Session 3147

# Implementation of design principles and methodology of rapid product development in a multidisciplinary engineering technology project course.

**Dr. Kamal F. Bichara**

**Kent State University, School of Technology**

## Abstract

This paper describes the design, delivery and outcome of a senior level Engineering Technology project course. Students in the course represent a variety of engineering technology academic disciplines including electronics, mechanical, systems/industrial and computer design and animation. The course design emphasizes concurrent engineering principles as applied to rapid product development including integrated activities, from design, modeling, simulation, analysis, testing to production.

The project selections were guided by a focal objective: The selected projects are part of a new showroom where campus visitors are able to learn about the exciting aspects of Engineering and Technology. The produced projects are currently part of what is referred to as "The Technology Zone" and are permanently housed in the Campus presentation room of the Engineering Technology department.

## Introduction

In an effort to promote the various disciplines represented in the campus offerings in engineering technology (ET), the University committed in 1999 the main conference room of the Engineering Technology center to become a presentation room showcasing the best illustration of student creativity. The decision was aimed to provide high school students, teachers, guidance counselors, and the community at large an opportunity to experience the creative ability of ET students in conceiving, designing, and producing quality useful industrial as well as consumer oriented devices and products.

A plan was formulated which involved using an Engineering Technology Project course (TECH 36095) to engage students in the design and prototyping of working projects that would be targeted to depict one of the six associate of applied science degree programs offered. These degrees are in Mechanical, Electrical/Electronics, Plastics Manufacturing, Computer Design and Animation, Systems/Industrial and the recently introduced degree in Engineering of Information Technology.

The Engineering Technology course is a junior/senior level course. Eight students were registered in the course during that semester. All students in the class had previously completed an AAS degree in one of the specialty areas mentioned above.

The presentation room project was named the “Technology Zone” (TZ). The project parameters were formulated. In a broad sense, the project includes two parts: (1) a multimedia supported show featuring the working projects with onscreen graphics, animation texts and surround sound to provide the needed information about the individual project as it is operating. (2) A side display section, which includes individual projects in glass cases with controls accessible to visitors to interact with the project and take part in controlling its functions.

The multimedia supported show is fully automated. A master (64) channel controller board was used to interface to the various project parts under the control of a program written in Visual Basic with programmed port address/timing information.

In addition to the (64) channel master controller, each of the designed projects uses a micro controller programmed and interfaced to perform the desired functions.

The devices that are part of the multimedia show were to be recessed in the ceiling (drop ceiling with tiles). They consist of glass cubes that will descend from the ceiling as the show commands.

The Technology Zone (TZ) and its related projects have been open for public viewing for over a year.

In the section below, we discuss the course philosophy, methodology used for rapid product development and key design and function features of each of the TZ student projects.

**Engineering Technology Project course description, aims and objectives**

The course was designed to deal with the research, development and design of a project in the field of engineering and technology. The project focused on applications dealing with control, automation and information systems.

The course aimed at giving students experience in managing their own time to complete a project in engineering design, development, and research that is initially specified only in terms of the final desired outcome. Throughout the one semester course, students were taught to develop a professional approach in their project work and to develop their communication skills, both written and oral, to a standard expected by industry of a new graduate.

**The course overall objectives**:

1. To apply scientific and/or engineering principles to the solution of a practical problem of engineering design, development, and research.
2 To manage time effectively and produce written progress reports and a final report

on time.
3. To make effective lecture presentations of their project work and demonstrate the project in the laboratory.
4. To write a project report that would be satisfactory in literary terms, completely describes the project work and which critically relates the work to current technical practice.

Students were taught that all projects whether in design, development, or research must progress through the following phases: project definition, requirements capture, problem analysis, literature search, detailed project work, testing, and critical appraisal.

## The Presentation Room

The layout of the presentation room was changed to incorporate the Technology Zone, with custom furniture designed and built to accommodate the side display. The room layout is shown in the Figure 1.

