Multi-annual Strategic Plan

Draft

European Technology Platform Nanoelectronics

Version 2.2, February 21, 2008

Preface

This document was prepared by the AENEAS association of R&D actors in the field of ENIAC on behalf of the ENIAC Joint Undertaking. It is to be read in conjunction with the second edition of the ENIAC Strategic Research Agenda issued in Budapest on November 28, 2007, and Council Regulation 72-2008 of December 20, 2007, describing the rules and procedures of the ENIAC Joint Undertaking.

Content

The Nanoelectronics context

Nanoelectronics is the essential hardware enabler for electronic product and service innovation in key growth markets for the European industry. ENIAC, the European Technology Platform for Nanoelectronics, was launched in 2004 with the overall aim to guarantee Europe the earliest possible access to leading-edge integrated components and design skills for application in high-technology products and services, thereby reinforcing Europe's existing industrial strengths and ensuring that core intellectual property is generated and benefited from in the region.

The ENIAC Strategic Research Agenda (SRA) was established through the concerted efforts of experts from industry, academia, and public authorities across Europe. Top executives of leading European companies and research organizations have signaled their full commitment to reaching the ambitious goals set out by the SRA and the Joint Technology Initiative in Nanoelectronics proposed by the European Commission. The ENIAC SRA is the common envelope encompassing definition and execution of R&D in nanoelectronics in Europe for all players (industry, academia, and public authorities) and all mechanisms for public-private partnership (national, transnational, and EC).

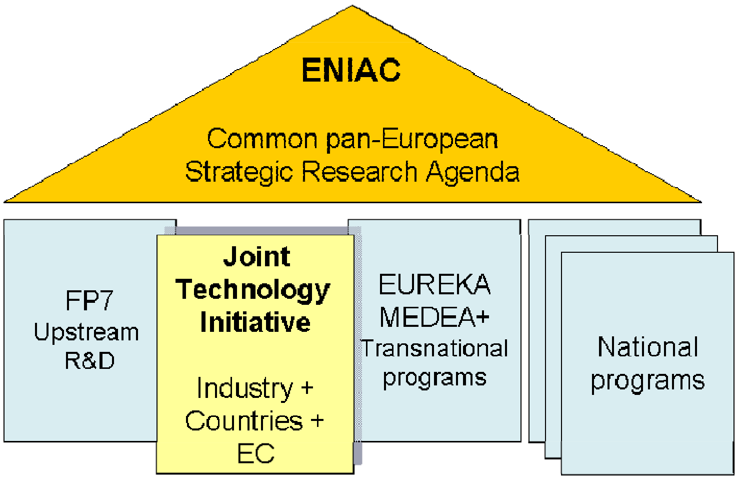

Figure 1 – SRA is the umbrella for nanoelectronics R&D in Europe

The second revised edition of the ENIAC SRA was presented on November 28, 2007, in Budapest. Starting from an overall vision of the global and European landscape between now and 2020, the Agenda defines the critical societal needs and lead markets that are enabled by Nanoelectronics. These applications are then translated and detailed into priorities for each of the technology domains underpinning the Nanoelectronics research challenge. The Agenda concludes with a critical assessment of the European ecosystem and puts forward proposals for moving forward towards full realisation of the ENIAC ambitions. It is planned to continue issuing revisions every two years.

The ENIAC Joint Undertaking as approved in Council Regulation 72-2007 on December 20, 2007, is a partnership model that can combine the public and private efforts needed for resolving the downstream-oriented research priorities in the ENIAC SRA. Anticipating the installation of the ENIAC JU, a group of key stakeholders cooperating within ENIAC established the AENEAS association to enable participation of all industrial and academic stakeholders actively engaged in nanoelectronics R&D in Europe. The rules and procedures for the JU and the AENEAS association and the interactions foreseen between these two bodies are described in detail in the corresponding founding documents.

In the set-up of the ENIAC JU, a Multi-Annual Strategic Plan (MSP) is foreseen. The AENEAS association is chartered to draft this MSP that will outline the JU strategy and plan as it evolves over time as a function of research priorities and stakeholder commitments. In connection with the MSP, AENEAS will also propose Annual Work Programs (AWP) on which the ENIAC JU bases its annual calls for project proposals. It is planned to update the MSP in the same frequency as that of the ENIAC SRA, that is, every two years.

Joint Undertaking Research Agenda

Scope and focus

Because of the anticipated step-wise growth of the JU footprint, the ENIAC JU Research Agenda (RA) will consist of a selection of downstream oriented R&D priorities from the ENIAC SRA. To be able to maintain consistency for the expected duration of the JU roadmap, topic selection within the MAWP will be primarily along the axis of long-term societal needs and lead markets. The six societal segments identified in the ENIAC SRA are Health and Wellness, Transport and Mobility, Security and Safety, Energy and Environment, Communication, and Infotainment, leading to segmentation in six application-specific subprograms. Many of the challenges listed in the ENIAC SRA technology domains can be mapped on the applications in these lead markets, notably topics from More Moore, More than Moore, and Heterogeneous Integration. However, in the technology domains Design Methods and Tools, and Equipment and Materials, cross-domain and cross-application aspects are dominant. Challenges in these domains can be handled only as generic enablers, serving all ENIAC societal needs and lead markets. Therefore, the RA is complemented with two subprograms that are technology-specific, bringing the total on eight.

Not covered in the initial phase of the RA are the upstream oriented R&D priorities identified by the ENIAC SRA for the period beyond 2013. This includes most of the content listed for the technology domain Beyond CMOS. These priorities are recommended for inclusion in the coming calls in the regular FP7 program. The allocation of individual R&D priorities will be revisited when updating the ENIAC SRA and MSP.

