A COMMUNITY COLLEGE - INDUSTRY PARTNERSHIP TO DEVELOP AN AUTOMATED SYSTEMS TRAINING PLATFORM

Abstract

SMC International Training, Inc., Intel, the National Science Foundation and Maricopa Advanced Technological Education Center (MATEC) partnered in 2001 to develop a technician training platform for highly automated production systems. The system was to have broad but significant applications in a variety of high tech industries including electronic and nano devices, aerospace subsystem manufacturing, thin film and optics production, biomedical device material handling, and highly automated cargo transport control and monitoring systems. Twelve community colleges in the seven states vying for national recognition as high tech manufacturing regions were invited to join this coalition. These educational institutions participated with industry partners in the conception of and ultimate realization of the HAS 200 (Highly Automated System) Training Platform, currently available from SMC - International Training. HAS 200 training systems were installed at the Pilot schools over a 12 month period in 2003 – 2004. The Pilot group has been facilitated and coordinated by MATEC, a National Science Foundation National Center for Advanced Technological Education. This paper describes the long range planning and implementation of this project, and lesson learned during this long term development partnership between industry and academia.

Equipment Concept Development

The role of manufacturing and production technicians in many industries is rapidly changing. Technicians are now required to have a working understanding of modern manufacturing concepts. Thus, educational institutions at both the two- and four-year levels must have the capacity to teach Factory Dynamics Concepts (theory and practice) including: Theory of Constraints, Tool Capacity Utilization, Throughput, Cycle Time, Yield, and Manufacturing Automation Systems. This requirement has created a need for a hands-on training and education system that emulates a modern manufacturing environment (e.g., a 300mm semiconductor manufacturing facility, or “fab”) with a MES (Manufacturing Execution System) to integrate production processing with the ordering processes for system optimization, WIP (Work in Progress) identification and tracking systems, and an AMHS (Automated Materials Handling System).

Intel, its industry colleagues and its education partners recognized this need and approached the problem in two steps: 1) skills standards development and 2) collaboration to develop and pilot the training and education system to emulate the modern manufacturing environment. A collaboration of industry and educators conducted a year-long study to create a formative set of skills standards to guide technician education.[1,2] Published in 2002, *The National Skills Standards for Technicians in Highly Automated Manufacturing Environments* (www.matec.org/work/skills)[3], took a forward look at the knowledge, skills and abilities required. A clear need for the understanding of workflow concepts, factory metrics and manufacturing execution systems emerged from this study. It is important to note that these components are emerging in automated fabrication facilities in all types of industries including, but not limited to semiconductor manufacturing, food processing, metals, wood, and plastics fabrication, electronics, automotive, and distribution facilities.

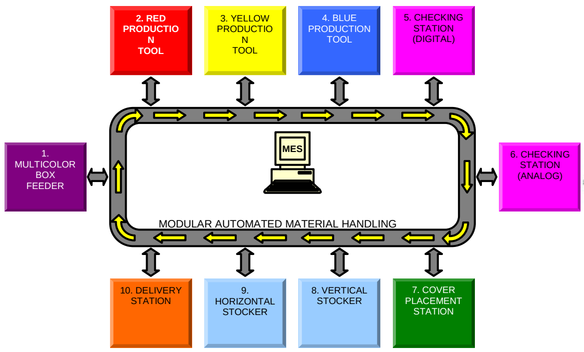
The second challenge was to create a laboratory-learning environment that simulated a sophisticated manufacturing operation that could be deployed in a community college or four-year college setting. In the late 1990s some Arizona educators had started discussing how community colleges might better prepare students for automated workplaces. The discussions widened to include Intel and the SMC International Training Corporation (SMC-IT). Intel defined "use cases" that specified how the tool was to be used. For example the tool should command the movement of materials and execution of processes through the master control of a Manufacturing Execution System (MES). Multiple Process tools working efficiently at high speeds should automatically issue quality metric data fed into a statistical process control data center. The MES should anticipate process variations and automatically feed forward the corrective actions. Data should stream from tools, stockers and inventory control with Work in Progress (WIP) monitored in real time.

Driven by the Skill Standards and the industry input that defined how the system was to be used, SMC-IT designed and developed a unique, 11 station laboratory tool for automation systems training called the HAS-200. Working with MATEC, a pilot group of 12 community colleges and Arizona State University joined the pilot program and purchased the new tool in 2004.

