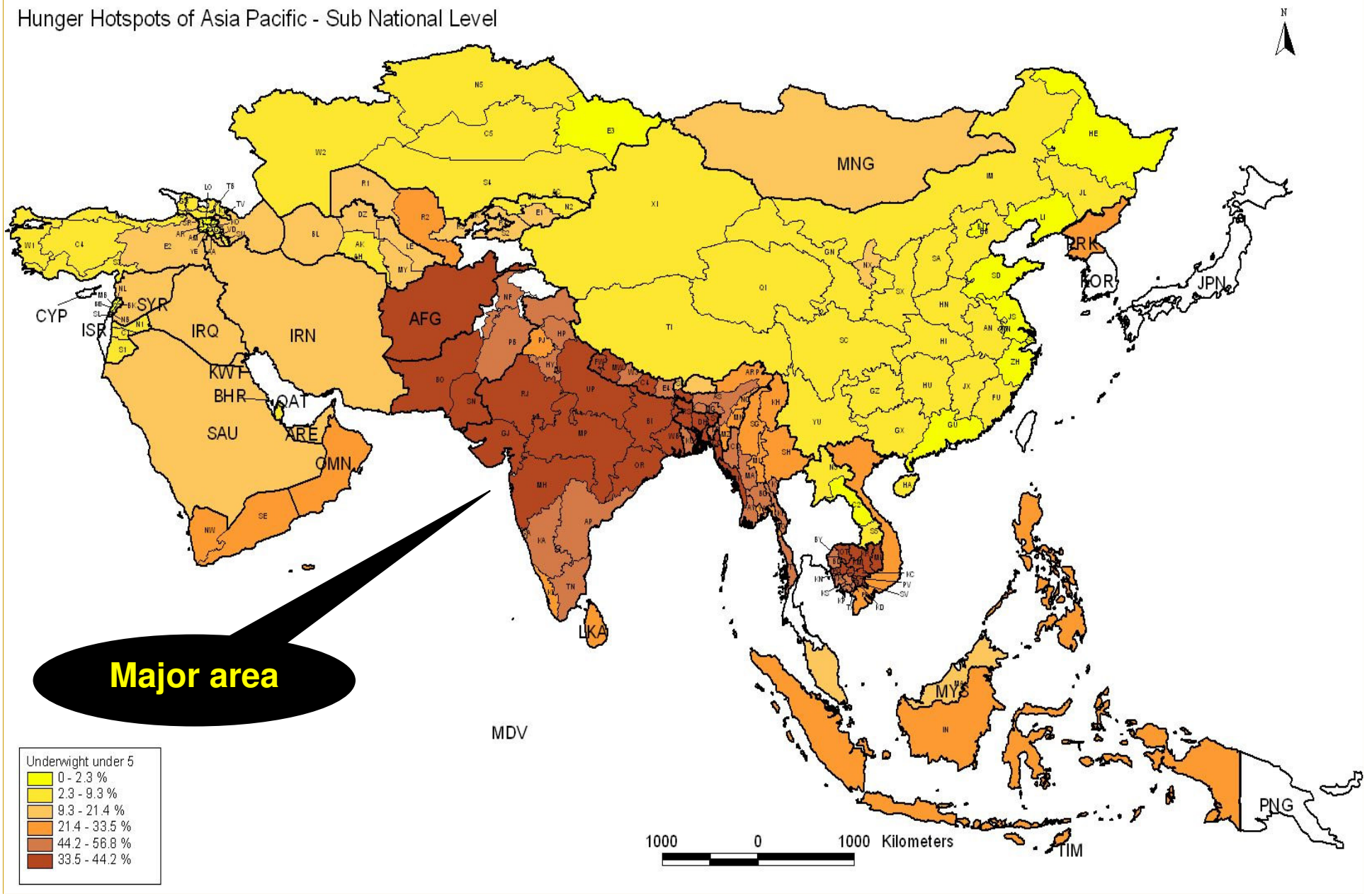
Indian Agro-based Sector : Background

- Post Independence
  - Backdrop - Great Bengal famine of 1943
  - Mismatch between food requirements and production– dependency on aid
  - Cases of Starvation deaths
- Green Revolution
  - Scenario change – self sufficiency
  - Increase in Food grains production: 74 MMT (1966-67) to 212 MMT (2001-02)
  - Increased farmer's income
  - Several technological advances
- Onset of Knowledge era

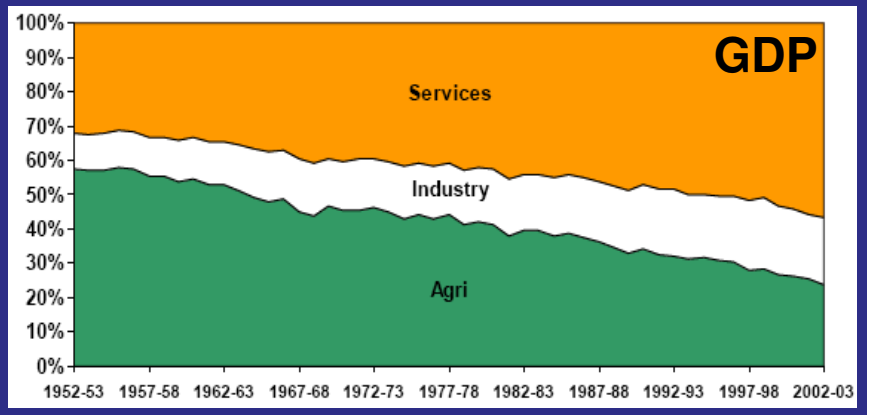
Crops	Global production share	Global rank
Rice	21%	2
Wheat	12%	2
Sugarcane	23%	2
Pulses	26%	1
Cotton	14%	3

Hunger Map


Hunger Hotspots of Asia Pacific - Sub National Level
N
MNG
PRK
ROK
JPN
CYP
SYR
ISR
IRQ
IRN
AFG
KWT
BHR
QAT
SAU
ARE
OMN
LKA
MDV
MYS
PNG
TIM
Major area
Underwight under 5
0 - 2.3 %
2.3 - 9.3 %
9.3 - 21.4 %
21.4 - 33.5 %
44.2 - 56.8 %
33.5 - 44.2 %
1000 0 1000 Kilometers

Challenges

- The "Rosy Picture "
  - Agriculture is the backbone of our country and economy, which accounts for almost 30 per cent of GDP and employs 70 per cent of the population

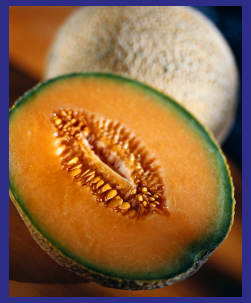


- The "Population"
  - 1,065,070,607 (July 2004 est.)
  - Growth rate 1.44% (2004 est.)
- The "Available Land"
  - In 1952, India had 0.33 ha of available land per capita, which has reduced to 0.12 ha by the end of year 2004.
- The "Big Question"
  - Very difficult to assume that food requirement for the population of 2020 AD will be supplied by the technology of today.

"Technology Revolution"

Going Ahead - Challenges & Opportunities

- National Policy Issues
  - Crop Diversification
    - Apart from seed, fertilizer and water - **marketing**, **storage** and **processing**
  - Processing/Value Addition
    - Globalization & Consumer awareness

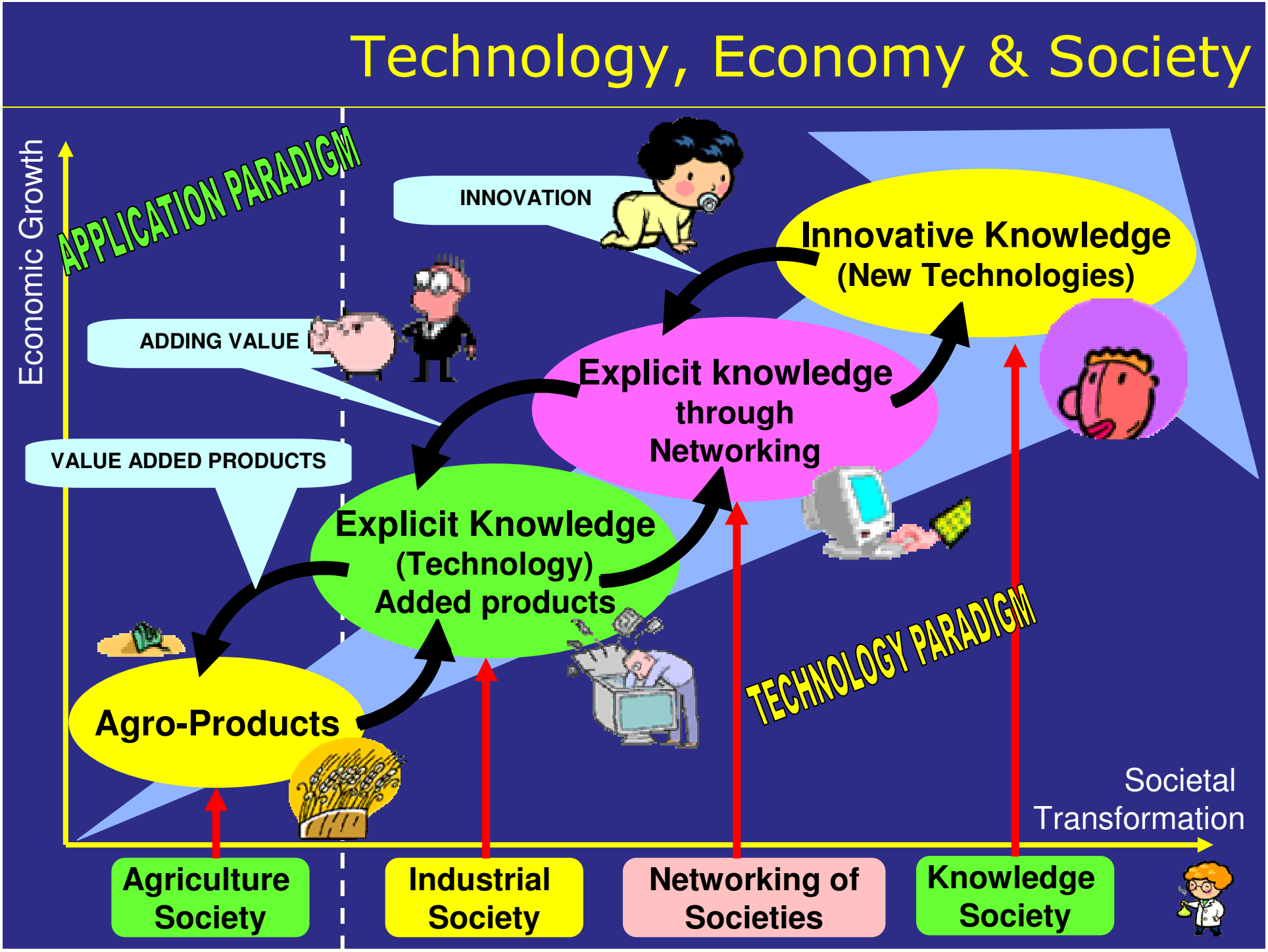

  - Infrastructure support
    - Enhance technological support & extension
    - Irrigation – still conventional techniques
    - Connectivity (transport, communications, power etc.)
  - Equitable growth
    - Only 0.3% of agricultural GDP is spent on R&D
    - Statistics of 2020 AD
      - Share of agro sector in GDP will reduce to 15% due to faster growth in non-agro sectors
      - 45-50% of the population in agro sector – migration of work force to non-agro sector