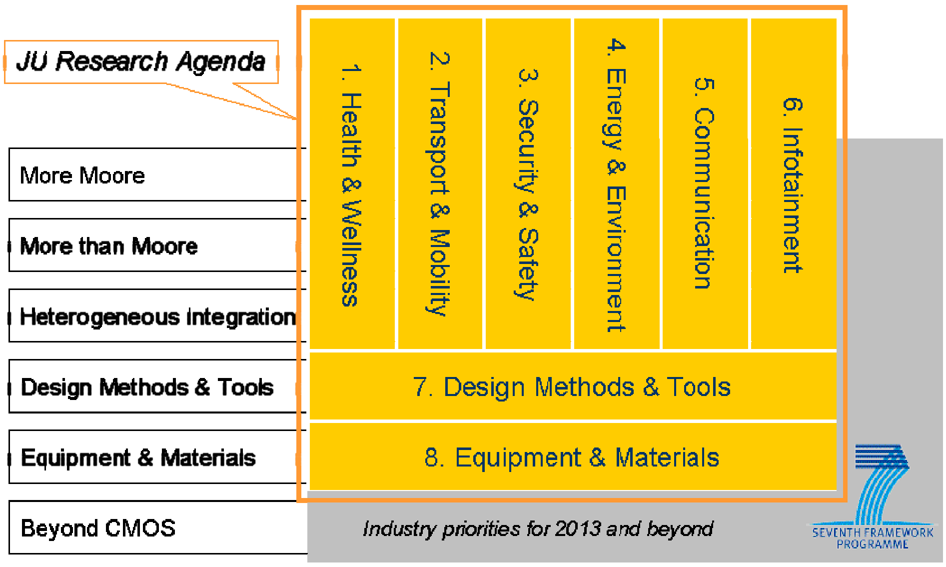

Figure 2 – Mapping the JU RA on the SRA technology domains

Subprogram 1. Nanoelectronics for Health and Wellness

Market relevance

The increased demand for and escalating cost of achieving personal wellness and health standard in Europe creates opportunities for e-Health, a generic term covering the application of Information and Communications Technologies (ICT) to a whole range of functions in the health sector. e-Health is estimated to account for 5% of the total EU Member States' health budget by 2010. Equipments and services for medical care as well as for early diagnostics and for prevention will rely increasingly on specific electronics and sensors achieving a better efficiency at a lower cost. This will develop a new market per se of integrated semiconductor microcircuits and microsystems, which is expected to grow significantly in the coming years.

Societal benefits

The quest for better health and wellness of our European society calls for more sophisticated tools and methods in order to reach the high expected standard of living of an ageing population. They are many societal benefits to develop and use application specific nanoelectronics for healthcare and wellness. It ranges from efficient, easy to use and cheaper diagnostic techniques made available to the doctor and to the citizen in order to promote preventive actions – e.g. through environmental and food control and through early disease detection –, to patient- and therapy-specific tools made available to clinicians in real time in order to enhance the efficiency of the healthcare. Remote patient supervision using biosensors, bio-data analysis and communication technologies is another major opportunity for cost saving in an ageing society and for patient requiring prolonged medical care.

Technology challenges

Micro/nanotechnologies offer powerful ways to bring added value in innovative solutions for a better personal health and wellness, in terms of cost, sensitivity, accuracy, automation and new functionalities. This applies in healthcare applications such as diagnostics, drug delivery and minimally invasive disease intervention, as well as in environment control (water, air, soil), agriculture and food.

- Early diagnostic and prevention will be made possible through improved biosensors allowing many diseases to be diagnosed – even before sufferers complain of symptoms – by 'in vitro' analysis or ‘in-vivo’ monitoring of biological samples (blood, saliva, etc.) and parameters (e.g. for cardiovascular & respiratory pathologies). Smarter and cheaper solutions will help to spread these techniques to the physician and to the citizen (‘the doctor in your pocket’). Similar tests will identify those pre-disposed to certain diseases, allowing them to enter preventive programs that will identify early onset of the disease.
- More targeted therapy will be achieved by combining imaging with therapy, which will assist in healing or eradicating specifically diseased tissues. Testing in real time individual response to drugs will help to tune the therapeutic protocol and reduce side effects. Smart devices will also help to monitor the healing process (e.g. using smart band-aid with impedance changes for wound healing). In the same way smart automated drug-delivery systems will help to apply therapy where and when it is needed. Specific techniques like deep brain stimulation will particularly benefit from miniaturization and real-time patient specific protocols.
- Through early detection and targeted healing techniques, many therapies will become non-invasive or minimally invasive, reducing at the same time the cost and improving the chance of total recovery.
- Remote patient supervision using biosensors and tele-monitoring networks will favour a therapy at home, addressing through the same technologies the wellness of the patient, the cost of hospitalisation and the monitoring of elderly people and of patient requiring prolonged medical care.
- Nanoelectronics will revolution prosthetics, especially when electronic function will provide patient-specific aid, e.g. through bio-implants restoring sight or hearing or through brain-prosthesis interfacing for patient suffering paralysis.

- Finally the huge potential for parallelisation and performance of the nanoelectronics will directly benefit the analytical and research laboratories in providing tools order of magnitude more efficient and thus enabling rapid progress in healthcare techniques and the more efficient and screening of the drug potential of new chemical compound using bio-electronic devices.

In order to bring to maturity these innovations which involve nanoelectronic-based systems, many technical challenges have to be addressed.

- Miniaturised biochemical sensors need to be improved in terms of sensitivity, specificity and miniaturisation. These sensors should target whenever possible non-invasive techniques (e.g. optical).
- Micro- / nanofluidic technologies (e.g. for lab-on-chips) will need the development of a full set of building blocks (e.g. microvalves, electrowetting, etc.), possibly using embedded reagents on chip, and of the associated design methodology and tools.
- Structured and functionalised nanoparticles will have to be developed for medical imaging, analysis, biosensing, physical therapy and targeted drug delivery.
- The capability to image in 3 dimensions in real time for diagnostics and healthcare (e.g. surgery) will require the development of imaging devices (with enhanced sensitivity and dynamic range, lower noise and multispectral and high speed capability) and image processing.
- Ultra-low power devices will be made possible by the continuous progress of leading edge nanoelectronics: this will particularly benefit wireless portable or implantable systems, and stay within the maximum thermal loads that implanted devices can impose on the human body.
- Powering implanted sensors and prosthesis will need the development of either remote power techniques (e.g. rf), energy scavenging solutions or of micro-(bio) fuel cells.
- The heterogeneous integration of diversified technologies (e.g. Si + plastic), of biocompatible and bio-resistant materials, surface chemistry and of low temperature wafer-level packaging made after full-wafer biological post-processing will allow breakthroughs for portable / in-vitro and implantable / in-vivo applications in pushing the miniaturisation to its technical and economical limits. Efficient and shorter test and qualification methodologies will need significant developments.
- The system integration will be particularly challenging, not only because it brings together very different technologies in the same miniaturised package. It has also to take into consideration how the analyte has to be sampled and concentrated in order to span order of magnitudes difference in size and concentration (e.g. in analysing pathogen’s DNA in litres of contaminated water). It may also imply the development of dedicated communication protocols within and between heterogeneous wireless sensor networks used e.g. for telemonitoring in hospitals, laboratories, on the road / ambulance, paramedic, institutions, and home care. It finally includes the development of specific embedded software.
- A final technical challenge is the reliability of such highly complex heterogeneous systems achieving almost zero failure rate under harsh conditions over the whole lifetime of the system.

