Perspectief

#02 _ Smart Systems in Package (SmartSIP)

STW Programma

SMART SIP

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STW program
SmartSiP

Executive summary

A SmartSiP (smart System-in-Package) is a heterogeneously integrated, miniaturized, networked, energy autonomous and reliable SiP, where the smartness is realized by the embedded system. SmartSiP is a result of integration between advanced SiP technologies and cutting-edge embedded systems knowledge.

In recent years, we have witnessed two important technology development trends for micro/nanoelectronics:

- One is the emergence of an increasingly diverse area of Micro/nanoelectronics that goes beyond the boundaries of Moore's law into the area of "More than Moore" (MtM). From application perspective, MtM enables functions equivalent with the eyes, ears, noses, arms and legs of human being, along with the brain provided by microprocessor and memory subsystems. From technology perspective, MtM refers to all technologies based on, or derived from, silicon technologies, but do not simply scale with Moore's law, such as high-voltage, power, analogue, RF devices, solid state lighting, sensors and actuators.
- Another is increased dependence on embedded software and systems. Superior hardware technology alone cannot guarantee the business success. More and more software of greater functional diversity and architectural complexity will be embedded in hardware systems, partially fuelled by a need for additional and heterogeneous functionality, real-time performance, distribution across sub-systems, re-use for multiple systems, and use of platform technology, and long life time reliability. As systemability is becoming one of the key success criteria for future product development, there is urgent need to integrate hardware technology with embedded systems for SmartSiP product development.

However, so far little research is devoted to the inter-cutting gap and the link between the hardware and software technology domains. More than ever, industries need support of fundamental knowledge to deal with the multidisciplinary based hardware and software co-design challenges of SmartSip, based on systemability requirements.

The aims of this program is to develop leading competencies and knowledge for SmartSiP creation, by solving the key interaction challenges between advanced SiP technology and cutting edge embedded systems, to empower the middle and long term technology and business development of national industries.

Three research themes are defined for the first phase of the SmartSiP program. The essential characteristic of this program is to enforce multidisciplinary, gap-bridging, innovation of SmartSiP via hardware and software co-design, thus to achieve breakthroughs in the "melting pot" between hardware and software.

1. The technology landscape

Why SmartSiP

According to Eniac [1] and ITRS [5], micro/nanoelectronics industry is moving from the pure scaling process, usually known as the Moore's evolution, to a high level integration of digital function driven technology and non-digital function driven technology called "More than Moore". See Figure 1 for the nanoelectronics development roadmap [1,5].

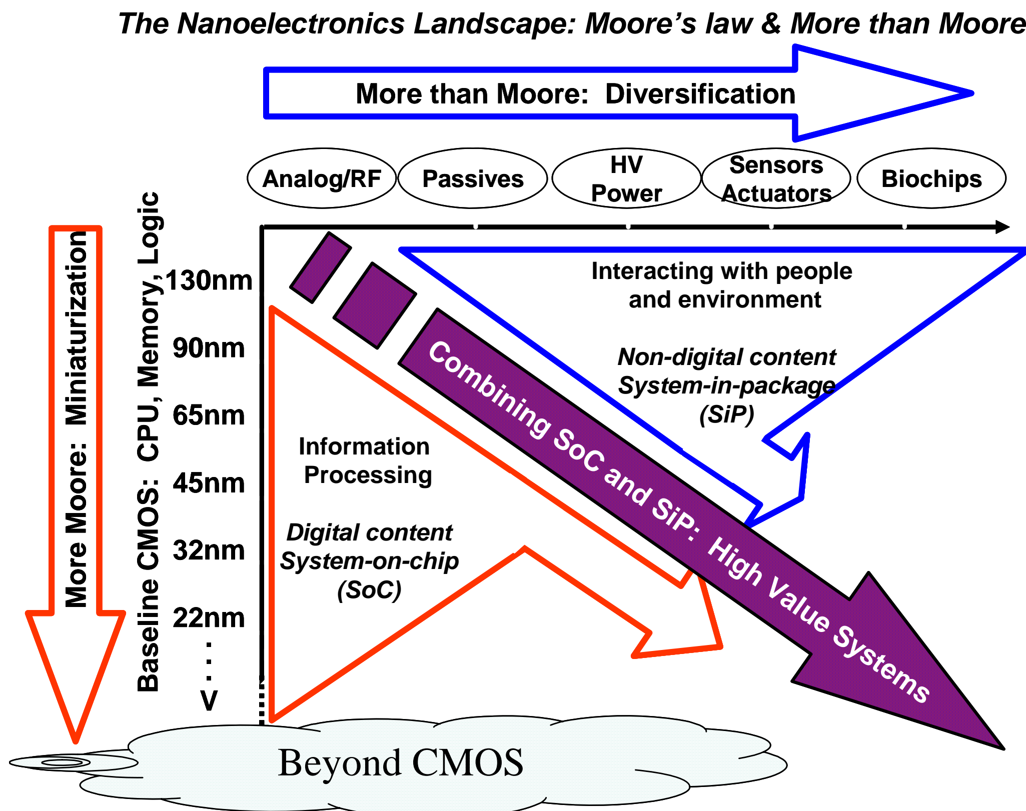


Figure 1. Nanoelectronics development roadmap

Driving by this roadmap, the future of ICT will see a combination of 'More Moore' and 'More than Moore' components, combined in one package ('System-in-Package' or SiP). With such a SiP solution, the application benefits from a comparable level of miniaturization to that achievable with a "System on Chip" (More Moore) solution, from the enhanced functionality of "More than More" solutions and it also benefits from having each part of the system fabricated in an optimum process technology. The technology behind such SiPs is heterogeneous integration. Heterogeneous integration will not only bring all these components together into one package but also provide an interface to the application environment. It therefore represents the glue between the world of micro/nanoelectronics devices and systems that humans can interact with. Heterogeneous integration has to ensure the integration of components based on different technologies and materials. For example, an ultra-miniature single-package bio-sensor could contain photonic components for detection, RF components (using InP or GaAs) for communication, logic components for data compression and communication protocols and energy scavenging or energy storage components (thermo-electrics, fuel cells, thin film batteries) for power supply [1].