Going Ahead - Challenges & Opportunities

- WTO Issues
  - Unable to have access to world markets despite Indian Agriculture produce being internationally competitive
  - Quality Regulations

- Movement towards Knowledge era – Adoption of Optimal Farm practices
  - **Right Choice** of Fertilizer - Primary, Secondary and Micronutrients, and Organic manures
  - **Right Quantity** in relation to inherent nutrient status of soil and crop requirement
  - **Right Balance** of fertilizer and pesticide use
  - **Right Method & timing** to reduce losses
  - **Right Management Practices** in all farming operations

Technology, Economy & Society



Indian Farmer - A Centre Point of Development

- More Profits
- More Investments

- Conservation of Resources
- Sustainable Environment

Natural Inputs
Soil & Water

Enabler

Optimum Balance

Markets

Hi-tech Agriculture

Knowledge

Feedback

Technological Support

- Improved Quality
- Higher Value

- Better Productivity
- Cost Savings

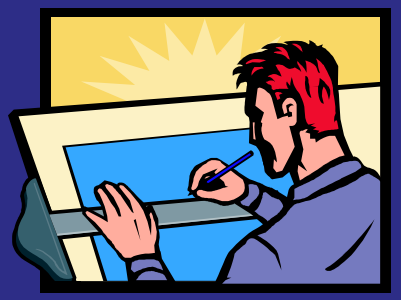
Interaction Perspective

Basic Agri R&D

User satisfaction

CSIO

Instrumentation for Process variable measurement and Engineering



Primary Knowledge (Agriculture)

Technology Paradigm

Available knowledge
New applications
Ready to use Products/Spin-off's

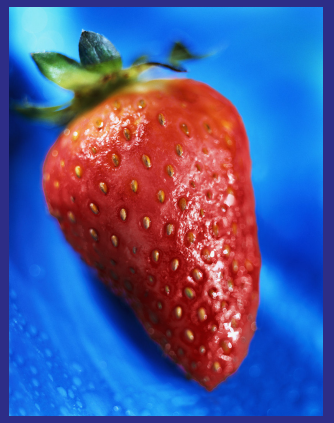
New Turnkey Solutions
Application specific products
at process / plant level

Futuristic Applications
- Guarding Nations food issues
- Regulatory methods through advanced sensing
- Quantification of Quality

Technology revolution

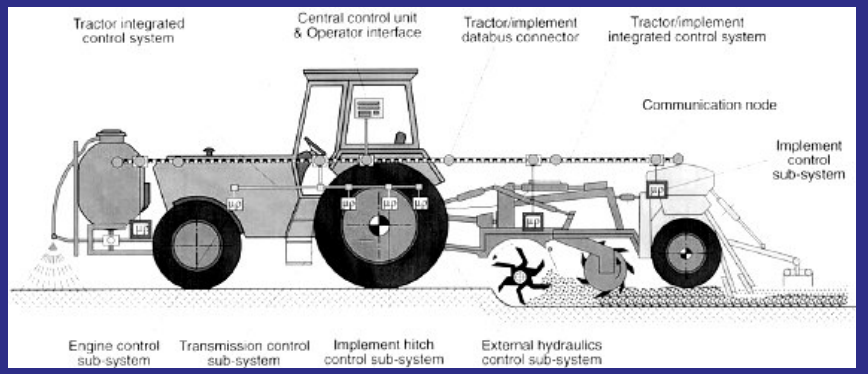
Application Paradigm

- Pre-harvest
  - Natural resource management
    - Soil & Water
  - Precision Agriculture & Crop Health
    - Nutrient
    - O_2/CO_2
    - Photosynthesis Rate
    - Disease detection and remedies
- Post-harvest
  - Sorting/grading /packaging/storage
  - Processing
- By-Products & Quantification of Quality
  - Product quality regulatory methods
  - Toxic components : Heavy metal trace, Aflatoxin, Cyanides, Glucoalkaloids ,Pesticides estimation etc.
  - Active components : Cysteine sulphoxide alliin, Polyphenols, Lactic acid, Absorbic acid etc.

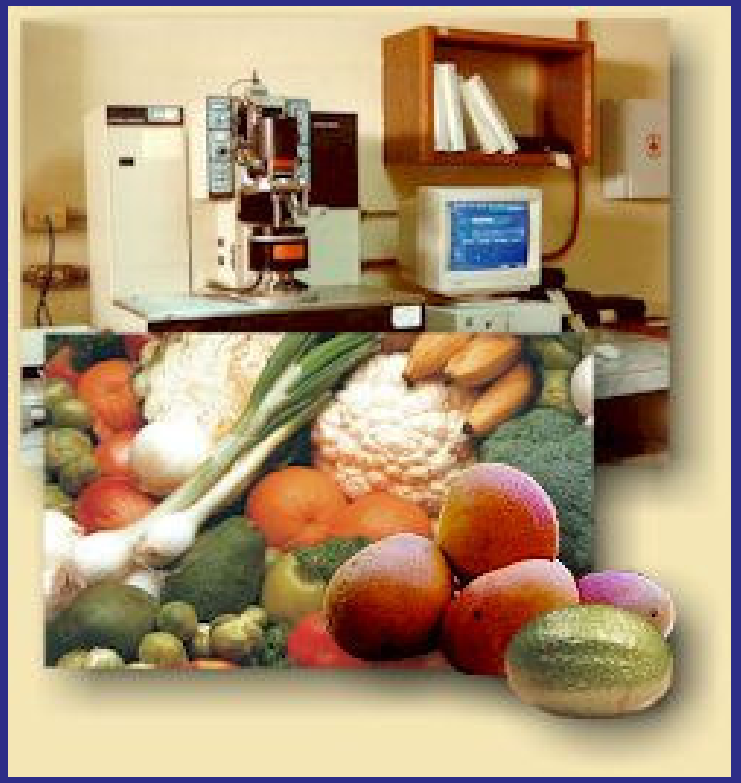
Pre-harvest

- Natural resource management
  - Soil : Moisture, NKP, pH, Salinity, Conductivity
  - Water : Irrigation, Water table, pollution monitoring and control
- Precision Agriculture & Crop Health
  - Information
    - Yeild mapping
    - Previous agricultural applications
    - Intensive soil/crop sampling info
    - Weather data
    - Remote sensing
  - Variable Rate Management
    - Fertilizer and lime
    - Plant populations
    - Differential hybrids
    - Pest control
    - Organic amendments



Post-harvest

- Storage
  - Grading
  - Sorting
  - Packaging
  - Quality enhancement
- Processing
  - Food
  - Fermentation
  - Extracts
  - Medicinal herbs processing



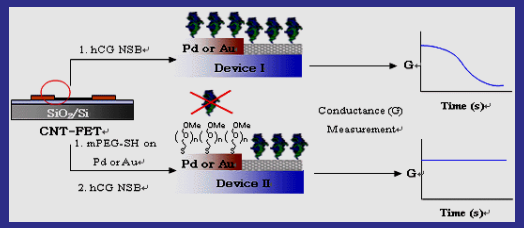
By-products & Quantification of Quality

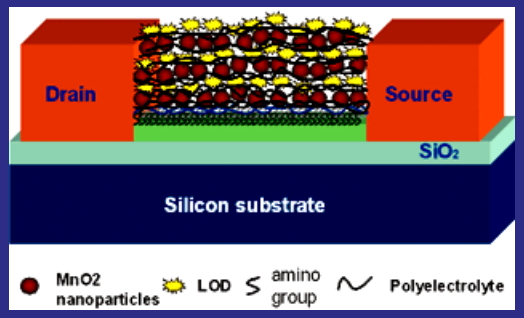
- Finished products
- Mandi level quality control
- Characterization of food/agri products
- Regulatory methods
- Standardization methods & instrumentation

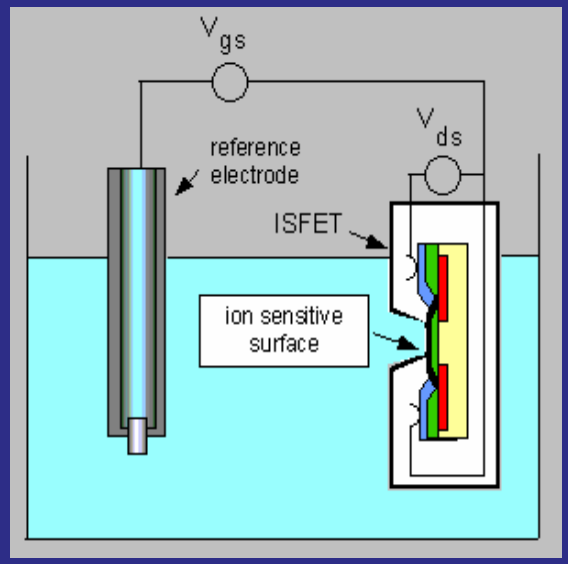
Some of the Emerging Technologies / Techniques

- Biosensors, incorporating a biological material, like enzymes or antibodies.