Organization

In many respect this domain is emerging and opening significant opportunities. Besides few well-established markets, new applications and emerging solutions have the potential to evolve in mass markets. As rapid changes are expected in this field and as flexibility is needed in the definition of priorities and milestones, several medium-size projects should be decided, amounting total resources in the range of 80 person years per year, for a typical duration of 3 years. The first call for proposals is expected in 2009. Priorities will be refined until end of 2008.

Subprogram 2. Nanoelectronics for Transport and Mobility

Market relevance

Mobility and safety are clear societal needs for the future intelligent road. As the volume of traffic on our roads continues to increase, there will be an increased demand for safety, emission control, fuel saving and comfort. The automotive industry represents 3% of Europe's gross domestic product and 8% of EU government's total revenues. Electronic components have reached 20% (of which Microelectronics is 44 %) of the car value, and the figure is growing to about 25% (Microelectronics even growing faster to 55%) in the next five years. In total Automotive components represented 19% of European electronic component market in 2006, with a stable growth rate around 3.5%. Nanoelectronics will also give an essential contribution to the integration of all other modes of transport (air, rail and waterways) that are projected to form the largest part of freight transport and to contribute significantly to passenger traffic in year 2020.

Societal benefits

The European transport system is a vital element in ensuring Europe's economic and social prosperity. It serves key roles in the transportation of people and goods in a local, regional, national, European and international context. On the other side it is a major cause of energy consumption and casualties. In Europe, road transportation alone accounts for 21% of fossil fuel consumption, and 60% of all oil. There are 5 deadly accidents every hour, and road accidents are the main cause of death in the under-45 age group. The enabling technologies addressed aim at a quick move toward the goal of zero road fatalities and at a radical reduction of both the overall emissions and primary energy use. An integrated approach that links all modes of transport (air, rail, road and waterway), is essential for ensuring that sustainable and competitive transport solutions make a visible and positive difference for Europe, its citizens and its industry.

The variety and the relevance of the electronic development made for the transport sector are common in several other application areas such as manufacturing, energy and ICT.

Application Areas

The societal and economical benefits as described above require the introduction of Nanoelectronics in all aspects of Automotive industry:

- More sophisticated engine management units, coupled to sensors and actuators can further reduce fuel consumption in present internal combustion engines, allowing to reach the target of 30Km/liter for medium class cars
- Further on, power electronics and power management units will allow to move to hybrid and afterwards full electric cars. It is expected that the process will require several steps, involving increasingly more sophisticated systems of energy storage (batteries, super-capacitors) and energy management.
- Active safety will see an increased use of detectors (solid state optical and IR cameras, ultrasonic sensors, radars) coupled to high performance logic for real time obstacle detection and driving assistance.
- Passive safety will rely on increased use of sensors distributed through all the car or plane, and connected by RF or power-line. Energy scavenging will be the medium-long term energy source.
- Traffic congestion can be reduced by the use of more sophisticated navigation systems, based of wireless communications and GPS, to exchange data with road infrastructures and among the cars themselves.

Technology challenges

- Efficiency increase and reduction of pollution in Internal combustion engines will require advanced mechatronics for fuel and air control, coupled with low-cost sensors and highly efficient computing units, based on the most advanced CMOS technology.

- Hybrids and full electric vehicles will require power electronics and sophisticated and reliable power management systems, able to withstand high voltages and power surges, in order to manage power distribution among engine(s), batteries, supercapacitors, and the external power supplies. The same basic technologies could be adapted to power management in industrial applications, and to the exploitation of renewable sources, mainly photovoltaics.
- Increased safety will require a variety of sensors embedded into the car, together with optical and radar sensors, coupled with high speed, low cost data processing for collision avoidance.
- Distributed sensor networks, communicating through RF and supplied by energy scavenging, can strongly reduce car weight and costs, and could be applied to a variety of segments including aeronautics and large structures, like building and bridges. It will require, in addition to reliable technology for sensors and energy scavenging sources, high performance low power logic for sensor data acquisition and handling and low cost RF COMS technology.
- All electronic systems for automotive applications have to withstand very harsh environments, including high temperatures, humidity, vibration, fluid contamination and electro-magnetic compatibility. The safety-critical nature of automotive systems will require extreme reliability, measured in parts per billion instead of today's parts per million.
- Cost of high performance logic for assisted driving systems must be reduced for a widespread adoption, while reducing energy consumption and increasing frequency capability through development of advanced CMOS logic technology.

Organization

Start of project is linked not only to technical priorities, but also to the existence of running project in the same areas.

Safety

- Assisted driving: sensor and processing integration for increased road awareness: optical, infrared sensors, radar to follow, fast data processors, advanced display systems (250 person years, 4 years)
- New methods for fail safe and fault tolerant electronic systems, new methods and technologies for improved availability and increased lifetime of the electronic system (100 person years, 3 years, start 2010)
- Car-to-car communication: low cost RF communication systems for car to car or car to road communication. Interconnected road sensor networks. Integration with navigation systems. (200 person years, 4 years, start 2011)

Environment-energy saving

- Technology integration for hybrid or full electrical car: energy management, power electronics (120 person year, 3 years, early 2009) sensor development and integration (90 person year, 3 years, end 2009)
- Advanced mechatronics for internal combustion engines: sensors and actuators for air and fuel injection, for exhaust and combustion control, high temperature electronics for engine management, processor with embedded NVM. (250 man-years, 4 years)

General

- Internal car wireless or powerline network: low cost RF systems, low cost powerline devices, security algorithms (120 person years, 3 years, start 2010)
- High density sensor networks: pressure, mechanical sensors, chemical sensors in a second moment. Wireline interconnection followed by low power RF interconnection and energy scavenging from vibration or heat. (150 person years, 4 years, start 2011)

Subprogram 3. Nanoelectronics for Security and Safety

Market relevance

Statistics show that we live in a much safer world, yet there is still constant demand for increased safety and security in virtually every aspect of our lives. Ubiquitous security is a major challenge for the information society, as tremendous amount of data circulate and is stored all over the world, available from anywhere at anytime. It is clear that security and safety not only constitute a major market in themselves. They are also generic enabler for many other applications and support related services.

It is clearer and clearer every day that, if not desiring to "pay for security", end customers are avoiding to use new services whenever they do not have the relevant level of trust in the whole chain.

Safety, i.e. fault tolerance or fault avoidance of any automatic systems is growing in parallel as a generic requirement for embedded devices, as they are penetrating many life sensitive application such as transportation systems, health-related devices, etc.

Societal benefits

Security reflects itself in public demand for personal emergency and home security systems, and for government led protection from crime and terrorism. However this is always accompanied by the need of personal protection without restriction of liberty or limitation of privacy, which means that safety and security systems need to be reliable, easy to use and capable of safeguarding the privacy of end users. It is also in this area that ambient intelligence's ability to recognize individuals and be responsible to their individual needs will be highly valuable.

