Emerging markets, agility and advanced manufacturing: new opportunities

CENAMPS – United Kingdom
Centre of excellence for nanotechnology, micro & photonic systems
Speeding technology to market…

Dr Gerson Machado DIC PhD, Chief Executive Officer, gerson.machado@cenamps.com

AbineeTec 2003 - Sao Paulo 7th October 2003

www.cenamps.com

Nanotechnology, Micro and Photonic Systems

Agenda

- Overall nanotechnology and market issues
- Trends in international investment and technology
- Some opportunities in nanotechnology and nanomanufacture
- Polymers and electronics, minifabs opportunities
- UK MNT network and CENAMPS

Nanotechnology, Micro and Photonic Systems

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A 21st century world

Information Explosion

Complex Technologies

Global Economy

Cognitive Revolution

International Partnerships

Diverse Workforce

Finite Resources

Creative Transformation

Environmental Sustainability

Continuous Innovation

Demographic Shifts

Infrastructure Renewal

Career-Long Learning

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Innovation vis-à-vis productivity

The source of wealth is something specifically human: *KNOWLEDGE*

Knowledge applied to tasks we already know how to do is *PRODUCTIVITY*

Knowledge applied to tasks that are new and different is *INNOVATION*

Managing for the Future: The 1990s and Beyond
Peter F. Drucker, 1992

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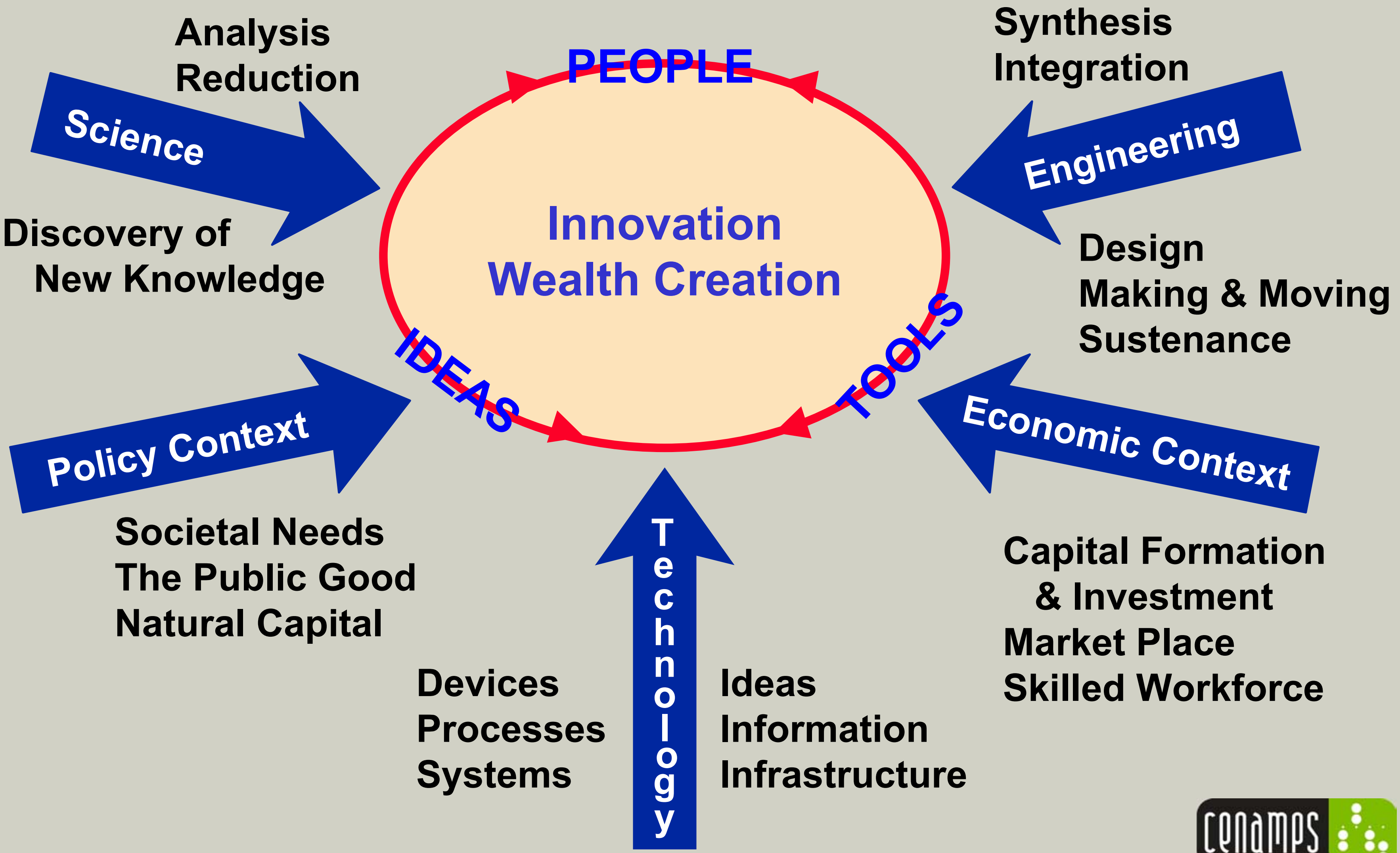
Innovation system concurrent integration



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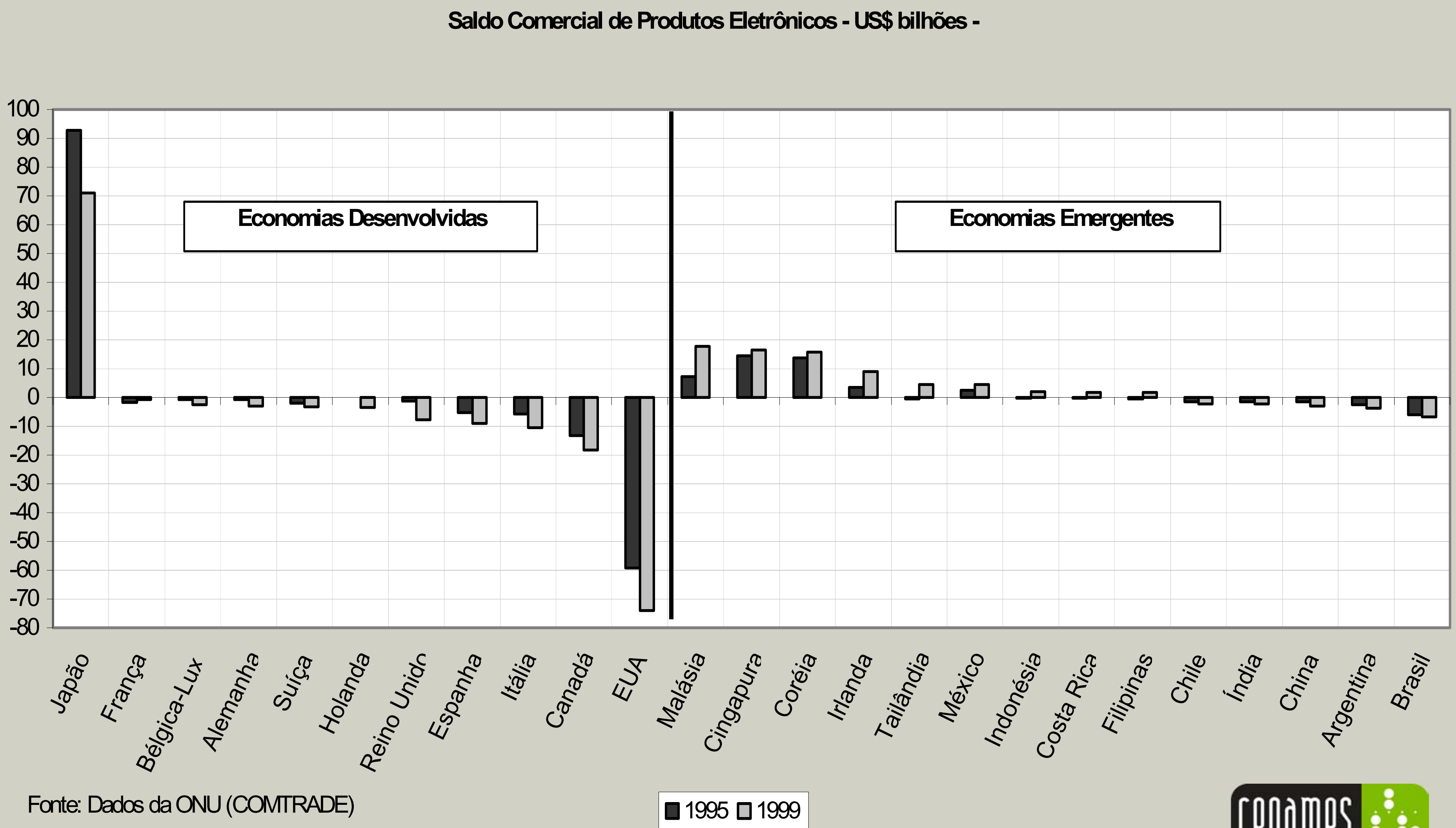
Trade balance in electronic products worldwide



Fonte: Dados da ONU (COMTRADE)

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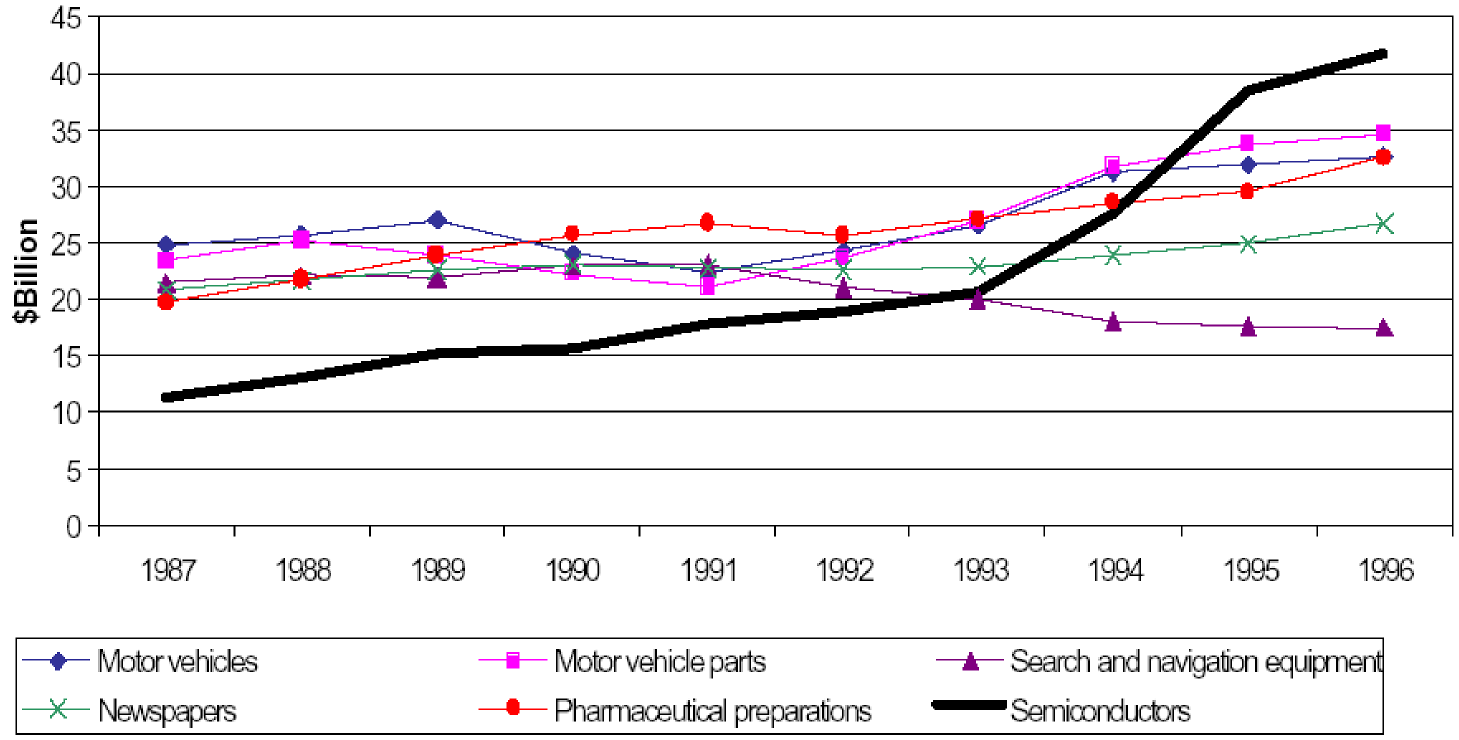
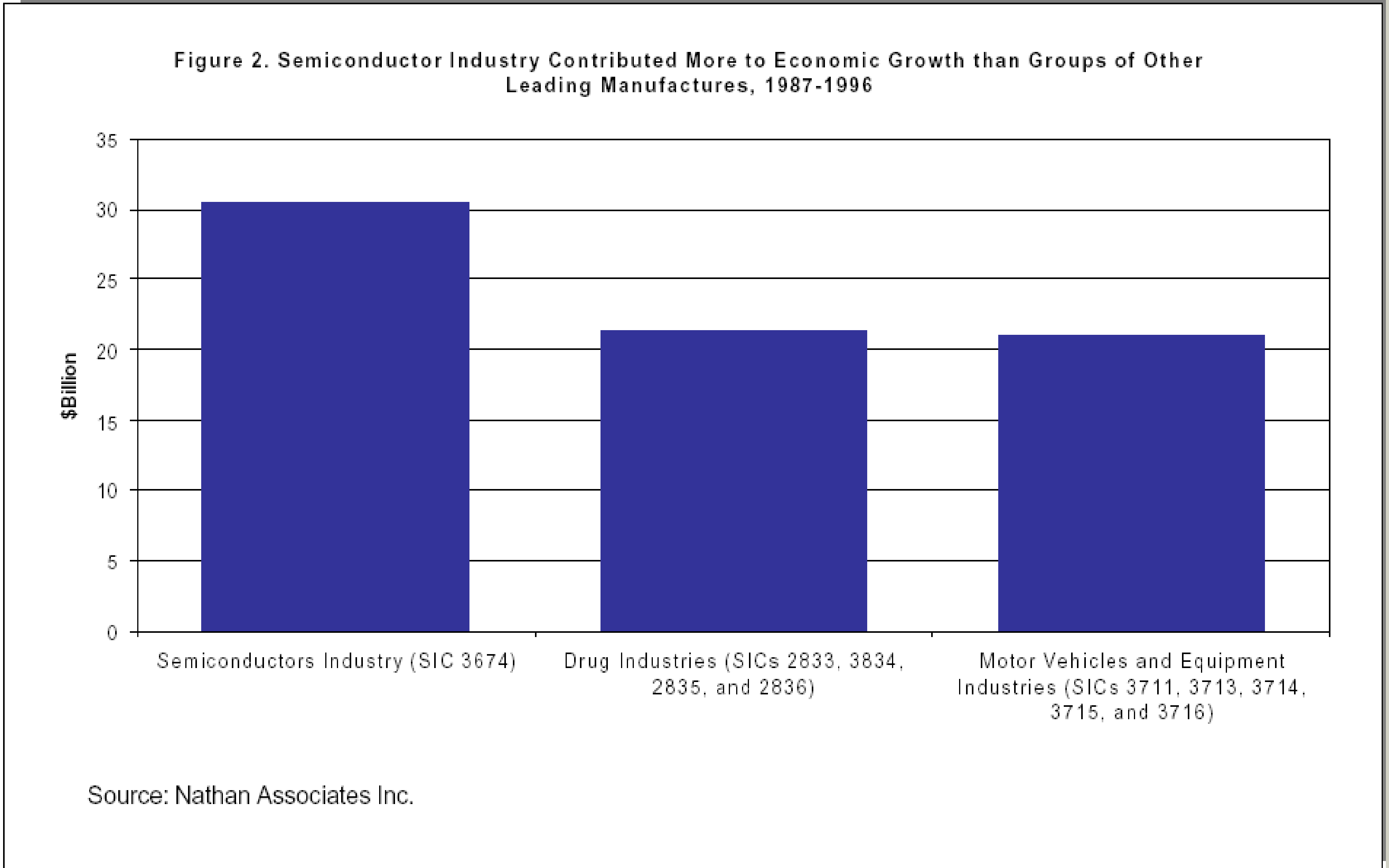
Semiconductors: contribution to economic growth

Figure 1. Semiconductor Contribution to Economy Leads All Manufacturers

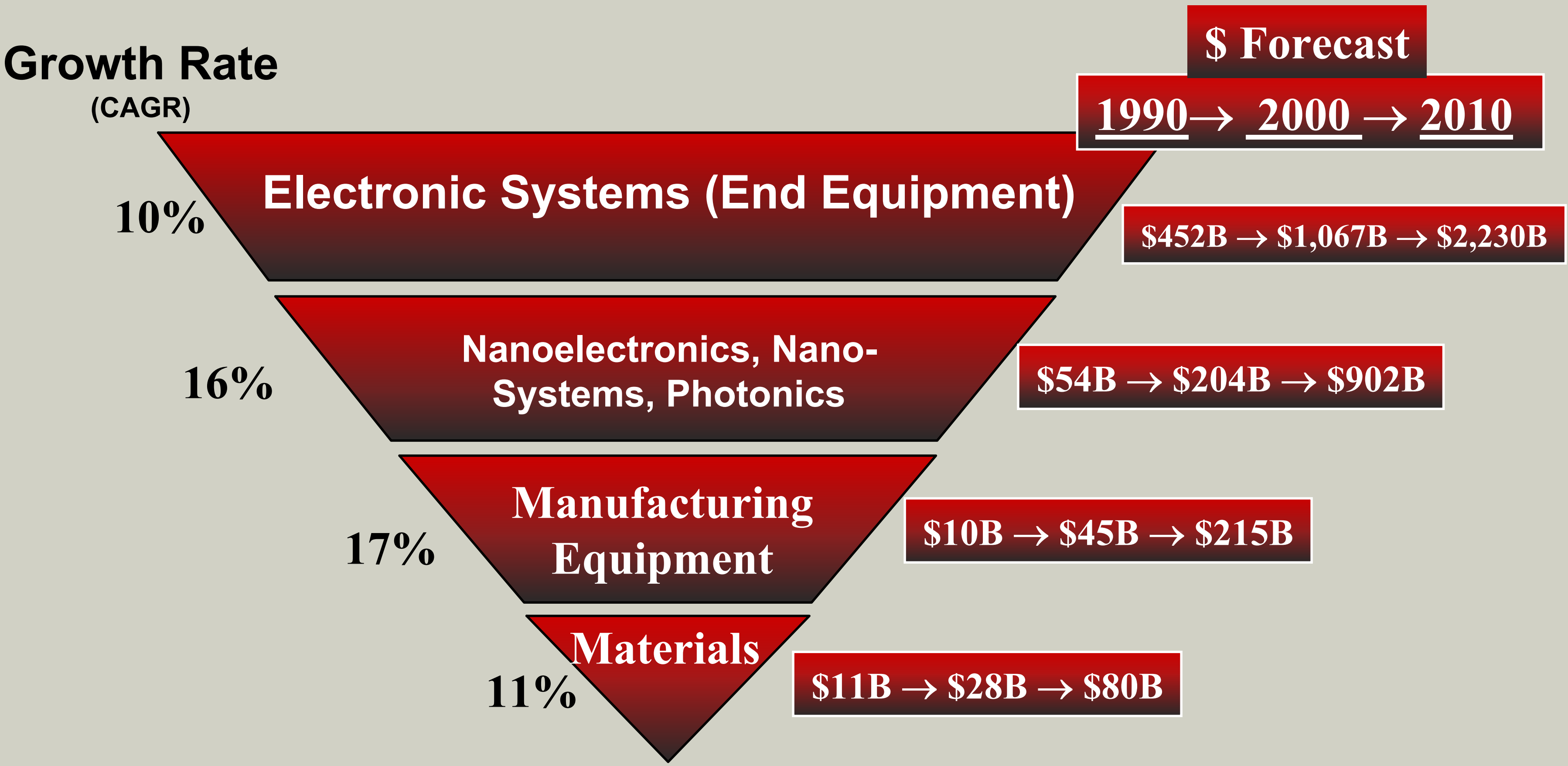


Note: In 1987 there were 11 other manufacturing industries not shown on this figure whose contribution to the U.S. economy exceeded the contribution of the semiconductor industry.
Source: Table 1.

