

CATRENE

*Cluster for Application and
Technology Research on
NanoElectronics*

A PRIVATE-PUBLIC PARTNERSHIP FOR GROWTH
THROUGH INNOVATION IN EUROPE

WHITE BOOK



(Σ! 4140)

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PART A: RATIONALE AND ORGANISATION

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EXECUTIVE SUMMARY

IMPORTANCE OF ELECTRONICS AND SEMICONDUCTOR INDUSTRY FOR SOCIETY

Electronics and information systems play an ever increasing role in the worldwide economy, representing already today nearly 10% of gross domestic product (GDP). They have penetrated and transformed all aspects of life - including transportation, communications, health, government services, banking systems, entertainment and education - and have created millions of jobs in industry and services. They have also been the motor of productivity growth. Micro- and nanoelectronics are the key enabling technologies for electronics and information and communications technology (ICT) and, as a consequence, the semiconductor market is increasing at double the rate of GDP growth. Information technologies and electronics have played a major and critical role for innovation: ICT patents account for more than 85% of all high-tech patents in Europe, the USA and Japan.

In the foreseeable future, the role of electronics and information systems will further increase as European society is faced with structural problems such as ageing of the population, exploding healthcare cost, transportation bottlenecks, rising energy costs and the need to increase productivity to be competitive on a worldwide basis. European citizens are expecting better health systems, safer cars, improved energy management, improved telecommunications and information access, better entertainment and security everywhere.

These societal challenges are also major opportunities for European industry. The challenge is to be the first to address these new lead markets and to become worldwide market leaders in a number of these domains.

ECONOMICS OF ICT INNOVATION

To make these new products and services affordable for the population at large, strong progress in nanoelectronics in terms of costs and integration is necessary. Indeed, the growth of the ICT industry is mostly based on strong and steady technological progress in semiconductors - doubling of performance every two years, and 40% reduction in price per function each year - supported by a very high level of R&D, nearly 20% of sales. In the past decades, this technological progress has lowered the cost of a large number of products and services, making them available to the population at large, and therefore the contribution of the micro- and nanoelectronics industry goes well beyond its GDP numbers.

Leadership in new markets is strongly related to leadership in micro- and nanoelectronics. This requires a high level of R&D and also major investments in infrastructure. Recognising this fact and the key role of this industry, public authorities in all regions of the world are providing different types of financial support to these industries. These increasing costs make it also impossible for most companies to maintain technology leadership on a stand-alone basis: co-operation is more and more cross-border and not limited to R&D.

A COMPETITIVE PLACE FOR EUROPEAN INDUSTRIES

Over the past decade, the European semiconductor industry has been able to reinforce its position through very high R&D efforts at all levels of the value chain. These efforts have been

supported by public authorities both at the national and European level. As far as cross-border co-operation is concerned, the EUREKA JESSI, MEDEA and MEDEA+ programmes have been particularly effective in developing links between European companies and with public research institutes. However, the level of funding for these programmes has remained flat and has not followed the evolution of total R&D effort. Overall public funding for R&D in semiconductors is about a third of the average funding ratio for European industry.

A real weakness is also the fact that, despite very good positions in telecommunications and automotive markets, European industry is almost completely absent from the computer sector. Overall, the rate of innovation in ICT is significantly lower with 40% less ICT patents application to the European Patent Office by the EU-25 than by the USA or Japan. At the same time public authorities in Europe are underinvesting in ICT use. They represent only 20% of the ICT market, while taking about 45% of GDP.

It is clear that these market and technology trends will continue at least for another decade. A large part of the success in innovation resides in the speed of converting technology to solutions for the final customer: a proactive innovation model must be deployed all along the value chain, linking closely technology challenges and market needs. There is also no doubt that investment efforts, particularly in R&D, will have to increase, maintaining the same very high level of R&D to sales.

PUBLIC SUPPORT MUST BE CONTINUED AND DEVELOPED FOR EUROPEAN PROJECTS

Public support for R&D must be increased to follow these increasing costs and also to catch up with competitors. In particular, for the sake of efficiency in use of public money and because the first targeted market is Europe as a whole, cross-border programmes will become structurally more and more important.

The proposed CATRENE programme reflects all of the above. It embraces all key actors in the value chain - including applications, technology, materials and equipment suppliers - as well as involving both large companies and small and medium-sized enterprises (SMEs) around a number of market opportunities and societal challenges (lighthouse projects). This new organisation reflects the increased importance of this industry but is also in line with a number of trends towards greater focus existing in national programmes.

At the same time, CATRENE intends to keep the strong points of its predecessors in terms of efficiency and flexibility and strong involvement of public authorities.

Given its importance it will interact with other programmes in the nanoelectronics field - national, EU framework and Joint Technical Initiatives (JTI) - and with other EUREKA clusters such as ITEA2, EURIPIDES and CELTIC.

It may be decided later by the stakeholders that CATRENE will be merged with the European Nanoelectronics Initiative Advisory Council (ENIAC) JTI, if and when appropriate.

CATRENE is an four-year programme, starting 1 January 2008, but extendable by another four years and as such ending 01.01.2016; this is in line with the changing landscape of the semiconductor industry as well as the present view on technology evolution and the time span over which most of the major applications will develop. Resources required will be annually around 4,000 person-years, equalling about € 6 billion for the extended programme.

INTRODUCTION: FROM MICROELECTRONICS TO NANOELECTRONICS

A SUCCESS STORY ...

For more than a decade, the EUREKA JESSI, MEDEA and MEDEA+ programmes have made it possible for Europe's industry to reinforce its position in semiconductor process technology, manufacturing and applications, and to become a key supplier to markets such as telecommunications, consumer electronics and automotive electronics.

At the end of these programmes, European industry has successfully:

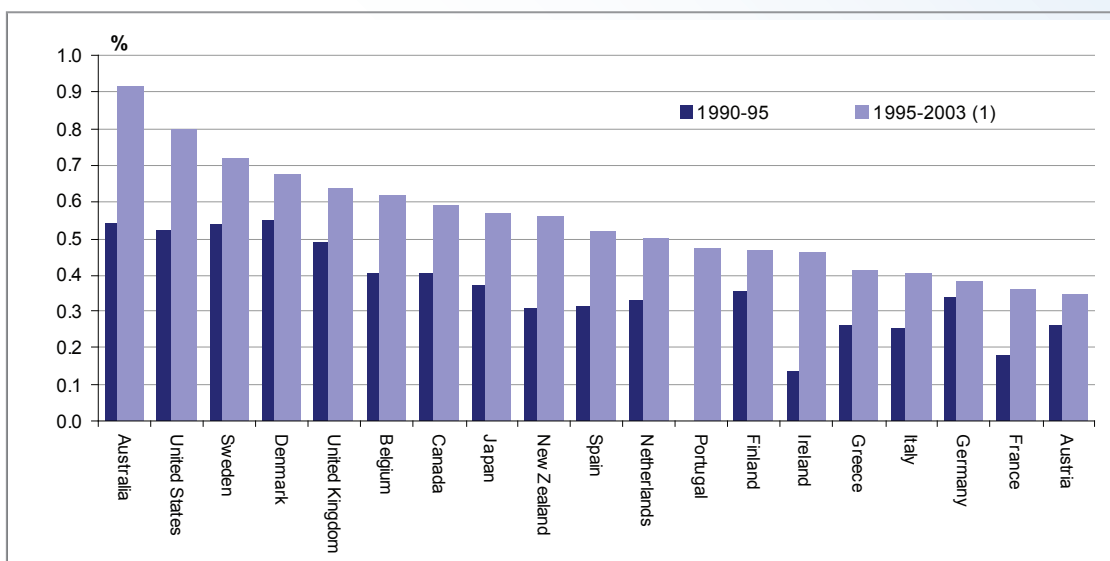
- Conquered vital high technology domains through technical innovation;
- Learned horizontal and vertical co-operation; and
- Produced industrial champions.

Since 1998, all three major European semiconductor manufacturers have entered the ranks of the top ten largest semiconductor companies in the world. In lithography, there is European leadership with a market share exceeding 50%. European semiconductor companies have a 12% market share in worldwide sales. And, for the whole information and communications technology (ICT) sector, Europe now has a 20% worldwide market share, which demonstrates clearly that semiconductors have become one of the strongest segments in European ICT, starting from a situation that before JESSI many saw as hopeless.

... IN A STRONGLY GROWING MARKET

This robust position has been achieved in a market that has experienced strong growth. Electronic devices and systems have become the major drivers for innovation in a number of domains; the contribution of ICT to the GDP of developed countries is large and growing very significantly - Figure 1.

Fig. 1 - Contribution of ICT investment to GDP growth, 1990-95 and 1995-2003, in % points



Source: OECD

The market for electronic equipment has been increasing worldwide at double the rate of gross domestic product (GDP) and, within this market, growth in the semiconductor industry has been even stronger.

Over the past 15 years, the average growth rate of the semiconductor industry has been more than 10% a year. The importance of this industry will further increase as nanotechnologies enter new fields such as e-health, energy savings, logistics and security. It is fair to say that nanotechnologies will be essential in providing solutions to the social challenges facing us in the next decades. Today, the semiconductor industry is a strongly value-adding international industry worth US\$ 250 (€ 185) billion, up from only a few billion in the 1970s.

INFORMATION TECHNOLOGIES MORE IMPORTANT THAN EVER

Recent reports commissioned by the European Union and by the EU Presidency - the Aho report: Creating an innovative Europe; and the ISTAG report: Shaping Europe's future through ICT - clearly demonstrate that innovation is essential to maintain productivity growth, economic growth and the continuation of our European socioeconomic model. At the same time, these reports underline the key role that information technologies (IT) have to play. Nanotechnologies are the core of IT products and mastering these technologies is the basis of European ICT leadership.

NEED TO CONTROL THE KEY TECHNOLOGIES

A good counter example is the personal computer (PC) industry in which Europe has a very weak position, mainly because the two key technologies - microprocessors and operating systems - are de facto monopolies or duopolies of US companies. While no PCs are assembled in the USA, it is clear that the PC industry is US dominated because of its control over these key technologies.

On the other hand, when Europe has led in standards setting and its industry has developed the key technologies such as for GSM mobile telephony, MPEG audio and video compression, or smart cards, the European economy at large has benefited strongly.

When measured against the EU Barcelona objectives for 3% of GDP to be spent on research, the European semiconductor industry has been leading not only in terms of research and development (R&D) investment but also in terms of the ratio of industry to public funding. Reinforcing this public funding should be a priority in the context of the whole EU innovation strategy.

It is worth remarking that most developed countries outside of Europe are already heavily engaged in strong support to their semiconductor industries, both in manufacturing and R&D - technology and application. This is the case in the USA, South Korea, Israel, India, Japan, Singapore, Taiwan and, more recently, China.

These are major strategic programmes put in place to master and then dominate the semiconductor market. It must be borne in mind that, in the near future, the countries mastering semiconductor technology will be the ones playing the leading role in the key applications for energy, transport, security, logistics, health, industry, consumers, communications and even agriculture.

Indeed, it is now only possible to be the market leader in these reactive and complex applications and systems markets if the systems or applications designers are very close to the technologies and are driving technology development to their needs. To design efficiently in advanced technologies, the designer should be able to work closely with the device-engineering team and feel part of the development/manufacturing line. This is what is developed within the current MEDEA+

programme, where the applications objectives, derived from societal needs, are driving the technology developments to guarantee Europe's competitiveness in today's and tomorrow's market.

In order to develop European competitiveness further in the tradition of the successful JESSI, MEDEA and MEDEA+ programmes, ***we propose a new programme called CATRENE.***

**THE VISION OF THE CATRENE PROGRAMME IS:
TECHNOLOGY LEADERSHIP FOR A COMPETITIVE EUROPEAN
ICT INDUSTRY**



CHAPTER 1: THE CATRENE PROGRAMME

1. MAJOR TRENDS

R&D SPENDING IN TECHNOLOGY AND ARCHITECTURE WILL CONTINUE TO RISE AS PROGRESS IN TECHNOLOGY CONTINUES.

Neither the International Technology Roadmap for Semiconductors (ITRS) nor Moore's law seem ready to slow down. With every new step, we achieve higher performance, longer battery autonomy and wider accessibility by democratising the cost of access to the technology - for instance mobile Internet or high definition television (HDTV). With every new node come new options - such as radio frequency (RF), embedded micro-electro-mechanical system (MEMS) and sensors - that are able to multiply the possibilities offered by the technologies and push disruptive innovation in products and services. But, as we approach the atomic scale, a completely new set of technical roadblocks arises: the need for new materials, more constraints on devices and process specifications, more hidden effects that become critical, and ever more differences in each option from the core process whereas they used to be more or less simple derivations. Therefore, as in the past, R&D spending in technology and architecture will double within the next five to six years, creating new problems for European industry to finance competitiveness and for the European public research ecosystem to maintain the pace set by this international industry.

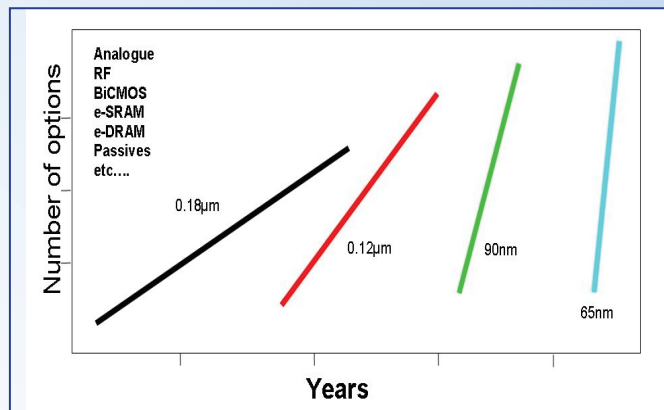
NEW APPLICATIONS WILL ADDRESS SOCIAL NEEDS

A new wave of applications arrives every five to seven years, relaunching the semiconductor market. The next wave will certainly be related to resolving social problems and the quality of life of end-users. But fulfilling these needs will require systems of much higher complexity, generating very high technology development costs and there are particularly numerous roadblocks for geometries below 45 nm.

TECHNOLOGY OPTIONS ARE INTRODUCED MUCH FASTER...

As Figure 1-1 shows, there is already a clear trend towards a very fast introduction of system-on-chip (SoC), network-on-chip (NoC) and system-in-package (SiP) devices that integrate new electrical functionalities but also demand a higher level of engineering skills and technology.

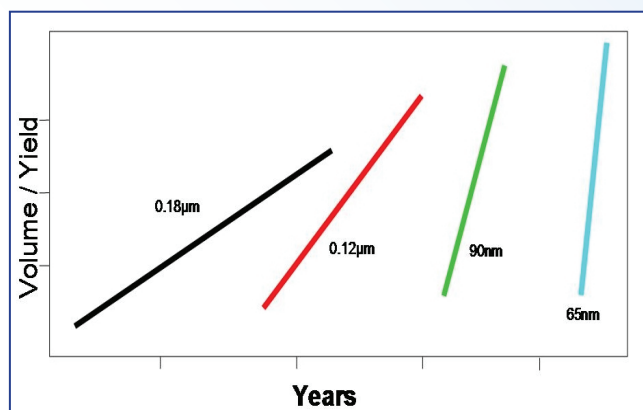
Fig. 1-1 - Acceleration: more options in a shorter time frame for system on chip



...WITH FASTER RAMP-UP OF VOLUMES AND YIELDS

Serving these new mass markets also requires efficient manufacturing and strong industrial flexibility to control the costs. As Figure 1-2 shows, volumes and yields have to be brought up much faster than in the past.

Fig. 1-2 - Rocket ramp up: volumes and yields



Finally, the market is becoming very volatile, with fewer killer applications but with the development of multiple new mini-applications that are starting to be produced also by electronic device manufacturers in emerging countries such as China, Malaysia and Indonesia, not to mention Taiwan, South Korea and Singapore.

HIGHER COMPLEXITY AND FASTER RAMP-UP REINFORCES THE NEED TO COLLABORATE

These trends bring added complexity, with a need for improved productivity in designing products faster and faster, as well as high tooling costs and design-to-product expenditures. As a result, very few companies can afford their own R&D in all segments of nanoelectronics; and most gain by collaborating along the value chain from the computer-aided design (CAD) software manufacturer, to the test equipment producer, or from the substrate provider to the final original equipment manufacturer (OEM) or the operator.

However, companies active in the same or adjacent segments can reduce the load by sharing efforts through co-operation in pre-competitive R&D. Public funding for such efforts, particularly those that are close to the market, must take this into account. Flexibility in terms of partnerships and fast decision making are essential because technology cycles are so short - only a couple of years. Programmes that do not meet these criteria are likely to become irrelevant for maintaining European industry technological leadership.

As a suitable vehicle for multinational R&D co-operation, private/public partnerships (PPPs) and particularly the EUREKA JESSI, MEDEA and MEDEA+ programmes have proven to be very effective. In general, co-operation and alliances are not limited to R&D but are pursued in manufacturing and business partnerships.

