4-2005

The MEMS Applications Engineer

Mario H. Castro-Cedeno
Rochester Institute of Technology

Recommended Citation

Castro-Cedeno, M.H. (2005)The MEMS Applications Engineer. Paper at the 2005 ASEE Middle Atlantic Section Conference, Binghamton University, April 8-9, 2005.

Session 1234

The MEMS Applications Engineer

Mario H. Castro-Cedeno
Rochester Institute of Technology
1 Lomb Memorial Drive
Rochester, NY 14623-5603

Abstract

Micro-electro-mechanical systems (MEMS) are miniaturized devices that can sense the environment, process and analyze information, and respond with a variety of mechanical and electrical actuators. Although a few very successful applications have been demonstrated, these have been in very large markets such as accelerometers for the deployment of airbags and assemblies of micro-lenses for televisions and light projectors. Many more applications are needed to fulfill the expectations of futurists and MEMS promoters. Future applications in traditional industrial and consumer products will evolve as MEMS demonstrate that they can reduce cost and improve performance when compared to discrete traditional components.

A new kind of system engineer will integrate the various sensing, computing and actuating elements into single chips by re-using existing designs for components. The designs will be available in a catalog of intellectual property available for license. Because of the standard designs, the chips will be produced cost-effectively by commercial foundries in smaller quantities than is possible today.

This article describes the MEMS Applications Engineer position and the body of knowledge required for the position. It also describes the tools needed to design the MEMS of the future.

Introduction

MEMS are a logical extension of microelectronics and IC technology[1-3], incorporating traditional electronics with mechanical systems like sensors and actuators. MEMS can include two or more of the following subsystems: sensors, actuators, a power supply, a central processing unit (CPU) or microprocessor, and/or a communication interface (see Figure 1). Micro-optoelectromechanical systems (MOEMS) are similar to MEMS with the addition of optoelectronics. A MEMS (or MOEMS) device can sense the environment, perform calculations with the information, and initiate actions or signal the outside world. It should be noted that both MEMS and MOEMS vary in complexity. Some may lack the computational capability, the actuator, or other subsystems, but as long as they include more than one feature, it is appropriate to call them MEMS/MOEMS.

