Project Plan and Product Specification

EML 4551C – Senior Design – Fall 2012 Deliverable

Team 13: Smart Materials Museum Exhibit Design

Glen Ashworth, Laura Wainikainen, Daniel Roque, and Isaac Piersall
Department of Mechanical Engineering, Florida State University, Tallahassee, FL

Project Sponsor

Challenger Learning Center

Project Advisor:
Dr. William S. Oates, Ph.D.
Department of Mechanical Engineering

Table of Contents

Introduction

Acknowledgements

Our team would like to thank our advisor Dr. William Oates of the FSU-FAMU mechanical engineering department for assisting us throughout the project. Also, we would like to thank Ms. Susan Borland and Mr. Harry Hawbecker of the Challenger Learning Center for consulting with us throughout the planning and execution of the project.

Problem Statement

The goal of this project is to build a smart material museum exhibit that is interactive as well as informative. Smart materials have a tremendous number of uses today, and yet a majority of the public is unaware of their utility. This project aims to increase public awareness of these materials, while providing the Challenger Learning Center with a new museum exhibit to attract visitors. The exhibit should be simple enough for grade school students to use and understand, while being safe and robust enough to stand up to repeated use. The exhibit should be completed and ready for display at the conclusion of the senior design project.

Operating Environment

The museum exhibit will be displayed in the Challenger Learning Center, located in Tallahassee, Florida. The exact placement of the exhibit will be determined by the sponsor, but will most likely be placed inside the facility's mock NASA mission control room. This control room is used to conduct mock NASA flight missions, simulating events such as launch, flight emergencies, and landing. Mission control is used primarily by students in grades 5^{th}-8^{th}. If the sponsor chooses not to place the exhibit inside mission control, it will simply be on display for all patrons of the Learning Center.

Assumptions

- The end user will be a 5^{th}-8^{th} grade student
- The exhibit will fit in to the Challenger Center's theme of space exploration
- The exhibit will be used indoors in a fixed location
- The microcontroller will adequately control the power applied to the piezoelectric ceramic to get optimum output
- Voltage from the amplifier will not exceed 250V/mm so as to not have a depolarizing effect on the ceramic
- The maximum number of users at a time will be one person

Limitations

- The funds for the project are limited, although they may grow depending upon the final design and grants received.
- The displacement of the piezoelectric ceramic is very small
- The number of ceramics and lasers used will depend on the final budget allotted
- The final exhibit must be safe for use around school-aged children

Expected End Product

The expected end product of this senior design program is a museum exhibit ready to be displayed and used by children. A manual describing the exhibits features and capabilities will be included as well. The manual will include a replacement parts guide in the event of any component failure. The software code designed for the microcontroller will be included in this manual as well. Also, a brief background will be included to highlight smart material features for educational purposes.

Product Specification

The construction of the museum exhibit will consist of three main devices; the smart material, a laser and mirror, and an amplifier/controller. Smart materials consist of many different types, including but not limited to thermoelectric, self-healing, magnetostrictive, piezoelectric, and shape-memory materials. This project will focus on the piezoelectric ceramic type of smart material.

Lasers and Mirrors

The laser(s) chosen for this design project will be of the low-powered design type. This exhibit will be used indoors, in a relatively small location, so minimal power will be required. Safety, of course, is paramount in any design. Any combination of lasers and mirrors must have safeguards to prevent from shining in the eyes of any visitors to the Learning Center. Factors also desirable when it comes to laser selection are durability and cost. Many different types of lasers are available, including solid-state, gas, excimer, and semiconductor lasers. The laser must also be permanently mountable. The mount must be secure because the final output of the laser depends on the proper positioning of the laser. The power source is also another consideration. Many lasers are simply battery powered. If the exhibit is to be displayed all day, batteries would simply run out and need to be replaced. The laser must have a dedicated power source that will not have to be adjusted unless the laser fails and needs to be replaced.

The laser must be reflected off of the piezoelectric ceramic surface. The ceramic is mounted like a cantilevered beam. In order to utilize the maximum displacement from the ceramic, the laser must be pointed near the end of the ceramic. The mirror material could be made from glass, acrylic, or reflective tape. Reflective tape would be the lightest choice, and would be easily mounted with an adhesive backing. Weight of the mirror may alter the expected output if the added mass changes the response of the system. Acrylic mirror is ten times stronger than glass, and does not shatter when it breaks, which makes it a viable alternative as well.

