TRANSLATING SCIENCE INTO TECHNOLOGY AND TO PRODUCTS: INDIAN EXPERIENCE

Dr. S. Sivaram
National Chemical Laboratory,
Pune-411 008, INDIA

Tel : 0091 20 2590 2600
Fax : 0091 20 2590 2601
Email : s.sivaram@ncl.res.in
Visit us at : http://www.ncl-india.org

Workshop on
Nanotechnology : Making the leap toward commercialization

January 7,2008

INDIA AND TECHNOLOGICAL INNOVATION : AN EVOLVING LANDSCAPE

- **India is poised to play a key and distinctive role in the emerging knowledge economy**
- **A long national tradition of scholarship in arts and sciences and a burning desire among the young to be educated against all odds**
- **A strong and growing educational infrastructure to cater to the aspiring millions of young men and women**
- **Generous state support to S&T**
- **India is becoming attractive for Indian professionals to either stay back or return back**
- **India's ensuing demographic profile will make available more educated and qualified professional in the age group of 20 to 35, the youngest work force in the world**

THE INDIAN NATIONAL INNOVATION SYSTEM : HIGHER EDUCATION AND RESEARCH

- **IIT = 8, IIM =7, NIT = 10, IISER = 5, Central Universities = 18, State Universities = 217, Private Universities = 130, Colleges = 17,625, Institute of Medical Sciences = 6, Medical Colleges = 783, Teacher Training Colleges = 900**
- **Total enrolment = 15 million**
- **Number of engineers graduating per year > 500, 000**
- **Number of Ph.D's granted in science and engineering = 6000; Target increase to 15, 000 by 2012**
- **Investment in higher education by Government = $ 1.5 billion (~ 30% of total budgetary allocation to education)**
- **Expenditure on education : 4.5% of GDP**

THE INDIAN NATIONAL INNOVATION SYSTEM : HIGHER EDUCATION

- **Central, state and private universities**
- **Indian Institute of Science (IISc)**
- **Indian Institute of Science Education and Research (IISER)**
- **Indian Institute of Technology (IIT)**
- **Indian Institute of Management (IIM)**
- **National Law University**
- **National Institute of Technology (NIT)**
- **Institute of Medical Sciences**
- **Industrial Training Institutes (ITI)**
- **Colleges**

THE INDIAN NATIONAL INNOVATION SYSTEM : INSTITUTIONS OF GOVERNMENT

- The Atomic Energy Research Establishments
- The Council of Scientific and Industrial Research
- The Indian Council of Medical Research
- The Indian Agriculture Research Institutions
- The Indian Space Research Organization
- The Defense Research and Development Organizations
- The Indian Metrological Department
- Research Institutes of the Departments of Science and Technology, Biotechnology and Ocean Development
- Ministry of Non Conventional Energy Resources
- Ministry of Communication and Information Technology
- Ministry of Environment and Forests

HUMAN RESOURCES IN R&D : A COMPARISON

Country	Number of people in R&D*	% Science & engineering students**	R&D expenditure (% GDP)	Human develop-ment index rank
Japan	5,085	20	3.1	11
United States	4,526	19	2.7	10
Russia	3,415	40	1.2	62
S. Korea	2,979	41	2.5	85
China	633	25	1.2	63
Brazil	324	40	1.0	63
India	120	20	1.0	127

* Per million
** in tertiary education

Source : UNDP

EXPENDITURE ON R&D BY FIELD OF SCIENCE (2000)

	% Share expenditure	
	Public	Private
Natural Science	87	13
Engineering and technology	88	12
Medical science	35	65
Agriculture	77	23
Total	72	28

INDIA`S SCIENTIFIC PROWESS

- Number of science Ph D's per year : 5000
- Number of engineering Ph D's per year : 1000
- Number of scientists working in public R&D : 1,20,000
- Number of scientists working in private R&D : 37,000
- Number of scientists retiring per year : 5,000

Wealth creation through science and technology innovations must largely occur in public institutions !

RESURGENCE OF INDIAN NATIONAL INNOVATION SYSTEM : KEY DRIVERS OF TRANSFORMATION

Economic factors

- Strong economic fundamentals
- Appreciating rupee / huge foreign exchange reserves
- Increasing consuming class
- Strong top / bottom line growth in manufacturing and service sectors
- Exports emerging as focus of growth
- Competitive business environment

Enablers

- Improved infrastructure, such as, ICT, roads, primary / secondary school education
- Increasing private investments in higher education
- Venture financing for early stage innovation
- Public-private partnership in R&D
- Higher education in English
- Greater functional autonomy to R&D institutions
- Greater budgetory resources for NIS

Drivers

- India emerging as R&D hub for global companies
- Young S&T talent pool
- Favorable demography >70% population <35 years age!
- Favorable IP regime post 2005
- Strong diaspora with high technical and managerial skills

Performance of NIS

- Improved focus and spread
- Change in mindset – from being just generators of knowledge to creators of wealth

Products and services for the emerging markets : Wealth at the bottom of the pyramid

- A four door automobile for less than $ 2500
- A mobile phone for less than $ 25
- A PC for less than $ 200
- Lowest cost producer of off –patent generics
- Long distance calls at less than 10 cents per minute
- A heart valve for less than $ 400
- A by pass coronary surgery for less than $2500
- A cataract eye surgery at less than $100
- A baby diaper or female sanitary napkin at less than 10 cents per single use
- Shampoos , tooth paste and other personal care products at less than 3 cents per single use
- Vaccines that can be transported without a cold chain
- Full human genome sequencing in seven days at <$1000

➢ *Examine product design and development ground up*
➢ *Re-examine afresh cost -performance paradigms*

Summary

- Indian economy is turning a corner and reaching a tipping point
- India is an innovation destination with a unique and valuable opportunity
- India's market place is opening up new opportunities for life style products driven by a nation with largest number of young people with high disposable income

India is a developing country with a highly developed intellectual infrastructure

Jack Welch, Ex CEO, GE

COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH (CSIR)

- A 64 year young, not-for-profit R&D organization
- 38 laboratories ; several outreach centers
- 22,000 strong work force, 5000 scientists / technologists
- 2,500 Ph. D`s
- CSIR's R&D areas :

  Aerospace and aeronautics, Bio-sciences and bio-technology, Chemicals and chemical technology, Coal, gas and petroleum, Construction technology, Drugs and pharmaceuticals, Earth and ocean resources, Ecology and environment, Electronics and instrumentation, Food processing, Leather and leather goods, Machinery and equipment, New materials, Mining and metallurgy

CSIR : TECHNOLOGY FOCUS

- **Technology for economic growth**
  - **To enter into partnership with industry**
  - **Emerge as a significant global player in public R&D**
  - **Assist the nation in deriving enhanced and sustainable value from indigenous resources**
  - **Provide S&T based solutions to mitigate the vulnerability and improve the quality of life, especially, for the weaker and disadvantaged sections of the society**

NATIONAL CHEMICAL LABORATORY

A SNAP SHOT

- Established : 1950
- Location : Pune, India
- Total personnel : 1700
  - Permanent Staff : 886
    - Scientific : 264
    - Technical : 383
  - Research Fellows (CSIR, UGC) : 416
  - Project Staff (M.Sc's) : 379

One of the largest publicly funded research institution in India

NATURE OF RESEARCH

- Contract research
  - Client / Business driven
- Basic research
  - Curiosity driven

CREATING VALUE TO ITS CUSTOMERS

- **NCL' s portfolio of programs include process and product development, reaction engineering, pilot plant experiments, process design and engineering, process simulation and modeling, computational modeling, technical consulting and continuing education**
- **NCL has the capability to deliver solutions to customers across the full spectrum , from laboratory scale development to design and operation of batch and continuous pilot plants and preparation of basic engineering packages for chemicals , polymer and materials**
- **NCL is focused on creating value to customers through innovations, IP, development of non-infringing processes and science based understanding of complex phenomena**

TECHNOLOGY AND INDUSTRIAL RESEARCH : PRODUCTS IN MARKET (2002-)

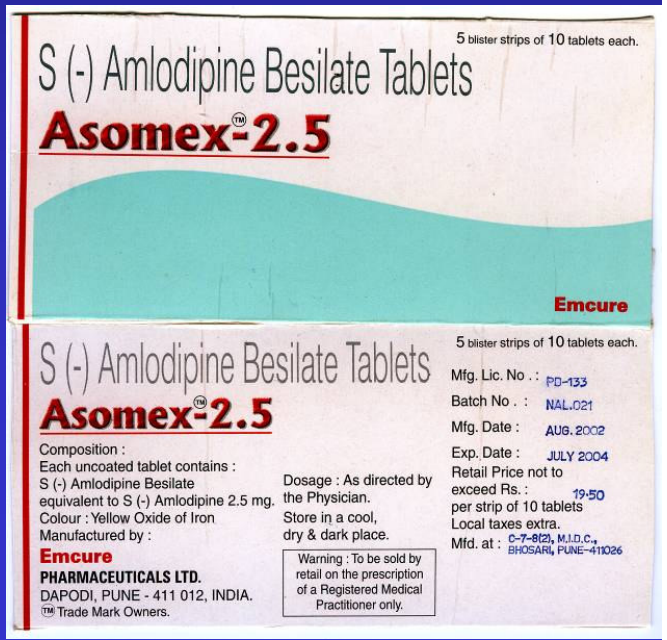
Membrane Filters (I) Ltd.