To summarize, SiP refers to (multi-)functional systems built up using semiconductors and/or in combination with other technologies in an electronic package dimension (mm scale) [1].

SiP focuses on achieving the highest value for a single system package by extreme miniaturization, heterogeneous function- (such as electrical, optical, mechanical, bio- etc.) integration, short-time-to-market and competitive function/cost ratio. Its concept applies to quite diverse technologies, such as semiconductors, sensors, actuators, power, RF modules, solid-state lighting and health-care devices. Its applications cover nearly all aspects of human life, such as telecommunication, automotive, environment, healthcare, security and energy efficiency. Here are a few examples:

Figure 2 shows a single CMOS sensor SiP, used as a multifunctional smart system device which can detect crossing vehicles, the status of incoming traffic, tunnel/ bridges, mist, fog, rain, and ambient light intensity, while operating as controller of several actuators, with rich embedded software.

Figure 3 shows a wireless, network-compatible micro sensor SiP, on a flexible, folded substrate with an edge length of 6 mm, as part of the Fraunhofer IZM's eGrain roadmap. This SiP consists of small sized and intelligent sensor nodes, which are able to receive, process, store and send data in a network environment. Currently a SiP with a size of about 1 x 1 x 1 cm^3 is realized. In the future around 4x4x4 mm^3 nodes are in the focus equipped with their own power supply and communication unit as well as featuring its own data processing capacity. In order to reduce the physical space requirements of such wireless SiP nodes, new integration technologies are required which also use the third dimension for systems integration.

Figure 4 shows a smart implantable medical systems, herein a cochlear electrode array. In the decades ahead, the medical world will experience major paradigm shifts from curative to preventive care, from generic to patient-specific care, and from clinical to ambulatory and 'at-home' care. Because of these shifts, and also because of demographic trends and an increased public awareness of the importance of healthy behavior, a large need (and hence potential) can be foreseen for novel monitoring systems for ambulatory use. At the heart of these systems are advanced signal-processing techniques that operate on a multiplicity of signals produced by non- or minimally-invasive sensors.

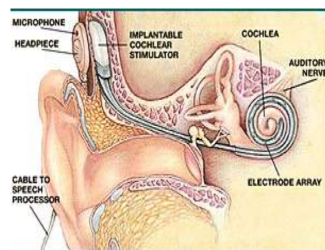


Fig2 Fig.3 Fig4a and b

Being able to invent and manufacture multi-functional SiP is not sufficient to meet the application needs. Superior technology alone cannot guarantee the business success. As an example, figure 5 shows the set of cumulative interdependent challenges for the coming 15 years for IC technology. It is well known that huge effort is made to lower dielectric constant k in the backend stacks of IC from 2.3 to 2, which is a 15% improvement, but this effort so far leads to serious yield issues while better software optimizations (e.g. algorithmic optimizations, or better exploitation of the memory hierarchy) can improve power efficiency and performance by factors between 2 and 10. This triggers an important question: Are we using the right approach? It becomes obvious that simultaneous changes are needed in process technology, materials, device architectures, design technologies and the creation of software-dominated platforms for future application domains. Figure 6 shows the autonomous sensor SiP architecture, wherein system design and hardware / software

integration are essential [4]. Another trigger for hardware and software co-design is due to the fact that the dramatically increased number of design tasks and their complexity are already leading to a phenomenon known as the “design gaps” - the difference between what should theoretically be integrated into systems and what can practically be designed into them, and what should be manufactured versus what has been designed.

The functionality and market appeal of smart SiPs are strongly dependent on the sophistication of the software that is embedded in it. There is a strong trend for more and more software of greater functional diversity and architectural complexity. Taking automotive industry as an example, it is estimated that 70% of future innovations will be software-related and most other sectors are moving in a similar direction. The growing needs for embedded software for SiP is fuelled by a need for additional and heterogeneous functionality, real-time performance, distribution across sub-systems, re-use for multiple systems, and use of platform technology, and long life time reliability needs. As systemability is becoming one of the key success criteria for future technology development, there is urgent need to integrating SiP technology with embedded systems. Figure 6 shows the autonomous sensor SiP architecture, wherein system design and hardware / software integration are essential [4]. Another trigger for hardware and software co-design is due to the fact that the dramatically increased number of design tasks and their complexity are already leading to a phenomenon known as the “design gaps” - the difference between what should theoretically be integrated into systems and what can practically be designed into them, and what should be manufactured versus what has been designed.