Semiconductors: contribution to economic growth



The value of systems in the electronics industry: market sectors



Source: SEMI-SEAJ, SIA WSTS, IC INSIGHTS, Rose Associates, SEMI Consensus Forecast

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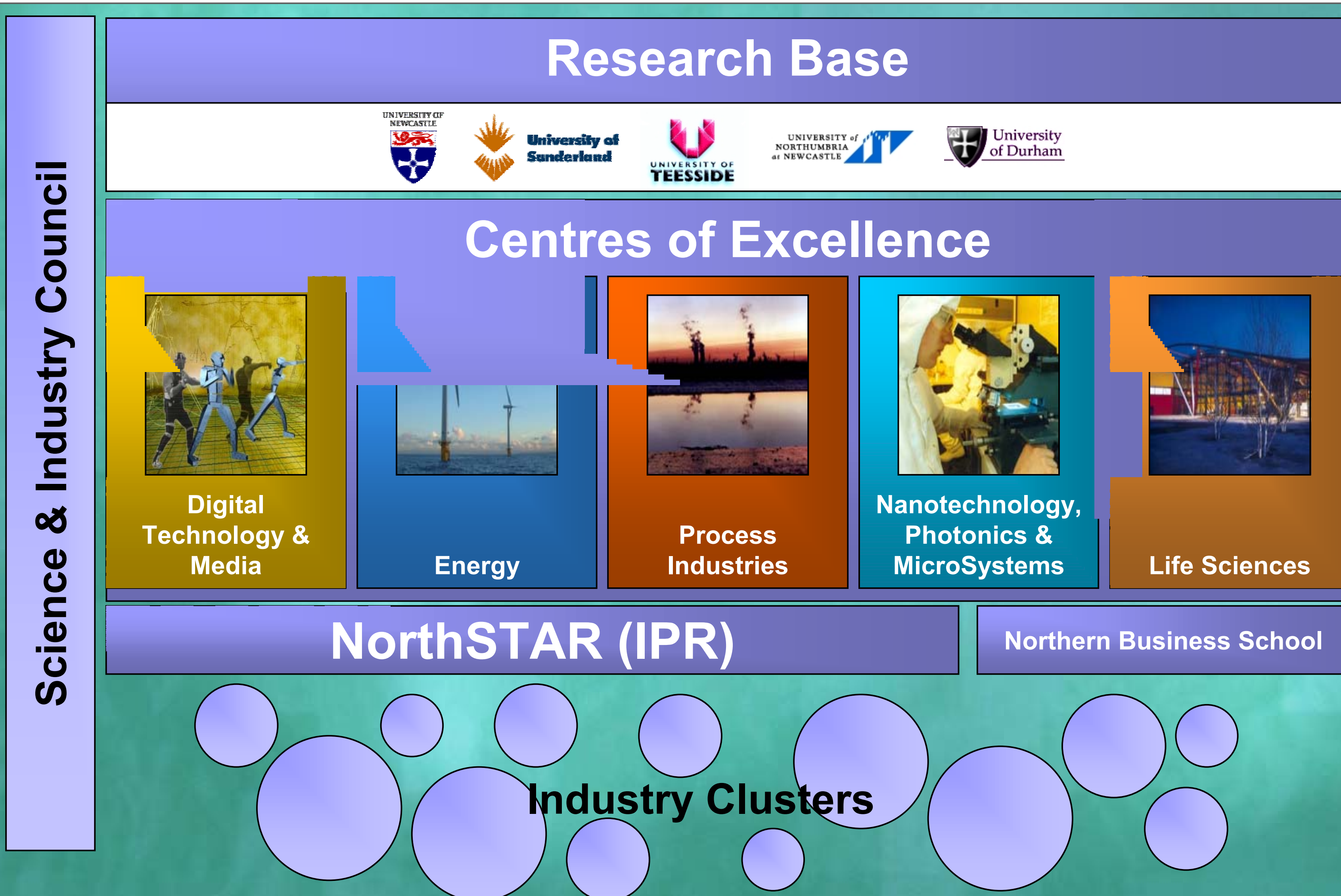
Five centres of excellence



Cenamps - mission

To generate entrepreneurial wealth and employment through establishing sustainable technology-based activity and business-driven R&D linked to agile manufacturing companies and international trade

To be a leading worldwide provider of late-stage research and risk-reducing entrepreneurial services for next-generation technology and product development including proof-of-principle, investment, incubation, advanced manufacturing and commercialisation activities

To leverage resources and facilities of partner universities and companies worldwide as appropriate to perform business-driven R&D ahead of industrial needs by typically 1 to 5 years in the fields of nanotechnology, microelectronics/microsystems, photonics and related materials, systems and commercial techniques

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The four-pillar-model of technological capability

Companies

Intra-firm effort:
* Technological learning
* Skills development
* Research and development

Inter-firm relationships:
* Interactive learning
* Technological alliances
* Joint R+D

Technology institutions

Standards, measurement + testing
Quality assurance + certification
Technology consultancy
Management consultancy
Technology information + demonstration
Technology extension
Research + development
Intellectual property rights protection
R+D financing
Technology assessment

Education institutions

Comprehensive primary education
Technology-related secondary education
Vocational training
Higher education
* engineering
* management
Ongoing training
Public and private providers

Framework conditions

International level	Macroeconomic policy	Industrial policy	International technology transfer	Resource endowment
National government	Fiscal policy	Economic promotion	Foreign buyers	Attitudes and values
Provincial govnmt	Tax policy	Regulations	International standards	Openness to learning and change
Networking	Trade policy	Property rights		
Local government	Competition policy	Infrastructure		

Adapted from PACA-RALIS Jorg Meyer-Stamer 2003

Concurrent technology development and transfer

Business development expertise	**Substantial regional resources**

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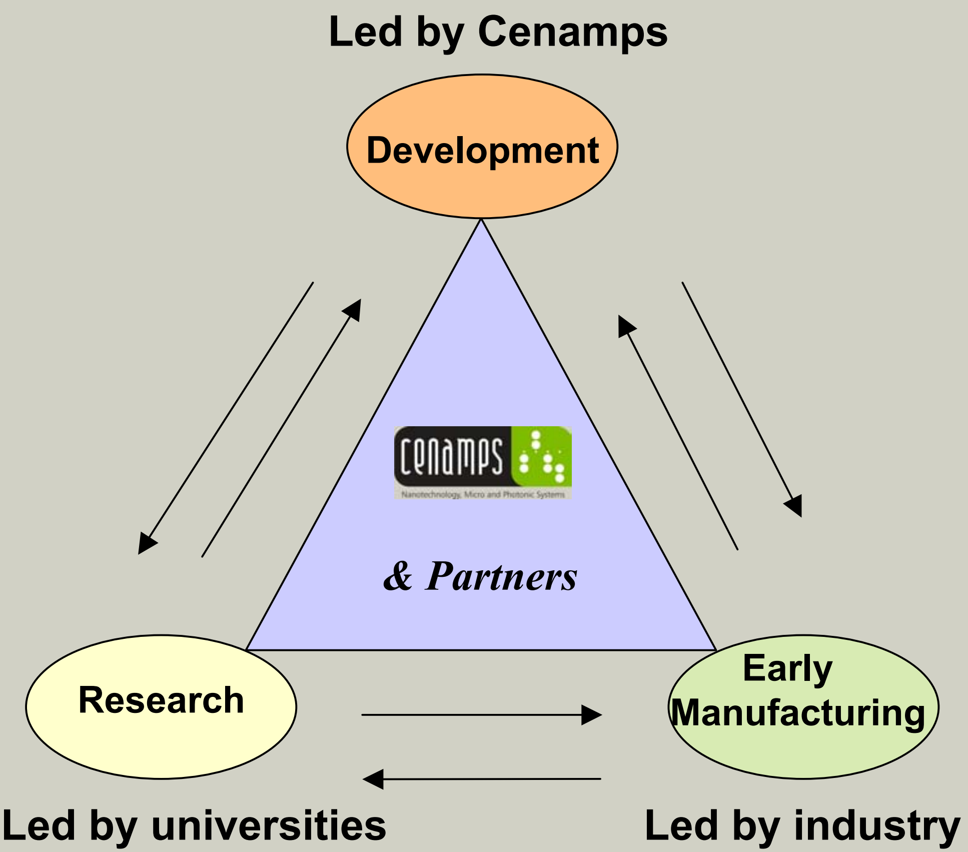
Management skills	**Commercial discipline**



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Where to go and not to go in nano investments

Segment	Commercialization to pursue	What to avoid
Tools	fundamental advances in nanoscale (or sub-nanoscale) techniques for visualization, measurement, and manipulation advances in process control	promises of very large near-term revenue opportunities competing on the basics of microscopy ignorance of potential entrants from semiconductor capital equipment markets
Materials	disruptive new material applications arbitrarily long nanotubes	rapid growth expectations, high investment requirements yet another carbon nanotube or nanopowder company loose grips on scalability or application value
Electronics	disruptive new electronic applications of unique nanomaterial properties	sustaining developments in microprocessors and other large, ordered arrays of transistors quantum computing
Biotech	tools to help with target identification and understanding of disease mechanisms new vehicles for drug delivery	undifferentiated new entrants into biotech field promises of rapid success in new drug process
Assemblers	none yet	getting private investment involved at this stage

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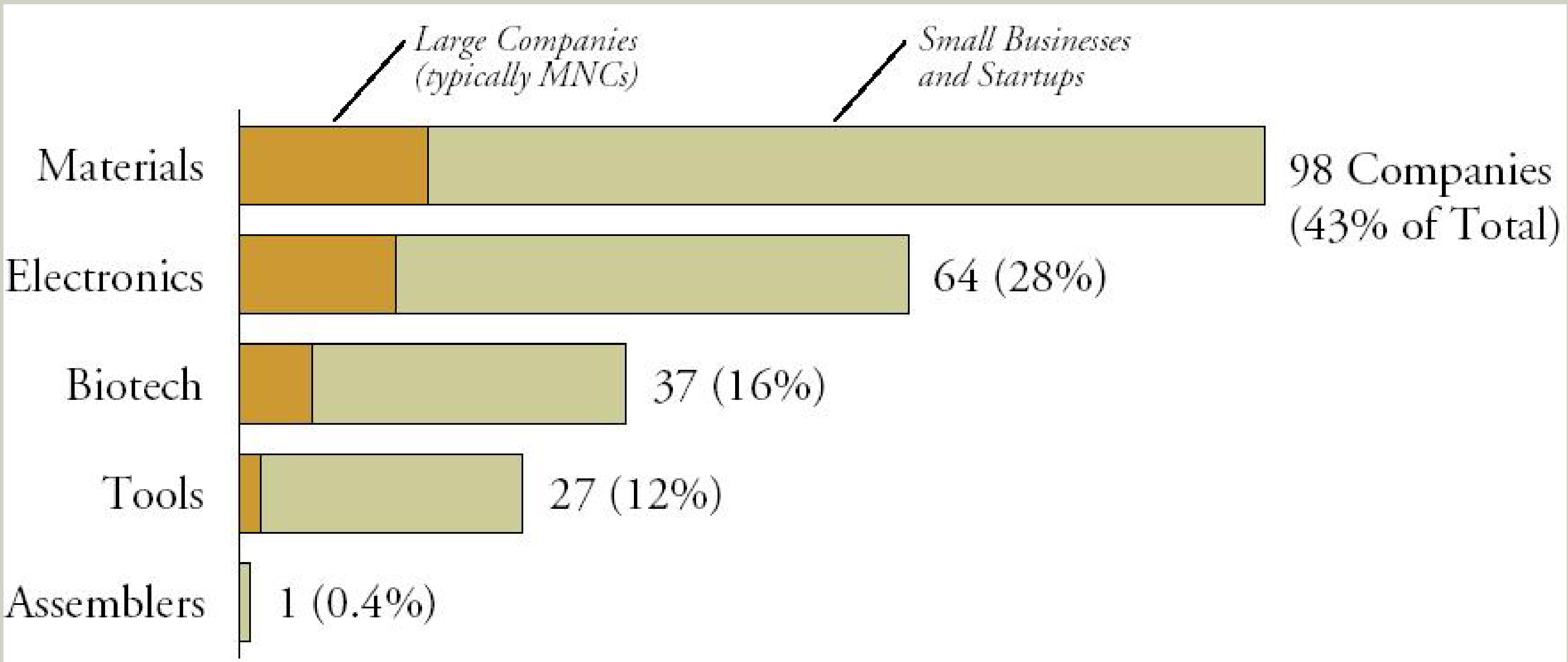
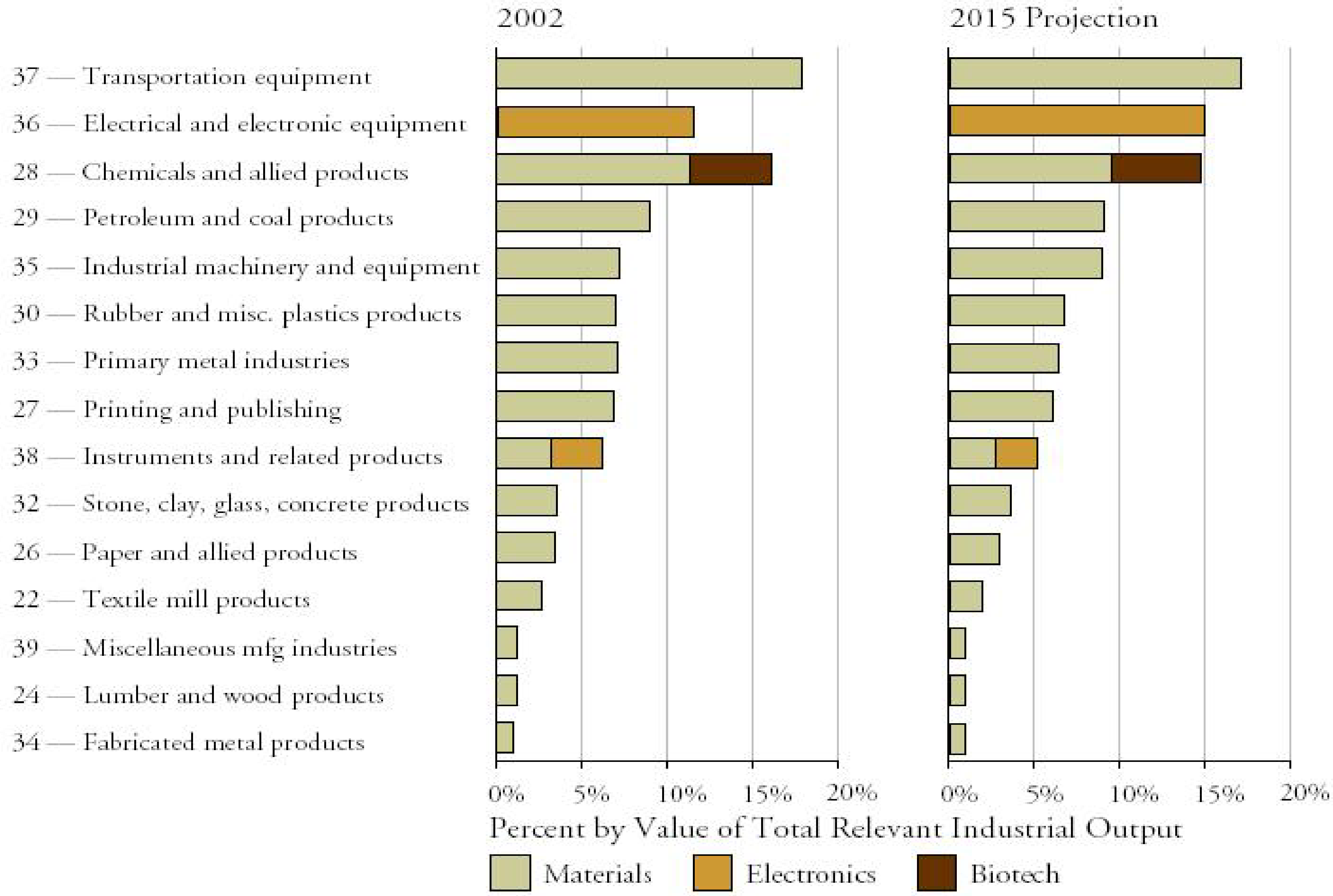
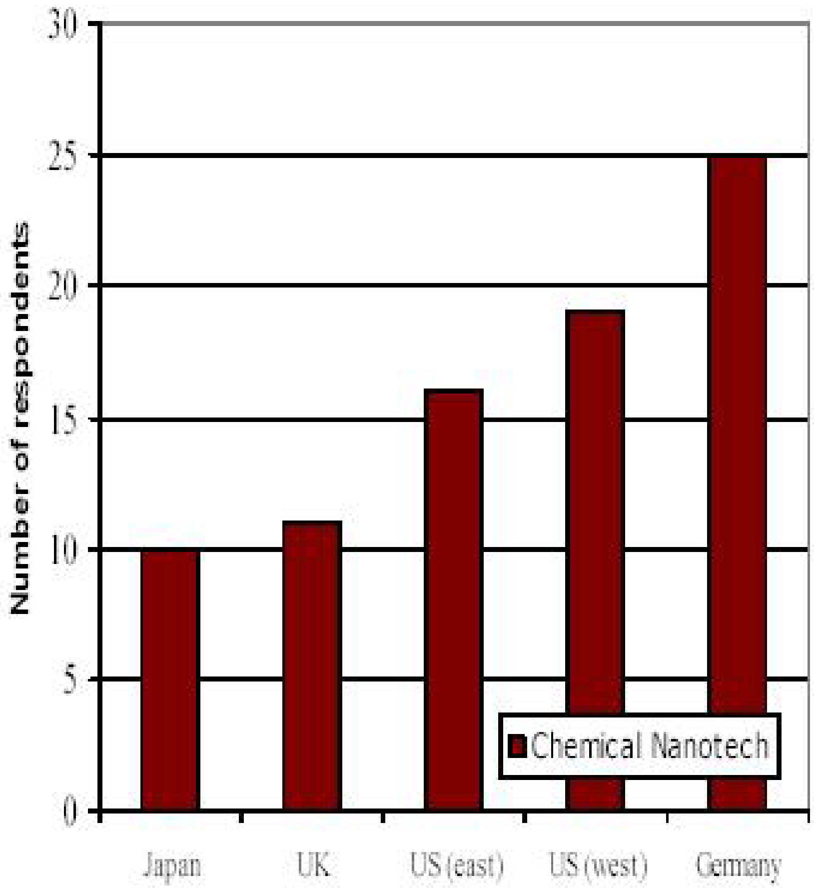
Profile of current nanotech company focus



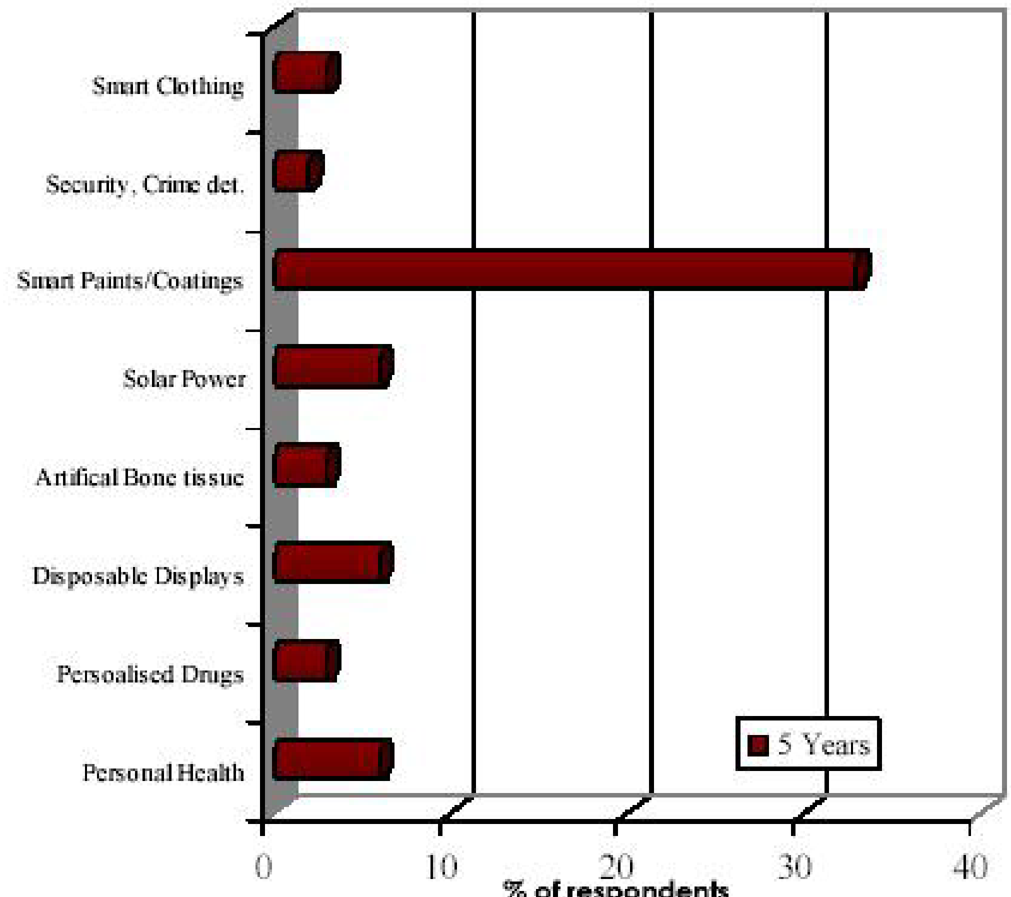
WW industrial output by SIC sectors likely to be nanoinfluenced



Most sophisticated Nanotech Regions



Most promising Nanotech Applications



3i survey, Economist Intelligence Unit July 2002

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Nanotechnology apps

Nanotechnologies

Energy
- Carbon nanotube use (fuel cells)
- TiO2 nanoparticles (solar cells)

Life Sciences and Medicine
- Quantum dots for biological imaging
- Drug targeting

Telecom
- Quantum dots lasers
- Single photon source for quantum cryptography

Chemistry
Nanoparticles for catalysis

Automotive industry
- Composite materials
- Nanostructured glasses
- Sensors

Cosmetics
- TiO_2 nanoparticles for UV filters

Building industry
- Nanocomposite plastics with nanoclays

Food industry
- Nanocomposites for gas barriers

IT
- Flat panel displays (carbon nanotubes as electron emitters)
- IC : NT for transistors
- Quantum computing ?