- Sensors based on an electric signal
  - Potentiometric / Amperometric Chemical Sensors, Metal Oxide Semiconductors (MOS), Field Effect Transistors (FET) or Conducting Polymer Sensors (CPS).







Some of the Emerging Technologies / Techniques

- Sensors based on interaction by electromagnetic waves
  - Visible, ultraviolet and infrared (NIR, FTIR, Thermography)
  - Microwaves
  - Radiowaves, X-rays and high frequency waves (Nuclear or Electronic Magnetic Resonance)
- Sensors based on interaction with;
  - Ultrasound waves
  - LF & HF signals
    - Dielectric spectroscopy

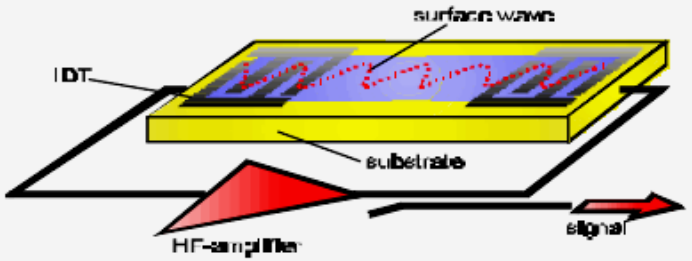
Wavelength Meter(m)	Region	Interaction	Examples
	Radio frequency (1-10m)		Water, salt, density, particle size
10 exp -1	Magnetic resonance (0.01-10m)	Electron / nuclear spin	Water, oil quality
10 exp -3	Microwaves (0.01-0.15m)	Dipole (4-15 cm)	Water, density, sucrose, Fat, density
	Far-IR MIR (2.5-30 mm) Raman thermography (1-15 mm)	Vibration and rotation	Qualitative, quality, temperature
10 exp -6			
10 exp -7	NIR(700-2500 nm)	Vibration overtones	Water, oil, protein, qualitative measures
10 exp -9	Visible(400-700 nm) Ultravoilet	Electrons	Many organic compounds, colour
10 exp -11		Ionisation	Foreign bodies
	X-rays		
	γ-rays	Ionisation	

Some of the Emerging Technologies / Techniques

- Sensors based on variations in frequency, for instance Quartz Crystal Microbalance (QCM) and Surface Acoustic Wave (SAW).
- Sensors involving selective agents, such as molecular films or complexing films.

SAW Sensors for in-situ Bioanalysis in Aqueous Media

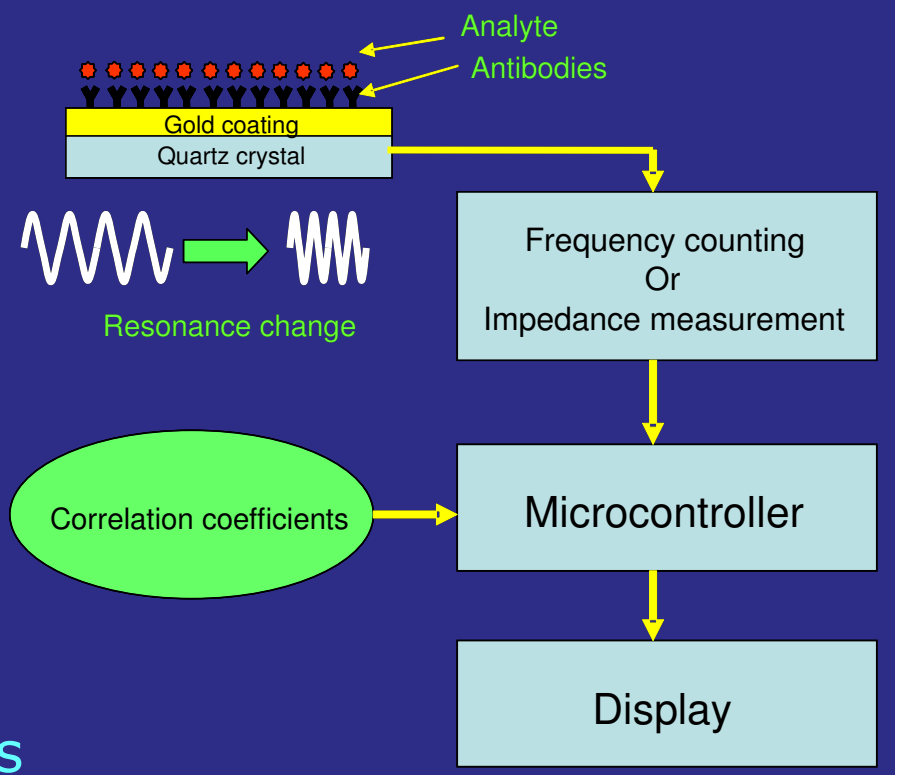
Principle of Operation



Special SAW devices using **horizontally polarized surface shear waves** (HPSW, STW) are able to operate in water. For biosensing applications SAW devices must be coated with a **polymer shielding** layer (polyimide, parylene) to **prevent corrosion effects of the aluminium structures**. To create a **biosensor** the shielded devices are coated with a **sensitive layer enabling specific biological interactions**. These interactions are detected by **determining changes in surface wave velocity** caused by **mass adsorption** or **viscosity changes** in the sensing layer.

Quartz Crystal Microbalance

- Quartz Crystal at specific cut resonates at fixed frequency.
- By thin film deposition of antibody on the Quartz, specific molecules get attached and alter the frequency of resonance
- This technique is useful in the development of Bio-Sensors.
- Can be used to establish bio-chemical parameters. (tea, spices etc)



Instrumentation -- Changing Scenario

- Technology and Evolution has similarity.
- Tug of war between old and new technology.
- Survival of the fittest.
- Instrumentation and Automation is truly multi-disciplinary with multi-facet application domain.
- Industrial automation has traversed a long journey from mechanical to the current day electronic and IT – Paradigm.
- The electronic instrumentation witnessed a phenomenal change from analog to digital domain.
- Digital domain changed from SSI to VLSI covering a journey from discrete IC to large plant level control through
  - Digital IC based design
  - Microprocessors/ micro-controllers of 8 bit to 16 bit capabilities
  - PLC – based compact solutions
  - PC – based open architecture with full flexibility and portability
  - Embedded based customized solutions

Instrumentation -- Changining Scenario

- The modern measurement techniques and instrumentation based thereupon call for convergence of various faculties
  - Physics
  - Chemistry
  - Biology
  - Computer Science
  - Mathematics
- Present day Instruments are becoming more and more rich in Information Technology and call for :
  - Reliability
  - Redundancy
  - Cost – effectiveness
  - Master-Slave Configurations
  - Security of data at various level

Instrumentation -- Changining Scenario

- Users put different constraints
  - vagaries in the input raw material
  - changing agro – climatic / process conditions
  - varying market demands
- This calls for knowledge based embedded System design where domain-knowledge is integrated in the system with flexibilities in knowledge change-over (switching of algorithms in an algorithm bank)
- This sets a total harmony among Process Engineers and System Designers so that issues related to speed, data handling capabilities, data storage, mixed signal situations, real-time environments, data safety, security through appropriate encryption and decryption techniques, reliability, configurable systems, hot-standby, dynamically configurable systems, etc. can be handled
- This truly is Convergence of Technologies – a Consortium Concepts

MISSION

- To be a leader at national level for designing and scientific and industrial instruments, instrument systems and devices

- To play a lead role in providing repair, maintenance & calibration services and training of instrument technologists

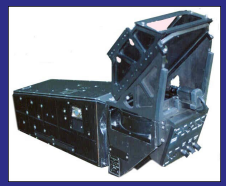
- To be a custodian of instrumentation activity in the country

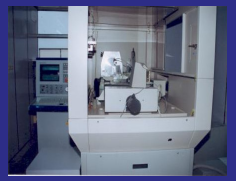
- OUR MOTTO

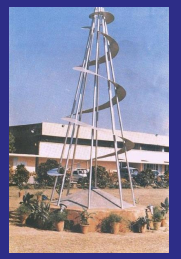
  To bring the benefits of Modern Science & Technology to every Indian

MANDATE

- Research, design and development of scientific & industrial instruments, components and systems
- Service, maintenance, testing & calibration of instruments/components
- Human resource development in the area of instrumentation
- Technical assistance to industry

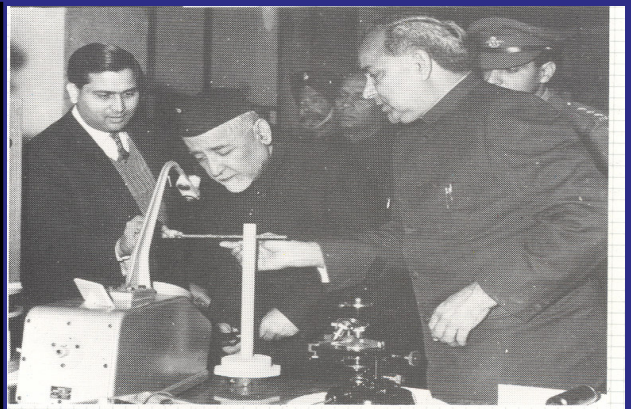




HISTORICAL BACKGROUND

-Established in Oct'59 (Recommendations of a Committee set up by Planning Commission)