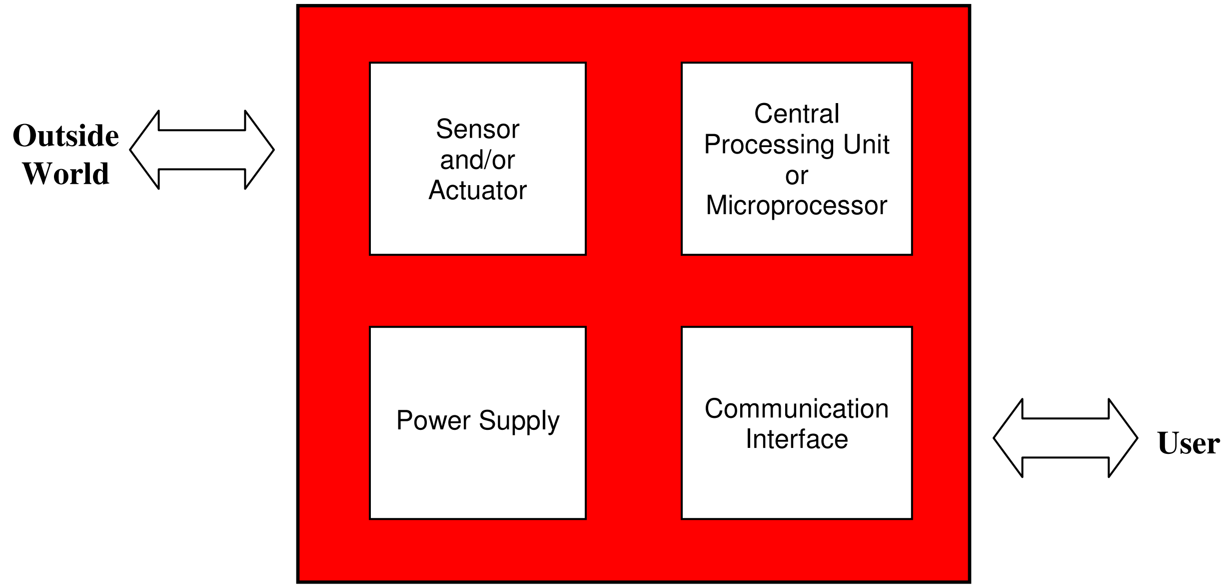

Figure 1 – Components of MEMS

As an extension of IC technology, the production of MEMS devices benefits from years of IC manufacturing experience and can even be produced in similar equipment. Technologies such as microlithography, chemical and plasma etching, vapor deposition, and electroplating can be used to create the microstructures of MEMS. Silicon is the most common substrate but silicon carbide, metals, and plastics are also used. Table 1 presents a brief history of the technology. Some examples of MEMS are the accelerometer that deploys automobile airbags and the pressure sensor that optimizes the fuel/air mixture in a fuel injection system. Figure 2 shows that MEMS accelerometers are not only a technology milestone, but a market success as well.

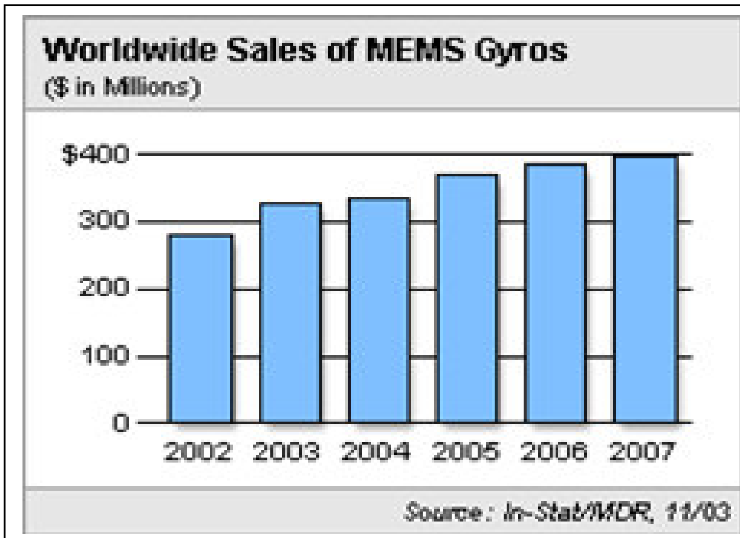

Figure 2 – Automotive MEMS

Table 1 – History of MEMS

1947	**Shockley et al./Bell Labs – Invention of the transistor**
1958	**Kilby/Texas Instrument – Invention of the integrated circuit**
1959	**Feynman – "There Is Plenty of Room at the Bottom"[1]**
1962	**Tufte et al./Honeywell – First etched silicon membrane**
1972	**National Semiconductor, Inc. – Commercial silicon pressure sensor**
1977	**Texas Instrument – Thermal print head**
1977	**IBM – Ink jet nozzle**
1982	**Petersen – "Silicon as a Mechanical Material"[2]**
1983	**Angel, et. al. – "Silicon Micromechanical Devices"[3]**
1980–1990	**Beams, motors, valves**
1990–2000	**Accelerometers, gyroscopes, hinges, automotive applications**

1 R.P. Feynman, "There Is Plenty of Room at the Bottom," December 26, 1959, lecture at the California Institute of Technology.

2 K.E. Petersen, "Silicon as a Mechanical Material," Proceedings of the IEEE, Vol. 70, No. 5, p. 420, May 1982.

3 J.B. Angel, S.C. Terry, and P.W. Barth, "Silicon Micromechanical Devices," ***Scientific American*****, Vol. 248, p. 44, April 1983.**

In 2004, well over $300 million in MEMS accelerometers were sold worldwide and the size of the market is expected to grow to $400 million by 2007. Other examples of proposed MEMS applications in the automobile industry are shown in Figure 3.

