# Fall Final Deliverable

**EML 4551C – Senior Design – Fall 2011 Deliverable**


Team # 4

**William Ehlers, Daryl Montooth, Redan Reyes, Manuel Santos**

*Department of Mechanical Engineering, Florida State University, Tallahassee, FL*


*Project Sponsor*

Eglin Air Force Base

*Project Advisor(s)*

**Dr. William Oates**

*Department of Mechanical Engineering*

**Table of Contents**

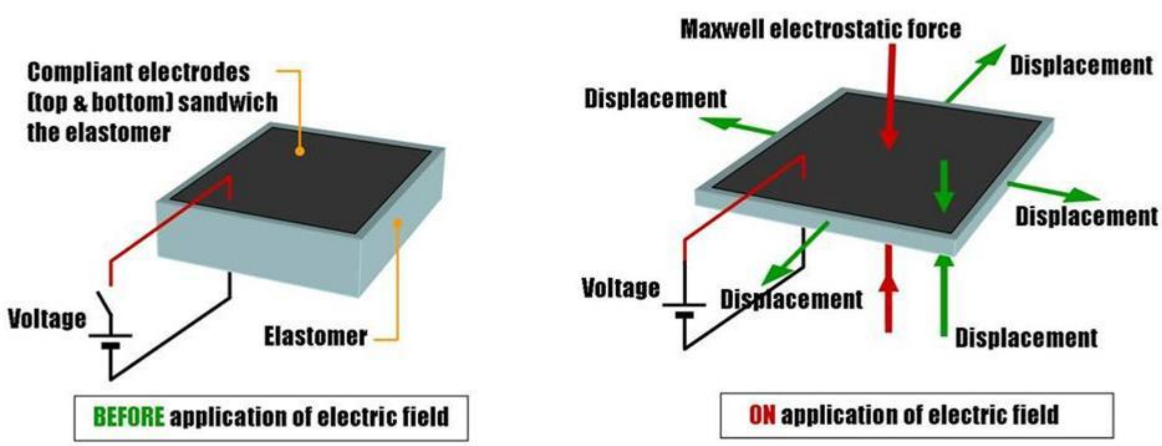
## Introduction

Our project is sponsored by Air Force Research Laboratory Munitions Directorate at Eglin Air Force Base in Pensacola, Fl.

The purpose of this project is to design an electro-active membrane for micro air vehicles. We want design a light membrane that enhances the aerodynamic properties of the micro air vehicles. These electro active membranes, when voltage is applied, experience a force on both sides compressing it. This compression causes displacement throughout the surface. Throughout this report we will present multiple concepts which try to achieve better flight characteristics for micro air vehicles. We will compare these results to rigid wings, which are currently in use for these micro air vehicles, to determine the effectiveness of our membranes. A large increase in lift is something of great importance to us when considering designs.

**Figure 1 –** Micro Air Vehicle's are very small in wingspan, as shown next to a hand.

2 (a) 2 (b)




**Figures 2 (a) & (b)** – Forces on the membrane cause the thicknes to decrease and surface area to increase, allowing the wing to deform in shape and change the aerodynamics.

**Chosen Design**

The chosen concept of varying both the overall pre-strain and the nature of its application to the membrane (i.e. bi-axially, etc.) is to be implemented as it has the greatest potential for performance improvement based on our means of experimentation. There is much data on the drastic nature of change in material properties and lift characteristics when altering the pre-strain. We will be utilizing 300% biaxial pre-strain as a base value for comparison, and with data for this value readily available, calibration of our analytical approach (i.e. ensuring correspondence of our calculations and those for like experiments) will be less difficult.

Why Optimize? We have noticed that in data available, incrimination of pre-stretch values above and below 300%x300% has been drastic for actuators experimentally similar to ours. This leaves room to establish that while this base value exhibits the best potential for performance given its compared values and experimental geometry (of biaxial symmetry, i.e. circular), a variation in symmetry and intensity of pre-stretch could improve overall membrane performance, especially given the elliptical nature of our setup.

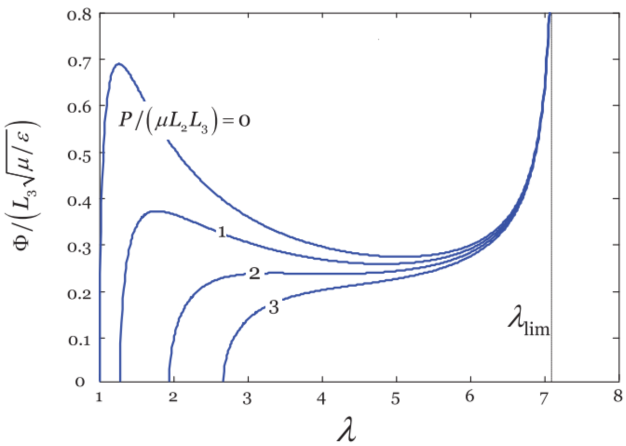



**Figure 3** - Characteristic behavior of dielectric elastomer subject to equal biaxial forces (normalized voltage vs. strain).

