Science – Engineering – Technology

Perspectives on Research and Innovation

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Knowledge to Prototype to Product

- Science ↔ Engineering ↔ Technology synergy
- Pursuit of knowledge in India – then & now
- IMPRINT: drive for translational research
- Technology – the last and elusive mile
- Technology development at CGCRI
- Science to society (Indian context)
- Concluding remarks (way forward)

♦ Institute Public Lecture "Vimarsh" ♦ IIT Indore ♦ 20March2023♦

HISTORY OF INDIAN INSTITUTES OF TECHNOLOGY

VISION of IITs:

The basic function of IITs is production of **scientists and engineers** of the **highest caliber**. Goals and tasks of the institutes should **relate continuously to changes** taking place in the **socio-economic development** of the country and rapidly exploding universe of **knowledge in science and technology**.

Teaching

Research

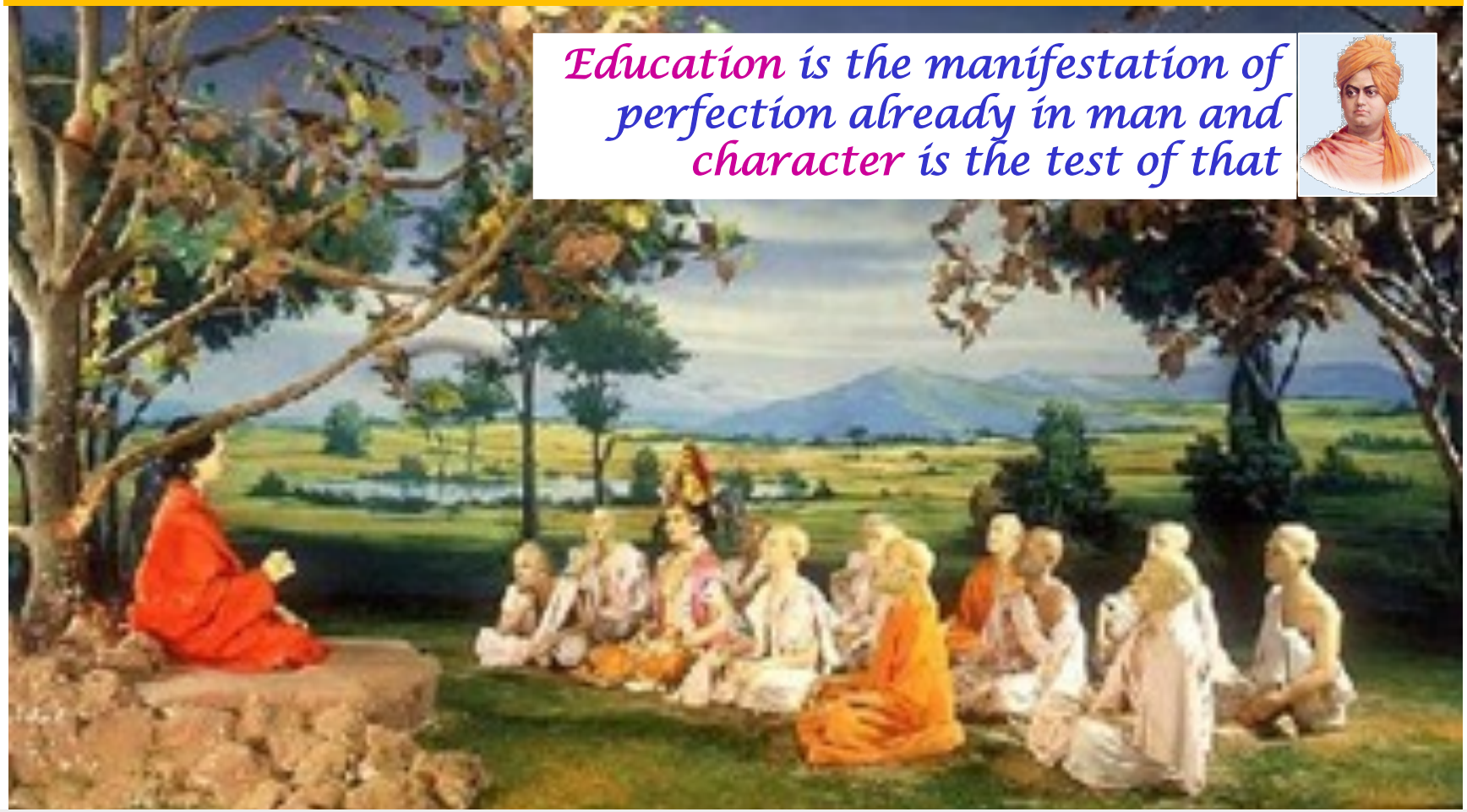
Genesis (Chronologically):

1945: N. R. Sarkar Committee Report recommending establishment of IITs
1951: IIT Kharagpur
1956: Indian Institute of Technology (Kharagpur) Act; 1961 amendment (INI)
1958: IIT Bombay 1959: IIT Kanpur 1959: IIT Madras 1961: IIT Delhi
1994: IIT Guwahati 2001: IIT Roorkee 2008-2016: 16 more IITs were added

Eminent Universities/Institutes in Engineering in Pre-Independent India:

1> CoE, Guindy, Chennai (1794)
2> CoCE/University of Roorkee (1847)
3> CoE, Pune (1854)
4> CEC/BEC/IIEST, Shibpur (1856)
5> University of Bombay (1857)
6> Pleaders Survey TS/NIT Patna (1886)
7> VJTI, Mumbai (1887)
8> FTE, MS Univ, Baroda (1890)
9> Jadavpur University (1906)
10> IISc, Bangalore (1909)

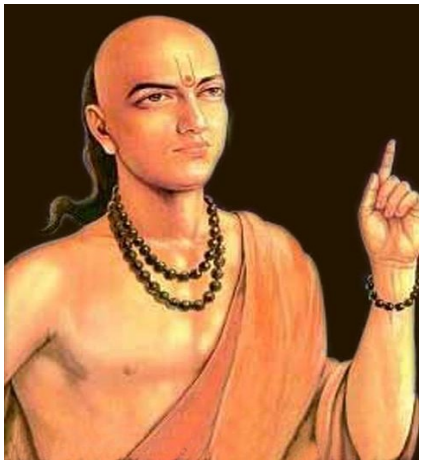
Education in Ancient India (3000 BC)



- **Education** (is) … imparting or acquisition of **knowledge**
- **Knowledge** is awareness through time and stages of **learning**
- **Learning** accrues through stages, experience, and self-study

The highest education is ….. but makes our life in HARMONY with all existence - *Tagore*

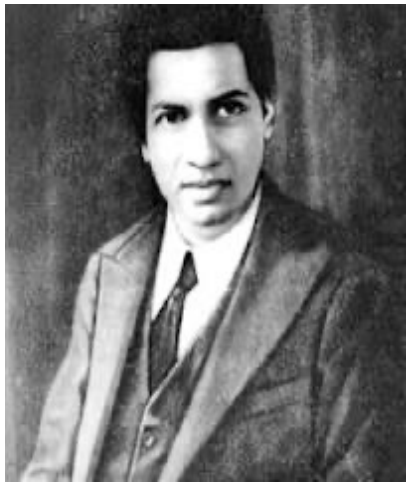
Kanad (600 BC)



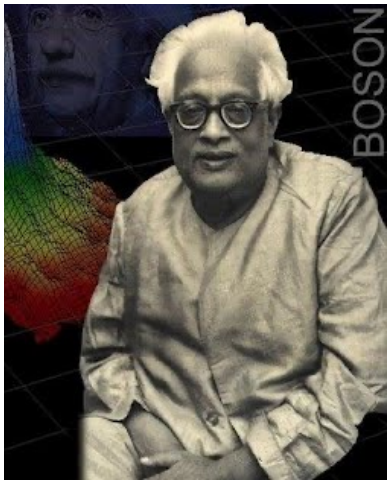
Aryabhatta (476-550 A.D.)

Sir JC Bose (1858-1937)

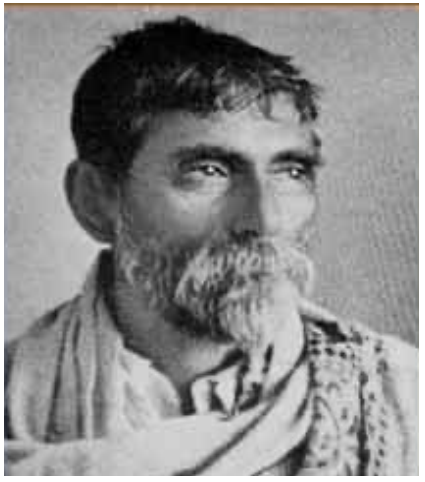
Sir CV Rāman (1888-1970)



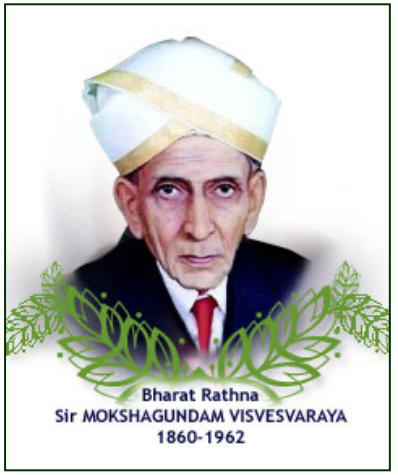
S Ramanujan (1887-1920)



SN Bose (1894-1974)

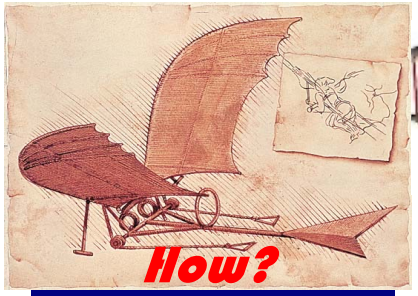


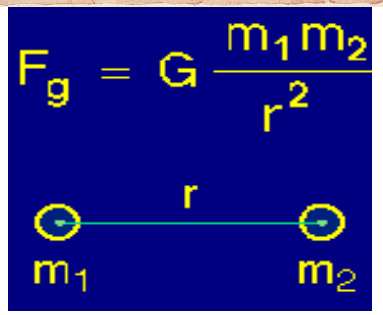
PC Ray (1861-1944)



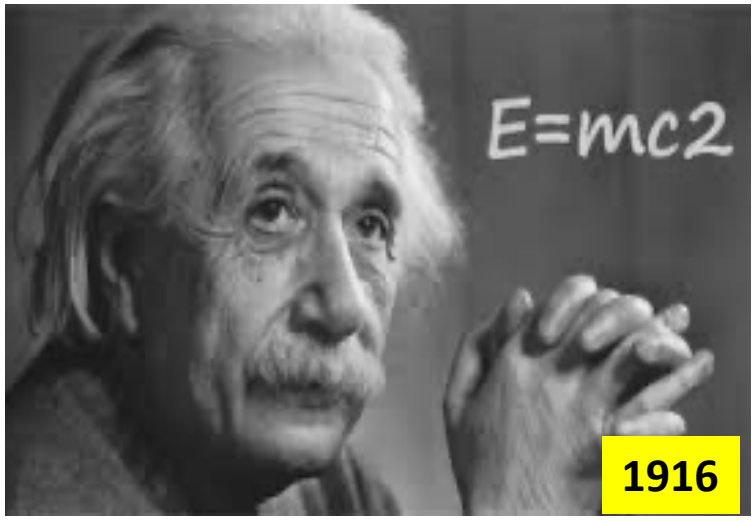
M Visvesvaraiah (1860-1962)

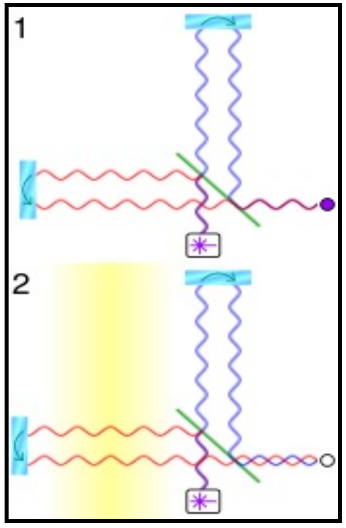
SCIENCE ↔ ENGINEERING ↔ TECHNOLOGY

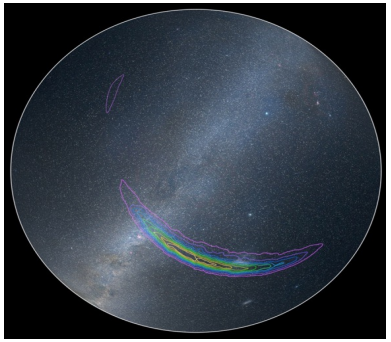




Laser Interferometer Gravitational-Wave Observatory (LIGO)

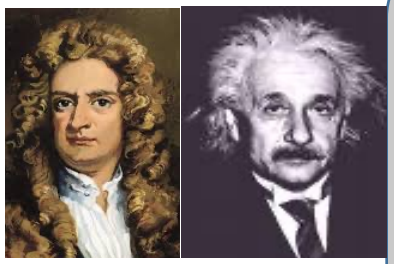






11Feb2016

THE PERPETUAL TRIAD



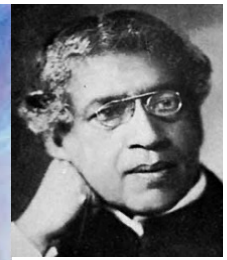
SCIENCE

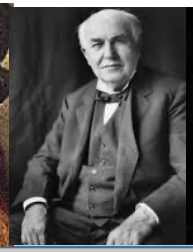
Know-why?