Ocular implants (Biopore)

Fine chemicals

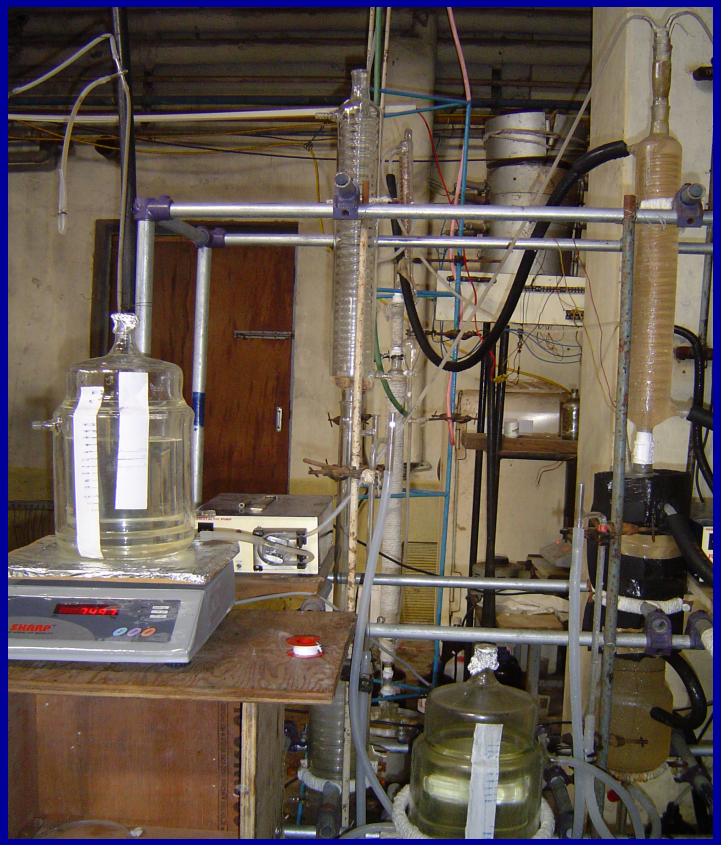
- **THPE (Excel Industries)**
- **ATBS (Vinati Organics)**

Emcure Pharmaceuticals



TRANSLATING CHEMICAL PROCESSES FROM BENCH TO MANUFACTURING

2005

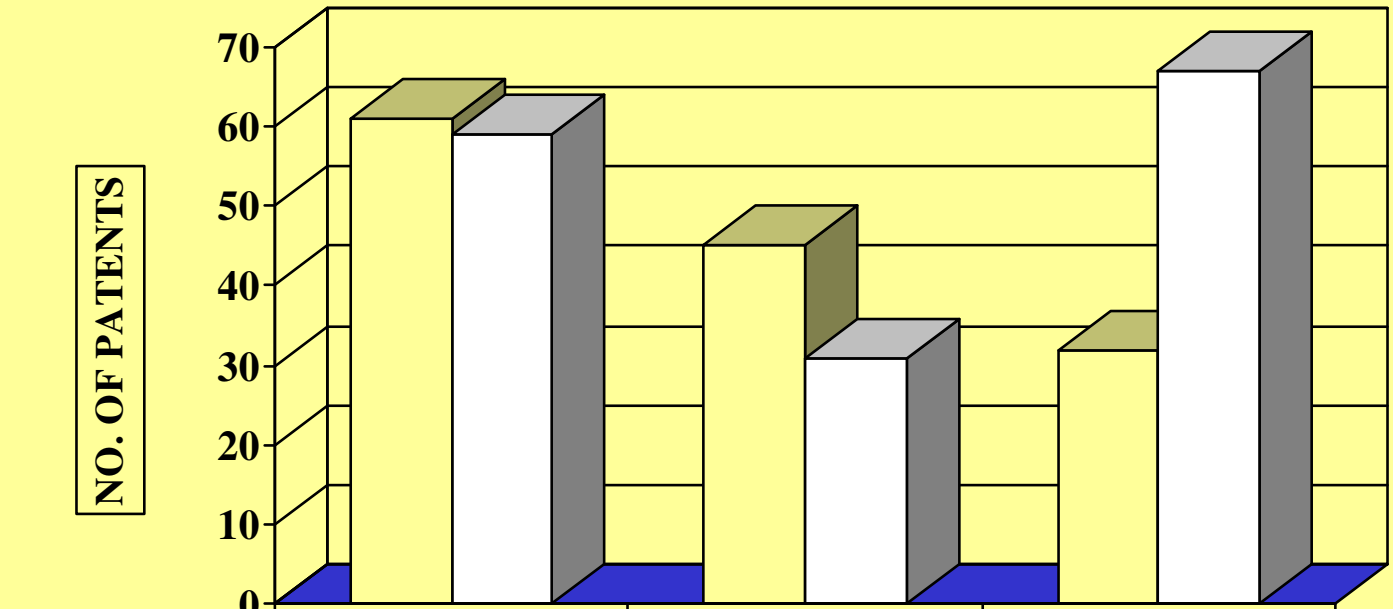


Bench scale Epichlorohydrin facility at NCL

2007

3000 tpa Epichlorohydrin plant at Rayong, Thailand

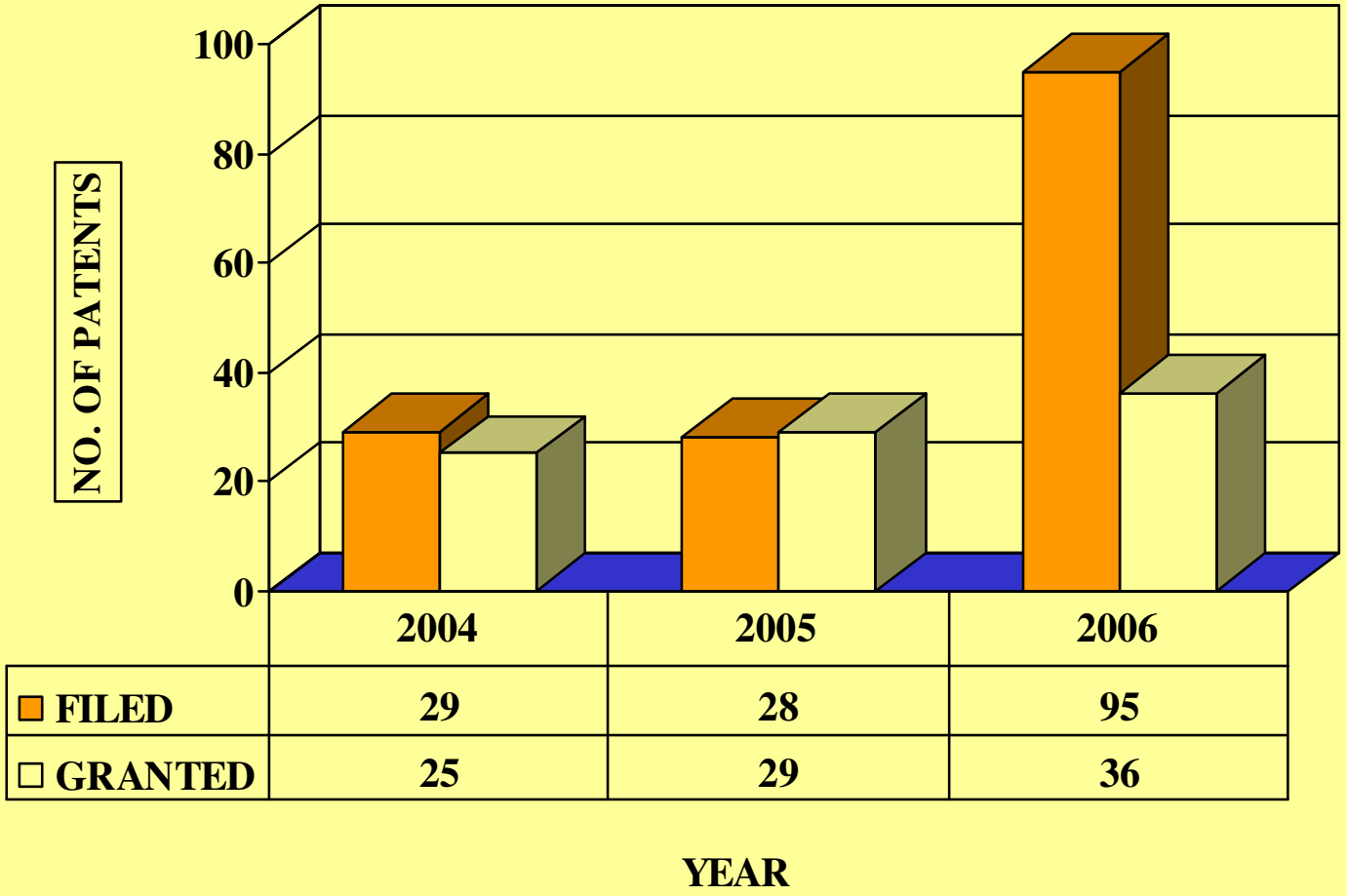
INDIAN PATENTS FILED & GRANTED (2004-2006)



