MEDEA+ Scientific Committee

Assessment of European Universities

And

Research Organisations in Microelectronics

Final report

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"In a knowledge economy, science is exerting a more important and direct influence on innovation, especially in fast-growing new industries. The intensity and quality of industry-science relationships (ISR) thus plays an important role in determining returns on investment in research, in terms of competitiveness, growth, job creation and quality of life. They also determine the ability of countries to attract or retain increasingly mobile qualified labor."

[J. Guinet et al., 2002]

1. Objectives of the study

The MEDEA+ Scientific Committee accepted the task of making a comparison of the efficiency of European universities & research centers

(i) with respect to the American and Japanese “counterparts”
(ii) related to schemes implemented to support research in universities & research centers with a focus on :

- source of financing
- strategy
- business model
- IPR-policy.

In order to perform this comparison, the following target groups where identified:

- Europe:
  - Universities
  - Research institutes
- USA:
  - Consortia (Int’l SEMATECH, SRC,…)
  - Research institutes / Universities
- Japan:

  Consortia (ASET, SELETE,…)

2. Approach followed for the Assessment

Starting from the objectives summarized in § 1, a specific list of research centers and universities among the target groups was defined (see Appendix 1) and early November 2001, a questionnaire addressing the major topics was prepared and sent out.

At the time of the first Scientific Committee meeting (31 Jan 2002) the initial responses to the questionnaire had been received. The input-gathering was continued, but the responses were disappointing (often incomplete or not quantitative). It was decided that the responses to the questionnaire would be considered as useful reference information, but as statistically not relevant enough.

Also, the Scientific Committee advised to compare Europe only with the USA, i.e. to exclude Japan, where the university system is too different. However, in view of the many problems of the Japanese industry, a number of changes are being implemented in universities (such as relaxing the ban on universities and university professors to engage in business), government labs and consortia[1]. It will be interesting in the future to evaluate whether these measures were successful and - if so – whether they are applicable to Europe.

In fact, the same holds for the US system: by observing the changes, explaining certain phenomena becomes easier. In case the effects of the change are positive, it is then easily concluded that Europe needs a similar change in culture, if we do not want to fall behind. Important examples of such changes in the system are: (1) the ruling that government money could be used in the 'competitive world', which made DARPA funding extremely important; (2) the Dole-Blayh Bill, voted about 2 decades ago, that allowed university professors to own IP and that created a large innovation drive.

The current situation in selected Japanese and US consortia is briefly described in Appendix 2.

On the other hand it was suggested that Taiwan and Korea would be included in the benchmarking (provided sufficient information could be gathered), given the impact that government laboratories (e.g. ITRI) seem to have had on industry (in conjunction with immense financial incentives). It was thought to be interesting to study also the relationships between the labs and the industry today, given the large industry that was established.

If an assessment is carried out, the first question is what parameters should be used and how to obtain quantitative data. For this, one can study various so-called **output indicators** for the regions being compared, such as number of publications (per million of inhabitants), citation indices and impact factors, number of patents (per million of inhabitants) and so on. The corresponding figures can be found, e.g. in the OECD data bases or in publications from the EC. The first problem encountered, however, is that for the corresponding numbers there is a very large spread across Europe[2]. When analyzing the major output parameters, it is clear that differences between "Europe" and the US exist, but that there are always countries performing better than the US.

We then turn to the **input indicators**, such R&D effort as % of GNP, or number of researchers in public and private organizations.

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[1] As a general observation, the committee suggests that in future efforts of this kind, the questions of a questionnaire would address *changes* in the system, which are easier to identify and are more significant than actual observations.

[2] E.g. for number of publications (per million inhabitants): 1431 in Sweden, 963 in The Netherlands, 949 in the UK, 708 in the US, 657 in Germany, 652 in France, 498 in Japan (data from OECD, 2001)

Country	R&D effort (% of GNP)
France	4.95
US	4.2
Japan	3.86
Germany	1.9
Italy	1.4

Note: data involve federal budget for R&D (both military and civilian) (for 2001 for Japan and Italy, 2000 for Germany, 1999 for France and US)

Again a large spread is seen, but the input parameters certainly do not indicate a large discrepancy between the US and "Europe" as a whole.

Since a thorough study of the input and output parameters was beyond the scope of the project, the Scientific Committee decided to follow a more qualitative approach, and base its report on Assessment of the European Universities and Research Organisations in Microelectronics on information available within the time frame alloted and on personal experience of the individual committee members.

The final report based on discussions in the Scientific Committee is submitted to the MEDEA+ Office in preparation of the Board meeting of 11 June 2002. After having received feedback from the MEDEA+ Board, consensus will be saught and – upon initiative from the MEDEA+ Board – recommendations to the authorities can be prepared.

3. Definitions and Observations

3.1. Definitions

First, we would like to start by making a distinction between **basic research, applied research and development**. Since the report by V. Bush (science advisor to President Truman) [V. Bush, 1960] there is a general consensus that basic research should be the responsibility of a nation's (research) universities, as the private sector often would not invest adequate funds in research at the basic end of the continuum. At a certain point, basic research reaches the stage where there is potential for applications. The applied research then typically follows, where often research institutes come in, and joint activities between the research teams and industrial teams are deployed. Later, the effort continues in the development stage where new products and processes are developed and this clearly involves the private sector.