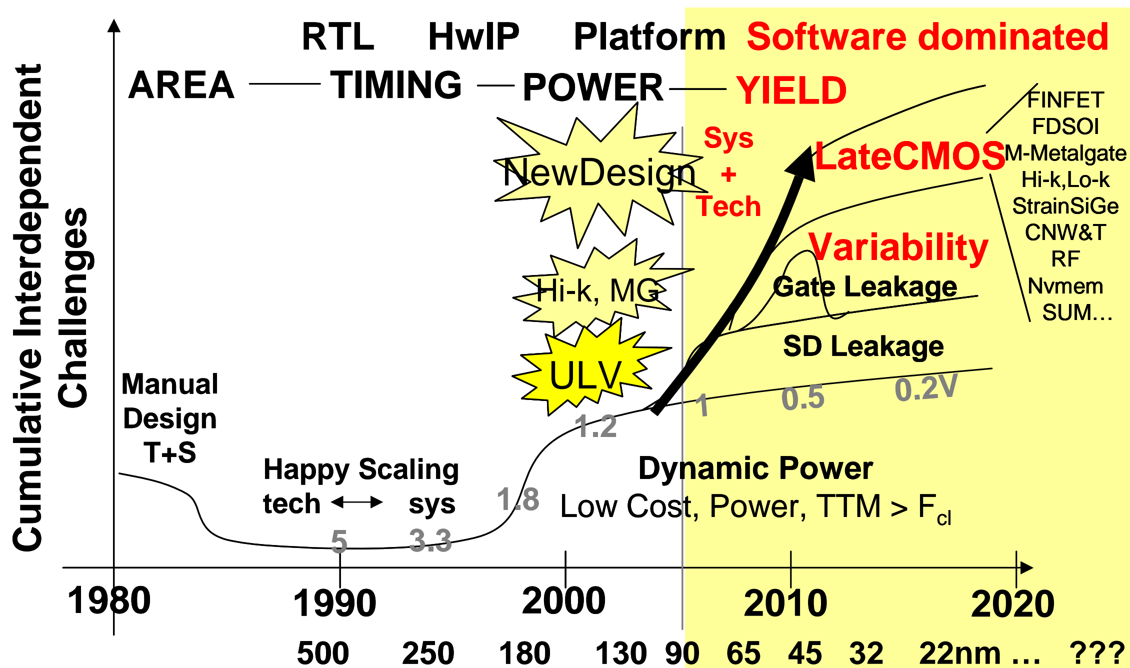


Figure 5. Cumulative interdependent challenges for CMOS technology

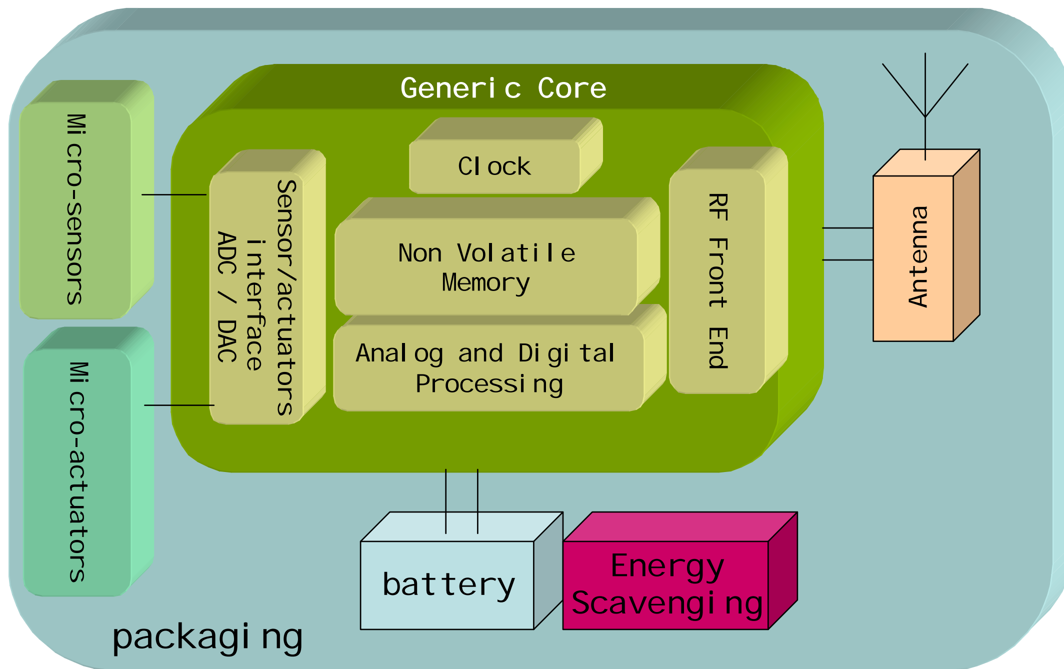


Fig. 6 Autonomous sensor SiP architecture

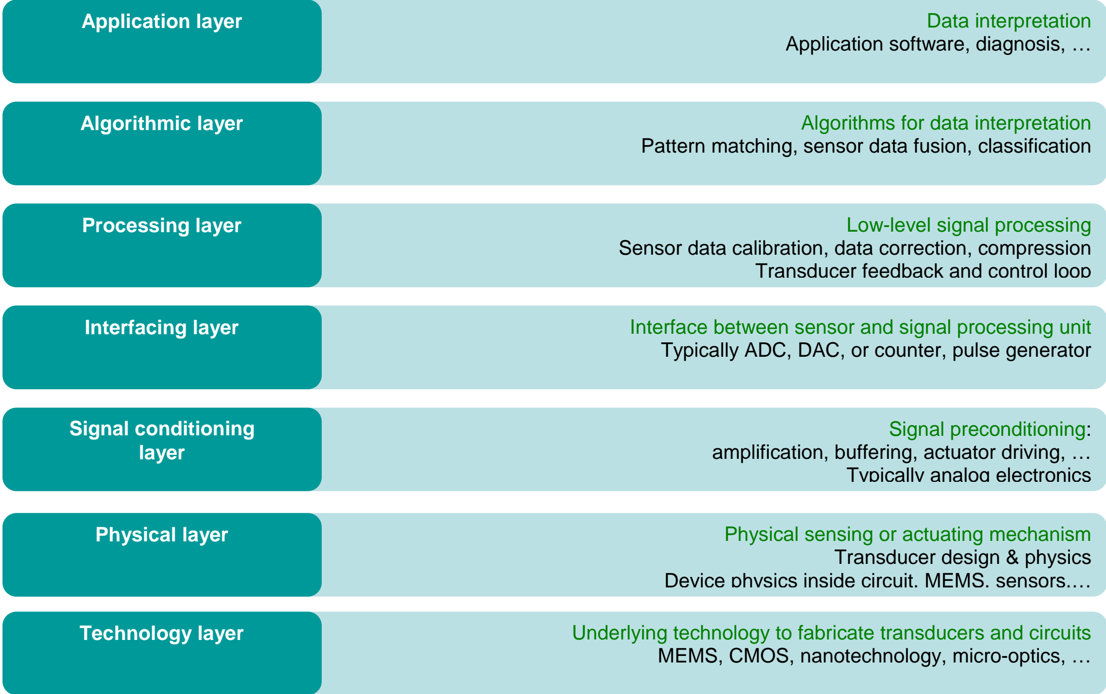
What is SmartSiP

SmartSiP is heterogeneously integrated, miniaturized, networked, energy autonomous and reliable SiP, where the smartness is realized by the embedded system. It is a result of integration between advanced SiP technologies and cutting-edge embedded systems knowledge. The embedded system contains highly complex hardware and up to millions of lines of software. Smart SiP is becoming increasingly complex, involving different disciplines and principles. New features are needed like ubiquitous information, security, ease-of-use and the integration of heterogeneous functions. Besides, they