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Carbon nanotube applications

Carbon nanotube (SWNT, MWNT)

Nanoelectronics

- Single Electron Transistor
- Logic gate implementation (IBM)
- Information storage (Nantero, US)

Fibers (Nanoledge, F)

Composite reinforcement
Electromagnetic shields
Heat sinks

Ultra-sensitive sensors (Nanomix, US)

Flat Panel Displays (ISE in Japan)

H_2 storage alternatives for Fuel Cell industry

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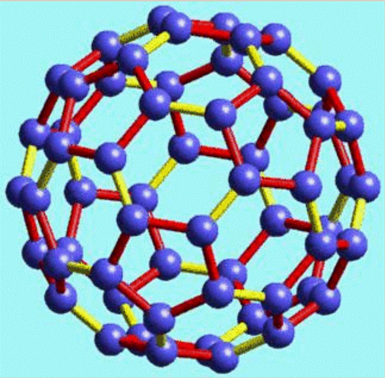
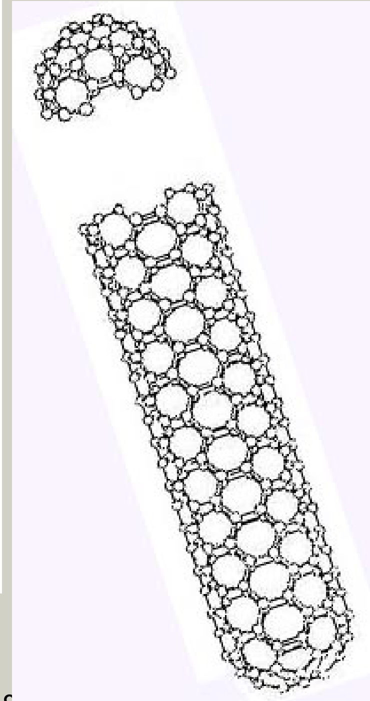
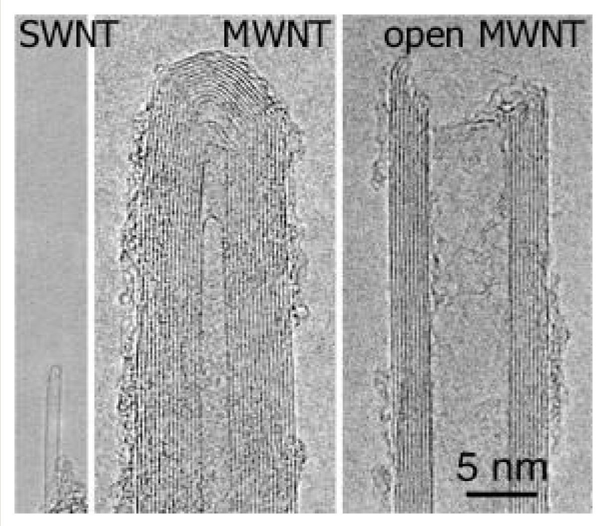
Carbon nanotubes properties

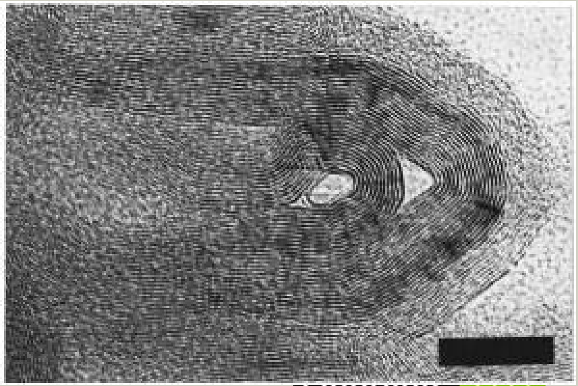
Properties

- **Diameter:** 0.6 – 1.8nm (SWNT), 5 – 100nm (MWNT & CNF)
- **Electrical:** Metals/Semiconductors
- **Density:** 1.33 – 1.40 g/cm^3 (Aluminum: 2.7g/cm^3)
- **Tensile Strength:** $45 \cdot 10^9$Pa (High tensile steel alloys $2 \cdot 10^9$Pa)
- **Current carrying capacity:** 10^9A/cm^2 (Copper: 10^6A/cm^2)
- **Heat Transmission:** 6000 W/mK (Diamond: 3320 W/mK)
- **Field Emission:** 1-3 V/µm (Molybdenum tips: 50-100V/µm)
- **Cost:** 100-1000$/g (Gold: 10 $/g in Oct 2000)









Technological impact

- Main stream microelectronic devices ….. Many industrialists including CEO of INTEL predict that in 10-15+ years the Si industry will be complemented by 'a carbon nanotube based device architecture or molecular electronics'

- Polymer composites …… enhancing the properties of polymers both structurally and electrically

- Displays …. An emissive technology will replace the LCD screens eventually. It could be FED based on CNT structures

- Pharmaceuticals …. Drug delivery for efficient and therefore lower dosage, bio-molecular sensors

- Energy sources ….. In enhancing the surface areas of Li batteries and possibly longer term hydrogen storage arena

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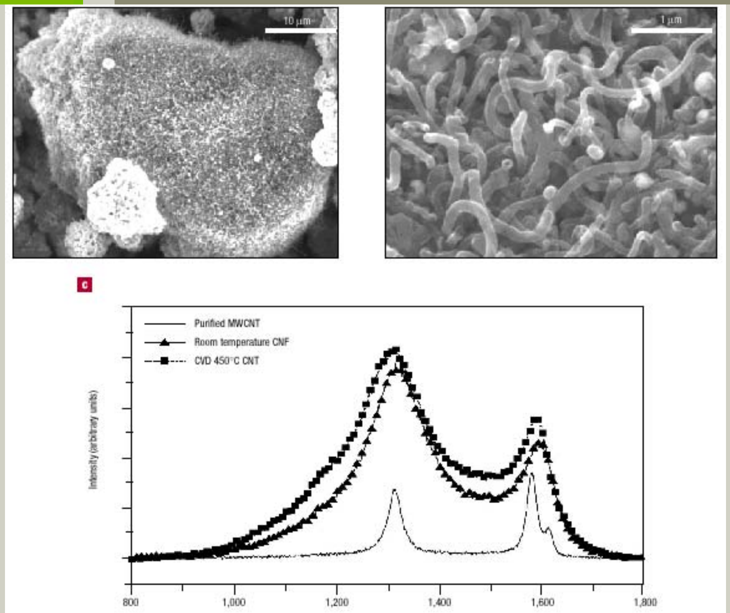
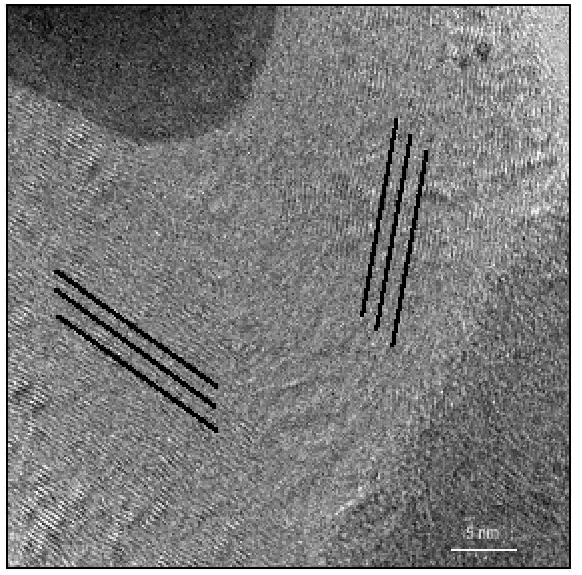
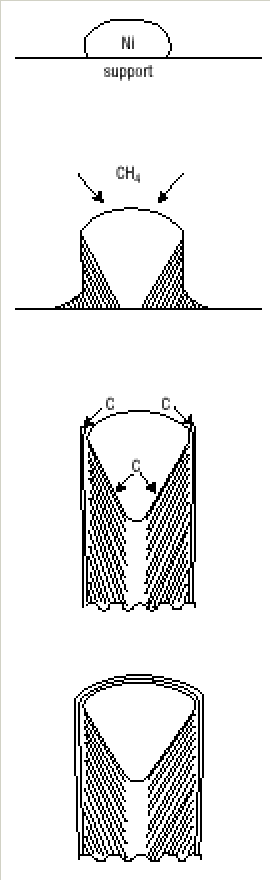
Large-area synthesis of carbon nanofibres at room temperature

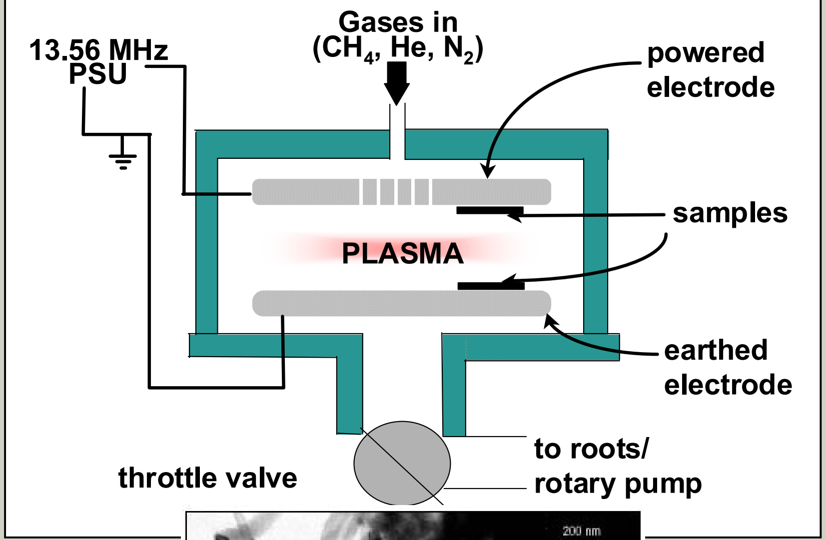
nature materials | ADVANCE ONLINE PUBLICATION | www.nature.com/naturematerials

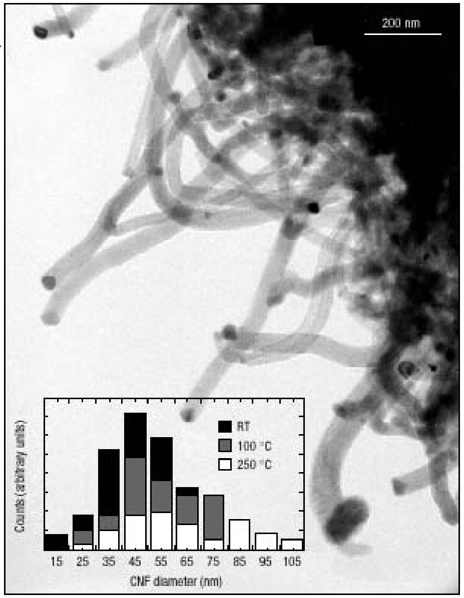






r.f. plasma enhanced chemical vapour deposition





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SWNTs offer various opportunities

ELECTRICAL

Electrically Conductive Composites
- Electrostatic Dissipation
- Shielding
- Conductive sealants

Energy Storage
- Super Capacitors
- Fuel cells

Electronic Materials & Devices
- Conductive inks and adhesives
- Electronic packaging
- Device and microcircuit components

MECHANICAL

- High performance composites
- Coatings – wear-resistant and low-friction
- High performance fibers
- Reinforced ceramic composites

THERMAL

- Thermally-conductive polymer composites
- Thermally-conductive paints & coatings

FIELD EMISSION
- Flat Panel Displays
- Electron device cathodes
- Lighting

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Large and growing market

- ABS, polycarbonate, etc. with conductive "fillers" to provide: antistatic, ESD

- Plastics are replacing metals

- <u>Markets</u> <u>Products</u>
  - Electronics – Chip trays, packaging
  - Automotive – Fuel lines & filter housings, auto body panels
  - Industrial – Explosion proof housings & conveying systems

- Products enabled by high conductivity or EMI/RFI shielding

  - Fuel Cells – Bipolar plates, electrodes
  - Electronics – Component housings, etc.
  - Aerospace – Conductive sealants

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Nanomanufacturing

NANOSCALE Structures and Functionality

NanoSCIENCE
* Physics * Chemistry
* Materials * Biology
* Information Sciences...

NanoTECHNOLOGY
* Design * Fabrication
* Integration * Characterisation
* Production/system, ….

APPLICATIONS
* Biological, medical, health
* Electronics, optics, devices
* Energy, chemical, environment
* Structural, coatings, ….

IMPACTS
* Society, economy
* Ethics, legislation
* Education , training ...

NANO-MANUFACTURING
* Materials
* Processes
* Instruments
* Modeling
* Structures
* Products

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Nanomanufacturing perspectives

- Engineering-directed exploration of underlying interdisciplinary nanoscale science
- Infrastructure for experimentation, theory, modeling, simulation, control
- Emphasis on nanomanufacturing education
- Collaboration with academia, industry, government and international institutions
- Emphasis on manufacturing synthesis
- Learning from nature / biomimetics
- Multi-domain technologies, multi-functional devices /systems

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New engagement models with less TTM

- Identification of key opportunities
- Creation of bilateral partnerships with engineering, sales and marketing concerns worldwide
- Minority equity positions worldwide to engender trust and align goals
- Aligned protection of intellectual property
  - Critical for new generation of international start-ups
  - Important for increasing velocity of dealmaking between UK worldwide
- Recognition of what each country's companies are generally good at
  - New ideas and technology on both sides
  - Making those ideas work for worldwide customers in major trading blocks
- Focus on new applications nearing commercialisation

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From inward investment to joint WW investment

VentureWire Alert [mailto:alert@venturewire.com]

VentureWire Alert,Thursday, July 10, 2003

[…]

The largest round of the day went to ZettaCom, a provider of fibre-to-fibre configurable optical technologies that raised a $19.2-million Series C co-led by Investcorp and Norwest Venture Partners. Investors including China Development Industrial Bank, JPMorgan Partners, k1Ventures, US Bancorp Piper Jaffray, and Venrock Associates also participated in the round.

[…]

CHINA IS INVESTING OUTSIDE CHINA FOR ACCESS & TTM!!

OTHER COUNTRIES ALSO INVESTING WW

NEW INDUSTRIALISING COUNTRIES WILL INVEST IN DISRUPTIVE TECHNOLOGIES and AGILE MANUFACTURING

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Example of areas for cooperation with the North East of England / the UK

- Wireless communications
- Nanotechnology and microsystems
- Consumer electronics and agility: SoC, new materials, DET
- Photonics
- Energy generation and storage
- Hydrogen economy
- Biotech and pharmaceuticals
- Process intensification and the chemical industry
- Digital and media including creative games and GRID computing
- New venture funding and global market reach

- KEY CENAMPS FOCUS:
  ADVANCED FUNCTIONAL MATERIALS, BIOTECH, ELECTRONICS/PHOTONICS

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Manufacture of advanced functional materials (AFM’s)

Top-down printing & bottom-up chemistry
to create a valuable self assembled molecular (‘SAM’)
world class manufacturing facility

- **SENSORY (Controlled release) MATERIALS & (Targeted delivery)**
  - **Homecare**
  - **Food**
  - **Healthcare**
  - **Personalcare**
  - **Fabric/textile care**
- **PERFORMANCE MATERIALS**
  - **Opto-Electronics**
  - **Electro-Ceramics**
  - **Coatings Composites & Thin Films**

Ray Oliver ICI 2003

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Chemical nanotechnologies and CENAMPS + CPI

SENSORY MATERIALS
ICI
P&G
Others

PERFORMANCE MATERIALS
ICI
DuPont Teijin Films
Others

Cenamps + Centre for Process Industry

WILTON
CENTRE + Filtronic

World Class Characterisation & Measurement

Clean Room Facilities*

Wide ranging (T, P) facilities & Scale-up

Creation of an Advanced Material Exhibition (to showcase products)

Creation of National Educational Programmes (ages 8-18)

DuPont, P&G, Avecia, ICI, Teijin, Huntsman, Lucite, BASF…

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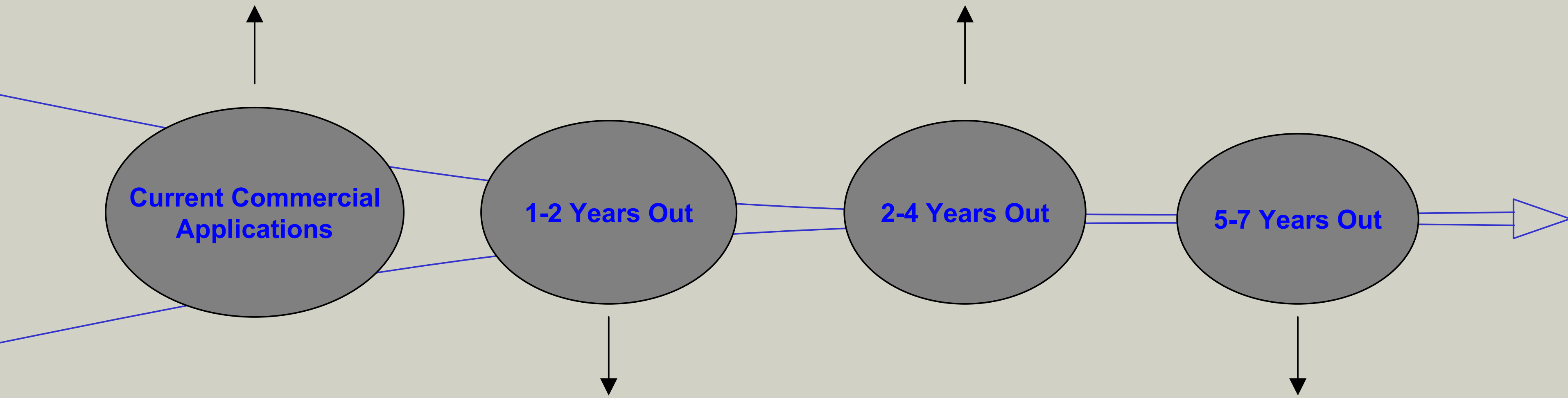
Indicative commercial roadmap

Pigments, Cosmetics, Sunscreens, Catalysts, Drug (A.I.) Delivery, ‘Lab on a Chip’, SPM/AFM, photonics, electronics…

Commercial Volumes of C-nanotubes, Large area displays, Nanoscalar Powders, Next Gen. Lithography Biocompatible Composites, e-ink & e-paper Portable Energy & Power, Flexible Solar Cells.



Adv. Flat Panel Displays, incl OLED’s & FED’s, Adv. Batteries, Solar Cells, Biosensors, Low Cost Synthesis of C-SWNT/MWNT Micro Fuel Cells, Photovoltaic Cells

Macro Fuel Cells, Nanoelectronics, Plastic Chips, Flexible Displays Bottom-up Molecular Fabrication, First Biomimetic Composites.