Unravel nature

Curiosity/need inspired act

Discovery

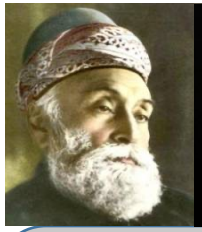

ENGINEERING

Know-how?

Product/device

Invention

SOCIETY



TECHNOLOGY

Know-what sells?

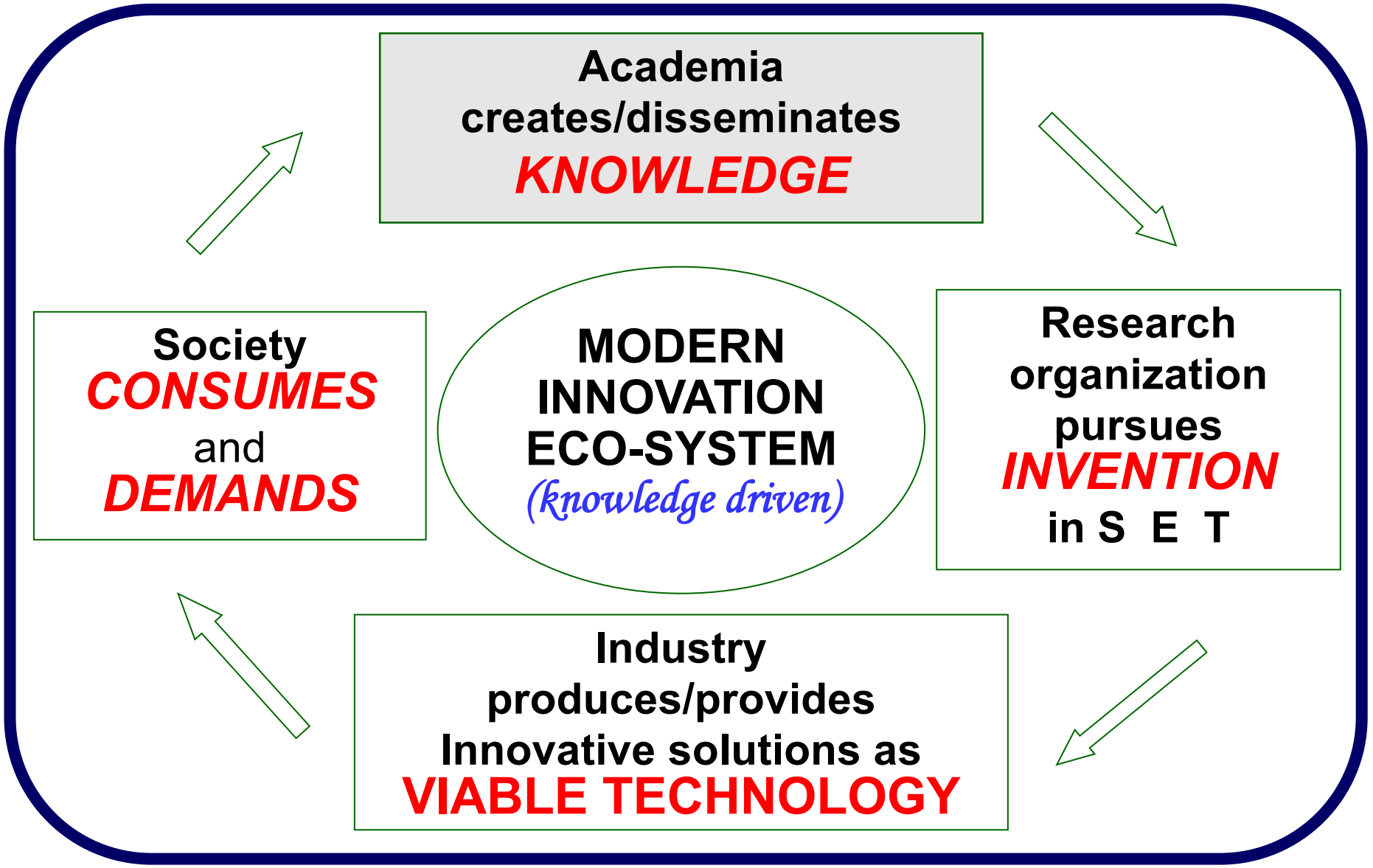
Multiple copies

Innovation

SET [Science-Engineering-Technology] **PATH TO PROSPERITY:**

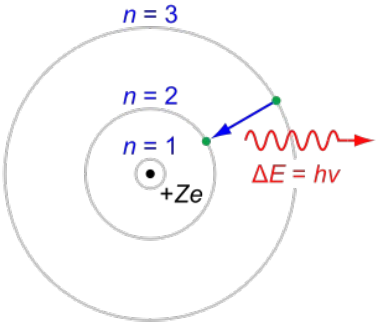
(a) Knowledge (data to wisdom)**; (b) Opportunity** (job and business)

Innovation Eco-system



Pasteur's Quadrant

Bohr



Pasteur

Average Academic and Industrial R & D

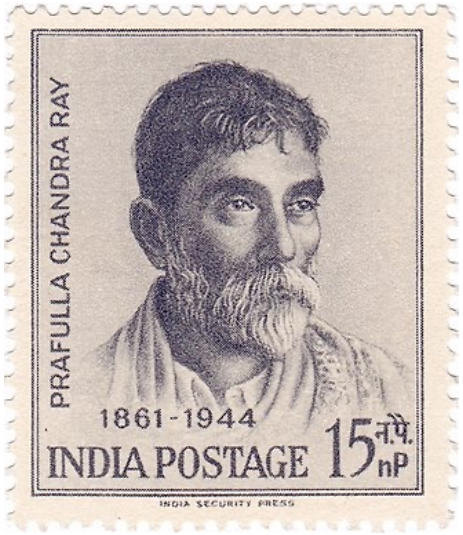
Edison

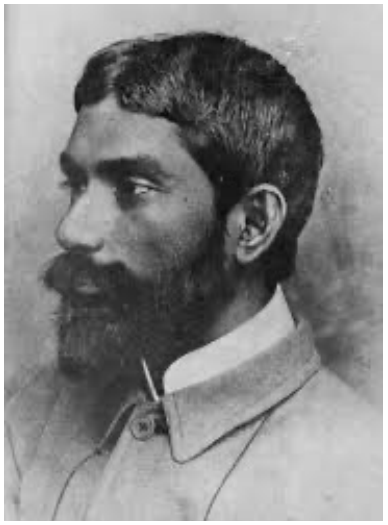
Fundamental Research

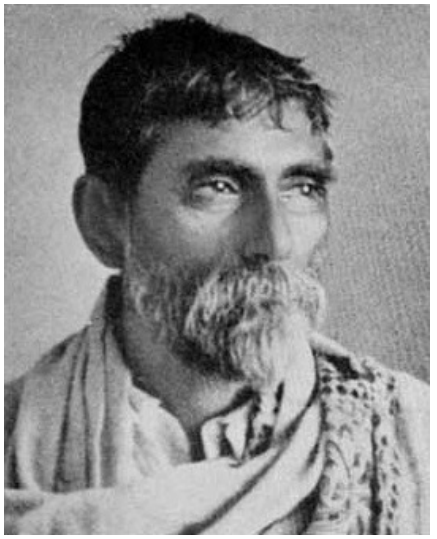
Use Inspired Research

Acharya Sir Prafulla Chandra Ray *CIE, FNI, FRASB, FIAS, FCS*

2nd Aug 1861 – 16 Jun 1944





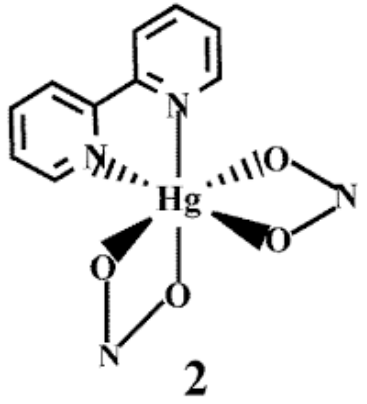


- **BSc and PhD, University of Edinburgh (1882-1888)**
- **Royal Society of Chemistry** honored by awarding the first ever ***Chemical Landmark Plaque*** outside Europe
- Founder, **Bengal Chemicals & Pharmaceuticals** (**India's 1st**)
- He started a new ***Indian School of Chemistry*** in 1924
- ***President*** of the Indian Science Congress (1920 session)
- First "***Palit Professor of Chemistry***" of Science College
- 107 papers in all branches of Chemistry by 1920

