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THE ARCHITECTURE AND THE APPLICATIONS VISION OF THE EMBEDDED SYSTEMS

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Abstract

Embedded systems (ES), as specialised devices for data processing and communication, are used in larger systems or machines, to control and add computing and communication capabilities to products, equipping them with new, very useful and exciting functions. In this way, they also add new value to traditional or existing goods. In this paper is defined the orientation in the area of embedded computer structures, nano-scale electronics, and software, that provide intelligence to products, processes, and services, and also are considered the applications vision of the embedded systems. In this context are presented applications drivers for industrial systems, technology domains and challenges in assuming embedded systems properties.

1. INTRODUCTION

In the last three years, European industry leaders have joined forces to create a novel European Technology Platform, named ARTEMIS (Advanced Research and Technology for Embedded Intelligence and Systems), as public-private partnership with the common goal of defining and driving a coordinated research and development strategy on a pan-European level in the area of embedded systems.

The term **Embedded System (ES)** includes devices, software, middleware and tools for the construction of intelligent and specialised components used in a larger systems or machines capable of monitoring and control a wide range of industrial and domestic appliances. ES, today, are just about everywhere, and are so universal because they add computing and communication facilities to everyday products or services, equipping them with new functions, adding new value to traditional goods. Already about 90% of computing devices are in ES and, with the current growth rate, the number of embedded programmable component will reach 16 billions by 2010 (about 3 embedded devices per person on Earth) and over 40 billions worldwide by 2020.

Intelligent functions embedded in components and devices will be a key factor in revolutionising industrial production processes, from design to manufacturing and distribution, particularly in traditional sectors. These technologies add intelligence to the control processes in manufacturing shop floors and improve the logistics and distribution chains, resulting in an increasing productivity in a wide range of industrial processes. The design and production of ES has become a major driver for IT industry in developed countries and has also generated eco-systems of small and medium-sized enterprises, large industry actors, and research organizations. An important realization of ES is **Cooperating Object (CO)**, which are networked, embedded devices, including sensors and actuators, which can be heterogeneous, but nevertheless able to cooperate together to achieve specific goals. CO embodies the deep embedding of computing, networking, sensing, and actuating capabilities into the physical world. The availability of significant computing power at the level of sensors and actuators will enable them to behave in intelligent ways and the fusion of data from a wide-range of such geographically dispersed devices may give rise to applications which could profoundly affect the way we live and work.

2. DRIVING APLICATION IN ES FOR INDUSTRIAL SYSTEMS AND OTHER DOMAINS.

The driving applications have a visionary, medium to long term perspective, and they raise a number of important technological challenges. As market are increasingly becoming bottom-up driven, implying that the availability of components determine the product, these driving applications will correspond to future product and service markets that are expected to have fast growth rates due to socio-economic trends. Among these visionary applications, the most important are related to:

- Big systems, as industrial systems from automotive, aerospace, manufacturing, and process industries.
- Mobile objects, defining nomadic environments (''walk, talk, hear, see'').
- Major public infrastructure for improved mobility for people and goods.
- Private infrastructure, as private space (homes, houses, and offices).

For industrial systems (manufacturing and process industries), ES will precisely control process parameters, including the active reduction of pollution, which reduces the total costs of manufacture. Farther competitive advantage in manufacturing industries is assumed by efficiency, meaning 100% machines and technological lines availability, and low maintenance that reduce also costs. This will not only augment manufacturing, but also assure jobs in the design and manufacture of the manufacturing equipment itself. Manufacturing flexibility is very important to assure agile adaptation to market demands, particularly for product customisation, thus reinforcing the competitive position. Improvement in end product quality can be achieved through active control of the manufacturing process, moving from *off-line* to *in-process* quality control through advanced embedded intelligence in the manufacturing machines and technological lines. Also, improved man-machine interaction using advanced intelligent embedded systems and *human-in-the-loop* control systems, improves quality and productivity, by assuming zero operation errors, and reducing accidents. In the model for world class manufacturing (Figure 1), ES can be implemented in different areas of activity, such as simultaneous development of products, production processes, and logistics, assuring sustained market competitiveness in the condition of manufacturing globalization.