The programme introduced in this White Book continues the tradition of JESSI, MEDEA and MEDEA+ and aims at maintaining European technology leadership and mastering the

technological bricks to support the different applications of nanotechnologies.

PUBLIC SUPPORT IS AN IMPORTANT FACTOR

There is a market deficiency in microelectronics because public governments have been structurally and massively supporting this industry all around the world. This is due to the fact that it has a structuring effect on the industrial and economic system of the knowledge society. Europe has not followed this trend and today is at a crossroads and should step up in the world competition with the same kind of support.

Microelectronics is a powerful enabler for technological bricks that are the foundations of the products and services in tomorrow's knowledge society. And it is known for its structuring effect on local industry and academic research. Therefore, governments all around the world have been outbidding each other to attract major industrial sites and the R&D centres of the top companies. Over the past six years, R&D spending has doubled in this sector, yet European public aid has remained constant whereas other countries in the world have announced billion-dollar aid plans and aggressive top-down orientation and co-ordination of public research through major dedicated institutes.

Countries have also pushed very strongly to create the appropriate ecosystem to foster the blooming of semiconductor R&D and manufacturing. This includes tax exemptions, focus towards the creation of the complete value chain, local market as a driver with support on infrastructures and sponsoring first users to initiate network ecosystems.

1.1 NANOELECTRONICS - CONTINUING SEMICONDUCTOR TECHNOLOGY REVOLUTION

In the late 1960s, Intel co-founder Gordon Moore predicted the number of transistors on a chip would double every 18 months; an observation now referred to as 'Moore's law'.

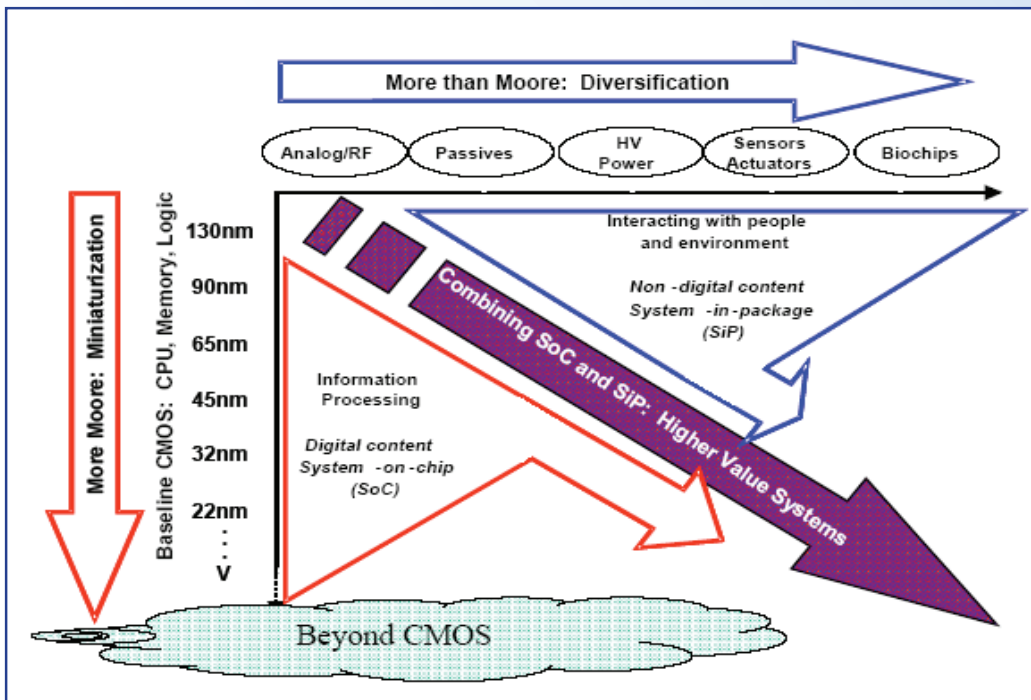
This trend continues, particularly for memories and microprocessors, which depend on size and power reduction for introduction of ever increasing complexity - Figure 1-3.

At the same time, a greater variety of semiconductor devices can be combined on the same chip in SoCs or in the same package using SiPs. This concept, known as ‘more than Moore’, adds a lot of other devices on top of the pure CMOS process - such as analoge/RF, passive, high voltage (HV) power, sensor/actuator, biochip and MEMS components - that are processed embedded in the chip/package instead of being added at systems level. This improves system integration by an order of magnitude and opens new application fields.

Fig. 1-3 - Semiconductor technology trends

Table 1-1 - Performance improvement in a decade

PERFORMANCE ITEM	IMPROVEMENT FACTOR PER DECADE
Packing density of transistors - e.g. storage capacity of DRAMs	100
CPU processing cost per millions of instructions per second (MIPS)	1,000
Cost per MB of storage capacity of hard disk drives (HDDs)	1,000
Bandwidth of networks	1,000
Cost of bandwidth - cost per bits per sec per km	30



Source: MEDEA+, Intl. Tech. Roadmap for Semiconductors (ITRS) 2006

The impact of this evolution can be measured in Table 1-1. This evolution continues: the ‘micro’ of microelectronics has shrunk and the smallest structures in silicon chips are measured in billionths of a meter, meaning nanometres.

This is the world of nanoelectronics. It makes possible a new generation of advanced devices with easy-to-use features that conceal great complexity. These tiny nanochips will power pervasive networks of miniaturised devices that have ever increasing intelligence and communicate among themselves. This is the Internet of things.

In fields such as e-health, transportation and security, the amount of data being generated and transmitted on a continuous basis will be so large that automatic decision making will become a necessity. Without this level of intelligence at the captor level, this ‘network of things’ will not be exploitable. At the same time, data compression will be essential. To make all this possible, nanoelectronics still has a long way to go.

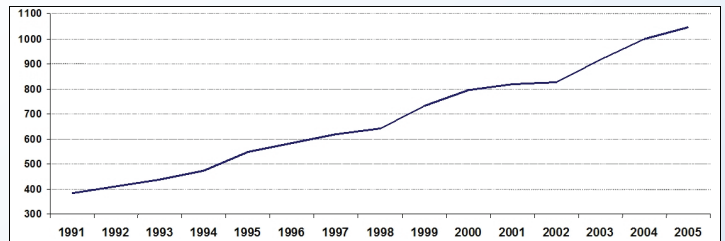
While nanotechnologies respond to a number of these needs, their availability generates new, often unexpected, applications at an affordable price. An example from the recent past is the introduction of cameras and MP3 players in mobile phones - see also Table 1-2 showing mobile phone evolution.

NEW TECHNOLOGY NODES ENABLE:

- Cost-efficient products
- Unprecedented functional performance
- New application fields and markets

This can be seen clearly in Figure 1.4 by looking at the telecommunications sector revenue for the last 15 years.

Fig. 1-4 - Telecommunications sector revenue (US\$ billion)



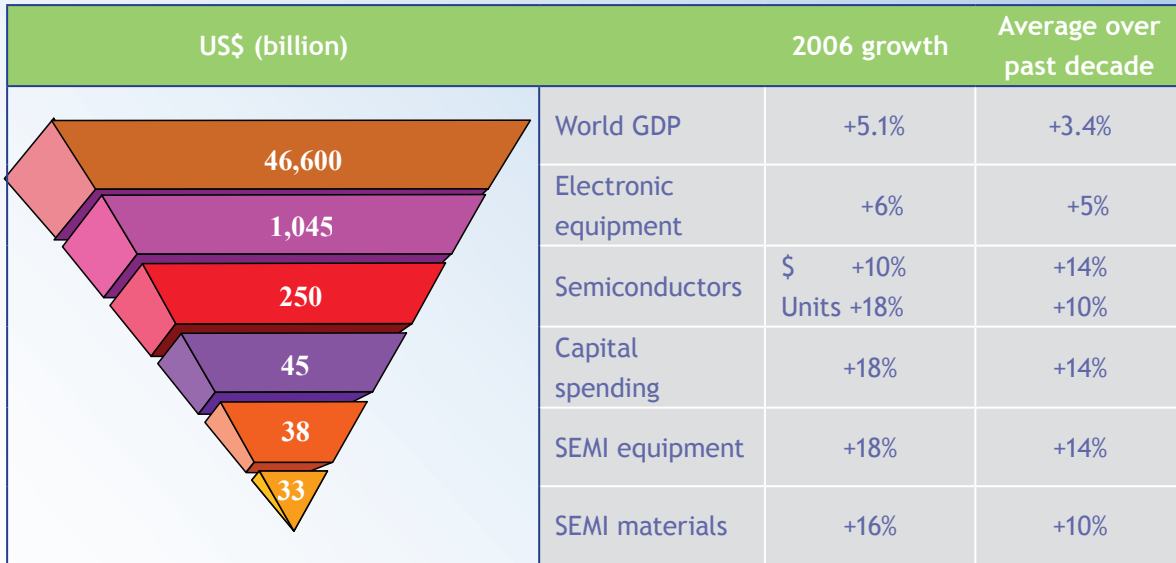
Source: OECD

Table 1-2 - Mobile phone evolution 1986 to 2006

1986	1989	1996	2006
Ericsson 450 Combi 4 kg 3-hour autonomy	Hotline 900 pocket 630 g 1-day autonomy	GH388 245 g 3-day autonomy	V600i 102 g 12-day autonomy
			
			

1.2 NANO ELECTRONICS - GROWING STRONGER THAN THE ECONOMY

Fig. 1-5 - The pyramid of goods and wealth



Source: Future Horizons IFS2007, March 2007

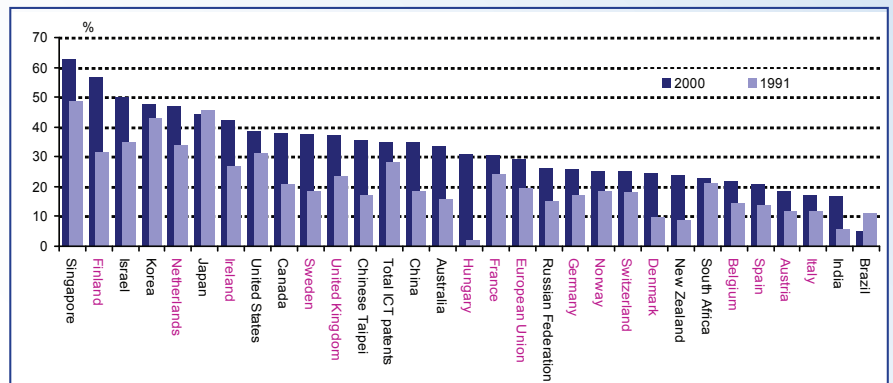
The pyramid of goods and wealth shown in Figure 1-5 illustrates that electronic equipment takes an increasing part of world GDP and that, within electronic equipment, the part of semiconductor products continues to rise.

As was pointed out in the 2006 ISTAG report, ICT - and particularly nanotechnologies - is no longer an enabling technology but in many cases the constitutive technology, i.e. the solution itself. This is why these technologies are taking a greater part of the total value chain.

A good measurement of the importance of ICT and of the focus of countries to it is shown looking to the level and trend of the percentage of ICT patents per country - Figure 1-6.

Recognising this fact means also acknowledging that it is important to maintain and even reinforce our efforts to retain European leadership in this field. It will be difficult for Europe to have acceptable economic growth

Fig. 1-6 - ICT patents as a % of national total in selected countries (according to the residence of the inventor, by priority year)

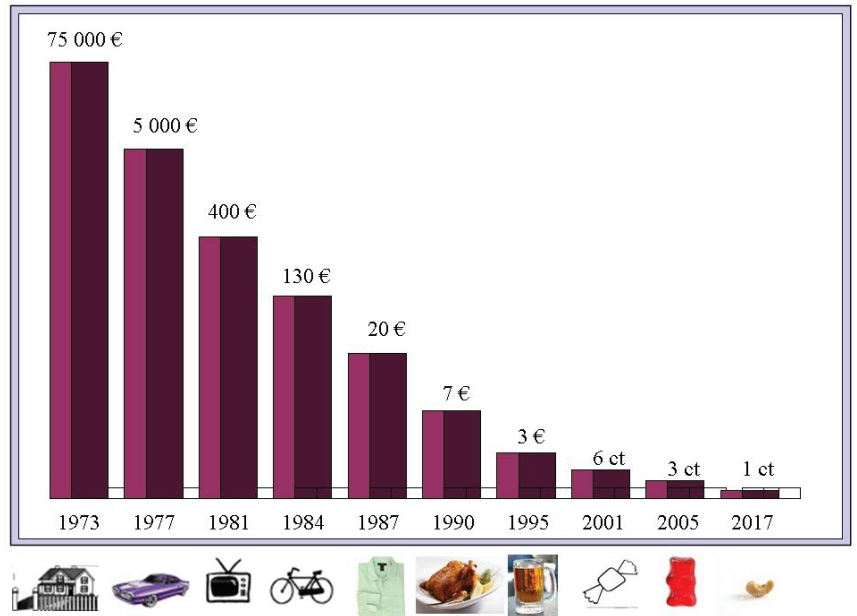


Source: OECD

if it does not play a major role in ICT and particularly in nanotechnologies. Currently, the EU lags behind its international competitors in expenditure on R&D in ICT. It spends 0.3% of GDP on ICT R&D, compared with 0.55% in the USA, 0.75% in Japan and 1.35% in South Korea. And the strong European efforts in R&D in nanotechnologies are largely industry financed.

Nanoelectronics is decisive for innovation, with a high leverage impact on the entire high tech industry and on the whole European economy. The value creation is extremely high. Today the worldwide semiconductor market is in the range of US\$ 250 (€ 186) billion with a leverage impact of around US\$ 5 500 (€ 4 090) billion for the ICT industries alone.

Fig. 1-7 - Evolution of 1 MB DRAM prices



1.3 SOCIETY BENEFITS EVEN MORE THAN SALES NUMBERS SHOW

‘More Moore’ has created an environment of fast cost and price decreases as demonstrated in Figure 1-7, showing the evolution of memory prices. A major reason for the continued success of the semiconductor industry is its ability to continue shrinking structures. Small structures are providing more memory capacity, faster processing performance and lower power consumption per function, so that higher and higher chip functionality can be accommodated in smaller sizes. Cost per bit is decreasing, while capacity and speed is increasing.

All of this means that society is getting benefits far greater than shown by sales or economic growth numbers.

Technological progress has been so fast that, in developed countries, semiconductor revenue growth has slowed from about 12% to around 8% a year, while in developing countries large opportunities remain as illustrated in Figures 1-8 and 1-9. No other industry can demonstrate such overwhelming growth, whilst penetrating almost all parts of life.

