

A Massively Large Student Modeling Assignment (MLSMA)

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Abstract

Most curricula in engineering and technology find a “capstone project” to be highly beneficial in preparing soon-to-be-graduated majors. One consideration that confounds a successful capstone project is matching a task of sufficient significance with realistic expectations of student success. Students may possess the requisite skills but a project that tests those skills may be difficult to identify. But more likely, student skills (along with time and motivation) may preclude engaging in a significant project.

An important part of a significant project is the management of resources—both technological and manpower—and though individual assignments may make grading and evaluation easier, the significance of the problem must necessarily be reduced. One person simply cannot accomplish an involved task in one semester. The answer is to engage in a group project, but a group project appropriate for modular solution.

A group of seniors in the Graphic Information Technology program at Arizona State University were organized to model the university’s 13,000 square foot Microelectronics Teaching Factory (MTF), an on-site class 100 clean room integrated circuit manufacturing facility. This assignment posed several significant modeling challenges. First, like any process facility, the “as built” condition of the MTF differed significantly from the original engineering and facility drawings. Although full construction drawings (in electronic format) were available as the basis for modeling the facility, these drawings had to be physically checked against what existed on the manufacturing floor. Second, students were unfamiliar with the processing equipment used in chip manufacture so they had to employ a full panoply of skills to gather sufficient information before modeling. They used the original construction drawings, engineering drawings from equipment manufacturers, on-site sketches after donning “bunny suits”, and digital photographs. MTF managers allowed students full access to the facility and it was common to see modelers, looking like snowmen, up on lifts measuring details.

The result of the project was an accurate description of the MTF suitable for an “as built” model; models were appropriate for training, promotion, and hopefully as the basis for eventual maintenance and redesign. Additionally, the assignment prepared this group of seniors to expect tasks of similar significance once they enter the workforce.

Introduction

Most teachers of CAD and related topics struggle with a difficult problem: How to develop technical skills and understanding to the point where students can engage in significant design and modeling tasks. This is often addressed in senior-level capstone courses and much has been written about their benefits. Another solution may be to make internships an integral part of the undergraduate curriculum, or by designing the program around co-op experiences. However, a downside of both internships and co-ops is that the activities (usually) occur off campus, and out of the structure of curriculum. In other words, there *may* be significant benefit, but weaving those benefits into other curricular activities may be problematic.

Capstone courses, as beneficial as they may be, suffer from sheer numbers. It may take one or more FTE faculty to supervise a large capstone class. Multiple topics or assignments must often be entertained, or a single topic (problem) subdivided so that numerous groups can work on pieces of the task. Although this mimics the manner in which large industrial problems are solved, the educational benefits are suspect. Such a micro-view is taken that the entire process (often the most educationally beneficial aspect) is lost.

An approach that draws from each of the previous examples is the *senior independent group project*. A small, focused team of motivated students can be assembled to apply their CAD skills and knowledge to a significant modeling project. Until this point for them, CAD had been acquiring analysis and modeling skills, and applying those skills to individual parts, or at the most, small assemblies. The question was: Would those skills suffice in a project much greater in scale, a project that had not been defined (and delimited) by the instructor?

The Modeling Team

The assignment functioned within a three credit hour omnibus (494) course for four seniors in Information and Management Technology. These students had a background of 14 hours of related graphics coursework: two courses in engineering design graphics and CAD; two courses in 3D technical modeling and animation; and one course in 2D and 3D technical illustration. The students had little or no familiarity with microelectronics fabrication, process manufacturing, or industrial facilities design. All students worked at least part time and were full time students.

This was a student directed project. That is, the group had to negotiate a division of labor, scheduling of modeling tasks, and control mechanisms. Team members brought experience from two management courses to the assignment. These courses stressed management dynamics and small group interaction and formed the basis for the group skills team members brought to the task.

In order to address the most serious weakness of group projects—one person doing all the work—the most accomplished modeler was taken out of production and put into management. This was an instructor decision.