For automotive industry, as main targets are the reduced fuel consumption and pollution, to obtain *100% safe* car, by using more intelligent systems, so called *active safety* systems, based on sensors, actuators and smart software embedded in through vehicle. This is valuable for road-transport in general. ES are also key technologies for smart production in the field of car manufacturing in general, and in the integration of supplier chain and related logistics as presented in Figure 1.
In addition, the vision of customisable car offers higher added-value to the user, and good possibilities of product differentiation to the manufacturer, in turn yielding improved competitive advantage.

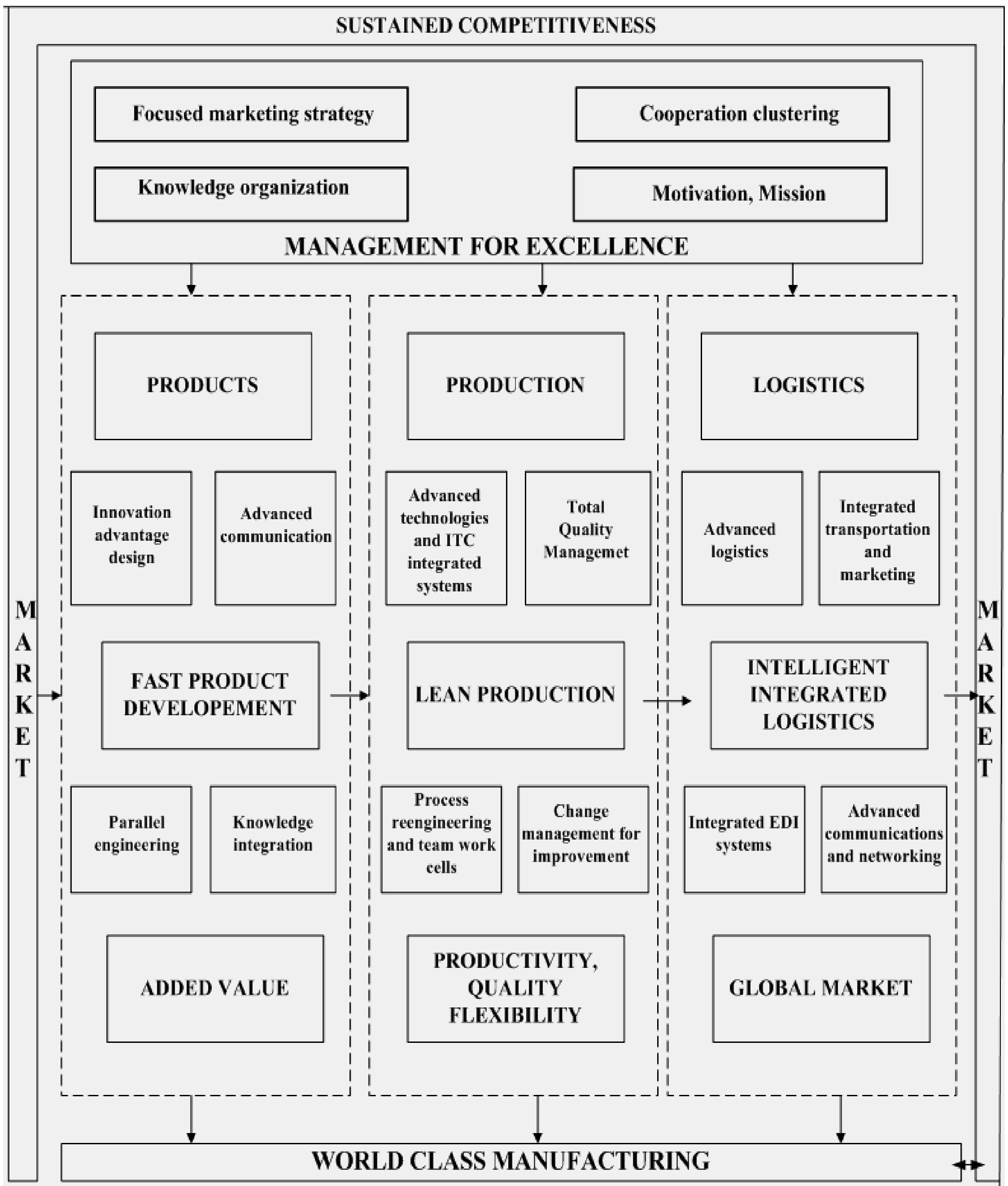

Figure 1: Model for world class manufacturing

For aerospace industry, ES will be the key enablers and differentiators, assuming support the vision of extremely customisable, affordable, and life-cycle sustainable products and services, for environmentally friendly, safe, secure, for fuel and energy reduction, and time efficient transfer of goods and people. ES will support advanced

diagnosis and predictive maintenance, assuring greater life-cycle supportable product, fast prototyping, composability and advanced verification and validation strategies.
The applications vision for **mobile objects,** in a nomadic environment, is of a personal, smart devices companion, linked to the user by body-area smart sensors, and connecting him to multimedia or other services and computing resources. Key enabling technologies for such a devices will address software techniques for low power systems, intelligent interfaces, including displays and body-area sensors.

The vision for **private infrastructure** is of systems which know and recognise individuals and can adapt to their requirements and to long- term changes in those requirements, at home and in the office. Key technologies to this will be the development of both wireless and wired communications of techniques for managing sensors information, making such systems intelligent, self-installing, self-maintaining, self-repairing and affordable.

For major, **public infrastructure**, the ES can support all aspects off life-cycle of such infrastructures, including logging of system data, maintenance, alarms, and action by emergency services, authorisation of access and usage, charging and billing under the range of different conditions of usage. For intelligent infrastructures are needed hardware and software technologies to be developed, system organisation and management tools as support.

