Eurotraining survey on Microsytems training requirements

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Abstract

One objective of the Eurotraining MST project is to identify training and education needs in the area of micro/nanosytems and to define a training roadmap. This paper describes the methodology used in this task and gives the main results. The first part is a comparison of Microsystems and Smart systems definitions and a description of the different relations between Nanoelectronics, the More than Moore approach and the smart systems concepts. The three European platforms (ENIAC, EpOSS and ARTEMIS) appear as the corresponding initiatives. The second part of the paper is a short survey of MEMs market. The evolution of skills and training needs are studied to identify the most important training areas and the areas not yet covered by the market. The third part of the paper is an analysis of questionnaire data sent to FSRM and LETI customers in order to identify training requirements. The fourth part is a qualitative analysis based on FP7 projects training activities and discussions with important industrial Microsystems actors. Finally we try to conclude giving some recommendations and defining as examples a few specific courses in the Microsystems area.

1. Microsystems and smart systems

Microsystems include specific technologies generally at micron scale for sensing and actuating and standard microelectronic technologies for signal processing and control command. Smart systems are defined by EPOSS as miniaturized systems including microsystems, micro or nanoelectronics and embedded software. In this training roadmap we prefer to limit the survey to strictly defined microsystems including integrated sensors and actuators technologies. Integration technologies (to design SIP modules for example) are also considered. In addition specific electronic functions (mixed signal functions) and some specific technologies (polymers, embedded memories and embedded RF functions) are also included in this analysis.

Currently, there is no common definition of "systems integration". It is understood here as the progressive combining of components to merge their functional and technical characteristics into a comprehensive, interoperable system (interoperability meaning the ability to exchange and use information). Miniaturised integrated systems often use technologies from optics, mechanics, electronics, fluidics and thermo-dynamics and make use of various materials: silicon and non-silicon (e.g. polymers). Biological components are used, too. Systems integration may be based on monolithic, hybrid, multi-chip modules or other techniques spanning several scales of size in a range between nano and macro. Such a broad definition reflects industrial reality and the large potential for miniaturization to improve existing products and create completely new ones. “Smart System Integration” using integrated micro and nanosystems, put also particular emphasis on the clever interfacing, interaction and communication of the integrated smart system with its environment, with other smart objects and the system environment it is embedded in. Smart systems integration will make a significant impact on the competitiveness of entire sectors such as aeronautics, automotives, homeland security, logistics, medical equipment, process engineering, new communication media and many more.