Equipment Overview

The HAS 200 Training Platform was designed to serve as a training platform for the system knowledge and skills discussed above (Theory of Constraints, Tool Capacity Utilization, Throughput, Cycle Time, and Yield, and Manufacturing Automation Systems) by including a MES, automated storage and handling, and product identification and tracking systems. Additionally, the HAS 200 can be used for hands-on instruction and lab activities covering the underlying mechanical equipment, actuators, sensors, programmable logic controllers (PLCs) and SCADA (Supervisory Control and Data Acquisition).

The HAS 200 is an integrated 10-station production cell, made of industrial hardware components. There are additional separate stations for raw material inventory and a computer interface station for system operation and control. The integrated ten-station system includes one container retrieval station, three container filling stations for three different colored products (small red, yellow and blue plastic beads), two test stations for product integrity that measure the height of the product in the container, a cap and label station, both a horizontal and a vertical storage station for dealing with work in progress, and a dispatch station. Nineteen different products can be produced by combining three different colors of beads in three different weight options. Additionally, the system comes with a MES, EdMES and a visual supervisory suite, 3D Supra. The EdMES software will ultimately have the functionality described earlier. A schematic of the system layout and a photograph are provided below below.



Pilot Consortium

Community Colleges across the country were recruited by MATEC to participate in the Pilot program. The project would support up to 12 schools. The pilot schools would get a special price for the new trainer, get training and support from SMC-IT and were expected to participate in curriculum development to support the equipment. The curriculum to be developed was defined to be a single three or four credit course with 15 modules, entitled “Fundamentals of Highly Automated Manufacturing Systems,” or FHAMS. Additionally, the pilot group would get group and individual training, work with SMC to debug both the hardware and the beta version of the MES software and make suggestions for changes that would enhance the system for education and training. The community colleges were selected and contracts signed in the fall of 2002 for participation in the HAS 200 pilot group.

HASS-200 Pilot Group Community Colleges

Arizona State University Polytechnic, Mesa AZ	Hillsborough Community College, Tampa FL
Bristol Community College, Bristol MA	Maricopa Skill Center, Maricopa Community Colleges, Phoenix AZ
Central Arizona Community College, Coolidge AZ	Mesa Community College, Mesa AZ
Chandler Gilbert Community college, Chandler AZ	Mohawk Valley Community College, Utica NY
Chemeketka Community College, Salem OR	Pima Community College, Tucson AZ
Columbia Gorge Community College, Dalles OR	Quinsigamond Community College, Worchester MA
Dona Anna Branch Community College, Las Cruces NM	San Juan Community College, Farmington NM

In the spring of 2003, several faculty from each of the pilot schools attended a 4-day training session hosted by MATEC at Arizona State University using the first installed system. The workshop was taught by Intel and SMC-IT personnel and covered details of the system and some of the supervisory modules, some hands-on exercises on the recently installed system at Arizona State University, as well as logistic and installation information and requirements for the pilot systems that would be delivered in the subsequent 6-9 months. The EdMES software was not available at this time, so all activities during the workshop were conducted in the manual mode. Faculty also shared ideas for how to integrate the system into existing programs and courses in a variety of programs.

The next phase involved delivery and installation of the HAS 200 trainers from Spain to the pilot schools. All installations were completed by the end of 2004 with a beta version of the EdMES software. Installation involved one full day of training at each pilot school and included one software representative and one hardware representative from SMC-IT plus one community faculty from the pilot group who served as a stateside representative of SMC-IT and who coordinated technical issues that occurred with the newly installed systems with SMC-IT in Spain.

Once the installations were complete and the pilot group faculty had some time to run their own systems, they began the task of developing curriculum for the system. MATEC spearheaded this effort by providing leadership and coordination of the development activities as well as a web forum for file and information exchange and a repository for the FHAMS curriculum as it was developed. MATEC also hosted a pilot group meeting at its annual conference each July from 2004-2006. Additionally, they offered a professional development workshop at each of these conferences that specifically supported the technology of the HAS 200. MATEC also provided the format and final editing of the FHAMS curriculum modules and houses these modules on the MATEC website (www.matec.org). Regular phone conferences and communication among the pilot schools and with SMC-IT in Spain has also been supported by MATEC between the annual meetings.