Microcontrollers and Amplifier

The piezoelectric bender(s) and the laser will be controlled through a microcontroller. However, most microcontrollers will only output 5v and only a few milliamps which will work to power the laser, but the piezoelectric bender needs 100's of volts. This means that the control signal from the microcontroller will need to be amplified so that it can supply the needed voltage, current, and frequency.

The best choice in microcontrollers would be one that is already attached to a board, such as the Arduino Uno or Dragon 12. The Arduino Uno is affordable, about $30-$40, has a total of 14 digital input/output pins, 6 of which have pulse width modulation (PWM), 6 analog pins and a 16 MHz crystal oscillator. The Dragon 12 is more expensive, about $150, but not only does it have 89 I/O-Pins, 8 PWM pin, and clock speeds up to 25 MHz It also has a built in LCD display, 4X4 push button matrix, 4 eight segment digital displays, and many more peripherals. There are also other Arduinos that have more I/O pins, and the more I/O pins there are the more expensive the boards become, but they are still less expensive than the Dragon 12 board, mostly due to the fact that the Arduinos have fewer built in peripherals.

The amplifier needs to be able to produce around 200 volts and its output will be controlled by the microcontroller. This can easily be the most expensive part of the project, some amplifiers costing $2000 - $3000. These can produce a maximum 200 volts, maximum current of 200 mA, out power is 40 watts, and can reach a frequency of 250 KHz. A less expensive model can produce 175 volts, 60 mA, 16 watts of power, and 30 KHz. One of the lesser expensive models will most likely be chosen for this project.

Piezoelectric Ceramics

These ceramics are the type of smart material that will be implemented in our project. These special ceramics demonstrate piezoelectricity. This charge accumulates in the ceramics in response to mechanical stress. When pressure is applied to one of these materials, the crystalline structure produces a voltage proportional to the pressure. There is also an effect when this is applied conversely. When electricity is applied to the ceramic, the structure changes shape producing dimensional changes in the material. Voltage changes the dimensions of the ceramic for as long as the voltage is applied.

Behavior in these ceramics is very interesting indeed and the results subject to force or electricity can be calculated. At low input frequencies, the relationships between the force being applied to the ceramic and the electric field or charge produced by the piezoceramic can be calculated using the following equations:

1) $E = -(aT)$; with a = piezoelectric voltage constant, T = stress on material

2) $Q = -(bF)$; with b = piezoelectric charge constant, F = applied force

As mentioned earlier dimensional changes can also be a result of applied electricity and can be determined as follows:

3) $\Delta h = bV$; with Δh = change in height or thickness, V = applied voltage
4) $S = bE$; with S = strain, E = electric field

Piezoelectric sensors are also available that uses the piezoelectric effect to give the electrical charge given produced by the pressure, strain or force.

There are also effects if the ceramic is exposed to an alternating electric field. The ceramic would then change its dimensions cyclically at the frequency of the electric field. Its effect is not infinite as there are factors that come into play while it is being exposed. A piezoelectric material will depolarize when exposed to a strong electric field. How much it depolarizes is dependent on strength of the electric field, time exposed, temperature, grade of material and more. For the most part, voltage between 200 – 500 V/mm or greater has depolarizing effect. Electrical limits are not the only ones as there are mechanical limits as well. If too much mechanical stress is applied it can destroy the alignment of the dipoles in the material. The amount of stress it is capable of withstanding varies depending on grades and brands of piezoelectric materials.

Project Plan

Code of Conduct

The code of conduct lays out the framework for team member responsibility. Positions, such as team leader, treasurer, sponsor liaison, and webmaster are assigned.

Problem Definition

Smart materials are relatively unknown to the general public, especially younger students. This design project aims to increase public knowledge of these dynamic and useful materials. The museum exhibit must demonstrate the properties of the smart material, while being a source of entertainment as well.

Needs Assessment

The needs assessment deliverable evaluates the problem posed by the sponsor and attempts to explicitly state the intentions of the project. This deliverable will assess what is requested from the Challenger Learning Center, as well as any constraints posed by their request as well. Additionally, this report will adequately explain what the project is about.

Project Management

Our team will work collectively to design and assemble the exhibit that displays the piezoelectric ceramic. The other components will be arranged in a specific manner so that they work together to produce a viable product. Upon usage students will gain a better understanding of smart materials and their use in space exploration.