This security and safety must also be based on standards and technologies on which European public authorities can rely for keeping their own independence regarding other continents, i.e. generally based on standards accessible to open market, or open source, and not in the hands of a single organization.

Application Areas

The societal benefits as described above are applicable whenever life, privacy or public missions are at stake. There is a long list of "candidates", from which the most relevant will be described shortly:

- The most visible one is payment. Although payment though internet or mobile phone are fastly growing, they are huge improvement to achieve in order to get general confidence in these systems; in parallel, new type of attacks are created every day, and should be taken into account for new systems.
- Another type of applications, which has still a very large potential is e-Health and e-Government type of transactions: citizen identification, exchange of medical files, tax payment, e-voting.
- The third large area is transportation, where safety related requirements will grow as electronic is penetrating cars, trains, airplanes. Car market, in particular, will simultaneously impose safety along with severe cost constraints.

Technology challenges

Security and safety can never be achieved through one single technical element, but only by a coherent combination of technologies in a relevant architecture. These technologies will encompass sensors, computing and protection areas. Nanoelectronics will provide the necessary sensing and computing devices, and with reliability and trust at cost levels that allow safety and security to be built in the fabric of our environment. Related safety and security systems can be divided into two groups.

- Low cost personal emergency and home protection systems that are affordable for consumers.
- High performance high efficiency systems for applications such as banking, passports and other identification cards, public infrastructure, transportation, telecommunications and other safety critical systems. The applications in this second group address secure

access and the rapidly growing e-Government solutions in which sensors, smart cards and ID devices are the most evident components.

Organization

A common building block can me named “trusted devices”, and must be the first project to be launched. Based on this building block, three application segments can be derived

- Trusted devices, requiring new technical nanoelectronic techniques from systems aspects like programming methods, separation of concerns and specific middleware, etc, to hardware technologies like new memory architectures, processor and cryptographic, resistance to side-channel attacks, anti-tampering coating and packaging (120 person years, 3 years, start immediately)
- Smart Secure portable objects (120 person years, 3 years, start immediately)
- All-in-one spectrometry sensor, including emission, detection, front end processing, computing and decisions (120 person years, 3 years, start mid 2009)
- All-in-one imaging sensors, including emission and active imaging, detection, processing in focal point, pupil post processing and tracking treatments (120 person years, 3 years, start mid 2009)
- Secured RFID device; trusted e-Tag technology for mass markets (120 person years, 3 years, start mid 2009)

Subprogram 4. Nanoelectronics for Energy and Environment

Market relevance

Coming from 3.1 million GWh in 2003, Europe will need in 2020, electrical energy of about 3.6 million GWh according to a study by IEA (International Energy Association). By using intelligent, innovative electronic components and systems, 0.7 million GWh or more than € 100 billion (€0.16 per kWh) can be saved, thereby helping European energy policy and industry competitiveness.

The World market for power semiconductors is in the range of 10 –15 B€/year not included the control market and also not included the replacement market for breakthrough technology for power-saving equipment.

Societal benefits

The impacts on the European society are multifarious and will affect all domains (private, industry and public). The goal is to protect the natural resources and the environment in Europe in a sustainable manner. The overall target is to prevent the waste of energy by using obsolete equipment and carelessness. An efficient use of energy is the political, social and technical challenge of the next decade. Focusing on micro-/ nanoelectronics approaches in particular the challenge to save electrical energy consumption in Europe in the range of more than 20 % until 2020 is feasible. This will reduce CO_2 emission in the same order of magnitude in order to achieve the Kyoto protocol targets and will limit the energy cost increase. The usage of efficient power supply and intelligent energy control in new products could save up to 30% of the power consumption by simultaneous increase of safety, functionality and convenience.

The European microelectronic research and development sector is requested to provide innovative technologies as basis for new energy efficient products and intelligent power management. Through consequent and combined efforts at European level there is the historical opportunity to extend the technological leadership of the European industry in this field and to strengthening its competitiveness.

Application Areas

The societal benefits as described above can be realised if technological innovations are introduced in those applications, where energy consumption can be reduced without loosing functionality, performance and comfort. There is a long list of “candidates”, from which the most relevant will be described shortly:

- The most visible one is lighting. Most of the actual illumination systems have a rather limited conversion rate from electrical power to light power; large parts still are converted in heat. There is a huge potential for energy saving in the private domain, in industry and in the public domain.
- Another type of applications, which has still a very large potential for energy saving is the conversion of electrical power into movement, be it in industrial machines, in the cars or in the motors as used in private households, like in washing machines, motors for pumps etc.
- The third large – often still ineffective – energy consumer is the supply and the conversion of electrical energy. Examples are power supplies as used for portable computers and mobile phones and stand-by switches for TV, recorders and computers.
- Also the electronic equipment itself still uses many components, which are only optimized with respect to performance and price, but not to energy saving.

Technology challenges

To enable the development of innovative energy efficient products in the above mentioned application areas and to optimize energy conversion itself, research and development with respect to the following technology approaches – on several levels - has to be undertaken:

- Innovative systems and architectures for power electronics in order to optimize the coefficient of efficiency. These technology challenges on system level refer directly to the first three described applications: controlled drives, lighting and intelligent power supplies and stand-by management.

- Heterogeneous system integration technologies for high power modules and System-in-package technologies taking into account highest currents, voltages, temperature as well as ESD, EMC and robustness aspects (from high power module to high power system in package - SiP). The challenge here is to make the power electronic devices useable for industrial applications and/or for applications under harsh conditions like in transportation (e.g. at the engine of a car or a high-speed train)
- Completely new or improved semiconductor technologies, using leading edge technology knowledge for low power consumption and extended lifetime (e.g. high frequent and low-loss switching, digital power conversion)
- New semiconductor materials like SiC or GaN, thin substrates and interconnect materials to improve performance and reduce cost

Organization

It is essential to address the field of energy efficiency in a general, structured and sustainable manner. According to the identified application areas and the related technology challenges first projects with high energy savings potential shall be:

- Intelligent drive control (200 person years, 4 years, start early 2009)
- Daylight linked dimming systems): (200 person year, 3 years, start immediately)
- Digital power conversion (120 person year, 3 years, start mid 2009)
- Efficient power supplies and intelligent stand-by solutions; this is a cross-domain challenge (100 person year, 3 years, start end 2008)

Projects to be planned in a later phase shall be based on the first results from the last two project focus areas

Subprogram 5. Nanoelectronics for Communication

Market relevance

People are becoming used to having easy access to friends, family and information services and more frustrated when that access is not available to them. Making information available anywhere at any time relies on connectivity and communications, increasingly via the use of wireless-based networks (e.g. cell phones, Wi-Fi networks) to meet the 'anywhere' requirement. In future, communication systems must be even easier to use than they are today, even to the point where specific connectivity channels become irrelevant to the user. Information will simply tunnel itself to its destination by whatever communications channels are available.