Fundamentals of Highly Automated Manufacturing Systems Course Outline

Unit	Topic	Unit	Topic
1	HAS 200 System Overview	9	Production Tracking
2	Intro to 3DSupra & Actuator Movements	10	Intro to SPC Charts
3	Sequences	11	Problem Solving & SPC Charts
4	Cycle Time I	12	Locating Bottlenecks
5	Cycle Time II	13	Work Order Management
6	Routine Procedures & Documentation	14	Factory Metrics

The curriculum units were developed by individuals in the group and are being beta tested by others. At this point, the completion of the FHAMS modules is a function of getting the final version of the MES software installed on the pilot systems. Installation is anticipated in January 2007. Although most schools have not and will not add an entire new course based on the HAS 200 as the “Fundamentals” course, the unit modules are currently being implemented in a variety of courses in different curricula at all the pilot colleges.

Lessons Learned

Did we achieve the original goal? The original goal was to produce a system that would allow faculty to teach some of the more esoteric aspects of Factory Dynamics using empirical techniques. While the tool has proven to be useful to teach some of the aspects of automated manufacturing, robotics, and networking, it cannot yet be used to teach the Factory Dynamics topics as planned. The system identification and conception was good and the project will eventually reach the intended goals. However, the delays with testing, debugging, and redevelopment of the Manufacturing Execution System (MES) software (EdMES) have made the factory dynamics concepts difficult to teach with the system thus far. On a positive note, there will be software revisions soon that should satisfy most all of the initial goals.

Did the product development process and experience work for both the industry and educational partners? The design and development process worked well once it got started. CAC and Intel had been talking with SMC about the tool without moving beyond the conceptual phase. Finally, SMC created their International Training (SMC-IT) organization and MATEC and Intel began to apply the skill standards they had very recently compiled and presented them to SMC International Training. SMC-IT came up with the manufacturing process (colored beads in plastic containers) quickly, defined the functionality of the MES, and introduced the idea of a visual supervisory suite (3DSupra) which was not part of the original concept. The inputs of industry leaders including Intel as well as all the educational contacts and experience of MATEC and the pilot group gave this project a very powerful protocol for developing the best product of its type. Additionally, the cooperation with experts on the MES functionality level has provided professional and state-of-the art knowledge for all members of the development team not currently knowledgeable on this topic.

What changes might be made for the "next time"? The development of the software for the Manufacturing Execution System (MES) has by far been one of the project's greatest challenges. The software challenges faced for the HAS-200 are currently available only in sophisticated commercial MES systems. Applying the necessary algorithms to the new developing training platform has taken more time than anticipated. In retrospect, the development in this area could have been scheduled in a more graduated approach, so that supervisory and control functionality preceded the fully developed MES functionality for testing and implementation.

From SMC-IT's perspective, their own lack of proficiency in MES, has been the cause of much delay in the software development. They may have been better served with a more local partner for this effort to provide more opportunities for the hardware and software development processes to interact during all development stages. This also may have provided more opportunities for testing subsystems as they were developed. Nonetheless, even four years after starting, this project is on the cutting edge of applied MES platform development for production industries.

On the other hand, one of the original specifications for the MES was that it should be in a programming language that would be familiar to a college student, that it is modular, and that it is documented to the point that a student could write additional modules and link them into the program (e.g., an Advanced Program Control module). Without these strictures it would have been possible for us to partner with an existing Automated Manufacturing vendor to modify their MES to work with the HAS-200. This partnership might have also increased the visibility of the system in industry and might have been an additional source of financial support and subsidies for the colleges. The college faculty has reinforced the merits of this pathway (using commercial instead of proprietary software) noting that they could possibly be using the system to the full capabilities of the MES at this point in time.

For the supporting curriculum, each pilot group faculty originally envisioned using the HAS 200 for different applications and different programs at their own institutions, these included degree and certificate programs in automation, robotics, electronics, advanced manufacturing, and others. This caused some disconnect in the early stages of curriculum development. Additionally, the pilot group got a late start with this activity, even with the curriculum that was feasible to develop with the HAS 200's current capabilities. In order to keep the curriculum on track and focused on the FHAMS course units, MATEC provided additional coordination and oversight of the production. The curriculum may have been better framed as a collection of independent modules rather than as an actual academic course to better fit the mindset of academic faculty and the structure of existing programs and courses. Finally, more effort to establish partnerships with engineering and technology universities and colleges near the pilot schools could have added additional perspectives on possible training and educational opportunities for using and applying the system as well as additional expertise. For example, Hillsborough Community College (HCC) in Tampa, has partnered with the University of South Florida's College of Engineering (also in Tampa) to develop and implement laboratory exercises for classes in both the electrical and industrial engineering departments. These departments have, in turn, offered technical expertise to support the equipment.