Modified from Ray Oliver ICI - 2002

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Cenamps/Durham advanced agile manufacturing programme

•Practical understanding of **manufacturability** as related to emerging minifab market opportunities with polymers, semiconductors, biotech and photonics

•Pilot and introduce smaller scale, highly scalable, transformable and **modular production technology** covering the whole spectrum of semiconductor fabrication

•Integrate laboratory based work at universities with higher scale, pilot environments in industry and systems optimisation digital enterprise work to facilitate **Agile Design and Manufacture**

•**Planning and synchronisation methods** for the new generation agile semiconductor / hybrid facilities and their respective production networks

•**Risk mitigation** for industrial implementation by the introduction of physics based modelling, simulation and real-time control to predict manufacturability, adaptability and reliability.

•Develop and deploy advanced ***Digital Enterprise Technology*** based workflow methods and computational tools for managing collaborative and distributed innovation in new products, manufacturing systems and business processes.

•Industrial feasibility studies, technology management, business and network analysis and **evaluation for disruptive technologies**.

•Effective **life-cycle management** of the design, production technology and production network operations to ensure **long-term competitiveness** and ability to rapidly respond to dynamic market changes.

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Brazil-UK research networks bring mutual benefits

- A report published today (12 June 2003) found that the UK and Brazilian academics benefited from the opportunities of working more closely and had planned further activities in the future.

  Groups of UK and Brazilian scientists, funded by the Higher Education Funding Council for England (HEFCE) and Brazilian federal and state agencies, have been collaborating on industry-related research projects for the past three years. The networks are in the areas of industrial catalysis, corrosion protection (both primarily geared towards the oil and gas industries) and phytopharmaceuticals.

  The principal aim of the project was to find out if research programmes, led by consortia of UK and Brazilian universities and research centres, could be enhanced through international collaboration, and to find out if university expertise could be exploited to the mutual advantage of universities and industry in the two partner countries.

  The report, 'UK-Brazil Collaborative Research Networks: evaluation of pilot project', available from HEFCE's web-site www.hefce.ac.uk and the Brazilian Embassy web-site www.brazil.org.uk, considers how each network developed and offers advice to anyone wishing to set up similar networks. Around £225,000 was given to the UK networks, with each having access to up to £33,000 per year. The UK networks were expected to raise funding for research projects from industry or Research Council grants and other sources.

www.hefce.ac.uk/Pubs/RDreports/summary/summ32.htm

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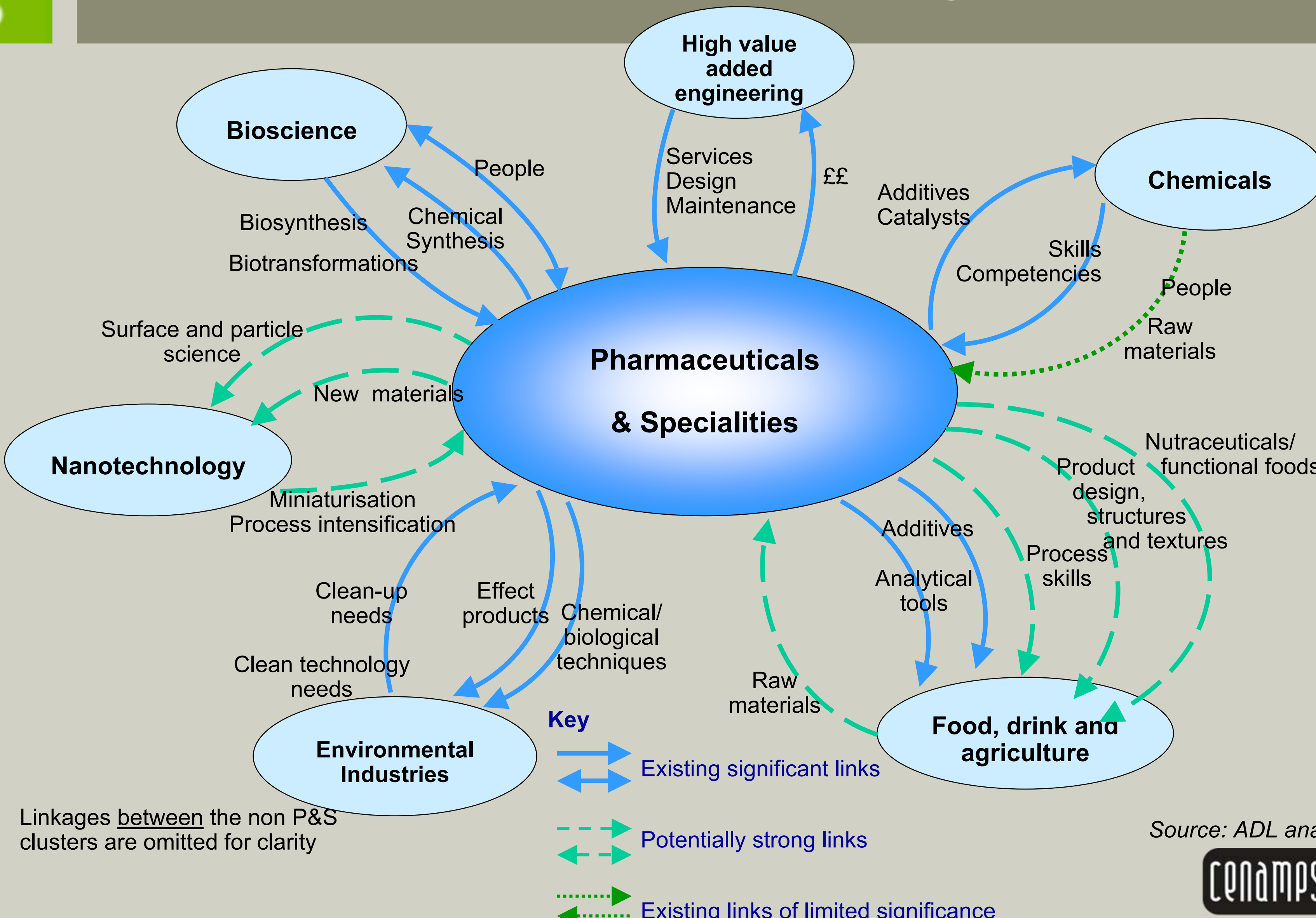
NE cluster linkages



Linkages between the non P&S clusters are omitted for clarity

Source: ADL analysis

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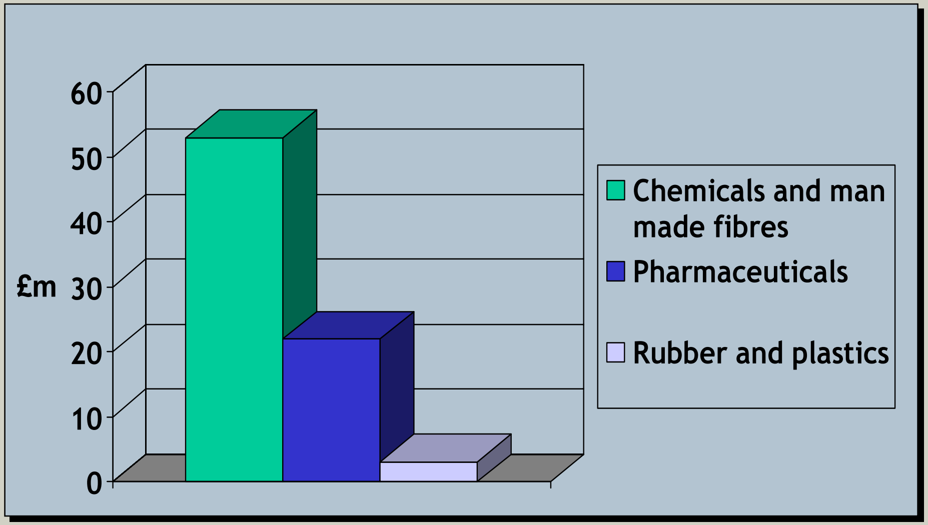
Chemicals cluster R&D spend in the NE

- Greater than £ 90 million from 7 leading P&S companies alone



- The companies are classified as pharmaceuticals/biosciences, catalysts, surfactants, consumer/industrial products

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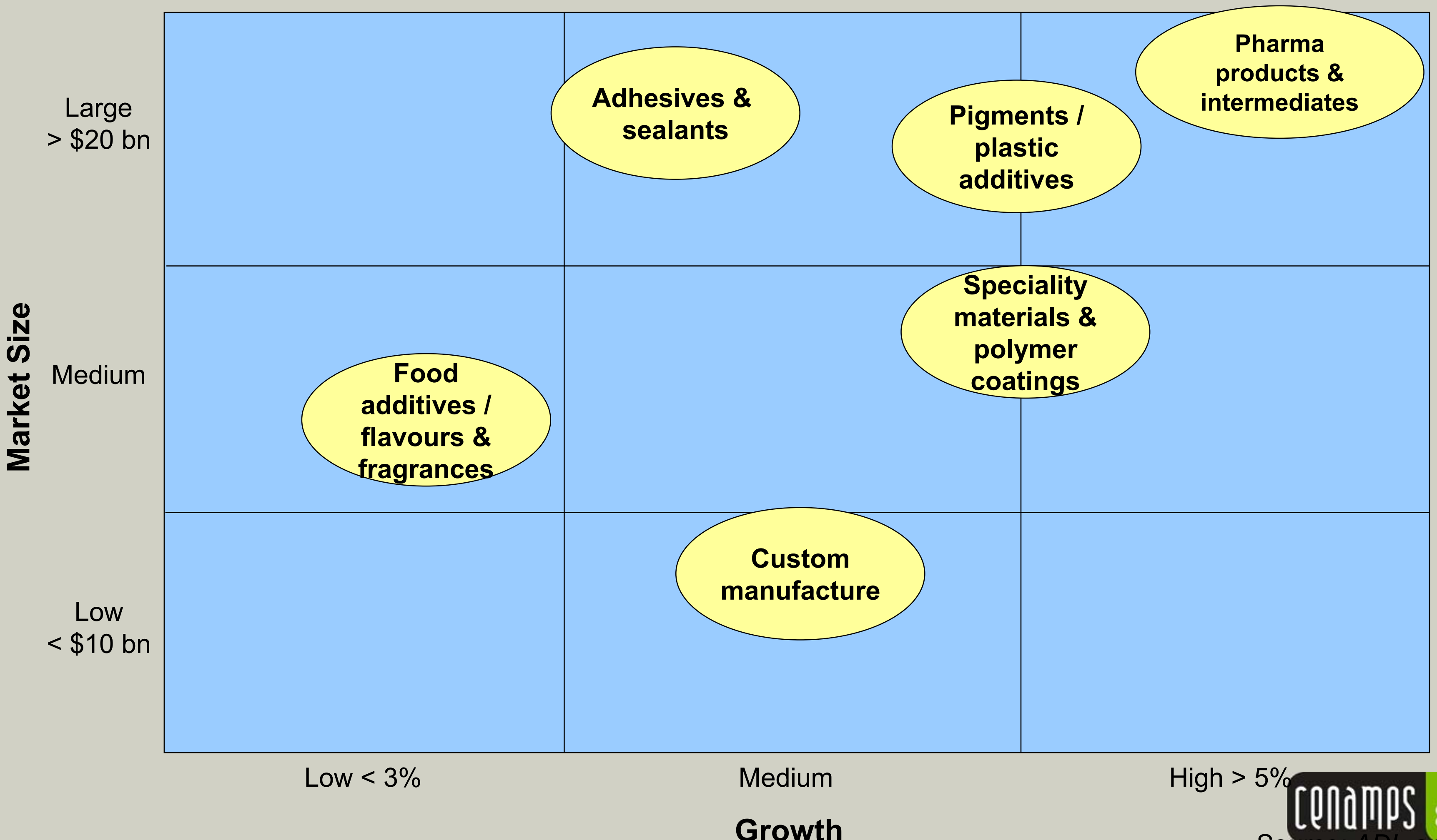
Attractiveness of the segments will be influenced by growth prospects and profitability



Source: ADL analysis

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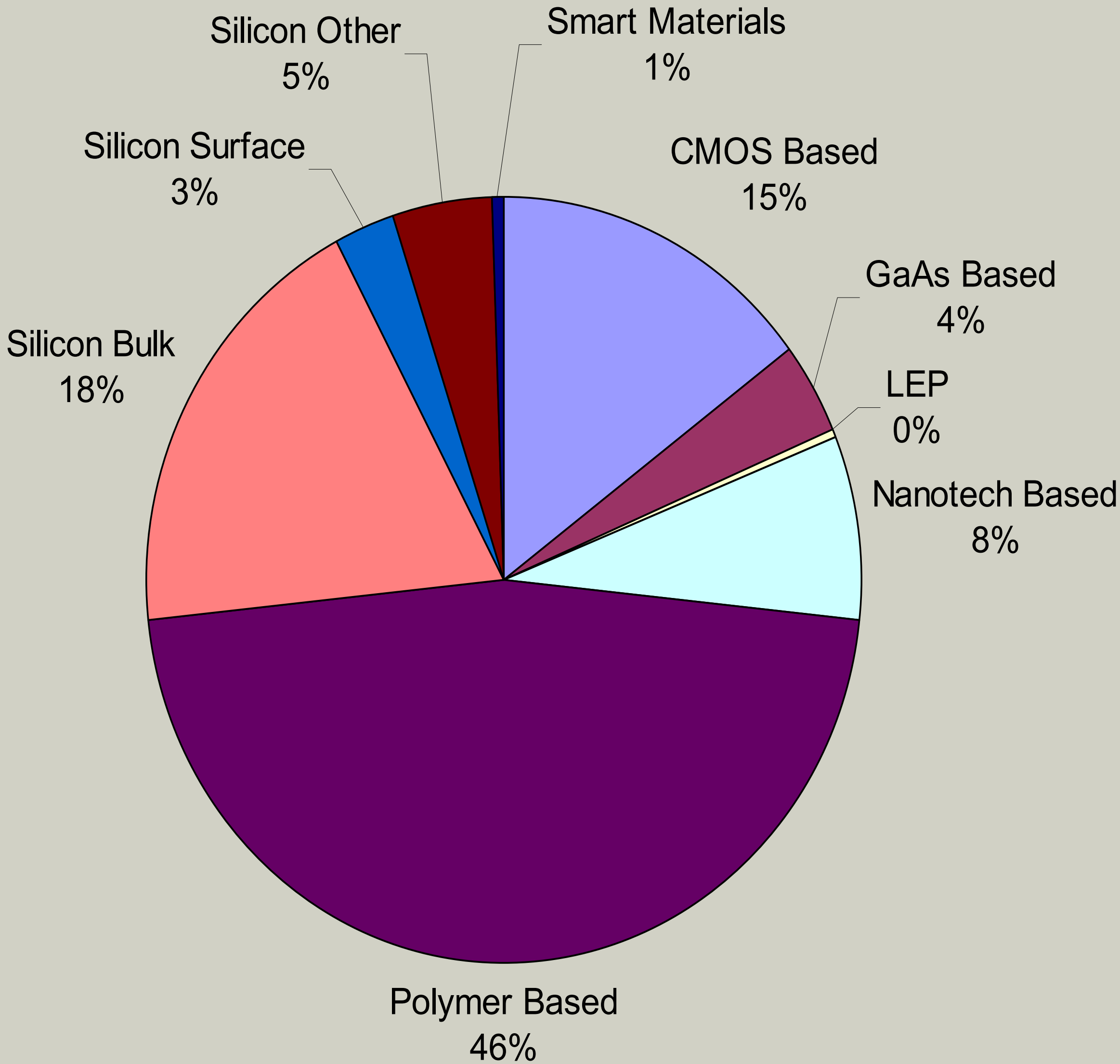
MNT market: breakdown by technology



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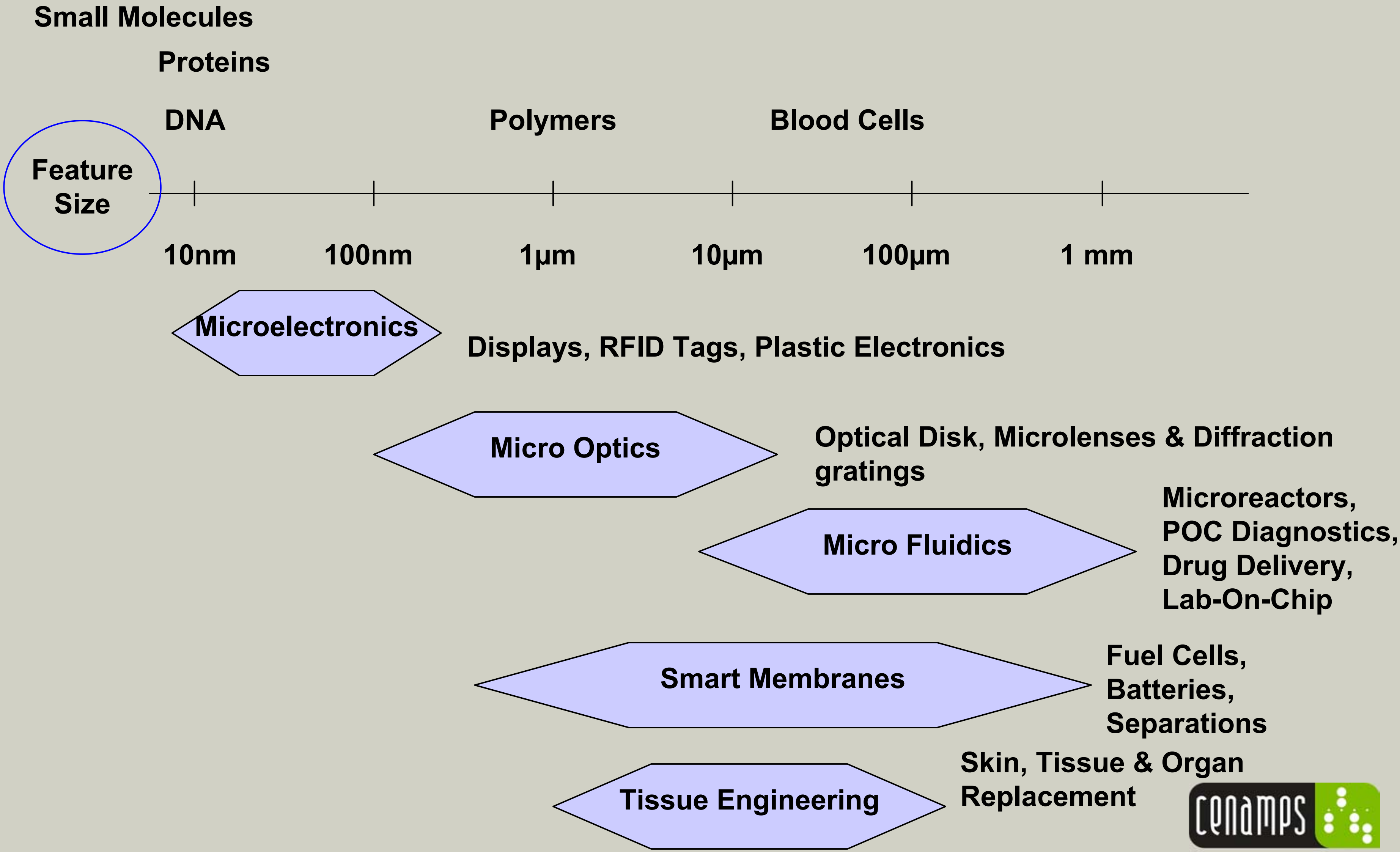
Polymer microsystems applications overview



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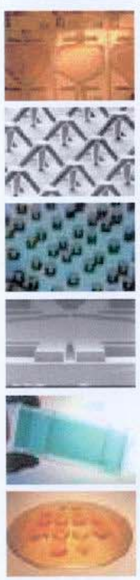
Combining silicon, polymers and hybrids

From silicon to polymers



Microtechnology — Plasturgy

Lithography – Etching		Replication - Milling	
.1 µm	1 µm	100µm	1 mm
µelectronics	Optical disc MOEMS	µFluidics µFuel cells	BioTech. Connectors Optics

Polymer MEMS

Plastics advantages :

- Transparency
- Large surface
- Replication : Very low cost fabrication processes / high volumes
- Prototyping