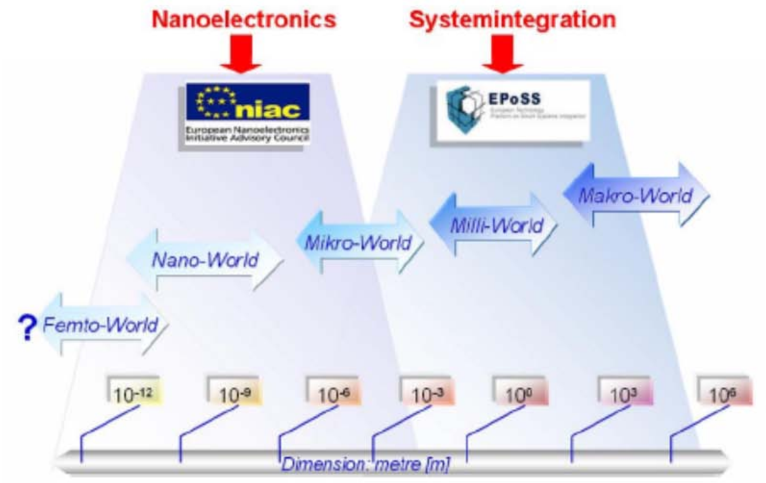

Figure 1: Nanoelectronics and smart systems

Systems integration has several facets: integration of different components and functions into a small system, integration into the macrosystem, and integration into the application system. All raise new technological challenges. So far a parallel development of various technologies has been sufficient to meet customers’ needs. A major challenge is to integrate the multitude of different components, produced in very different technologies and materials. The link between application and technology has to be tightened, both in research and in product development by systems integration methodology and technology, and by adapting organisational structures. These challenges are a unique chance for European researchers and technicians to use their technological excellence and consolidated knowledge in miniaturisation techniques, system know-how and manufacturing processes to achieve a unique selling proposition. The systems approach calls for integrated design and manufacturing and the transdisciplinary combination of technological approaches and solutions. A set of compatible technologies and design tools will ease the combination of different modules.providing integrated systems with unprecedented functionality and performance. To achieve this, numerous problems must be solved, e.g. coupling molecular level structures and devices to larger-scale platforms and devices, combining "top-down" and "bottom- up" assembly in order to create new classes of functional materials or to manufacture an integrated system, controlling the interface between biological and nonbiological components in one architecture, and coupling mechanical forces across nano, micro and macro scales, including the control of fluid-state transport or optical behaviour.

2. MEMS market evolution and training needs

The Microsystems domain is different from electronics. In this area actors are small and medium companies (Bosch, Tronics, Memscap…) and foundries (ST in Europe). Microsystems market is now 40 times smaller than electronic market. Separation between design and technology is effective in microelectronics but not in Microsystems industry and generally the same companies are involved with both activities.