We have several **partially government-funded research laboratories in Europe**, but they are rather exceptions (CEA-LETI, IMEC, the Fraunhofer institutes, RAL, NMRC, …). It also should be stated that they do not fulfill the same function as the universities (they also have few students per invested €). Moreover, linkage exist between the scientists at these centers and the local universities (where staff members often have teaching assignments), but at the same time there is often competition for a small group of graduate students.

We also do not include the **industrial research laboratories**, which exist in both continents, and of which quality is comparable, but when considering the investments even there we are factors off (to be investigated – private Research investment is probably a factor 2 higher in US, but the “Intel-effect” must be taken into account).

We want to focus here at the beginning of the continuum, i.e. on the basic research which is performed mainly at the universities. The logic used is fairly simple. When universities are doing basic research, new ideas are generated that industry can build on, and industry will participate in investments in applied research at the research institutes and later in development. **Hence, the government’s investment in university research is a strong driver for the industry’s investment in R&D and thus for innovation and for economic development.**

As far as the role of universities in fostering economic growth is concerned, we want to distinguish between the **education and the research component**. In its analysis, the Scientific Committee in fact started from the assumption that the major objective of the public research system is to provide industry first and foremost with efficient access to

(i) a pool of highly skilled young employees (*the education component*);
(ii) research infrastructure (*the research component*);
(iii) and results of long-term research, in particular the new concepts (*the research component*).

In conclusion, any study of the impact of government-sponsored research has to deal with three dimensions (at least):

(i) **the infrastructures** (both **material** and **human**), most often the result of local and national policies, vastly varying in Europe (in particular the personnel management policies);

(ii) the **organisation** of the research (universities, government labs, research centers etc…), usually with varying missions and operation modes;

(iii) the **culture** and procedures, again very varying between countries, and inducing vastly different changes in organizations, with a very special common role played by European programmes[3].

We will address these subjects in § 4 below:

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[3] At the same time, we would like to stress that these European programmes influence only a very small part of the overall research operations.

- infrastructure (both human resources and equipment);
- organisation;
- culture.

3.2. Observations

The following observations are at the forefront of our study:

1. **(Infrastructure-related)** -- The **centers-of-excellence** in certain locations of the US attract many excellent foreign students and are real **"brain magnets".** Combined with flexible and open career structures, a strong entrepreneurial culture, high living standard and quality-of-life, they breed the scientific capability that can transform them into pivotal points in certain fields. Although European research may perform better in some fields than the US counterpart, why is it that very few centers-of-excellence (type Stanford, Berkeley, Harvard, MIT, …) seem to exist in Europe, despite the fact that much effort is being devoted by public bodies to the creation of research centers and technology parks?

2. **(Organization and culture-related)** -- Why is it that EU companies often prefer to work with one of the US universities, while the same experience is likely to be available in EU? The Microelectronics Industry in Europe is more prone to invest in American Universities, which often seem to be more effective in generating useful information and valuable results.

4. Building a framework towards insight

4.1. Infrastructure – (A) human resources

Talent is one of the primary factors in our analysis: without talent, no good research, no drive for start-ups, no innovation.

It is tempting to start the analysis from the thesis that the general quality of professors and university staff is better in the United States than in Europe. It is the committee's conviction that this is not true, in fact, quite on the contrary: we dare to posit the thesis that the University staff in Europe can be of equivalent quality in many cases.

Problems in Europe are not linked to immobility resulting from professors obtaining a permanent position. In fact, it appears that tenure is much more widespread in the US and that there are lots of problems with poorly performing professors and staff members there. This still leaves us with the question, why the US systems seems to perform so much better. On the positive side, it should be stated, of course, that we have many examples of extremely active (and with a workload higher than in industry) and dedicated professors in the US.

This issue was controversial and it raised discussion. This is related to the underlying statistics leading to quality distribution functions with a different distribution. The conclusion appears to be, that **the average quality of academic staff is probably the same in US and Europe**, but (1) the sample is larger in the US (see EE departments at major US universities, have doubled in size in last 10 years!); (2) the spread is much more pronounced (and, in fact, promoted) in the US, with a large portion of top performers.

If there is no direct quality difference related to the individuals, then **the reasons must be found in differences in the environment, in the culture**. The performances **at the level of the universities as a whole** are often quite different in the US and Europe, and **there are major qualitative and quantitative differences**: the peak performers are attracted and promoted by the system, the environment, the culture! The system attracts top performers (globally!), gives them better resources and stimulates the top performers even further …

It is **hard to make a general assessment of the respective research environments**, because of their sheer diversity, scope and size. Note: the “sheer diversity” works in two directions. 1- Europe versus US; 2- within Europe; it appears that France is at a disadvantage, e.g. professor does not get “a package”; cannot start a company etc. While preparing this report, we had only limited access to existing studies and literature. Therefore, we had to restrict ourselves to general comments based on personal experiences and a limited amount of scattered data. A thorough investigation of the question would certainly be worthwhile.

We would like to add a sobering example. **The number of professors in Microelectronics in the Netherlands** (all categories: full professors, associate and assistants - about 30) **is less than the number of professors in that field at the University of California in Berkeley alone**, i.e. not even taking into account UCLA, UCSB, UCSD, UCD, UCR and all the private universities (such as Stanford, Caltech, Santa Clara) and the universities of the State University system.

Furthermore, the US has an **effective policy of letting top professors come in and letting students from** foreign universities **study there and immigrate**. It is effectively cultivating its supply of top scientists and engineers. See e.g. CIS at Stanford, where huge chemistry and physics departments interact with the EE department. New professors often have double assignment (EE + chemistry; EE + physics) which allows very efficient networking.