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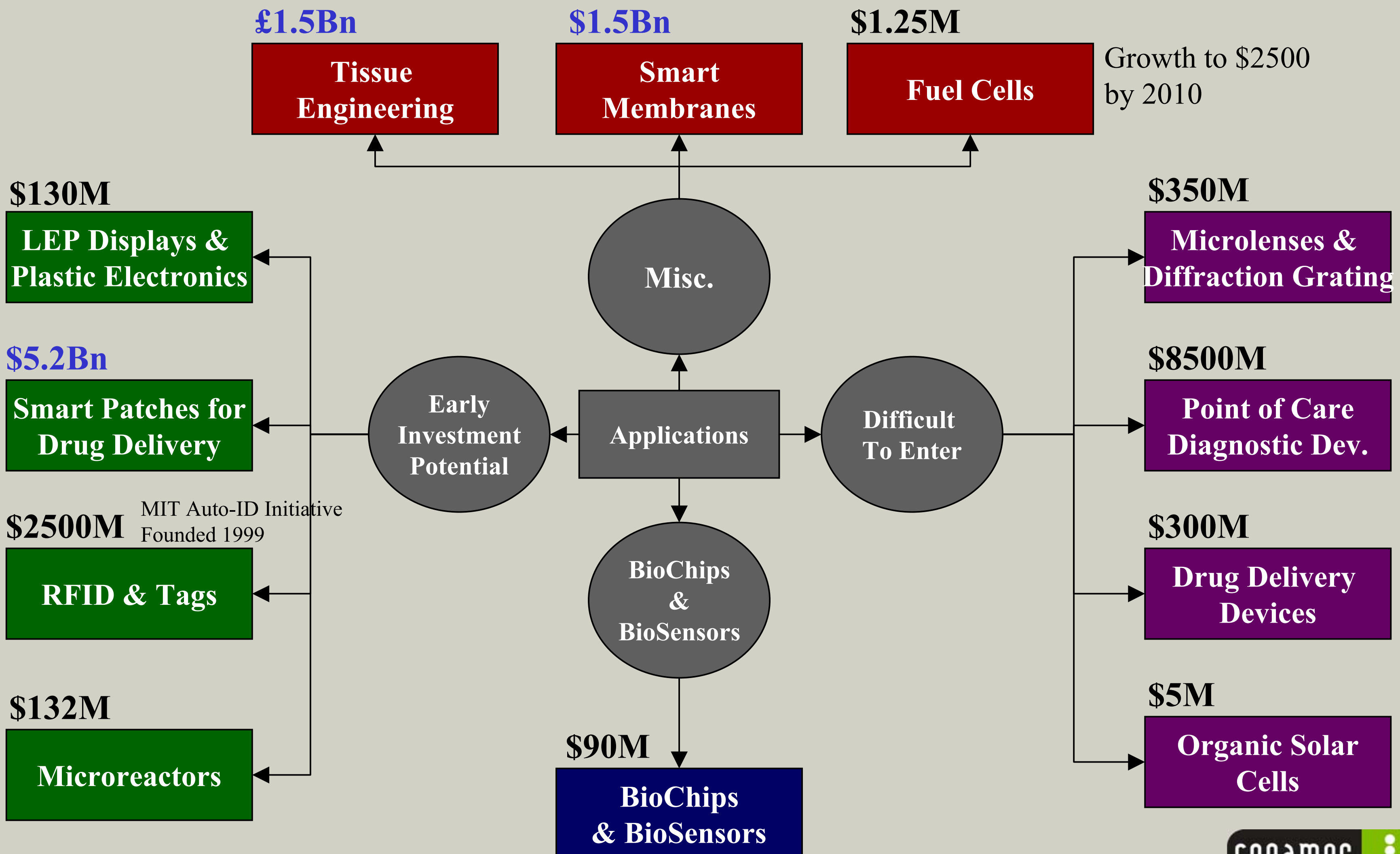
Polymer microsystems applications market - 2005



Polymer share increasing from 5% in 2000 to 20% in 2005

Source TFI 2003

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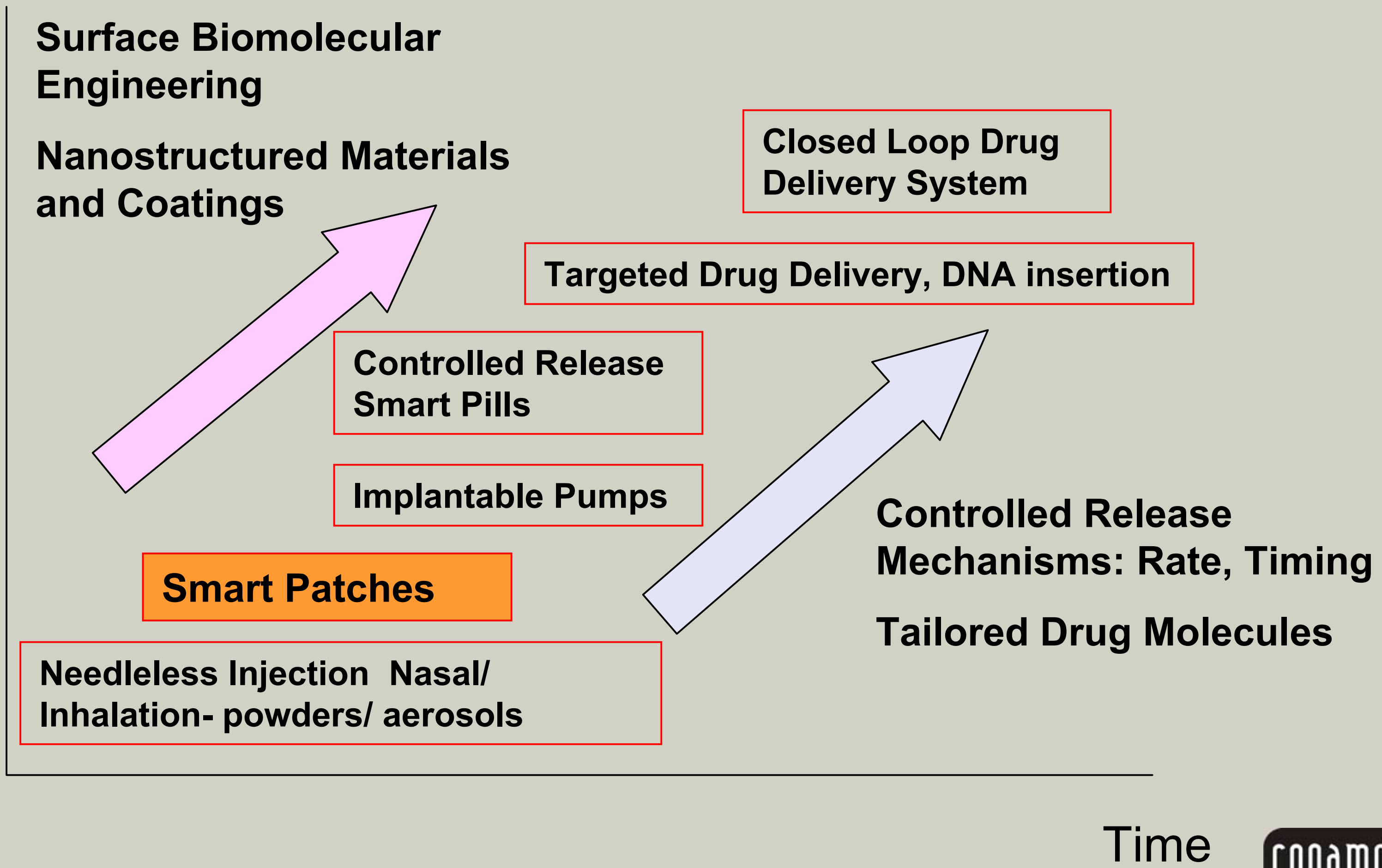
Drug delivery trends



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Cancer results from the gradual accumulation of multiple genetic changes in single cells

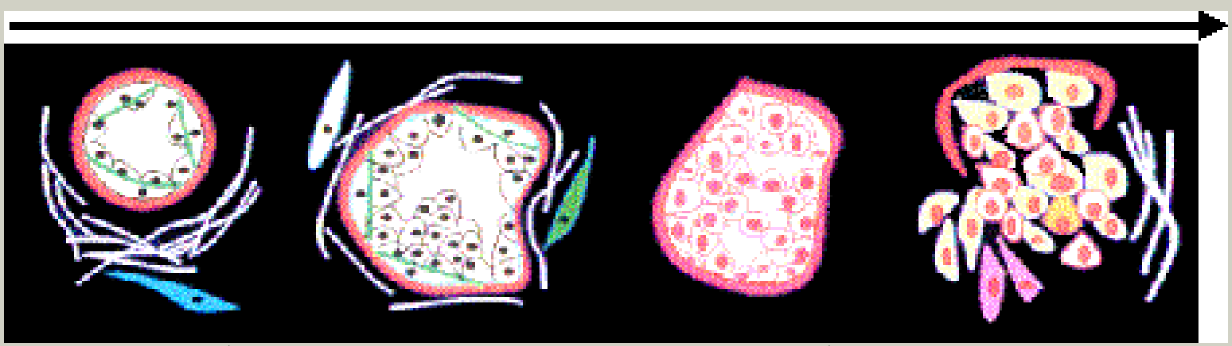
Where We Want To Be ← **Where We Are**

Detection and Diagnosis

Detection and Diagnosis

Malignant Tumors With Metastases

Year 0 Year X Year Y Year Z



Prevention

Prevention

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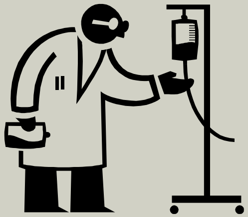
Current Healthcare

Initial Visit

X-Ray/Radiologist

Biopsy/Removal

Pathology

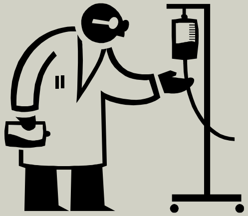


Chemotherapy/Radiation

- Many Visits (Doctors don't talk)
- Long Period of Time
- Detection is too late
- Poor quality of life (anemic, hair/weight loss, deplete bone marrow)
- High Cost
- Significant Death Rate

Future Healthcare with Nanotechnology

Initial Visit



Nanoparticles

- Two Visits
- Short Period of Time
- Early detection
- Better quality of life
- Low Cost
- Reduced Death Rate

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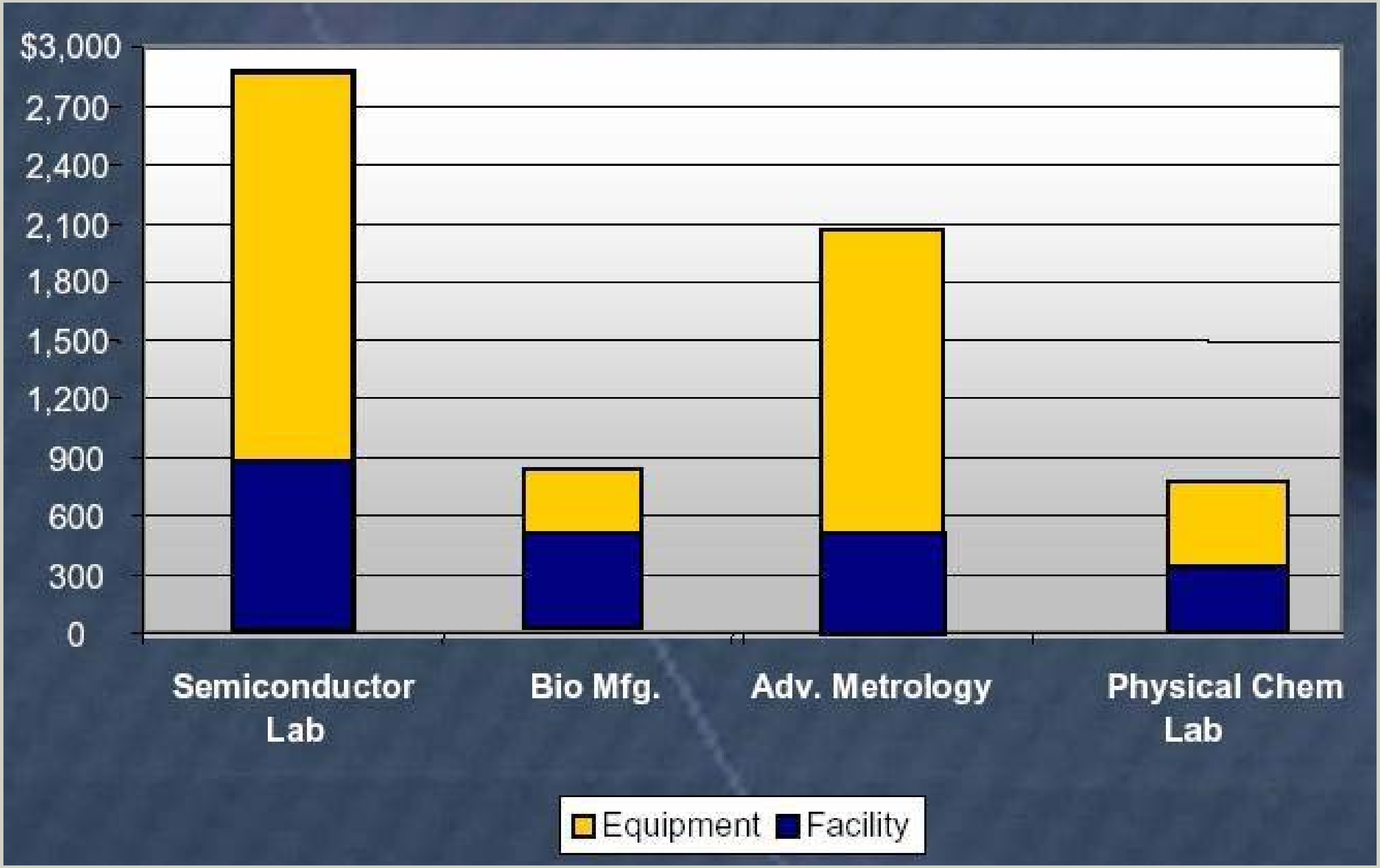
Facilities to equipment costs



M+W Zander 2003

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Semiconductors: megafabs and minifabs

- A fab today is expected to mass-produce millions of chips monthly over several years in order to justify construction price tags over $2 billion, but system-on-chip SoC shipments generally peak at 200,000 units or less
- SoC orders are three or four digits smaller than orders for DRAMs
- SoC chips require quick turnaround and are composed of a wide mix of components, including CPUs, DRAMs, SRAMs, flash, logic and analogue
- Production can change almost daily: difficult to precisely control
- Joint private, academic and government project to create minifabs that are just 10% the size and cost: minifab capacity of 100 lots/month (2500 wsm)

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Paradigm business shifts in the semiconductor industry

- Trend in broadband-networked digital consumer electronics
- Shorter cycle-time minifab operations, single-wafer cleaning
- Stringent surface contamination control requirements
- Environmentally friendly technologies
- Changes required of gate-insulator materials and forming methods

DRAM Era	System-on-a-Chip Era
Personal computer	Networked digital consumer electronics
DRAM	System LSI (or SOC)
Capital spending	Knowledge creation on silicon
Commodity sales	Solution offering
Long cycle times (longer than 3 years)	Short cycle times (typically a few months

Many companies are investigating adoption of the new paradigm including Sony, Toshiba, Toyota, Sharp, Sanyo, Epson, Rohm, Tokyo Electron, Ebara, DNS, Ulvac, Shimizu, Obayashi, Taisei together with several leading universities and the Ministry of Economy, Trade and Industry of Japan (METI) – HALCA project (Highly Agile Line Concept Advancement)

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Paradigm technology shifts in the semiconductor industry

Technology Area	DRAM Era	System-on-a-Chip Era
Product mix	Low	High
Product volume	High	Low or variable
Fab size	Megafab	Minifab (or multiple miniline fabs[1])
Market driver	High throughput	Short cycle times
Process model	Batch processing	Single-wafer processing
Inspection model	Long-loop feedback	Short-loop feedforward
Yield management	Steady enhancement	Prompt, accurate estimation

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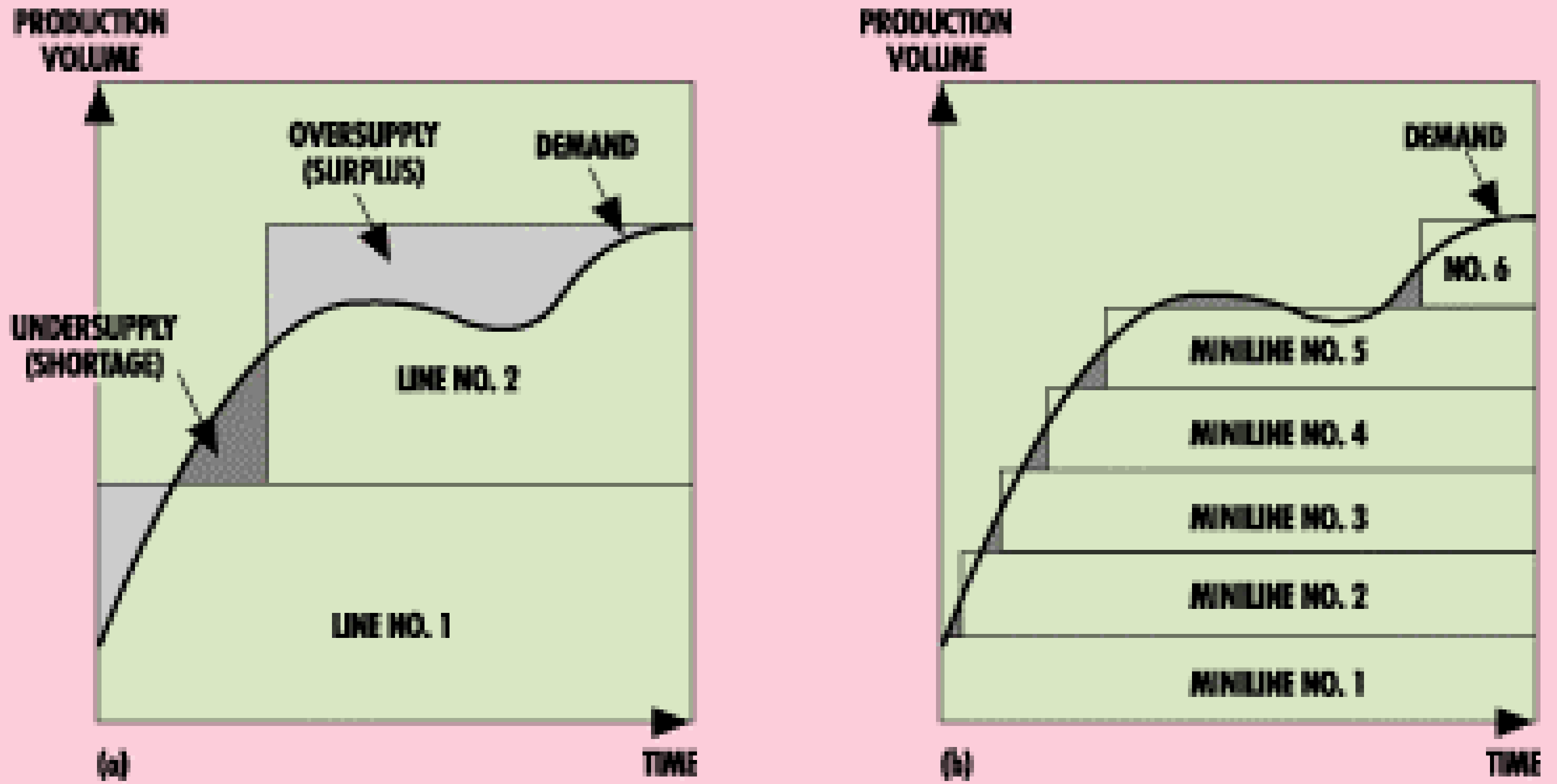
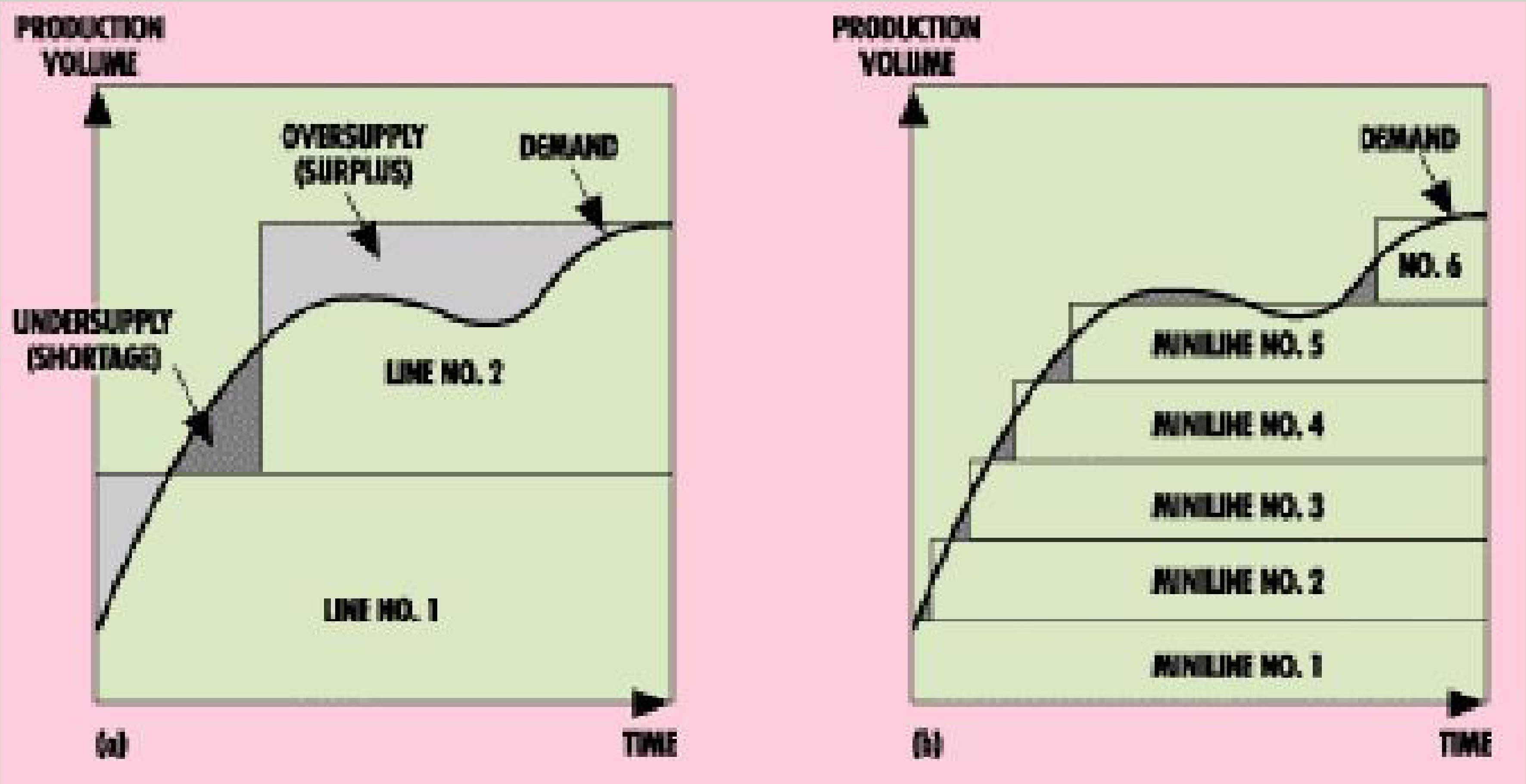
Production volume over time at a megafab (a) and a minifab (b)