Concluding Remarks

The HAS-200 can be used to teach most of the topics currently covered in existing Manufacturing Science, Robotics, Automation, Controls, and Electrical Troubleshooting course offered at Community Colleges, Technical Schools, in-house corporate training centers and Universities. Twelve community colleges and two universities are currently using the system to teach various aspects of these topics in a number of different courses. Several systems have been used for operator and/or incumbent worker training in conjunction with local workforce boards. One Masters Degree Thesis has been completed and a second one will be by June 2007 using the HAS 200 integrated production platform**.**[4] Its important to note that the scope of both of these projects are outside that of the original concept but clearly indicates the viability of this system and its ability to support academic work at all levels. Additionally, a large number of demonstrations and hands-on activities and lesson on other topics have been developed by the pilot group for their own courses, recruiting, training etc.

The HAS-200 pilot program intended to provide community colleges with a system that can be used to teach the emerging skills and knowledge required for highly automated environments in a relatively affordable manner and to allow the pilot schools to share their instructional materials, best practices, and experience. The network of pilot school functioned reasonably well providing a supportive learning and sharing environment for the faculty involved, enhancing the productivity of the group. MATEC realized the importance of this aspect and provided the important infrastructure to facilitate this group. The pilot group is still closely networked and will likely remain so. This network will help to continue the development of a shared curriculum; troubleshoot problems; and provide professional development opportunities for the faculty involved. For the community colleges involved, the support provided by MATEC and SMC-IT has been invaluable.

The HAS 200 also provided the infrastructure for several other grant projects awarded to several of the pilot group community colleges in the past four years. These grants provided additional resources to the pilot schools and were integrated into the pilot group's activities, broadening the scope and applications of some the activities and the curriculum. Additionally, the system has drawn the attention of several in-house corporate training organizations. This may lead to either the purchase of a system by these organizations or to the collaboration between the companies and their local colleges where the colleges may have the opportunity to develop and administer training to corporate employees on a contract basis. Finally, the HAS 200 has been an important piece for recruitment of students and industry to get involved with manufacturing and production curriculum at the pilot schools. The system is a high-profile, visible sign that the college is serious about its technical programs.

Since the HAS-200 is designed to be open and flexible, it is possible that the tool can be modified or extended in any way required to meet the demands of a corporation or of a particular industry. This will ultimately allow the training to be designed so that the transfer of skills and knowledge from the HAS-200 environment to the real world is a near transfer.

Preparing the high technology industry's technician workforce with the skills and knowledge to be successful in the future will not be trivial. The exponential change in technology related tools for all of us has increased our ability to be productive. Future successful technicians will have high levels of software, troubleshooting, problem solving, and knowledge access skills. That, in addition to the variety of skills they have today will surely lead to higher levels of innovation, job satisfaction and further revolution in our technology industries.

A final observation reflects well on the initial development plan, i.e. the trends and directions anticipated over four years ago and the need for education and training in this area are even more valid today. Industries are continuing on the course that this project envisioned bringing more automation and MES into their facilities. This reinforces the education goals for the project and ratifies the investment made by the parties.

Acknowledgment

The project was supported by funding from the Intel Foundation and by significant investment by both MATEC and SMC-IT.

References

1) M. Lesiecki and B. Simington, "Development of Skills Standards for Technicians Working in highly automated Environments – A Key Component of Effective Manufacturing, presented at the IEEE Advanced Semiconductor Manufacturing Conference, Boston, 2002.
2) B. Simington and M. Lesiecki, "A Systems Approach to Automation Education and Training," presented at the IEEE Advanced Semiconductor Manufacturing Conference, Boston, 2004.
3) Lesiecki, Michael, Simington, Robert B., *Skill Standards for Technicians in the Highly Automated Manufacturing Environment*, Tempe, AZ: MATEC, 2002.