The Future of MEMS

Figure 4 is a roadmap for the future of MEMS, listing applications that will likely become possible as the technology is developed. It is expected that increasingly complex systems will

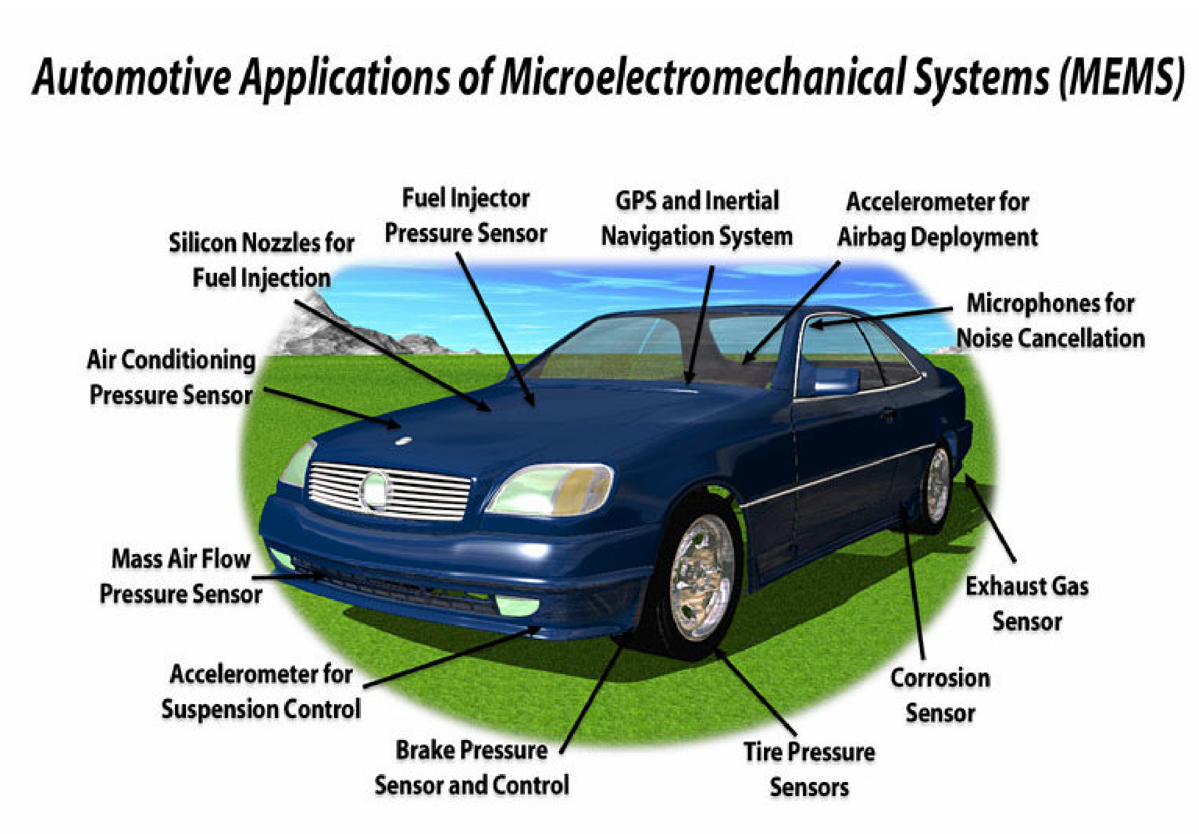

Figure 3 – Automotive MEMS

become possible in the future, but technological achievements alone will not result in the large market penetration forecasted for MEMS technology. It is reasonable to expect that the majority of future MEMS applications will be invented for civilian or commercial applications. The inventors of these future applications will have different education, experience and goals compared to today's MEMS engineers.