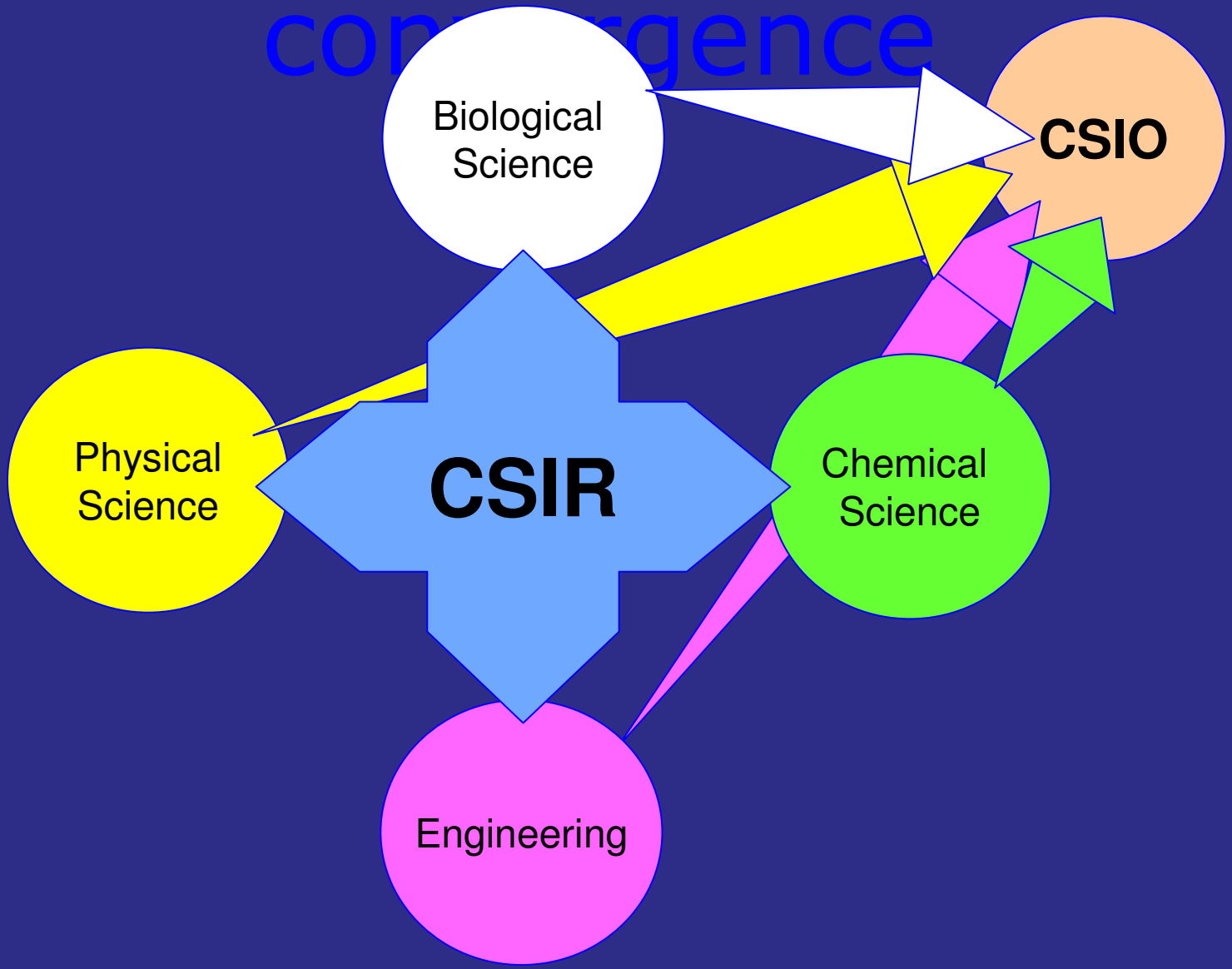
Dr. Zakir Hussain at CSIO — 1967

- Initially located in CSIR bldg, N DLI, CSIO moved to Chandigarh in '62
- Indo-Swiss Training Centre (ISTC) was established at CSIO in coll. with Swiss Foundation for Tech Assistance, Switzerland

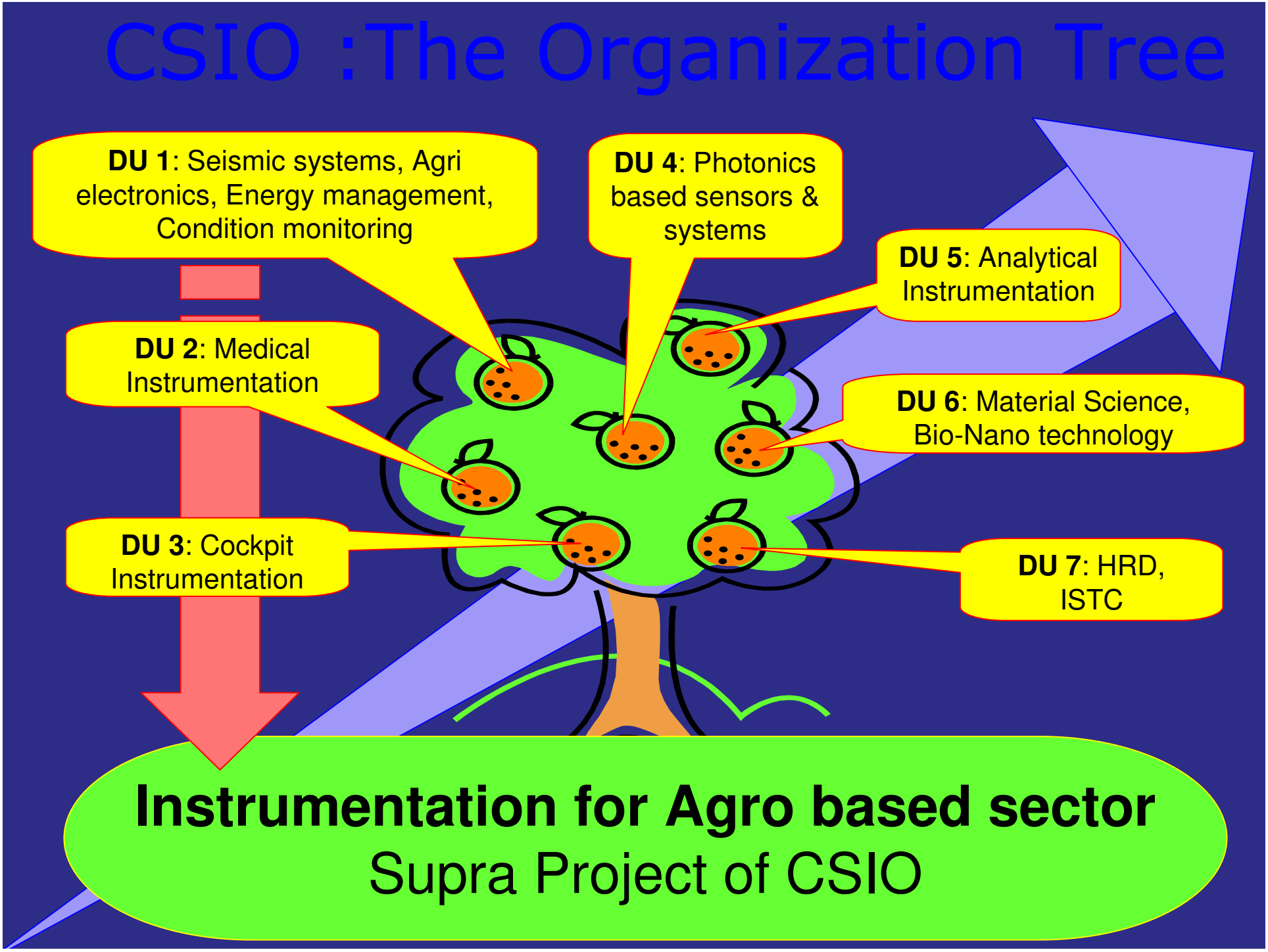
- ISTC inaugurated in Dec'63 by Pt. Jawahar Lal Nehru, the then PM
- ISTC School building opened Dec'64 by Sh. M.C. Chagla the then Union Education Minister

- A 4-storey building & workshops were inaugurated in Dec'67 by Dr Zakir Hussain, the then President of India