The Microelectronics Teaching Factory

The modeling assignment concerned the modeling of the Microelectronics Teaching Factory (MTF) at Arizona State University's College of Technology and Applied Sciences in Mesa, Arizona. The MTF is a partnership of industry and education in a high technology facility designed to prepare students for direct entry into the global semiconductor workforce. The courses taught in the facility provide students with comprehensive theoretical and practical experience in a wafer fabrication environment. The facility covers all aspects of design, fabrication and application of microchips.

The intended uses of the completed model were to:

- Create an “as built” virtual model of the facility for future construction and expansion.
- Use that model for training and virtual tours.
- Extract views suitable for promotional literature, both print and Web.

Working with Richard Newman, Director of Training Operations for the MTF and John Robertson, Academic Coordinator, the students were given access to the facility as construction and installation was finalized. Because the majority of equipment was donated from the MTF’s industrial sponsors, final arrangement and configuration of equipment was not known at the time the project commenced. Figure 1 shows a general layout of the facility. The visitor corridor at the bottom of the diagram allows observation of the facility without actually entering the clean room environment. Figure 2 shows a typical view of the type of equipment and architectural and equipment details found within the facility.

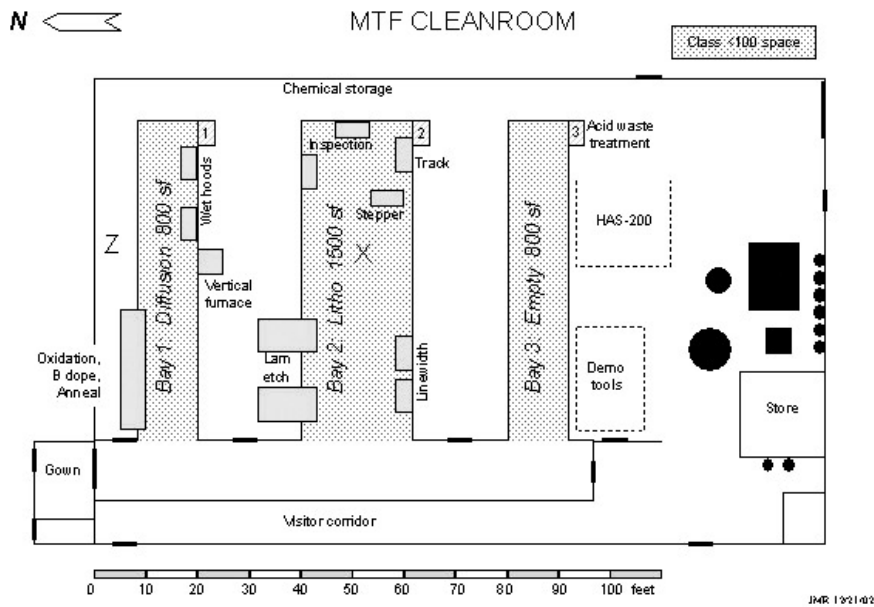


Figure 1. The floor plan of the Microelectronics Teaching Facility.



Figure 2. Typical architectural and equipment details of the MTF.

The Educational Benefits

By far the greatest educational benefit of the project was the necessity for students to work from a wide variety of data sources. These included:

- Electronic CAD files (2D)
- On site sketches
- Digital photographs
- Vendor literature, specification sheets
- Verbal descriptions from the client and representatives

General information was available in AutoCAD .dwg format. However, these construction drawings were only a starting point because ultimate installation decisions had to be made based on the particular equipment that was donated. Students were required to enter the facility (Figure 3) as factory workers to measure equipment, sketch components, and take digital photographs for reference.



Figure 3. Students in the MTF.

Students used this variety of data sources to create their models. Doing this kept individuals from relying solely on a particularly favored technique. For example, were a student accomplished at working from engineering drawings, and no drawings were available for a particular detail, other data sources had to be entertained.