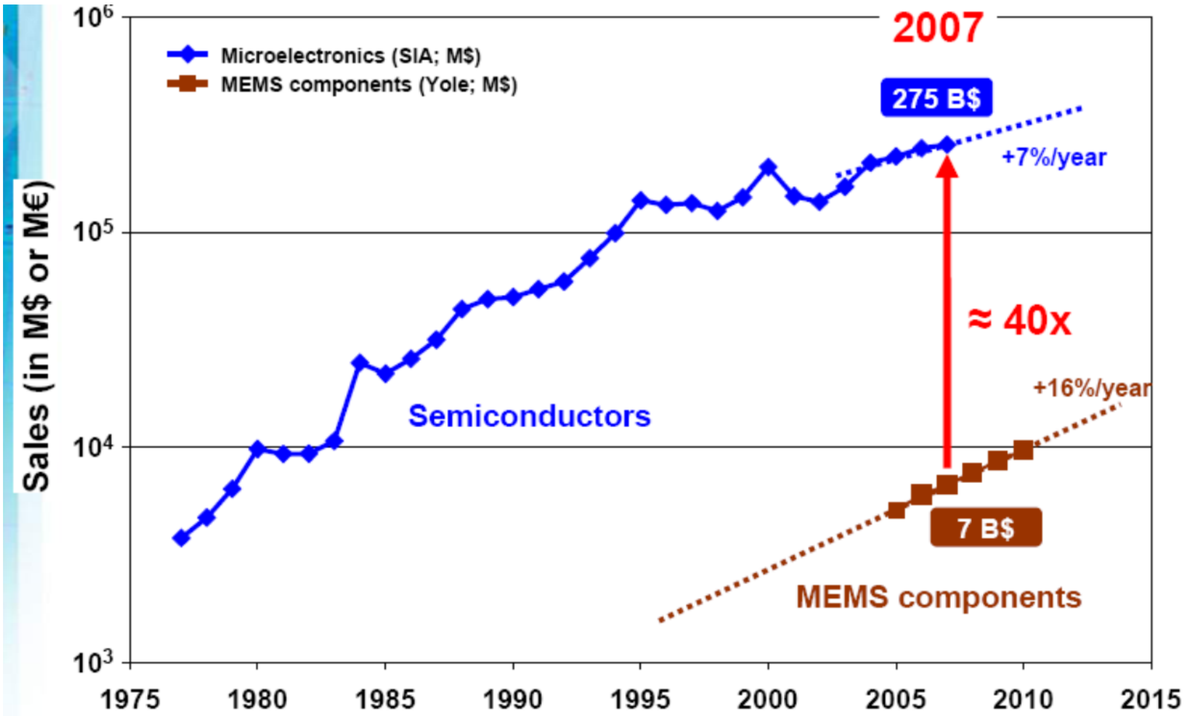

Figure 2: MEMs market

The relatively small size of Microsystems market explains the difficulty to have a common training strategy applicable to different Microsystems areas. In Microelectronics industry equipment suppliers and software suppliers are able to develop specific training materials because many designers and clean room operators are using same equipments and same software. In Microsystems industry it is not the case and only a few people are working with a defined technology. That explains training is generally internally organized. Nevertheless more or less generic technologies have been identified and can be considered as the minimum training background knowledge for Microsystems production activity and research. This background can be defined as follows:

- Knowledge of main MEMs applications
- Principles of MEMs and design methodology
- Description of specific MEMs technologies and related equipments
- Introduction to advanced topics (NEMs, biointerfaces, 3D assembling, new materials)
- Introduction to process with selected practicals.

This will be proposed as a standard MEMs introductive course.

To have a more precise definition of training needs, it is possible to have an analysis of the different MEMs products and to identify the required competences to produce these devices.The main objective of this survey is to list training requirements and to define some recommendations. The first task is to identify the most important competences required for microsystems design and to identify specific skills and competences.It is possible to define two classes of competences:

- The basic competences include physics, material sciences, signal processing and electrical engineering with a special focus on mixed signal integrated circuits design. We consider integrated circuits process technologies and complex SOC design are studied in NanoEurotraing program and not in MSTEurotraining program.

- Specific Microsystems fabrication competences are mainly specific process technologies (deep etching and grinding process), packaging and interconnect technologies. Other specific technologies can be identified: microfluidics, flexible substrate and polymer electronics process, surface chemical processing, miniaturized vacuum technologies. micromechanics is not considered as a specific competence because it is not so different from traditional mechanics. Deposition and lithography technologies are inspired from Microelectronics technologies.

More than the control of each process step, the Microsystems design seems to be the most important competence. Microsystems design includes not only the control of a complete design flow generally based on a top-down methodology but also the multiphysics approach allowing use of different physical principles and different technologies. Applied to a defined application area this design competence (design of system architecture and design of the different parts of the system) it is a very important differentiation factor to insure competitiveness. One other competitive advantage is the precise knowledge of different MEMs markets and estimation of cost interest of miniaturization and collective process in a given application area.

In the future many applications will be developed around biology and electronics interfaces. NEMS appear now as extremely miniaturized devices and introduce new problems. Use of organic materials and development of new smart materials for energy applications appear also promising. To have a more precise definition of training needs, it is possible to have an analysis of the different MEMs products and to identify the required competences to produce these devices. An interesting analysis is given figure 3 comparing different MEMs products.
According to this analysis the main training needs may be specific training for the most important MEMs products: RW heads, inkjet heads and MEMs displays. That would minimize importance of emerging technologies and future of smart systems. In fact a large set of competences is necessary and the multidisciplinary approach is important. Future product generations will be smart integrated systems of increasing complexity which use the convergence of a whole range of technologies for the improvement of the characteristics of the overall system. These systems are often networked, energy autonomous, miniaturised, reliable. They are becoming increasingly complex, involving other disciplines and principles. Often operating within larger systems they are embedded in, they interface with each other, with their environment and with the individual persons.