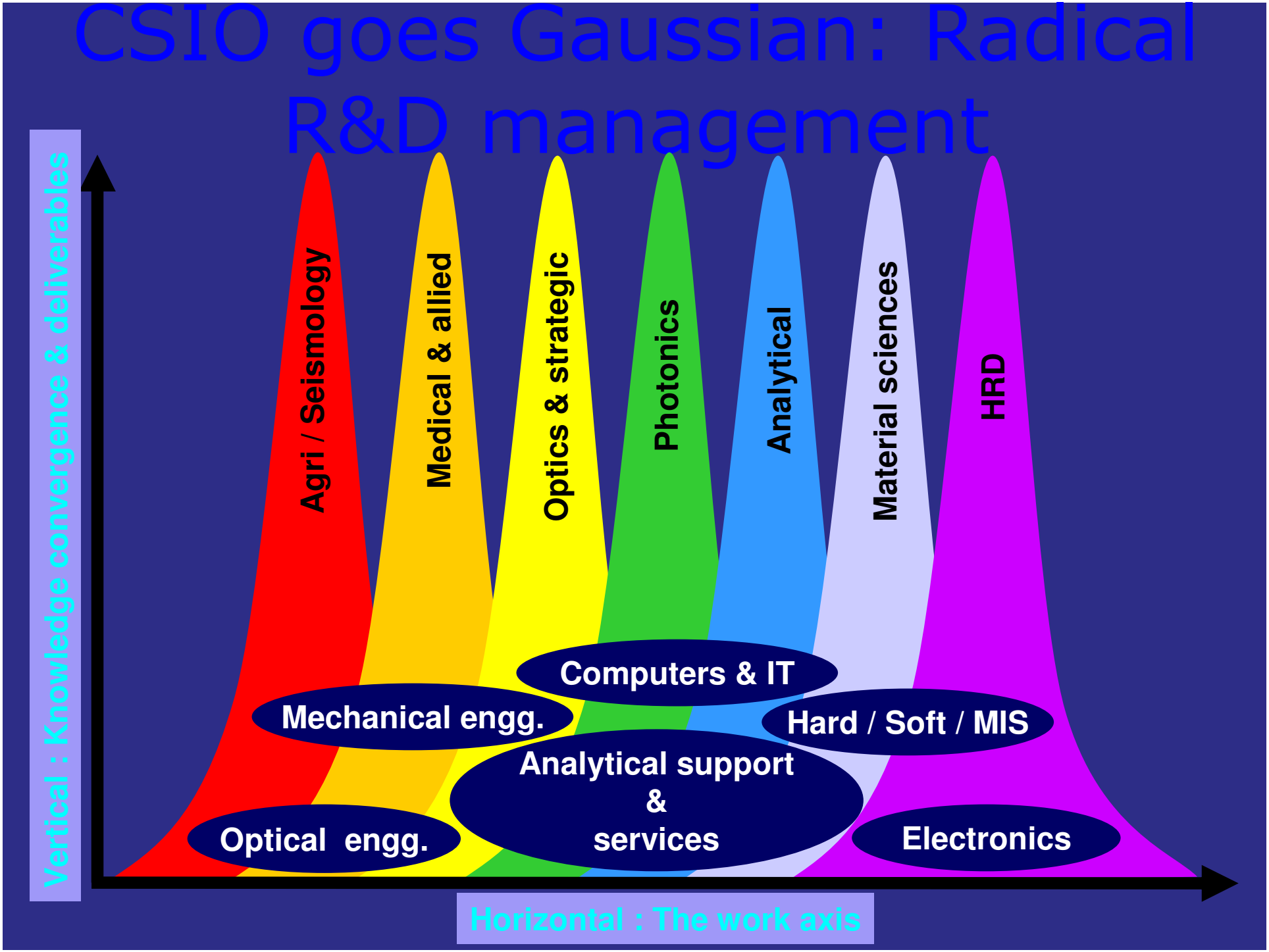
CSIO a center of convergence



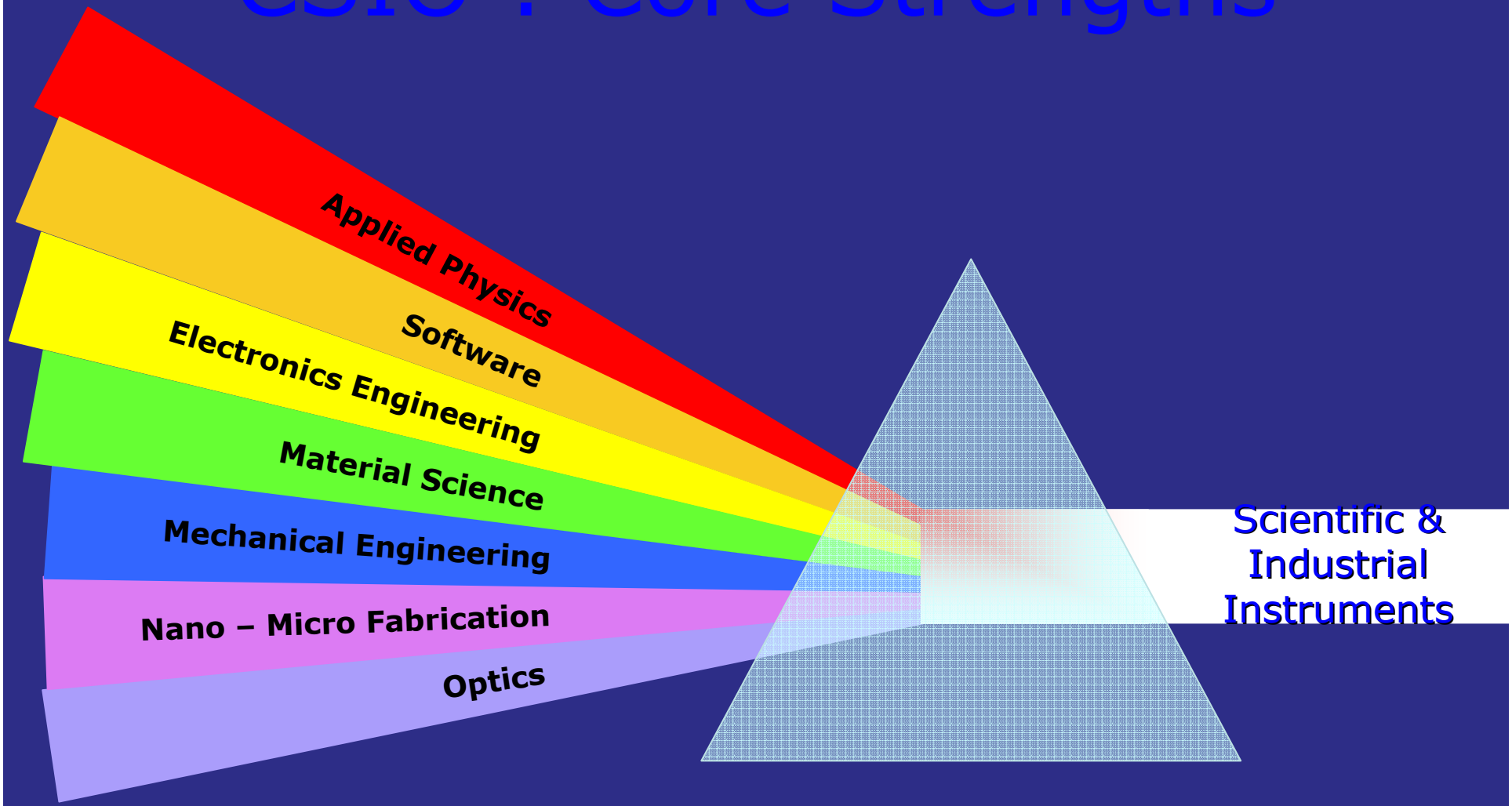
CSIO :The Organization Tree



CSIO goes Gaussian: Radical R&D management

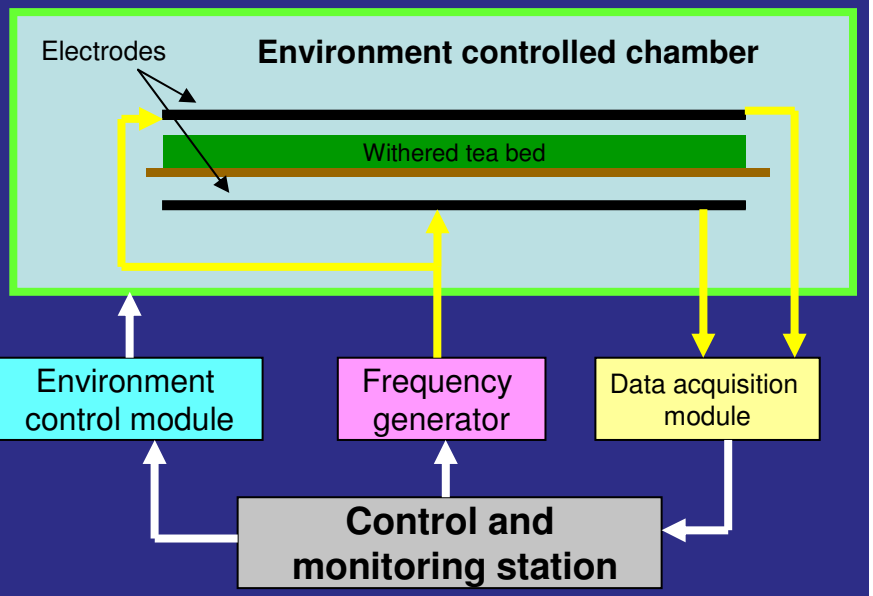


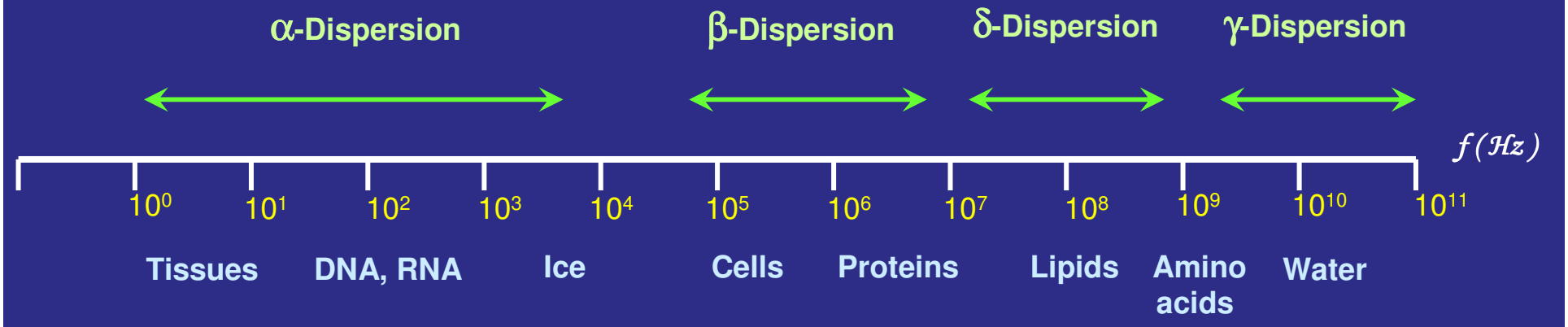
CSIO : Core Strengths



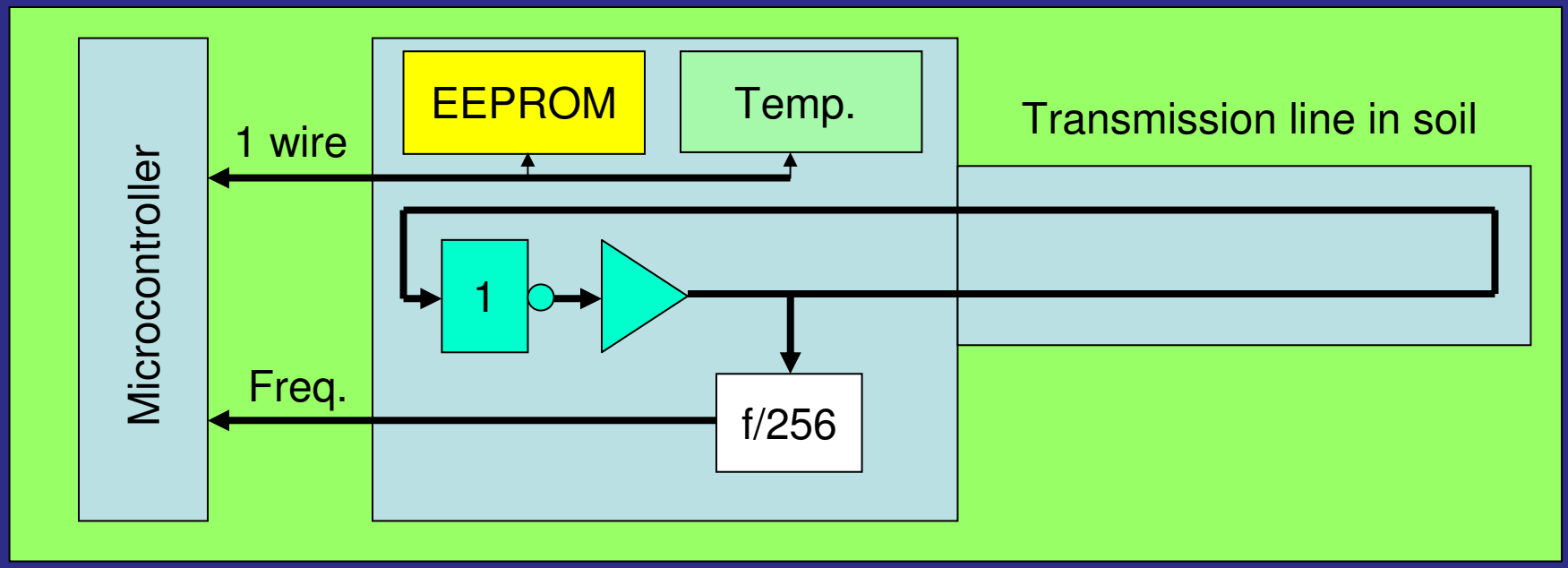
Dielectric Spectroscopy

- Dielectric properties of biological materials are characterized by α-β-δ-γ dispersions.
- Enzymes undergo conformal changes under varying electric fields and give rise to a change in resistance ΔR or change in capacitance ΔC.
- ΔR/ΔC versus frequency sweep help in targeting specific molecules under study.