At the same time, the bandwidth of communication systems will have to increase dramatically in order to cope with the increasing amount of data that people will want to move around (e.g. voice, pictures, video, file transfer) and they will need to become much more secure against eavesdroppers and hackers.

In the same way as security, communications is a common factor driving functionality for a broad and still expanding portfolio of products and services. As an example the advent of low-cost mobile telephony was made possible thanks to the dramatic evolution of several semiconductor technologies

- Logic CMOS in order to be able to compress and encrypt the voice on the fly (as well as handling the complexity of large networks of mobile users)
- RFCMOS, BiCMOS and power (III-V) semiconductors in order to manage the telephone to air interface
- Analog technologies to optimize energy consumption
- Embedded and stand-alone memories both for the SIM card module and for the various components of the handset itself

Today the handset market only is expected to represent 1.2 billion units in 2008, making it the complex manufactured object produced in the largest volume ever, with more than 3.5 billion subscribers expected et the end of the year, more than one half of the planet’s population! The services made possible by this technological advances, essentially wireless operators, have grown in only 10 years to represent more than 400 billion dollars in turnover and 6 million jobs worldwide (2004 figures, increasing vastly year on year).

Nanoelectronics will be needed not only to meet the miniaturization and low-power requirements of handheld portable communications devices. It will also be needed to allow much more functionality, in terms of the number of different communication channels, to be packed inside them. The 'multi-band multi-mode' devices that this enables will be the key to decoupling communication from specific communication pipes, heralding a whole new era of seamless communications. Moreover, crossing the borders between the application domains, handheld devices will host more and more features. One standard feature is currently the embedded camera. The underlying technologies, especially the silicon image sensor will evolve toward higher resolution and more compactness. As an example this application, phone cameras, is currently one of the major drivers of the 3D packaging technologies. But it will in turn be a driver of low-cost memories to allow eg picture and movie storage. Another standard feature of todays, even entry level, phones is the digital music player. Other requirements are following suit. Next in line are the localization (GPS or Galileo when available) and mobile TV. At the same time identification and payment through near field communications are already making inroads into the public acceptance. In a few years from now other features such as health monitors, image projectors etc will have to be included. So the communication domain opens and interacts with several if not all the other application domains in that it will often be the driver for the development of low cost technologies changing the field in these other application domains.

At the same time, wireless communications channels will move to higher frequencies in order to increase data rates and maximize spectrum usage, be it for portable or fixed equipment, over a variety of frequency domains. All this (new features, new communication channels, including high bandwidth, embedded seamlessly in the environment of the user) represent the long-expected transition to the fourth generation (4G) of mobile communication. This will require ever-greater integration of RF interfaces and the development of new RF architectures that allow circuitry to be re-used across many different RF channels and modulation schemes.

As portable communications devices pack more functionality, low-power consumption will become an even more critical requirement. The need to keep devices active for long periods of time between battery recharges, or even to make them autonomous in terms of energy supply, will require the integration of energy scavenging devices that pull and store power from the local environment. At the same time, affordability, reliability and environmental compatibility (disposability, recycling and re-use) will be other major drivers.

It should also be recognized that the pervasiveness of wireless systems is possible only through the huge underlying infrastructure of wired channels in homes and in the public domain. These data transmission functions need to be continuously upgraded by implementing high-volume, low-cost nanoelectronic devices.

Societal benefits

The societal benefits of working in this domain are clear. The communication domain, as explained above, as a pervasive effect on different other kind of activities, so being present there is an entry point to many other markets. The communication domain has many European system integration companies so the acceleration of research for micro and nanoelectronic components dedicated to this domain will help reinforce the leadership of these European companies.

Of course the development of services, though a seemingly distant effect of technological development will be made possible by the development of improved technologies for communications. The expected mobile TV explosion is one example of this aspect.

What we have seen for GSM, that is the ecosystem of important players in the semiconductor market for wireless are all strong in this market, but other more application-oriented companies are also very significant suppliers for specific components and IPs, important if not dominant players in the equipment market for equipment, important players in the service area is not a coincidence can be reproduced with the new generation of communication devices. Of course technology on its own will not sustain the development of this ecosystem but the fast pace at which it evolves requires the proximity of all actors in the value chain. Thus a close cooperation, to begin with, with ARTEMIS is important for the success of this application domain.

This represents of course a huge number of jobs across Europe.

Technology challenges

The communication domain is really technology-hungry, tapping on every single aspect of the ENIAC SRA. Particularly It requires progress not only from the More Moore, but also from the More than Moore domain, while the advances of packaging and heterogeneous integration are often driven, in Europe by the communication domain. In turn the equipment material and manufacturing and design technology domains are needed to contribute to the technological advances of the communication domain.

Some of the challenges, outlined above, are (not an exhaustive list of needs):

More Moore

- Low cost, low power, and high density logic and memory technologies available at the right timing:
- 32 nm (2010 or 11) and 22 nm (2013) low cost low power processes
- Non volatile (Flash and next generation) for the same technology nodes

More than Moore

- Analog/RF technologies
- BiCMOS/RF-CMOS technologies with higher than 200 GHz transition frequencies

- Versatile RF technologies to allow for multiple standard, allowing Software Define Radio schemes
- Low power RF technologies for near-field communication
- Passives components and filters
- Analog technologies

Heterogeneous integration

- 3D integration: Medium density 10^2-10^3 contacts /cm² before 2010; and high density > 10^4 contacts/cm² after 2012
- Passives, filters co-integration

Organization

The below projects could be presented and supported in the frame of the ENIAC JTI:

- High density, low form factor, low power dedicated non-volatile memory systems for mobile communications, for image and movie storage. (150 person years, 3 years, start 2010)
- Low power high density CMOS logic technology for mobile base band; increase of power efficiency and computing power for better bandwidth utilization; derived from 45nm CMOS with low power options (200 person years, 3 years; end 2009)
- 3D stacking technology process allowing for instance the integration of high density memory and digital base band for mobile handsets (150 person years, 3 years, start 2010)
- Low power, medium data rate, RF/analogue technology and demonstrators, for sensor networks, ambient intelligence and smart tags (150 person years, 3 years, end 2010)
- High frequency technology integration for high bandwidth wireless and/or 100 Gbit/s optical communications (to be detailed for the 2009 call).