In the past, the goals of MEMS engineers were to develop devices of increasing complexity and to demonstrate applications of the technology in new fields. The ultimate success was to demonstrate a "killer" or inevitable application that could create a new market that is large enough to sustain a new industry and its support infrastructure. Accelerometers, mirror arrays and ink jet nozzles are some examples, and the search continues, with RF-MEMS used for wireless-ID tags as the next likely success story.

But "killer" applications are few and far between and it is expected that in the future, smaller markets will be addressed. The extreme small market is a custom application resulting in a one-of a-kind device or at most a few thousand devices. This could be done cost-effectively by re-using existing MEMS components and assembling them into systems. There is no need to re-invent the technology for a MEMS mirror or a thermal actuator because patents already have

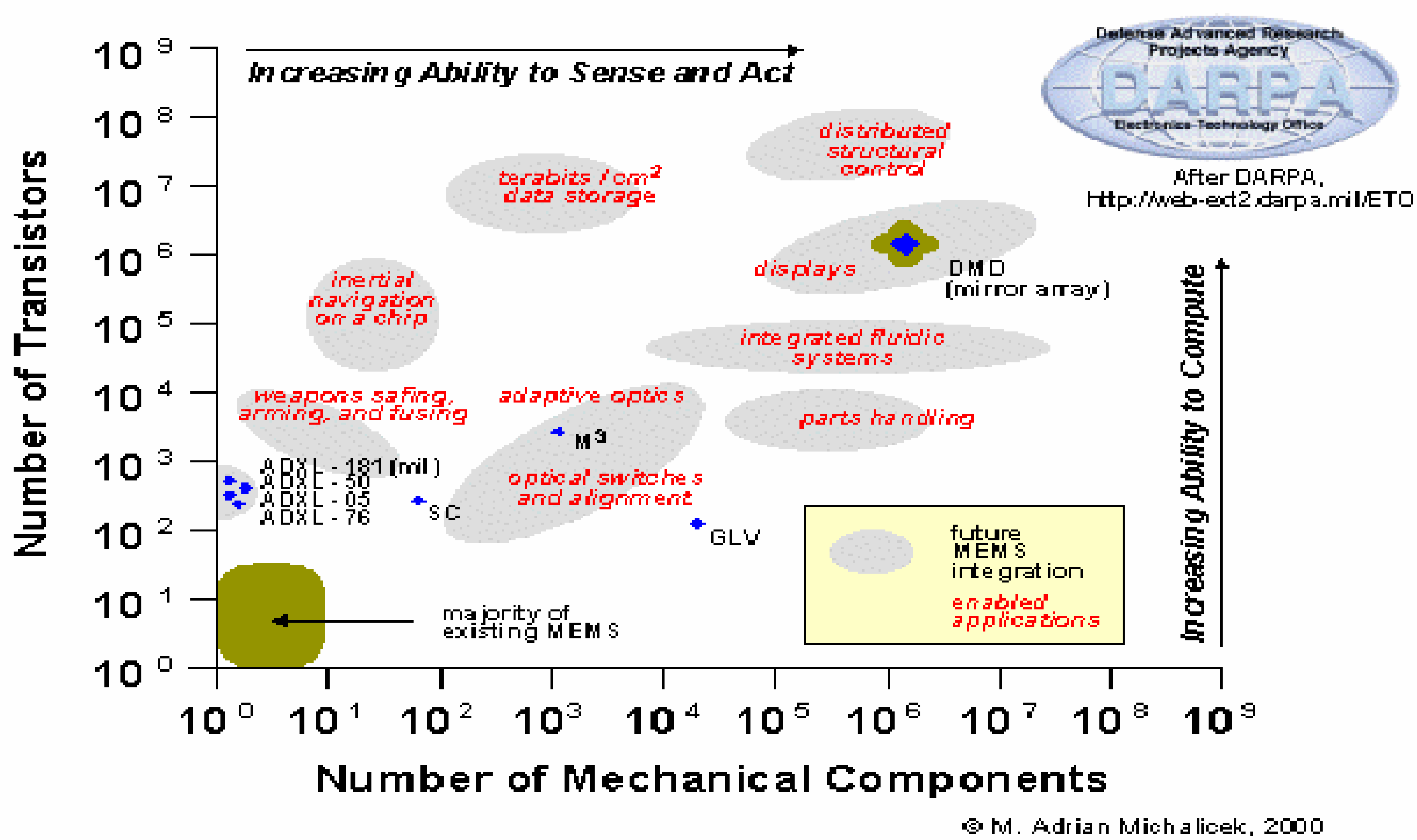

Figure 4 – MEMS Roadmap by DARPA

been granted for examples of those components. With access to intellectual property in the form of a catalog of designs for microprocessors, memory, sensors and actuators, the future MEMS engineer's tasks will be to select the appropriate components and to optimize the design