Transmission line based soil moisture sensor



When the transmission line is buried in soil, the pulse will interact with the stored water in soil. Higher the moisture, higher is the effective dielectric permittivity of transmission line, leading to a lower wave propagation velocity v_p and a lower frequency of the ring oscillator.

Vehicle mounted Soil testing system

Different soil sensors are mounted at back of the tractor and draw the soil map of the field as tractor moves. The most resulting data is a set of maps representing variation in soil characteristics that influence yield such as:

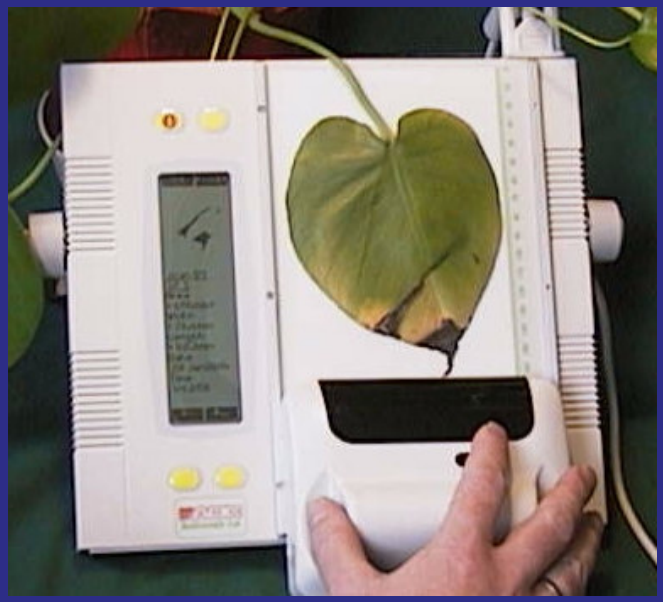
- Soil pH
- Macronutrient level (nitrogen, phosphorous, potassium etc)
- Soil texture (Clay content)
- Soil moisture and temperature
- Cation exchange capacity
- Soil compaction
- Depth of any root restricting layer
- Soil structure and bulk density

Photosynthesis Measurement

- Biological reaction in which CO_2, water and light energy ultimately produce oxygen and carbohydrates
- Link between inorganic and organic world
- Rate of photosynthesis is proportional to the amount of available light. Light quantity (intensity) and quality (spectral composition) are important for the plant growth.
- In the system, photosynthesis is measured by monitoring the consumption of carbon-dioxide either in closed system, or in flow-through system in which air is pumped through a photosynthetic chamber holding leaf.

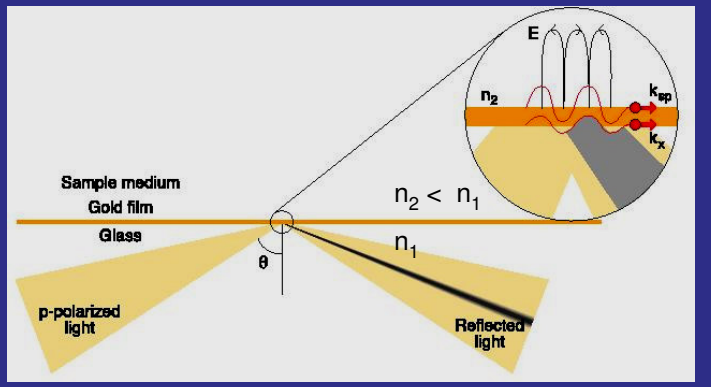
Calculation of leaf area

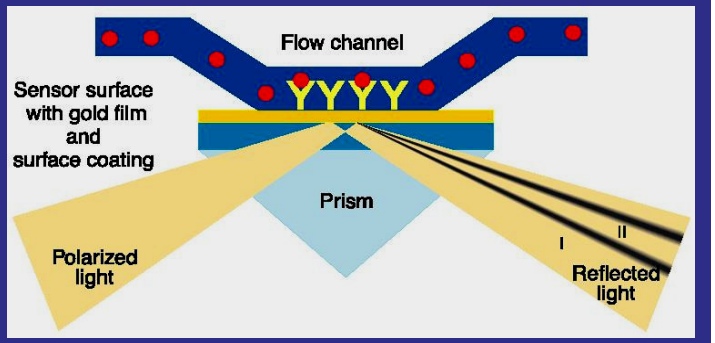
- Used to measure the surface area, circumference and other dimensions of leaves.
- Hand-scanner captures the leaf image.
- The software analyses the image to provide the measurements.
- The integrated graphical screen previews the scanned images and provides results
- The product stores results and scanned images for transfer to a computer.

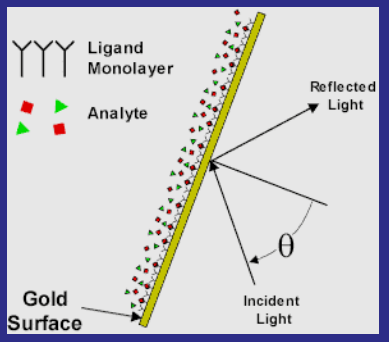


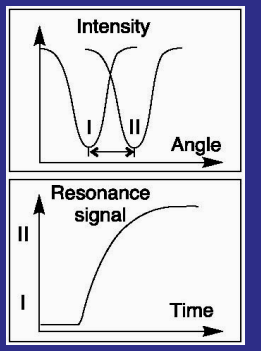
Surface Plasmon Resonance

- Photon energy excites the sample say tea liquor (low RI n2) as compared to transmitting glass (RI n1) through a gold deposition layer
- Under maximum energy transfer resonance takes place. This condition can be achieved by either;
  - Varying angle of incidence θ, or
  - Varying the wavelength of excitation
- Intensity *Vs* θ or Intensity *Vs* λ gives mass of the specific molecule selected and hence its concentration
- By selecting the appropriate antibodies and adhering to the gold thin film only specific molecules get attached and contribute to the measurement
- Wide applications e.g food safety, medical diagnostics, water quality, flrvourides, beverage quality etc

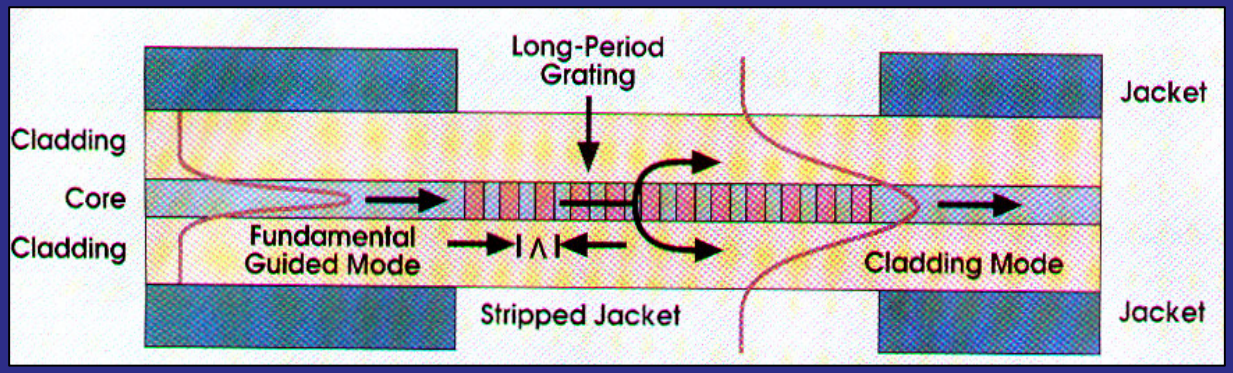


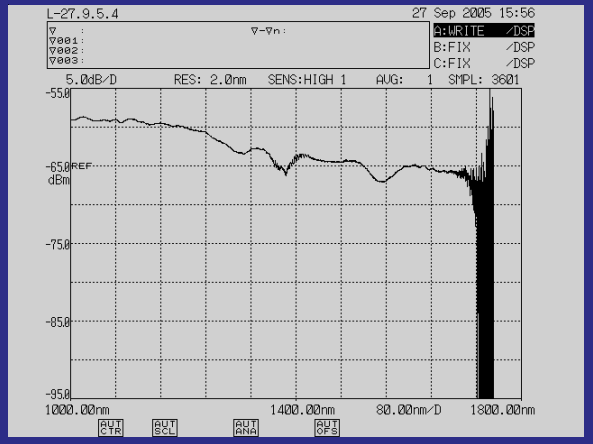






Fiber optics based measurement

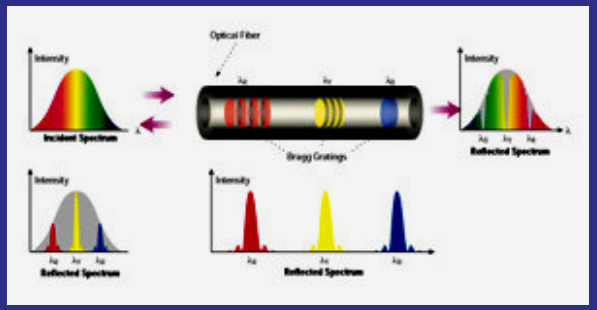




- On a conventional fiber bragg grating or long period grating is created using phase mask technique.
- Using the facilities available at CGCRI & CSIO such fiber-optic sensors can be developed and put either on withering troughs or fermenting floor / CFM
- Laser beam is sent through the fiber and the transmitted beam undergoes a change in the amplitude or phase which is related to the concentration of the specific molecule

