# A SUGGESTED MODEL PROGRAM FOR CIM EDUCATION

Sema Alptekin Colin Benjamin Yildirim Omurtag

Engineering Management Department
University of Missouri-Rolla
Rolla, Missouri 65401-0249, USA

## ABSTRACT

This paper describes the model CIM program successfully developed by the Department of Engineering Management, University of Missouri-Rolla. The program has employed a strategy of industry/university collaboration in developing a vibrant, multi-disciplinary approach to CIM education incorporating a laboratory intensive curriculum. Adoption of the integrative philosophy of a CIM enterprise should facilitate the continued development of a coherent, integrated CIM program.

## INTRODUCTION

The growth of Engineering Management (EMgt) programs in the last several years at the undergraduate and graduate levels has been phenomenal. It appears that as early as the 1940's, there were Engineering Management type programs offered in the United States. However, the major growth in this field did not take place until the mid-sixties and early seventies. With the ABET accredited Engineering Management B.S. programs now being offered in the country, the discipline of EMgt has arrived in the field of engineering education as a distinct entity. The Engineering Management Department at UMR is the leader in this field and ranks among the top 10 in the Industrial Engineering/Engineering Management categories in the nation today.

Current interest in Computer Integrated Manufacturing (CIM) as a strategy for restoring the competitiveness of the manufacturing industry in the USA has required the development of a strategy to incorporate CIM concepts into our curriculum. The CIM philosophy focuses on integrating all of the business and engineering functions of a firm using computers, from planning--through design to shipping.

EMgt type programs typically possess faculty whose multi-disciplinary backgrounds are ideally suited for initiating a CIM education program. They possess the ability to bridge the gap between traditional Operations Research topics and CAD/CAM, FMS, Decision Support Systems and Manufacturing Systems Engineering and Management.

This paper describes the development of a successful model program for CIM education in the independent EMgt department at UMR. Even though the first concrete steps to develop laboratory based CIM education were taken only four years ago, the great success the department has achieved in CIM education is mostly due to a fertile environment and the creation of a sustained CIM focus in the curriculum.

## MODEL CIM PROGRAMS

### Industry Initiatives

In recent years, several initiatives have been launched by industry, professional institutions, and academia to define the essentials of a model CIM program for institutions of higher education. CIM advocates have faced the challenges of articulating relevant CIM curricula [1], developing collaborative strategies to stimulate and maintain cooperation among academia, the business community, and the professional institutions [2], and identifying the appropriate implementation strategy for various situations.

IBM's program entitled "CIM in Higher Education Alliance" announced in December 1988, provides a good illustration of industry's important role in CIM education. The Alliance, which currently lists over seventy member schools provides a forum for educators to exchange ideas and technologies in the pursuit of sharing CIM opportunities in both education and industry.

The Alliance is an outgrowth of a major CIM initiative announced in September 1982 by IBM after the formation of a task force in 1982 under the direction of IBM's Eric Bloch, currently Director of the National Science Foundation (NSF). The task force engaged in discussion with higher education and during the summer of 1983, IBM announced a $50 million grant to 22 institutions for CIM academic progress.

The IBM concept of a CIM enterprise model [3] in which Computer Integrated Manufacturing harnesses information system technology to integrate manufacturing and business objectives provides a good framework within with CIM education programs to be modelled. IBM support has assisted the development of a variety of model CIM programs at institutions such as University of Alabama, University of Cincinnati, Fox Valley Technical



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College, University of Missouri-Rolla, The Pennsylvania College of Technology, and University of Southwestern Louisiana.

Professional Institutions

The professional manufacturing engineering institutions have sought to identify the actions needed to mobilize manufacturing engineering to meet the challenges of the 21st Century. An interesting initiative is the recent study conducted by AT Kearney Inc., commissioned by the Society of Manufacturing Engineers to explore the future role of the manufacturing engineer [4].

This and other related studies can provide invaluable information and guidelines for development of model CIM programs. Manufacturing engineers will need relevant education and training to use the new technologies effectively while obtaining the "breadth" skills required to enable them to contribute as team members.

Academia

The academic community has been in search of consensus on the future direction of CIM education. Studies by McCluckie [5], Mortensen [6], Francis et al [7] offer various approaches for enhancing the quality and effectiveness of CIM engineering education. Alternative approaches for implementing a CIM program have been explored. One possibility is to assign responsibility for program development and operation to an established IE/ME/Engineering Management Department. Another possibility is to attach the CIM program to a university-based Research/Productivity Center. The best approach requires a careful analysis of each particular situation and the development of an appropriate strategy to take full advantage of existing opportunities. The model CIM program adopted by the University of Missouri-Rolla will be described below to illustrate this concept.