	2004	2005	2006
FILED	61	45	32
GRANTED	59	31	67

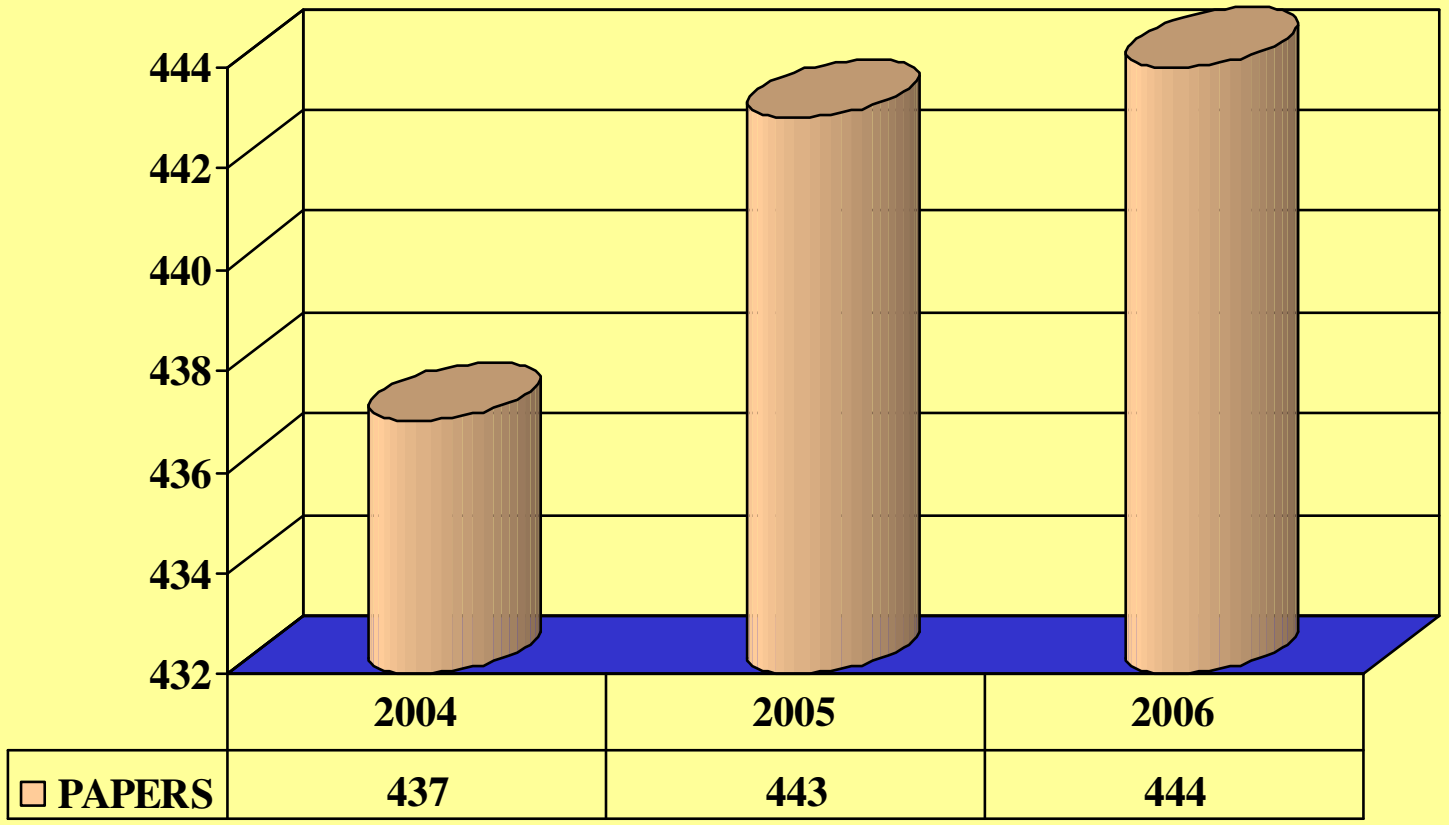
YEAR

FOREIGN PATENTS FILED & GRANTED (2004-2006)



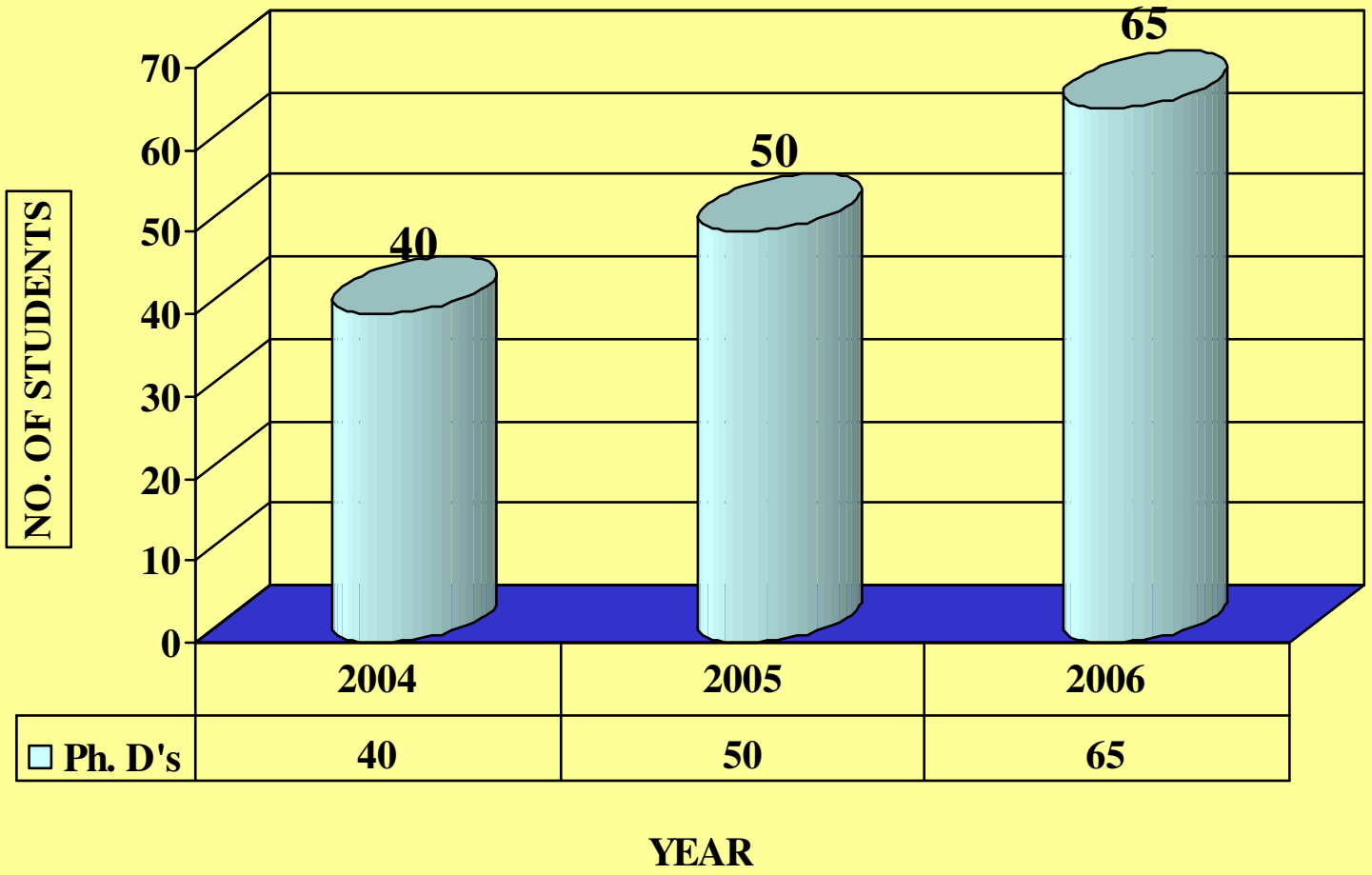
RESEARCH OUTPUTS AT NCL (2004-06)
PUBLICATIONS