In view of the comparative size of EE departments in the US versus Europe (doubled in the US in last 10 years, at best status quo in Europe), the **number of graduating Ph.D. students in Microelectronics** is certainly larger, although exact figures are missing. An indication is that getting educated people in Europe is much more difficult than in the US (see e.g. OECD tables, NSF indicators for quantitative figures).

It is noted that there is a **significant drain of young research personnel out of Europe**. In 1996, 7638 professionals from the EU were granted permanent US visas [Mahroum, 1998]. Between 1988 and 1996, the number of PhDs obtained by foreigners in the US rose from 3.300 to 8.000 annually, up to a total of 55.000. The majority of these foreign PhDs then remain in the US: in 1996 73 % decided to stay [COM, 2001a]. In science and engineering, 8760 of PhD students graduating in the period 1988-95 were Europeans. US Department of Labor statistics show that 5 years after graduation over half of these are still in the US [Mahroum, 1998].

The EC started a discussion on the pros and cons of this brain drain. European doctoral graduates have a much higher stay rate in the US than e.g. their Korean or Japanese counterparts: only 8% of Japanese graduates stay. The case of Taiwanese expatriates returning to their country (helped by governmental or industrial incentives) and building up or at least strengthening the local semiconductor industry is also noteworthy. It is an example of **brain circulation**, referring to the cycle of moving abroad to study, taking a job abroad and later returning home to take advantage of a good opportunity. This form of migration will increase in the future, especially if economic disparities between countries continue to diminish [Johnson & Regets, 1998]. Also, the home country must offer good opportunities in terms of positions (i.e. offer good “packages” in terms of salaries, staff support, infrastructures, etc.), of innovative climate (i.e. centers-of-excellence for research) or support new business ventures in order to attract these expatriates with potential for high added value for the home country.

Here it is found that Europe seems to have a double disadvantage: (1) if the elements contributing to an attractive and innovative climate are missing, the home country will not benefit from the reverse brain drain; (2) young potentials in the US are not attracted by Europe in a similar way as young potentials in Europe are attracted by the better climate in the US.

4.2. Infrastructure – (B) funding

We would like to start by an important up-front comment. It may **appear that “mega”resources are concentrated on a relatively small number of Universities** (such as e.g. Stanford U., UC Berkeley, MIT, Carnegie Mellon U.). However, it is not true that Microelectronic Research is concentrated in just a few centers: SRC e.g. gives out research funds to more than thirty institutions. However, quite a number of 'top-of-the-bill places' have been able to assemble a very large group of competent researchers, often from various departments (EE and computer science, chemistry, materials science, physics and applied physics, mechanical engineering, etc.), efficiently drawing from all available resources, thanks to well-guided but local policies. The networking starts at the local level! This is especially effective in enhancing the strength of these Universities, which are thus highly qualified and attract more funding from Industry (even European!) and from the Funding Agencies.

The US funding of research in Microelectronics comes from different sources: (1) DARPA, (2) NSF, (3) industry-directed open sourcing such as SRC, (4) 'closed' programs of Research Associates set up by individual Universities and Research Institutions, (5) the state, the region (see e.g. case of Albany!) and (6) endowments. The amounts in the latter category are not small: a number of universities have endowments in the billion-dollar range resulting from donations that can be huge[4]. **The resulting size of funds available to university-level research is astounding**, as well as the relative ease by which funds are made available to researchers with a proven track record.

A recent position paper from SIA has put this statement in a somewhat different perspective, by stating that federal investment in university-based research has declined in real dollars in several fields (math, physics, chemistry, electrical engineering) in the 1990s. The same paper urges the US Congress to double the NSF, DOE Office of Science, the NNI and the IT research budgets over the FY2002 to FY2006 time period, and to significantly increase the DOD’s long-term, high-risk research [SIA 2002]. Among these measures, the SIA supports doubling the budget for the NSF from 4.4 billion $ in FY2001 to 8.8 billion $ in FY2002. These investments in university research are considered essential if the semiconductor industry (i) is to continue driving the productivity improvements and thus the federal budget surplus, and (ii) is to solve the challenges posed by the ITRS and by the transition to an alternative for planar CMOS devices.

It should be kept in mind that other resources are very specific to US universities: donations and endowments allow universities to set strategies in new areas, eventually with high risk, before any funding agency has started to become interested in the field. They can also rely on local governments to have their own initiatives, quite often of megascale, as in the case of The State of New York for the Albany facility (NanoTech) or the State of California program in nanotechnologies. Such funding is essential to create the infrastructures, either material or human (the "named" chairs in universities), thus creating the conditions for competing for contracts down the road, as contracts cannot provide the infrastructures in the first place.

MEDEA+ is the new industry-initiated pan-European Programme for advanced co-operative Research and Development in Microelectronics. It has been set up and labeled within the framework of EUREKA to ensure Europe's continued technological and industrial competitiveness in this sector. MEDEA+ started in January 2001 and focuses on "system innovation on silicon for the e-economy". The central objective of the industry-driven multi-project MEDEA+ programme is to stimulate innovation and provide the technology platform which will allow the European microelectronics industry to stay in the group of worldwide leaders. The eight-year MEDEA+ programme (2001 - 2008, in two phases of four years each), channels private and public funding into microelectronics research & development projects. They associate semiconductor manufacturers, their suppliers, system companies and design houses, private research institutes and the academic world. This co-operation helps participants to share know-how and speed-up projects. It reduces cost and the big risks which are inherent to innovative high-tech R&D.