Fig. 1-8 - Long-term semiconductor growth

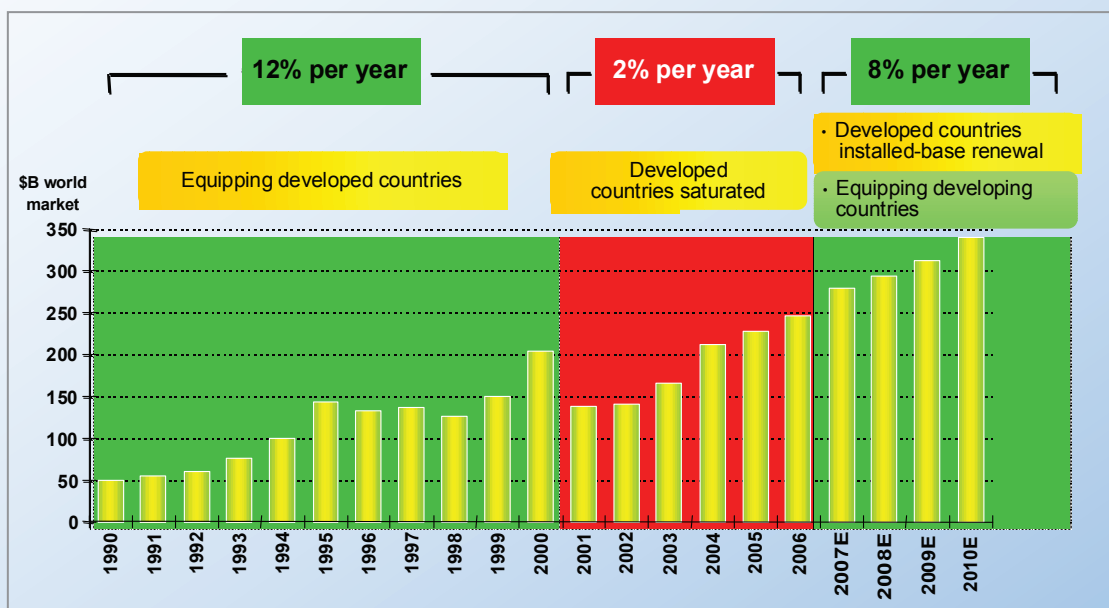
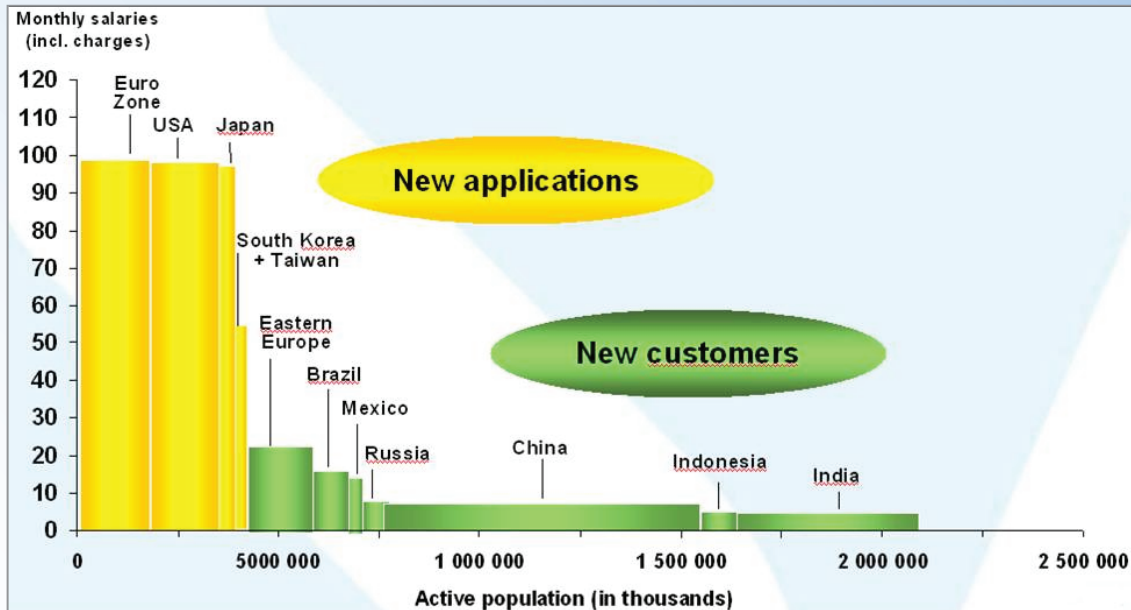


Fig. 1-9 - Economic imbalances generating market potential



Source: Intl. Labour Office, Estin & Co., ST

1.4 MICROELECTRONICS: A MAJOR WORLDWIDE CHALLENGE WITH PUBLIC GOVERNMENTS IN COMPETITION AS MUCH AS COMPANIES

What makes the semiconductor industry unique is its high dependence on R&D and manufacturing investment, together with its high economic stake on a world scale. All along, countries have been competing with each other to develop domestic champions and attract investments from foreign companies thanks to public support because of very high cost of R&D and hi-tech manufacturing investments.

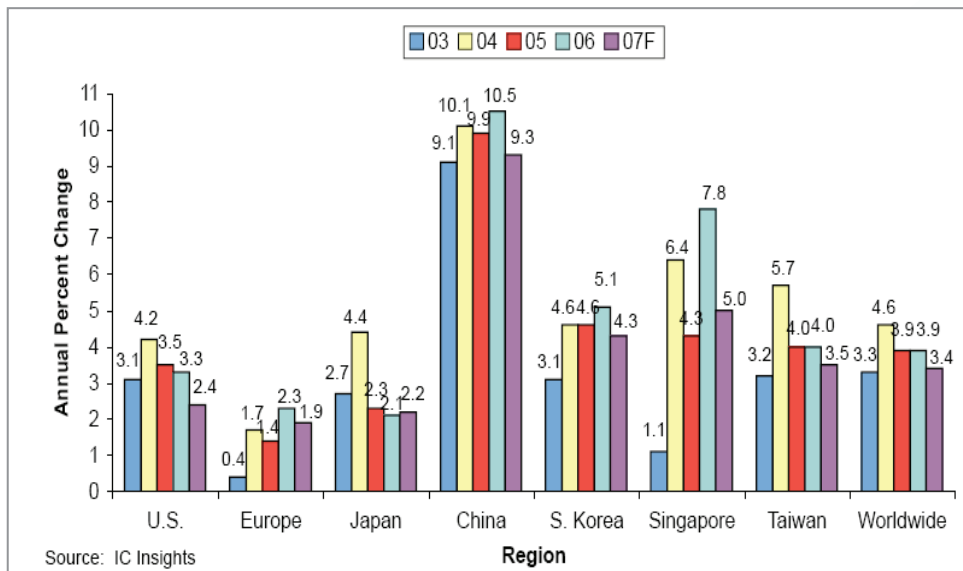
This trend of rising cost and risk and increasing international public support has been growing exponentially over the past decade and will continue to do so over the next. For example, R&D spending has doubled in the past six years and companies in this industry will continue to spend around 18 to 20% of their sales on R&D. They will also spend between 12 and 20% of their revenues on buying expensive top-of-the-line machinery as an entry ticket just to be on the playing field.

All countries that have decided to foster development in this industry have taken a strong public stance on its behalf and engaged in actions to attract its actors. They have all been rewarded by strong economic returns and a positive impact on their local economies. Historically, we can mention the USA that initiated the early wave in the early 1970s, then Japan at the end of the 1970s, followed by Europe positioning itself at the end the 1980s and, finally, Singapore, South Korea and Taiwan in the 1990s with a new push from the USA. Today we see China and India making similar moves.

The USA has always managed to keep several actors in the top ten and has developed a strong electronics industry around the computer. Japan managed to create a worldwide leadership in semiconductors and electronics and a complete ecosystem of international leaders in substrates and equipment. Europe has been able to position three companies in the top ten when there was only one in 1990 and has developed a strong economy in telecommunications and automotive electronics. Taiwan announced an unemployment rate below 3.8% and a very high export rate, mostly in high-tech products. South Korea has overcome the Asian stock market crisis where it hit its most severe downturn by focusing

on high technologies; it now has the highest GDP growth - 5.1% in 2006 - and three national champions in IT: Samsung, LG and Hynix, covering most sectors of the fast growing IT economy, as can be seen in Figure 1-10.

Fig. 1-10 - 2003 to 2007 GDP trends



These countries have understood the structuring aspect of this industry for the economy, intellectual capital creation and the excellence of the academic research. They also understand that there will be no strategic technical independence without mastering these technical bricks and the tools to manufacture them.

LARGE SET OF MEASURES TO ATTRACT SEMICONDUCTOR R&D AND MANUFACTURING

There are three important factors in the lack of competitiveness of Europe for semiconductor sites:

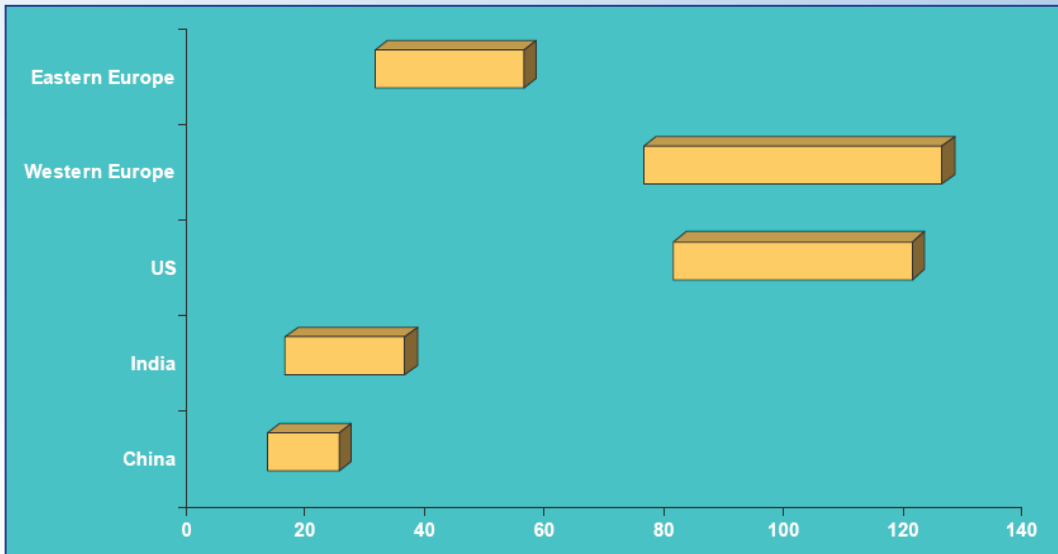
1. A euro/dollar exchange rate that has artificially increased the cost of European manufacturers in a market indexed on dollars;
2. Cost of the workforce; and
3. Cost of capital.

If we look at the cost of a qualified workforce, it is much lower in Asia than in Europe - we can read for instance in the 2005 Competitiveness Report from the European Semiconductor Industry Association (ESIA) that the hourly cost projected in 2010 will be five times higher in Germany than in Singapore or ten times higher than in China.

But beyond these points, we see that most Asian countries have added very favourable tax incentives, including property tax inducements to attract specific industries in their technology clusters. Their governments bet on generated economic growth to compensate for their losses in taxes and they won.

On the contrary, the level of taxes in Europe is such that you could pay hundred millions of euro a year in property tax on a mature 300mm wafer fabrication plant (fab) - without depreciation over the years. This compares unfavourably with the examples of dedicated tax-free zones in India, South Korea or Taiwan that were created to attract foreign investment in high technology domains as seen in Annex: Aid and Support. These types of tax incentive or simply a more favourable tax system in other countries are in direct competition and must be compared with the level of European public funding. They may even be valued higher at the time of investment as they are less risky - automatic eligibility - and without delay.

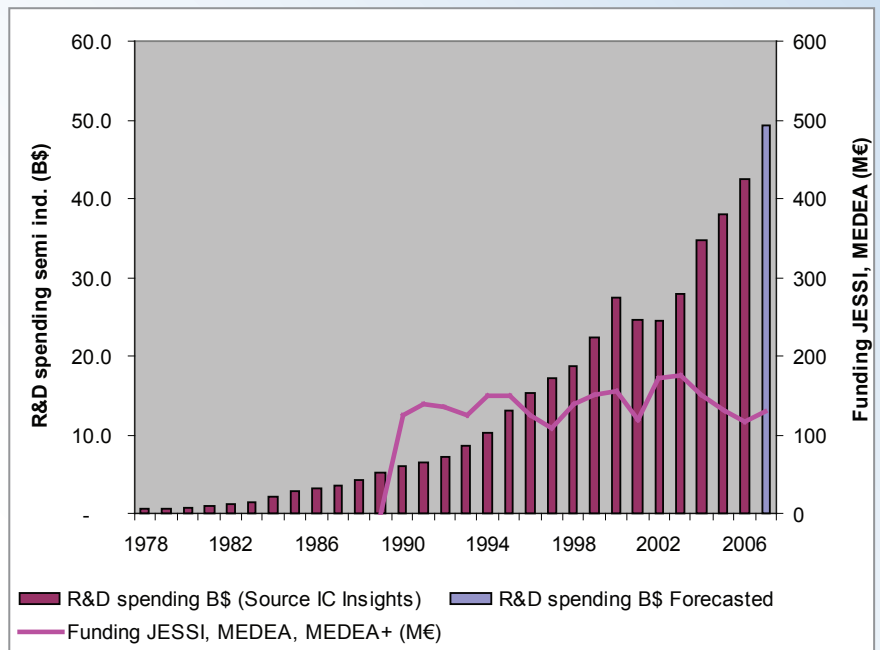
Fig. 1-11 - Comparative engineering costs
(loaded annual costs in US\$)



Source: NAE, iSuppli

By comparison, Europe must adapt to the rise of these new giants as the USA did. For instance, we can observe the very aggressive positioning of US states competing to attract semiconductor investments and R&D and to conserve a critical mass with the rest of the world - see Annex. Interestingly, the Asian countries also play on the same level as western nations with the complete set of political tools: large research institutes with clear priorities, R&D grants, instigation of public-private partnerships, access to capital, money, standardisation, market creation and sponsoring. More details on the competitiveness of European countries compared with international rivals can be found in The European Semiconductor Industry: 2005 Competitiveness Report presented by the European Electronic Component Manufacturers Association (EECA) and ESIA to the European Commission - see also Figure 1-11.

Fig. 1-12 - Growing global semiconductor R&D spending and fairly flat aid in EUREKA microelectronics programmes



Since the beginning of the EUREKA JESSI microelectronics programme in the early 1990s, public support in Europe has remained flat, whereas industry has increased spending significantly and nations in the rest of the world have augmented their amount of support accordingly - Figure 1-12.

2. EUROPE'S ASSETS AND CREDENTIALS

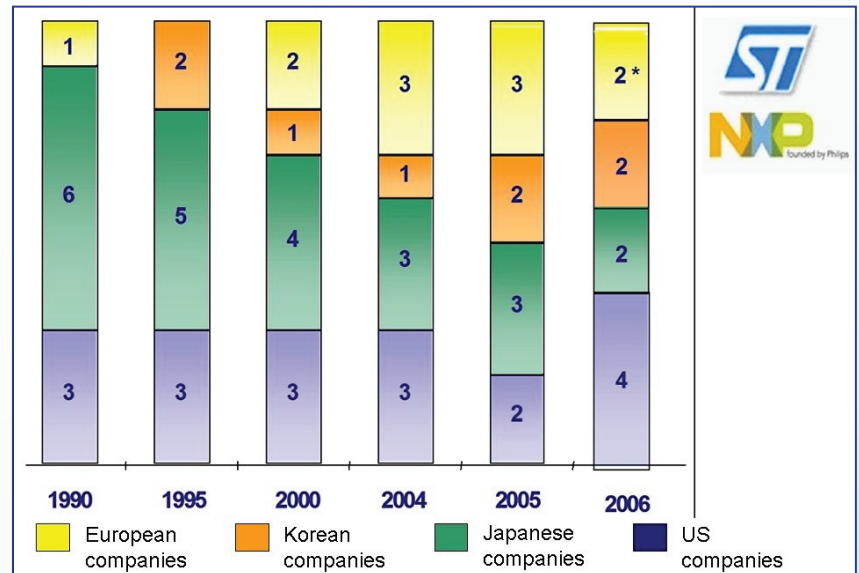
As a result of the EUREKA JESSI, MEDEA and MEDEA+, national and EU Framework programmes, Europe's semiconductor industry has not only recovered lost terrain but has built up technical leadership in some essential domains.

2.1 POWERFUL INDUSTRIAL BASE IN EUROPE

During the past two decades, Europe has established a powerful industrial base in semiconductor manufacturing, materials and equipment as well as in semiconductor applications. There is a steady improvement of Europe's industry in the worldwide ranking of integrated circuit (IC) manufacturers, and Europe's industry now leads in several application areas. In 1990, there was only one European company in the top-ten global league of semiconductor suppliers. In 2005, European semiconductor companies held three of the top-ten places in the worldwide ranking; and leading European research institutes are recognised as having world-class expertise - Figure 1-13.

EUROPEAN R&D IN
NANOELECTRONICS TODAY IS AT
WORLD-CLASS LEVEL

Fig. 1-13 - Global top-ten ranking of semiconductor companies



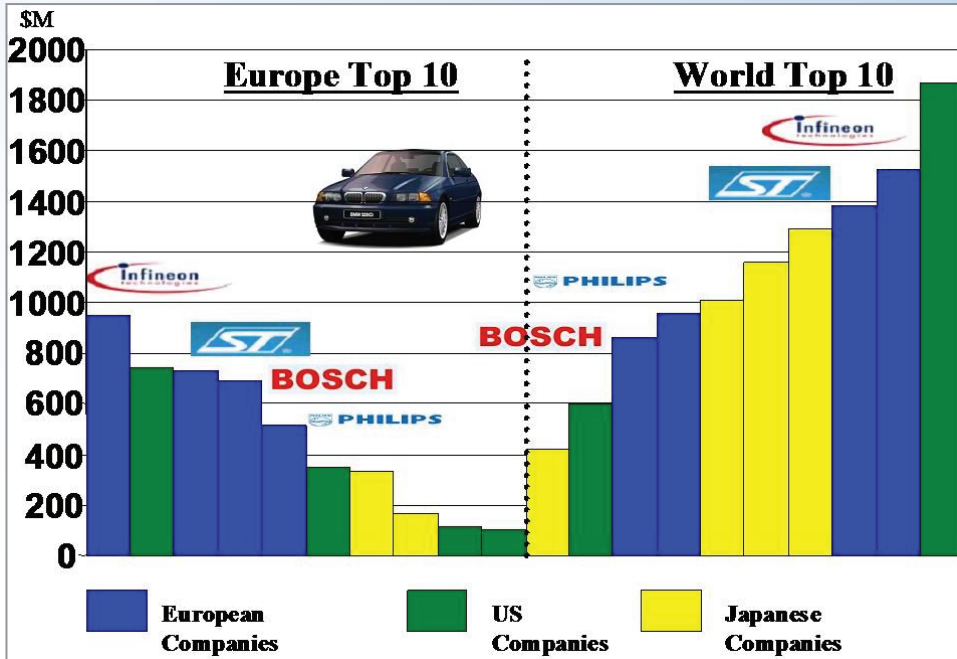
LEADING EUROPEAN COMPANIES
COMPARE WELL WITH THEIR
COMPETITORS IN OTHER WORLD
REGIONS

The European market represents about 17% of the world market for semiconductor products. With its market share of 12% worldwide, the European semiconductor industry has built up a very honourable position with leadership positions in a number of segments.