➢ $6\ Hg + 8\ HNO_3 \rightarrow 3\ Hg_2(NO_3)_2 + 2\ NO + 4\ H_2O$

➢ $NH_4Cl + AgNO_2 \rightarrow NH_4NO_2 + AgCl$

➢ $RNH_3Cl + AgNO_2 \rightarrow RNH_3NO_2 + AgCl$

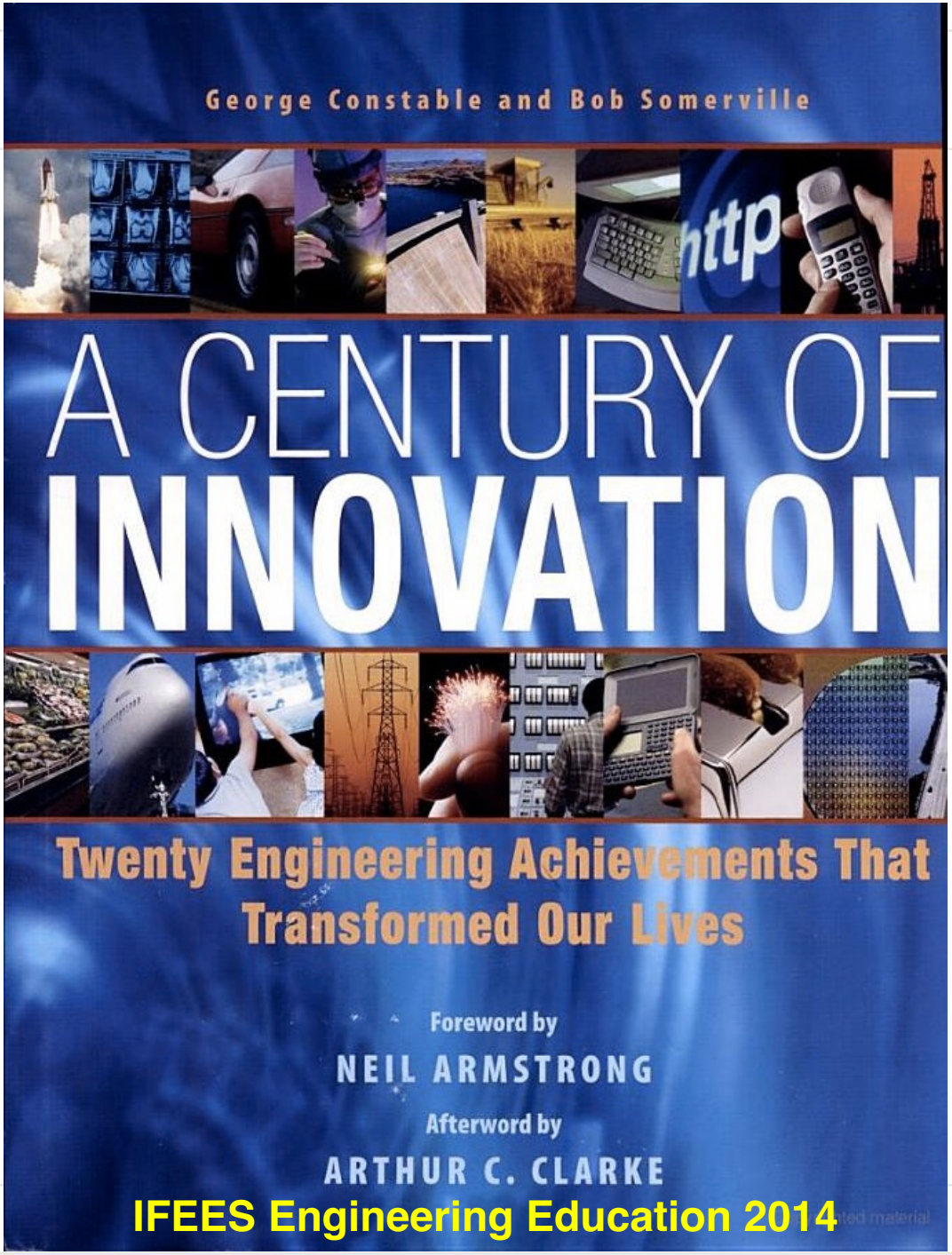


2

Mercurous Nitrite, $Hg_2(NO_2)_2$

$2Hg + NO_2.H + HO.NO_2 \rightarrow Hg_2(NO_2)_2 + H_2O$

$4Hg + 4HNO_3 \rightarrow Hg_2(NO_2)_2 + Hg_2(NO_3)_2 + 2HO$

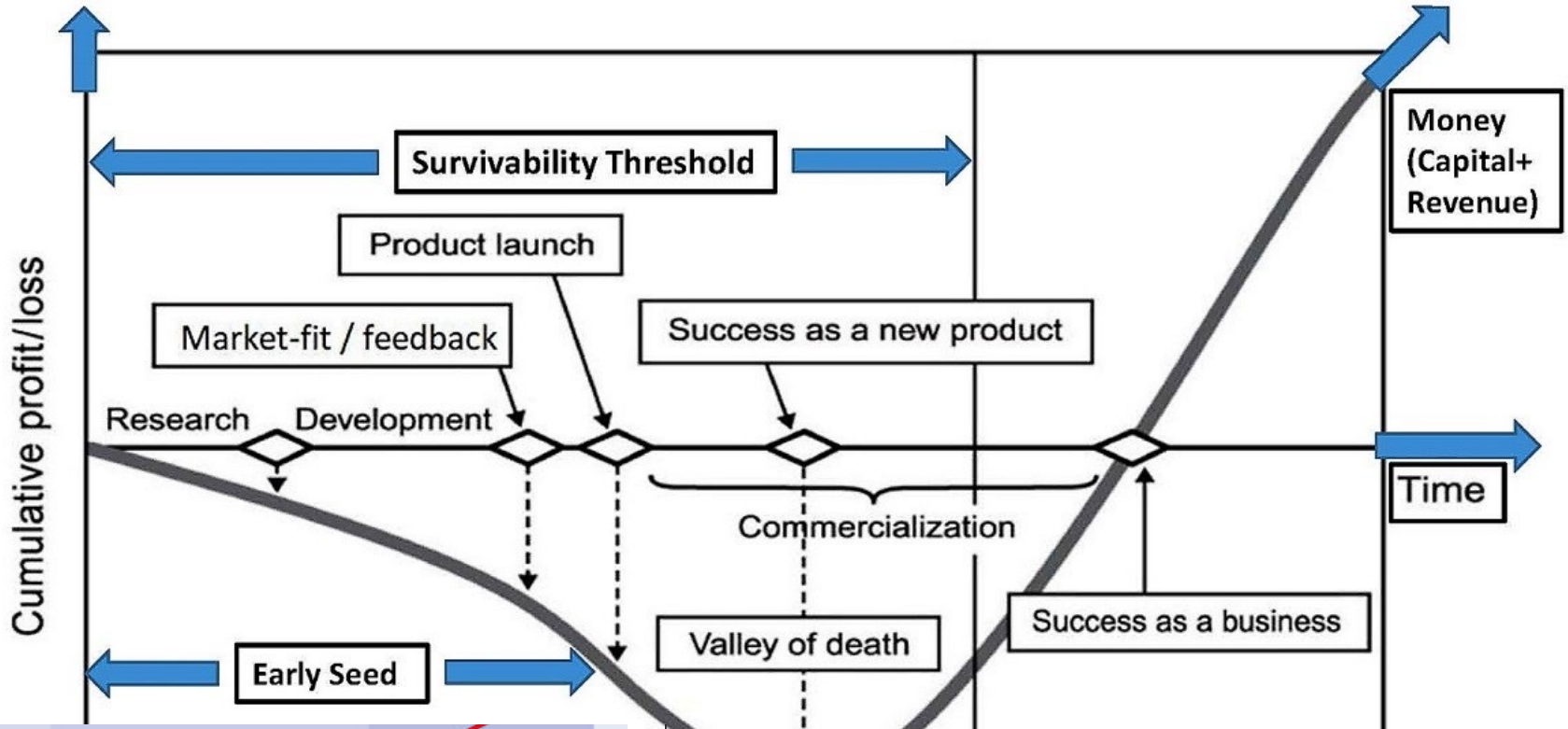


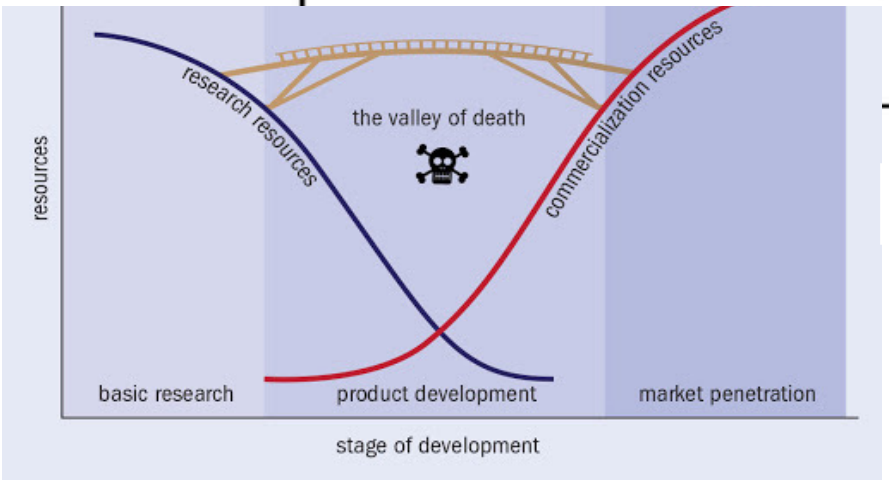
A CENTURY OF INNOVATION

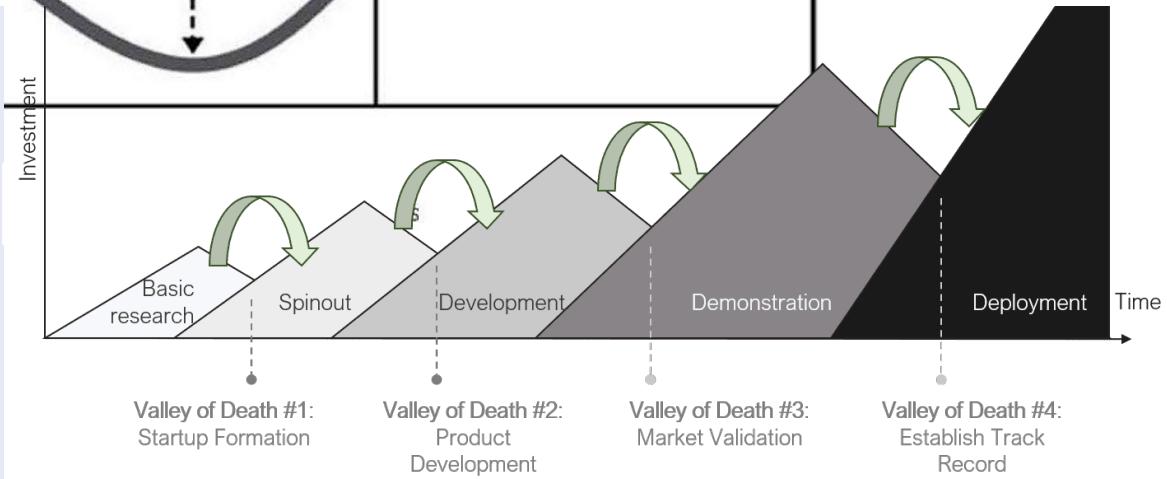
1. Electrification
2. Automobile
3. Airplane
4. Water Supply and Distribution
5. Electronic devices/gadgets
6. Radio and Television
7. Agricultural Mechanization
8. Personal Computers
9. Telephone
10. Air Conditioning, Refrigeration
11. Highways
12. Rockets and Spacecraft
13. Internet
14. Imaging
15. Household Appliances
16. Healthcare Technologies
17. Petroleum and Petrochemical
18. Laser and Fiber Optics
19. Nuclear Technologies
20. High-performance Materials

Startup Port – Tactical Roadmap Execution

(Financial Cycles Of A Startup's Journey)







Global Perspective

14 Grand Challenges for Engineering in USA in 21st Century

Grand Challenges for Engineering (USA):

An initiative of *National Academy of Engineering*, USA to define the *21st century's Grand Challenges* covering *sustainability, health, security and joy*


Make solar energy economical


Provide energy from fusion


Develop carbon sequestration methods


Manage the nitrogen cycle


Provide access to clean water


Restore and improve urban infrastructure


Advance health informatics


Engineer better medicines


Reverse-engineer the brain


Prevent nuclear terror


Secure cyberspace


Enhance virtual reality


Advance personalized learning


Engineer the tools of scientific discovery

Chair: William Perry (50 subject experts from 40 different countries)

'IMPacting Research, INnovation and Technology

www.imprint-india.org

सत्यमेव जयते

IMPACTING RESEARCH INNOVATION AND TECHNOLOGY
IMPRINT
INDIA

November 5, 2015

AIM: INCLUSIVE GROWTH AND SELF RELIANCE by
translation of knowledge into viable technology

Ten Technology Domains of IMPRINT

Living world

Healthcare Technology

Sustainable habitat

Energy Security

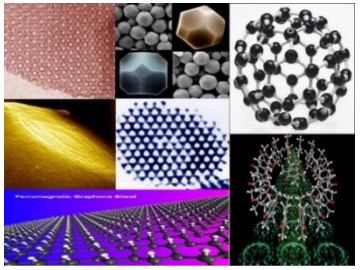
Water and River Systems

Environment and Climate Change

Materials world

Manufacturing Technology

Defense and Security



Nano-Science and Technology

Advanced Materials

Computer Science and ICT

IIT Kanpur - the National Coordinator

Synergy with National Missions

SCIENCE IS UNIVERSAL BUT ENGINEERING SOLUTIONS MUST BE LOCAL

Prime Minister Modi

Million Challenges, Billion Minds

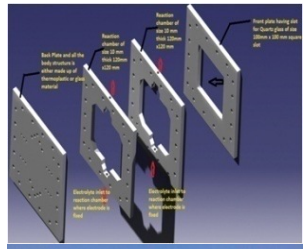
ENERGY

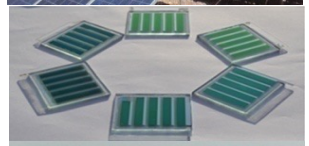
Objective:

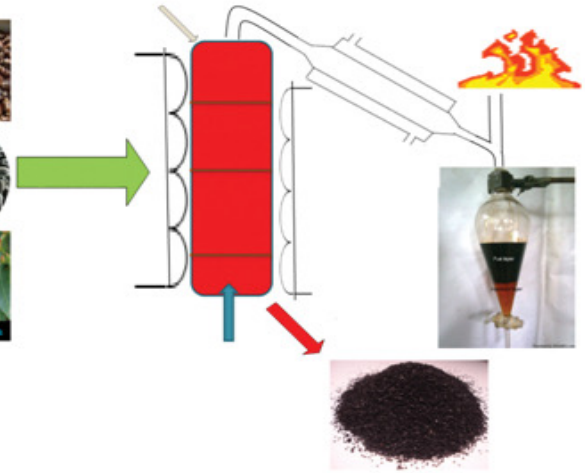
Attain energy security and make alternative and renewable energy affordable