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[4] Recently, Gordon Moore (from Intel) donated $500 million to Caltech, half for earmarked projects to be chosen by his foundation, the other half completely free. In Stanford, several recent donations have been in the tens of millions of dollars range.

As for the European scene, in May 2002 the European Parliament gave its go-ahead to the Commission's proposal for next EU Research and Development Framework Programme (FP6). "I welcome this key vote", said Research Commissioner Philippe Busquin. "This new R&D Programme will run until 2006, with a €17.5 billion budget, a 17% increase on the last programme. A major innovation in FP6 is the way in which researchers will work together in Europe: on a selected number of priorities, in an integrated way, and with streamlined administrative procedures. Once the Council has endorsed Parliament's vote, it will be the first time that the scientific community and industry will have more than six months to draft proposals before the formal entry into force."

FP6 represents the third operational budget line within EU overall budget, after Common Agricultural Policy and Structural Funds. It will be instrumental in achieving the March 2000 Lisbon European Council goal of turning Europe into the world's most competitive knowledge-based economy by 2010. It will also greatly contribute to the creation of the European Research Area (ERA), a true European internal market for research and knowledge, where EU and national R&D efforts are better integrated.

It should be realised, however, that FP6 thematic areas include life sciences, genomics and biotechnology for health, information society technologies, nanotechnologies and nanosciences, "intelligent" materials, new production processes and devices, aeronautics and space, food quality and safety, sustainable development, global change and ecosystems, citizens and governance, and other promising research areas, including support for small and medium-sized enterprises (SMEs) participation. FP6 shall also address research and innovation, human resources and mobility, research infrastructures, and science/society relationship [EU2002]. This means that the impressive budget for FP6 must be put into perspective, as it covers a wide range of scientific domains. It is hoped that the actual funding for microelectronics projects in FP6 will be higher than in FP5, and will at least be in the 100 M€/year range.

As a result, it is the **general impression among the European Universities (and Research Institutes) that there is a significant lack of straight funding for technology**. Europe does not have anything matching DARPA. In microelectronics, we have nothing matching the SRC. The main technological funding agency in the Netherlands - the STW - gets just 8% of the total funding for scientific research (while in the US, the DARPA budget exceeds the budget of NSF). Few of our companies donate money to university programs – often, they say they are already paying enough taxes. In the US, on the contrary, industry donations are stimulated by tax deductions of R&D investments and expansion of this system is being considered.

A distinction should be made between (1) financing of operations and (2) infrastructure and human resources. Funds for the second category often come from the endowment, and are not visible in the funding tables. See e.g. in the US, where $700 million is made available in 2002 for the National Nanotechnology Initiative (NNI). In Europe, it appears that in 6FP, the funding for basic & long-term research has largely disappeared (used to be in “FET open call”).

It has been stated that the US and Europe spend about equal amounts of their National Product on institutional research (see above, in §2, for the input indicators). But the comparison of figures is lopsided. Often the fact that in the US local and state authorities spend a lot of money on the set-up of universities and institutions is not taken into account in the statistics, and neither are the considerable endowments and investments by private parties. In the US, investments are not taken into account; also, in the US salaries are taken from tuition and hence not counted; in Japan, investments are seldom counted in the statistics. This indicates that one should be careful with interpreting the numbers.

It appears that in any case a vicious circle is created, whereby more funds generate more qualification and the latter attracts, in turn, more grants and more people (students and professors).

4.3. Organisation

The **top universities in the US are graduate schools**. Hence, professors can concentrate on graduate teaching and research, unlike their European colleagues who have often a large teaching load at the undergraduate level and spend more time on administration. In Europe, universities are flooded with students, in the US professors focus on research (and graduate students). Due to the pyramidal structure of schools, with graduate schools at the top, the focus can go to the research.

The major US universities that have both undergraduate and graduate schools have a balanced population (about equal size for undergraduates and graduates), and therefore focus on the graduate students.

Although Europe does not have a system of graduate schools, it should be noted that the "Bologna agreement"[5] will introduce a system with Bachelors' and Masters' education which will give the students much more mobility in Europe. In the medium term, students will take their Bachelors' locally, but then move to the better universities to get their Masters', which will create de facto graduate schools at the best universities.

Another positive evolution are the doctoral programs that are emerging, and in which students are awarded scholarships and are recruited globally (see e.g. U. Lausanne).

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[5] Declaration of 19 June 1999 by European Ministers of Education convened in Bologna: (1) agree to construct a "European Higher Education Area" based on fundamental principles of university independence and autonomy to ensure that higher education and research in Europe adapt to the changing needs of society and advances in scientific knowledge; (2) work to increase international competitiveness of European system of higher education; (3) agree to work together to adopt a system of comparable degrees to promote European citizens and adopt a system of two main cycles—undergraduate and graduate with the second leading to the masters or doctorate; (4) also agree to establish a system of academic credits (such as the European Credit Transfer System) that would be easily transferable to promote widespread student mobility, improve access for students and training opportunities, recognize staff work in Europe, promote European cooperation in quality assurance working toward compatibility, and promote European dimensions of higher education. This is an agreement moving Europe toward comparable degrees and cooperation in quality assurance. (from www.chea.org)

In European Universities nearly all governing bodies are nominated by election and, somehow, must respond to those who elected them. Thus, specific, rather than general interests are sometimes pursued. In American Universities, the President is usually nominated by the Regional Government if the university is public, or by the Board of Trustees if it is private. He influences the salary of professors (a spread of 2.5:1 is not unusual), distributing the available space and resources according to efficiency principles. In Europe, efficient universities have similar salary systems; see e.g. U. Cambridge or Imperial College in London, where the salary spread for professors was allowed to increase with respect to 10 years ago. The President of a US university also has the money to undertake strategic moves (using the endowment funds), a possibility not available in government sponsored institutions where decisions come from government.