Features of fiber-optics based measurements

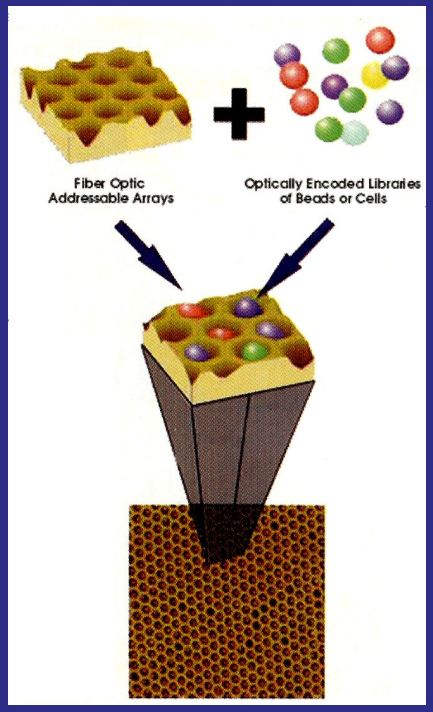
- **FO sensors**
  - Immunity to EMI/RFI/EMP-Resistance to harsh environment
  - Flexibility & geometric versatility-Small size & light weight
  - Distributed Sensing
  - Large Bandwidth, High Performance & Reliability
  - Same fiber as sensor & data transmitting channel



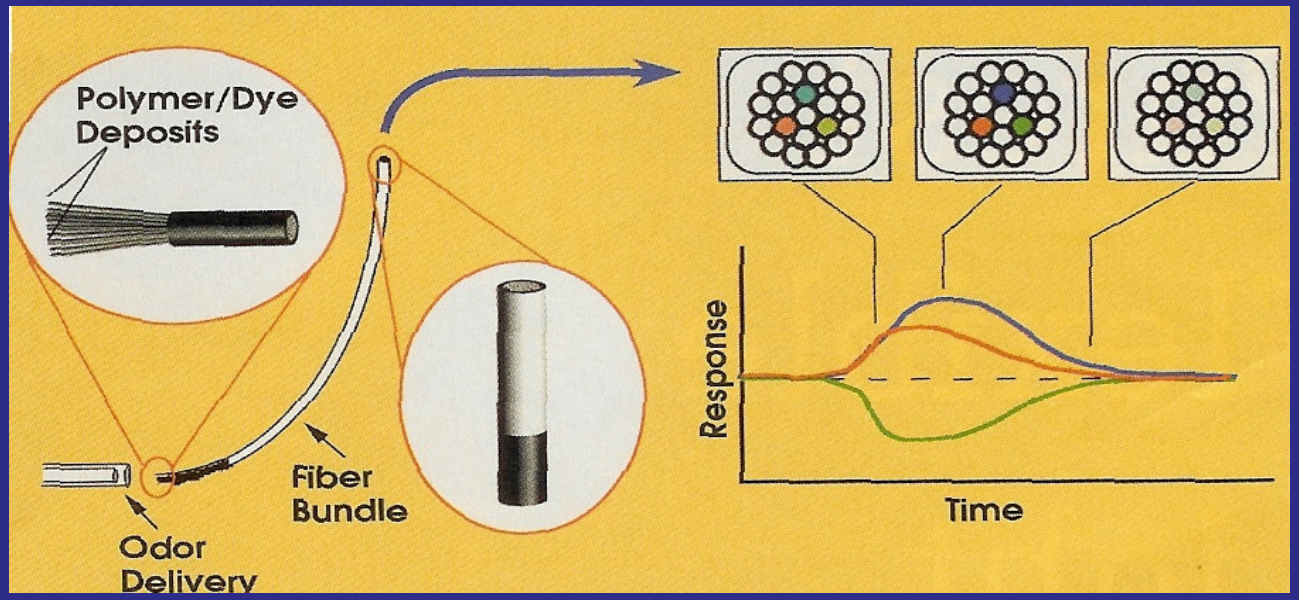
- **FBG's**
  - Longest interaction at λ_B
  - Wavelength coded information- multiplexing
  - Interferometric Sensitivity to strain, temperature and other measurands

- **LPG's**
  - Couple guided core mode into cladding modes
  - Function as λ dependent loss elements
  - Change in strain, temperature or external R.I. causes large shifts in λ resonances
  - Measure concentration of analytes, liquids and Bio-organisms
  - Simultaneous multi-parameter
  - Sensing with a single grating

Photonics Nose (tea industry)



Arrangement of FO arrays with wells filled with coded beads

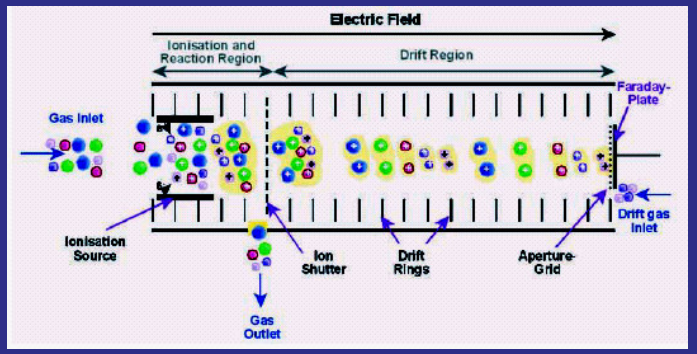


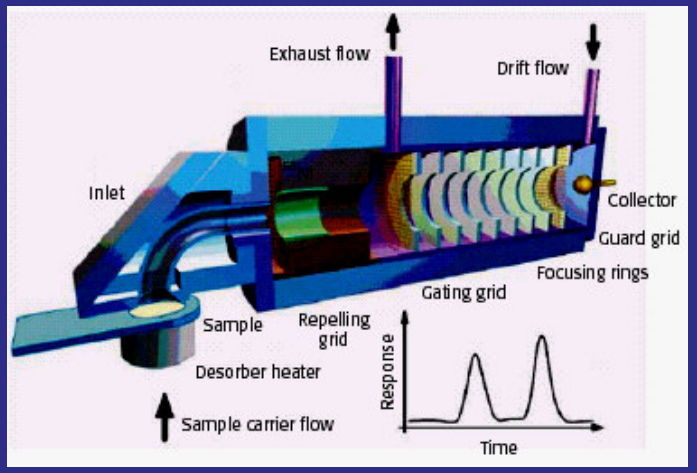
Connection of Sensor Arrays into Neural Networks based on Brain's Neural Properties

- Uses randomly ordered self-assembled FO sensor arrays (<1 mm dia)
- Fiber chemically treated to create a tiny well at the end
- Wells filled with coded beads or other particles using self assembly process
- Interaction with environment shifts dye's fluorescence

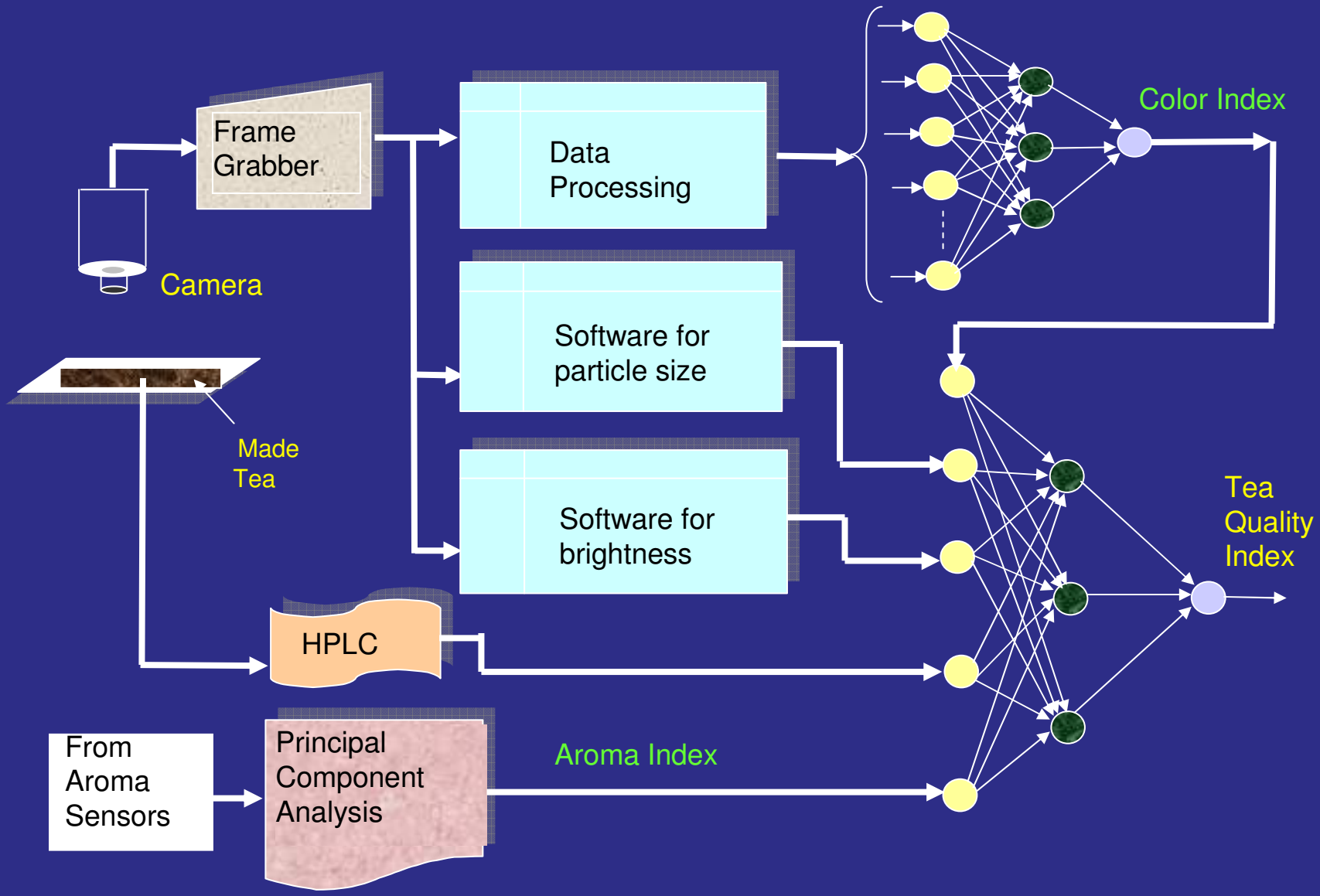
Ion Mobility Spectrometry

- Analytical tool for detection of trace quantities of gaseous organic compounds at atmospheric pressure based on difference in mobilities of ionic species.
- Sample & carrier gas ion formation in ionization chamber
- Ions drift under the influence of electric field with velocity based on their mass
- Lighter ions moves faster & detected earlier
- Heavier ions have low mobility & detected later