Subprogram 6. Nanoelectronics for Infotainment

Market relevance

Nanoelectronics for entertainment is a huge market. Its definition is not very precise as some convergent products are not necessarily considered as “entertainment”, for example, smart mobile phones used for video or MP3 playback or home networking devices used to send video streams to HPNA/UPNP devices. Key domains that are for sure considered as “infotainment-related” are digital set top boxes, digital TV, DVD/BluRay/HDDVD, digital camera, portable players, video gaming, and flash memory, in total good for a world market of $ 34B (2008 estimate) in which flash memory alone, a European strength, represent almost 1/3.

Societal benefits

The impact on European society will be directly perceived by the citizens; better and smarter SoCs will allow the development of new products (triple play boxes is an recent example) or the evolution of existing ones (DVD → BluRay).

European Consumer Electronics companies are competing with Chinese ones and cannot anymore expect to win on the “price battle”. Therefore, developing rapidly (short time to market) smarter, better and more advanced ICs will be key for these companies to keep their technological and innovation advantage.

Europe is leading the world industry in the professional equipments domain (studio encoders, cameras…). This business is a powerful tool for imposing new standards (MPEG2 → H264 or SD → HDTV for example) allowing the European industry to keep an advance on the matching end-user products.

A direct impact on employment can be forecasted.

Technology challenges

The “infotainment” end products have some very strong characteristics that are shaping the market that have direct impact of business in nanoelectronics:

- **Short commercial life time**: The end products have a very short commercial life time: new products are appearing only a few months after the previous versions were launched. The design time of new ICs is very short (6~9 months): this implies the use of advanced tools and methodologies to shorten this period and massive reuse from previous designs (through the use of dedicated tools). The short design time does not easily allow for several cuts (prototypes) of ICs, this also implies the use of advanced verification and validation tools & methodologies.
- **New features**: The customers are expecting new products to be both better in term of features. Example: Apple iPod. **I**f the feature level of a new product is not significantly better than the previous version, customers will expect a very low pricing (the product becomes a “commodity”, example: DVD players). Adding new features is generally translated to a) faster and more complex SoC → smaller lithography and advanced tools/methodology b) smarter IP blocks → advanced architectures, heterogeneous system integration technologies
- **Cost:** Price is a strong selection criteria when buying an end product. Sometimes the only selection criteria. Costs is not only important for the wafer process, it also strongly affects packaging.
- **Low power:** low power and energy saving techniques have a significant impact here (see the appropriate paragraph for challenges) as a reduction in power requirements will have an impact on the packaging (cheaper package) and on the global solution overall price (cheaper power supply, plastic enclosure instead of metal etc. All this having direct impact on competitively.

Organization

Most of the technologies that are required for nanoelectronic for entertainment are also required by other applications (low cost packaging, smarter SoCs, advanced tools and methodologies, etc).

The following subjects are therefore more “applications related” than “technology related”:

- Portable & mobility consumer electronics devices
- Home equipments: Set Top Boxes, Triple play boxes, gateways etc.
- Professional equipments

The above projects may represent up to 350 person years of industrial R&D effort, over approximately 3 years time and require the cooperation of several teams. The first call for proposals is expected in 2009. Priorities will be refined until end of 2008.

Subprogram 7. Design Methods and Tools for Nanoelectronics

Market relevance

Europe has a strong position in the modeling, simulation and design of complex IC systems, well distributed among industry, including SME's, research centers, and Universities. There are more than 300 among fabless companies and Design Houses in Europe, for a yearly revenue of around 1 B$. They are spread over a large number of European countries, even if the largest concentration is in UK. Designers also form a large part of R&D personnel of Semiconductor Companies. The total number of engineers involved in the field of IC design in industry, not including software design and system architectures, which are covered by ARTEMIS, is probably exceeding 15000 units. Europe does not have any large EDA industry, but several small initiatives are present, mostly originated as start-up from Universities and Research Centers, and major US EDA vendors have development centers in Europe, often derived by the incorporation of European start-ups. The transition from Microelectronics to the emerging world of Nanoelectronics, with 'More Moore', 'More than Moore', 'Heterogeneous Integration', and 'Beyond CMOS' domains, will open up many opportunities for European Industry, provided it is able to retain and capitalize its leading position on the cross-cutting issues of modeling, simulation and design.

Being a cross-cut technology, the impact of Design Tools and Methodology is felt mainly through its effects on innovation and productivity. The efficient use of TCAD platforms is expected to provide a 40% cost reduction in technology development for 2007 (ITRS Winter Conference, Makuhari, Japan, Dec. 2007).

Societal benefits

Being Design Methodology and Tools an enabling technology, its direct social impact is limited to its ability to provide high skill jobs and to promote the formation and growth of innovative SMEs across all Europe. However the indirect impact is quite large and affects all main application drivers identified in the ENIAC SRA. The growing "design gap" between the technology performances made available by the Moore's Law and the designer capability at exploiting the potential of complexity, is further increased by the appearance of added functionality offered by "More than Moore" technologies and in-package integration. All main applications envisaged in the fields of energy, transports, health, communications, and others, require to combine high throughput data processing, very low power consumption, efficient integration of different functions, high reliability, which represents a severe challenge for all designers. The development of a comprehensive set of Design Tools and Methodologies, including TCAD, is a necessary requirement for the European Industry, to be able to deliver value-added devices needed by main application fields.

Application Areas – the technology domains

The Program will address the major technology domains of Nanoelectronics and will mostly handle the tasks related to hardware implementation, with specific emphasis on design of devices, circuits and IP blocks aiming at providing accurate physically-based models and simulation frameworks.

- **More Moore:** the development of a deeper physical understanding of transistors and memory cells is needed to handle the problems of complexity and power consumption. Design will help to overcome the problems of variability and reliability of deep submicron CMOS that cannot be solved by technology alone.
- **More than Moore**: the large spectrum of new non-digital functions added on silicon requires the development of new modeling and design tools to cover not only the already known fields of high frequency, power and analogue, but also sensors and actuators, which involve micro and nano mechanics and fluidics.
- **Heterogeneous Integration:** the trend towards an increasing integration of different functions, to reduce device footprint and consumption, and to increase reliability requires to consider together silicon chip, packaging and system aspects. Cross-disciplinary design capabilities and new tools must be developed to design Systems in Package (SiP to optimize system partitioning, and to match the resulting multi-physics environment.