Source for Reference: http://www.bimat.org/polImage.cfm?doc_id=704&Size_Code=Doc

Optimizing will ensure membrane deformation and frequencies experienced therein will be the most stable, maximizing the dependability of the membrane, and allowing us to make the best use of our limited time at the REEF facility. Also, the range of applied voltages between desired states of deformation will be minimized, decreasing the potential for fatigue when cycling from one to the other. The Nelder-Meade method utilized in an experiment of comparable optimization (source: Modeling Dielectric Elastomer Actuators, Wissler 2007, http://www.empa.ch/plugin/template/empa/*/78910) is to be considered among techniques of direct optimization provided by our advisor (MATLAB functions fminsearch and fmincon).

**Customer Needs**

- Total Wingspan must be less than or equal to 6 inches

- Time Response of membrane from rest to full deformation

- Stabilization through gust alleviation

- Light-weight (Micro Air Vehicle)

- Membrane Deformation when a voltage is applied

- Improved response at modal frequencies (compared to previous experiments)

**Experimental Setup**

This research project will be conducted in an experimental format. In order to test and justify the validity of our selected design, Team 4 intends on recreating the original concept created by our predecessors. This original concept with the 300 % by 300 % prestrain will serve as the control design for our experiment. Therefore, our selected design of varying the prestrain will have a reference data to compare to. The REEF facility at Eglin Air Force Base will serve as the main facility where the majority of our important data recordings will be conducted. This experiment will require certain forms of equipment for proper execution and data recording. Most importantly the REEF facility houses a large wind tunnel where our wing will be placed and tested in. A series of probes and other measuring devices throughout the wind tunnel will be connected to a computer where software like LABVIEW will be used to record the data. In addition, there will be special devices used to measure induced air flow properties such as the sting balance for drag, lift, axial forces, and etc.