Themes:

- Fusion technology
- Clean coal technology
- Renewable energy
- Hydrogen based energy
- Energy storage
- Energy systems & efficiency
- Revise energy strategy







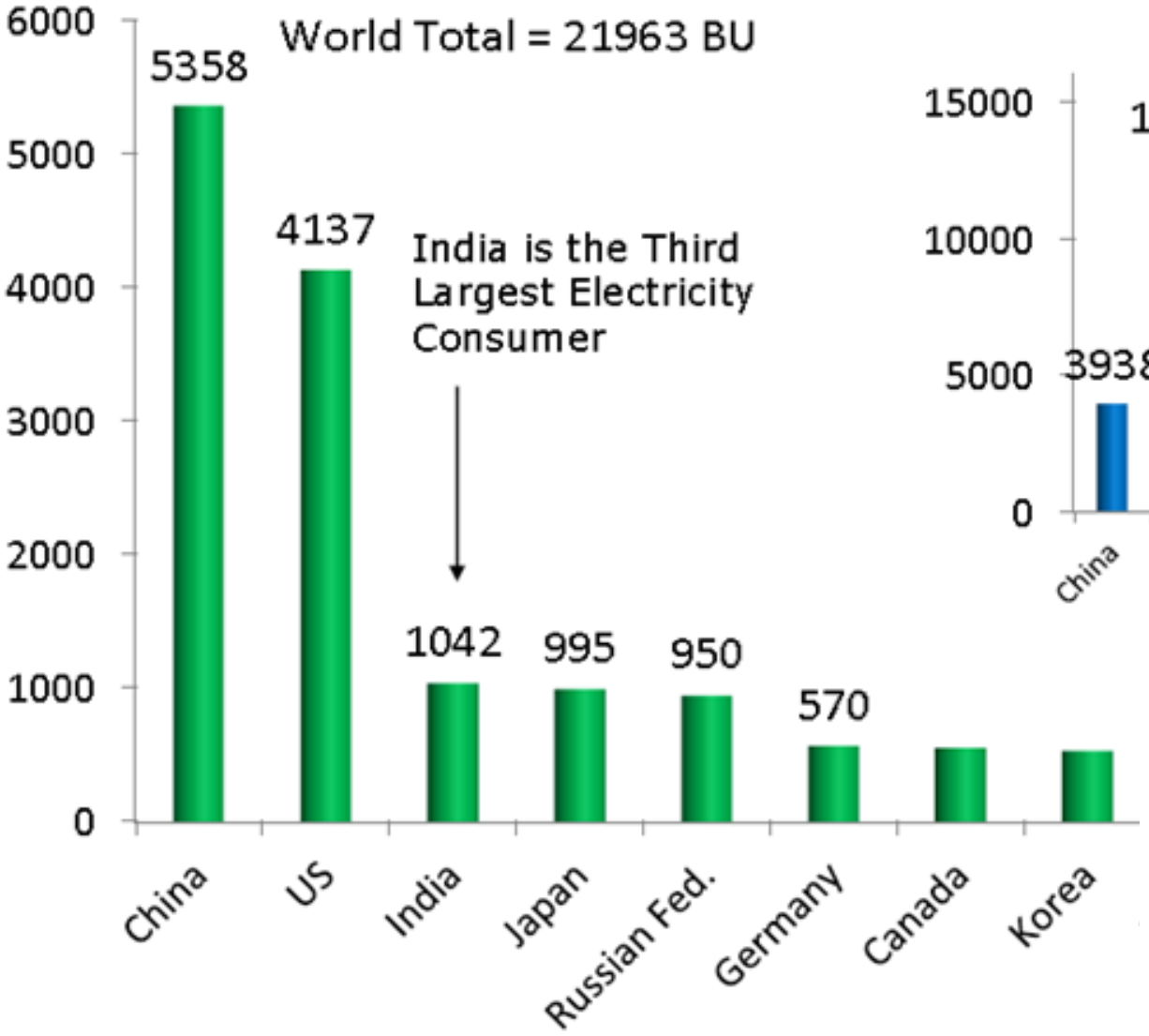
IIT Bombay

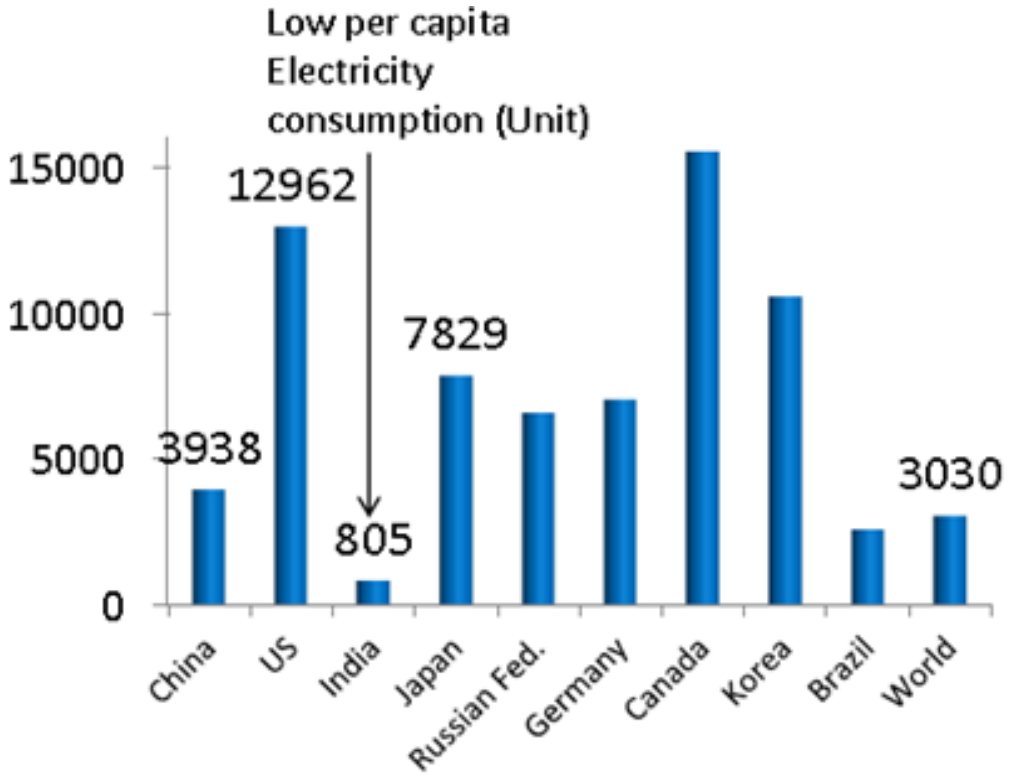
Total Installed Capacity in India (June 2017)

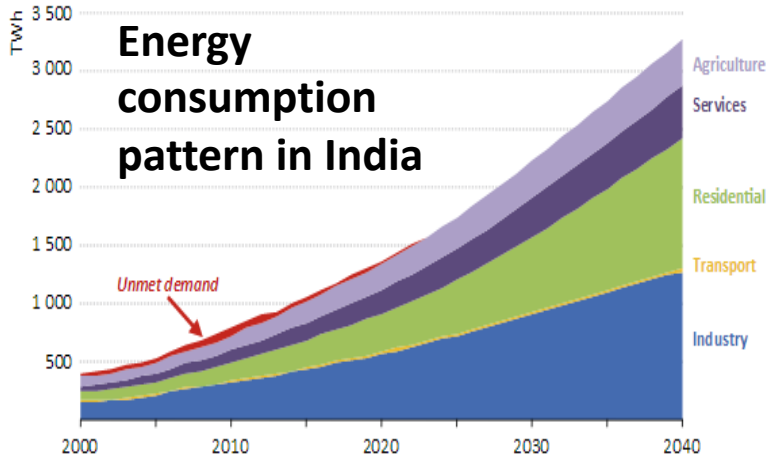
Sector	MW	% of Total
State Sector	1,03,868	31.55%
Central Sector	81,622	24.79%
Private Sector	1,43,740	43.66%
Total	3,29,231	

Fuel		MW	% of Total
Total Thermal		2,20,576	67.0%
	Coal	1,94,553	59.1%
	Gas	25,185	7.6%
	Oil	838	0.3%
Hydro (Renewable)		44,614	13.6%
Nuclear		6,780	2.1%
RES (MNRE)		57,260	17.4%
	Total	329,231	100%

Electricity Consumption in (BU)



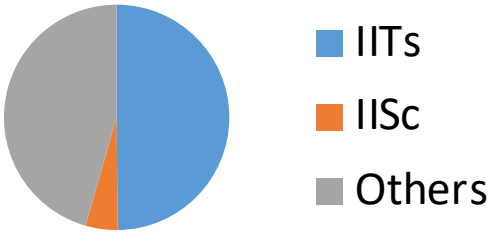




Overview of IMPRINT – Phase I

- Call for proposal: 29Jan16 to 25Feb16
- 2612 proposals received
- 10 domains, 84 themes
- 5217 individuals involved
- 198 Institutions (PI or Co-PI)
- 608 Participating Institutions
- Cumulative funding requested = Rs 4773,37.95 L
- Phase I: 2612 Proposals
- Phase II: 924 Proposals
- Phase III: 458 Proposals
- > 500 reviewers
- APEX Committee: 259 Proposals

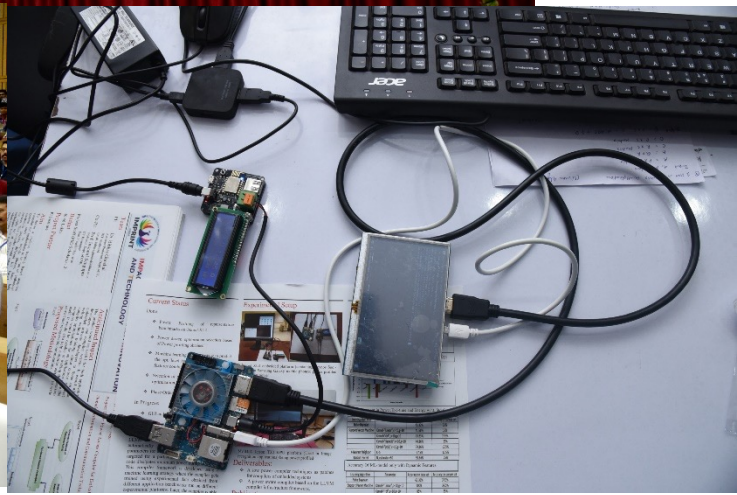
Distribution of Projects



WAY FORWARD – IMPRINT II

- **Difficulties faced:** 50% from multiple ministries – delay – operational challenges – only 142 of 259 after 3 stage screening could be initiated
- **New scheme:** MHRD + DST joint initiative for about 200 + 225 = 425 projects of 3 year duration (@ Rs 2 Cr per project) over 4 FYs (2018-19 to 2021-22)
- **Research objective:** Themes/topics/targets under 10 Technology Domains with input from industry, government departments, science/engineering academy and policy makers
- **Project type:** Translational research leading to commercial product/process, prototype, models
- **Proposed corpus** = Rs 970.5 crore (50-50 sharing by MHRD + DST/SERB)
- **Implementation authority:** SERB with separate PACs under the guidance of National Coordinator
- IMPRINT II: MHRD + DST (SERB) = 50-50; Jan 2019 onward
- IMPRINT IIA + B: 2145 → 1648 → 122 + 4 = 126
- IMPRINT IIC.1 (Regular): 499 → 166 → 56 + 6(?)
- IMPRINT IIC.2 (Consortium): To be launched

Tech-Ex (IMPRINT I) – 4th Aug 2019 – IIT Delhi



Handheld Device

TECHNOLOGY PROTOTYPE 2

Development of Artificial Pancreas for Closed Loop Blood Glucose Control of Type-1 Diabetic Patients in India

*PI: **Radhakant Padhi**, IISc Bangalore*

Domain: Healthcare

Efficient Glycemic Control for the Management of Diabetes Complications: Intervention with Novel Point of Care Device for Community Healthcare