The **organization inside European Universities is often less flexible and less efficient than in the US**. This has to do in part with the constraints related with the very nature of public entities of the European Universities and, partly, to an insufficient competition among professors and researchers. The university management does not have the power to set the professor’s salary. Clearly, also, the salary scales are not competitive with industry and on a world basis (only in the UK have the rules on professor salaries been relaxed, with huge increases and therefore new recruitment policies and levels). Such policies have been implemented with great success in Southeast Asia, with the result that they were able to attract back the best people which had been trained in the US, had had excellent careers there, and came back to staff industry, government labs and universities.

Europeans have a tendency to over-organize things, instead of leaving it to a free competition to acquire programs and sell research ideas. We often seem to think that a subdivision and distribution of labor is an effective way of organizing research. Nothing is further from the truth! However, our way of doing things sustains poor quality. Europe thinks that by over-organizing things, it can beat the numbers game mentioned above. In particular, there is a general tendency to maximize the utilization of capital equipment, not seeing that this often leads to a *waste of human capital* (researchers are idle, while waiting for equipment to become available). The lack of equipment and facilities means that many bright ideas in Europe are never developed, or are developed at such a slow pace that they are overtaken by activities in the US or in Asia. Universities there invest at a much larger rate than in Europe. In Japan and the US investments can amount to 25% of the overall budget, which is unthinkable in Europe: in France the average figure for investments is 12% in industry and 5% at the university.

On the European scene, to a large extent we still see **a patchwork of nations with various funding schemes at the national and regional level**. For the newly emerging scientific domains these should be replaced by supra-national mechanisms and the European Research Area (ERA) advocated by Commissioner Busquin intends to compensate for sub-critical regional efforts.

The EC funded research programs offer the possibility to organize research in a supranational way, to create critical mass and to avoid duplication. In recent years, they have been launched on a wide scale in all EU countries and support industry, institutions and universities in a balanced way. This has the consequence that for example in 2000 15.408 project proposals were received in Brussels and Luxembourg, out of which 4.413 were selected for funding with 25.275 participants. This results on average in 5,73 participants per project and 0,97 million € requested financial contribution per proposal [COM, 2001b]. **The EC admits that the problem of sub-critical project sizes and resources exists**. Thus, in order to reach the necessary critical mass and to effectively pool financial and intellectual resources, FP6 will introduce new instruments, such as networks-of-excellence and integrated projects. Another problem is the widespread feeling, that **the EC management of proposals and projects has been over-regulated**. It typically takes one year from the date of a published call until the project starts with a large amount of documents requested from the proposers. Here again, the EC has made a pledge to speed up the project selection and negotiation processes in FP6, but it appears that the required paperwork will not be diminished. In addition, with its emphasis on Networks of Excellence and Integrated Projects, there will be no scheme to explore new concepts in small-scale projects, as in the 5th FP. Such programs, often limited in size, will no more be at the focus of FP6. Also, national schemes exclude supporting transnational efforts, which are becoming more numerous due to industry consolidation. Hence, a form of **“cross-border funding”** should be agreed upon.

On the other hand, also in Europe there are **positive examples of how to stimulate researchers to participate in multinational projects** and to transfer quality results into practical usage by industry. In the Eureka initiative, projects are funded equally by the national governments and the involved partners. Large programmes, like JESSI, MEDEA, ITEA focus on important areas of microelectronics and information and communication technologies. They have few projects, e.g. MEDEA had approx. 30 with a total budget of 2 billion € over 4 years. Proposals and projects are co-ordinated by the partners involved with an overhead of far less than 1 % of the overall project costs. The time between submission of a proposal and labelling by the Board is normally a quarter of a year.

The various funding schemes each have their value, and neither large neither small project sizes is necessarily bad. A *portfolio* of projects is needed and the various programs are used to effectively distribute the money. What is important, is that there seems to be no more room for small transnational projects.

4.4. Culture and attitudes

The **dynamism in the top US institutions is astounding**, often derived from the drive of highly motivated individual professors - we can all name the illuminating examples. Somehow, these professors are able to motivate fund providers both from industry and from government to support their often very daring initiatives. European professors on the other hand are hampered by antiquated or downright unresponsive funding systems.

This is a cultural element that must be changed if we are to improve the performance in Europe.

The mentality in the US is quite different from that in Europe, there is a **general acceptance of the idea that it is always very worthwhile 'to try something new'**, especially by people who have an excellent past track record. Ambitious and daring initiatives are often very welcome, even though the goals may seem very far off and skepticism at the least justified.

This mentality adds to the statistics: **one must try a lot to get good results**. The president of Princeton University once said: “I know that less than 10% of our research will produce effective results, only I do not know which 10%”!