Production volume over time
at a megafab (a) and a minifab (b)



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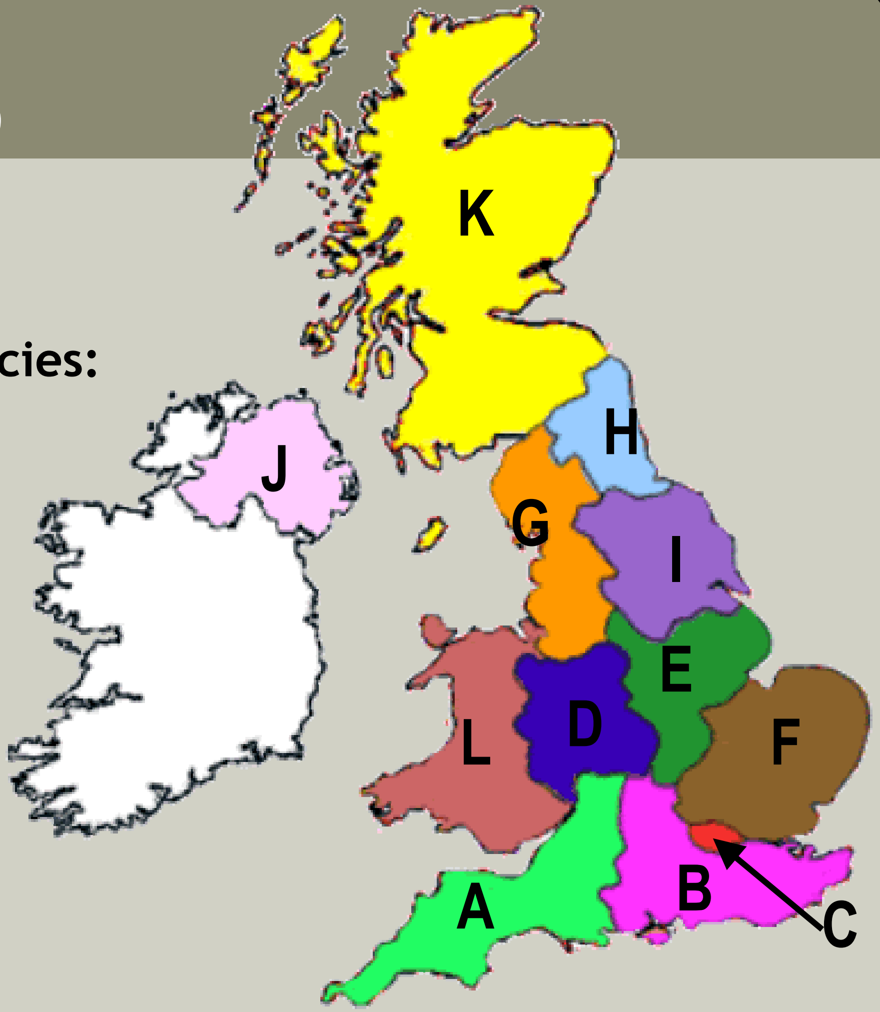
The 12 UK Regions
12 UK Development Agencies (DAs)



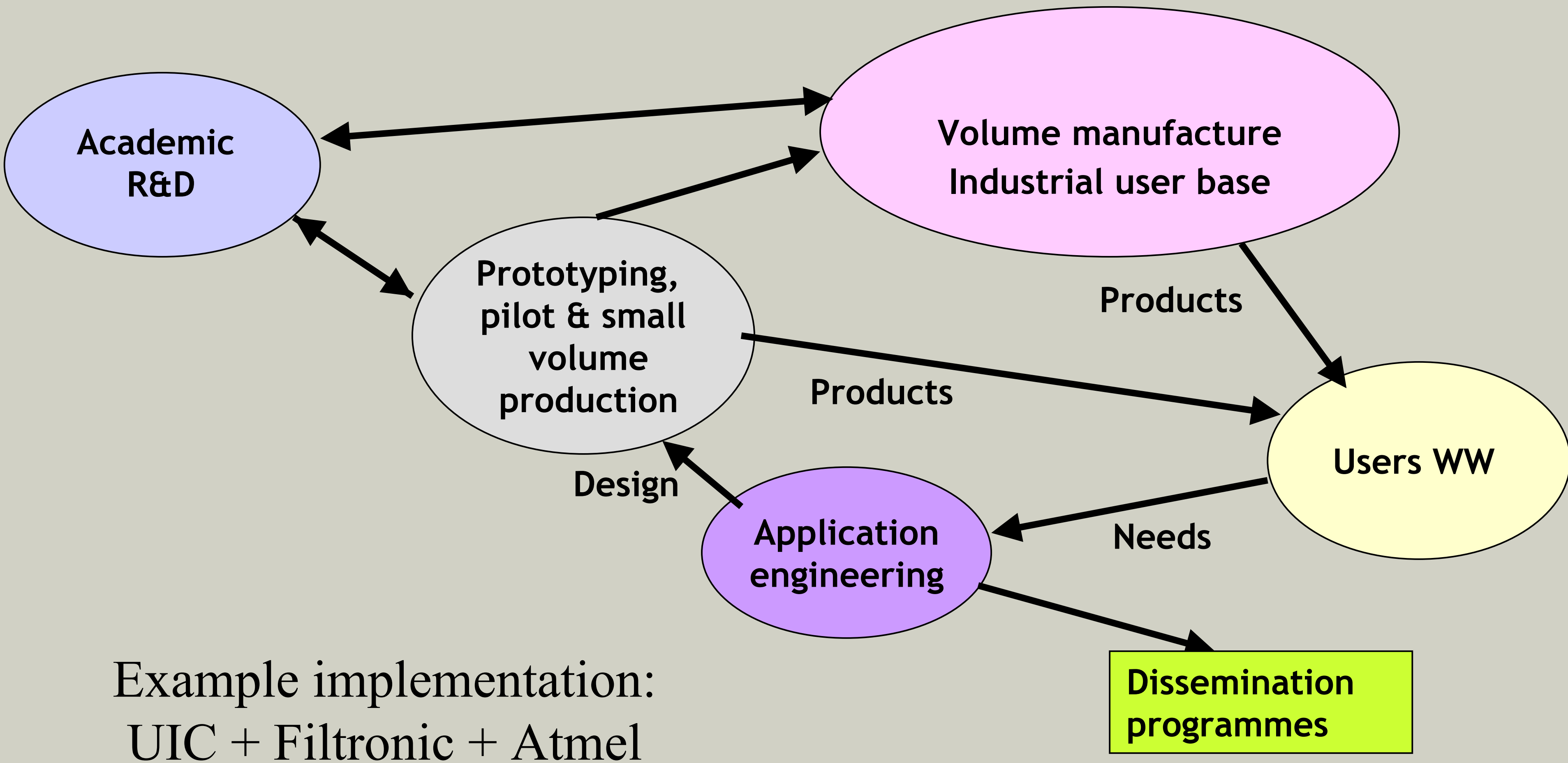
9 English Regional Development Agencies:

A. South West of England
B. South East of England
C. London
D. Advantage West Midlands
E. East Midlands
F. East of England
G. North West
H. One North East
I. Yorkshire Forward

3 Devolved Administrations:

J. Northern Ireland
K. Scotland
L. Wales

Technology insertion: combining a hub and spoke model with national strengths



Example implementation:
UIC + Filtronic + Atmel

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CENAMPS - opportunity for collaboration

- A combination of physical and distributed facilities
- State-of-the-art facilities for research and small volume manufacturing at Newcastle and Durham universities
- Most modern facilities in the UK for semiconductor and compound semiconductor manufacturing – both world class
  - Atmel site – mini-environment
  - Filtronic – largest compound semiconductors plant in Europe
  - Small & large companies already active in micro/nano/photonics
- Large chemical nanotechnology cluster already in billion+ nano exports
- Tradition in manufacturing, best return on capital of any region in UK
- International and national synergies

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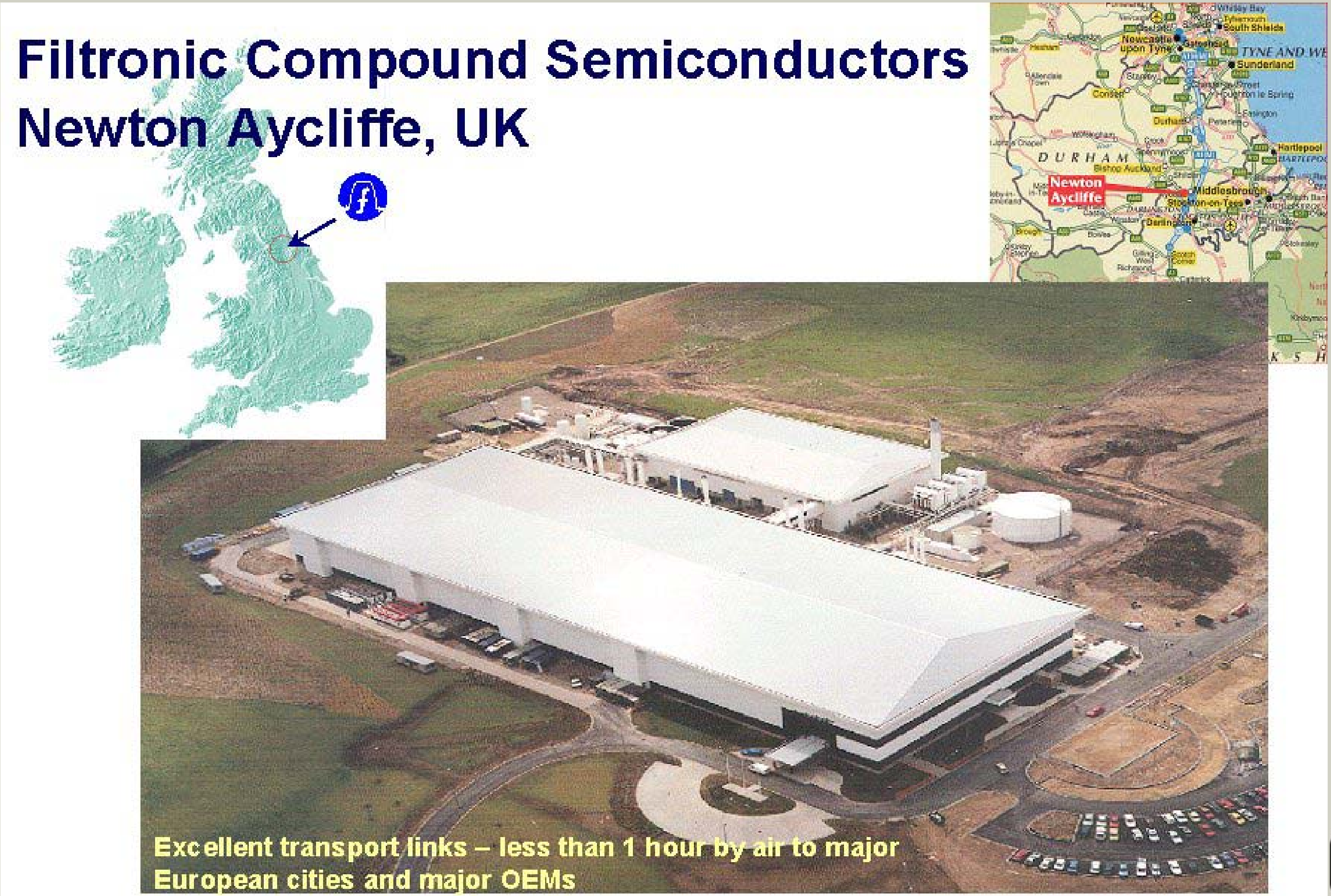
Automotive & Aerospace, Information & Comms Technology, Advanced Manufacturing & Materials, Security



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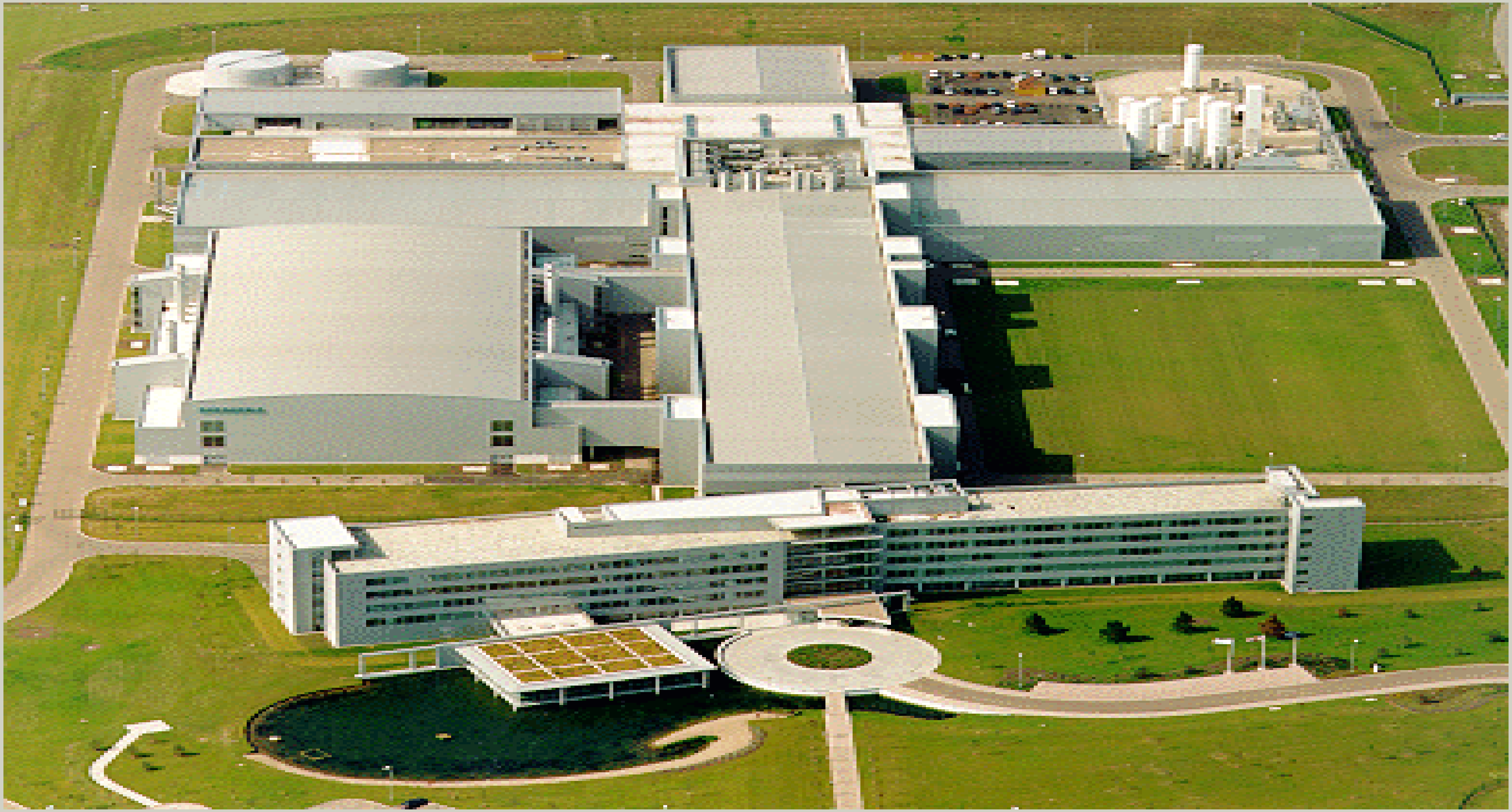

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Objective of capital projects fund is to...

- Accelerate the commercialisation of MNT for the wider benefit of the UK economy
- Provide open access (on fair and equitable terms) to Microsystems and Nano Technology platforms and associated knowledge
- Development of critical mass of capability whilst avoiding duplication of provision

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Through projects which implement...

" Industry/market facing UK based facilities which provide cost-effective open access for organisations and individuals to capabilities, processes and associated knowledge leading to marketable products, and services."

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UK MNT network objectives

Creating wealth from the technology/research base of UK by:

Improving the competitiveness of existing companies through regeneration of the technology base of those companies, leading to products with more competitive cost and/or performance with other global players

Starting new companies to deliver globally competitive MNT products and services.

UK MNT network objectives

Improving the Competitiveness of UK industry by:

- Enabling the development of new products and processes that can compete in global markets
- Improving productivity through greater automation, more efficient processes and better use of resources in all parts of the technology supply chain
- Reducing time to market for MNT based products and services by speeding up the technology development and transfer processes and:
- Increasing the number of suitably skilled people available to organizations throughout the supply chain
- Fostering effective supply chain partnerships that strengthen the technology supply chain for UK industry

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UK MNT network objectives

Starting New Companies by

- Funding Applied Research that will lead to products and services that can be spun out into viable commercial enterprises.
- Developing Entrepreneurship Skills to provide leadership for start-ups.
- Providing Incubator Facilities to help start-ups through their early phases of assistance.
- Improved Access to Funding/Grants.
- Developing and Protecting IP that is the core of the products or services that are spun out.