Product Specifications and Project Plan

This deliverable will clearly define the plan of action intended for the project and will include a detailed schedule, which will include various milestones and tasks. The product specifications portion will explain the main components of the project and how they will work.

Component Selection

Our smart material to be used in the exhibit will be piezoelectric ceramics, which is not to be confused with piezoelectric crystals. Other vital components to the project will be microcontroller, amplifier, and lasers. Each component will be selected with budget and reliability in mind. It is also key that all of the components are in sync and can be used together.

Conceptual Design Review

Once a solid understanding of the needs and specifications of the project is reached, conceptual designs will then be produced. Multiple designs will be generated and evaluated. Upon gauging the feasibility of each design based on certain criteria, a final design will then be chosen.

Midterm and Final Design Presentations

The design presentations will be presented to both the Challenger Learning Center and the FAMU-FSU College of Engineering, so that both groups understand the project and its progress. There will be multiple design presentations throughout the semester to ensure adequate progress being made.

Budget Estimate

Material	**Quantity**	**Estimated Cost**
Piezoelectric Ceramic	2	$300
Piezoelectric Ceramic Mount	2	$50
Laser	1	$25
Laser Mount	1	$25
Microcontroller	1	$50
Amplifier	1	TBD
Exhibit Case	1	TBD
Exhibit Stand	1	TBD
Mirror	1	$10

Budget Summary

The amount of money available for the project is at least $500. After selecting a final project design, the design will be submitted to Challenger Learning Center and the Florida Space Grant Consortium in an attempt to secure more money. The Challenger Learning Center also has access to some materials through the FSU surplus program, and they will attempt to source whatever materials they have access to for free.