to meet requirements. This is similar to the neighborhood PC retailer that buys subassemblies and builds them into a system. The devices can then be manufactured by MEMS foundries. Each foundry will offer different components in its catalog because their equipment and processes vary, but by selecting from these standard components, a design engineer is assured that the system he/she designs can be fabricated cost-effectively.

The tools of the MEMS application engineer of the future will include system modeling software similar to today's software, but capable of incorporating components from the foundry catalogs (see Figure 5). Present as well as future tools can model multi-physics systems in which more than one field force (inertial, thermal and/or electrostatic) influence the behavior. The goal of the MEMS applications engineer of the future will not be to design new components, but to integrate existing and proven components, insure compatibility and meet requirements. This role is similar to the role of today's electronic or systems engineer building a new cellphone, or an automotive engineer selecting components to build next year's model. This new role de-emphasizes manufacturing; which will become a specialty.

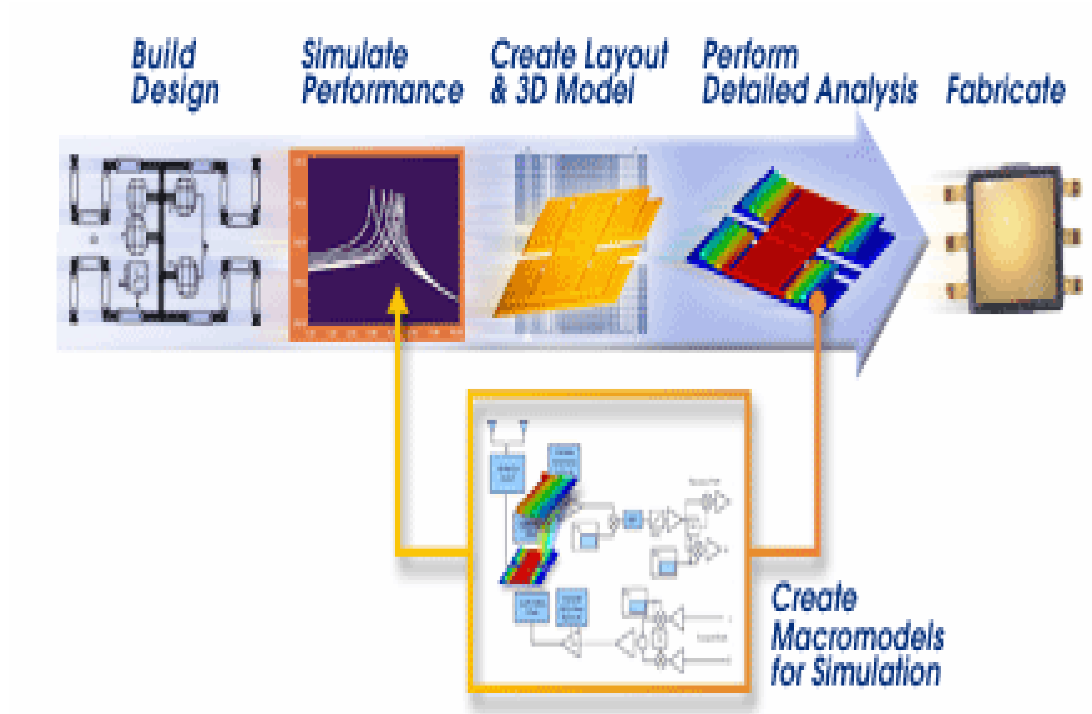

Figure 5 – MEMS Design Software by Coventor, Inc.