*PI: **Navakanta Bhat**, IISc Bangalore*

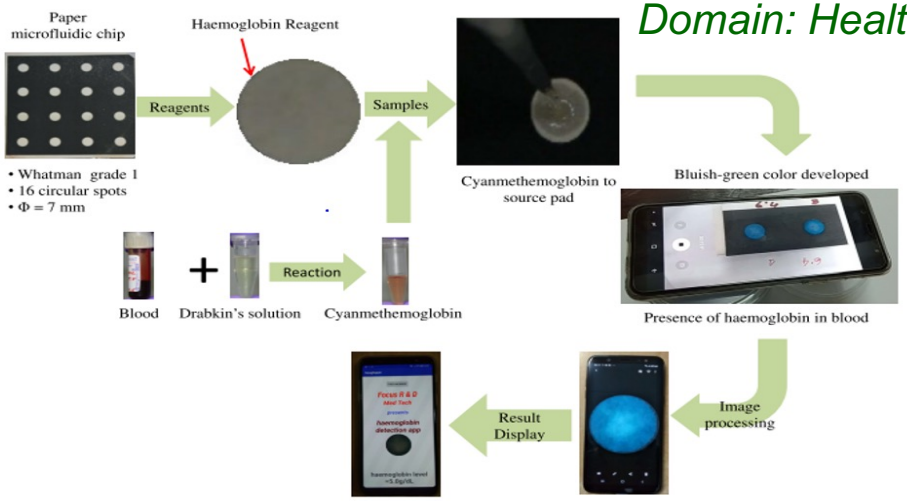
Domain: Healthcare

TECHNOLOGY PROTOTYPE 1

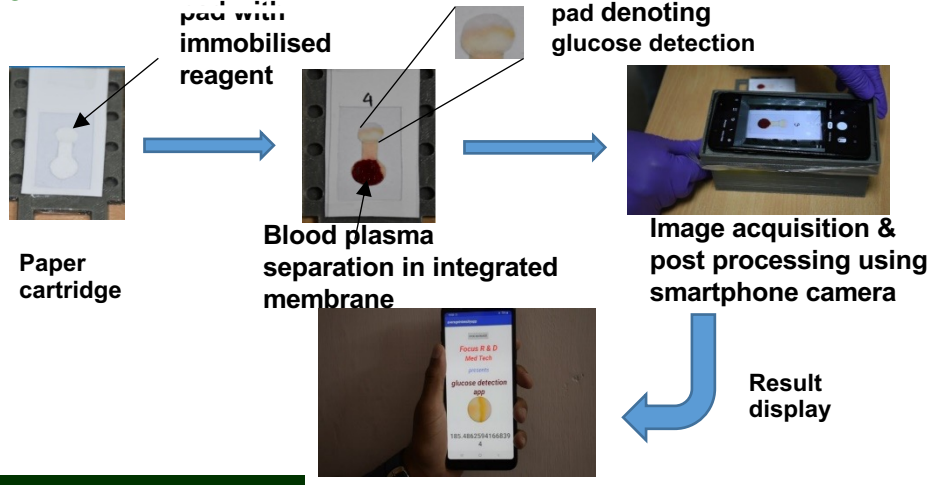
Development of Smartphone Integrated Generic Microfluidic Devices for Rapid, Portable, and Affordable Point-of-Care Diagnostics

PI: ***Suman Chakraborty****, IITKGP*
Domain: Healthcare

Process flow for haemoglobin detection



Process flow for glucose detection



TECHNOLOGY PROTOTYPE 3+4

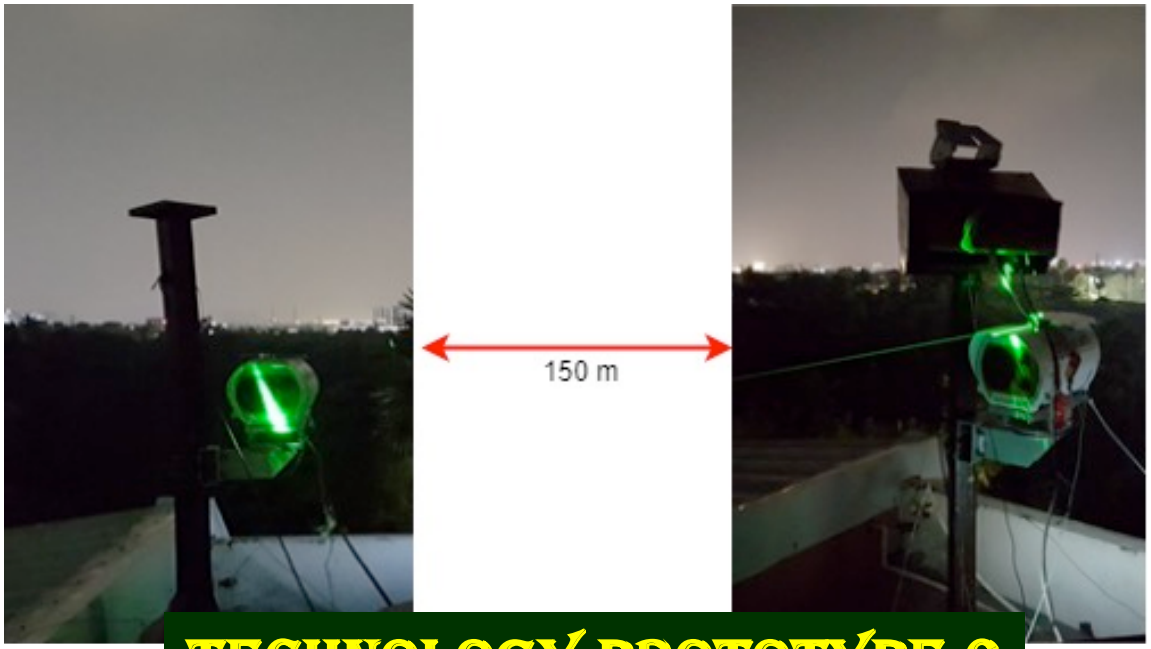
Multifunctional in situ gelling, self-administered paint-on wound dressing for trauma care of in-field soldiers

TECHNOLOGY PROTOTYPE 5

PI: ***Rinti Banerjee***
IIT Bombay

Free space optical link for line of sight communication near border areas

PI: ***Anil Prabhakar****, IIT Madras*



TECHNOLOGY PROTOTYPE 6

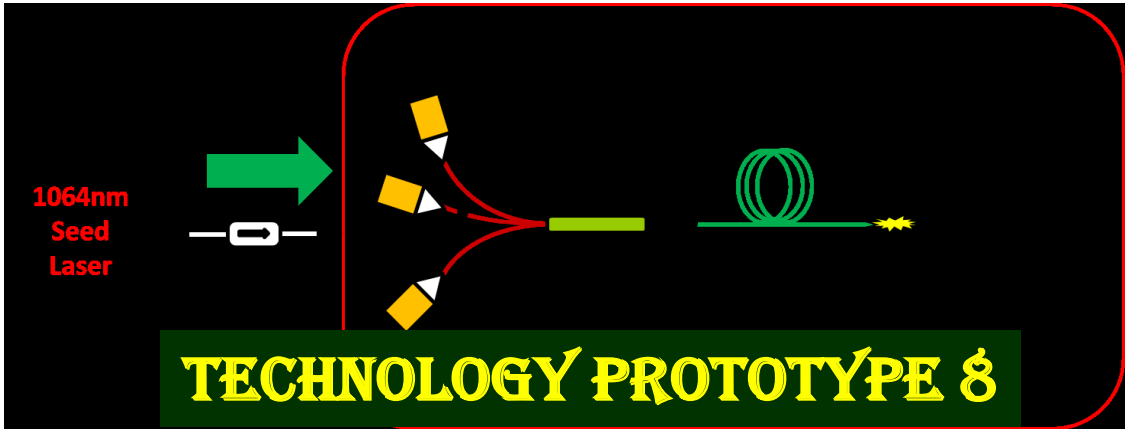
Development of high energy and high power density Li ion battery

PI: ***Subhasish Basu Majumder****, IIT KGP*

TECHNOLOGY PROTOTYPE 7

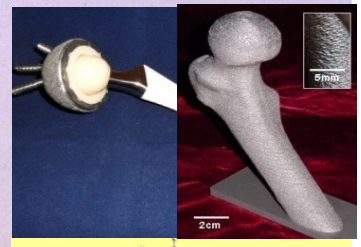
Power Scalable kiloWatt Class Laser Sources for Directed Energy Applications Through Coherent Beam Combining of Narrow Linewidth Fiber Lasers

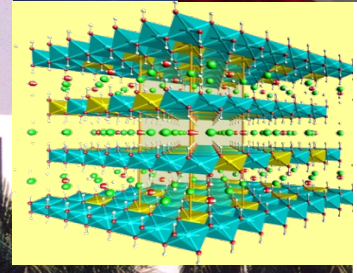
PI: ***Balaji Srinivasan****, IIT Madras*