EXAMPLE OF AUTOMOTIVE ELECTRONICS

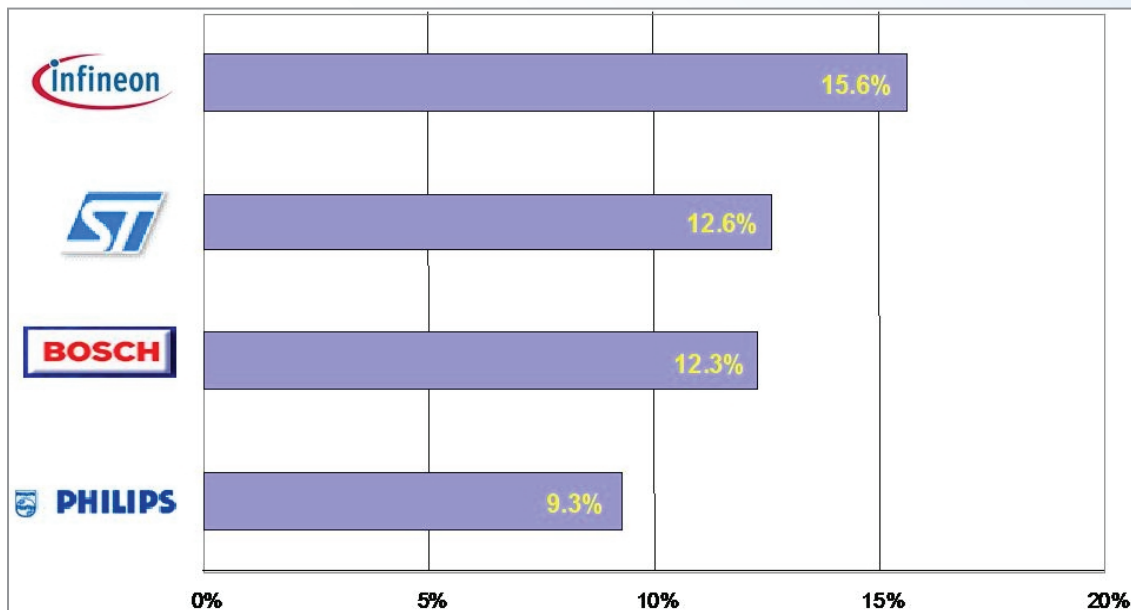
In the automotive market, European semiconductor companies have a 45% market share in Europe and supply 28% of the market worldwide - Figures 1-14 and 1-15.

Fig. 1-14 - Top suppliers in semiconductor automotive applications (2005)



Source: Strategy Analytics/MEDEA+

Fig. 1-15 - CAGR 2000/2005 of European companies related to their automotive applications activities



EXAMPLE OF TELECOMMUNICATIONS ELECTRONICS AND ANALOGUE APPLICATIONS

Telecommunications is also a very strong sector with three European semiconductor companies in the top ten and three of the top four in analogue application-specific ICs (ASICs) (1, 3, 4). These functions require the most advanced technologies and often very custom and specific manufacturing facilities - see Tables 1-3 and 1-4.

Table 1-3 - Ranking 2006 for sales in wireless semiconductors (sales in US\$ million)

2006 Rank	Company Name	2006 Revenue
1	Texas Instruments	6,150
2	Qualcomm	4,529
3	STMicroelectronics	3,360
4	Freescale Semiconductor	2,561
5	Intel	2,220
6	NXP	2,000
7	Renesas Technology	1,896
8	Spansion	1,774
9	Sharp Electronics	1,541
10	Infineon Technologies	1,456

Source: isuppli

Table 1-4 - 2006 ranking for sales in analogue ASICs (sales in US\$ million)

2006 Rank	Company Name	2006 Revenue
1	STMicroelectronics	3,365
2	Texas Instruments	2,620
3	NXP	2,162
4	Infineon Technologies	1,743
5	Freescale Semiconductor	1,317
6	Qualcomm	1,131
7	Sony	1,101
8	RF Micro Devices	992
9	Matsushita Electric	902
10	Toshiba	803

Source: isuppli

Europe is also the place of international giants in telecommunications electronics - such as Alcatel-Lucent, Ericsson, Nokia and Siemens - that are key in maintaining a competitive European market and relevant R&D - Table 1-5.

Table 1-5 - Ranking of OEMs by amount of worldwide semiconductor spending in wired/wireless applications (spending in US\$ million)

2006 Rank	Company Name	2006 Revenue
1	Nokia	10,208
2	Motorola	7,604
3	Samsung Electronics	5,064
4	Sony-Ericsson	3,136
5	Cisco Systems	2,947
6	LG Electronics	2,325
7	Alcatel-Lucent	1,493
8	Siemens	1,343
9	NEC	1,337
10	Sharp	1,281
11	Matsushita Electric	1,197
12	Ericsson	1,144

Source: *isupli*

EXAMPLE OF CONSUMER PRODUCTS

In spite of the very intense Japanese and Korean competition in consumer products, European companies are standing up with two European companies selling ICs in the top six. Most of the Japanese are fuelled by their sales of captive ICs for flat screen panels - Sony, Toshiba, Matsushita (Panasonic) and Renesas (Hitachi) - that have been a strong source of growth in the past few years. The European actors are mostly positioned in set-top box and video-over-IP with analogue and logic components - Table 1-6.

Table 1-6 - Ranking of semiconductor vendors by amount of IC sales (apart from memories and discrete components) in consumer products

2006 Rank	Company Name
1	Sony
2	Toshiba
3	Renesas Technology
4	Matsushita Electric
5	STMicroelectronics
6	NXP
7	Fujitsu
8	Samsung Electronics
9	Media Tek
10	NEC Electronics

Source: *isupli*

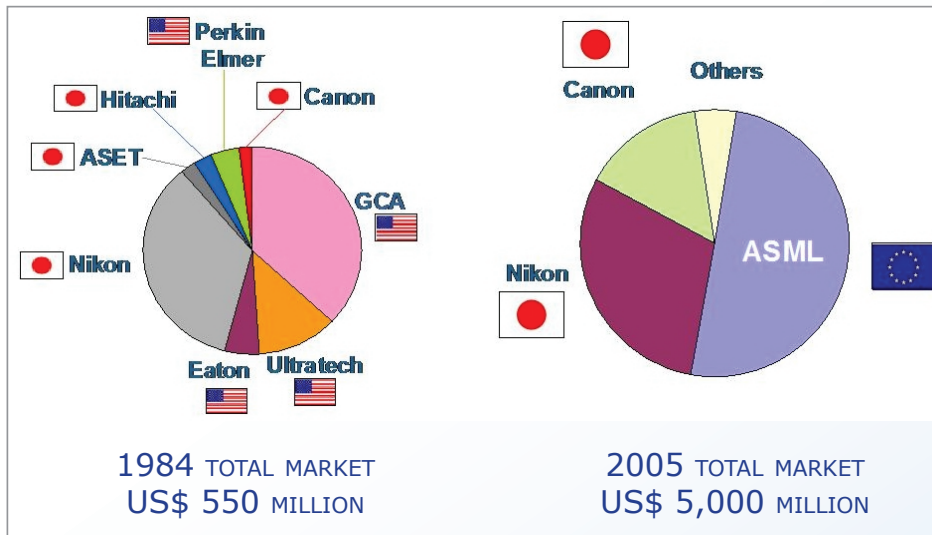
Europe has also several major actors in consumer products with OEMs or operators.

LEADERSHIP IN EQUIPMENT AND MATERIALS

Some European material and equipment suppliers have established themselves as world leaders, such as in the crucial strategic lithography sector - Figure 1-16.

Fig. 1-16 - European leadership in lithography

A decade's investment strategy based on clustering in high-tech hotspots has created 'ecosystems' comprising semiconductor companies, semiconductor equipment suppliers, systems companies, applications providers, service sectors and research institutes. There are several of these successful private-public partnerships spread across Europe. They create jobs, economic growth and innovation leadership.



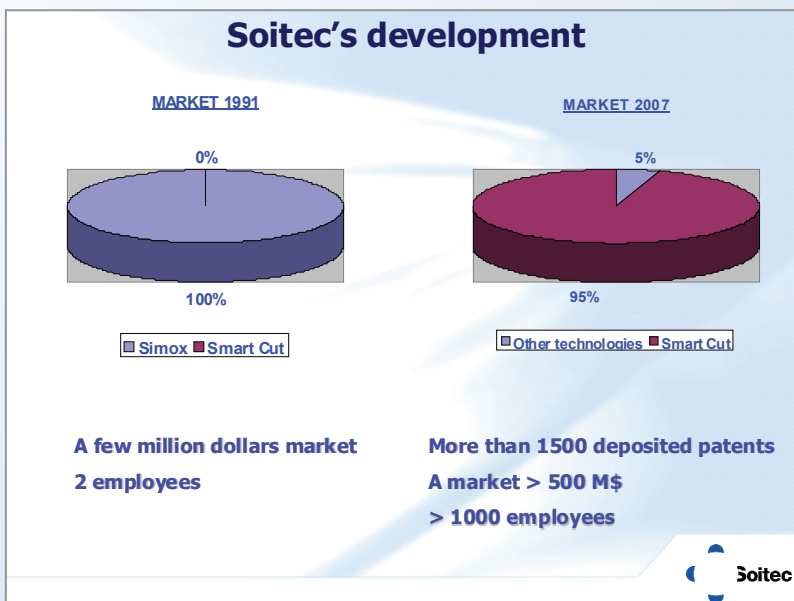
Source: ASML/ MEDEA+

In the materials sector, SOITEC has established a worldwide leadership on advanced silicon-on-insulator (SOI) and engineered substrates - Figure 1-17.

BOTH IN TECHNOLOGY AND IN CERTAIN APPLICATIONS, EUROPE HAS TOP CLASS CENTRES OF GRAVITY

Fig. 1-17 - European leadership in SOI substrates

The Dresden cluster, for example, has created at least 15,000 permanent jobs at semiconductor plants and their local suppliers, attracting more than 30 international equipment and service suppliers. An independent study on the economics of Dresden, carried out by the German Institute for Economic Research (DIW), came to the conclusion that tax revenues and social security contributions are surpassing 'investments', i.e. subsidies supplied by public bodies.



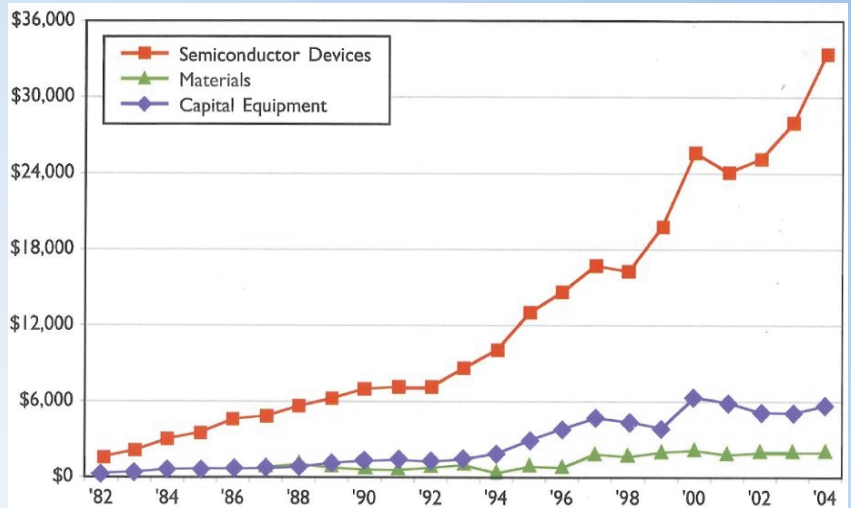
Another high tech cluster is in Crolles: this initiative near Grenoble, together with the CEA-LETI scientific institute, has generated within a decade over 6,000 direct jobs and another 14,000 indirect ones linked to micro- and nanoelectronics.

2.2 SUCCESS BASED ON STRONG R&D EFFORTS

The semiconductor industry has unique dynamics that require very large investments. To maintain leadership, European companies have invested some 20% of annual sales in R&D in recent years, surpassing even the pharmaceuticals sector, but also spending more than their peers in other areas of the world - Figure 1-18.

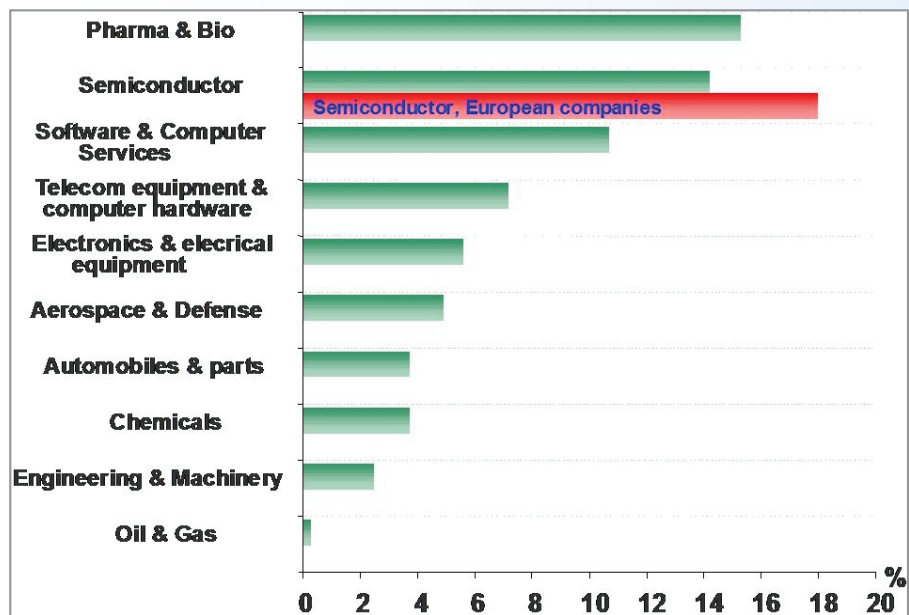
Public support for this effort in the context of co-operative programmes has been essential in building such a position. It would be a major mistake to believe that the sector no longer requires public sector investment. It is also tempting to suppose that because chips are now so ubiquitous, they can simply be taken for granted. The sector continues to be characterised by very fast technological evolution and strong R&D efforts, even when added value may be changing in nature - Figure 1-19.

Fig. 1-18 - Nanoelectronics R&D as % of revenues



Sources: S&P, SIA, SEMI, INFRASTRUCTURE Advisors

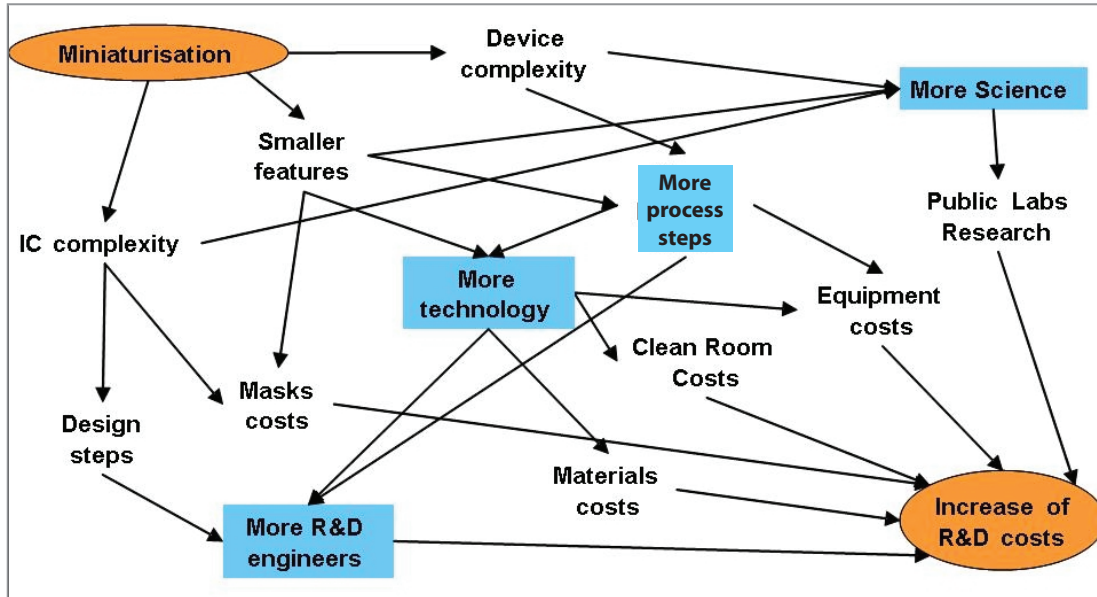
Fig. 1-19 - R&D spending (US\$ million)



Source: MEDEA+/European Commission

The reason is that R&D costs are directly linked to miniaturisation as can be seen in Figure 1-20.