Figure 1: Room Layout

## Technology Zone Projects

As stated above, the Technology Zone consists of two parts (A) the multimedia supported project show, (B) the side display.

## The Multimedia Supported Project Show

The show is designed using 3D stereoscopic techniques viewed while wearing goggles during the show. The show features four-design projects initially recessed in the ceiling in glass cubes. Four individual reversible motors drop and elevate each of the cubes upon receipt of a signal from the main controller board.

These four cubes are:

- Miniature guillotine cutter (featuring mechanical engineering technology)
- Injection molding machine (featuring plastic manufacturing engineering technology)
- Animatronics bear (featuring computer design and animation)
- Laser communication cube (featuring electronics and engineering of information technology)

Initially the presentation room is dark with celestial effects as phosphoric paint on the walls creates an outer space ambiance.

**The Miniature Guillotine**

The Guillotine cutter, shown in Figure 2, serves as a cutting machine that produces pieces of material at a specified cut length. There are several different components that are involved to make a properly functioning project.

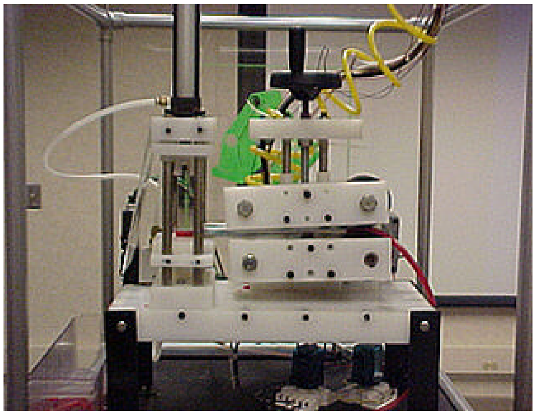

Figure 2: Miniature Guillotine

In order to gain an overview of the exact procedure, we will describe the process. The first step is a piece of material that starts out in a puller belt assembly that transfers the material from a coiled position into the second compartment. The cutting system is step two of the process. All of the cutting occurs in this phase. The part is incremented by the belts to a preset length. Once the belt has moved "x" distance they stop. The air cylinder is then energized so it will cut through the part. The process then runs in a continuous loop until the operation is timed out by the master controller. There are several components that go into making all parts run uniformly. The design includes: Frame Assembly, Belt Assembly, Cutting Head Assembly, Pneumatic System, and Electrical System. All timing and control functions are governed using a Motorola MC68HC05 micro controller.

In the actual operation during the show, spooled licorice is fed to the cutter. The cutter processes and cuts typically 15, 2 inches pieces. These are served to the audience.

**Plastics Injection Molder**

The Plastics Injection molder shown in Figure 3 & 4 takes raw high density plastic and transforms it into a desired finished part defined by a manufactured mold.