TECHNOLOGY PROTOTYPE 8

INNOVATIONS IN ADVANCED CERAMICS AND SPECIALTY GLASS AT CSIR-CGCRI

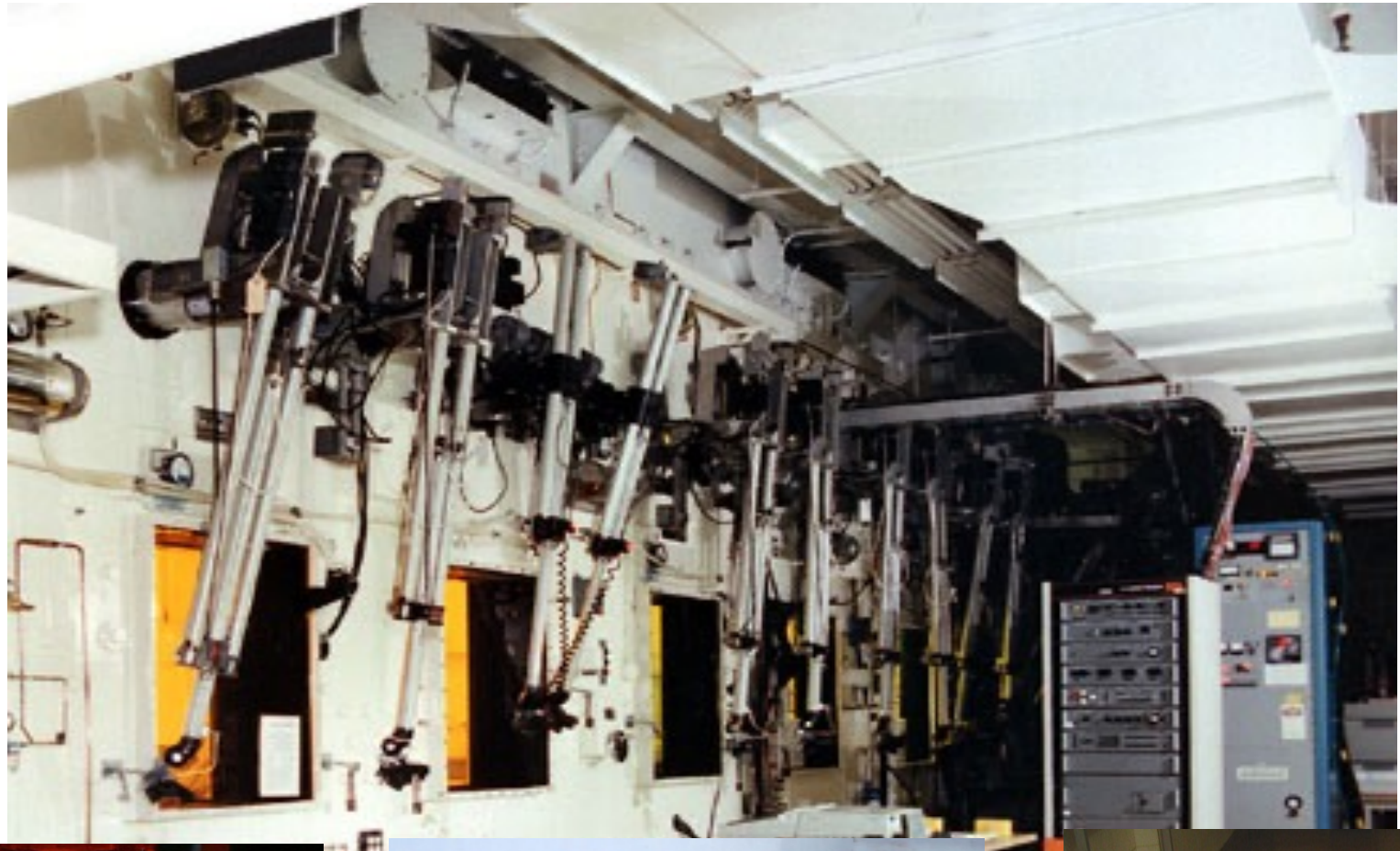


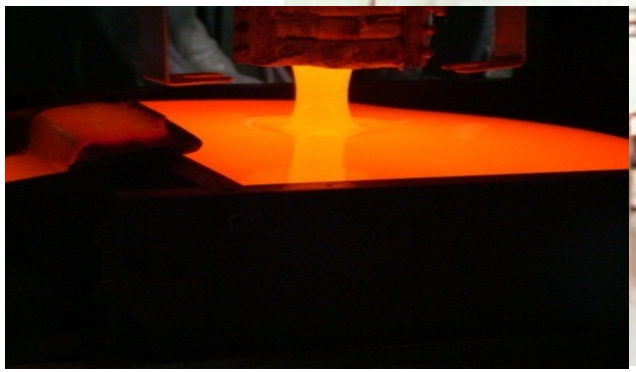


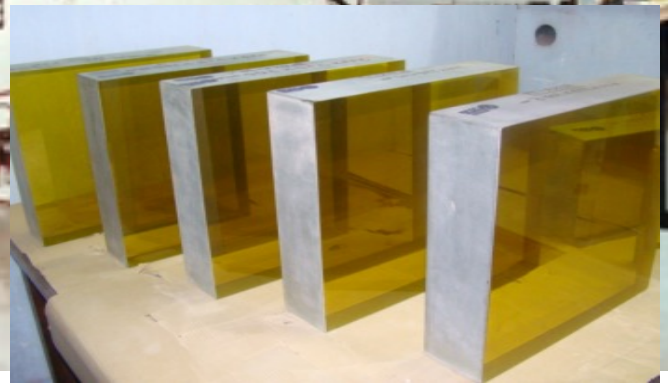
स्थापित 1950 ♣ हीरक जयंती वर्ष 2010-11

FOUNDED 1950 ♣ DIAMOND JUBILEE 2010-11

Radiation Shielding Window Glass for HOT CELL at Tarapur



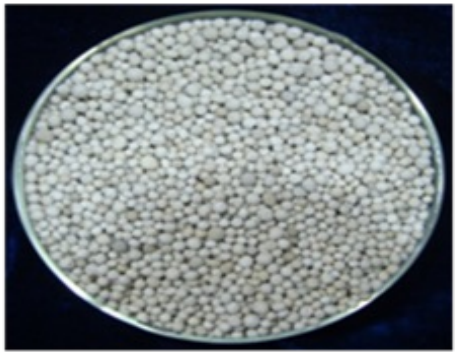




Glass Nodules For Nuclear Waste Immobilization

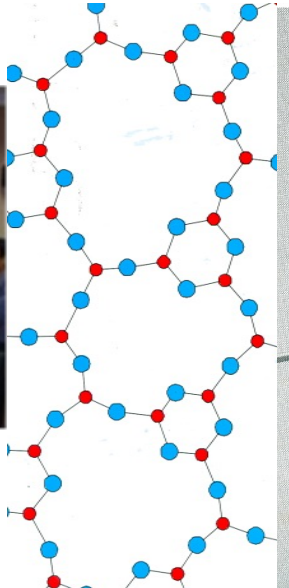
- PROCESS TECHNOLOGY DEVELOPED FOR MAKING SPECIAL GLASS NODULES (FRITS) WITH DESIRED PROPERTIES
- PRODUCTION HAS BEEN TAKEN UP IN COLLABORATION WITH M/S. H. R. JOHNSON, MUMBAI
- TECHNOLOGY LICENSE AGREEMENT SIGNED WITH HR JOHNSON, MUMBAI On May 11, 2012
- First 10 TON has been transferred to Tarapur Unit of BARC
- TECHNICAL AGREEMENT SIGNED BETWEEN CGCRI & H JOHNSON
- DAE PLACED ORDER TO H R JOHNSON FOR FURTHER 10 TONS
- PROPOSED MODEL: PRODUCTION BY HRJ WITH DIRECT ORDER FROM BARC + CERTIFICATION OF THE QUALITY BY CGCRI

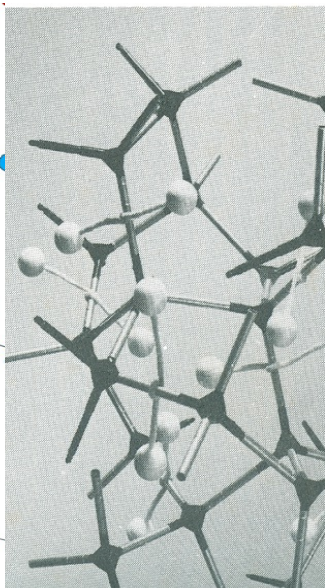
Borosilicate glass frit developed at CSIR-CGCRI, Kolkata



Borosilicate glass beads developed at CSIR-CGCRI, Kolkata

Exchange of Technical Agreement document with M/s H R Johnson, Mumbai

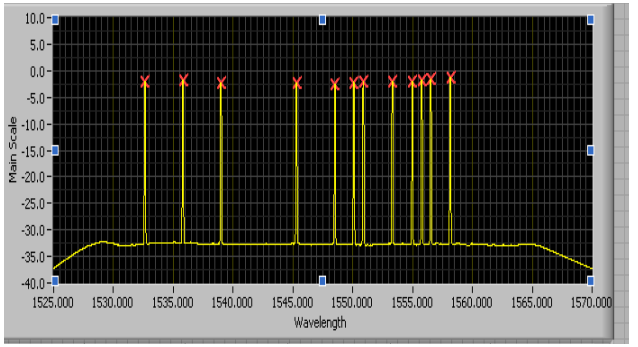




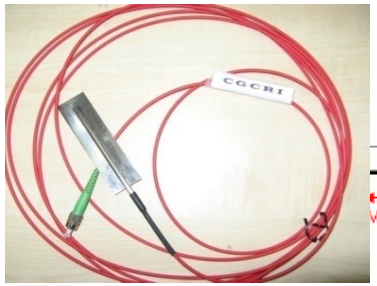
Er Doped Fiber Amplifier (EDFA)

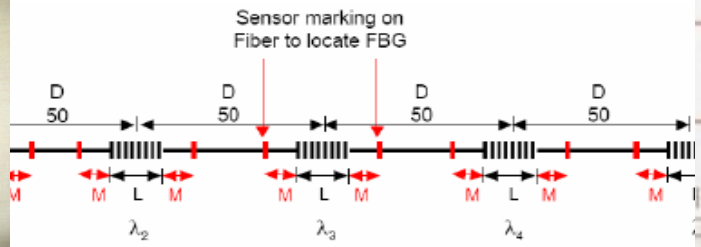
Module for 10Gbps 40λ network of BSNL

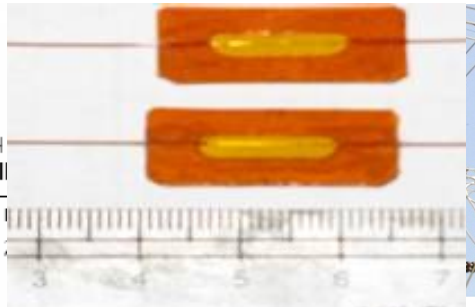
Technology transferred to and marketed by NEST Trivandrum



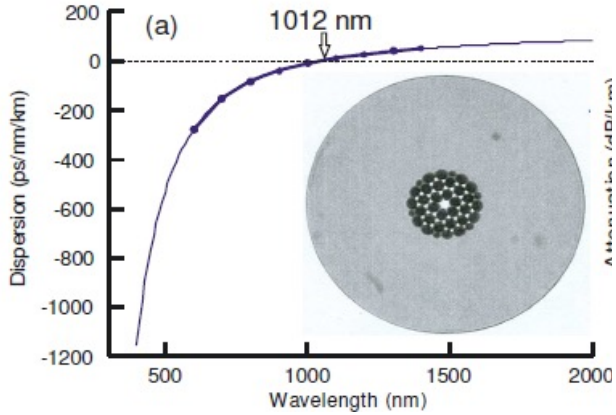
FBG Based Sensor for Structural Health Monitoring

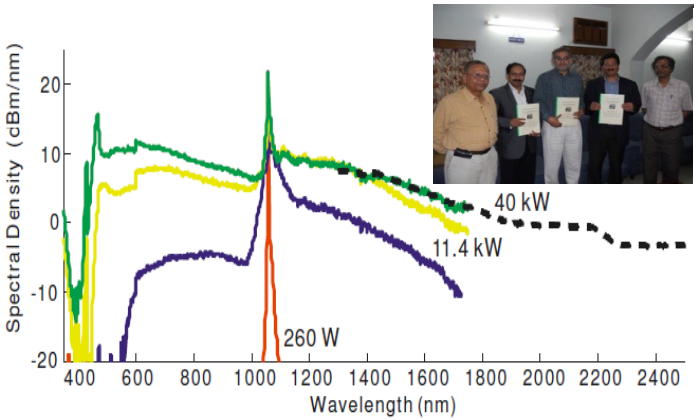


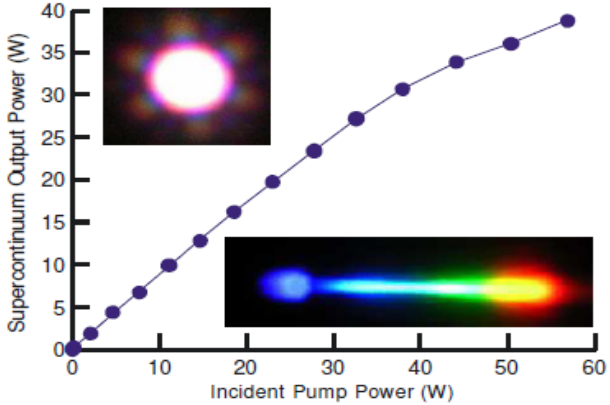




DIODE PUMPED PCF BASED 39 W SUPERCONTINUUM LIGHT SOURCE



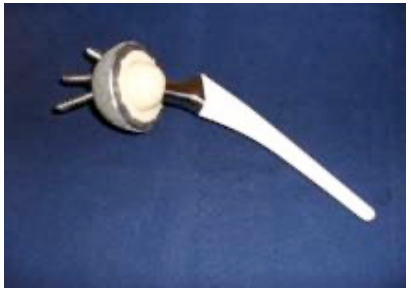




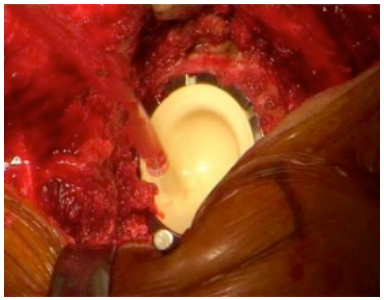
HIP JOINT PROSTHESIS

Hemi- and total hip joint prosthesis

Hip implants with ceramic head and cup



Ceramic-to-Ceramic total hip joint prosthesis with HAp coated stem



During the surgery

Post operative X ray

Patient walking unaided

CSIR Technology Award 2010 to Late Dr D Basu and Group, CSIR-CGCRI

Societal Impact of CSIR Developed Ceramic Hip Prosthesis:

- About 4 lakh patients need hip-replacement every year in India
- CSIR-CGCRI collaborated with Padmabibhushan Dr K H Sancheti
- Imported prosthesis costs > Rs 1.5 lakh, hence un-affordable to most
- Technology transferred to an Indian Company for low cost manufacture
- Clinical trials over, several patients operated, ethical clearance obtained
- Current cost is about FIVE times cheaper than international/imported price
- Service life in ceramic joint is longer (at least double) than in metallic implants

CSIR Intervention Makes Tile Manufacturing Profitable

Increasing Affordability through Import Substitution

Fired tiles from roller hearth

Packing of finished product

Interaction with tile manufacturers

Background

Vitrified porcelain tiles contains ~ 20wt.% (imported) Ukrainian Clay ►Raises cost of production ►Imposes import dependence

CSIR Intervention

CSIR-CGCRI Naroda Centre developed an alternate body mix for granito tiles by replacing expensive Ukraine clay with a local clay through a novel/inexpensive innovation