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UK MNT network components

Technology Transfer Institutes
Research and Development Centres
Military Research Centres
Commercial Companies
Academic Research Institutes

Organisation	Type	Age	Financials	Commercial Revenue	Research Revenue	Staff	Researchers / Engineers	Students / Operators	Areas	Spinouts
ACREO	Tech Transfer	~5	Eqpmnt E18M Budget E14M	Total revenue 2002 €25.6		202 in 2002			10	9 in 4 years
APM	Device/founrdry	~2	Capital $50M			212	E ~ 70	O ~ 30	6 (Si)	
Bosch	MPW service	5 yrs	N/A	NA	NA, EU 50% fund	5	5	Shared	3 (Si)	18 runs
BSAC	r+D	6+yrs		Industry Subscription		130	120	Shared	11	3++
Cambs IRC	R (PhD)	~1	Equip E3.3M Facils E7M		E3M	60		12	2	
CRC Aus	Tech Transfer	~2		$Au64M		100	60	30	11	1+2coming
Cronos	Device/founrdry	4	val$38M			80			3 (Si)	
CSEM	Tech Transfer	>5	Capital E27M Budget E40M	Total revenue €4M		350			7	11/5yrs
DALSA	Semis, MEMS	?	Rev $112M						1	
DIMES	R+D	>5	Capital E6M		E21M	~260	160	80	5	
Fraunhofer IZM	Tech Transfer	10		E11M	E11M	355	170	170	8	
IMEC	D/Tech trans	10+	Invest E70M	E53	E53	1200	912	200?	11	19 tot
INEX	Tech Transfer	>3	Invest E14M			30			7	2 tot
ITRI	Tech Transfer	>15	Facils E30 Equip E27	$219M	$256M	4590	3535	370	4 (Si)	100 (incl TSMC?)
Kelvin Nano	Tech Transfer	~5		E6.4M		110	55	25	2	1
Kist	R+D	>5yrs	IIMC £13.2M			330 (14 IIMC)		19		
KTH	R+d	>10		SKr3	SKr 52	29	29	70	4	
LETI	D/Tech trans	>10	Invest E200M E20M/yr	E40M	E80M	774	570	200	10	~30 tot
MC2	R	~5	Invest E80M tot Facils E17M Equip E15M		E18M	220			5	
MCNC	Tech Transfer	>5							7	Cronos+
Mesa +	R+D	>5	Capital E160M	E5M	E15M	380			5	9/2yrs
MIC	Tech Transfer	>5	Equip E20M Facils E4M	E2.5M	E3.7M	110			7	10/5yrs
Micralyne	D/Manuf	>5		E6M		100			10	1
MIT - MTL	R+d									4+
NMRC	r+D	>10		E11.7M	E3M	97			11	2(2001)
PHS MEMS	D/Manuf	5	Invest E40M			75			5(coms)	
RAL CLRC	r+D	>5	Invest E35M	E7.5M	E7.5M		50	30		
Sandia	R+D	>10	Invest $114M		$50M	274			5	1 (MEMX)
Scottish MC	R+d	>10	Invest E13M			30			4	4
Nanofab Facil	R		Invest $64M	$24M	$16M	200 Open lab facility for members)			8(Si)	~2
Walsin	Manuf	>10	Equip $50M						~3	
Warwick Uni	R				E5.5M	16			2(Si)	

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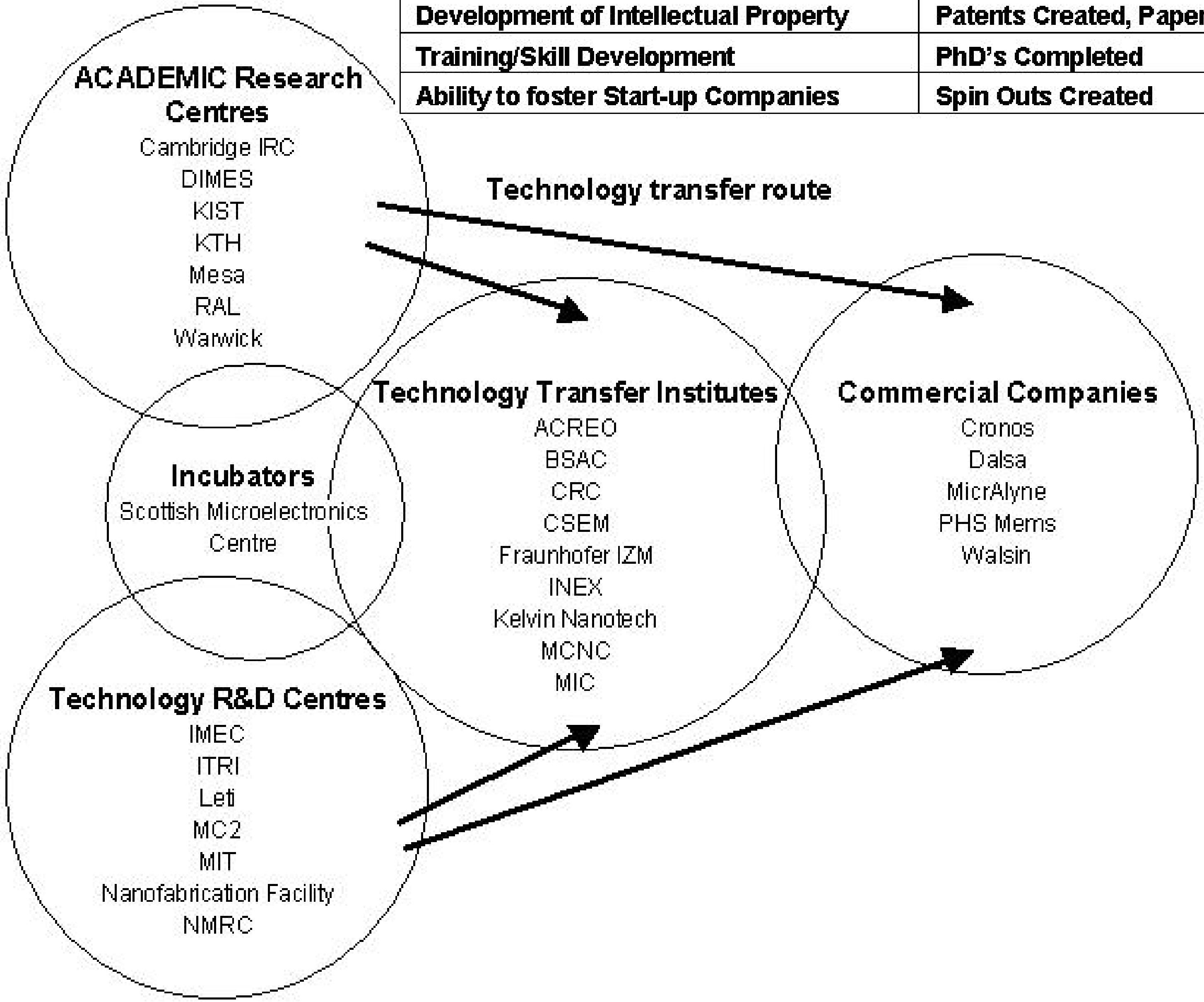
Criteria	Metric
Ability to engage with industry	Industrial Revenue for node
Development of Intellectual Property	Patents Created, Papers Published
Training/Skill Development	PhD's Completed
Ability to foster Start-up Companies	Spin Outs Created



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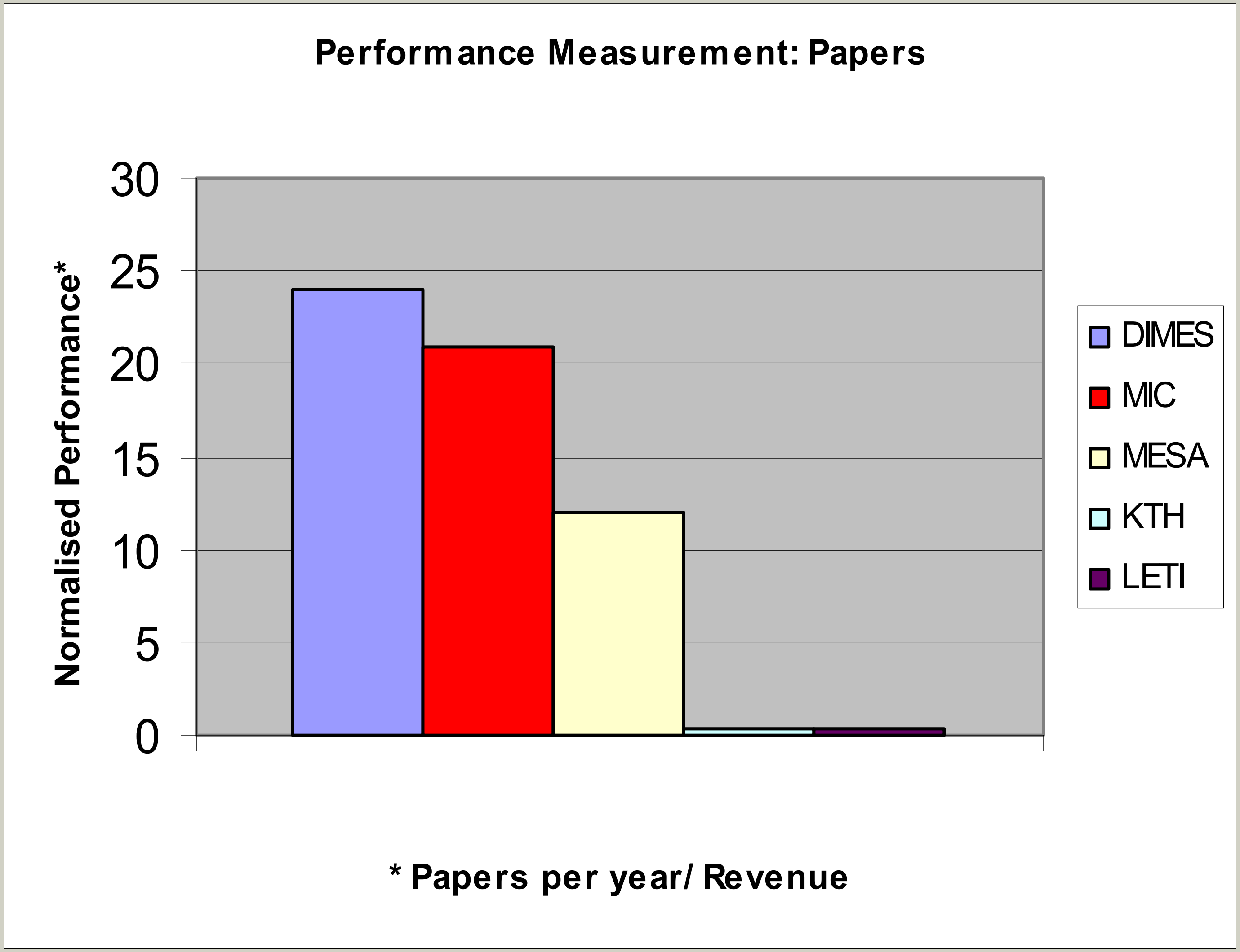
Performance measurement: papers



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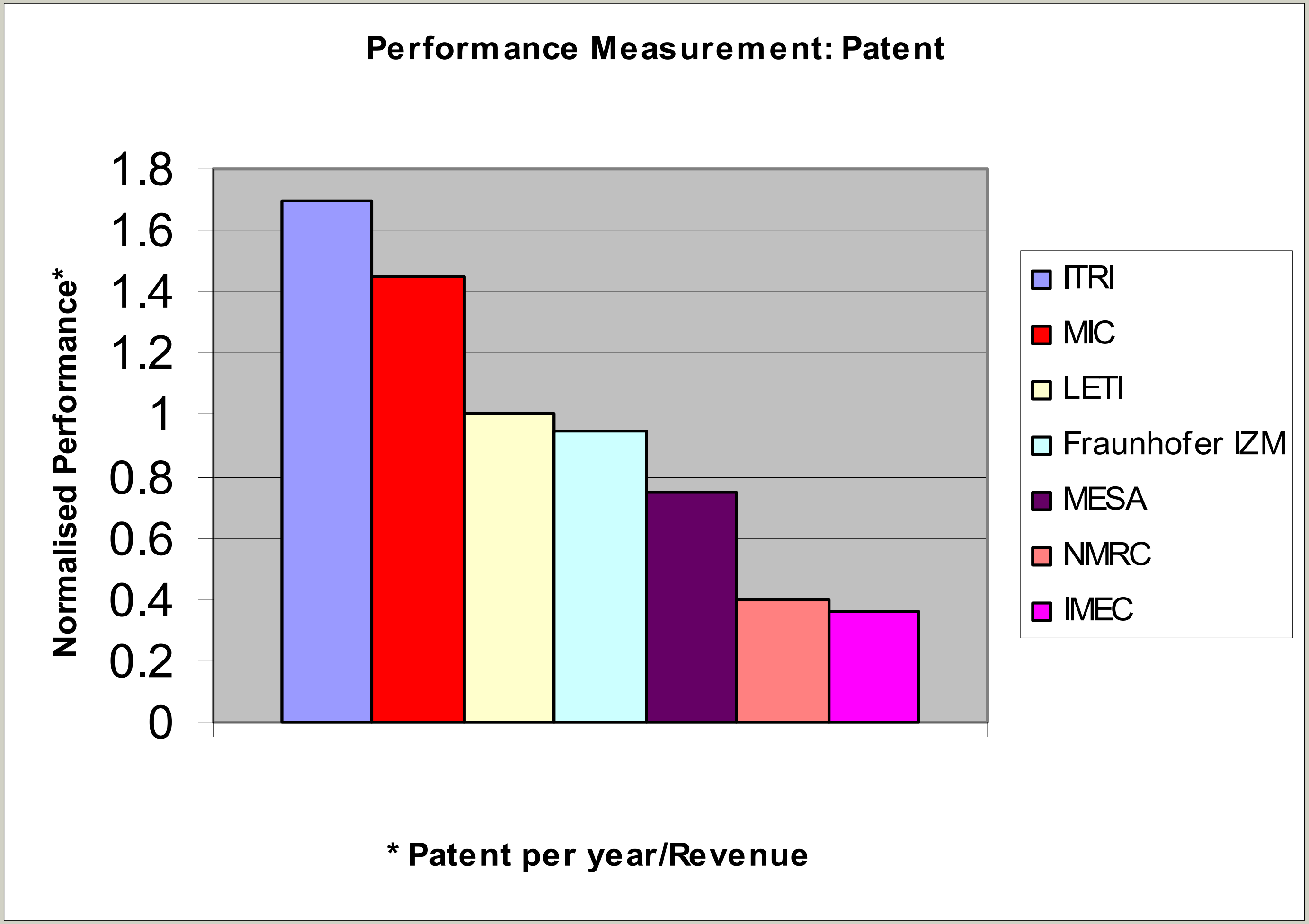
Performance measurement: patents



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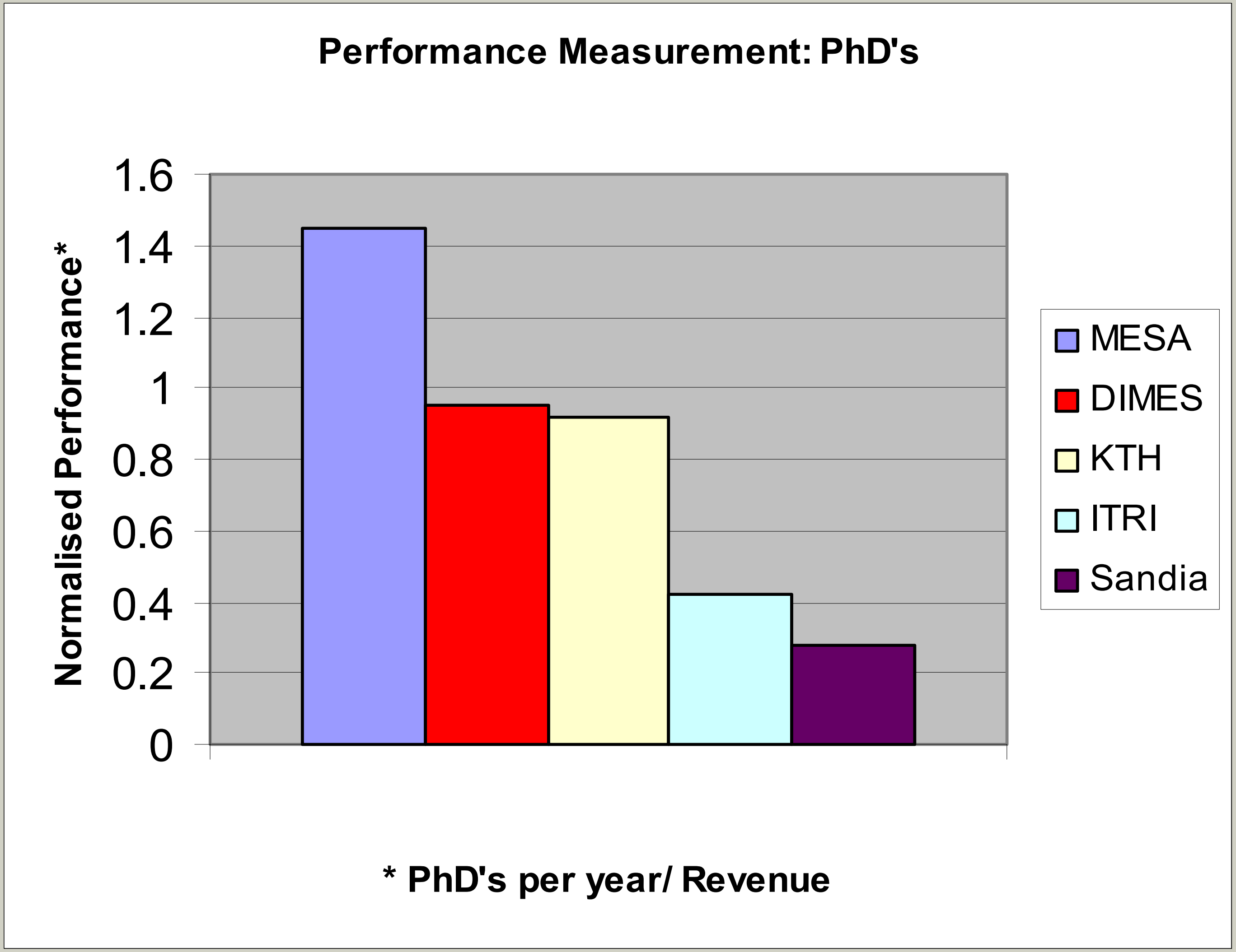
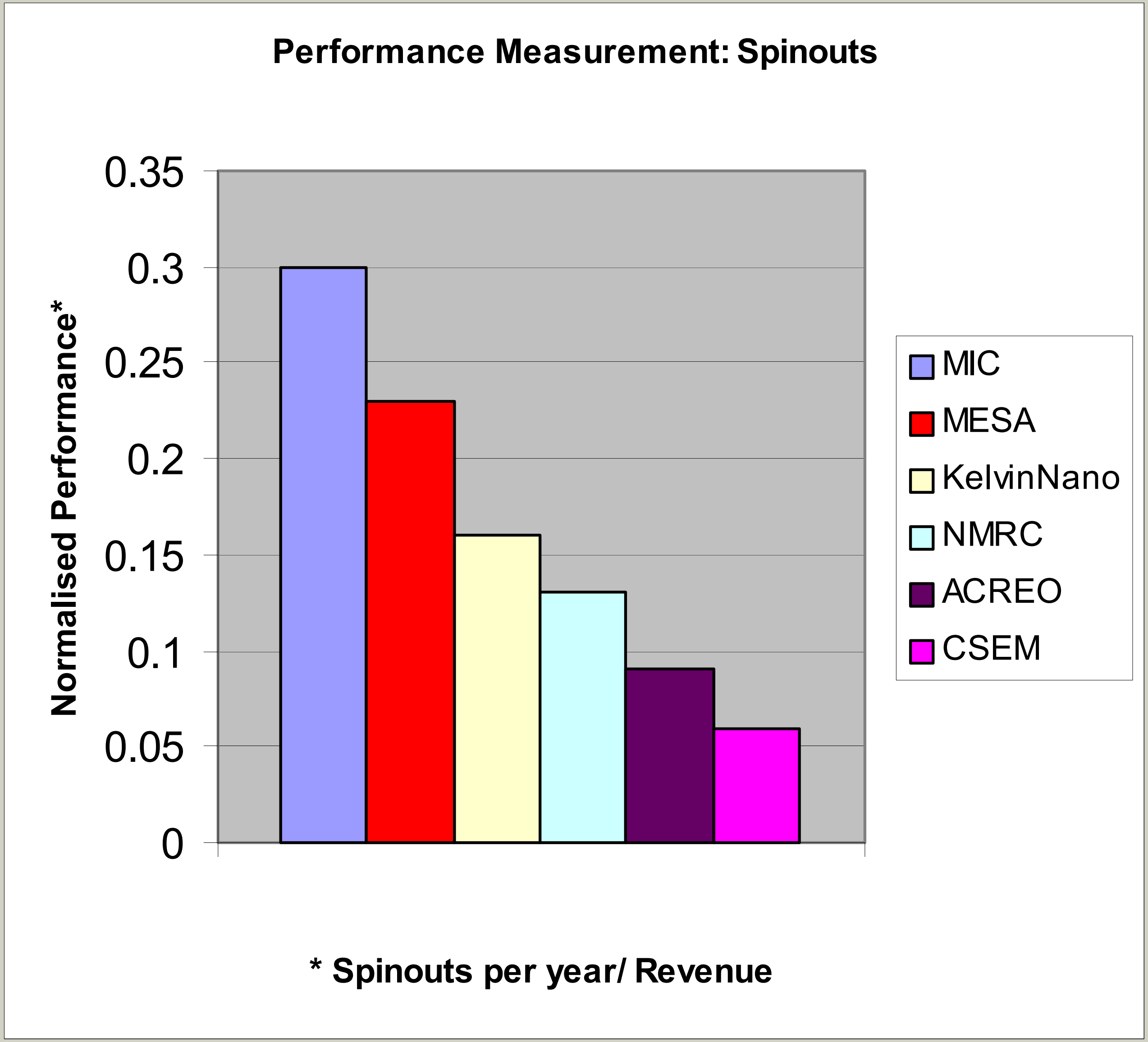
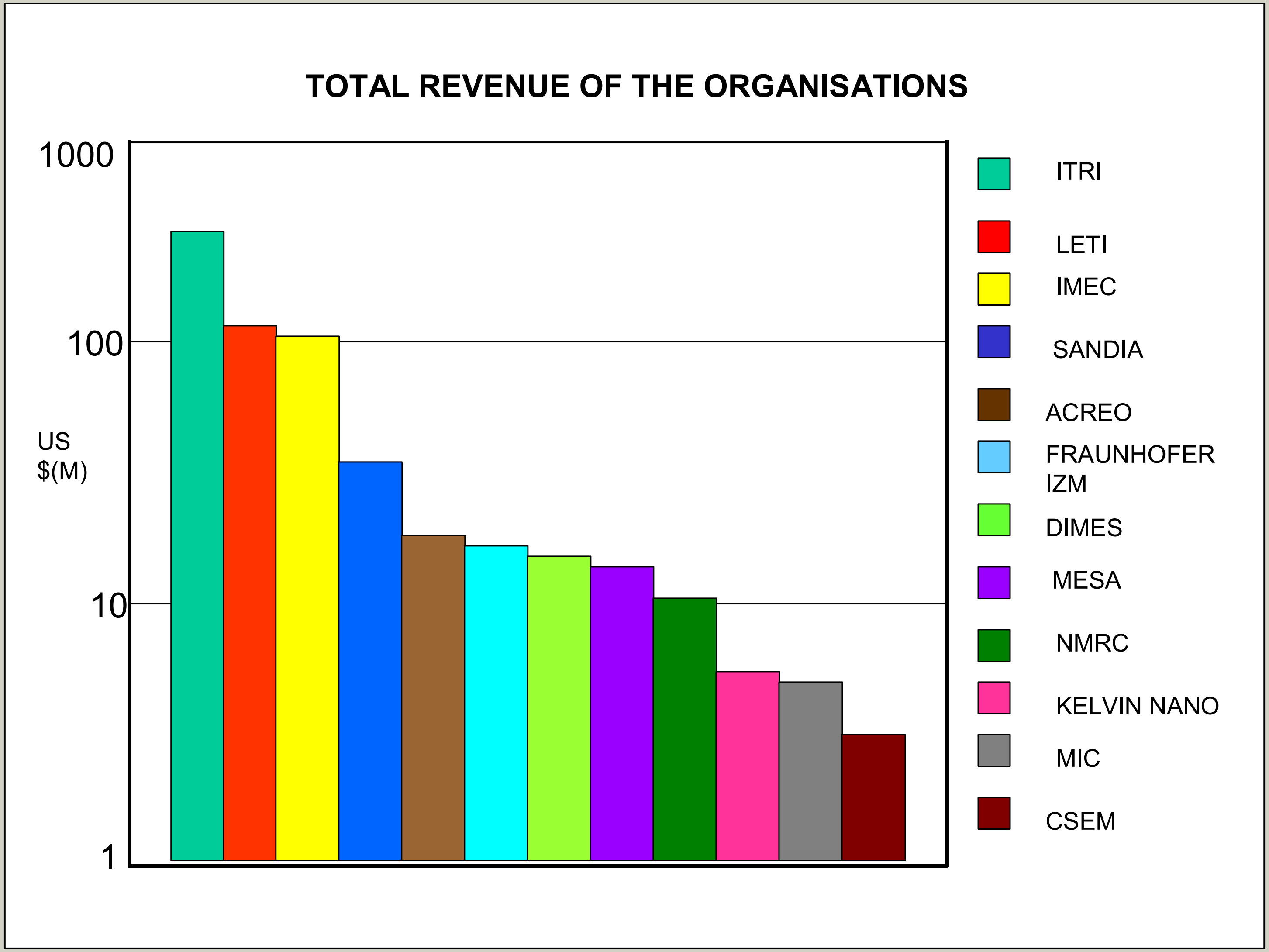
Performance measure: PhDs