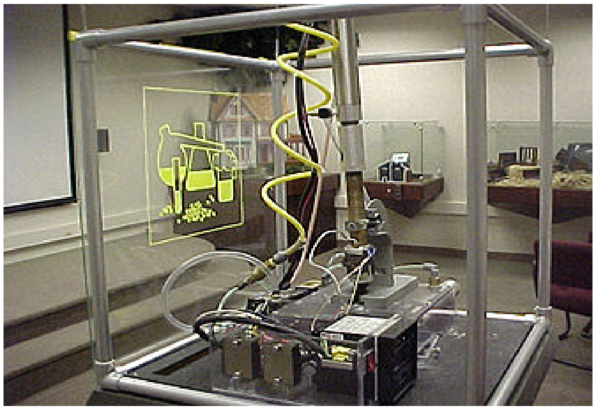

Figure 3: Plastics Injection Molder Design

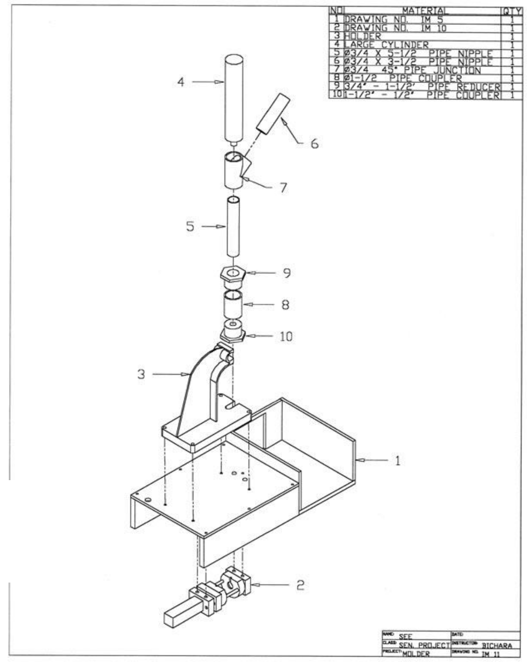


Figure 4: Plastics Injection Molder
Partial Part Design

The molder runs on regulated air power. It uses a motor, a molder (barrel and base), a framework for the barrel, the mold housing, mold slide carriage, air cylinder, heater to melt the raw material for forming, an injection piston, a cutter, a plunger and air solenoids. All timing and control functions are governed using a Motorola MC68HC05 micro controller.

**Aircraft Tire Pressure Watchdog**

The aircraft tire pressure watchdog is a pressure monitoring system designed to monitor aircraft tire pressure and to provide a visual warning signal to the pilot through easy to view LED color