## UMR ENGINEERING MANAGEMENT CIM PROGRAM

### Overview

The BS degree in Engineering Management constitutes the foundation for the CIM education at UMR and is based on a three plus one formula where three years' worth of technical manufacturing engineering course content is blended with a year's worth of techno-managerial course content to synthesize an effective CIM education for the graduates of this ABET accredited program [see Table 1]. This model is supported by the recent SME commissioned study conducted by the AT Kearney, Inc. [4]. In this report, a massive revamping of the educational system is recommended to provide specific tools and training required by the manufacturing engineer of the 21st Century. Significant increases are forecast in the use of computer-based technologies such as Artificial Intelligence, Automated Material Handling, Sensor Technology, Laser Applications, Integrated Manufacturing Systems, Advanced Inspection Technologies, Flexible Manufacturing Systems and Simulation as well as managing the technology to create what may be best called Computer Integrated Enterprise (CIE).

### CIM Laboratories

In our model CIM program, extensive use is made of the Computer Integrated Manufacturing (CIM) laboratories which were designed on a three-tiered approach to laboratory needs in this area [8]. The ultimate goal is to replicate an actual industrial operation. At the next lower level is the industry grade comprehensive system operated in the lab and finally the bench scale modeling of manufacturing systems using physical simulation components such as the Fischertechnik modules. The following laboratories have been developed to support this approach:

- o Industrial-grade CIM Laboratory
- o Physical Modeling laboratory
- o Building Blocks of Automation Laboratory
- o CAD/Simulation Laboratory

The following sub sections will describe the industrial-grade CIM laboratory which represents our major investment.

### Industrial-grade CIM Laboratory

The primary mission of the CIM laboratory is to provide a facility to encourage cross-disciplinary teaching, research, and service in integrated manufacturing. Accordingly the main objective of developing the CIM lab is the creation of a highly-integrated and flexibly-automated manufacturing system that allows students, researchers, and engineers from industry to learn, experiment, and improve this new technology.
The CIM laboratory is located in the Engineering Management Building's first floor and occupies an area of 5200 square foot. It is equipped with industrial-grade equipment and provides the integrated manufacturing system required by faculty and students to explore specific areas of interest [9-11]. The layout of the facility is given in Figure 1.

Physically, the CIM lab contains two cells: The Flexible Manufacturing Cell (FMC) and the Flexible Assembly Cell (FAC). The components of the FMC are a CNC mill, a CNC lathe, a loop conveyor, a servo robot, a quick changer for end effectors, a pneumatic robot, an automated storage and retrieval system (AS/RS), a bar code reader, programmable controllers, a packaging machine and micro-computers. The core of this cell was bought as a turn-key system in 1987 to include the AS/RS, the loop conveyor belt, the pick-and-place robot, and the milling machine. Proprietary software which runs on a micro-computer and a proprietary LAN is used to control and integrate the material handling components of the cell [12]. The other components of the FMC (the GE robot, the lathe, the packaging machine) were added to the system in 1988 to increase the flexibility of the overall system [13].

The Flexible Assembly Cell (FAC) was designed and implemented as a term project by a team of students in 1989. The layout of the assembly cell is given in Figure 2. The components of the FAC are a servo robot (IBM 7535), a conveyor system, various sensors, fixtures, a feeder, a PLC, and a micro-computer. These two cells are integrated and

Table 1: UMR Engineering Management
Manufacturing Engineering Preference
Last Two Years Model Curriculum

| Fifth Semester | Credit | Sixth Semester | Credit |
|---|---|---|---|
| English 160 Technical Writing | 3 | EMgt 252 Financial Management | 3 |
| BE 110 Mechanics of Materials | 3 | EMgt 282 Production Management | 3 |
| EMgt 208 Engineering Economy | 3 | EMgt 382 Methods of IE/OR | 3 |
| EMgt 230 Management Accounting System | 3 | EE 281 Electrical Circuits | 3 |
| Met 121 Met for Engineers | 3 | ME 227 Thermal Analysis | 3 |
| EMgt 265 Management Practices | 1 | Elective Mfg Engineering Pref | 3 |
| | | Sample: | |
| | | EMgt 257 Materials Handling | |
| TOTAL CREDITS | 16 | TOTAL CREDITS | 18 |

| Seventh Semester | | Eighth Semester | |
|---|---|---|---|
| EMgt 251 Marketing Management | 3 | Humanities & Social Science 2xx | 3 |
| Humanities & Social Sciences 2xx | 3 | EMgt 260 General Management | 3 |
| Electives Mfg Engineering Pref | 12 | EMgt 334 CIM | 3 |
| Sample: | | Electives Mfg. Engineering Pref | 6 |
| EMgt 357 Advanced Facilities Design | | Sample: | |
| EMgt 361 Project Management | | EMgt 333 Management Info. Systems | |
| EMgt 372 Prod. Plan. & Scheduling | | EMgt 377 Expert Syst. in Mfg | |
| EMgt 375 Total Quality Management | | | |
| TOTAL CREDITS | 18 | TOTAL CREDITS | 15 |