It should also be emphasized that the US are able to change drastically regulations whenever it is needed, even when it goes completely at odds with the prevailing culture: The Dole-Bayh Bill of 1981, which authorized universities to hold the patent and licensing rights to discoveries that were produced with federal funding. This led to the explosion of patenting by universities and of their start-ups. In the late 90'ies, 5% of all US patents where granted to universities, ten times more than in the preceding decade (see NSF 2000 Science and Technology indicators). In the ‘90ies, the development of the dual-use policies at the US department of defense allowed to use civilian products in military systems, but also provided the framework to allow funding of civilian commercial technologies, starting with SEMATECH [OSTP, 1995]. These two actions, with far-reaching consequences (the defense R&D budget thus funneled in open industries is not commensurate with European budgets), have been made in spite of their obvious contradiction with the “dogma” that government should not interfere in industries subject to open competition, in fear of destroying the "fair" balance between companies.

The **European system of IPR handicaps the European scientists** via-à-vis their American colleagues and this leads to **fewer patents for the European scientists.** But it also indicates a difference in business-oriented attitudes. Of all US patents, 40% are based on European research; on the other hand, European inventions only use US science in 30% of the cases [K. Debackere, 2002]. This indicates that the quality of the basic science is comparable, but also that the US researcher is better aware of the European science and that he puts it into practice.

This is also reflected by the fact that, in a growing worldwide competition, **the percentage share of European patents has decreased by 6 points** (from 23.9% to 17.4%), **while US remained relatively constant** (from 50.8% to 49.1%) between 1985 and 1999. In part, this reflects the fact that two new players in patent-granting lag behind in Europe, namely universities and start-ups.

Researchers at US Universities are masters at networking and at establishing ways of facilitating research. Think of MOSIS (cheap access to silicon foundries for prototyping), but also of the internet. They are connected and cooperating long before the Europeans are. In addition, they dispose of an impressive number of very effective scientific media - in particular in the context of the IEEE - allowing them to reinforce their interests, exchange ideas, put up lobbying efforts and establishing standards. We did not succeed in organizing our scientific bodies well, and piggyback on the IEEE. Europe follows the US in many of its aspects, but at a distance. We got internet alright, but later.

The European response to MOSIS, named EUROPRACTICE came also later, but offers many new features that have no equivalent in MOSIS, such as cheap access to major CAD tools for universities and a full coherence between foundry services, design kits and CAD tools. Unfortunately, this service, which is a key infrastructure for education in microelectronics, is jeopardized by the fact that the EC considers it as a project instead of a service, and is severely endangered every 2 or 3 years[6]. The cancellation or a major reduction of the EUROPRACTICE services would be dramatic and would definitively push European companies to increase their cooperation with American universities.

US researchers are also very motivated at sharing their know-how by the invitation-only workshop system, where very efficient networking takes place and where the best researchers share their knowledge to become even better. Such workshops are sponsored by the various agencies in a very flexible manner. Nothing similar exists in Europe, certainly not the Human Capital and Mobility (HCM) schemes which are over-regulated and time-consuming. In addition, the disappearance of the NATO scheme (more precisely its transformation to support Eastern European countries) leaves a void in Western Europe.

Such cultural differences between Europeans and Americans make the latter **more flexible and more pragmatic in pursuing project-oriented research**. As a result, when the need arises of setting up inter-disciplinary teams, US Universities are quicker than European Universities in re-configuring departments or even entire Faculties. In Europe the traditional organization in Departments is more difficult to overcome. However, emerging disciplines such as bio-electronics, molecular electronics, polymer electronics, require the coordination of efforts and skills from various disciplinary areas and thus a re-configuration of disciplines in newly organized centers.

The US is not afraid of supporting straight innovative developments at US companies if it is deemed of national interest: the rules of fair competition do not apply if the national interest is at stake: see e.g. the development of Scalpel, directly aimed at the strong European position in lithography. This is done in a way whereby the (US) competition rules are not infringed on but the national interest is served best[7].

And finally it is fair to state that **the public and the press have an attitude which is more supportive of innovation and technology**.

5. Industry-Science Relationships

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[6] It is noted that also in Taiwan a multimillion-dollar-per-year program is being established in support of SOC processing for universities.

[7] An example from another industry is the Partnership for a New Generation of Vehicles (PNGV), established in 1993 by the federal government and the US automotive industry to establish global technical leadership and drawing upon the resources of federal agencies, the national laboratories, universities, suppliers and 3 major US automotive companies (see www.uscar.org/pngv).

Public research, business and government are three spheres that have been increasingly working together in recent decades. This convergence and gradual crossing-over has been referred to as the **Triple Helix model** [Viale & Ghiglione, 1998]. At the level of the 'actors', the convergence can be seen e.g. by academic researchers becoming entrepreneurs, or entrepreneurs spending time in a university laboratory; at the level of the 'institutions' we see hybrid agents of innovation, such as university spin-offs, or VC companies set up by universities; finally, the level of the 'regulations' is important as it provides policy tools and sets guidelines for policy incentives. The **evolutionary interpretation** of the Triple Helix model – which stands opposite the **neo-corporatist model** – assumes that universities, government and industry are learning to encourage economic growth through the development of "generative relationships", i.e. loosely coupled relations and joint undertakings that persist over time and induce changes. In this context, it is important to stress **the role that universities can play as catalysts of socio-economic development**. It is our impression that the European universities often still have to find the way towards spontaneous university-industry relations and related technology transfer processes. In the cases, however, where this is occurring (e.g. Cambridge, Leuven, Grenoble, Lyon, Munich, Sophia Antipolis, Dublin, Glasgow …), an environment emerges that stimulates innovation which in turn attracts talent and resources.