Total Number of Papers (1950-2006) : 9616



Ph.D's AWARDED (2004-2006)

Total Number of Ph D Thesis (1950-2006) : 1566



EXISTING BUSINESS MODELS

- **Sponsored / Collaborative /contract research**
- **Technical service**
- **Consultancy**
- **IP licensing**
- **In-house development of processes and products followed by licensing (with or without IP)**

KEY FEATURES OF THE PRESENT BUSINESS MODELS

- **CONSULTANCY**
  Problem solving for industry
  Often knowledge required is not scientifically challenging

- **CONTRACT RESEARCH**
  An industrial project executed at CSIR Lab/s

  Indian Industry
  (a) Non-availability of required infrastructure
  (b) Non-availability of required technical skills at industry

Often, it is cost effective for an industry, when such requirement is infrequent. Scientific input required for such projects are not of cutting edge.

KEY FEATURES OF THE PRESENT BUSINESS MODELS

- **TECHNOLOGY TRANSFER**

(a) Reverse engineering/technology ; Increasingly less relevant

(b) Knowledge driven innovation

Industry often lacks adequate resources to convert early stage knowledge into marketable technology

- **COLLABORATIVE RESEARCH**

CSIR and industry both participate intellectually in co-development. However problems are very context specific and does not lead to generation of globally competitive new knowledge

EFFECT OF PRESENT BUSNESS MODELS ON SCIENTISTS

- **CONSULTANCY**

  Scientists are in comfort zone and financially rewarded. Consequently, high risk of obsolescence

- **CONTRACT RESEARCH**

Scientist's science base erodes and Institutions loose sight of its mandate and ability to generate cutting edge knowledge. Institutions generate cash but not wealth. Scientists are financially benefited in the short term.

EFFECT OF PRESENT BUSINESS MODELS ON SCIENTISTS

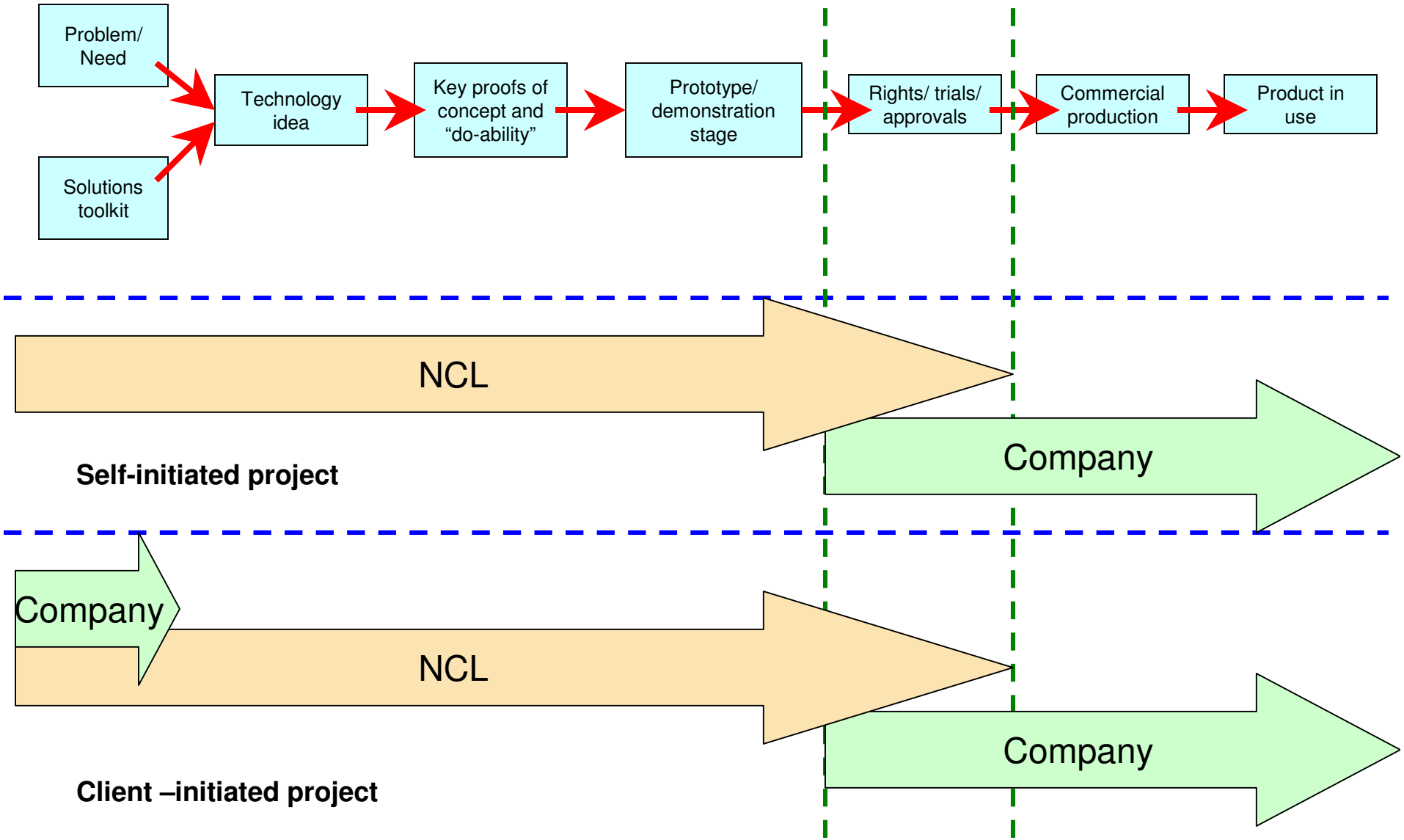
- **TECHNOLOGY TRANSFER**

  - **Technology developed is not aligned to market/customer needs**
  - **Down payment fee for technology transfer is perceived high by Industry. As a result the technology is either not sold or often under costed to be sold.**
  - **Industries confidence in CSIR technology is limited due to the limited stake of the laboratory in the technology transfer. Scientists are benefited very little for taking high risk.**

- **COLLABORATIVE RESEARCH**

  - **CSIR and scientists stand to gain if project is selected well . Part of the project cost is covered and if it leads to IP generation then there is a chance of wealth generation for CSIR.**