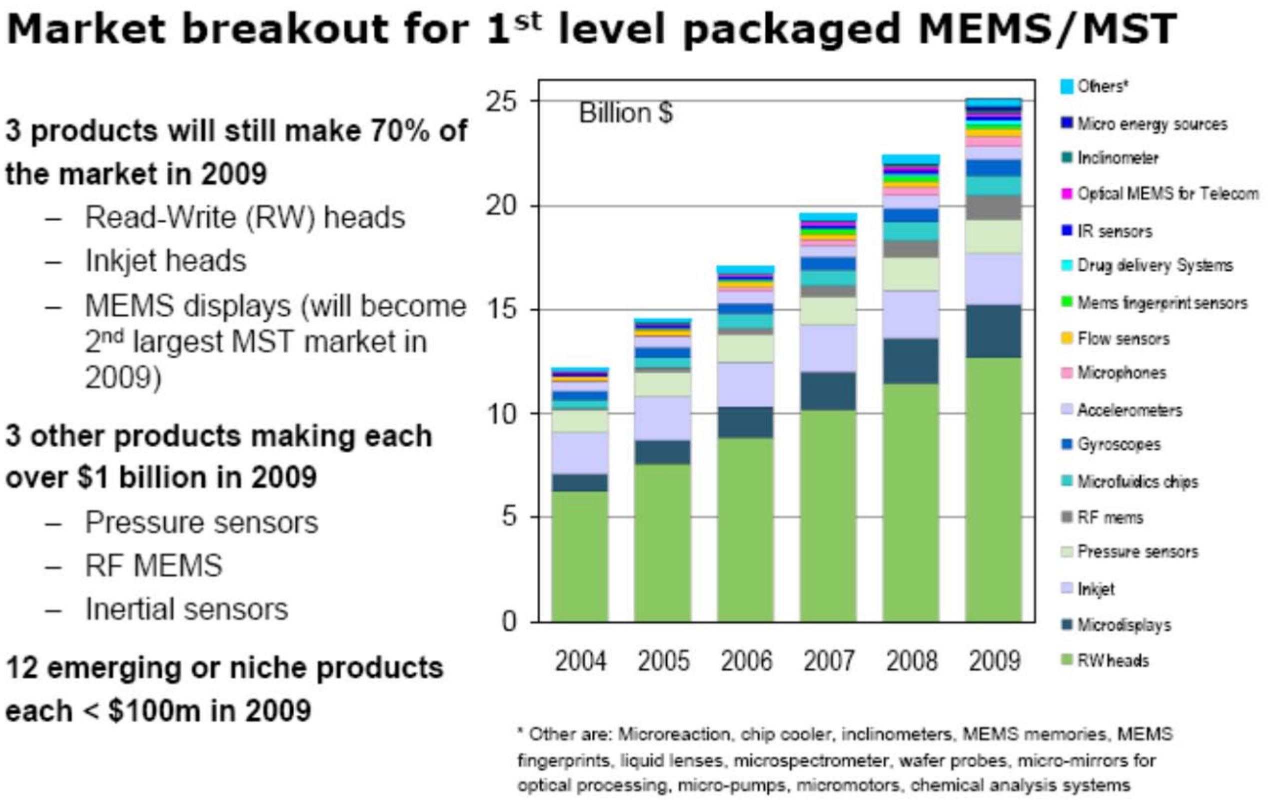

Figure 3: MEMs market in 2009 (Patrick Salomon, COMS 2008)