Technological/Societal Benefits

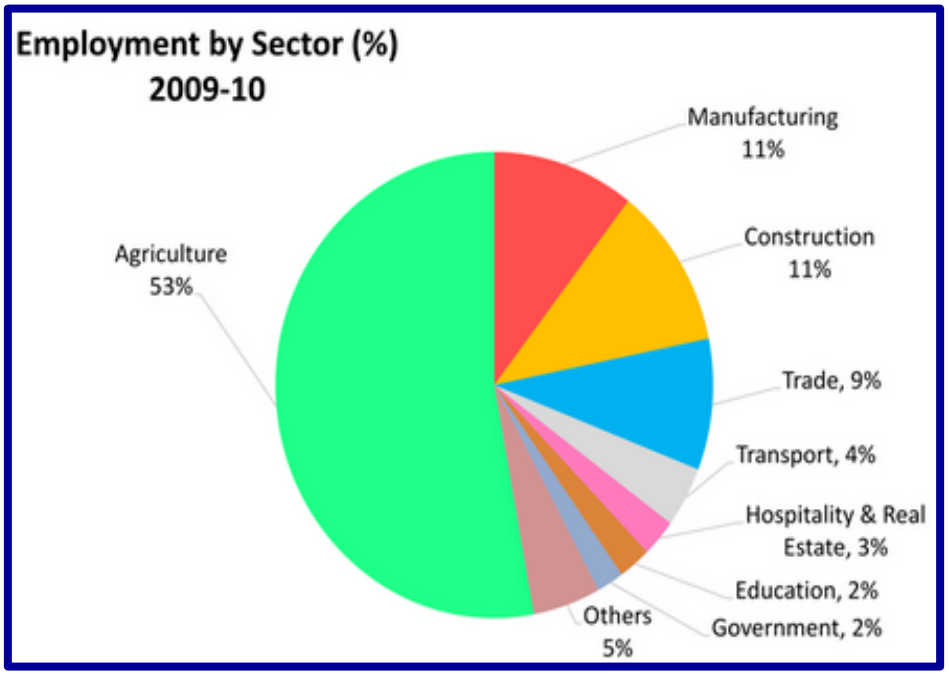
- **Ukraine clay needed in body mix reduced from 20% to < 1%**
- **Monthly import reduced from 11,950 to 3500 million ton**
- **Number of units jumped from 14 in 2005 to 64 in 2011**
- **Monthly production (average) increased by 6 fold**
- **Net profit margin rose by Rs 3.56 crore per annum per unit**

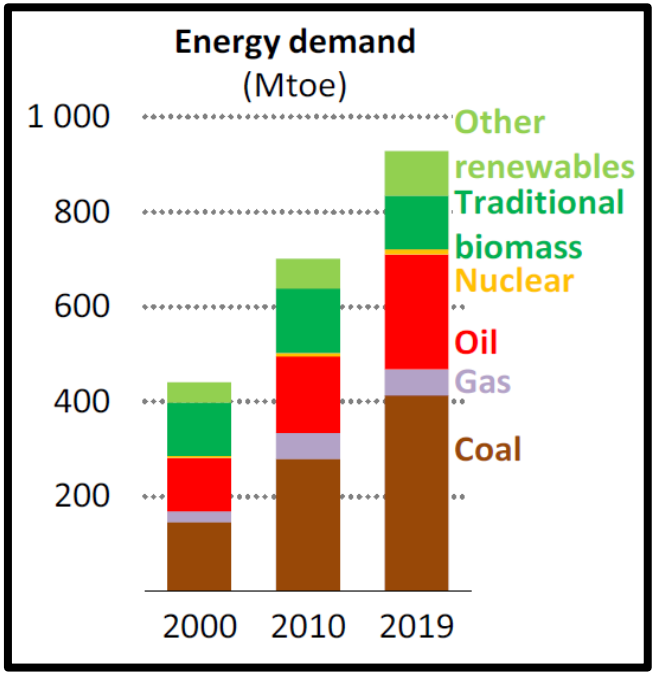
INDIA - UNITY IN DIVERSITY

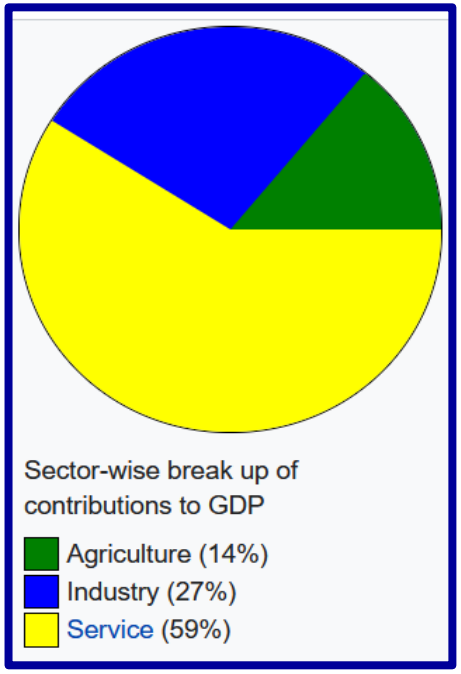
INDIA AT A GLANCE – RELEVANT FACTS

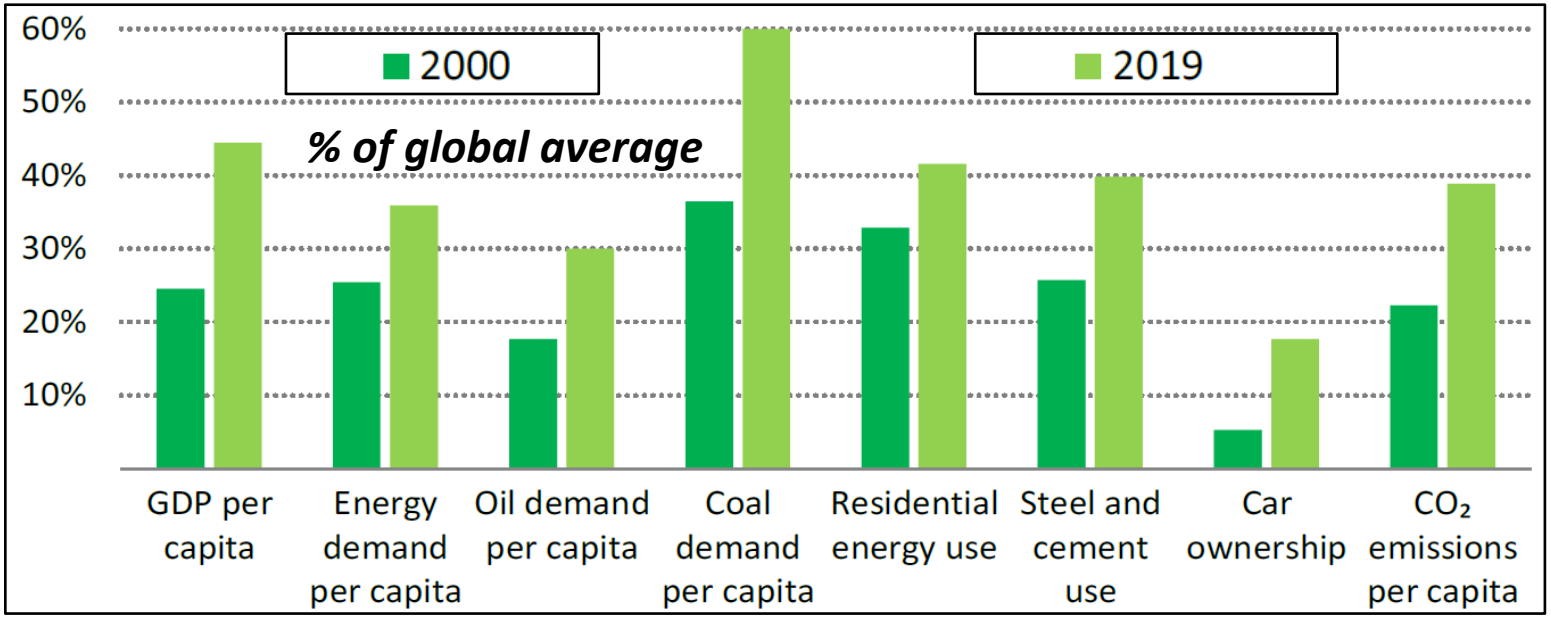
- **History:** One of the oldest (> 5000) and richest (until 1700) civilization
- **Size:** 7th largest area (3,287,263 km²), 2.4 % earth's surface
- **Expanse:** 3214 km north-south; 2933 km east-west; 7517 km coastline
- **Population**: ~1.4 bn (2nd most populous); > 800 m below 35 yrs
- **GDP:** $ 3.46 trillion (5th, nominal); $ 11.67 tn (3rd, PPP terms)
- **S&T:** Successfully conducted **Lunar and Mars** missions; **satellite** launching capability; **nuclear energy** harnessing state
- **Life expectancy** (65.4 years) is close to world average (69.8 years)
- #1st: Drug/pharma; #2nd: Steel, Cement, Coal, Telecom, Food + Argi, #3rd: Electricity, Construction/Real estate; #4th: Auto, Mining; 9th: Aviation
- **Diversity:** 28+9 = 37 states/territories, 22 languages, 8 main religions
- **Economy: Income** per capita ~ **$2,500 (142nd)**; Population (BPL) ~ 22%; **HDI**=132nd; Unemployment~7%; GII=40th, Literacy~74 %; **GER**~20% (primary=93%, secondary=69%, post-secondary=25%)
- **Challenges:** ***poverty, hunger, health care concern, security threat*** Export ($421bn) < Import ($612bn); Inadequacy of basic amenities
- **Engineering solution needed** for: **energy**, **defense, water, education**