Driving and visionary applications for ES have the potential to stimulate research and development in many areas, in which can be obtained competitive advantage through the evolution of existing technical and industrial strengths [3, 4].

3. RESEARCH AND DEVELOPMENT SCENARIOS AND PRIORITIES FOR EMBEDDED SYSTEMS

Investments in R&D has a direct impact on economic growth as is presented in Table 1, for R&D parameters in Europe (EU-25), compares with those of USA and Japan, the main competitors on global market (Source : European Commission; Figures from

Table 1

Competitors **R&D parameters**	**EU-25**	**USA**	**Japan**
R&D intensity (% GDP)	1,97	2,59	3,2
Researcher per thousand labour force	5,5	9,0	9,7
Scientific publications per million population	639	809	569
High-technology export as share of total manufacturing export	19,7	28,5	26,5

2003).Despite having the largest share of scientific publications and despite the present level of investment in R&D, EU-25 lags behind in key areas, most significantly in the intensity of R&D investment, in the ability to retain leading researchers, and incorporate high-technology in total manufacturing exports. These parameters are critical to ability to convert scientific knowledge into economically beneficial developments. Any high-tech product, such as those incorporating Embedded Systems activities is typically more *R&D intensive* than products of mature markets.

The worldwide R&D in the field of ES is expected to double over the next 10 years, in order to support the growth of this expanding market [1, 2].Precompetitive, collaborative R&D is a key enabler of Europe competitiveness, and the funding support of public authorities plays a catalytic role in stimulating synergetics efforts between all organizations involved (large companies, SMEs, Research Institutes, and Universities). For European R&D in ES is proposed the following scenario [1]:

- **The industry** assumes to doubles its R&D effort in precompetitive, collaborative R&D over next 5 years (>70 mil.Euro in 2005, and 150 mil. Euro in 2010).
- **Public authorities** contribute funding is at the same level, while **industries** allocates the corresponding resources, together with **research institutes** and **universities**.