- **Design for Manufacturing** and **Design for Testability** are important for all technology domains. The problems introduced by the increase in design complexity, by parasitic effects and by device variability cannot be solved at the technology level. Embedding them in the design flow to insure the robustness of the product to process spread can significantly increase manufacturing efficiency and decrease time-to-market, thus contributing to increase the competitiveness of European industry and allowing a faster deployment of applications. Testing complexity and cost is rapidly growing with the complexity of the devices and of the integrated functions. Taking the opportunity of reduced cost of logic devices, and integrating some testing function inside the device themselves can strongly contribute to reliability and cost reduction, especially for special functions, like analogue and high frequency.

Technology challenges – from basic research to system level

Design methodology and tools must cover all the area from the modeling of the single nanodevices, to the integration in package. Main challenges, along the design chain are:

- **Bridging the gap with embedded systems (ARTEMIS Workprogramme)**: a continuum between hardware and software and between individual components and overall system enables continuity from Application SW down to Silicon. In the short term the challenges are tools for HW/SW co-design, development and implementation of SW/HW interfaces. In the medium term the focus should move to simulation of incompletely specified systems, metrics for the design process and constraint-driven automatic partitioning
- **Design for variability,** as a first priority, fast and reliable extraction procedures of parameter fluctuations have to be developed in tight collaboration with modeling experts, aware of the model meaning and limitations. In the medium term, compact models are needed to capture both simulated and measured statistical variability of devices, and methodologies and tools to extend the modeling of variability to circuit blocks and IPs.
- **More than Moore devices:** in the short term behavioral models of new devices are needed to asses their compatibility with system integration**,** including also mechanical and fluido-dynamical modeling. In the medium term these models must be interfaced among them and with standard logic design tools to allow for the integration of the full device, either in silicon or in package.
- **RF/AMS:** in the short term .RF (up to 100Ghz) modeling of devices and circuits, including compact modeling is needed to be followed by a complete verification flow for analogue and RF circuits including package and process variability.
- **Low Power**: in the short term tools must be developed for dynamic voltage & frequency scaling, use of multiple threshold devices and optimization of static power. In the medium term methodology are needed for the estimation of power consumption at system level, and optimal system partitioning.
- **Design for Reliability**: in the short term reliability models are needed for single devices, based on the characterization of physical and aging effects. In the medium term propagation of device degradation to circuit level, and strategies for fault tolerant design, including mixed-signal and RF functions, must be developed.
- **Design for Manufacturability**: in the short term there is a need for extraction and modeling layout constraints, and extensive characterization of process variability. In the medium term tools will be developed for yield-aware design flow and optimization of placement and layout.
- **Design for Testability**: in the short term tools for increasing testability of logic and memories and tools for BIST architecture generation. In the medium term, development of BIST concepts also for analogue, RF and added functions (e.g. sensors), and optimization of testing partitioning between on-chip BIST and ATE, and between on-wafer and final test.
- **Advanced Architectures**: in the short term modeling and optimization of Network-on-Chip , Multi-Core-Architectures and reconfigurable systems. In the medium term the development and evaluation of innovative communication concepts, and self-adapting architectures for application-specific requirements.

Organization

Modeling, Simulation and Design activities will be embedded in most application projects. However large, specific projects are needed to develop tools and methodologies of common interest:

- Device/circuit/system variability, including system reliability (200 person years, 3 years, start early 2009)
- HW/SW model driven high level synthesis flow, reuse and associated design (200 person years, 3 years, start mid 2009)
- Multi-physics and Atomistic Modeling and Simulation for More-than-Moore design issues (200 person years, 3 years, start mid 2010)

Subprogram 8. Equipment and Materials for Nanoelectronics

Market relevance

The equipment and materials industry that supplies the nano-electronics industry is a significant pool of know-how in Europe. The equipment market is a highly competitive market, often creating spill-over effects to other high-tech industries like medical and automotive. The pallet of players is also very divers, from large multinationals to small companies with a unique product. Another dimension is given by the manufacturing hierarchy of equipment and component suppliers to the first mentioned group. In total over 300 companies are directly and significantly involved in semiconductor, supporting more than 250 clean rooms in Europe. The association of R&D activities with volume production and strong manufacturing facilities has a profound impact in developing local ecosystems. The capability for Europe to maintain and develop a profitable and consistent manufacturing base is of key strategic relevance both in economic and political terms

Societal benefits

Equipment and materials suppliers often enable the high integration and simplification of modern semiconductor appliances, as such allowing a broader group of the community to take advantage of the latest technologies. Special attention is also given to the use of less toxic materials, and the use of less materials all together, in order to reduce the impact of the manufacturing process on the environment. And last but not least special attention is given to increase energy efficiency in the manufacturing process, like the purification of silicon. Although these techniques do not directly contribute to the More Moore and More than Moore strategies, they warrant that the semiconductor industry in Europe stays competitive without sacrificing the sustainability of the industry. Moreover manufacturing of semiconductor can act as a powerful engine for economic growth and high quality jobs.

Application Areas

As the equipment and materials research is focusing on moving the limits of the capabilities of the industry, it is enabling all segments previously described, with a significant focus on mass manufacturing like automotive, with high reliability requirements, and telecommunications, with extreme requirements towards energy efficiency and integration.

Technology challenges

- **Substrate Materials:** Development of CZ crystal ingots/wafers with optimized defect properties; Development of thin top Si layers for SOI wafers, improving the surface and on wafer; Edge roll-off improve technologies like smart cut and strained silicon
- **Device processing equipment and chemicals:** Equipment for furthering the ITRS roadmap in deposition, thermal treatment and etching; Handling of flexible substrates and ultra thin wafers; Development of Atomic Layer Deposition, electro-plating, and selective deposition processes; Implement technology platforms that allow deposition of multiphase materials such as controlled nano-porosity materials and nano-laminates, bio-materials and self-assembly layers; Moving the limits of bulk and surface purity of (machined) ceramics; Laser based shaping systems, like for drilling of microscopic holes for thru-via wafer level connection
- **Lithography:** Lithography tools to reduce the feature sizes following Moore's law, tools and methods to optimize the image and reduce operational cost by improving yield and optimizing mask design methods; Lithography tools for flexible substrates and 3D applications; Development of Hyper Numeric Aperture immersion technology; Defect suppression for advanced photomasks production and self-aligning chemistries for processing of advanced lithographic masks; Nanometer Scale Lithography & Process & Control; multi beam technology (MBT); wafer and lithography mask positioning; lithography process control
- **Maskless Lithography:** Maskless lithography in the lithography process for beyond 32nm manufacturing; engineered substrates (SOI-like, 450mm); Nano-imprint lithography tools