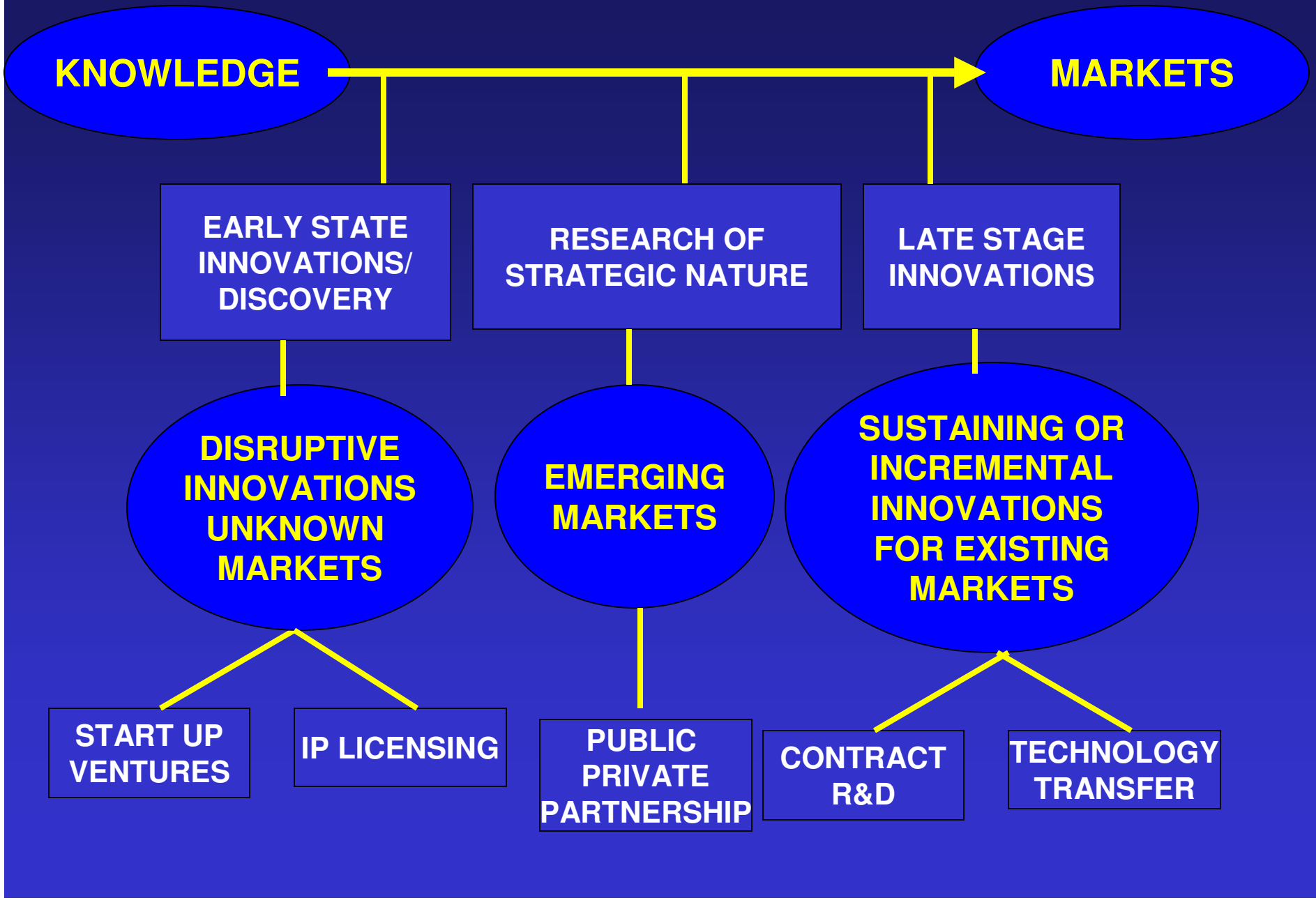
Technology development & transfer: Conventional models

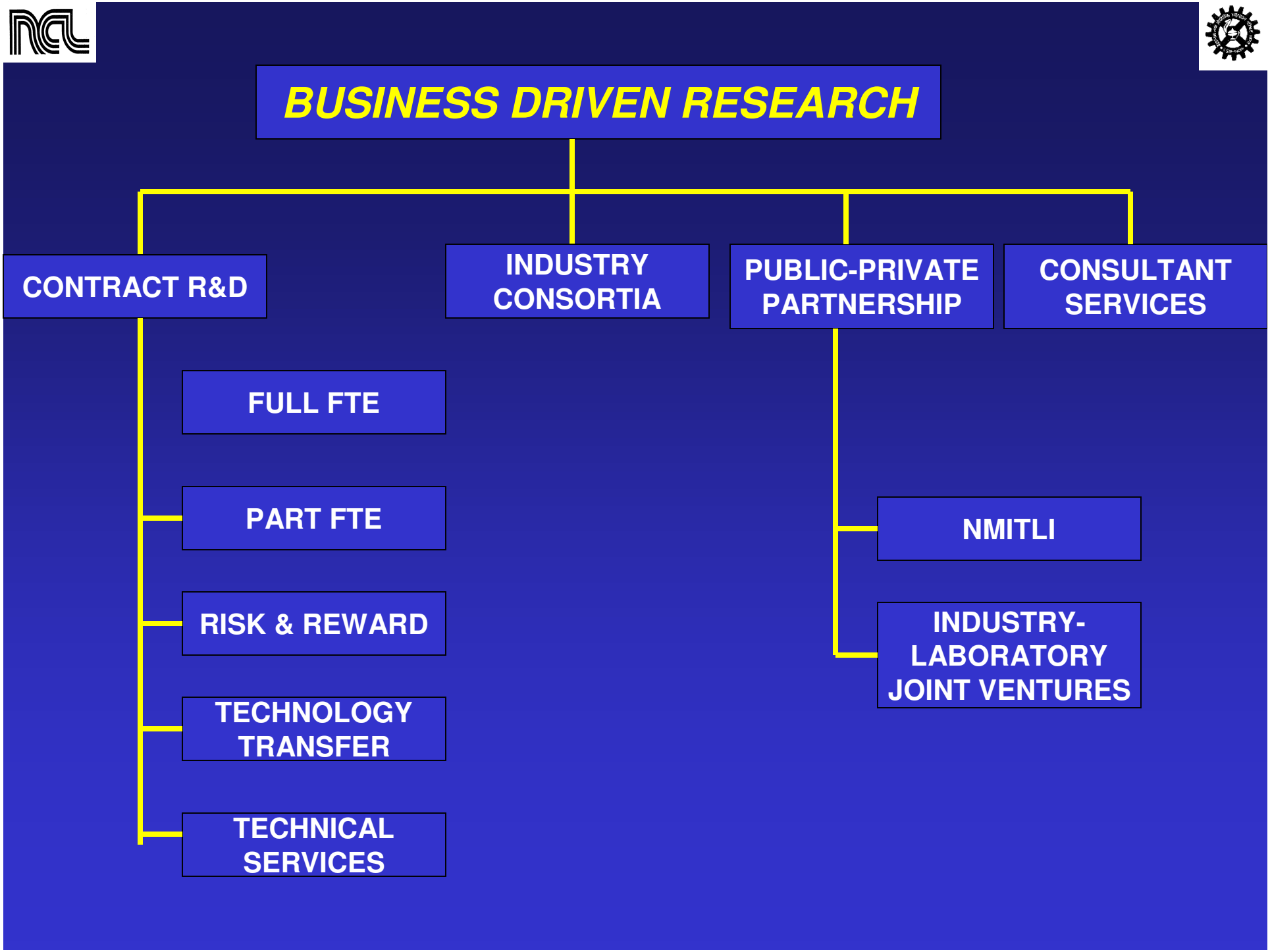


NEW INITIATIVES

- **Mission mode programmes through public-private partnership (NMITLI - New Millennium Initiative for Technology Leadership for India)**
- **Knowledge alliances through public-private partnership; creating jointly owned and managed research entities with industry**
- **Encouraging knowledge driven entrepreneurship**
- **Co-share / co-locate industry R& D and R&D service organizations in CSIR laboratories**

LINKING KNOWLEDGE TO MARKETS




BUSINESS DRIVEN RESEARCH
CONTRACT R&D
INDUSTRY CONSORTIA
PUBLIC-PRIVATE PARTNERSHIP
CONSULTANT SERVICES
FULL FTE
PART FTE
RISK & REWARD
TECHNOLOGY TRANSFER
TECHNICAL SERVICES
NMITLI
INDUSTRY-LABORATORY JOINT VENTURES