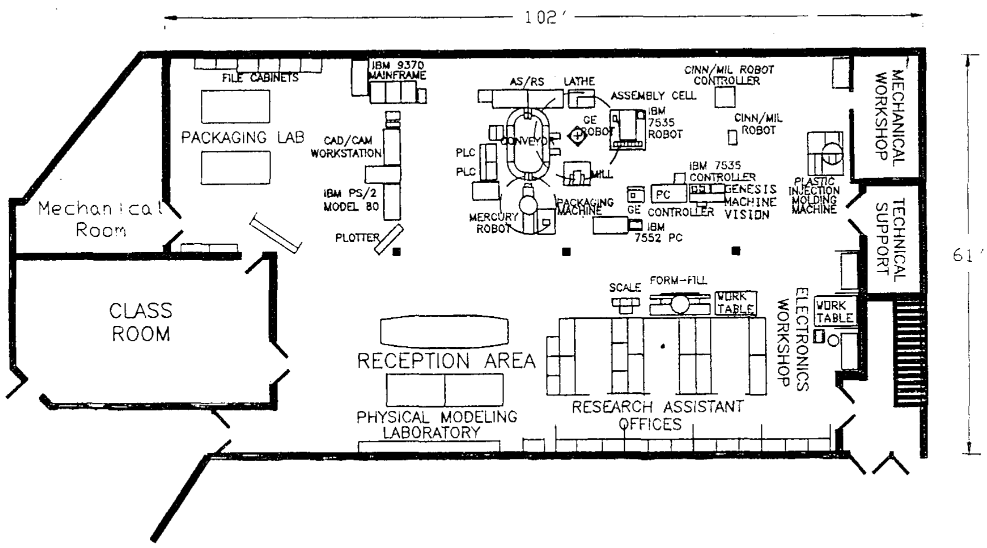


Figure 1. Layout of UMR Engineering Management CIM Laboratory

together comprise a Flexible Manufacturing and Assembly system. An in-house developed semi-intelligent software (FASIAC) is used to control the system. This flexible and semi-intelligent system is utilized to manufacture and assemble a growing number of products in the CIM facility and provides students with hands-on experience in CIM related areas. The products being manufactured and assembled in the CIM lab are described in the following subsection.

## The Products

Currently five products are being manufactured in the CIM laboratory (see Figure 3). The design and manufacture of these products were accomplished by students as term projects for various CIM courses.

The Key Chain product was used during various lab demonstrations in the initial phase of laboratory development. The main purpose of the selection of

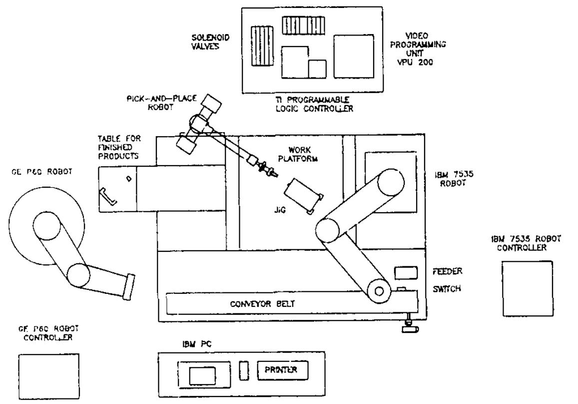


Figure 2. Layout of Flexible Assembly Cell

this product was to demonstrate machining and programming flexibility. In this scenario, visitors to our lab are asked to enter their initials via a terminal. An in-house developed computer program generates the NC part programs for the milling machine to engrave their initials along with other information such as the University of Missouri (UM) logo, Engineering Management, and UMR letters on the key chain. The raw material is stored in the AS/RS on a pallet. The parts are then picked, placed on a conveyor and delivered to the GE robot. The GE robot loads the part on the Dyna 2400 Milling machine. After the milling operation is over, the GE robot unloads the part and places it on the pallet positioner. The part is conveyed to a station where it is picked up by a pick-and-place robot and loaded in a packaging machine. This machine then bags the key chain with a chain in a plastic bag. The empty pallet is conveyed to the AS/RS for storage.

Another product is the three level maze which consists of four 5.0 x 2.5 x .5 inch plexiglass plates, a metal ball and four fastening pins. The top plate is used to enclose the first level of the maze. The first level of the maze is milled in the second plate. The second and third levels are milled on both sides of the third plate. The fourth plate is used to enclose the third level of the maze. The Dyna Myte 2400 mill is used to manufacture the components of the maze.