- **Metrology:** Enable nanometers scale manufacturing by developing ultra fast, high resolution inspection, review and metrology process control tools; High resolution advanced particle beam technology; Ultra fast electron beam inspection; Nanometer-scale optical inspection (high resolution & rapid imaging and metrology); Integrate new devices design, inspection and metrology (see also design for manufacturing - DFM); Mask and wafer metrology for double patterning; Develop options for in-line fast print metrology for improved process control
- **Packaging and final testing:** 3D packaging, flexible packages, wafer level packaging techniques, multi-level packaging techniques that enable SIP (system in a package) and highly interconnected systems wafers; Free sensing and bonding area's for wafer level packaging; design-for-test methodologies (DFT) to allow efficient and cost effective testing of hybrid and/or memory intensive applications, design-for-manufacturing (DFM) in order to achieve higher yields and increase competitiveness
- **Manufacturing technology and automation:** Flex Fab Model: To enable the European industry to stay at the forefront of electronics developments & applications through chip making, integration and embedded systems capabilities with adapted volume process chains for cost effective manufacturing; Reducing cycle times; Improving reproducibility, through use of AEC and APC and virtual metrology; Improving the equipment effectiveness; Reducing environmental impact; Maintaining cost decrease per functions, despite greater variability in technology and product demand.

Organization

Project in this field offer ample space for cooperation between competing semiconductor manufacturers because of the advantage in sharing development costs of new equipment and materials. They can involve different levels of the supply chain, offering opportunities for high tech SMEs. Typically equipment development projects are close collaboration between a key equipment supplier, eventually a number of component suppliers and material suppliers, and one or several strategic key lead customers that are willing to put the new development to the test. Key in this process are also research institutes. Possible projects envisaged for the first years are:

- Advanced Equipment and Process control for increasing productivity and sustainability of semiconductor fabs in Europe (450 man-years; 3 years, start 2009)
- Fab automation and flexibility increase through transport and scheduling systems; managing and optimizing the material handling vehicle flow: optimizing delivery time, vehicle availability; scheduling and dispatching strategies (100 man-years, 3 years, start 2010),
- Lithography process for beyond 32nm manufacturing; extension of immersion lithography with improved material and equipment; double exposure and metrology; new resist and mask concepts (350 man-years, 3 years, start 2009)
- Sustainable manufacturing; reduction of environmental impact of semiconductor manufacturing; reduction of C02 footprint, and of water and energy consumption (100 man-years; 4 years, start 2009)
- Assembling technology for System-in-package; through-silicon-vias; testing and reliability for known-good-dice; die alignment and handling; innovative package materials (150 man-year; 3 years)
- High-throughput testing platform for logic devices and memories; integration of testing equipment and BIST; on-wafer reliability tests (100 man-years, 2 years)

As many of the players are SME companies, there are several needs for these companies that need to be fulfilled in order to facilitate their presence in ENIAC projects. First of all these companies don't have the resources to follow the process of project development etc. They also require short focused projects, as they have a different business strategy, SEMI will function as an interface to consolidate and channel the information to this community, and consolidate their feedback.

Implementing the plan

Priorities and synergies

Large financial long-term commitments are required from all parties for the JU to become a success. To guarantee a smooth transition from the past into the future, all existing mechanisms need to be examined and tuned under the guarding umbrella of the ENIAC SRA. This includes securing the position of the ENIAC SRA research priorities in FP7, managing the alignment with the EUREKA cluster MEDEA+ and its successor CATRENE, and guarding the complementarities with ENIAC's sister platform ARTEMIS. The public and private partners in the JU are key stakeholders in defining policies to guide this transition process.

The ultimate choice of topics to be included in realizing the subprogram ambitions must be done in close consultation with all public and private stakeholders. Leading criteria for selection are industry urgency, synergy with other JUs (notably ARTEMIS, Innovative Medicine, and Clean Sky), synergy with adjacent European Technology Platforms (notably EPoSS and Photonics21), and alignment with country and EC policies. This will be a continuous process.

Within each subprogram in the RA, the JU targets for a limited number of large vertically integrated projects with a 2-4 year duration leading to representative demonstrators. Each of these large projects can be complemented by a supporting set of smaller projects to accommodate stakeholder needs that cannot be accommodated otherwise. The combination of these two groups of projects should result in a fair and realistic representation of all players in the underlying nanoelectronics R&D ecosystem in Europe, including large companies, SMEs, institutes, and universities.

Executing the R&D subprograms listed above will strongly stimulate the nanoelectronics ecosystem and the high-tech economy in Europe. On the other hand, to be able to overcome these global technology challenges in an effective manner and realizing the ambitious goals set in each of these subprograms, the tissue of the nanoelectronics ecosystem needs to be nurtured and improved as well. Examples are technology transfer mechanisms, value chain impact, education, standardization, public procurement, regulations, and infrastructure management, as described in the ENIAC SRA. The JU must ensure that these ecosystem issues are addressed by stimulating and aligning actions involving the main bodies in place today, including AENEAS, MEDEA+/CATRENE, the ENIAC Scientific Community Council, and the national and regional competence clusters in Europe.

It is evident that the landscape surrounding the JU is complex. Sharing of experiences is essential, and exchanging resources across related initiatives and bodies can be a valuable enabler. Therefore, the ENIAC JU will share its Office functions the ARTEMIS JU as far as realistically possible. Also, the JU will seek leverage of operational and content-related efforts through cooperation with the MEDEA+/CATRENE Office.

Call process guidance

The JU will have one call for project proposals every year. From 2009 onward, an optional Project Outline (PO) round is planned, followed by a formal FP round. The anticipated schedule for this two-step process is call open in February, PO close in May, FP close in August, with project selection in November.

In order to be able to start the first R&D projects for ENIAC JU before yearend, the first call is planned to open in May 2008 and close in September, with project selection in November. In view of the short time line, project consortia will be asked to submit a Full Project proposal (FP) for this call. In order to prepare for the FPP, AENEAS will facilitate open and informal workshops for project preparation and consortia building. To enable a rapid start, AENEAS will stimulate redirection of presently existing initiatives and consortia in domains relevant for realizing the RA ambitions.

The 2008 and 2009 calls will see a balanced selection from the RA R&D subprograms as per the below schedule. The call content for 2010 and later years will be determined in conjunction with the third edition of the ENIAC SRA, planned for November 2009.

2008	Nanoelectronics for Energy and Environment Nanoelectronics for Transport and Mobility Nanoelectronics for Security and Safety Equipment and Materials for Nanoelectronics Design Methods and Tools for Nanoelectronics
2009	Nanoelectronics for Health and Wellness Nanoelectronics for Communication Nanoelectronics for Infotainment Design Methods and Tools for Nanoelectronics Equipment and Materials for Nanoelectronics

Figure 4 – Preliminary focus areas for the JU 2008 and 2009 calls

References

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