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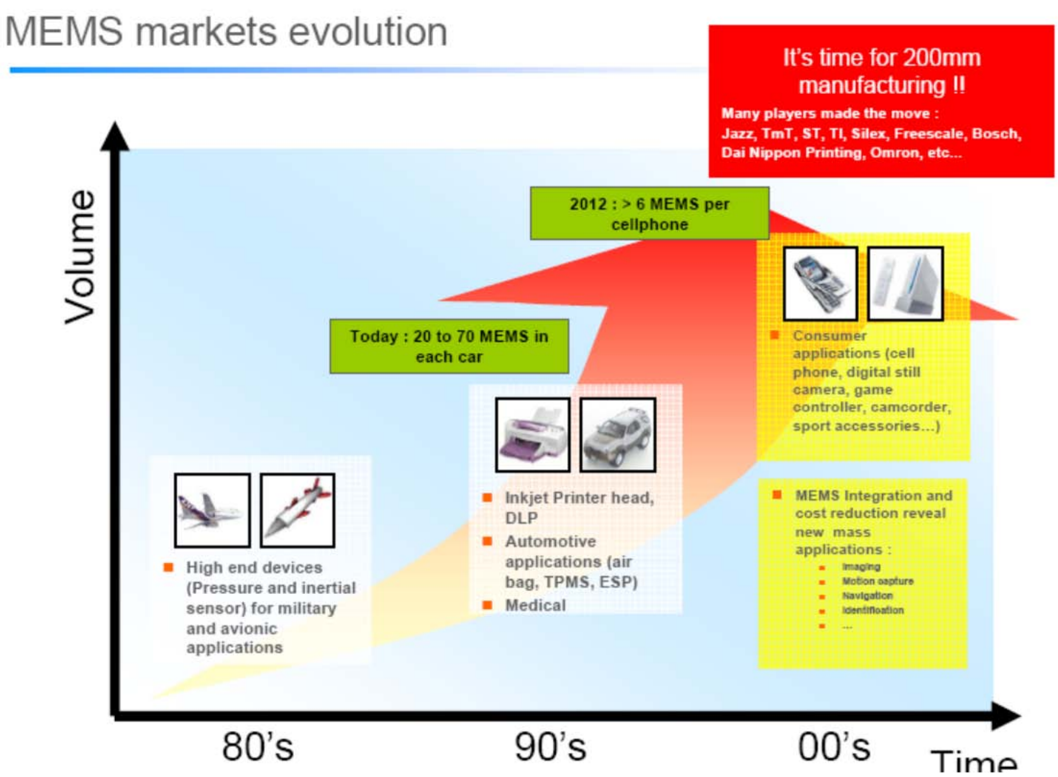

Figure 4: MEMs market evolution

New features like ubiquitous information, security, ease-of-use or the integration of mechanical, optical or biological functions will be developed using different technologies. Figure 4 shows evolution of products with increase of complexity and opening to new markets especially consumers and health care products

3. Analysis of questionnaires

WE developed in Eurotraining project a questionnaire adressing MEMs training users and contacts in Industry. The first one was sent to FSRM customers and the second one to LETI contacts. Results of this enquiry lead to propose a typical course sent to the same data base members. Choice was to send a very simple questionnaire to optimize feedbacks with special attention to training domains and training duration. The main conclusions (Figure 5,6 and 7) are the following:

- Even if new topics are identified, traditional competences remain interesting (sensors and actuators principles, fabrication methods).
- A training duration of 2 days is generally required.
- Interest of practicals and hand-on exercises is not clearly expressed. Compatibility with a short training duration is maybe the reason.

4. Recommendations coming from analysis of funded European projects and discussions with industrial managers.

The MINAM vision report addresses the strategic research priorities in four key areas:

- manufacturing of nanomaterials,
- processing of nanosurfaces,
- micromanufacturing processes
- development of integrated systems and platforms for micro- and nanomanufacturing.

In its conclusions, the MINAM report states that Micro and nanomanufacturing technologies are becoming a source of major competitive advantage in sectors such as consumer electronics, automotive, healthcare and defense industries. Some of the major challenges facing the European precision manufacturing companies today are increasing demand for a wider variety of microproducts and an increasingly global and distributed supply chain. One of the objectives of MINAM is the establishment of the technology base for batch-processing a variety of materials that will become an integral part of production equipment and manufacturing platforms for the factory of the future. Based on these reports, we can identify some of the skills that engineers will have to master in the close future:

- Cost effective design of MEMS for consumer markets
- Legal issues related to health care markets
- Production techniques for very high volumes and all subsequent topics, such as
    - 8” standardized processes
    - Wafer level packaging and testing
    - High speed automated handling and assembly
    - Quality control
- Batch processing, not only for Silicon wafers