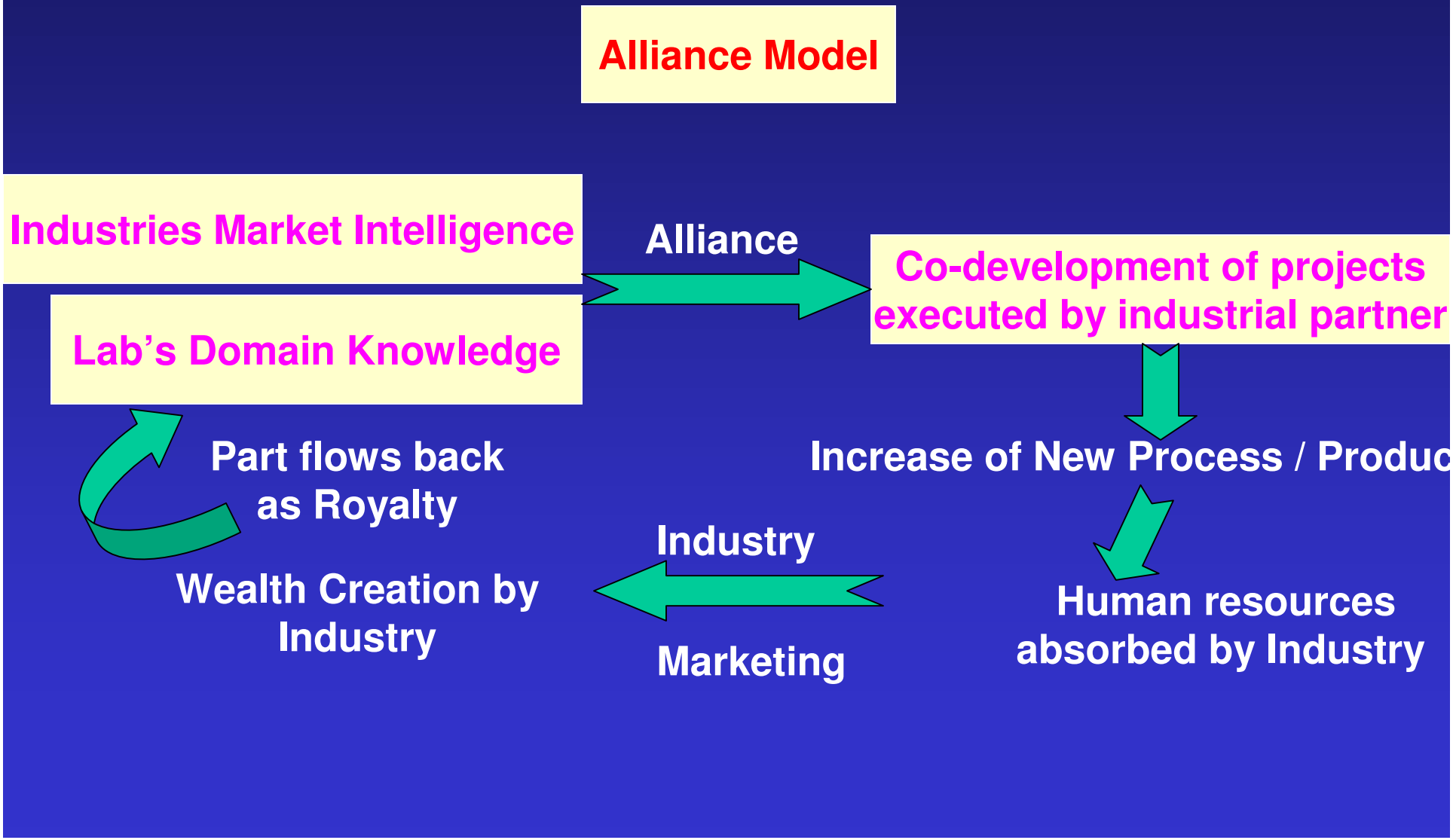
PUBLIC-PRIVATE PARTNERSHIP : CONSORTIUM MODEL

- **Areas of common interest to a few companies – access to generic knowledge**
- **Consortium agreements with service modules**
- **Project Advisory Boards with company participation**
- **Benefit sharing and possibility of bilateral projects**
- **Ownership of IP and proprietary knowledge vests with NCL/CSIR**
- **Rights of first refusal to consortium partners**

KNOWLEDGE ALLIANCES THROUGH PUBLIC-PRIVATE PARTNERSHIP

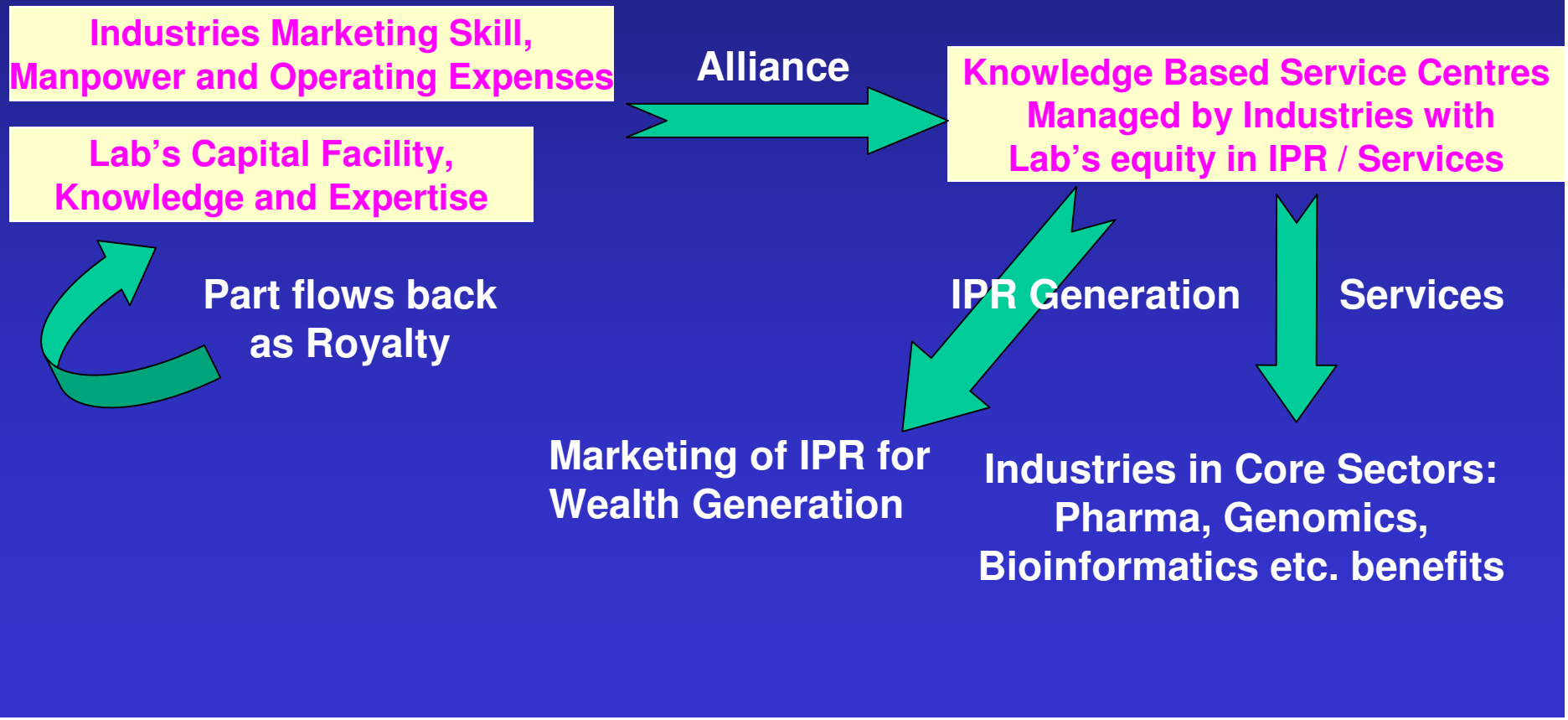
- **Industry partnership through consortia or bilateral agreements**
- **Relevant to knowledge intensive areas with anticipated long gestation period for attaining market maturity**
- **Opportunities for spin off technologies**
- **Industry has a ring side view of the developments through an annual subscription membership and periodic participation in presentation of results**
- **First right of refusal of licensing technology or IP; Free access to all knowledge of a generic nature**