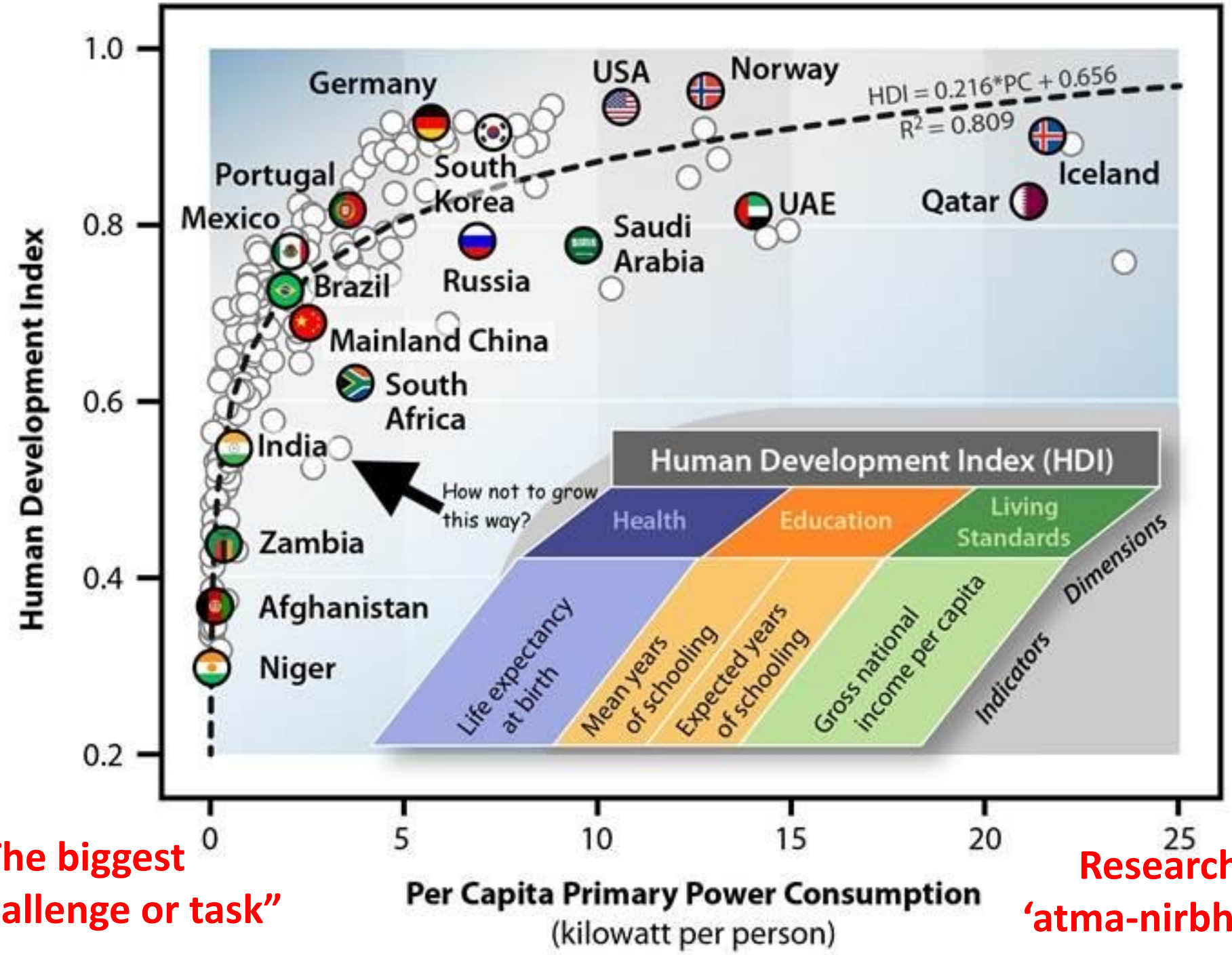
Puzzles of Indian Economy







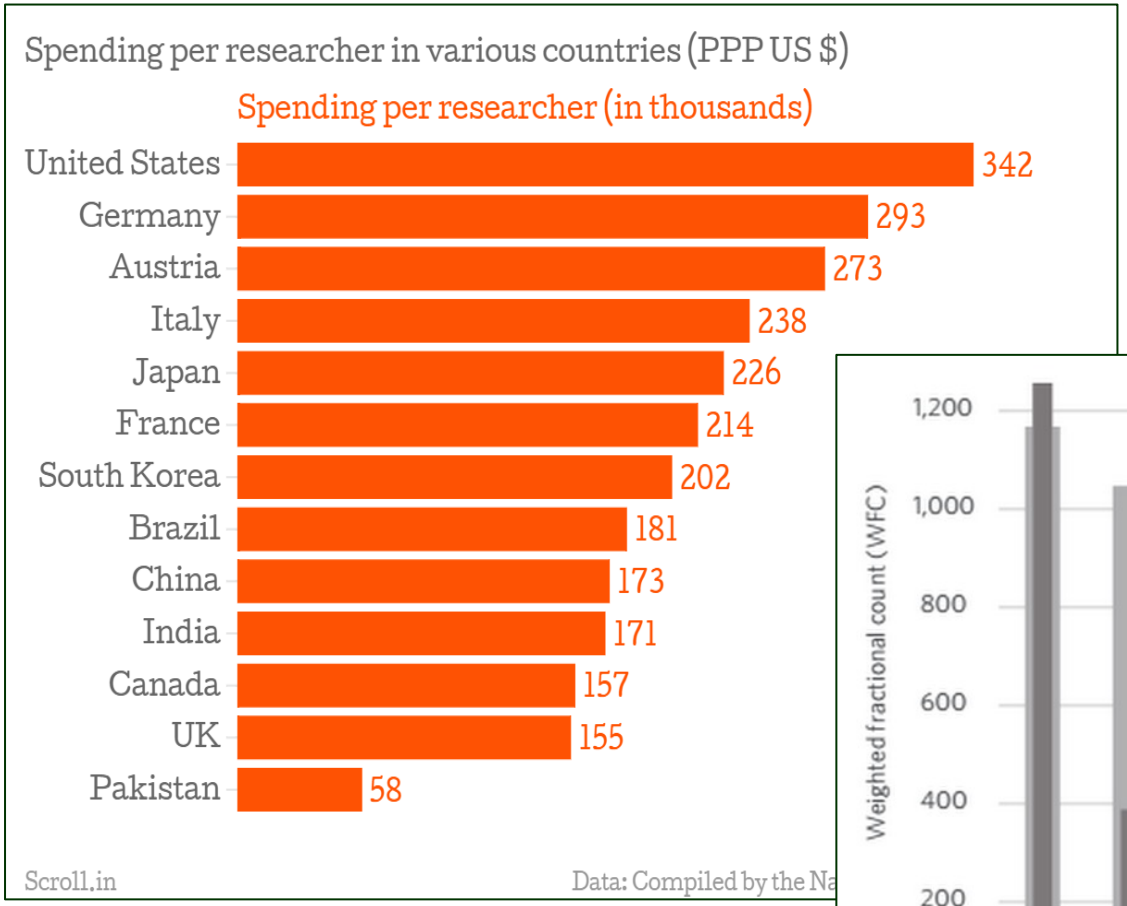




"The biggest challenge or task"

Research and 'atma-nirbharta'

Where do we stand and why?



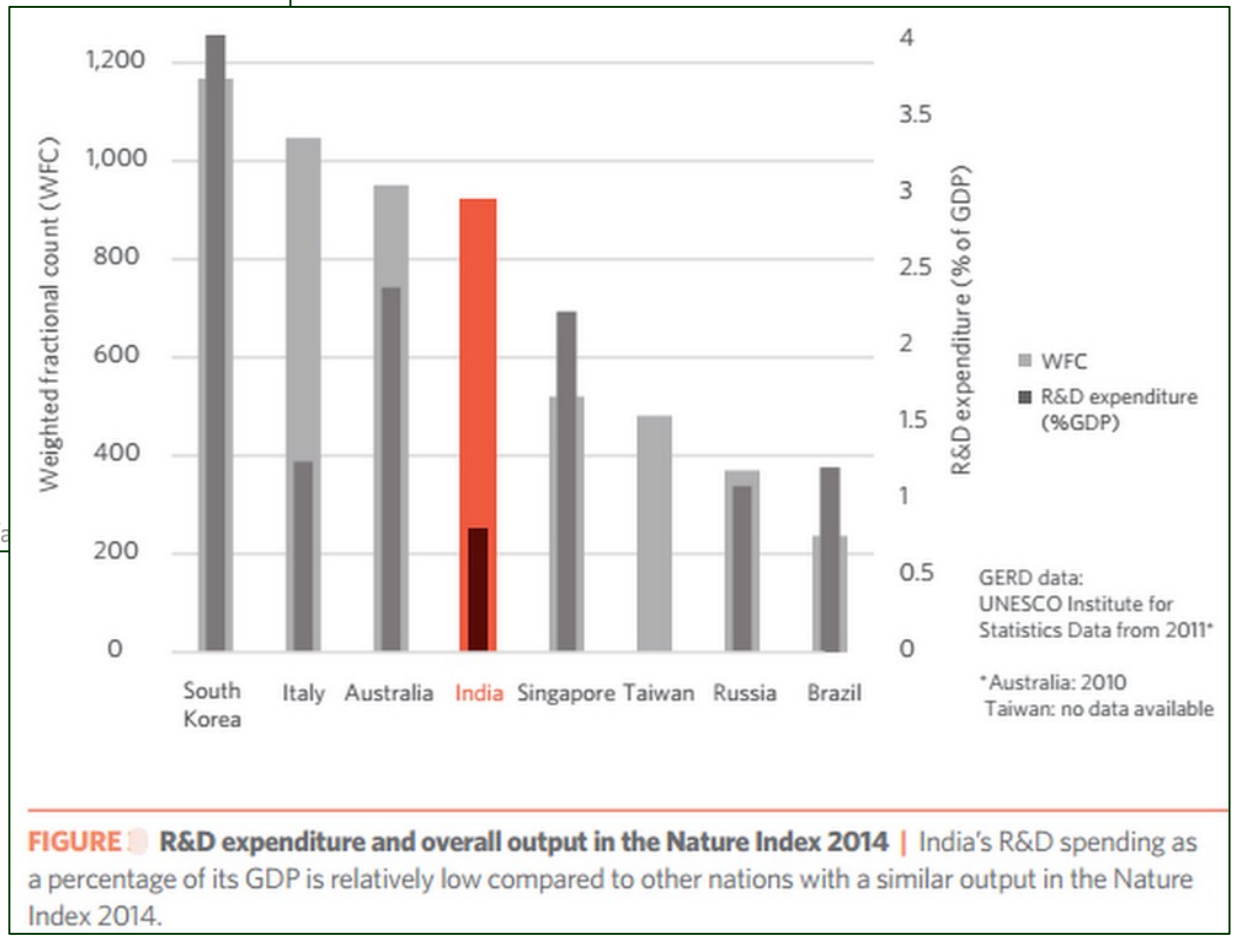


FIGURE **R&D expenditure and overall output in the Nature Index 2014** | India's R&D spending as a percentage of its GDP is relatively low compared to other nations with a similar output in the Nature Index 2014.

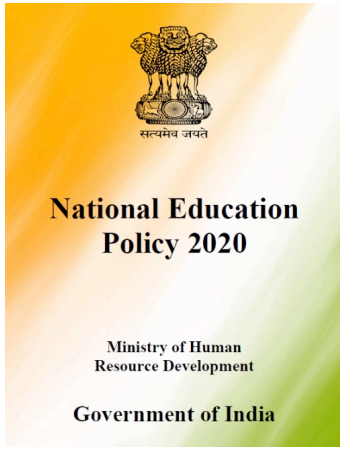
Why translational research is difficult in academia?

- **Technology development** is painfully time consuming, highly prone to the risk of failure, possibly less rewarding and glamorous
- **Infrastructure** needed is large and expensive (equipment, synthesis or processing set up, trial/test rig, etc.) and difficult to maintain
- **Rules, regulations and systems** are not conducive or encouraging
- **Initiative and output,** during development, is not easily quantifiable
- **Evaluation/assessment** in academic world is heavily biased only towards knowledge generation/dissemination but not translation
- **Translational effort** is usually a team effort and difficult to identify the real inventor/innovator (who owns the invention/innovation)?
- **Commercialization mechanism** (bench scale to saleable product) usually does not exist in academic set up
- **Saraswati versus Lakshmi** – strange perception that pursuit of knowledge has nothing to do with monetization and a professor must remain perpetually poor

National Education Policy 2020

THE VISION OF THIS POLICY:

- ✓ Transforming India, that is Bharat, sustainably into an *equitable and vibrant knowledge society*, by providing high-quality education to all, and thereby making India a global knowledge superpower
- ✓ Fundamental duties and constitutional values, bonding with one's country: deep-rooted pride in *being Indian*
- ✓ Global well-being, thereby reflecting a truly *global citizen*
- ✓ 66 page document divided into 4 parts and 27 chapters
- ➢ *Approved by the Union Cabinet on 29th July 2020, replaces NPE 1986*



Important Features (I):

- ❖ **Aspirational but grounded in reality**
- ❖ **Providing sustainable growth model**
- ❖ **Offering universal access to education**
- ❖ **Aimed to build social, moral and emotional strength and character**
- ❖ **Vocation training and teacher training**
- ❖ **Research essential for quality teaching**
- ❖ **Poor quality universities – to phase out**
- ❖ **Government or private – equivalent**
- ❖ **New multi-disciplinary courses**

Important Features (II):

- ➢ **Shift of focus – teaching to learning**
- ➢ **Removal of strict divisions (science, humanities, commerce, engineering**
- ➢ **Job creation not only job seeking**
- ➢ **Flexibility of degrees – length, choice**
- ➢ **Common entrance test (Olympiad)**
- ➢ **Difference public and private removed – education for all**
- ➢ **Foreign direct investment (FDI) open**
- ➢ **Foreign campus of Indian universities**

What is NEW?

- Degree not by rote or courses but by research (holistic framework)
- Multiple lateral entry and exit options (flexible credit transfer)
- Credit accrual system (digital) – academic credit bank (new)
- Age limit raised, extended, even removed – age no barrier
- Olympiad score based entrance to college/university – new concept
- Graded autonomy of Board of Governors – academic+financial both?
- Accreditation of institutions is a MUST – constant evaluation
- Vocation and professional courses, Multi-disciplinary, lateral entry
- Skill development and enhancement – curricular and vocational
- Online course and digital platform – open, digital, flexible platform
- Department of Education in all universities (train the trainers)
- International student offices and drive – go global
- Doctoral students to take courses on teaching and pedagogy
- PG program – one-two years (integrated bachelor + master degree)
- Outlay on Education ~ 6% of $3 trillion GDP (≡ Rs 1.26 lakh-crore)
- Institute development; National Research Foundation (NRF)

Synergy in Science-Engineering-Technology

- Science is pursuing the truth relentlessly, regardless of its necessity or immediate scope of application. Science provides clues, if not answers. Science extends as far as imagination goes. Science never fails, scientists can ….
- Engineering is all about enabling and providing solutions borrowing from the fundamentals of science
- Technology is the last mile for societal benefit, based on scientific discovery and engineering inventions & innovations
- Let us ensure that science ⇔ engineering ⇔ technology in India complement each other and flourish together so that our society soon achieves the desired culture, growth & prosperity
- If India has one unique resource and strength that entire world envies, that certainly is the *demographic dividend – YOUTH*
- Engineering can ensure self reliance and hence self esteem

INCREDIBLE INDIA

– DEMOGRAPHIC DIVIDEND

THANK YOU ♠ NAMASKAR ♠ JAI HIND