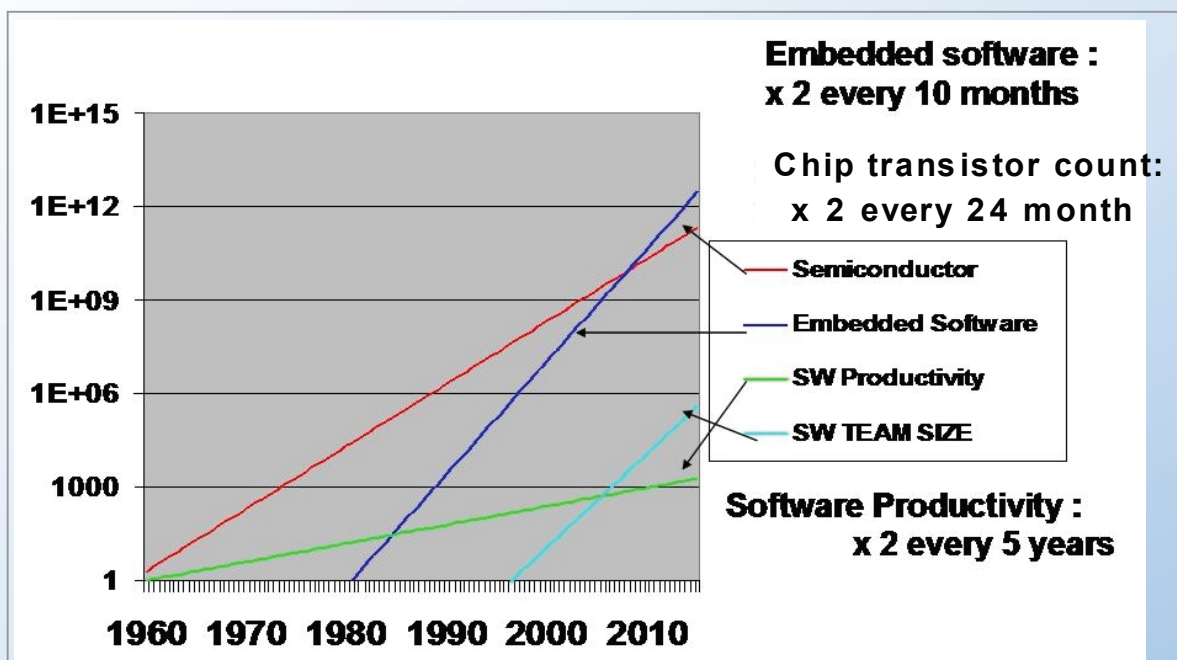
Fig. 1-20 - Each process generation: -50% in size and +25% in R&D costs



Source: STMicroelectronics

As a result, the number of transistors and the complexity of chips and embedded software grow very quickly - Figure 1-21.

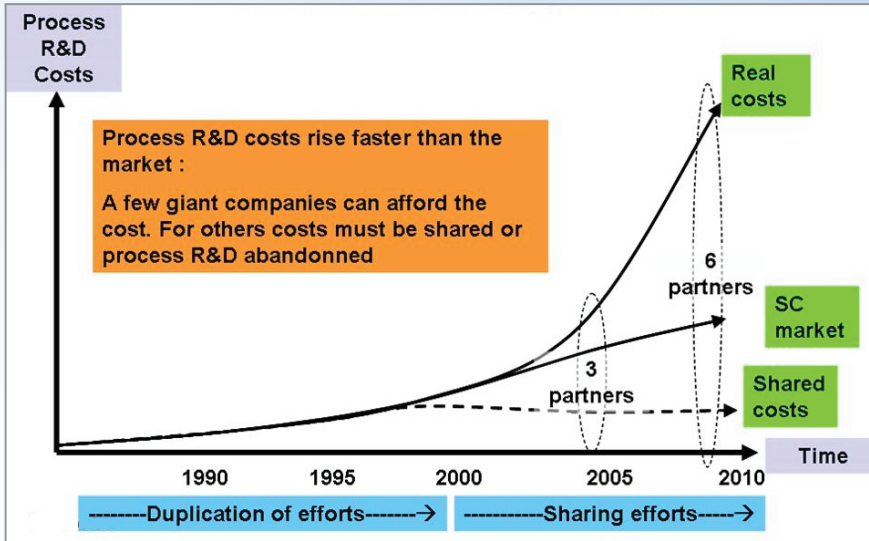
Fig. 1-21 - Growth factors



Source: STMicroelectronics

For this reason, process R&D costs are rising above companies' financial means, pushing them to share R&D costs - Figure 1-22.

Fig. 1-22 - Sharing R&D process costs shields from escalating spending

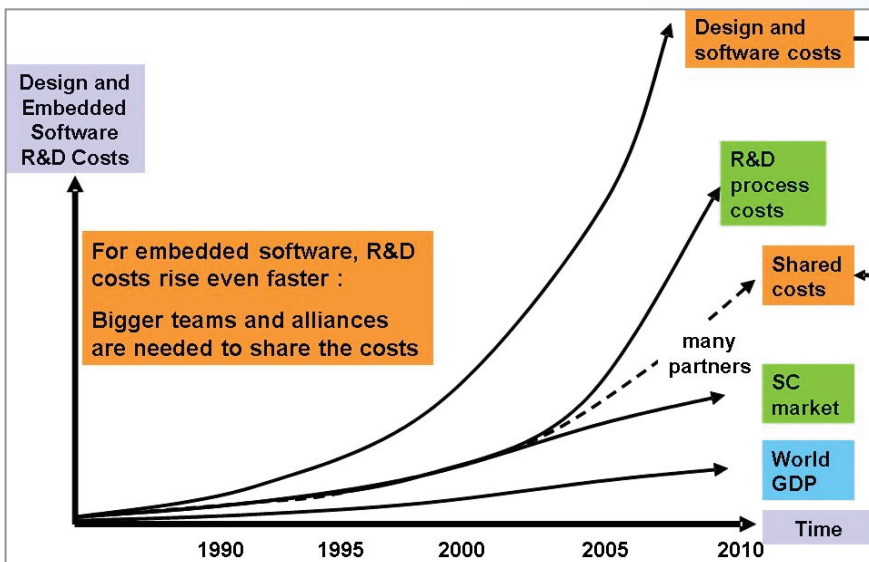


Source: STMicroelectronics

Nevertheless, in addition to this core process development, options or process variations developed separately still following the curve of fast rising costs.

Moreover, for computer-aided design (CAD) tools and embedded application software, the need to shared developments is even more urgent - Figure 1-23.

Fig. 1-23 - Design and embedded software R&D costs rise faster than anything else



Source: STMicroelectronics

2.3 STANDARDS - A WAY TO CREATE LEAD MARKETS

Europe's electronics and nanoelectronics industry can derive much strength from the existence of lead markets for new applications in Europe.

Such lead markets are often the result of the creation of new products and services, sometimes at the initiative of public authorities or sponsored by them, around new common standards, strong interoperating infrastructures and fast network externalities. The GSM mobile telephone service, MPEG audio-video compression standards and smart cards are perfect examples of the impact that such standards can have on the complete value chain from service provider to component supplier and of the leadership position that can result.

As nanoelectronics takes on a much greater part of the functionality of systems, semiconductor companies must play an ever larger role in defining these standards and in allowing the European ICT industry to take a leadership role in new domains. Therefore, standards should be an important point of co-operation in the new CATRENE programme.

Therefore, standards should be an important point of co-operation in the new CATRENE programme.

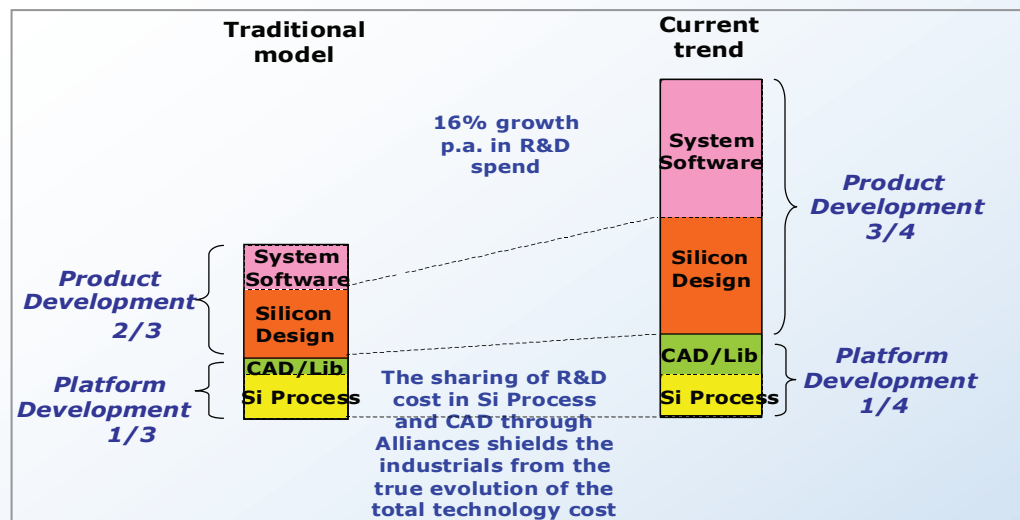
2.4 R&D REMAINS ESSENTIAL, ESPECIALLY WHEN CHANGING VALUE CREATION

European semiconductor companies serve global markets with a worldwide presence. As mentioned above, Europe only represents about 17% of the worldwide semiconductor market with a growth rate that is lower than the rest of the world. So competitiveness on a worldwide basis is essential. Cost pressure and increasing capital and volume requirements for new plants have led to large manufacturing outsourcing, impacting employment in Europe. Already, less than 50% of the European workforce of the semiconductor companies is working in manufacturing, whilst shifting more of the workforce into R&D.

In the meantime, we see that the role of silicon technology in the value chain is changing:

- For memories, the manufacturing technology is the product;
- For microprocessors, the technology is a key differentiator; and
- For consumer ASICs, application-specific standard products (ASSPs) and more globally dedicated products, things are changing. As shown in Figure 1-24, product development is becoming a larger and larger part of total R&D for such products.

Fig. 1-24 - Value chain change for dedicated products



This is due to today's worldwide price battle on semiconductor products resulting from the very low manufacturing cost obtained with standard processes in some countries thanks to:

- Low cost of capital;
- Reduced overheads and taxes;
- Low manpower costs;
- Large investment support; and
- Gigantic fabs - more than 60,000 a month for 300 mm wafers or 100,000 a month for 200 mm wafers, fully loaded.

In electronics in general, Europe has a stronger position in design than in manufacturing, with market shares of 27% and 20% respectively. In addition, in the semiconductor industry, product definition, applications R&D and design efforts remain largely concentrated in Europe. With increasing complexity of components, design represents an increasing part of the added value. At the same time, technology R&D has remained very strong. So, while the added-value picture is changing, the European semiconductor industry remains a true R&D champion, even surpassing the pharmaceuticals industry in terms of its R&D-to-sales ratio.

2.5 UPCOMING MANUFACTURING SCENARIOS

Depending on the products, there are globally three manufacturing models that will remain for the next ten years:

1. Fabs for memories and standard, very high volume, products such as microprocessors:

Here one or two similar processes are running with very few mask sets. These fabs are maintained fully loaded and the product cost is just a function of the manufacturing efficiency:

- Investment cost and cost of capital;
- Manpower, overhead and taxes; and
- Size.

2. Fabs for logic products made using standard CMOS processes:

Here there are a few processes running with a high number of products (mask sets). These fabs are maintained fully loaded thanks to the aggregation of worldwide market demand. In this foundry model, key cost parameters are:

- Investment cost and cost of capital;
- Manpower, overheads and taxes;
- Size;
- Flexibility on product mix within few processes; and
- Cycle time.

Under current economic conditions in Europe, the European integrated device manufacturers (IDMs) are no longer in a position to compete against this model; for this reason, the bulk of CMOS manufacturing is going to foundries that are also giving very high focus on R&D at the intersection of design and technology.

3. Fabs for dedicated products on 'more than Moore' processes:

These fabs are running different processes in parallel with a high number of products. The processes are largely tuned to each product and this where the design and device interaction is maximal. Key cost parameters are:

- Investment cost and cost of capital;
- Manpower, overheads and taxes;
- Flexibility on product mix within a large number of processes;
- Cycle time; and
- Control of a large number of different process routes.

Within Europe, the proximity of applications and system companies to the main IDMs in programmes such as CATRENE would favour this manufacturing model, providing that the cost of capital, manpower costs and taxes be controlled in a way that enables the European fabs to have a level playing field with competition.

The integration of an increasing number of functions and technologies on a single chip increases the complexity of design and applications R&D. At the same time, smaller geometries mean the link between design and technology is getting stronger. Therefore, the European semiconductor industry must continue its efforts in technology research to remain master of its destiny. This is only affordable through co-operation.

Key players in Europe are used to co-operating. In the high tech world of today and tomorrow, open innovation is the key to meeting the enormous challenges of complexity, cost and time to market as well as value creation. The European electronics industry has the track record and mindset to apply open innovation structures and networks successfully. Public-private partnerships are a major catalyst to develop open innovation structures and mindset.

Under the CATRENE programme, the objective of the European semiconductor companies is to increase the level of R&D investment in Europe in absolute value terms.

Nevertheless, despite the permanent and even increasing willingness of European companies to co-operate, due to the worldwide spread of the activities of a few actors, they are confronted by a real problem if limited to European territory. Through global alliances, European companies will also strengthen their European R&D and manufacturing base for higher added value and higher return on investment on products provided the global economic environment in Europe is at least on par with other regions. Furthermore, being more and more open to global problems and markets, European companies will better able to address European societal challenges.

The analysis from the European players is that they will maintain roughly the same R&D investment level as today as a percentage of revenue. The growth in absolute value is likely to be higher in Asia - taking into account also a faster growth of the market - than in Europe but Europe will grow anyway.

It is expected that within the time frame of the CATRENE programme, the total revenue of the European semiconductor companies should double, so most likely R&D will double and the goal of CATRENE is to ensure Europe captures a substantial part of this increase. Therefore the funding of CATRENE has to match the expected growth of the industry.

Europe's top class centres of excellence are attractive for talent; talent attracts talent, and an increasing intellectual property right (IPR) creation capability results. Global competence centres compete on the basis of highest competence versus cost. The competition for technology leadership in the nano-electronics industry is not coming from cheap labour countries, but from regions such as Silicon Valley and New York State in the USA, Taiwan, Japan and South Korea.

It is vital that Europe remains an attractive base for industry and continues to master its own destiny. Transfer of high-end manufacturing and R&D to new locations is a one-way traffic - what is gone, is gone for ever. It must be in the interest of Europe's society and the responsibility of the political environment to keep Europe's nanoelectronics assets and credentials in Europe;

EUROPE'S KEY PLAYERS IN ELECTRONICS ARE HEALTHY; THEY WILL SURVIVE, THEY ALWAYS HAVE THE OPTION TO OUTSOURCE (PART OF) THEIR ACTIVITIES – BUT CAN EUROPE SURVIVE WITHOUT HIGH TECH LEADERSHIP?

We cannot afford not to deliver on innovation. A major concern for Europe is the need to make the business environment more innovation-friendly. Urgent action is requested, before it is too late.

3. WHY DO WE NEED CATRENE AND HOW WILL IT BE POSITIONED IN THE EUROPEAN R&D LANDSCAPE?

As mentioned above, the European semiconductor industry is characterised both by very fast product and technology evolution and by strong growth. Indeed this industry spends nearly 20% of its annual € 28 billion turnover on R&D. About 80% of this R&D is carried out in Europe, which means a total R&D effort in Europe of about € 4 billion. Total public funding in Europe for this effort is in the order of € 650 million a year.

While this may seem like a large number, it is in reality below average. Overall in the European Union, about 2% of gross national product (GNP) is devoted to R&D - as compared with 2.6% in the USA and 3% in Japan. Of this 2%, about 45% - or 0.9% of GNP - is based on public financing. In absolute terms, this means that there is about € 200 billion spent on R&D in Europe, with about € 90 billion of public financing. If the semiconductor industry were to receive the same 45% level of public financing, it should be receiving about € 1.8 billion. Even if the financing of academic work in this field is added to the € 650 million of financing for industry, the result remains far from this figure.

At the same time, it should be realised that this industry does not benefit directly from public investment as is the case for the health and transportation sectors. In fact, the public sector is under investing in ICT. Public investment represents only 20% of the ICT market in Europe, with the public sector taking 45% of GNP.

As has been demonstrated earlier, the semiconductor industry is making a contribution to society which goes far beyond its contribution to GDP; it is simply the main enabler for most of the new services to which we have grown accustomed.