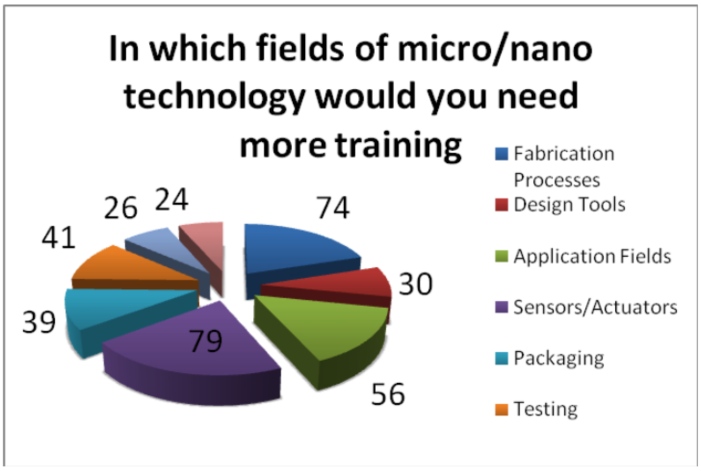

Figure 5: Training needs / areas

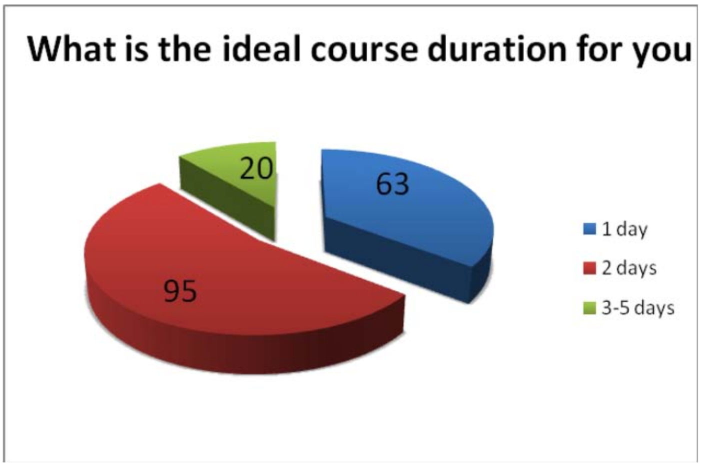

Figure 6: Expected training duration

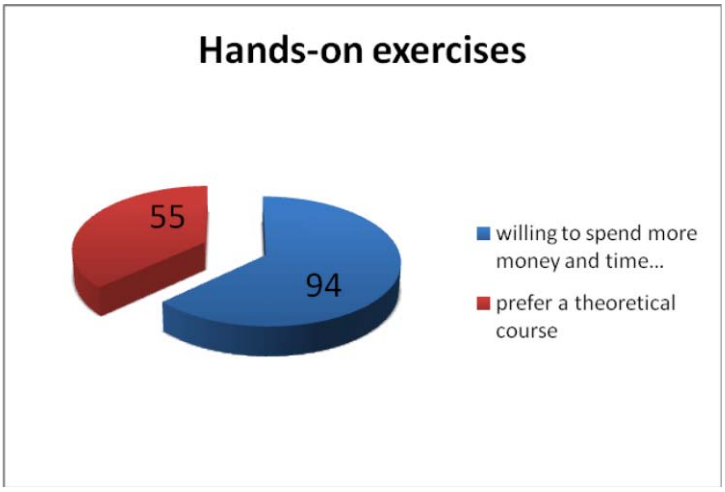

Figure 7: Interest of hand-on exercises

Low power techniques and energy harvesting technologies have been identifier as key points for MEMs applications. Design of integrated systems and principles of power electronics are basis courses of any engineering curriculum. They are enough to prepare engineers with general competences for the design of power electronics for harvesters. Specific training goes through forums, conferences and tutorials.
Various international conferences focus on power electronics. IEEE organizes the ECCE (Energy conversion congress and Expo) and the APEC (applied power electronics conference and exposition). The ISSCC (International Solid State Circuit Conference, a high level conference organized by IEEE) also hosts presentations and papers on power management.
Power management circuits for harvesters fabricated by MEMS technologies are dealt with also at the PowerMEMS conference which rotates between Asia, Europe and US. Recommendations for low power applications are the following:

- To promote highly interdisciplinary training courses in devices and materials for technology fusion. Nanotechnology (in a broader sense than nanoelectronics) makes it possible to develop new components which may be used together with electronic components in system design. This includes for instance micromechanical systems, photonic systems, biochemical systems. Also, the combination of digital and analogue/RF circuits may call for combination of different technologies. Together with electronic components, such components open ways to the design of new integrated systems and applications, and research and education is needed concerning such technology fusion options.

- To encourage the creation of courses in “ultra low-energy” designs (so topics will be a mixed of sub-threshold, asynchronous, fault-tolerant circuits and architectures, technology variations tolerance, power management)

Many recommendations are expressed in different areas and definition of general recommendations is not easy. Nevertheless if we consider two Microsytems training users groups definition of recommendations are more easy to define. The first one is the group of MEMs users and the second of MEMs manufacturers (design and process).

- MEMs users are mainly interested with short (two days) and state of the art overview training courses. Marketing and cost aspects have to be included in these courses. Even if this kind of course is generally provided from training centers and universities it seems difficult to find training with an effective state of the art overview of market and technical aspects.

- MEMs manufacturers generally developed internal training for specific used MEMs technologies. They occasionally use training centers and universities training courses if these courses are in relation with advanced microtechnologies or new technical domains. As examples the following technologies can be listed:

  - Advanced materials
  - Biointerfaces
  - Microfluidics
  - NEMs concepts
  - Low power technologies (scavenging and low power design)
  - New SIP and interconnect technologies

- Polymer technology use in Microsystems

For example the Eurotraing website proposes the following courses;

1: Course: Polymer Optoelectronic Technologies and their Applications
2: Course: Microsystems in Biomedical Engineering and Medical Products
4: Course: Labs-on-Chip Technologies: Basics and Applications
3: Course: Existing and New MEMS Emerging Markets

5. Conclusions

Analysis of questionnaires, discussions with MEMs users or manufacturers and analysis of different working groups or projects reports allow to define the main training needs for the next years. Eurotraining project integrates these conclusions and invite courses providers to propose courses in line with these recommendations.

Aknowledgments

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References

- http://www.eurotraining.net/

- http://www.smart-systems-integration.org/public/about

- http://www.smart-systems integration.org/public/documents/eposs_publications/060516_Vision_Paper_final_mit%20Deckblatt.pdf

- http://www.smart-systems-integration.org/public/documents/eposs_publications/EPoSS%20Strategic%20Reserch%20Agenda%202009%20-%20Pre%20Print.pdf

- http://www.smart-systems-integration.org/public/events/4th-european-conference-on-smart-sensing-and-context-eurossc

- ftp://ftp.cordis.europa.eu/pub/fp7/ict/docs/micro-nanosystems/g2-microsystems-proj-portfolio-07-08_en.pdf

- http://www.stimesi.org/

- http://www.fp6-minami.org/
- Darnell Group, “Energy Harvesting, Micro Batteries and Power Management ICs: Market Forces and Demand Characteristics, Second Edition”, http://www.darnell.com/store, Oct. 2008

- Darnell Group, “Energy Harvesting, Micro Batteries and Power Management ICs”, http://www.darnell.com/store, Oct. 2007

- iSuppli WTC, “Custom Technology & Market Briefing 7: Micro energy sources and micro energy scavengers market”, http://www.wtc-consult.com