The components of the maze are manufactured in the FMC prior to the assembly operation and stored in the AS/RS. Upon request, a pallet bearing the components of the specified product is sent to the assembly cell. The GE robot is used to move parts from the pallet to the line conveyor belt. The IBM 7535 is used to assemble the product. The GE robot picks up the finished product and places it on the waiting pallet, and the product is sent back to the AS/RS.

## LABORATORY DEVELOPMENT

At the Engineering Management Department we have been continuously upgrading our CIM laboratory [14]. As a member of IBM's CIM in Higher Education Alliance, the UMR Engineering Management Department has received a main frame computer (IBM 9370), an RT workstation, an industrial computer, and various software packages. Among these is the Distributed Automated Edition (DAE) software which will be used to integrate the design, manufacturing, planning and control functions of the CIM lab. Integration software that will tie all of the IBM computers with the existing equipment will be developed in-house by staff and students. Cell control software linking the IBM 7552 industrial computer to the various machine controllers will be developed. This phase will include writing drivers to link individual machines to the computer in addition to developing application programs to control the machines, schedule operations, and eventually communicate with the facility controller, the IBM 9370.

Facility control software will also be developed to supervise the different cells, schedule their operations, and keep track of production status.

Software developed will be enhanced where possible by the addition of artificial intelligence tools to make the system more adaptive to changes in the environment.

## CIM ENTERPRISE

Our long-term ideal is the evolution of our CIM Lab facility into a demonstration production facility illustrating the various facets of a CIM enterprise. A product mix specified by the marketing function will be designed for manufacturability and assembly by our engineering design and packaging students. These items will then be produced in a manufacturing and assembly cell designed by our manufacturing engineering and facilities planning students. The production management function will work with our process planners to develop the operation routes and methods required to produce the right quality of products, on time with the right quality. The entire project will require a business justification from our engineering economy students. Our information management and systems specialists will be faced with the challenge of designing appropriate decision support systems to facilitate informed decision-making by the various functions.

This approach will thus enable the integration of our courses around a central theme, facilitating the extension of the CIM integration philosophy into our CIM education program.

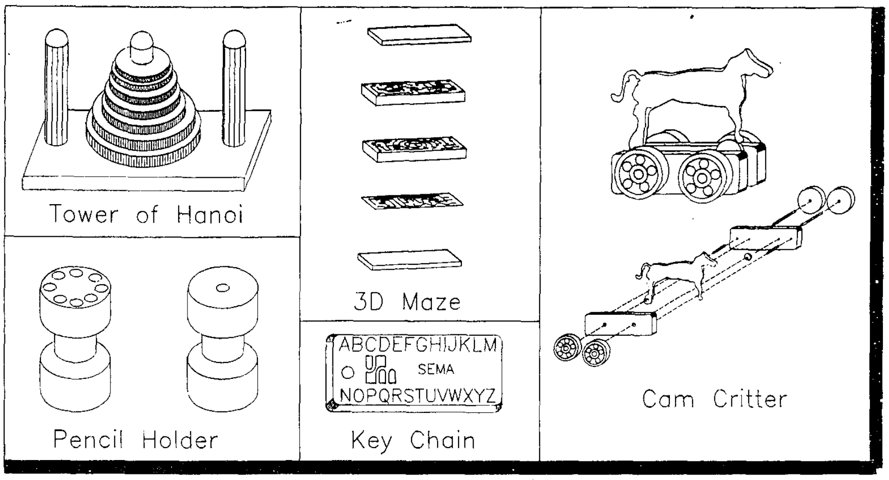


Figure 3. The Products

## CONCLUSION

The program described above is extremely successful and has received support from several organizations e.g. National Science Foundation (NSF), Society for Manufacturing Engineers (SME), Packaging Machines Manufacturers Institute (PMMI) and IBM. The student enrollments at BS, MS and PhD levels are soaring, making the EMgt Department the most resource critical department in the School of Engineering at UMR. We now have higher student credit hour/faculty, student head count/faculty, a very large MS program and the largest PhD program in the School of Engineering at UMR. Our faculty research productivity measured by publications/faculty and research dollars/faculty has also shown dramatic increases. We are experiencing growing numbers of transfers from other departments and schools throughout the nation into our undergraduate and graduate programs creating ever increasing budget constraints which must be relieved if we are to grow further.

In summary it may be concluded that the comprehensive, laboratory based CIM education formulated at UMR in the EMgt Department is a success model that should be considered by others who are contemplating launching or intensifying their own efforts in this area.

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