Educating the MEMS Application Engineer

Although MEMS and their applications are beginning to penetrate the undergraduate curriculum, most universities do not yet have a sequence of courses that would qualify a student for an entry level position in the MEMS industry. Today's MEMS engineer is, typically, a very specialized MS or PhD student or graduate. Their training includes interdisciplinary subjects from electrical, mechanical and systems engineering and the physical sciences. A significant component of the training is laboratory time in which the student learns to make devices. Today's education emphasizes equally the manufacturing of devices, design of components and the modeling and integration of systems. In the future, to be able to fit MEMS in the undergraduate curriculum, students should specialize in only one of the three areas.

Whereas today's MEMS engineer sees himself or herself as a MEMS specialist, in the future, the MEMS application engineer will see himself or herself as an automobile or aircraft engine designer, or as an entertainment engineer who design games or sports equipment. His/her specialty within the design team will be to develop chips that improve the performance of the product. A MEMS device will not be the end goal of the effort, but a necessary and important component or sub-system. His/her experience will be within an industry instead of focused on the technology. Many of them will opt for an MBA instead of an MS or PhD.

Universities will adapt to meet the demand for engineers that are MEMS literate and can use the technology to create useful devices within the context of their industry. Most likely, the majority of MEMS application engineers will receive their training at the undergraduate level. The degree of the MEMS application engineer will probably be in one of the traditional fields such as Mechanical, Electrical, Chemical or Civil engineering or engineering technology. They will gain their MEMS competence by taking a series of interdisciplinary courses in the form of a minor or sub-specialty. The capstone of this education will be a design course that requires development of a MEMS chip as part of a larger system, for example controller for a fuel injection system.

Conclusions

1. Today's MEMS engineers focus on increasing performance and in demonstrating MEMS applications in new fields. This is expected for a new technology.
2. Many applications of MEMS will require the development of custom chips to improve existing products. Industry will search for, and hire engineers that can do this. A generic title for this position is MEMS Applications Engineer.
3. The role of the MEMS Applications Engineer is not to develop new devices or processes, but to select from existing designs for devices and integrate components into systems. His/her role is the role of today's systems engineer, but the technology is MEMS instead of electronics.
4. The MEMS engineer will also need to understand his or her industry and engineering specialty electrical, mechanical, civil or chemical.
5. MEMS application engineers must learn the tools of the trade during their undergraduate education.
6. It appears that the most efficient training for MEMS applications Engineers could be a course sequence providing specialization within the traditional engineering specialties.

References

1. W.S.N. Trimmer, "Microbots and Micromechanical Systems," *Sensors and Actuators*, September 1989.
2. G. Stix, "Little Big Science," *Scientific American*, September 2001.
3. M.J. Madou, *Fundamentals of Microfabrication*, CRC Press LLC, Boca Raton, Florida, p. 450, 1997.

MARIO H. CASTRO-CEDENO

Mario H. Castro-Cedeno is Assistant Professor in the Department of Mechanical and Manufacturing Engineering Technology and Packaging Science at the Rochester Institute of Technology (RIT) in Rochester, NY. Before joining RIT in December of 2003 he accumulated 30 years of engineering and management experience at various firms, including NASA and General Electric. He was granted B.S. and M.S. degrees in Mechanical Engineering by the University of Puerto Rico and a Master of Engineering degree in Materials Science and Engineering by the University of California at Berkeley.