- are able to sense, diagnose a situation, describe it and qualify it
- mutually address and identify each other
- are predictive
- are (semi-)autonomous, intelligent, and decision-capable
- enable the product to interface, interact with the environment, with other smart systems, the systems they are embedded in and with individuals
- are able to act, perform multiple tasks and assist in different activities

Due to the application driven nature of SiP technologies, it puts also particular emphasis on the clever interfacing, interaction and communication of the integrated smart SiP with its environment, with other smart objects and the system environment it is embedded in. Unlike the traditional product development method of solving problems piece-meal at the components level, Smart SiP offers comprehensive and system level solutions by integrating heterogeneous technology, including hardware and software, based on multi-disciplinary co-design principles and systemability requirements.

The layer model below gives an illustration of the complexity present in the succesfull implementation of transducers functioning in a WSN environment.



The layer model details the different layers needed for a successful realization of the transducer module of the Wireless Autonomous Transducer in the network. The choices made in one of the layers impact the others. Also, choices made on the application or algorithmic layer can impact the on-board signal processing or the wireless communication requirements. Each and all of the layers have implications for the power consumption in the smartSiP, which is one of the most important boundary conditions (lifetime, autonomy).

Economic impact

The direct economic impact of smart SiP can be demonstrated as the following: In 2004 the world market for Microsystems technology amounted to an estimated 36 billion USD. A market analysis by NEXUS projects an increase of this market to 52 billion USD by the year 2009 [10]. Another scenario predicts an increase from 48 billion USD to 95 billion USD for the total MEMS supply chain [11].

However, these values are only a lower boundary of the whole market for smart SiP. A top-down approach to estimate the share of SiP in, for example, the automotive value chain, gives a more reasonable estimate of the true size of the SiP market. A rough estimate for the share of electronic systems in the automotive value chain is 20 percent, and this will increase to an average of 35-40% by 2015[2]. Recognizing that a major part of this value chain concerns wiring and non-intelligent electronic systems, one can safely assume that a share of at least 5 percent of the total automotive value chain can be targeted by smart SiP. This amounts to a market of approximately 45 billion USD for SiP in the automotive sector alone [3].

For the core technology for smart SiP, semiconductors industry and its suppliers, as the cornerstone of today's high-tech economy and modern society, represented a worldwide sales value of 340 billion dollars in 2005, supported a global market of more than 1.3 trillion dollars in terms of electronic systems and an estimated value of 6 trillion dollars in services, with applications covering virtually all aspects of human life [1]. The shift from the past era of Microelectronics, where semiconductor devices were measured in microns to the new era of Nanoelectronics where they shrink to dimensions measured in nanometers, along with the emerging of More than Moore technologies, will make this industry sector even more pervasive than it is today.

According to an OnWorld estimate, the number of WSN nodes deployed worldwide by the year 2010 reaches a total of 140,000 thousand units. This is subdivided over a number of important markets where the largest four are Industrial Process Monitoring (41,000 kUnits), Commercial Buildings (36,000 kUnits), Residential Buildings (32,000 kUnits) and Automatic Meter Reading (12,000 kUnits). The smaller emerging markets like Agricultural and Environmental, Healthcare and public safety would be responsible for another 5,000 kUnits. In order to get an idea of the market volume in money, one could estimate that the average cost for a WSN is between 1 and 10 $.

International landscape

In recent years, we have witnessed the emergence of an increasingly diverse area of Micro/nanoelectronics that goes beyond the boundaries of Moore's law into the area of "More than Moore" (MtM). From application perspective, MtM enables functions equivalent with the eyes, ears, noses, arms and legs of human being, along with the brain provided by microprocessor and memory subsystems. From technology perspective, MtM refers to all technologies based on, or derived from, silicon technologies, but do not simply scale with Moore's law, such as high-voltage, power, analogue, RF devices, solid state lighting, sensors and actuators.

As the key enabling technology for many existing and emerging applications, SiP and embedded systems have been drawing more attention from international innovation communities. In Europe several relevant ETPs (European Technology Platform) are established:

- Eniac for nanoelectronics [1]. Based on the needs of six application domains (Health; Mobility / Transport; Security; Communication; Education / Entertainment; Energy / Environment), Eniac organizes its Strategic Research Agenda into six Technology Domains:
    - "More Moore" covers the development of logic CMOS and memory technology, essentially controlled by scaling, and following Moore's Law;
    - "Beyond CMOS" covers the most advanced research activities to allow scaling of logic and memory functions to continue beyond the physical limits of Silicon-based CMOS technology;
    - "More than Moore" covers all additional non-digital functions, which do not simply scale with Moore's Law, like power, RF, sensors, actuators.
    - "Heterogeneous Integration" deals with the technology for the integration of the devices into a package, which will be an active part of the system;
    - "Equipment and Materials" take care of the development of new materials and specific manufacturing equipment for Nanoelectronics;
    - "Design Automation" deals with the challenge of providing efficient design solution able to handle the increasing complexity and diversity of Nanoelectronics technologies.
- Artemis for embedded systems [2]. It covers mainly the following common technologies
    - reference designs, that offer standard architectural approaches for a given range of applications to address the complexity challenge and build synergies between market sectors;

- middleware that enables seamless connectivity and wide-scale interoperability to support novel functionality, new services and build the ambient intelligent environment,
    - systems design methodologies and associated tools for rapid design and development,
    - generic enabling technologies derived from foundational science.
- EpoSS for smart system applications [3]. It addresses the trend toward miniaturized multifunctional devices and specialized connected and interacting solutions. Multidisciplinary approaches featuring simple devices for complex solutions and making use of shared and, increasingly, self-organizing resources are among the most ambitious challenges. EPoSS proposes a multilevel approach incorporating various technologies, functionalities and methodologies to support the development of new visionary products.