PUBLIC PRIVATE PARTNERSHIP MODELS

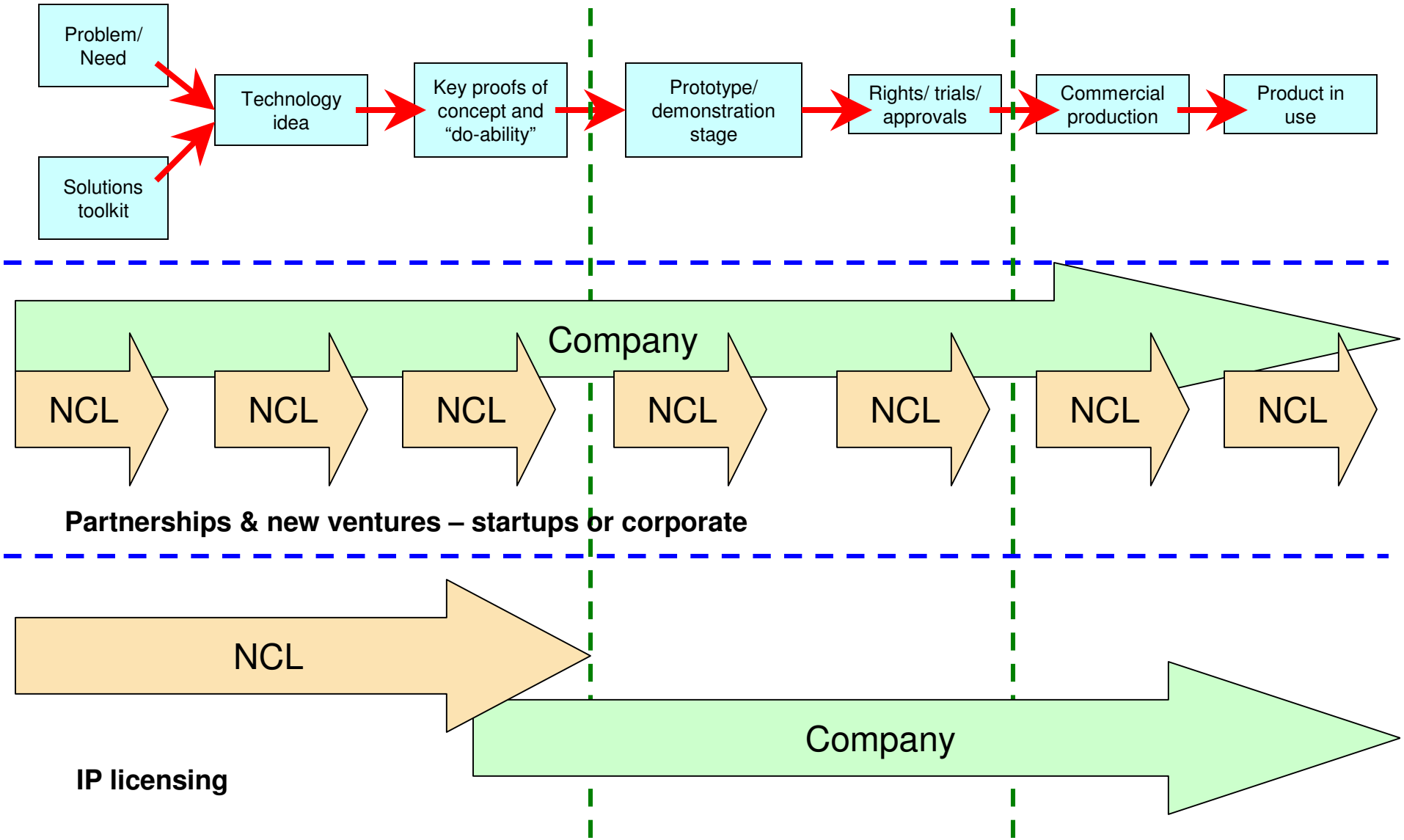


PUBLIC PRIVATE PARTNERSHIP MODELS

R&D Service Model



Technology development & transfer: Newer models



Technologies suitable for new ventures

- Products/ services based on the technology is clear.
- Value proposition of conceived product/service vis-à-vis competition is significant and easy to understand.
- Size and growth of potential market is attractive enough to justify the risk.
- The entrepreneur can be provided with sources of sustainable competitive advantage (ex: patents).
- Barriers to entry are not insurmountable (industry structure and competition; IP landscape)
- Typically:
  - Technology is a platform technology; results in more than one product based on same technology
  - Product/service can stand on its own; doesn't depend on too many complementary technologies/ investments.

SOME RECENT EXAMPLES FROM NCL

- ***EPICHLOROHYDRIN***

  -Process chemistry developed at NCL and IP generated: IP licensed to NCL; joint development of process technology and validation of process economics with industry; industry invests in commercial development

- ***VALUE ADDITION TO BIOMASS IN AN INTEGRATED BIOREFINERY***

  -Process developed at NCL in a public private partnership model with industry involvement from early stages of project conceptualization ; industry invests in technology demonstration and validation

- ***SOLID CATALYST FOR TRANSESTERIFICATION : BIO-DIESEL***

  - Basic chemistry discovered at NCL and IP generated : IP licensed to a start –up company, The start –up company raised finances based on the robustness of NCL IP; Technology validation by the company

TIME FROM BENCH TO TECHNOLOGY VALIDATION

- **Epichlorohydrin : > 7 years**
- **Biomass conversion : ~ 4 years**
- **Bio-diesel : < 3 years**

WHY SHOULD SCIENTISTS IN PUBLICLY FUNDED INSTITUTIONS BE INTERESTED IN TRANSLATING SCIENCE INTO PRODUCTS AND SERVICES

- Institutional compulsions
- Challenge of bringing good science to the market
- Financing R&D
- Becoming rich
- Altruism or doing good for the society which nurtured them; desire to act as transformers in society
- Creating wealth at the bottom of the pyramid
- Self actualization and growth motivation (according to hierarchy of human needs by Abraham Maslow)

At the end of the day, every scientist has this yearning for having been useful

BARRIERS TO KNOWLEDGE DRIVEN INNOVATIONS

- **Cultural barriers (knowledge is free, making personal wealth out of knowledge is not right, separating the goddess of knowledge from the goddess of wealth in the Indian pantheon of gods)**
- **Immaturity of markets and risk averse**
- **Inability to connect basic discoveries with potential applications**
- **Weak innovation eco systems (mentoring, venture and angel funds)**
- **Peer recognition systems heavily biased in terms of abstract academic research; not enough incentives for individuals who wish to translate science into products and services**

Innovation is no longer the ability to develop a new product and then just hoping that someone buys it. The new model asks where we should go, what should we bring with us , who should we partner with and what does the customer needs

