European Research in Embedded Systems*

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Digital information technology has revolutionized the world within less than four decades. It has taken the step from mainframe computers, mainly operated as hosts in computing centres, to desktops and laptops, connected by networks and found nearly on all office desks and tables today. Computers have become every day tools deeply integrated into all kinds of activities of our life.

More remarkable, however, is the less visible revolution where digital technology is increasingly embedded in all kinds of equipment and systems to provide new functionalities and improved operation at low cost. Embedded computers are now found in nearly all technical devices: in simple everyday home appliances; in facilities and facility management such as heating, air conditioning, elevators and escalators; in production units from robotics to production automation and control systems; in medicine where equipment for diagnostics and medical support is enhanced by computers and in the increasing variety of intelligent devices that are implanted into the human body. Remarkable is also the rapid proliferation of embedded systems in transportation, be it cars, trucks, ships, trains or airplanes.

Already 90% of all computing devices are in embedded and not desktop systems. The growth rate exceeds 10% per annum in all application sectors and there are forecast to be over 40 billion embedded chips worldwide by 2020. In terms of market value, for example, the Semiconductor Industry Association estimates that in 2006 the automotive sector alone will account for almost 8% of the world semiconductor market (the world semiconductor market is forecasted at approximately 200 billion in 2006). Even more striking is the growing share of the value of the final product that is due to embedded systems: 20% of the value of each car today is due to embedded electronics and this is expected to increase to 36% in 2009. In the same year, 22% of the value of industrial automation systems, 41% of consumer electronics and 33% of medical equipment will be due to embedded electronics and software.

Embedded systems have evolved from the simple stand-alone and single-processor computers of the eighties and early nineties, to the sophisticated multi-processor systems with increasing communication capacities of today. This evolution is driven by the constant need to bring to the users innovative products and services with increasing functionality at ever diminishing price. It alsoresults in significant technological, research and educational challenges. To face these challenges, European industry alone is expected to invest more than 22 billion

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euro in embedded systems research and development in 2009[1], a large increase from the 12 billion it invested in 2003.

These challenges, combined with the importance of the field for key sectors of European industry, from industrial automation and medical equipment to automotive and avionics, led the European Commission to devote a specific part of its IST Programme to embedded systems research. In the last three years that this programme is in operation, it has invested €140 million in collaborative projects between industry, academia and research centres, largely in the areas of systems design, safety-critical systems, embedded computing, middleware platforms, wireless sensor networks and distributed and hybrid control systems. Embedded systems are also one of the six *pillars* of ICT research in the European Commission's proposals for the 7th Framework Programme that is due to start in 2007.

Another important development is the set up of the Technology Platform ARTEMIS - *Advanced Research & Technology for Embedded Intelligence and Systems* in 2004. ARTEMIS is an industry-led initiative to reinforce the position of the EU as a leading worldwide player in the design, integration and supply of embedded systems. After it produced a 2004 manifesto called *Building ARTEMIS* that was signed by 20 executives of EU companies, it set out to establish and implement a coherent and integrated European strategy for Embedded Systems that covers all aspects - from research and development priorities to the research infrastructures needed, the standardisation policy, the educational curricula etc. In March 2006, this strategy was published as the ARTEMIS *Strategic Research Agenda*. While ARTEMIS seeks maximum commonality across application sectors, it is recognised that different application domains impose differing demands on the technology to be developed. ARTEMIS has therefore identified a number of representative *Application Contexts* in which: sets of applications can share common domain expertise, design characteristics and requirements so that they can, in turn, share methods, tools, technologies and skills; the domains have a large market value and are of sufficient strategic importance to Europe to justify the investment in a shared research agenda. These Application Contexts are:

- *Industrial systems* - large, complex and safety critical systems, that embraces Automotive, Aerospace, Manufacturing, and growth areas such as biomedical.
- *Nomadic Environments* - enabling portable devices and on-body systems to offer users access to information and services while on the move.
- *Private Spaces*, - such as homes, cars and offices, that offers systems and solutions for improved enjoyment, comfort, well-being and safety.
- *Public Infrastructure* - major infrastructure such as airports, cities and highways that embrace large scale deployment of systems and services.

[1] FAST Study on *Worldwide Trends and R&D Programmes in Embedded Systems in view of maximising the impact of a Technology Platform in the area*, 2005.

The ARTEMIS strategy is to establish common technology to support the development of high value-added Embedded Systems across these application contexts. The common technology will include:

- Reference designs that offer standard architectural approaches for a 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.

The overall target of European research in this area is to create an environment that favours and supports innovation in embedded systems and to focus the $R\&D$ resources on common and ambitious objectives. Rapid progress in that direction over the last years provides a lot of confidence that this will indeed be the case and that this collective effort will be successful.