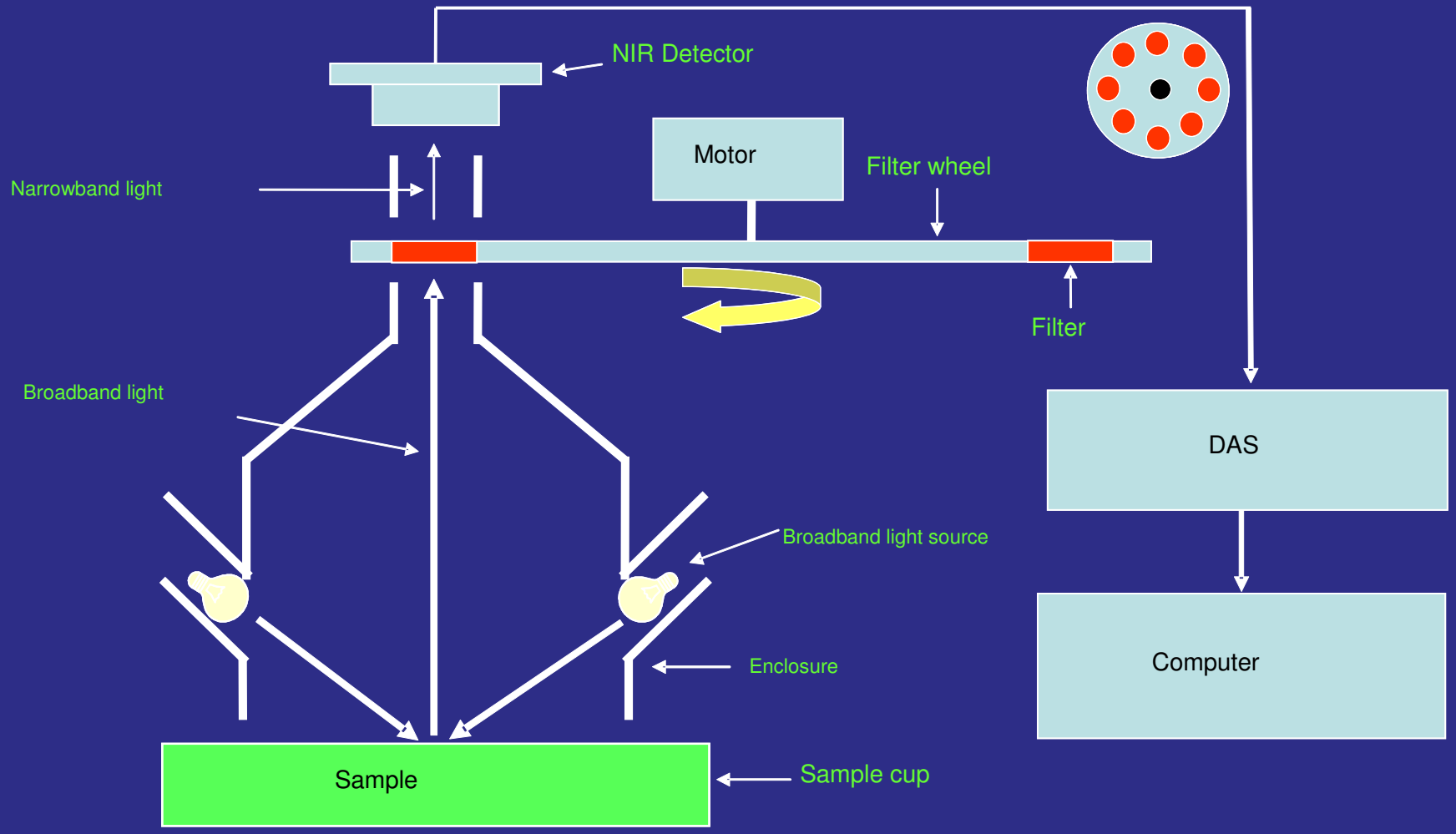




Tea Quality Quantification System



NIR reflectance



Expertise at CSIO

- Electronics & IT
  - Virtual Instrumentation & Embedded Systems
  - Simulation & Soft computing
  - Genetic Algorithms & Neural Networks
- Optics
  - Spectroscopy, FBG/LPG, thin-films
- Advanced materials for sensor development
- Biomolecular Electronics & Nanotechnology
- Mechanical fabrication
  - Precision machining, CNC, EDM etc

Equipments developed at CSIO

- Aflatoxin meter
- Field PH meter
- Digital Moisture Probe
- System for measurement of nitrite, nitrate, ammonia & phosphorous

Equipments developed at CSIO

- Inductive electromagnetic soil salinity testing system
- Specific Ion analyser
- NIR based cereal/grain analyser
- Laser land leveler

Equipments developed at CSIO

- Formaldehyde concentration measurement system
- Bamboo splitting /knot removing and slivering machine

Electro-optic Systems for Sorting, Packaging & Storage of Agricultural Products

- Electro-optical based on machine vision system
- Consists of conveying, singulation, orientation, imaging and processing units
- Throughput six apples per second
- Sorting based on colour, shape, size and external defects
- Imaging through 3CCD camera, DSP based processing

SUPRA Project of CSIO

- Country's pressing need of the hour
  - Enhancement of Agricultural Productivity at - Pre & Post harvest level &
  - Quantification of quality
- To cater to this National need, CSIO, based on its competence and experience, realised a Supra project entitled :
  - Advanced Instrumentation based Technological Solutions for Indian Agro Based Sector
- Aim
  - Integrated instrumentation system to enhance the agricultural productivity at Pre & Post harvest level along with quantification of quality

SUPRA Project of CSIO

- Instrumentation for Pre harvest applications
  - Plant physiology
  - Soil & water analysis
  - Precision farming
- Instrumentation for Post harvest applications
  - Quality assessment
  - Food processing industries
    - Tea, coffee, juices, soft drinks and alcoholic drinks
- Instrumentation for modernisation of Mandis
  - On the spot assessment of quality
  - Proper and accurate pricing and payment for farmer
  - Nationwide networking of Mandis
  - Statistical analysis of gathered data – assistance to national policy planning organs

SUPRA Project of CSIO

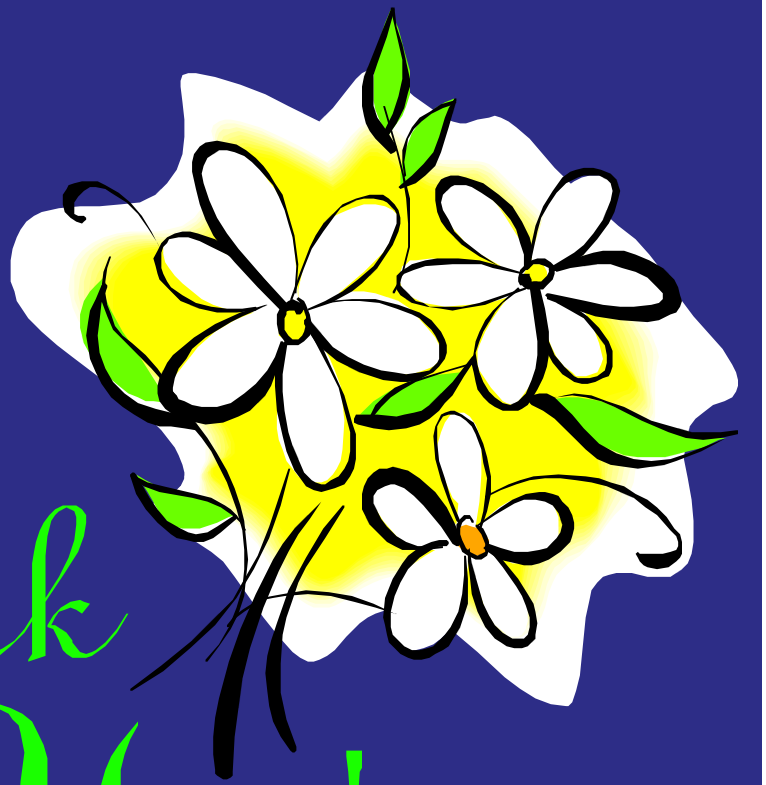
- Instrumentation for quantification of quality
  - Chemical : Fat, proteins, sugar, carbohydrates, fibrous contents, flavor etc
  - Physical : moisture, texture, colour, firmness, odour etc
- Turnkey Instrumentation
  - Controlled cultivation for tea and medicinal/aromatic plants
  - Biotechnology

Conclusion

- Agro-based is an important sector offering many challenging problems
- Convergence of technologies to tackle such cases
  - Pre-harvest, Post-harvest & Mandi level operations, Quantification of quality, Regulatory methods, Standardizaion & calibration.
  - Consortium concept, Instrumentation training & upgradation
- New transduction techniques are being continuously explored for advanced sensor development
- IT-based solutions based on inferential sensing, soft computing for future extraction.
- CSIO has identified Agro-based sector as SUPRA project
  - Stand alone gadgets with wireless connectivity
  - LCU & CCU for plant level management
  - Networking and Internet based architectures

TO FORGET HOW TO DIG EARTH &
TEND SOIL IS TO FORGET OURSELVES

MK Gandhi



Thank You!