The future of this industry in Europe depends very much on a continuation of public R&D

support. Lowering or delaying this support will immediately oblige the industry to adapt its strategy and certainly lead to a diminished role for Europe in the field of nanotechnologies as a whole.

Not only public support, but also co-operation is key. No company can afford to invest on a stand-alone basis in all areas of technologies and applications. Partners with the required expertise and weight can often not be found within national boundaries, so co-operation must be cross-border, if possible within Europe, in some cases outside Europe.

For such cross-border co-operation with public support to be successful, it must have the flexibility and the fast response to market opportunities that are typical for this industry. The EUREKA JESSI, MEDEA and MEDEA+ programmes have demonstrated how this can be done.

One of the successes of MEDEA+ and of the previous EUREKA programmes has been to foster a dynamic European ecosystem that gained a critical mass on a worldwide scale and has created champions. As done for MEDEA+ and the previous programmes, CATRENE has the goal to develop a complete ecosystem around the semiconductor industry.

EUREKA programmes are currently part of a global support network for nanoelectronics R&D that comprises also a national and regional level, including 'pôles de compétitivité', the European Framework Programme and the JTI level inside the Framework Programme, when available.

These levels complement each other in the following ways:

- National and regional programmes - including pôles de compétitivité - are mainly centred around one company or clusters formed around a research centre. In most cases, there is one pilot company driving other participants; they are very flexible and efficient. Procedures and timing are mainly defined by each state's own calendar;

- The EUREKA CATRENE Cluster, like the former MEDEA and MEDEA+ Clusters, will be centred on companies having a common interest to share development of close-to-market technologies and applications, even when based in different countries. This model has proved to be efficient and flexible; it only suffers from the fact that national funding calendars are not aligned, generating difficulties in some instances, mainly when building the financing schemes; and
- The EU Framework Programme is, by its nature, very open, oriented to the long term and totally non competitive. It is subject to the rules of the EU treaty and to specific rules on IPR. The JTI tries to combine some of the flexibilities of the EUREKA programme with extra funding from the Framework Programme. It will however be subject to the rules of the EU treaty and therefore may have different rules in terms of IPR, project approval and monitoring.

READY TO GO

CATRENE is ready to go and can start by Quarter 4 2007; there are six main reasons why CATRENE is imperative and should not be delayed:

1. Continuity:

The MEDEA+ programme has created co-operation between European companies on some major subjects. These programmes often require follow-on programmes to take care of market or technology evolution.

2. Efficiency:

CATRENE is supported by a very lean organisation and direct involvement of national Public Authorities. The industry-driven monitoring is fully transparent. This mechanism must be kept running without any interruption;

3. Flexibility:

With shorter introduction delays and increasing complexity, the introduction of new products and technologies requires cross-

border R&D co-operation that is very flexible concerning:

- IPR agreements;
- Number of participants;
- Project approval and start-up delay; and
- Reaction to market change.

Here, more than ever, speed is the differentiation factor;

4. Coverage:

The fact that this programme covers applications and the enabling technologies is another guarantee of future success for industry and society at large;

5. Market:

This programme is mainly market driven, allowing the exploration of new products and systems solutions; and

6. Level of funding:

In the next few years, the projected funding at the European level for both the Framework Programme and the JTI is simply insufficient to support a continuation and even less a broadening of current cross-border co-operation.

The objective in creating the JTIs has been to set up a mechanism for supporting cross-border co-operation making use of both national and European funding but based on a common research agenda. The aim was to have a total level of funding that was higher than the present EUREKA programmes and at the same time a flexibility of operation which would be similar to the EUREKA programmes, without the rigidity of the Framework Programme.

It is too early to say whether this objective can be achieved. The JTI has not formally been approved and a number of issues concerning its operation remain unclear. What is clear is that relying only on the JTI and its combined national and European funding mechanism

would at least in the next two years create a level of funding for the industry which is lower than what was available on average during the MEDEA+ programme. European funding is expected to increase from the third year but still requires new approval. It is also clear that there will be a number of constraints in terms of IPR agreements, project approval and monitoring.

Progress has been made towards using to a maximum extent the present MEDEA+ Office and structures for the European Nanoelectronics Initiative Advisory Council (ENIAC) JTI.

An actual merger between the CATRENE programme and the ENIAC JTI can realistically be expected in about four years when both funding and operating flexibility have been found satisfactory in the JTI. It is however also possible that both programmes will coexist for a longer period.

During their coexistence, work sharing between the two programmes is quite natural.

The key points of distinction between the two are:

- The JTI only addresses technology development - using applications as a motivator - whereas CATRENE addresses both applications and technologies. This is a key point of distinction;
- CATRENE focuses on near- and medium-term technology evolution whereas the JTI focuses on medium- and long-term technology evolution; and
- The JTI will have broader participation - more SMEs and research institutes - whereas CATRENE should have mainly industrial projects with fewer participants. The JTI requires the involvement of at least three countries, CATRENE requires only two.

There are also major differences from a process point of view of course. The JTI is much more formal whereas CATRENE should remain very interactive - between industry and public authorities - and have much less formality. Also the IPR situation is much more flexible.

As a consequence, projects which are close to market, require very fast reaction times, have a limited number of participants from few countries and start from a lot of existing IPR will almost naturally be carried out in CATRENE. Projects which are more fundamental, have a large number of participants and can be carried out in an open IPR environment will almost naturally be carried out in the JTI. The choice made will finally depend on the level of funding available and the participants.

ANNEX: AID AND SUPPORT

TAX AND INVESTMENT INCENTIVES COMPARISON

Country	Corporate Tax Rate	Tax Incentives	Other Taxes	Other Incentive Programmes
Germany	25%	n/a	Solidarity tax: 5.5% of corporate tax; Trade Tax, 18.37% (Dresden)	Tax-free investment grants available (until end of 2006)
Korea	25%	Full exemption on income tax for 5 yrs, 50% reduction for following 2 yrs	Property tax: 7% of building cost Land tax: .2 to 5% of land price Local education tax: 20% of the property plus land tax Rural development tax: 10 or 15% of land tax VAT: 10%	R&D tax credit – up to 15% of R&D expenses. Exemption on other taxes (see box to the left): full exemptions for 5 years, 50% reduction for the following 2 years Exemption of leasing costs available
Taiwan	25%	Full exemption on income tax for 5 years	Business tax (VAT): 5%; Land Value Tax	Investment tax credit of 13% can be used to offset up to 50% of income tax. Low-interest loans, R&D grants available for up to NT\$5 million
Japan	40.87%	Incentives offered by local governments: in Yokohama, large firms can pay half the regular income tax rate for 5 years.	VAT: 5%	Local governments offer incentives to firms investing in certain areas: in Yokohama, companies can receive rent and other subsidies amounting to 10% of the investment amount
China	15%	Full exemption on income tax for 5 years, 50% reduction for following 5 years	VAT: 17%	Incentives vary at the local level and may include free land or free or reduced rent for companies.
Malaysia	28%	Full exemption on income tax for 10 years	Sales tax: 5-25%	Other incentives include: matching R&D grants, Matching training grants, Start-up grants, Land subsidies, R&D investment tax allowance
Singapore	20%	Income tax exemption on qualifying profits for up to 15 years	VAT: 4%	Write-off for R&D expenses, partial grants for R&D projects
USA (Texas)	35% (federal)	Companies can qualify for a reduction in sales and property tax for 10 years	Property Tax: 2.8%; Franchise Tax: 4.5%	Franchise Tax Credit of 5% available for qualified R&D expenditures. Firms that invest at least \$250 million are eligible for credits of \$7,500 per employee hired, up to 500 employees. Federal R&D tax credit available.

Sources: Invest Korea, Invest in Taiwan, Greater Austin (TX) Chamber of Commerce, Infineon China, Malaysian Industrial Development Authority, Singapore Economic Development Board, JETRO, City of Yokohama, European Commission, Invest in Germany

ASIA-PACIFIC

In India, we see the example of the incentives and facilities offered to units for attracting investments into in the Special Economic Zones (SEZs), including foreign investment: duty-free imports, no income tax on exports for five years, 50% for next five years, loans up to US\$ 500 million in a year and exemption from local taxes - sales tax and service tax - central and state co-ordination.

In South Korea, we see the example of the Foreign Investment Zone (FIZ) with a corporate tax or income tax reduction - a 100% exemption for the initial three or five years and a 50% exemption for the next two years; reductions in property tax, acquisition tax and registration tax - 100% exemption for the initial three or five years and a 50% exemption for the next two years with the option for the local government to extend this period for up to 15 years.

In Taiwan, the technology parks are free of property tax.

NORTH AMERICA

We have the latest announcements from the state of New York proposing a US\$ 1.2 billion incentive to AMD to install its next facility alongside Albany and US\$ 300 million for Sematec to move its headquarters out of Austin, Texas.

CHAPTER 2: THE CATRENE PROGRAMME ORGANISATION: LIGHTHOUSE PROJECTS, WORK AREAS AND INDIVIDUAL PROJECTS

THE CATRENE AMBITION:
TO PROVIDE SOLUTIONS FOR
NEW LEAD MARKETS AND CREATE
EUROPEAN LEADERSHIP IN THESE
NEW MARKET SEGMENTS

This chapter first describes the way the work in CATRENE will be structured:

- Large **lighthouse projects**, addressing new lead markets and society needs, possibly also addressed by several EUREKA Clusters and national projects;
- **Work areas** are the specific fields of activity of lighthouse projects directly related to microelectronics. Work areas cover both applications and technology needed to support the lighthouse projects; and
- **CATRENE projects** directly supported by CATRENE are part of work areas.

It then describes the applications and technology work areas identified so far within CATRENE and their relationships with main lighthouse projects, markets and societal needs, with other EUREKA Clusters and their interrelations.

1. STRUCTURE OF CATRENE

1.1 LIGHTHOUSE PROJECTS AND CATRENE WORK AREAS

Innovation for growth in Europe is based on solving large society needs efficiently through new products and services, bringing more added value and employment. Experience shows that technology innovation plays a determining role in applications development, and that large applications markets also set new challenges for technology. Based on this view, CATRENE proposes an architecture of projects and programme management linking applications and technology closely.

Lighthouse projects address large and global socioeconomic needs such as transportation, healthcare, security, energy, environment, entertainment and communications through new R&D and deployment projects. They present a clear vision of the technical challenge and of the expected benefits and economic returns and are understandable by the public. Examples are mobile TV and autonomous vehicles.

The main added value of lighthouse projects comes from their ability to create a critical mass in terms of scope, effort, participation and support from public authorities around a well understood societal and technical challenge. Experience has shown that this is the way European leadership positions can be built.

Some of the lighthouse projects require complete value chains and new players. This means that more and new systems houses as well as service providers will be needed in the consortia.

The support of public authorities is essential in order to reduce risk but also to provide the legislation, regulation, and standardisation necessary to implement new value chains and in some cases to act as first user for the applications and/or provide the necessary infrastructure - such as car-to-environment communications.

Lighthouse projects that are sizable and visible are typically larger than the pure domain of the CATRENE EUREKA Cluster: they can largely overflow over several Clusters.

For the **CATRENE projects**, lighthouse projects must be seen as a framework, defining new important solutions inside lead markets offering major growth opportunities for the semiconductor industry. In order to assure the timely availability of semiconductor components and because of the R&D timing constraints, CATRENE projects in many cases need to be launched before activity on the subject is launched in other Clusters.

At the beginning of the programme, the following lighthouse projects are envisaged:

FOR APPLICATIONS:

- Towards autonomous vehicles;
- 20% energy saving in products by 2020;
- Ubiquitous health monitoring and treatment; and
- Secure technical society and communications.

AND FOR TECHNOLOGY:

- Next-generation equipments and materials.

Those projects are developed briefly in Chapters 3 and 4 and will evolve. Others may follow.

To improve efficiency, the programme will be organised in **work areas**. Work areas are the specific fields of activity in the framework of lighthouse projects directly related to microelectronics. Work areas cover both applications and technology projects needed to support the lighthouse projects.

CATRENE projects are directly supported by CATRENE and are part of work areas. The application projects will finally define the technology/process development needed.

The work areas have been identified for CATRENE and are detailed in the following chapters. Specific targets for each work area are described. Each specific project will propose roadmaps and when and how the expected results will be reached. These targets and roadmaps will be consistent with the lighthouse projects objectives.

1.2 CATRENE INTERACTION WITH THE OTHER EUREKA CLUSTERS

The ambition of the CATRENE programme is to achieve European leadership in a number of new application areas, part of ambitious lighthouse projects. The technologies required for such application areas are in many cases common.

IMPORTANT TRENDS

The objectives of CATRENE projects are defined on the basis of overall systems requirements. In electronic and information systems, complexity of systems is continuously increasing and, at the same time, more and more of this complexity is integrated in the micro- and nanoelectronics components.

This has a number of consequences:

- Increased demand for both 'More Moore' and 'More than Moore' technologies;
- More and more embedded software; and
- Packaging becoming a circuit element.

This obviously influences the CATRENE programme compared with the previous MEDEA and JESSI programmes. It may also change the interaction with other EUREKA Clusters.

CATRENE R&D projects cover everything that is inside the IC component. Other important considerations taken into account by CATRENE are:

- The combination of technology and applications is preferred in terms of demonstrating that the results at wafer level have a break-through impact at the systems level;
- The important challenge for co-ordination inside Industry and at European level concerning the definition of the specifications and standards;
- There is a general trend that basic technologies - wafer processing, assembly and software - are shared among the different applications;
- The increasing importance of embedded systems illustrates that pure software development and nanoelectronics are mutually dependent and fit well together; and
- Microelectronics development and packaging are more and more linked together within the advanced SIP where the structure of the final package is defined during the design of the die and the wafer processing.

RELATIONSHIP WITH OTHER EUREKA CLUSTERS

A good example is a modern or near future mobile phone that will also be equipped with a camera, a wallet and a navigator with all the related media and entertainment. A lot of technologies are used to design such a device and even more applications areas are addressed.

For all these features, specific and well adapted hardware with embedded software components are required that communicate with the system platforms defined thanks to the CELTIC Cluster.

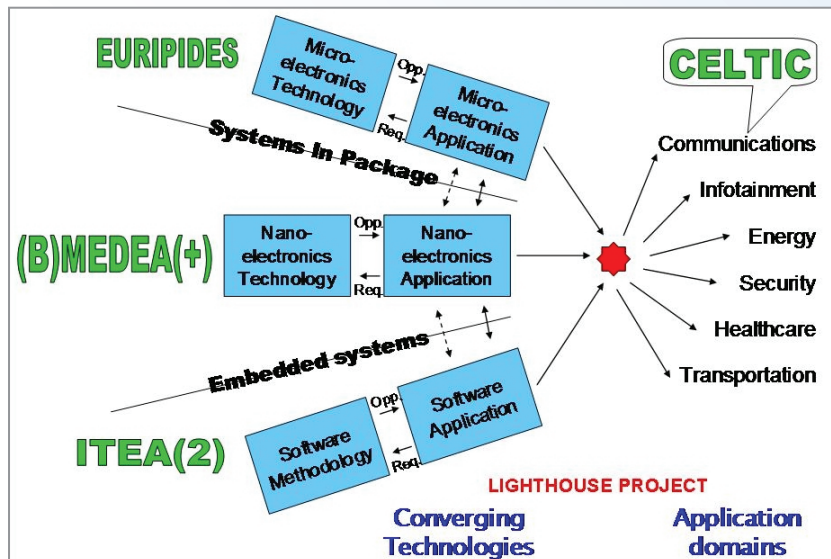
As another example, all security features in smart cards and any application of crypto technologies are based on hardware and software plus assembly - and plus process design such as non-volatile memories (NVM) and flash technology.

The ITEA2 Cluster is about software-intensive systems. This is not the case for smart cards for which a very tight integration and interaction with the underlying hardware is required. A typical smart card software implementation is never fully driven by pure functional considerations but by a mix of functional and security considerations strongly influenced by the hardware. The same applies for example in security products.

These trends are also taken into account by the programme. The consequence is that co-operation between the Clusters will be enhanced and increased every time it will be necessary. We will even envisage having cross cluster projects when it makes sense.

Figure 2-1 shows the co-operation scheme envisaged between the clusters.