Additionally, because the MTF is an integrated system, one system had to work with all others. This encouraged regular team meetings and the sharing of data. The student project manager was responsible for making the various sketches, photographs, CAD files, interview logs, and product sheets available to all team members.

The Model

The project manager created the overall facility model, assuring that individual systems would fit together. This was made available to all members of the modeling team. AutoCAD plans and elevations became the basis for modeling in *3ds max*. Some geometry and components were first constructed in AutoCAD and then imported into max, depending on the technical orientation of the individual team member. Digital photographs were outlined in Adobe Illustrator and the vectors brought into max for further refinement, and freehand sketches were scanned and vectorized.

The components were kept in separate files for ease of transportation between various team members. The base facility (walls, floor, major components) was kept in an abstracted, simple polygonal model for placement and fitting of components. In fact, the complexity of the final model (and workstation limitations) proved to be a considerable learning experience. Before this project, most student assignments could be archived onto a diskette, zip disk, or CD. However, the MTF modeling task generated gigabytes of data and final models of significant size. Following are images from the finished model.

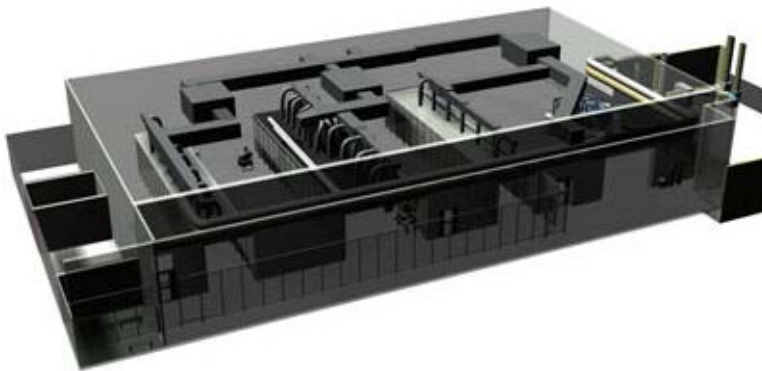


Figure 4. Overall view of the modeled MTF looking at the visitor corridor.

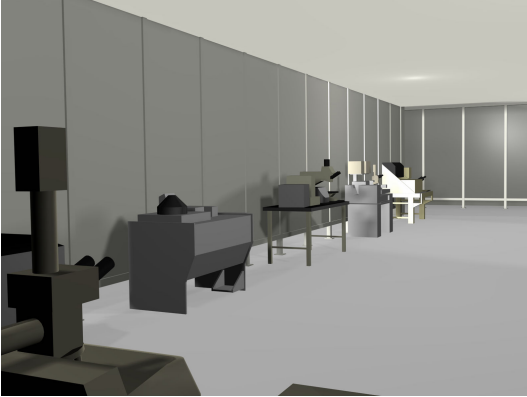


Figure 5. Modeled equipment bay.



Figure 6. Modeled RO water system.

Evaluation

The goal of this assignment was to put the team in a large-scale industrial modeling environment. It was not to cleave differences in student performance and reward. In fact, it was the instructor's *a priori* opinion that the process of analyzing, solving, revising, and presenting solutions—and interacting with factory personnel—would be the beneficial parts of the assignment. For these reasons, no assumptions were made as to how much of the facility, and to what level of detail, could be modeled in the time allotted.

The team met with the instructor once a week to review progress. The team met with factory personnel as needed, often daily. At the completion of the assignment, each team member submitted their individual work in a report with supporting files. They rank ordered themselves and others based on significance of contribution.

Because this assignment was treated as a job, final evaluations were in the form of a job performance review. All members kept their jobs; all members passed.