Performance measure: spin-out companies



Total revenue comparison



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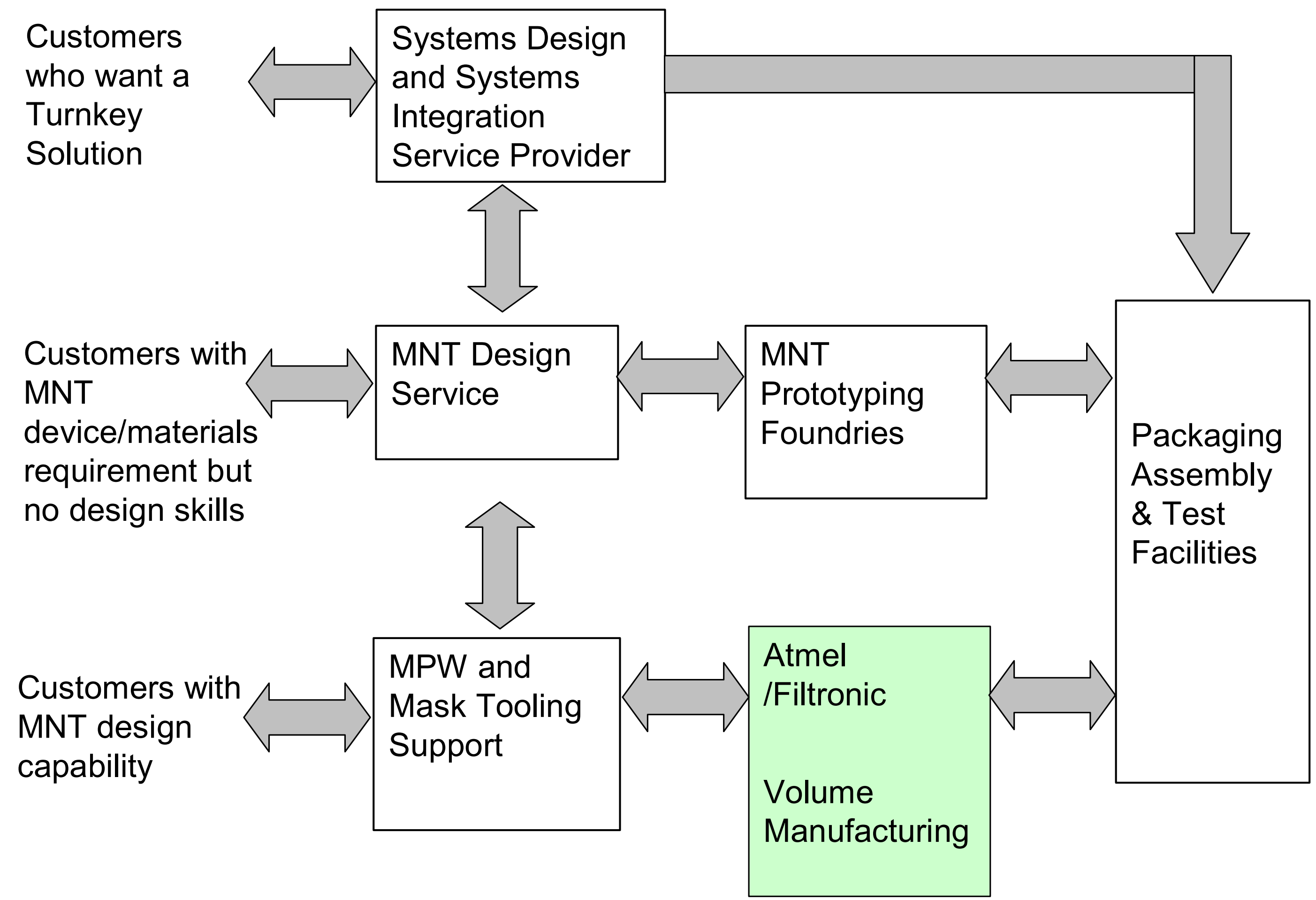
Cenamps services and functions to support volume manufacturing and technology access



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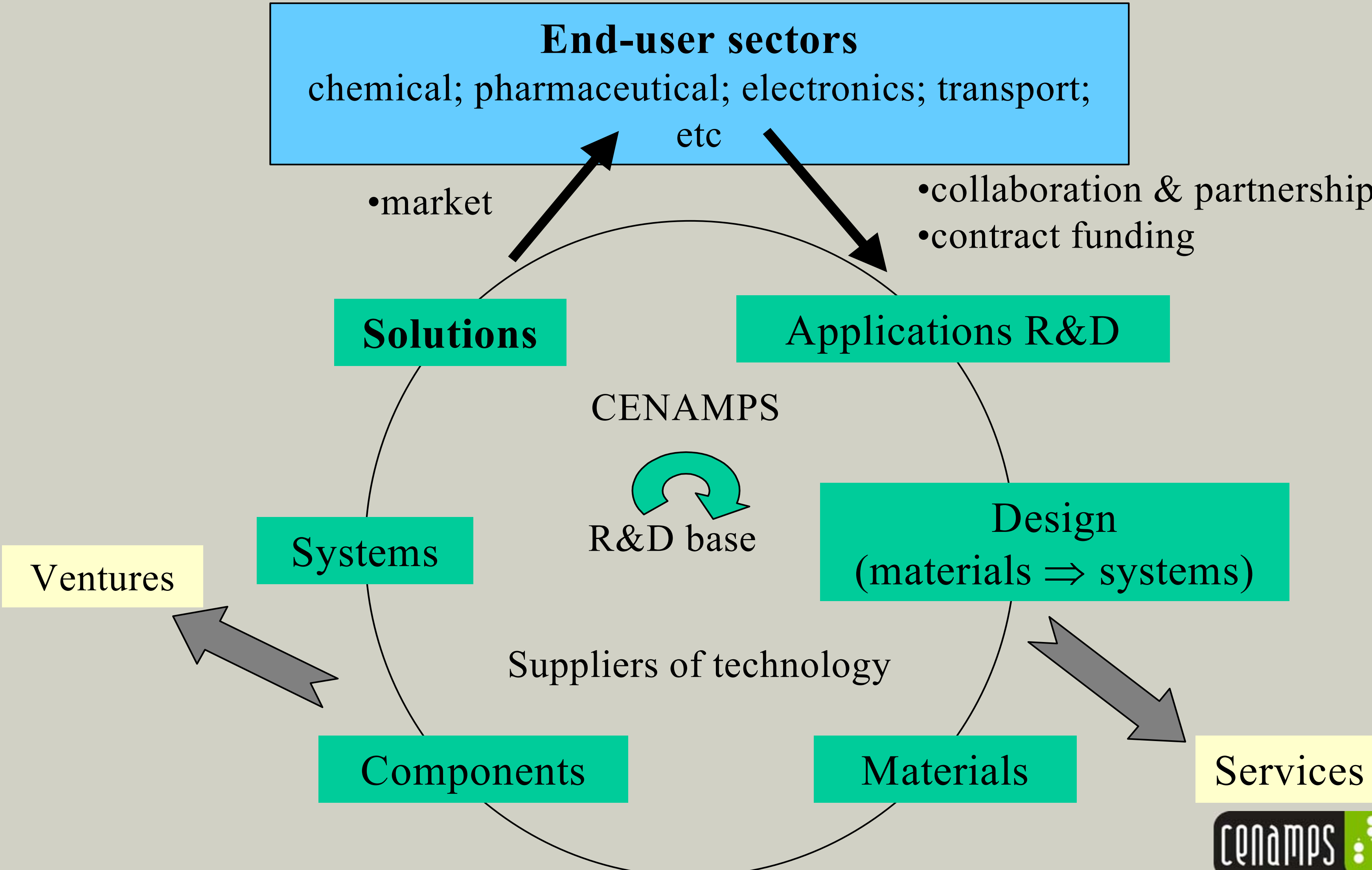
The sustainability cycle



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Preferred criteria for investment focus

- Cenamps and NSTAR will help to bridge the gap from laboratory to later stage funding including grants, seed, early stage and first round funding; typically 1-3m GBP at first round, less for seed. Key areas:
  - **Novel and advanced materials for industrial and medical use**, such as metals, alloys, glass, ceramics, industrial chemicals (organic and inorganic), plastics, composite materials and novel polymers.
  - Innovative **industrial processes** for production of advanced materials or aimed at substantially reducing the costs of production (**process intensification)**
  - **Biotech**
  - **Electronics and photonics** including semiconductors
  - Companies that can produce not only raw materials or devices but also **applications and particularly systems**
  - **Market technology horizon up to about five years**; e.g. nano-based cosmetics, lab-on-a-chip technology, flat panel displays, medical devices, optical technology that impacts broadband or medical apps.
  - **Support for partnering** and for helping companies locate in the UK.

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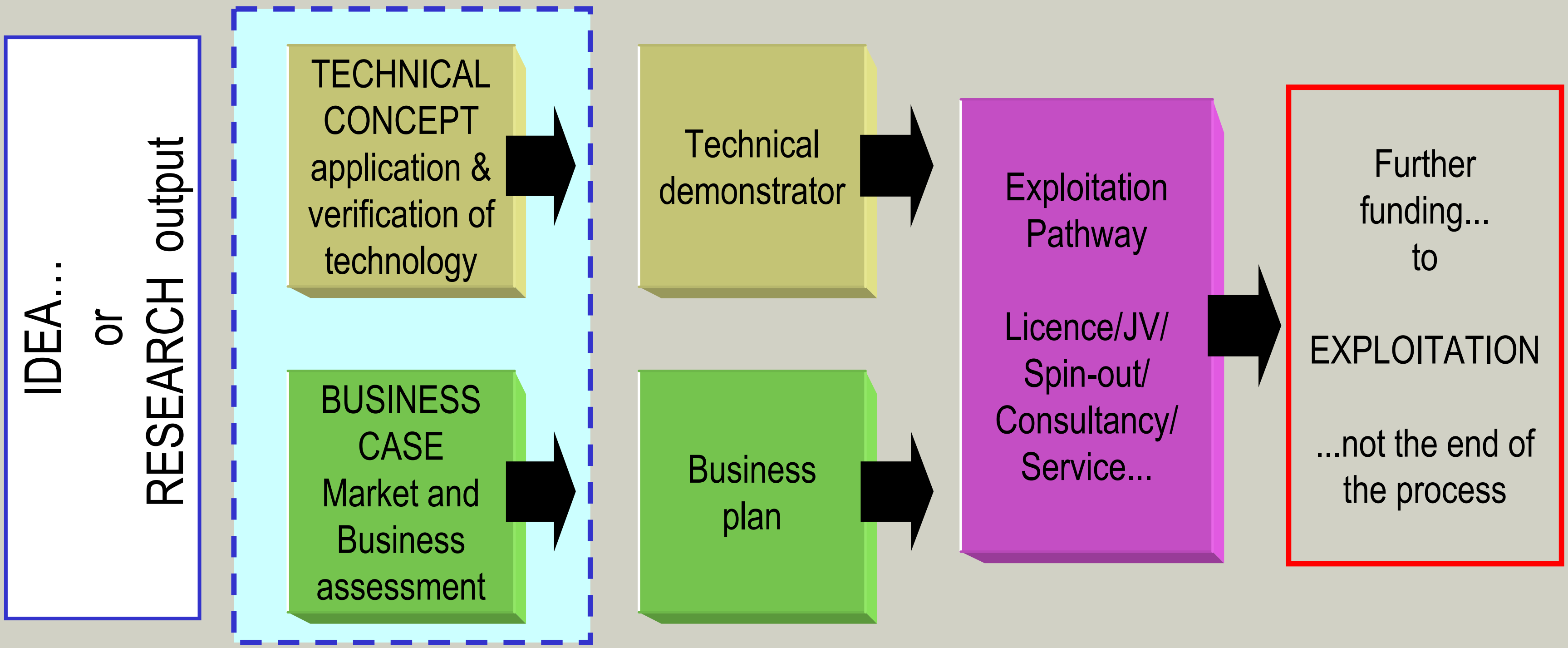
Building a model…
Early stages of exploitation of science & tech…



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Micro- Nano- Photonic (MNP) Cluster

Market need → **Design services** → **Manufacture**

Market need	Design services	Manufacture
		Existing fabs
Turnkey solution	Systems design & process integration	**Open-Access Agile Foundry at Filtronic** •Polymer MNP systems •Nanoscale materials AFM •Bio-systems •Comp'nd semiconductors •Post-processed Si wafers
MNP components	Chip design	
Foundry processes	Multi-project wafers Mask tooling support	
MNP AFM materials	Customised processes	**Open-Access Agile Foundry at Atmel** •Volume CMOS •Si-based MNP systems •Custom Si wafers

Package, assembly & test

Applications development

UIC research base + WW

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The CENAMPS hub & route to market

Filtronic site

- Compound semiconductors (Filtronic: 150mm)
- Bio- microsystems

(linked to: UIC CoEs)

- LEP
  Polymer electronics
  Polymer microsystems
- Ordered Nano-scale & Active Materials
  •organic & inorganic
- Applications Laboratory

(linked to: UIC; CIP; Epigem; other SMEs CoEs)

Atmel site

- Volume CMOS (Atmel: 200mm)
- Si-based Foundry (150 & 200mm)
  •RF/ mixed-signal ICs
  •Microsystems
  •Photonic systems
  •Custom wafers
- Microsystems Design Services

(linked to: UIC CoEs)

Product areas: micro- & flexible displays; lab-on-chip; microreactors; fuel cells; drug delivery; home medical systems; consumer smart materials; high performance materials & coatings; bio- & chemical sensors; RF & THz systems; MEMS & MOEMS; imaging chips

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Plenty of areas to work on…

- Material precursors: nanoparticles and nanostructures
- Processes for fabrication and integration:

  Bottom-up synthesis vs top-down miniaturization - convergence

  ⇒ Novel and hybrid processes, multi-domain processing

  ⇒ 3-D processing techniques: ultrasonic, imaging

  ⇒ Massively parallel processes for productivity and quality
- Theory, modeling, simulation and control
- Instrumentation: sensors and actuators
- Design and Integration of functional nanodevices (in vivo, in vitro, biomimetic)
- System architectures across dimensional scales

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Cenamps international services: development, training, investment & commercialisation

- **Technology development and insertion**
  - Find the appropriate technology partners, develop the technology, find the right business
- **Early stage investment and venturing**
  - Finding investors, equity gap funding, due diligence
- **Market assessment and market analysis**
  - Where will the market be, how big will it be – market structure and trends Partnering
  - Market & production resources, tactical & strategic partnerships
- **Strategic planning and business creation activity**
  - Business plans, emerging trends, technology audits & foresight, product development, marketing & technology proof of principle

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Current Cenamps projects – lets work together www.cenamps.com

- Nano-Electronics Systems Centre
- Pilot Line for Next Generation Display Technology
- Active Polymer Materials Centre
- Agile Manufacturing Mini-Fabs
- Transmission Electron Microscope (TEM)
- Si Manufacturing Node
- UIC Nanotechnology Institute at Newcastle University - bionano
- Laboratory for Processing Hybrid Nanostructures
- Nano-Chemical Analysis Laboratory
- Nano scalar/structured materials, products and processes programme
- Nano materials and characterisation programme
- Open Access R&D and Manufacturing
- Advanced displays (Community Hub)
- Cenamps epitaxy services
- EPSRC electronics manufacturing research

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