For all the above ETPs the significant role of SiP/ES are recognized, and some of the associated technological challenges are addressed in their Strategic Research Agenda. Due to partially the effort of ETPs, some mid-term SiP/ES challenges will be addressed in the ICT/ 7FP calls [9]. For embedded system, ESI and PROGRESS are the examples of national effort, while ARTEMIS and ITEA are those of the EU commitment: For nano-scale and multi-scale nanoelectronics, NanoNed and MicroNed are the examples of national effort, as well as the newly established Holst Centre[1], while ENIAC and Medea+ are the EU commitment. In Asia and USA much more effort has been spent on SiP/ES to empower the business success of the so-called “More than Moore” technology, the new paradigm of micro/nanoelectronics technology.

Innovative character

Driven mainly by society needs for More Moore, More than Moore technologies, more embedded systems and their integration, SmartSiP becomes an extremely rich innovation nest. In the following, some innovative characters will be summarized. Notice that the **SmartSiP program must focus on the integration of these innovative characters using multidisciplinary approaches**, instead of merely on solving one of the vertical challenges.

- *High levels of heterogeneity:*
    - *In used materials*: SiPs are made of very different materials which have to co-exist despite heir different behaviors (thermal expansion, biochemical interactions). These building blocks are prepared using various processes nodes, and will be exposed to a broad range of environmental constraints.
    - *Processing platform*: different functionality will be needed resulting in large heterogeneity of processing, memory, communication resources, and input and output devices.
- *Dynamism*: Scenarios of use are leading to dynamically changing requirements for the communication links that will build on various wireless standards. Ultimately, the radio components of SiPs themselves will have to optimize in real time to the best air interface for the targeted application requirements. Similar scenario changes will appear in other application domains. Run-time adaptation will be crucial for SmartSiPs.
- *Resource sharing* of platform resources leads to all kinds of uncertainties; availability of resources is therefore difficult to predict, and non-functional properties (like timing and energy requirements) are difficult to guarantee.
- *Complexity* is another driving characteristic for future developments in the field. Most of these systems are designed and built to embed intelligence and to enable the products with the ability to react to their environment and to provide relevant and ergonomic information to their users. The amount of multimodal data to be processed by the system

[1] Wireless Autonomous Transducer Solutions is one of the two program lines of the Holst Centre. This Open Innovation Research institute was established in 2005 and is supported financially by the Ministry of Economic Affairs.

is very large. The user interfaces have to cope with complex and variable environments while taking into account the context of use and rapidly changing user behavior.

- *Autonomous solutions:* Most of the basic functions embedded in the systems have to be designed according to strong power requirements exploiting the most relevant energy sources. In many applications, energy resources are often the main bottleneck preventing larger market penetration of autonomous devices in both industrial and consumer products.
- *Multi scale nature* (in both geometric and time domains) will have a very strong impact on the whole value chain of product creation process, from technology development to industrialization. Various constituting elements of SiP cover a very large-scale difference of geometric features, ranging from nanometers to millimeters. Moving from “Micro” to “Nano”, and from nano to multi-scale will come with a paradigm shift. Indeed, as can be illustrated by the evolution of inertial sensor generations, each step of miniaturization may require a change of design, technology and even a change of detection principle.
- *Convergence of sciences on the physical level of integration:* SiP innovation requires a large body of know-how. Taking a biosensor SiP as an example, it needs not only knowledge of electronic engineering but also chemistry and bioengineering. Chemistry, thermal, metallurgy, physics, electrical, mechanics, optics, electro-magnetics, and biology may all be involved in SmartSiP product creation.
- *Multidisciplinary* across hardware, software and application system engineering.
- *Stochastic in nature:* For micro/nanoelectronics, it is virtually impossible to design and manufacture product and process with deterministic performance. For design parameters, such as material/interface properties, geometric dimensions, process window, loading intensities, deviations represented by different statistic characteristics and magnitudes are inevitable. With the IC technology moving fast to Beyond CMOS domain, control of multi-variability at different scales become vital, especially if the performance at atomistic level has to be linked with micro or macro level requirements. Higher level processing has to deal and/or compensate for this variability. This requires a dramatically different design flow.

Notice that all these characteristics are intrinsically and nonlinearly interacted with each others, wherein there exists a big gap between technological development and the underlying fundamental understanding. An integrated and multidisciplinary approach is needed to find the optimal solutions, which will shape the technological environment in the coming 2 decades, and demand new research fields for scientific community.

Relevance for the Netherlands

As one of the important sub-domains of nanoelectronics, SmartSiP will play a pivotal role to further the economic development of our society:

- It represents a huge global market and is the key area of future growth,
- Leading Dutch industries participate in this market, with significant R&D investments,
- Dutch industry already possesses a unique global position, covering the complete value chain, with a strong participation of SME. Netherlands is one of the three nations (alongside USA, and Japan) that have retained this unique knowledge, infrastructure and intellectual property, providing the unique combination of fundamental understanding in SiP technology with applied systems engineering.
- Dutch academia provides “capability management” for the SiP industries. They play a prominent role in many technologies relevant to SmartSiP on a global scale.
- It is an all-pervasive industry, with very high added-value and knowledge intensive jobs.
- A significant participation in the global economy with a strong export volume.