Fig. 2-1 - Envisaged co-operation between the EUREKA Clusters



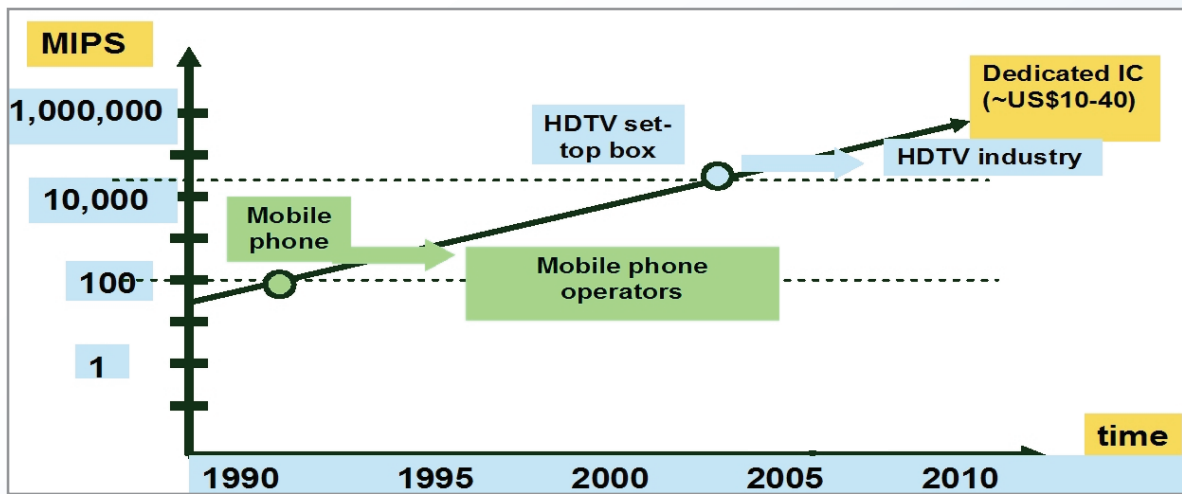
1.3 PROCESS/TECHNOLOGY PROGRAMME FOR APPLICATIONS AND LIGHTHOUSE PROJECTS

Although microelectronics technology is defined and built to cover the next generation of existing applications, experience shows that any time new technologies are made available; they open the possibility to invent totally new applications not envisaged before. This is illustrated in Figures 2-2, 2-3 and 2-4.

It is then mandatory to master those new technologies to participate in the game. Without timely availability of new technology, there is a major risk of missing new forthcoming applications.

Evolution of technologies and applications follows parallel development paths for their various generations: the CATRENE vision is that these evolutions can be managed efficiently by a shared vision of applications/markets and technology roadmaps.

Fig. 2-2 - Faster components open up new applications: innovation in ICT is directly dependant on IC technology performance



Source: STMicroelectronics

Fig. 2-3 - Parallel development paths in technology and application evolution

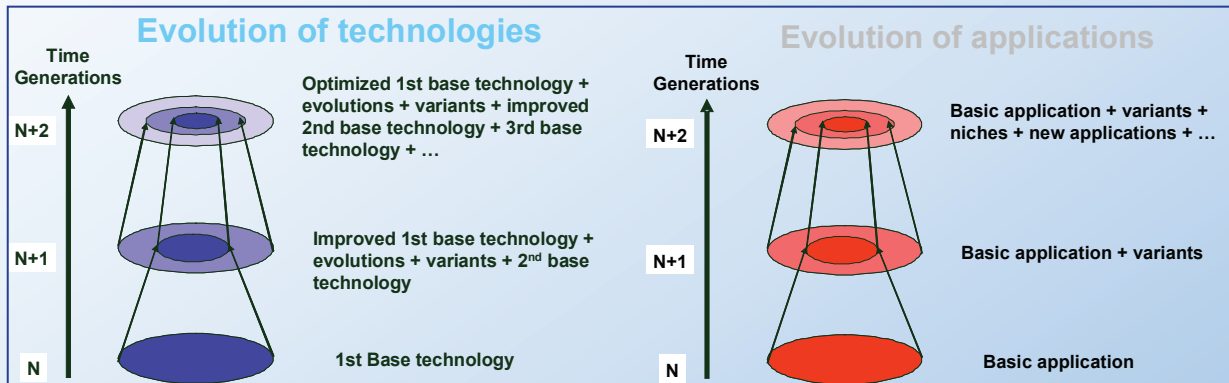
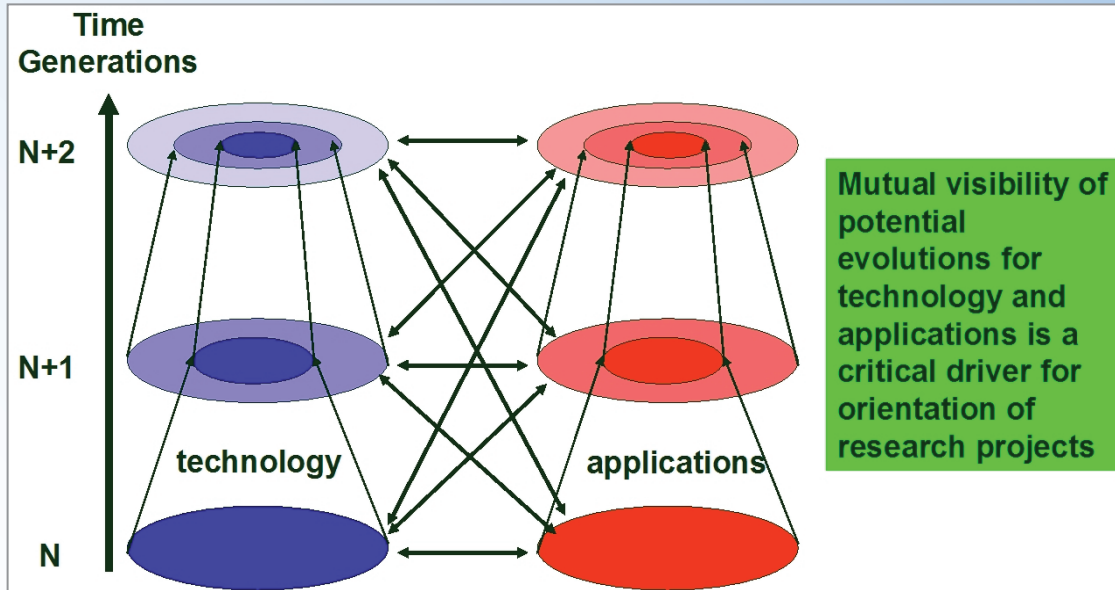


Fig. 2-4 - Applications and technology are closely entangled



While the applications work areas follow closely the societal needs described above, the strategy within this technology programme is to:

- Capitalise on today's technology strengths in Europe to increase further the market share in Europe's domains of excellence: automotive, analogue, industrial, wireless and wired, image sensor and memories;
- Develop R&D partnership with the mainstream CMOS European and global clusters to master 'more Moore' CMOS technologies below 45nm and be compatible with the foundry processes to offer double sources to the customers in basic CMOS;
- Innovate on 'more than Moore', based on mainstream CMOS technologies to differentiate European companies targeting applications described in Chapter 2. These enhancements will continue to be necessary to address applications such as RF, power, analogue and imaging;
- Provide the necessary co-ordination among European companies and European research Institutes in these research programmes; and exploit, mainly within the internal manufacturing facilities of the companies concerned, innovations enhancing the core CMOS processing; and
- Meet the physical challenges to overcome in technology such that the success factor of a design is based more and more on the close link between process and device characteristic. Smaller dimension increase the relative effect of parameter dispersion and the development of design-for-manufacturing (DfM) techniques becomes mandatory. Advanced characterisation methods have to be developed together with new device modelling and simulation approaches linked with new materials behaviour.

The complexity of the new processes, together with that of new SoC and SiP applications, requires very important developments in the fields of electronic design automation and design for testability. A full development is needed to handle the complexity of hardware-dependant software design - the optimal solution of partitioning between the hardware and software within the implementation of a SoC.

Due to the trend toward deeper integration of SoC devices and the heterogeneous integration of analogue functions, a radical improvement in mixed-mode design tools and methodologies is essential to reduce design cycles drastically and increase the productivity of designers.

Europe has already developed all the capability in these fields for the previous technology nodes; maintaining a leadership position is the only way to master advanced design.

1.4 CATRENE WORK AREAS

The foundation for the CATRENE programme is the ambition of Europe and European companies to deliver nano-/microelectronics solutions that enable lighthouse projects and respond to the needs of society at large, improving the economic prosperity of Europe and reinforcing the ability of its industry to be at the forefront of the global competition. This allows the creation of new GSM-like lead markets, which are the foundations for European leadership.

CATRENE is built on the convergence of applications and technology; the following key work areas have been defined on this basis:

APPLICATIONS WORK AREAS:

- High quality, high speed user-centred communications systems;
- Smart-card systems, trusted platforms and secure applications;
- Transport electronics for safety and security, environmental protection and communications;
- Healthcare devices and systems;
- Energy-efficient devices and energy control systems; and
- Devices and systems for digital entertainment.

TECHNOLOGY WORK AREAS:

- Electronic design automation (EDA) for extreme SoC and SiP design
- Process development: including next generation CMOS process (more Moore), process options (more than Moore) and heterogeneous systems integration;
- Manufacturing science : cross cut technologies, equipment and materials; and
- Smart sensor and actuator systems.

These work areas are briefly presented below, with the links to the societal needs and their mutual links.

2. CATRENE APPLICATIONS WORK AREAS

The matrix between applications work areas and society needs is defined in Table 2-1.

Table 2-1 - Applications work areas supporting society needs

		Society needs					
Work areas		Communications	Security	Transportation	Healthcare	Environment	Entertainment
	High- quality, high- speed, user- centered communication systems	X	X	X	X		X
	Smart-card system, trusted platform, secure platform	X	X	X	X		X
	Transport electronics for safety/security, environmental protection, communications	X	X	X		X	
	Healthcare devices and systems				X		
	Energy efficient devices and energy control systems	X			X	X	
	Devices and systems for digital entertainment	X		X	X		X

During the 21st century, these needs are expected to have increasing importance not only in Europe but worldwide. These are the areas where **high quality employment** and **value creation** will materialise - and this must be strategic for Europe and European companies.

As a result, this focused programme is derived from the applications' side - fully detailed in Chapter 3. It is addressing relevant needs of society and is narrow enough to provide a focus but broad enough to ensure the critical mass. The programme is built on proven European strengths and will act as the technology driver.

The CATRENE Applications programme covers the six work areas listed in Table 2-1:

2.1 COMMUNICATIONS

Communications is the sharing of information by a number of means. It addresses a key need of business and consumers. This industry is one of the most demanding, has to act fast, is market driven and is user centred. Europe has an impressive track record in communications, with a strong base in architectures, technologies and applications. Communications is a driver for miniaturisation, low power consumption and embedded software, and is challenged by fast integration of functionalities. The skill to provide standards and standardisation as a silicon solution provider is becoming the prerequisite for tomorrow's success in communications at large.

2.2 SECURITY

Security is becoming ever more important in all spheres of society. For the nanoelectronics industry, there is ample room for new business in security applications. Until recently, methods to handle security and privacy topics have been based mainly on the addition of software. But this has now completely changed with the new approach based on global security and integrity protection; this means protection mechanisms must be present in the basic hardware and hardware-dependant software, as well as in respective input/output systems. This market provides serious potential for European industry. Key market segments where European companies can play a leading role include open servers and PCs, mobile chipsets, smart-card and trusted personal devices, and consumer electronics. Already today, Europe is world leader both in chips and software for smart cards. The technology driver is mass customisation, high quality at low cost and 'zero energy' solutions.

2.3 TRANSPORTATION

Much if not most innovation in **transportation** by vehicle is now driven by developments in electronics. In fact, automotive electronics currently account for 20% of vehicle production costs and this is projected to double to 40% by 2010. Drivers demand ever higher levels of quality, safety, reliability and durability in vehicles. At the same time, car users want greater comfort, more real-time information to make journeys easier and a scale of in-vehicle entertainment not even imagined at the beginning of this decade. Moreover, legislation is becoming increasingly strict on exhaust emissions, energy performance and traffic regulation. Europe has a world-class position in technology and applications and has to enlarge its market share further.

2.4 HEALTHCARE AND AN AGEING SOCIETY

Healthcare electronics is already a well established business with a large turnover worldwide. In the EU, 9% of GDP is devoted to

healthcare cost, increasing by about 6% a year. In the USA, it is already about 14% of GDP. An ageing population in advanced countries implies a rapid increase in chronic diseases.

New developments now possible based on 'more than More' technologies include: small sensors and actuators combined with their associated electronics at affordable cost that are opening up a lot of possibilities and a market for diagnosis, prevention, treatment, follow up and monitoring. As a result of the availability of highly portable or personal or disposable systems build around sensors - and biosensors - and relatively cheap information processing, the penetration of electronics in healthcare, today somewhat limited to heavy equipment located in hospitals, is likely to have the same exponential growth already seen in telecommunications and automotive electronics.

The European micro-/nanoelectronics industry should be prepared, as a result of co-operation among systems companies and semiconductor suppliers, to meet the demand of this emerging market.

2.5 ENERGY EFFICIENCY

Clearly **energy efficiency** and energy reduction is a major 21st century's challenge. Environmental protection and sustainability will be obtained thanks to electronics systems through more energy-efficient products that contribute also to portability, energy-transformation improvement and fuel efficiency of vehicles.

A goal for product energy efficiency - standby power, induction, PCs, TV, lighting, general appliances... - to save at least 20% of total primary energy by 2020 should be achievable thanks to improved Europe competitiveness by setting minimum standards for the power efficiency of electronic household, industry and office equipment, and further research on new technologies closely co-ordinated with European energy programmes. This includes intelligent technologies and systems to save power per function.

On energy transformation, there is a major opportunity for improvement due to the size of current transformation losses, poor energy transformation and power distribution losses. New components and concepts from the semiconductor industry should be studied - including high voltage modules and integration technologies, high temperature electronics and innovative sensors.

Special attention should be dedicated to the fuel efficiency of vehicles as the transportation sector accounts for almost 20% of total primary energy consumption, directly linked to emissions. And the best way to meet the EU goal of 120 g of CO₂/km in 2012 is to explore the potential saving of 26% in energy consumption estimated in transportation. This should be achievable using improved electronic systems to monitor and manage power consumption and emission: full hybrid, power split transmission, high voltage applications, energy management, battery management, smart sensor and actuators.

2.6 HIGH QUALITY MEDIA AND ENTERTAINMENT

With the generalisation of digital video and audio multimedia, customers are now expecting more and more from their equipment in terms of:

- Better quality with higher definition and better sound; and
- Ubiquitous access to content - anywhere, on any terminal, using any network.

The way for Europe to get ahead of Far East competition is by creating advanced products and defining the standards for very high quality image and sound in digital cinema, home cinema, sound beyond 5.1 and more than video/audio - 3D, multi view angle and new interactivity.

Providing ubiquitous access to content means:

1. Development of trans-coding engines, protocol adaptation and a 'universal' media format; and
2. Exploring innovative solutions for new multi-network devices - software-defined radio, wideband reception, power-line transmission....

Media is not only about broadcast or access to content but also more and more about peer-to-peer communications; these will create greater complexity of home equipment. At the same time, home networking is an important challenge for the coming decades. Ubiquitous access is expected both to personal private and protected content and to public content, whatever terminal or transmission medium is used.

To be ahead of international competition means developing new architectures and new standards that can be imposed worldwide.

3. CATRENE TECHNOLOGIES TO SUSTAIN APPLICATIONS WORK AREAS

Application work areas set new technology challenges and requests. On the other hand, microelectronics perspectives and roadmaps are set for technology and its intrinsic evolutions. The two approaches are linked below.

3.1 NEW TECHNOLOGY CHALLENGES COMING FROM THOSE APPLICATIONS

Semiconductor technology development is entangled with applications. The inverted pyramid shown in Figure 1-3 of Chapter 1 could also be reversed: it is the large base of services and electronic devices that motivates and supports the heavy investments in R&D by semiconductor, equipment and materials companies.

To be able to design and produce the above applications, corresponding processes and technologies should be available; just to mention few examples:

- In the automotive field**, there is an increasing demand for more safety on the roads: collision-avoidance systems for cars will require the development of optical and infrared sensors, low cost solid-state radar and optoelectronic components for light detection and ranging (LIDAR). Low cost RF links will be required for car-to-car communications to increase driver awareness of surrounding traffic conditions. Real-time analysis of car status and traffic conditions - required for computer-assisted driving - will require a drastic increase in data-analysis capabilities that in turn will demand more advanced CMOS technology. The requirement is to be able to pack the computing power of a high-end workstation under the dashboard, at a price comparable to a low cost PC of today.
- In the field of energy saving and pollution prevention**, the introduction of hybrid or fully electric cars will require development of high power, high voltage electronics to manage the electric motors and energy transfer among batteries, generators and electric and internal-combustion engines. Combination with chemical sensors will insure better management of the combustion process.
- In the field of telecommunications**, there is an increasing requirement for higher operating frequencies, to support the growing demand for data transfer. Global networks that carry data over vast distances via satellite, micro-/millimetre waves or optical-fibre networks require extremely high frequency technologies, the main challenges being high-speed circuits and technologies operating at 40 GHz, 80 GHz or even higher. It will require both RF technologies for much higher frequencies than used today and the integration of optoelectronics devices. Reducing the cost of components and developing suitable packaging technologies for integration with logic devices will be major challenges.
- In the field of medical applications**, there is an increasing need for faster and more accurate diagnostic tools and for portable devices to support an ageing population. To be able to interface easily with the user, these devices will require friendly interfaces, real-time data processing and low power consumption. A recent analysis showed that this kind of wearable devices might need 500 times the power efficiency of today, at a fraction of the cost. In addition, further development of biological sensors is required, integrated with logic and RF devices to connect the measuring unit to a central support facility.