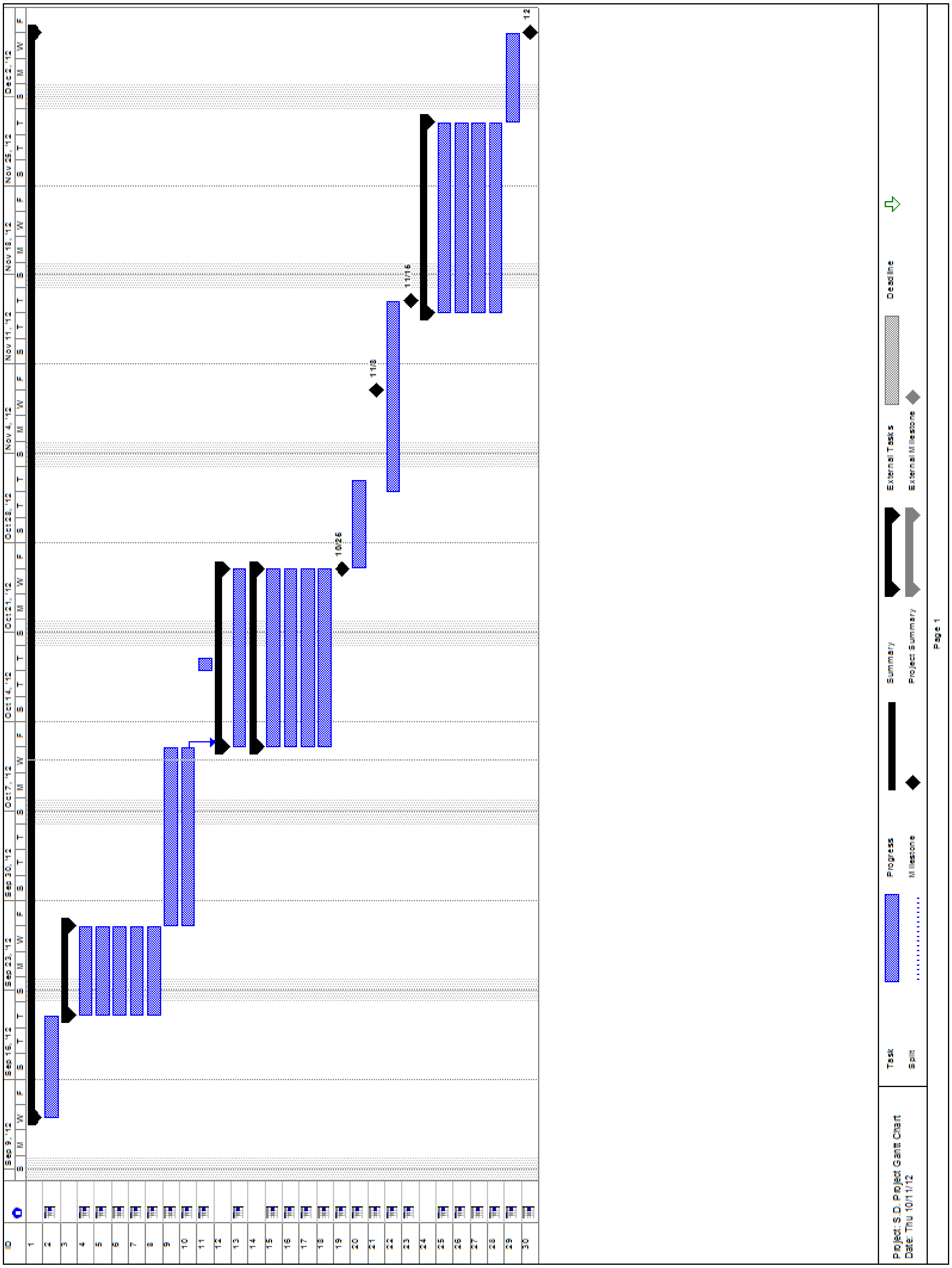
Schedule

The Gantt chart shows our schedule for the first semester of our senior design project. Next to each task is the allotted time to complete each task and the date in which it will be started and completed. There are five major milestones as well as 3 group presentations. The schedule is intended to keep each group member on track and ensure each task is performed in a timely manner. If there are any changes to the project schedule the Gantt chart will be updated and shared with every member of the group.

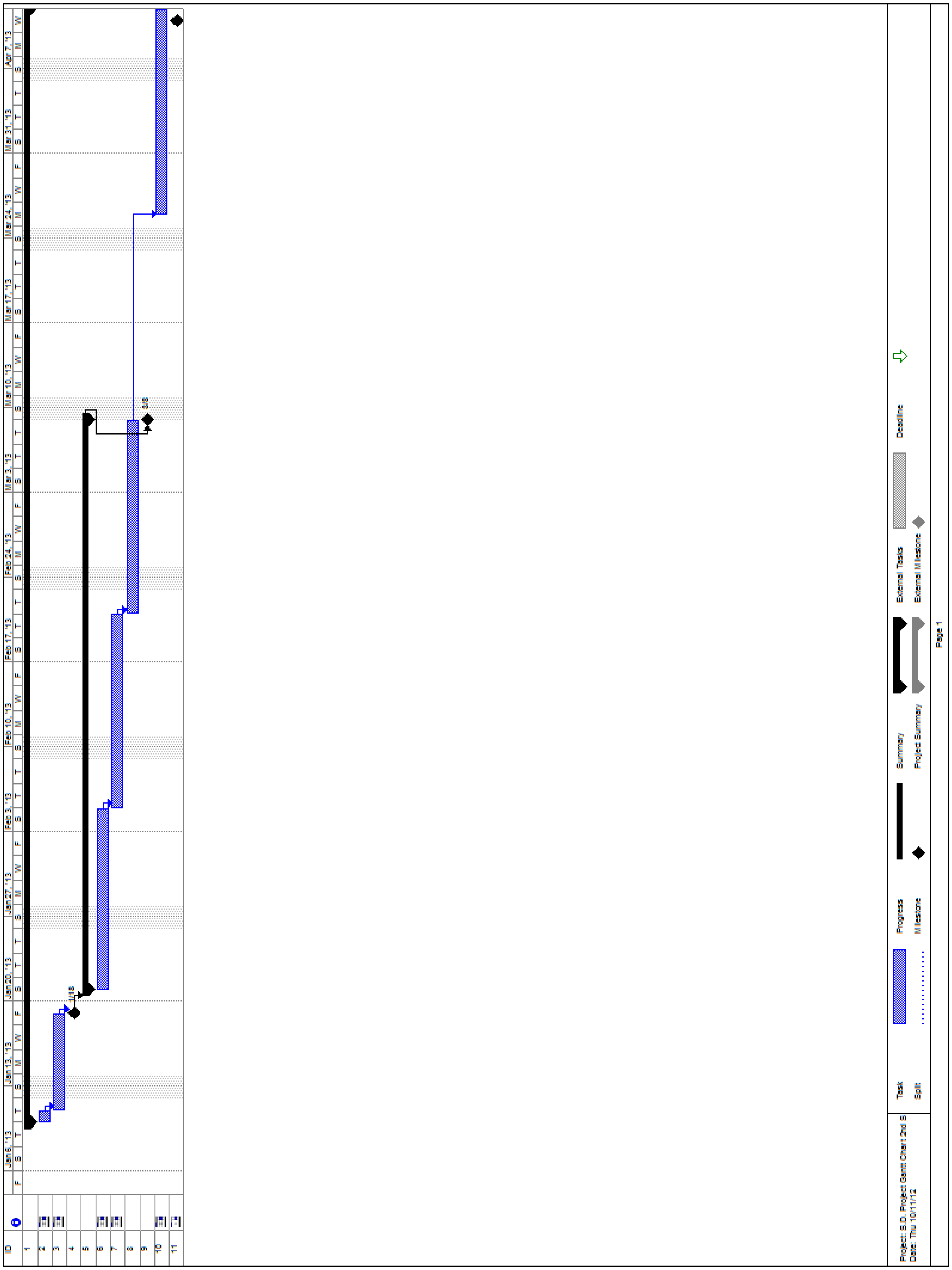
Along with tasks described in the Gantt chart we will have weekly meetings with our faculty advisor. Dr. William S. Oates. At these meetings we will discuss any updates to the project as well as brainstorm new ideas for improvement of the project. We will also have biweekly meetings with Dr. Amin. These meetings are brief so we will turn in our biweekly progress reports and update Dr. Amin on the progress of our project. During these meetings we will get feedback on our reports and discuss any new deliverables.