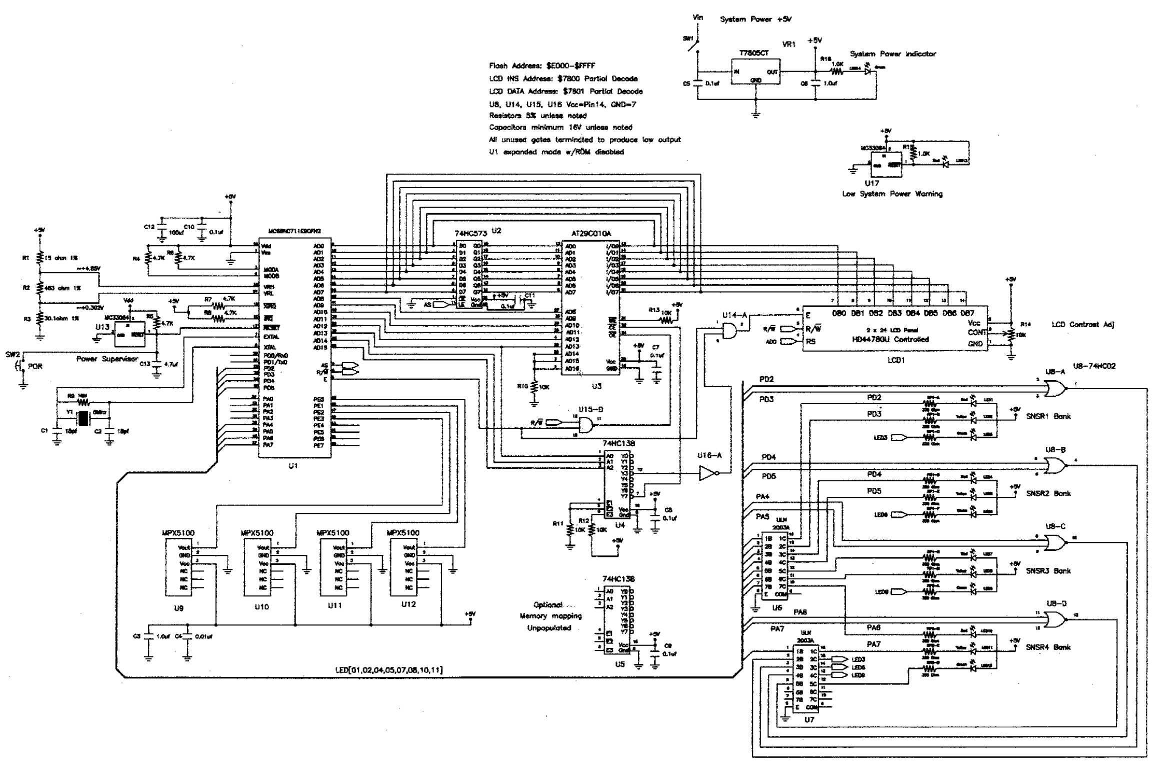

Figure 5: Schematic for main system board

coded light patterns as well as through a liquid crystal display panel. The system uses a micro controller and flash memory for its program and control functions. It is designed to monitor aircraft tire pressure in their pressure operating range of 0 – 15 lb per square inch (P.S.I.). The alerts follow the normal operation pressure schedule.

| | |
|---|---|
| Critical high Pressure Warning | 13.1 – 15.0 PSI |
| Slightly High Pressure Caution | 12.1 – 13.0 PSI |
| Normal Pressure | 3.7 – 12.0 PSI |
| Slightly Low Pressure Caution | 2.0 – 3.6 PSI |
| Critical Low Pressure Warning | 0 – 1.9 PSI |

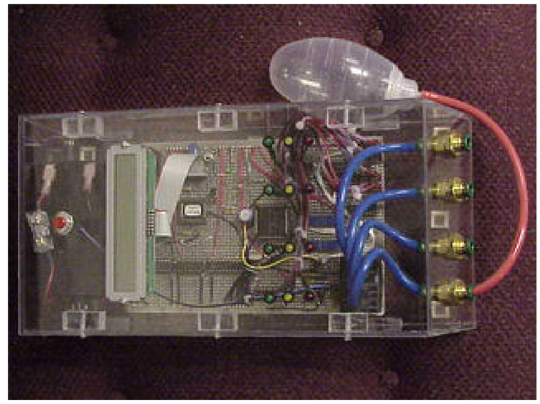

Figure 6: Aircraft Tire Pressure Watchdog

Figure 5 shows the circuit schematic for the main system board.

The pressure simulator enables the observer to vary the pressure level from 0 – 15 PSI through the use of a manually controlled air pump, and to constantly monitor tire pressure through the visual display showing the varying tire pressure conditions from a critical low of 0 PSI, to the critical high warning of 15 PSI at 15 PSI

Figure 6 shows the aircraft tire pressure watchdog device

**Side Display sample projects**

**Self guided trailer backup 'hitching' system**

The system is designed to give reliable guidance to a driver backing up a vehicle to align a trailer hitch with the vehicle hitch ball. The system uses a Motorola micro controller. It consists of a transmitter (attached to the trailer hitch) and a wireless receiver attached to the vehicle ball assembly.

The monitoring system is dash mounted. The monitor consisting of color-coded lamp indicators (light emitting diodes) including a 'stir' right lamp, a 'stir' left lamp and an 'on target' lamp. It is connected to the receiver through a modular telephone line (RJ11). The receiver gets an Infrared signal, which indicates the position of the trailer hitch. The program then analyzes the signal and activates the appropriate lamp (right, left or on target) effectively guiding the driver with real time signaling, to where the hitch and the ball are perfectly aligned without any human intervention.

Figure 7: Navigation Control System

The driver then can drop the hitch over the ball for a pleasant hauling trip!

Figure 7 shows the navigation system with the controls for visitors to test the automated guidance feature of the system.

**Advanced Climate Control System**

This project was designed as a household climate control system with some additional functionality. A typical residential temperature control measures temperature at only one point in a house, typically at thermostat; ideally this should be in the cold air return path. This type of installation assumes that the air flowing past the internal sensor is the average found throughout the house.

An installation such as this typically results in hot and cold spots throughout the house, and in instances where registers are located in the cold air return stream itself, the air from these vents will dramatically effect the average temperature of the air in the return stream, and ultimately be measured as an average for the whole house, thus causing the thermostat to turn off the desired device, heater or air conditioner, before the desired average temperature has been reached.