R. Kumpf

VP, Future Business Group

Material Science Group


THANK YOU

Venture Center

Seeding Tomorrow's Enterprises Today

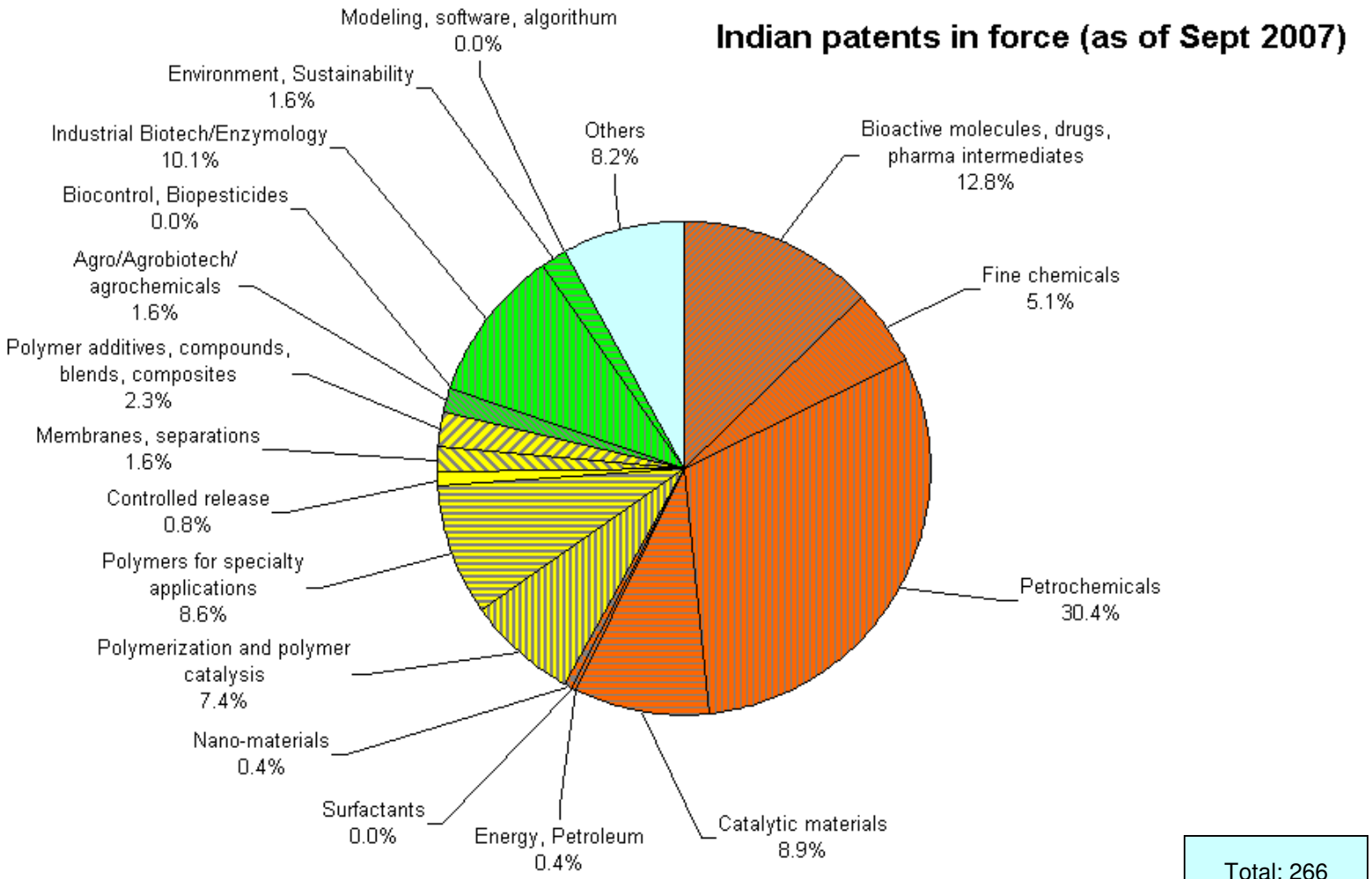
- The Venture Center is a ***technology business incubator*** specializing in technology enterprises providing products and services exploiting scientific expertise in the areas of ***materials, chemicals and biological sciences & engineering***.
- The Venture Center is the trademark of Entrepreneurship Development Center, a ***not-for-profit independent company*** floated by the National Chemical Laboratory, Pune.
- The Venture Center will initially occupy ***10,000 sq ft of built up area*** within the NCL Innovation Park and will consist of lab, office and hot-desking space for start-up companies, shared laboratories, analytical facilities, an information and learning center, and other supporting resources and services.

www.venturecenter.co.in

Potential products & services of resident companies

- Manufacturing
  - Materials science-centric products (Biomedical products and devices; Niche chemicals and nano-materials; Specialty materials science products for various sectors such as packaging, infrastructure, automotives, lifestyle products)
  - Biotech (for health, agriculture, energy, chemicals)
  - Niche scientific instruments and tools
- Software &Services
  - Process design and simulation
  - Research and technology management consulting; IP management services; Information research/ resources and scientific intelligence services
  - Drug discovery services

Indian patents in force: By markets



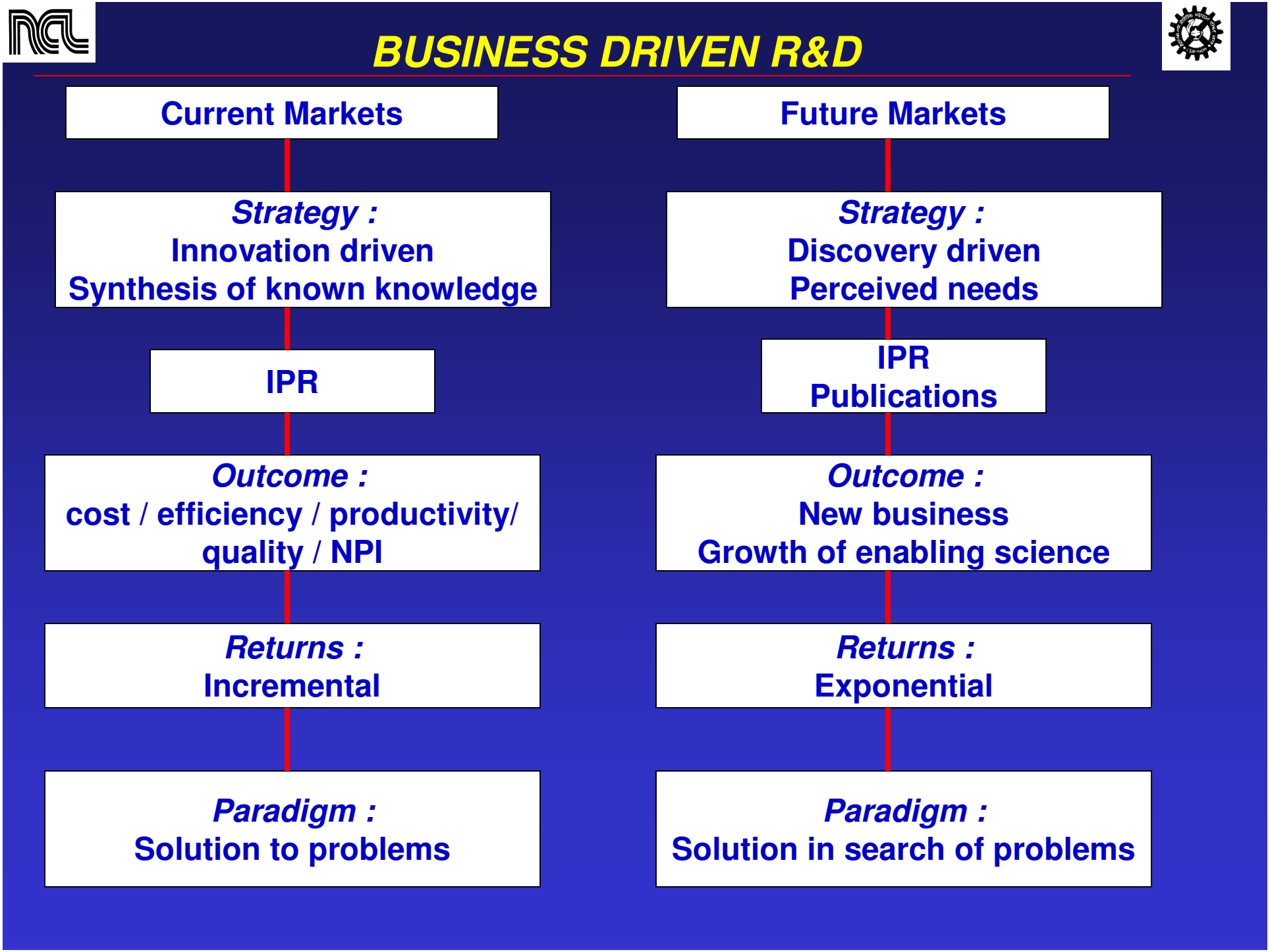
Example: THPE, GE Plastics/ Excel

THPE: 1,1,1-tris-(4-hydroxyphenyl) ethane

THPE is used as a branching agent in polycarbonates. The branching agents employed are tri-functional or higher molecules which can incorporate within a linear aromatic carbonate polymer chain and have a functional group left for further reaction which provides the branched molecule. Various branching agents have been utilized in polycarbonate to prepare a branched polycarbonate. One of them is compound 1,1,1-tris-(4-hydroxyphenyl)ethane. The utilities for these branched polycarbonates include film, fibers, sheets, tubes, rods and in particular blow molding applications such as bottles and various containers.

NCL developed a non-infringing, patented process for making THPE. NCL also developed a toll manufacturer for THPE in India for GE Plastics. Till then, THPE was produced by a single manufacturer in the world who could charge monopolistic prices.

BUSINESS DRIVEN R&D



BRIDGING THE CULTURAL DIVIDE : PRIVATE Vs PUBLIC

	Public	Private
Research focus	New discovery	Innovation
Know-how	To show	To keep
Mission	To generate results	To sell the results
Protection of rights	Less important	Very important
Decision	The Scientist	The Manager
Objectives	Fun, Folly, Freedom, Fame and Funds	Create value for shareholders
Time/Research duration	2 to 10 years <<time is quality>>	3 months to 2 years << time is money>>

S&T LINKAGES TO SOCIETY