Gantt Chart

Fall 2012



Spring 2013


Task
Split
Progress
Milestone
Summary
Project Summary
External Tasks
External Milestone
Deadline
Page 1

Tasks Descriptions

Fall 2012

S.D. Project Gantt Chart						
ID		Task Name	Duration	Start	Finish	Predecessors
1		**Fall 2012**	**61 days**	**Thu 9/13/12**	**Thu 12/6/12**	
2		Milestone #1 Code of Conduct	6 days	Thu 9/13/12	Thu 9/20/12	
3		**Milestone #2 Needs Analysis**	**5 days**	**Fri 9/21/12**	**Thu 9/27/12**	
4		Project Scope	5 days	Fri 9/21/12	Thu 9/27/12	
5		Problem Statement	5 days	Fri 9/21/12	Thu 9/27/12	
6		Justification/Background	5 days	Fri 9/21/12	Thu 9/27/12	
7		Objectives (Measurable Criteria)	5 days	Fri 9/21/12	Thu 9/27/12	
8		Constraints	5 days	Fri 9/21/12	Thu 9/27/12	
9		Milestone #3 Project Plan/ Product Spec	10 days	Fri 9/28/12	Thu 10/11/12	
10		Gantt Chart	10 days	Fri 9/28/12	Thu 10/11/12	
11		Discussion of Teams Eval. And Selection of	1 day	Thu 10/18/12	Thu 10/18/12	
12		**Milestone #4 Concept Generation/Selecti**	**10 days**	**Fri 10/12/12**	**Thu 10/25/12**	**10**
13		Functional Analysis	10 days	Fri 10/12/12	Thu 10/25/12	
14		**Individual Tasks and Assignments**	**10 days**	**Fri 10/12/12**	**Thu 10/25/12**	
15		Design Concepts Development	10 days	Fri 10/12/12	Thu 10/25/12	
16		Concept Evaluation and Selection	10 days	Fri 10/12/12	Thu 10/25/12	
17		Product Specifications for hardwar	10 days	Fri 10/12/12	Thu 10/25/12	
18		Performance and Functional Spec	10 days	Fri 10/12/12	Thu 10/25/12	
19		Midterm Presentation I	0 days	Thu 10/25/12	Thu 10/25/12	
20		Team Evaluation Report	5 days	Fri 10/26/12	Thu 11/1/12	
21		Presentation to MEAC	0 days	Thu 11/8/12	Thu 11/8/12	
22		Interim Design Review	11 days	Thu 11/1/12	Thu 11/15/12	
23		Midterm Prsentation II	0 days	Thu 11/15/12	Thu 11/15/12	
24		**Interim Design Deliverables**	**11 days**	**Thu 11/15/12**	**Thu 11/29/12**	
25		Bill of Material	11 days	Thu 11/15/12	Thu 11/29/12	
26		Work Orders	11 days	Thu 11/15/12	Thu 11/29/12	
27		Parts	11 days	Thu 11/15/12	Thu 11/29/12	
28		Machining	11 days	Thu 11/15/12	Thu 11/29/12	
29		Milestone #5 Deliverable Package Report	5 days	Fri 11/30/12	Thu 12/6/12	
30		Final Design Presentation	0 days	Thu 12/6/12	Thu 12/6/12	