This project sought to find cost effective solution to this common problem.The easiest way to assess a true average of whole house temperature is to place sensors in individual rooms. The search temperature transducer is the Analog devices AN22000. The AN22000's onboard signal conditioning and linear output make it an ideal sensor for this application.

Conversion from the linear output of the AN22000 into an 8 bit binary number was accomplished by an Analog-to-Digital converter.

The design of the chassis was intended to be a miniature card cage, however in the prototype stage bus connections were made by a much more bulky 60-pin IDE cable. Addressing of each card was performed by manual jumper manipulation.

As configured, the system accepts input from four sensors, three of which are located on the inside of the house, one on the outside. The three inside sensors are averaged, and displayed on the screen as the current inside temperature. The outside temperature is displayed directly on the display. The actual temperature of the three sensors is displayed on the bottom line of the display, allowing the user to quickly access hot or cold spots in the house. Output is via a standard set of relays that can interface to a common heating and air conditioning system.

The real strength of this system is that it is modular. The system accepts up to 8 cards. One would typically be the display, another the output, and at least one input. With only these cards, the system would provide more detailed information than a standard thermostat. However, by adding cards for temperature, or possible humidity, the system's functionality and flexibility become obvious. Since output and input modules use the same 8-bit data bus, module function is limited only by the necessity of the application, and actual programming can be modified by power users because of the use of the Motorola 68705 microcontroller's on-board flash memory.

The two figures below (Fig. 8 and 9) show the schematic diagrams for two of the system boards.

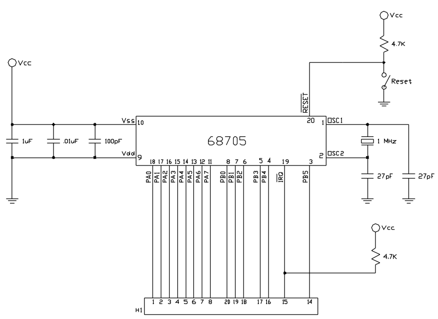


Figure 8

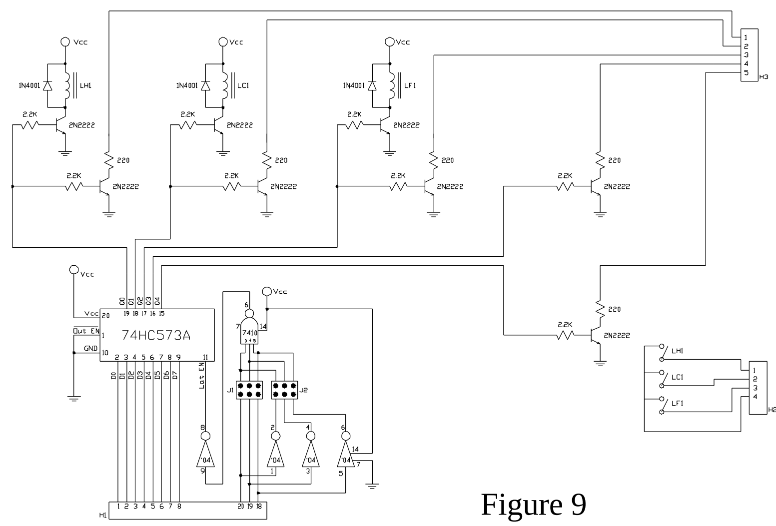


Figure 9

## Animatronics Project

The animatronics cube is shown in Figure 10. When the show features the Computer Design and Animation degree, the animatronics bear delivers the audio information while its eyes and lips move in synchronous with the spoken words. During this time an animated version of the same bear is showing in a stereoscopic mode on the large screen.

Figure 10: Animatronics Bear

## The Automated Doll House

The artistic project design consists of a 9-minute story with dynamic parts movement featuring 18 input/output lines. These lines control a ceiling fan, table chairs, bathtub fill and flushing, two fireplaces, porch light, various indoor lights and table lamps, etc. It provides a real inspiration for youngsters through fascination with technology.