Why it Worked

Several factors contributed to this project's success:

- The site of the task was on campus, actually in the same building as were the students' workstations. This eliminated the need to have off campus meetings and reduced the time lag in working off site. The greater the logistical overhead, the less significant the potential task. Meetings could be easily scheduled and the faculty member consulted. (This was probably the sharpest change from traditional classes where the faculty member was generally used as the source of all knowledge. In this case, the faculty member became *the source of all questions!*)
- Students approached the task as a job. As an individual in the work group, each was evaluated not only by their supervisor (faculty member) and the client, but by their peers as well. If assignments were accomplished in time and to specifications, they were paid (passed). If they missed deadlines or performed below expectations they were fired (failed). Students knew this at the beginning of the assignment, discouraging "cramming" at the end to make up work.
- A succinct division of labor and a division of technology were established at the beginning of the task. This was the supervisor's (faculty member) responsibility and was critical in eventual success. Because the MTF contained a wide range of technical modeling tasks, the equally wide range of student abilities and interests had to be matched to the job. Because the MTF was modeled much as the facility was physically built, systems and subsystems had to be identified (site, physical structure, utilities, HVAC, equipment, etc.). Students assigned themselves modeling tasks as if they were specific subcontractors.
- A project manager (student) was immediately identified to lead the team. As was mentioned earlier, a slightly different approach was taken. Many faculty who have led group projects have seen the way that the most talented and motivated student may (unfortunately) do most of the work, while marginal students do as little as possible. In the case of the MTF Modeling Group, the most accomplished (though, possibly, not the most organized) modeler was identified as the project manager. This accomplished several ends. First, the project manager had to work on organizational and communications skills, rather than rely on CAD skills that were already well developed. Second, team members had to stretch their technical skills and use the project manager as a source of information. The project manager reinforced CAD skills by acting as a resource to the team, relieving the supervisor (faculty member) from being the authority (this was, after all, the student's project, and not the faculty member's).

Conclusions

Of course, there were several concessions in using students in a project such as this. Because this was a project of fifteen-weeks duration, it was unknown at the onset how much of the facility could actually be modeled. A portion of the utilities and air handling systems were modeled but it became evident that these systems would require an effort at least as extensive as required for the facility and its equipment. (This was due partly to the “as built” nature of the utilities. There was incomplete documentation for utilities in the original construction drawings.)

Because of the size of the modeling files, only basic materials were employed. The level of detail of individual pieces of equipment would require the mapping of raster textures for controls, readouts, switches, etc. The 2D geometry files (hundreds), 3D geometry files (hundreds), and final models (nearly fifty) were a significant project management task.

Did the client get what they wanted? Yes and no. The model is useful for its intended purpose, although, the facility continues to be in a state of flux as new equipment is donated. To make the project viable, the six members of the team would have to be permanent employees of the MTF in order to update the model and create the images and animations for training simulations.

Of course, the final question is: “Did the students get anything out of the assignment?” and the resounding answer is, “Yes!” Students were able to accomplish modeling tasks that only a semester before they thought impossible. They had to become “quick studies” in the manufacture of integrated circuits, acquiring the vocabulary necessary to converse with the fab workers and engineers. And, surprisingly, it was the first time students had considered geometry they had to walk through, rather than hold in their hands. In other words, the sheer scale of the assignment was, in itself, a learning experience.

Each had to apply the full gamut of technical skills to accomplish their tasks. Several team members found that their technical skills were not up to the task, requiring new modeling techniques and methods to be developed. They expanded their technical modeling and project management skills during the course of the assignment, rather than simply applying an existing skill set. And in the end, they had to rely on each other, which may have been the greatest learning experience of all.

Postscript

After graduation, these four students followed widely varying careers. Nate Gelber, the project coordinator, works as a quality specialist at a North Carolina pharmaceutical manufacturer; Ryan Graham, who modeled machinery and instrumentation, is an instructional designer at the University of Phoenix Online; Jake Hibler, who modeled the HVAC and utilities, is a data manager at a Hollywood pre-production house; Mike Kelly, who modeled the RO water system, is trying to break into the major leagues. He had had a very successful minor league career before returning to school to complete his degree.

The project won the Undergraduate Research Competition Award the semester it was completed, and the files submitted to the Microelectronics Teaching Factory for their use. You can visit the MTF at <http://www.east.asu.edu/ctas/mtf/index.htm>.