Spring 2013

S.D. Project Gantt Chart 2nd Semester						
ID		Task Name	Duration	Start	Finish	Predecessors
1		**Spring 2013**	**66 days**	**Thu 1/10/13**	**Thu 4/11/13**	
2		D #1 Restated Scopes an	1 day	Thu 1/10/13	Thu 1/10/13	
3		D #2 Progress Report	6 days	Fri 1/11/13	Fri 1/18/13	2
4		Design Review Presentat	0 days	Fri 1/18/13	Fri 1/18/13	3
5		**D #3 Purchasing/ Assem**	**35 days**	**Mon 1/21/13**	**Fri 3/8/13**	**4**
6		Purchasing	11 days	Mon 1/21/13	Mon 2/4/13	
7		Prototype Building	12 days	Tue 2/5/13	Wed 2/20/13	6
8		Prototype parametric	12 days	Thu 2/21/13	Fri 3/8/13	7
9		Design review II Presenta	0 days	Fri 3/8/13	Fri 3/8/13	5
10		D #4 Final Report	13 days	Tue 3/26/13	Thu 4/11/13	8
11		Open House (MEAC, Jud	0 days	Thu 4/11/13	Thu 4/11/13	

Bibliography

[1] Schodek, Daniel. "Types and Characteristics of Smart Materials." *Smart Materials and New Technologies*. By Michelle Addington. Burlington: Elsevier, n.d. 93-108. Print.

[2] "Plexiglass Mirror." *Estreetplastics.com*. N.p., n.d. Web. 10 Oct. 2012. <http://www.estreetplastics.com/Plexiglass_Acrylic_Mirror_Sheets_1_8_thick_s/38.htm>.

[3] "Piezo Systems: High Voltage Piezo Linear Amplifier." *Piezo Systems: High Voltage Piezo Linear Amplifier*. N.p., n.d. Web. 9 Oct. 2012. <http://www.piezo.com/prodelect1epa104.html>.

[4] "Low Cost Piezo Driver / Amplifier A-301." *Low Cost Piezo Driver / Amplifier A-301*. N.p., n.d. Web. 10 Oct. 2012. <http://www.lab-systems.com/products/amplifier/a301.html>.

[5] "DRAGON12-Plus2." *Evbplus.com*. N.p., n.d. Web. 11 Oct. 2012. <http://www.evbplus.com/>.

[6] "Arduino." *Arduino*. N.p., n.d. Web. 11 Oct. 2012. <http://www.arduino.cc/>.

[7] "E650 Piezo Driver for Multilayer Bender Actuators, OEM Module / Bench-Top." *E650 Piezo Driver for Multilayer Bender Actuators, OEM Module / Bench-Top*. Physikinstrumente.com, n.d. Web. 11 Oct. 2012. <http://www.physikinstrumente.com/en/products/prdetail.php?sortnr=602100>.

[8] "P-871 PICMA Piezo Bender Actuators." *Physikinstrumente.com*. N.p., n.d. Web. 10 Oct. 2012. <http://www.physikinstrumente.com/en/products/prdetail. php?VID=tgVrju5GMEifJwti OZBkcv 27q>.

[9] "Piezo Ceramic Tutorials." *What Are Piezo Ceramic Materials?* Morganelectroceramics.com, n.d. Web. 9 Oct. 2012. <http://www.morganelectroceramics.com/resources/piezo-ceramic-tutorials/>.

[10] "Behavior of a Piezo Element." *Americanpiezo.com*. N.p., n.d. Web. 10 Oct. 2012. <http://www.americanpiezo.com/knowledge-center/piezo-theory/behavior.html>.