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Figure 11 and 12, show the dollhouse before the turntable rotates and afterwards as you are getting a tour of the house through the narrated story.

Figure 11: Front view of dollhouse

Figure 12: Inside view of dollhouse

**The Motorized Spotlight Project**

As stated earlier, during the multimedia show, as various cubes descend, motorized spotlights illuminate the respective cube with colored floodlights to accent and focus attention on it. This project facilitates this process by spotlighting the various individual projects in the TZ on command from the main controller board. The lights are moved by means of stepper motors (two rotational axes). Tilting motion has about 160 degrees of movement and panning nearly 180 degrees.

The micro controller unit (MCU) is used to control the light (on, off) and the two axes via stepper motor driver circuitry. The MCU tracks the position of each axis through software (open loop control) and issues commands to the drivers as needed. A master control system sends commands to the MCU. The MCU has all of the desired positions and sequences in memory and simply receives timing information from the master control. Thus the master control supply instructs the MCU when to move to the next position.

For ease of use, a programming interface was also needed. Each position programmed in the Erasable Programmable Read Only Memory (EPROM) is moved to RAM before execution to allow external manipulation if needed. A pendant was designed to allow incremental motion for positioning.

The spotlight schematic is shown in Figure 13 with the motorized light assembly shown in Figure 14.

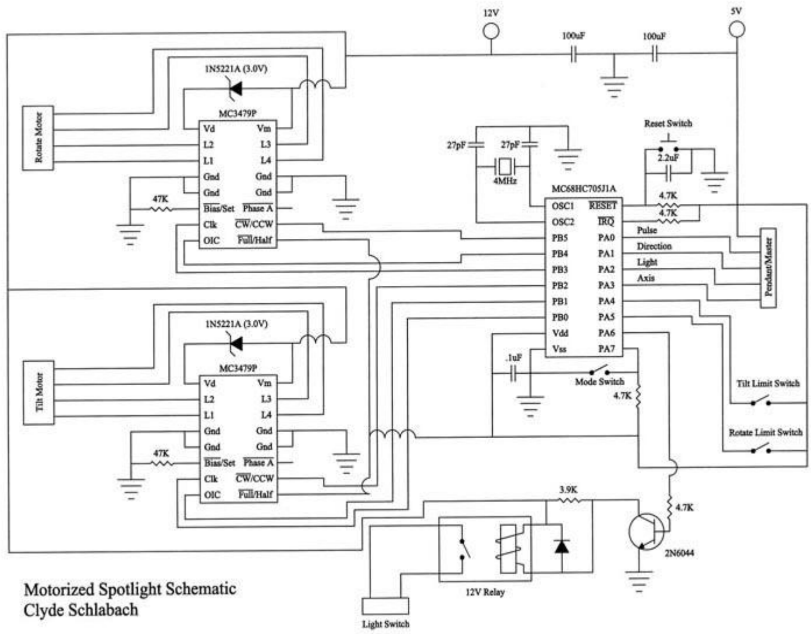


Figure 13: Motorized Spotlight Schematic

## Conclusion

Figure 14: Light Assembly

The techniques and methodology of rapid product design and development taught and observed in the Engineering Technology project course has proven to be effective. All eight students enrolled in the class produced working projects that met all of the design specifications without any compromise.

The acceptance of the Technology Zone by viewers from various constituencies from the University and the campus community and service area has far exceeded our expectations. We are already witnessing increased awareness in terms of added inquiries about the degrees offered and in increased enrollment in the technology programs for two years in a row. At the time of this writing, all eight students have graduated with a Bachelor of Science degree in Technology and all enjoy the benefit of a good job in their respective area of training.

DR. KAMAL F. BICHARA, Professor, School of Technology, Kent State University, Kent, Ohio 44242, USA.
Kbichara @Tusc.Kent.Edu