Taking automotive sector as an example, the combination of automotive, electronic, and software knowledge is both a strong point for the Dutch automotive industry as well as an increasingly relevant factor in automotive R&D. Electronics have supplanted mechanics as

the backbone of the car. SKF develops bearing integrated sensors for speed, position, load and torque measurements. NXP Semiconductors is a major supplier of SiPs and other electronic components (such as car radio IC, in-vehicle networking and car access ICs) and Siemens VDO is an important player in this field as well. A range of software houses supply the automotive industry with flexible staff, like Philips TASS, Atos Origin, Cap Gemini, Logica CMG, Ordina, ICT and Centric T-solve. Rialtosoft is a new company that has achieved an international position in power train software [7]. Industrial process monitoring / predictive maintenance and healthcare/wellness related markets are also of large importance for the Dutch industry (Philips, machine builders…).

Positioning with respect to other program/initiatives

Point-One is a national strategic innovation program for nanoelectronics and embedded systems via private and public partnership. The Strategic Research Agenda and major innovation effort of Point-One focus on mid-term objectives (2007-2011). Therefore SmartSiP will meet part of the future needs of Point-One, by focusing on long-term subjects that are not only scientifically very challenging, but also has strong application relevancy.

Memphis and SmartSiP are complementary to each other. Memphis aims at a large range of new and challenging applications by bridging the gap between hardware technologies of micro- and nanoelectronics and photonics, while SmartSiP aims at bridging the gap between hardware and software. The knowledge generated in SmartSiP will therefore enforce the memphis programme.

High Tech Systems In the Programme for High Tech Systems (HTS) the Institute for Precision Technology and the Dutch Manufacturing Institute were merged. It aims at the research areas in motion systems for semiconductor and pressure machines, nanopositioning and scientific instruments, and intelligent, autonomous motion for medical and household applications. SmartSiP research themes are not covered by HTS, although they are important enablers for HTS. Also, SmartSiP will probably be produced by the machines from HTS industry, but SmartSiP does not focus on production techniques.

High Tech Automotive Systems This innovation programme is a combined initiative of the Federatie Holland Automotive, the Automotive Technology Centre and the Competence Centre for Automotive Research. The programme aims to increase the turnover from 12 to 20 billion euro in 2015 by focusing on growth and innovation in the areas of driving guidance and vehicle efficiency. Driving guidance is the area of automotive ICT for navigation, infotainment, telematics and vehicle dynamics. Although some of these issues can involve packaging and/or embedded systems technology, the integration of these technologies as foreseen in SmartSiP is not on the research agenda here. Further, the focus of the programme is more on product development in a short to medium time span.

2. Research themes

Ambition and aims

Develop leading competencies and knowledge for SmartSiP creation, by solving the key interaction challenges between advanced SiP technology and cutting edge embedded systems, to empower the middle and long term technology and business development of national industries.

Key challenges

SmartSiP technologies and applications are pushed into an unknown level of sophistications. There exist two major paradigm shifts: One is caused by systemability requirements using system level design architecture, another by moving from "micro" down to "nano" and further to "multi-scale". For the first one, clearly we have to cope with giga-scale application dreams and system-level design challenges. For the second one, we have to cope with nano-scale, multi-scale and heterogeneous technology integration. The former is partly the focus of the ARTEMIS (embedded software), the latter of the ENIAC (nanoelectronics). Many excellent research activities are ongoing or will be started in both national and international levels. For embedded system, ESI and PROGRESS are the examples of national effort, while ARTEMIS and ITEA the EU commitment: For nano-scale and multi-scale nanoelectronics, NanoNed, MicroNed and the Holst Centre are the examples of national effort, while ENIAC and Medea+ the EU commitment. However, **so far little research is devoted to the inter-cutting gap and the link between the two vital technology domains (See figure 7 for the gap). More than ever industries need support of fundamental knowledge to deal with the multidisciplinary based hardware and software co-design challenges of SmartSip based on systemability requirements.** Examples are HW/SW design for power efficient ambient intelligent multi-core platforms; Cost effective and variability-resilient adaptive architecture design methods must be researched to build reliable systems from uncertain components with a given defect density and subject to increased soft error rates (fault tolerant design); Designing for testability, reliability and manufacturability from first principles of integrated hardware and software.

Gap between hell of design and technology

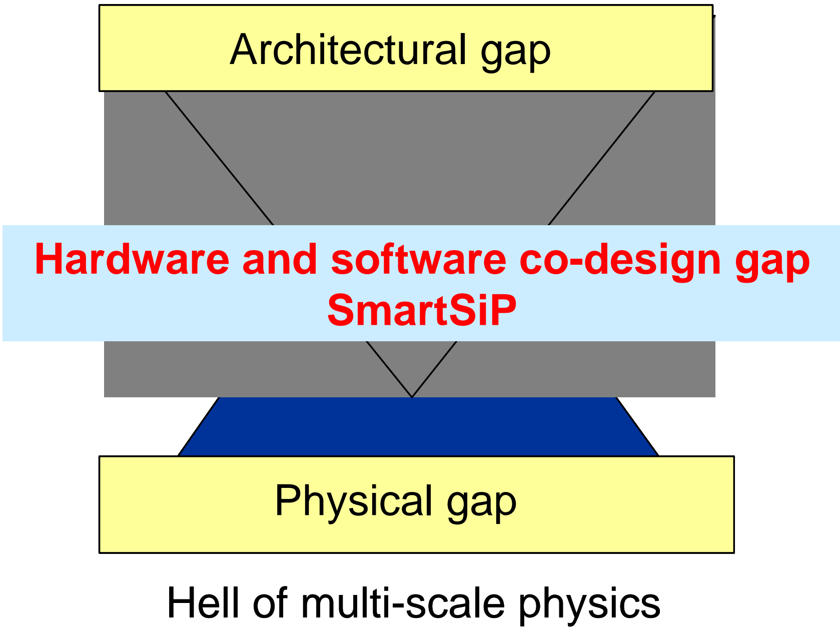


Figure 7, Hardware and software co-design gap

It is clear that the “living apart together” relationship between system, platform, IP creators and process development, and between pure software based on advanced system level method and hardware based on advanced nanoscale and multi-scale physics, is no longer possible nor appropriate for SmartSiP. There is an urgent need for a joint interdisciplinary effort to solve the scientific challenges associated with future SmartSiP development.