It is generally acknowledged that there is a much **more extensive and efficient interaction between Industry and University in the US than in Europe**. There are many reasons for that, in particular deeply rooted mistrust, disdain, even aversion towards industry, both in public and quite often even stronger in academic circles (in spite of the public rhetoric!). It is the responsibility of the various bodies to act to offset these deep cultural traits by providing measures which create driving forces to improve the relations between academia and industry. The gap in attitudes is even more obvious in the context of the microelectronics industry, which in the US exhibits remarkable phenomena such as Silicon Valley or route 128 in the Boston-area, which form a stimulating clustering of universities, research centers and electronics companies, covering all possible aspects of high-tech within a relatively small area.

The management of US companies believes in **the crucial role of Universities in generating knowledge at the pre-competitive (fundamental) level**. This is clearly apparent from a recent position paper from the Semiconductor Industry Association (SIA) in the US states that "corporate R&D rests on the fundamental understanding of physical properties that are developed at our universities" [SIA 2002]. That SIA document in fact contains recommendations to the US Government advocating a substantial increase in the level of funding for Universities.

The **European Industry often competes with Universities and Research Centers in being subsidized by public bodies and undercuts SMEs**. The official **European research budgets are indeed dominated by industry consortia**. This can be good in some aspects (if the funding agencies are able to control the operations), but certainly cannot be generalized. This is absolutely not the case in the US, where wide, diversified portfolios of actions are defined (see e.g. the portfolio of actions in the national nanotechnology initiative, NNI). In the 6th Framework Program, this aspect is even stronger than before. The result is that most funds for research in the European union are channeled to companies. Also in the US, companies are able to obtain a lot of money for research, mostly through request for the development of new technology of public utility (e.g. for defense purposes). In addition, the

US has large programs for pre-competitive research and for the stimulation of new companies, but the majority of the research money there goes to universities.

It is fair to say that there is **a better understanding and more mutual respect between Industry and the Universities** in the US than in Europe.

Partially, this is a result of a **higher mobility between the two communities in the US**. The American system requires professors to obtain a fraction of their salaries through industrial contracts (if they do not want to increase their teaching load). This has several benefits: it builds in a regular contact between the University professors and their industrial counterparts; it guarantees a more application-oriented approach in the university research, and it sets up employment channels for graduate students (who often spend summers in industrial trainee programs).

The university-industry partnership is also strongly supported by another cultural trait: contrary to Europe, **in the US a failure in business is nothing to be ashamed of**. US professors and their students have a strong motivation to start their own company. Combined with the better IPR regulation, this leads to a higher relative percentage of business ventures in the US than in Europe.

Also, there is a much **more developed eco-system to support innovation** (spin-offs, start-ups) in the US compared to Europe (compare Silicon Valley, Route 128 around Boston …). Another cultural difference: if successful as a businessman, the former student will donate some funds to his alma mater. In some cases, a portion (10-15%) of the shares of a spin-off go to the university, which is a kind of automatic pay-back (note: in France the CNRS wants cash, no shares).

One must take into account that the Microelectronics Industry in Europe is weaker and more dispersed. The Microelectronics Industry in the US is about 4 times larger than in Europe, notwithstanding comparable populations and gross national products (GNP) in the US and Europe. Hence, more resources are available to support research in Academia and Research Centers in the US. Also, with more companies available more links are created and these links are more efficient than in Europe, where the borders create barriers for efficient interactions and less opportunities exist than in the US.

6. Conclusions and Recommendations

In conclusion, we would like to offer to the MEDEA+ Board a list of 10 major recommendations that are derived from our study.

1. **A technology-oriented research agency comparable to DARPA should be created** at the European level, directed towards research at Universities and (academically oriented) Research Institutes. The key issue here, is that such an agency should aim at efficiency ("will it work in the market?") and not at fairness and redistribution. Sufficient networking should take place, i.e. networking the "guys with good ideas" will be very effective.

2. Investments have to be done at two levels: (1) the first one is the institutional level **(= the so-called "infrastructure")** by which top level people are attracted and well supported in their local environment (i.e. the basis) and (2) then ample funds are available for which they can compete with ambitious plans and ideas. In such a two-level competitive system, concentration in top places will automatically take place, not because it is organized that way, but because competition on quality (rather than on side issues) will favor the best and most dynamic groups (creating *de facto* centers-of-excellence).

3. **Research programs should have a minimal set of regulations** (see above under 1-; efficiency needed). They should aim at the foremost priority, i.e. the development of new science and technology in the most daring and innovative way possible. Secondary questions such as international cooperation, the setting up of consortia, matching rules etc. should be minimized so as to make the procedures as effective as possible from the scientific point of view.

4. **A portfolio of projects should be built up as part of an overall strategy and with the intention to safeguard diversity**. Apart from the large projects for consortia, mainly with industry and research centers, smaller and less-regulated projects should be promoted.

5. **Integration of the technological-scientific establishment in Europe** should be achieved, scientific societies better supported and integrated, quality of publishing enhanced and major conferences (like DATE, ESSDERC/ESSCIRC) better supported and enhanced. All this could be done in close collaboration with IEEE (and IEE), but work on integration has to take place!

6. A system of **elite workshops** among the top players should be installed (compare with the NATO schools; the Gordon Conferences in the US). Note: these workshops are not intended for dissemination of results but for efficient networking.

7. National authorities should agree on a system of **cross-border funding**, allowing regional funding to flow over national borders in support of industry-science linkages across Europe, in a supra-national interest.