- **In the field of high quality media and entertainment**, there is an increasing demand for digital data processing and a trend towards digital processing of analogue data - such as in digital cameras, digital TV and digital radio broadcasting, meaning again higher operating frequency and increased processor capabilities.

3.2 NEW GLOBAL APPLICATIONS REQUESTS

The many fields described above share the global requests summarised below. It should be stressed that these requests are common to all the applications, and can be solved efficiently only through specific technology projects with the appropriate critical size.

- **More and more computing performance** - algorithms are becoming ever more complex to address new needs such as higher definition, better quality living-room or nomad content, or for new applications like image processing in automotive or medical imaging; so many future applications will require in the order of GIPS.
- **More and more autonomy** - more and more terminals are becoming mobile and yet they need to embed ever more intelligence and data. We can see that in the convergent evolution of mobile cell phones over the last ten years while simultaneously keeping the same requirements for autonomy, but we see it also in the apparition of more and more communicating devices - from RF-powered microsystems to the pen or the watch - and the apparition of new energy sources from new batteries to fuel cells, micro-batteries or energy-scavenging devices.
- **Faster time to market and cycle** - this increased complexity comes with an acceleration in the time to market and the lifecycle of the products. It is more and more important to be the first on an international market; the ramp-up

cycles are much faster - less than a year - and more and more synchronous all around the globe. Being late cost even more market share and with this renewal cycle there is not much volume left for technology followers.

- **Reliability is becoming increasingly critical** - whereas reliability used to be critical only for transportation electronics or to avoid massive recall on consumer products, future applications such as in healthcare with for example lab-on-chip diagnosis or active security in automotive use are making reliability of electronics life-threatening issues. In parallel, keeping pace with the accelerated pace of complexity, new disruptive technologies and at the same time maintaining and increasing the quality and reliability level will become an everyday challenge for microelectronics.
- **Communications bandwidth** - this century will definitively become the century of communications: communications among people and among objects with simultaneous, ubiquitous and overlapping networks with increasing requirements on bandwidth. This will start with the disappearance of wires apart from power supply, complete saturation of all type of networks from body area networks to the local network and the increasing request and competition from the different media for broadband access based on bandwidth and quality of service. And new products will appear, such as sensor networks, automotive radar, and car-to-car communications. We are slowly running out of spectrum resource, searching for higher and higher frequencies and more and more optimised use of the spectrum through flexible and smart protocols and antennae.

- **New requirement from OEMs to have full platform tested supporting main operating systems** - the job of micro-electronics designers is slowly evolving because of the increased pressure over OEMs suppliers to provide faster more and more complex products to the market. Complete control over system hardware and software is now a standard request from the OEM to the semiconductor supplier that has to provide partly tested platforms with the implementation of the hardware-sensitive software blocs already integrated for the main operating systems.
- **Multidisciplinary innovation** - technologies are more and more interleaved with each other and innovation in one domain has major impacts on others so that we cannot completely separate research in specific domains. The next major disruptive innovations will be more and more interdisciplinary, spanning from design to technology, manufacturing, packaging, testing and software.
- **Flexible hardware:** Facing the growing cost of mask sets for future technologies and the increasing requirements for customisation and upgradeability from customers, architecture will move more and more to flexible, programmable, configurable hardware architectures. The increasing need for new cognitive and smart platforms capable of supporting multiple standards is also leading the way to such architectures. Having many challenges in common with multiprocessing, they will exist in different still unknown forms and will be a major innovation source for the next decade.

3.3 CHALLENGES IN MICROELECTRONICS TECHNOLOGY ROADMAPS

At the same time, microelectronics engineers have developed perspectives and roadmaps summarising challenges induced by technology and its intrinsic evolutions for more performance. The design of the dice that will be made to answer to such applications will be possible by meeting at least the following challenges:

- **Multiprocessing platform:** Multiprocessing is one of the major challenges for embedded systems in the next decade if not longer. It is a misconception to believe that Moore's law is enough to embrace the always increasing requirements for more processing power. Amongst many obstacles, the heat wall and the complexity of the systems will make it necessary to look at different architectures and new concepts such as asynchronous versus synchronous that will disrupt the way we design embedded systems for the next decade. These new architectures are a true challenge for the industry as they involve disruptive innovation at several levels - from the design of the core processors, to the intercore architecture and the modelling of each layer of the stack. There is a strong interdependency of the complete system from hardware macrocells to programming language for those specific hardware architectures that will require covering everything including compiler and software development tools.
- **Analoge design** - RF, analoge/mixed signal: Analoge and mixed signal design with new requirements on telecommunications in RF in terms of higher bandwidth challenges, wide range versus narrow range, multiple-input multiple-output (MIMO) and modelling, as well as analoge/mixed signal, digital signal processing (DSP), management of new energy sources, analoge signal processing,....

- **Low power and ultra low power:** The complete set of improvement tools from the cell/macrocell level to the interface between the software stack and the hardware, including all the tools for modelling and forecasting power consumption - from a complex nomad terminal to ultra low power Wibree wireless technology, RF identification (RFID) or sensor networks.
- **Workflow for faster time to market with increased complexity and increased integration:** Mapping of applications and partitioning tools, virtualisation tools, modelling tools, debugging, test and validation, system level tools,....
- **Master complexity:** Ability to model and design complete SiP systems simultaneously, together with hardware-sensitive software.
- **Algorithms for embedded systems:** New algorithms for embedded systems are coming, they include research and implementation of new algorithms mostly in image processing, but also in digital signal processing that cannot support real time in software. They require specific research studies to simplify - fast implementation - and partition them on a hardware platform so that they can be offered for consumer products.
- **Standardisation and interoperability work:** Standardisation is a major challenge for the industry facing the growing complexity of the chips and norms. Interoperability of models and chips at every layer will be compulsory to remain in the market - we can mention initiatives such as MIPI, KHRONOS, TLM and any new application-specific norm where microelectronics providers often confirm the doability of first products as for 4G communications, 3D, MPEG, etc.

4. CATRENE TECHNOLOGY WORK AREAS

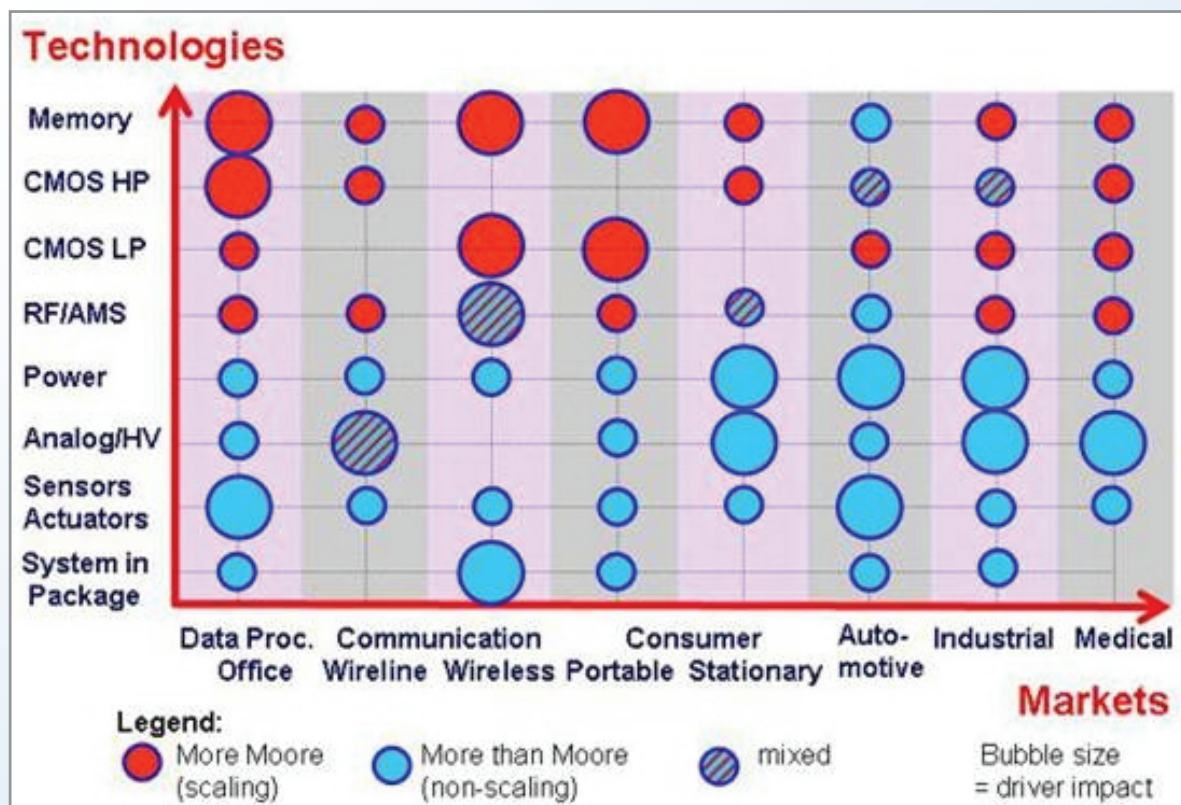
CATRENE enabling technology projects are essential building blocks in the nanoelectronics landscape. As indicated earlier, main application fields described in the previous section can only be developed if supported by the necessary and available technologies. Globally, there is no one-to-one technology or process covering each application field described but rather a set of processes, all CMOS based. Moreover, most of the applications described cannot be designed in pure CMOS alone but require 'more than Moore' process diversification - see Figure 1-3, *Semiconductor technology trends*, earlier in Chapter 1.

As mentioned earlier, the four main work areas identified by CATRENE are:

1. Electronic design automation for extreme SoC and SiP design
2. Process development including next generation CMOS process (more Moore), process options (more than Moore) and heterogeneous systems integration,
3. Manufacturing science : cross cut technologies, equipment and materials
4. Smart sensor and actuator systems.

These work areas are developed in detail in Chapter 4. Figure 2-5 *Market drivers for technology roadmap*, and Table 2-2 *Technology platform and equipment/material needs versus applications*, summarise the matrix between application needs and technology.

Fig. 2-5 - Market drivers for technology roadmap



Source ITRS/STMicroelectronics

Table 2-2 - Technology platform and equipment/material needs versus applications

BM+ WORK AREAS	High quality, high speed user-centric communication	Smart card systems and secure applications	Transport electronics for safety, security, environmental protection and communications	Healthcare devices and systems	Energy-efficient devices and energy-control systems	Devices and systems for digital entertainment
Smart systems, SiP, Sensors & Actuators	M	H	H	H	M	M
Electronic Design Automation for extreme SoC design	H	H	H	H	M	H
Technology Platform for Next Generation Core CMOS Process (More Moore)	H	L	M	M	H	H
Technology Platform for Process Options & Heterogeneous Systems (More than Moore)	H	H	H	H	H	H
Cross-Cutting Technologies	M	M	M	M	M	M
Equipment and Materials	H	M	M	M	H	H

NEEDS: H= High, M= medium, L= Low

Nanoelectronics development in Europe is the strategic enabler and needs to be supported, for both cost and time-to-market reasons, by a strong state-of-the-art technology base.

In addition to the semiconductor manufacturers, the ecosystem includes the technology research laboratories, the substrate suppliers, the gas and source providers, the equipment manufacturers and the electronic design automation and other software tools providers. This is the way to remain in the race. It is also the way to keep a competitive European equipment, EDA and substrate industry that can design tomorrow’s machines, tools and wafers.

4.1 ELECTRONIC DESIGN AUTOMATION FOR EXTREME SoC AND SiP DESIGN

Product design with its high added value needs effective and efficient design processes to ensure competitiveness of the European semiconductor industry. This industry has been growing so fast that overall development

process maturity has been barely achieved. Manufacturing processes are highly efficient and predictable but EDA lacks maturity in its engineering and performance. This causes a major bottleneck - the design gap - preventing full exploitation of the capabilities of silicon processes available today.

In addition, new applications systems are coming up. The manufacturing and application challenges behind these new developments are great: minimum structures for systems with the highest levels of complexity and reliability have to be launched in continuously shorter time frames on a competitive base.

To consider these requirements, the optimisation of manufacturing is not sufficient in itself. The semiconductor industry is only able to fulfil these requirements by employing design methods and tools which provide maximum support in the design of the products. Today’s most challenging factors that strongly determine product engineering are progressive miniaturisation, increasing complexity,

process variability, higher reliability requirements, continuously shortened product life cycles and increasing price decline. Only by solving these challenges will we be able to take full advantage of the technological possibilities and achieve economical success in the future.

Some of these challenges could be ignored previously. The requirements of modern EDA tools receive a new dimension, significantly exceeding levels for design and verification currently achieved by today's tools.

Only the industry developing the applications can specify and prototype its needs in the area of EDA. Several European universities have leading knowledge. Co-operation between industry and universities has led to the creation of new start-ups of EDA companies on a regular basis to provide new tools and methodologies and of course new jobs.

4.2 PROCESS DEVELOPMENT

Mastering process technology is a prerequisite for the most efficient design of chips on time and right first time. The full understanding of the physics of the process is the only way to design competitively and to differentiate a product from the mainstream. Furthermore, the fact that system partitioning is highly technology dependent requires a deep knowledge of available processes to design the cheapest and most efficient system for commercialisation. The market success of a chip or a system is highly dependent on the optimum use of technology obtained as result of close collaboration between the designers and the device engineers working in the wafer fabs. This is where the value is built.

As stated in the introduction, CMOS will remain the basic IC technology for the coming ten years, even if extensive research on alternative devices is leading to interesting results published in the literature. In some cases, these alternative approaches will bring new ideas or useful additions to the CMOS process, but will not replace CMOS in the short term.

The speed of innovation - being the first with a product or a technology - is the only viable way to compete. As a consequence, achieving a shorter development time and a faster ramp-up to production are the most important parameters.

From a technological point of view, Europe has good potential to provide solutions to the technical challenges in both the 'more Moore' and the 'more than Moore' domains to ensure steady progress.

Mastering the 'more Moore' CMOS axis at the relevant critical dimensions - technologies for logic devices, memory devices, low power and innovative device architecture - is the prerequisite to develop the technology platform for process options and for heterogeneous system integration in 'more than Moore'.

This means that innovative process steps and process modules mastering new materials and new composite substrates will be developed, generating new challenges in device and process integration.

Chapter 3 of this White Book describes all the technology areas that are covered within this programme. The objective of the industry is to launch projects in all those fields described that are important.

4.3 MANUFACTURING SCIENCE

The trend towards faster introduction of options, volumes and yields for more and more sophisticated technology places high demands on manufacturing tools and methodologies.

This requires the development in parallel of the processes for a manufacturing solution that is efficient and agile: resources management and recycling, safety, health and environment (SHE), line-operation effectiveness and line-variation control. These performance factors drive cost, productivity and speed - the key enablers for market success.

European players are benefiting from a favourable environment of potential collaboration - among laboratories, IC manufacturers, software companies, equipment suppliers, SMEs and design house - and have the skills to manage complex systems.

This is the key input for the R&D for new equipment in the fields where Europeans companies have process excellence - such as lithography for new generations of semiconductors and non-optical patterning methods - and for the development of new advanced substrates.

4.4 SMART SENSOR AND ACTUATOR SYSTEMS

Sensor and actuators have already been mentioned regularly in the previous section: semiconductor smart sensors and actuators combine intelligent control functions and some computing power with the basic sensing function. They are becoming part of many applications; smart sensor and actuator systems are expected to be one of the most powerful enabling technologies to solve many challenges arising in future society: communications, transportation, security, healthcare and the ageing society.

The average annual growth rate forecast between now and 2010 for the smart sensor market is as high as 21%.

To master these systems, Europe must create and explore relevant knowledge, push new and very complex applications, and care for reuse and multiple use. Lying at the border between application and technology, the research on smart sensors and actuators should cover:

- **On the technology side:** device miniaturisation and power consumption, MEMS-based devices, chip-stacking technologies, high temperature applications, low temperature processing and polymer electronics;
- **On the systems side:** energy management and energy scavenging, interfaces, architecture trade-offs, data-fusion techniques and algorithms; and

- **On the applications side:** general uses such as media, biochemical and biometric sensors, imaging, optical switches and display, storage devices, magnetic-field sensors and RF interfaces, as well as more specifically:
 - Mobile communications;
 - Security;
 - Automotive;
 - Healthcare;
 - Environment protection; and
 - Consumer/industrial equipment.

5. PROJECT FLOW

CATRENE will basically follow the same successful organisation of the projects flow that is in place for MEDEA+. CATRENE ambition is that thanks to the lighthouse projects approach, the synchronisation difficulties presently existing in MEDEA+ will be solved.



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