Research themes

3 research themes are defined for the first phase of SmartSiP program. The essential of this program is to realize multidisciplinary horizontal innovation of SmartSiP via hardware and software co-design, thus to achieve breakthrough in the “melting pot” between hardware and software. For each of the research theme, 3 –5 FTEs covering different disciplines are expected. It is required that each project addresses at least one aspect of vertical integration to achieve the integral, multi-disciplinary ambitions of the programme.

- Conceptual HW and SW building blocks for SmartSiP prototypes, especially in the light of multi-functional requirements.
- Multi-disciplinary methods and platforms for dependable SmartSip co-design (reliability, testability, manufacturability, stability, robustness, maintainability, availability, safety, security, etc).
- Vertical integration between different design abstraction layers, in particular those addressing
    - o the architectural gap between the application system layer and the SmartSiP system layer
    - o the physical gap between the SmartSiP system layer and its physical realization.

Application fields

To develop knowledge and technologies to serve long-term needs of the potentially high volume, low cost and high value markets, the following application fields (but not limited to) are recommended for SmartSiP program.

<u>Domotica</u>
SmartSiP can serve as the eyes, ears, arms and legs for Ambient Intelligence, enabling the infrastructure of a home (or office) to anticipate and adapt to the needs of its inhabitants. Based on the input from body networks and other environmental stimuli, behavior and needs of people can be anticipated, and access (doors), energy, lighting, and audio/visual experiences can be controlled. Combining smart nodes for these application domains is a first step towards the “internet of things”. Typical challenges are integrating signals of many different sensors (sensor fusion) into an intelligent sub-system and over the network, combining many smart nodes into reliable and secure applications (such as solid state lighting systems), and enabling easy installation and maintenance.

<u>Lifestyle</u>
Lifestyle covers a very broad application field and many consumer electronic products. Smart nodes, containing sensors, actuators, processing, and communication, can be mounted on a person’s body, e.g., for applications to improve fitness of body and mind. When interacting with objects containing smart nodes, a new generation of inside and outside toys and games may result, as well as some serious lifestyle assistance. Interacting with other people with smart nodes may enable new social interactions, with applications ranging from smart meeting badges with voting and interaction capabilities, to sports and mass meeting events like pop concerts and theme parks providing interaction and feedback from the audience.

Mobility and Logistic

SmartSiP associated technologies are essential for the further development of nearly all mobility and logistic applications. Taking automotive as an example, electronic systems for automotive systems have to withstand very harsh environments, including high temperatures, humidity, vibration, fluid contamination and EMC (Electro-Magnetic Compatibility). While these problems have largely been solved for conventional IC-style packaged devices, a whole new set of challenges will have to be faced when these sub-systems contain heterogeneous functionality, such as integrated sensor, actuator, Mechatronics or Optoelectronics functions. These application requirements call for comprehensive approaches beyond the capabilities of single components – the challenge for SmartSiP.

Logistics and communication are considered to be the backbone of globalization. They play an important role in the development of modern economic systems and sustainable economic growth. Radiofrequency Identification (RFID) has become a key technology in the ICT sector, because RFID tags can identify individual goods and commodities in real time and close the gap between the physical flow of things and the related information flow in IT systems. Effective integration of RFID with SmartSiP can provide added value to many industrial sectors, such as sea container identification and management. In 2006, about 6 million containers were treated by Rotterdam haven. Implementing SmartSiP devices on these containers will provide many benefits, such as security, transport efficiency, space optimisation.

3 Organization of the SmartSiP program

Budget

For this call a budget of M€ 5,0 is available which must be matched by the contributions of potential technology users (companies/institutes) to a total of at least M€ 6,25. The total costs of a project submitted under the SmartSiP program is maximized to M€ 1. Given the minimal 25% user contribution per project, a maximum of € 750.000 can be requested from STW per project. The users do not have to co-finance up-front in the program but should contribute in-kind (materials, equipment, facilities etc.) and/or financially in the project wherein they will participate.

Who can apply

Scientists holding a doctor's degree employed by Dutch universities or scientific institutes recognized by NWO are eligible to submit a (pre-) proposal under the program. Because SmartSiP is a multidisciplinary program, at least two research groups, with hardware- and with software- expertise, should be involved in the project proposal. In the ideal case two PhD students from both disciplines should perform their PhD research in the project, assisted by one experienced postdoc who secures the coherence between both research projects. In the project description it should be made clear what the added value of the multidisciplinary approach is for the project.

Proposals and selection

The selection of proposals will be done in two steps: a call for pre-proposals and an invitation to the applicants of pre-proposals to submit full proposals. The pre-proposals will be evaluated by the Program Committee. The STW board will decide on the funding of the full proposals.

Pre-proposals

Pre-proposals should contain a short description (3 A4) of the proposed research, utilization paragraph and estimated budget. The proposal should make clear which potential users will contribute to the project. Support letters are optional for the pre-proposals but can be included (letters of intent are accepted).
The pre-proposals will be ranked by the program committee on the basis of how well they fit within the scope of the program. The members of the program committee will first assess the pre-proposals individually before being discussed plenary in the committee. The program committee will advise the applicants 1) to submit a full proposal or 2) to adjust the proposal so that it would fit better into the program or 3) not to enter the subsequent selection procedure.
Note: If the full proposal budget is changed significantly with respect to the budget of the pre-proposal, STW has to be informed immediately.