8. Although the **IPR system** was not thoroughly studied, it is the Committee’s impression that it needs attention. More precisely, care has to be taken that the innovative ideas from our research universities and institutes are not only well protected, but that **the transformation of ideas into products and processes is supported and, in fact, stimulated** as efficiently as possible and that corresponding barriers are removed.

9. **The crucial importance should be recognized of the European Commission’s EUROPRACTICE Service**, which provides cheap access to silicon and CAD tools for more than 550 universities and research centers in Europe. The precarious status of this Service, considered up to now as a Project by the EC, should be modified and recognized as a key European Infrastructure. Financial support to this service (today 1 M€ / year) should also be adapted to match the dramatic cost increase of deep sub-micron technologies.

10. Once abroad **Europe’s scientists find it difficult to return**. In order to encourage them back, the private sector can play a useful role in joint ventures with the public sector, whereby research & engineering centers-of-excellence are set up. This could lead from brain drain to brain circulation.

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APPENDIX 1 – Target group

EUROPE

Research centers	**Response received**
DIMES	Y
FRAUNHOFER IIS-B	Y
LETI	Y
IMEC	Y
Universities	
University Bologna	Y
University Cambridge	Y
K.U. Leuven	Y

U.S.

Consortia	**Response received**
Int'l SEMATECH	N
MARCO Centers	N
SRC	Y
Research centers	
CITRIS	N
MIT	Y

JAPAN

Consortia	**Response received**
ASET	Y
SELETE	N
MIRAI	Y
STARC	N

APPENDIX 2 – A brief overview of the US and Japanese consortia

We briefly describe the key consortia on the international R&D scene, with emphasis on International SEMATECH (ISMT) and SRC driven from the USA, and the SELETE and ASET consortia in Japan.

ISMT is a non-profit research and development consortium with presently the following semiconductor manufacturers as members: AMD, Agere Systems (previously: Lucent Technologies), Conexant, Hewlett-Packard, Hynix (previously: Hyundai), Infineon Technologies, IBM, Intel, Motorola, Philips, STMicroelectronics, TSMC, and Texas Instruments. The mission of ISMT is to gain a manufacturing advantage for its members through cooperative work on semiconductor manufacturing technology.

The plan for the consortium was established in 1986-87 and it was intended to reinvigorate the U.S. semiconductor industry, after a report from a Defense Department Committee, emphasizing that the national security of the US should be more dependent on the domestic semiconductor industry, and had become too dependent on Japanese suppliers. SEMATECH was formed in 1987 after US semiconductor market share had been reduced from dominance to 39%. Meanwhile, the initial SEMATECH has been transformed in International SEMATECH (ISMT).

ISMT has 600 employees and an annual budget of approx. US$ 160 million. The conversion of the Austin, Texas, pilot line to a 300mm environment is planned over a period of 5 years.

While the consortium is now mainly funded through contributions from its member companies, it is clear that over the first 10 years of its existence a major portion of the investments was funded with the help of federal US grants. Moreover, even today organizations with government involvement such as SRC and DARPA are supporting ISMT.

Semiconductor Research Corporation (SRC) is a not-for-profit consortium of semiconductor companies, their suppliers and participating government agencies. It was established in 1982. Its primary goal is to help the industry plan, direct and fund university research in semiconductor technology. The SRC has a research portfolio of approx. $35M and since its start it has invested more than $400M.

In Japan, the recently initiated “Asuka” project is based on the assumption that the core competence of Japan’s semiconductor industry in the 21st century will shift from dynamic random-access memories (DRAMs) to System-on-Chip (SoC). As a result, systems, design technologies for large-scale integrated circuits (LSIs), leading-edge CMOS technologies, and small-lot/multi-products production technologies suited for the “SoC era” are becoming vital development themes. The Semiconductor Technology Academic Research Center (STARC), which was established in 1995 by the Japanese semiconductor industry, will handle the design technology development aspects of the new project.

The development target of the “Asuka” project is set at the 100nm to 70nm technology nodes, to be developed in the period from 2001 to 2005 and will be centered around the (chiefly) Japanese SELETE consortium. This work will be carried out together with the semiconductor equipment and materials industry, and will include advanced process module development and integration in a super-clean room for 300-mm equipment being built in Tsukuba (north of Tokyo) and expected to be completed in April 2002. This technology part will involve a staff of approx. 250 people.

Research in the Project “Asuka” will be closely linked with that of the “MIRAI” (Millennium Research for Advanced Information Technology) Project, a collaborative industry–government–academia project, that was formally launched on 1 July 2001, under the guidance of Prof. M. Hirose. The target of this 7-year project is to develop the 70-nm process technology for SoC products by 2004 and the 50-nm technology by 2008.

Budget estimates for Project “Asuka” include US$ 140 million (5-yr total) for the STARC side, and US$ 620 million (5-yr total) for the SELETE side. The clean room at Tsukuba will have a total area of 4500 m2, of which 3000 m2 will be used by Project “Asuka” and 1500 m2 by “MIRAI”. The total start-up investment for this super clean room amounts to approx. US$ 200 million. It is our understanding that all of the funds for the new Tsukuba clean room center will be provided by the Japanese Government.

Although the operating budget from SELETE is largely provided by the member companies (with the exception of a small part from government into STARC), the operations of “MIRAI” are supported by the Japanese Government (through METI). The 2001 budget for “MIRAI” amounts to approx. US$ 30 million.