Taking a leading position in ES requires significant investments in R&D by:

- establishing an environment supportive of innovation in which both cooperation and competition in technological development are enhanced ;
- proactively stimulating the emergence of new supply industry for new components, tools and design methodologies, supporting ES ;
- focussing R&D to make more effective use of resources, to avoid fragmentation, and to facilitate deployment ;

R&D approaches in developing ES are supposed to cut barriers between applications sectors, stimulating creativity and innovation, and to have multi-domain reusable results. This will be achieved by specifying on reference architecture that can support product development in a diversity of applications domains, as presented in Figure 2.The common technologies will include:

- **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 software,** that enables seamless connectivity and wide-scale interoperability, new services, and to build the intelligent environment ;
- **systems design methodologies** and **associated tools,** for rapid design and development.

Generic enabling technologies, derived from basic research in fundamental sciences, can be associated as innovative ideas in the field of new Embedded Systems.

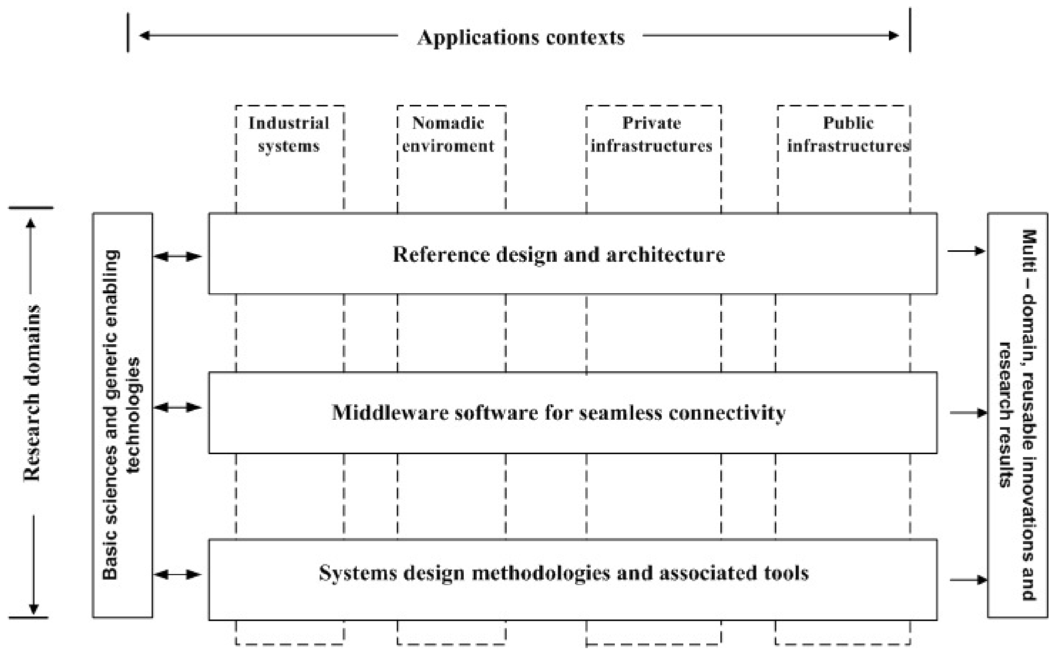

Figure 2: Reference architecture for product development in a diversity of applications domains for Embedded Systems.

4. CONCLUSIONS

The Embedded Systems add new value to traditional or existing goods and services, and represent a way to sustained competitiveness for world-class manufacturing on the global market. Visionary applications and their drivers must be targets and priorities for R&D as collaborative research in which industry leaders, emerging technology companies, research institutes, and universities will engage. The four areas of application context for ES (industrial, nomadic environment, private and public infrastructure), have the potential to stimulate R&D in the directions in which can be obtained competitive advantage through the evolution of existing technical and industrial strengths.

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