Full proposals

Full proposals must consist of a detailed description of the expected results, planning of the research and a utilization paragraph. The utilization paragraph should include the important industrial challenges that will be solved, the time frame to implementation and the expected bottle-necks during the implementation. Companies and institutes, which will potentially contribute, should be involved bottom-up during the preparation of the proposal.

The full proposal will be evaluated individually by experts (referees) and ranked by an independent jury of about eight (inter) national expert of universities (no applicants of this program) and industry. A full proposal will be evaluated only if it is preceded by a pre-proposal. The decision of the STW board will be based on the ranking by the jury and the

advice of the program committee. The program committee advises on the cohesion between the project proposals and their fitting in the program.

The guidelines for full proposals are based on the “Open Technology Program (OTP)” with as the main difference that the technology users (companies/institutes) should contribute for at least 25% of the total project cost. The proposals should therefore be accompanied by a ‘letter of participation’ in which their contribution has been made explicit and in which details are given on what, when and how these contributions will be made available. For more details see “richtlijnen voor het open technologieprogramma (www.stw.nl)”.

Evaluation criteria of full proposals

Full proposals will be evaluated on scientific quality and utilization perspective.

Scientific quality

- Originality and innovative character of the proposal
- Expected impact on the scientific community
- Research method
- Time schedule
- Budget
- Infrastructure
- Past performance of the applicants.

Utilization

- Potential economic impact
- Contribution to the development of applied knowledge;
- Impact on utilization if the project is carried out successfully;
- Different steps needed (time path) to utilize the results;
- Chance on patents and/or know how agreements.
- Participation of users

The program committee will use the following considerations to evaluate if the proposals fit the framework of the program:

- How well do the goals of the project fit within the ambition of the SmartSiP program. Do the expected results meet the industrial needs in the long term (2011-2013)?
- To what extent does the proposal fit within the research themes of the SmartSiP program?
- Does the program strengthen the SmartSiP expertise in the Netherlands in general and of the participants in the project in particular?
- To what extent is the project proposal multidisciplinary? What are the positive effects from the cooperation between the embedded system and system-in-package fields?
- Do the proposals overlap each other and if so, what are the consequences for the funding?

Time schedule SmartSiP proposals

Call for pre-proposals (3 A4)	Monday 28 May 2007
Deadline pre-proposals	Monday 25 June 2007
Notification to applicants about pre-proposal: positive / negative advice to submit full proposal	Monday 9 July 2007
Deadline full proposals	Friday 21 September 2007
Start review by experts	Friday 5 October 2007
Deadline protocol	Friday 2 November 2007
Ranking by Jury ready	Friday 30 November 2007
Advice Program Committee to STW board ready	Friday 7 December 2007
Proposal for funding send to STW-board	Friday 14 December 2007
Decision by STW board on funding plus notification to applicants	Friday 21 December 2007

4. *References*

1. SRA of Eniac, European Technology Platform of Nanoelectronics,
2. SRA of Artemis, European Technology Platform of Embedded Systems,
3. SRA of EpoSS, European Technology Platform of Smart System Integration,
4. Towards and Beyond 2015: technology, devices, circuits and systems, Medea+, 2006
5. International Technology Roadmap of Semiconductors
6. Orange book, Point-One, 2006
7. PSS Automotive, Vision for the Dutch automotive sector, Federation of Holland Automotive, 2006,
8. SRA of ESI, 2006
9. ICT call for proposal / 7FP, EC, 2006
10. NEXUS Market Analysis for MEMS and Microsystems III, 2005-2009
11. “The MEMS Supply chain size 2005-2010”, Yole Dévelopment SARL 2006
12. PROGRESS Embedded Systems Roadmap 2002 (needs updating)

5. *Appendix: SWOTs*

SWOT of the SiP eco-system in the Netherlands

Strengths

- Leading / unique industry base covering major value chain (Equipment/Semiconductors/Applications)
- Good R&D and prototyping facilities and strong competence base
- Momentum of Point-One (sector/approach/commitment) and more awareness for innovation

Weaknesses

- Not yet optimal eco-system
  - Fragmented strategy/policy/regulation/instruments; poor synergy
  - Value chains are not always well connected
  - Modest entrepreneurship, policy and culture
- High costs and lower RoI of R&D
- NL not attractive for international talents
- Conservative markets in the Netherlands

Opportunities

- Willingness of public authorities (national + EC) to support
- Industry acceptance of open innovation
- New pivotal institute for Open Innovation in SiP: The Holst Centre
- Positive global business prospects

Threats

- Increasing cost of research
- Competition by other countries and continents
- Competition by other research areas
- Further degradation of manufacturing competitiveness

SWOT of Embedded Systems eco-system in the Netherlands

Strengths

- Good organisation and quality of the academic ES and ICT fields
- PROGRESS: proven approach
- ESI (industry as laboratory)
- Good technological starting point
- Good mix of large and small industrial players

Weaknesses

- Link with applications can be improved
- Multi-disciplinary research still immature
- Dependability research: opportunity, but still weak
- ESI participation in academic research is weak
- Yet no 'science of ES'

Opportunities

- ES the 'motor' of almost all future (AmInt) systems
- NL companies need ES knowledge and people
- Extension of the PROGRESS approach

- ES master / BaMa “zij-instroom”

Threats
- Hard to connect SME
- Overhead of multi-disciplinary research
- ES just another buzzword
- Low number of new students
- Being passed by the international community

SWOT of Business Creation

Strengths
- High level system knowledge in selected application domains
- Strong technology capabilities and facilities (equipment, IC, packaging, system integration)
- Spirit and experience of Point-One

Weaknesses
- Still Missing fundamental knowledge
- No shared/aligned roadmap (technology / knowledge)
- No structured partnership (industries and academia; among industrial sectors)
- Resources not sufficiently shared
- Slow marketing engagement
- High development costs, longer time to market and limited access to talents

Opportunities
- Huge market potentials
- Huge IP opportunities
- Right enter moment

Threats
- Competition by other countries and continents
- Competition by other research areas