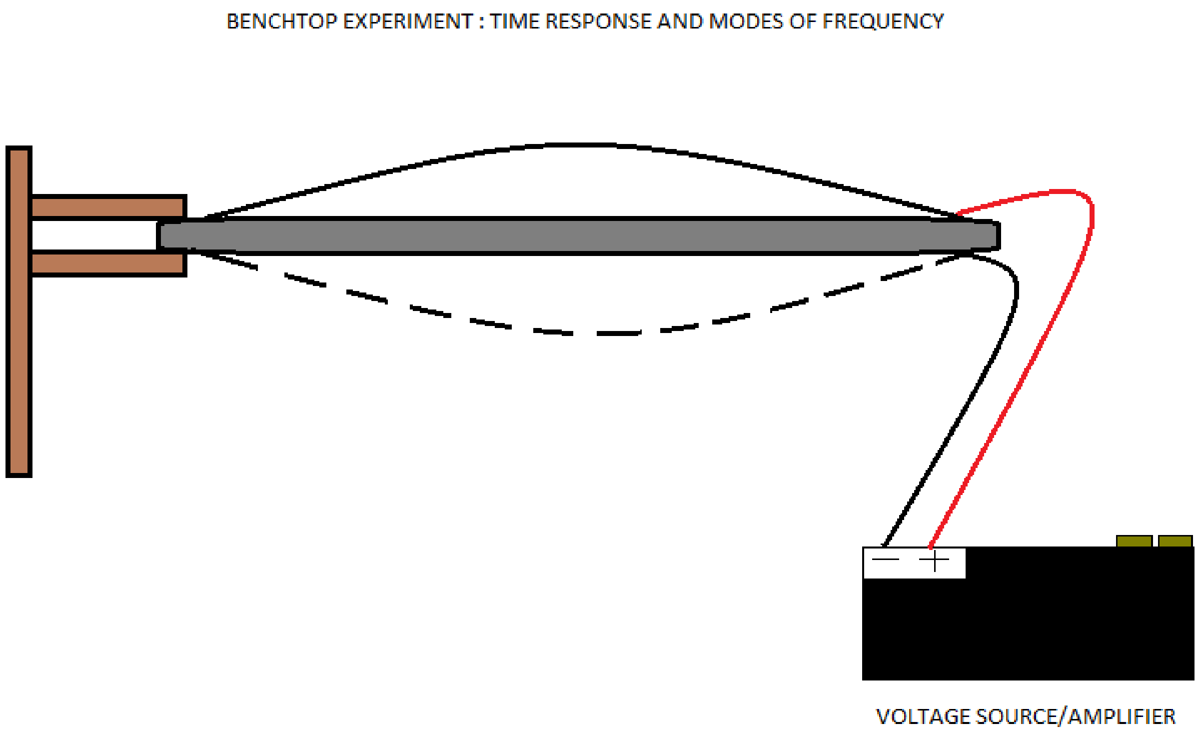



**Figure 4** - Benchtop Testing Setup

Figure 4 shows the first part of the experiment which will be for recording and observing Time Response and Change in Mode Frequencies. This can be conducted at the FSU COE facilities. In this part of the experiment the wing will be attached to a "shaker". This shaker will "shake" the wing. This shaking will induce vibrations throughout the wing similar to vibrations a wing would normally experience during flight. The time it takes for the wing to exhibit deformation after voltage application will be recorded. Then under the vibrational conditions, the wing be put through multiple variations in voltage to changes in mode frequency.

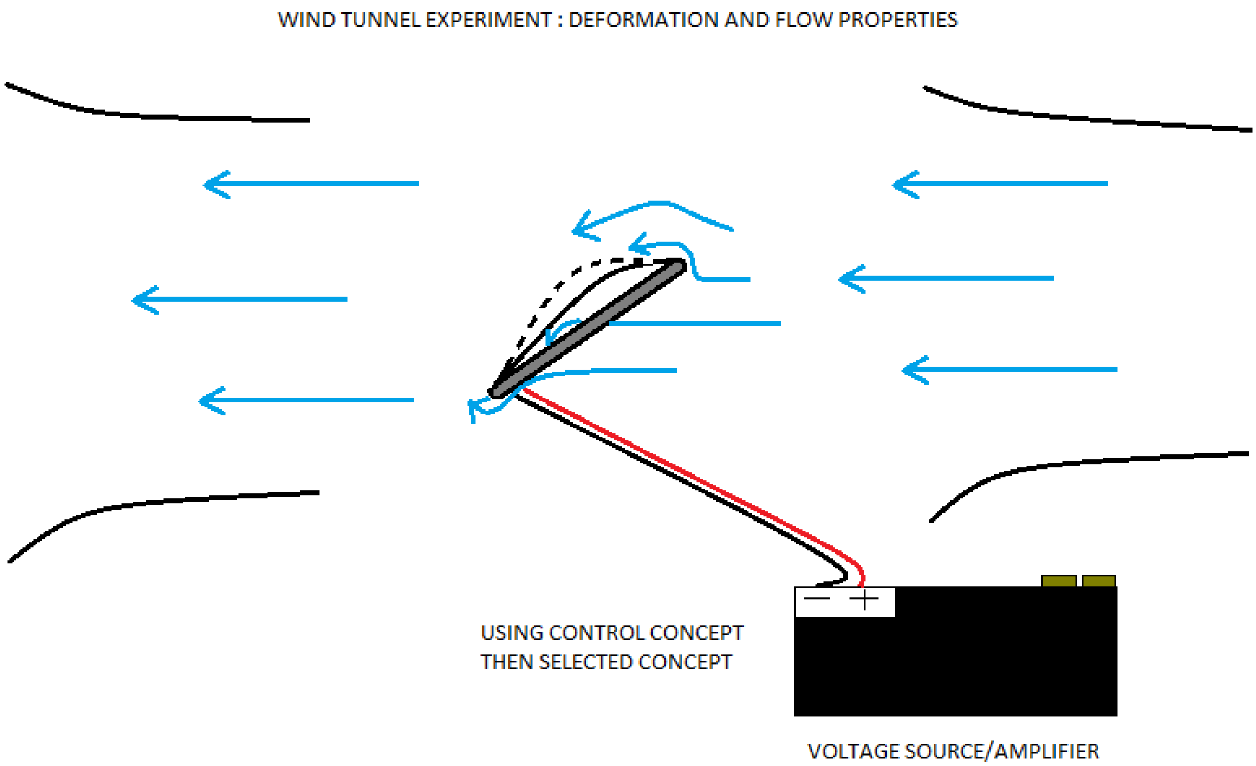



**Figure 5** - Wind Tunnel for Deformation and Flow Properties

Figure 5 shows the second part of the experiment which is intended to be conducted at the REEF facility at Eglin. In this part of the experiment, The wing will be placed on a sting balance inside the wind tunnel. The idea is to induce an air flow of about 10 m/s directly at the wing which will be oriented at varying angles of attack. During this time while air flow is induced, deformation should be observed and the various instruments will be recording the aerodynamic properties experienced by the wing before and after voltage is applied.

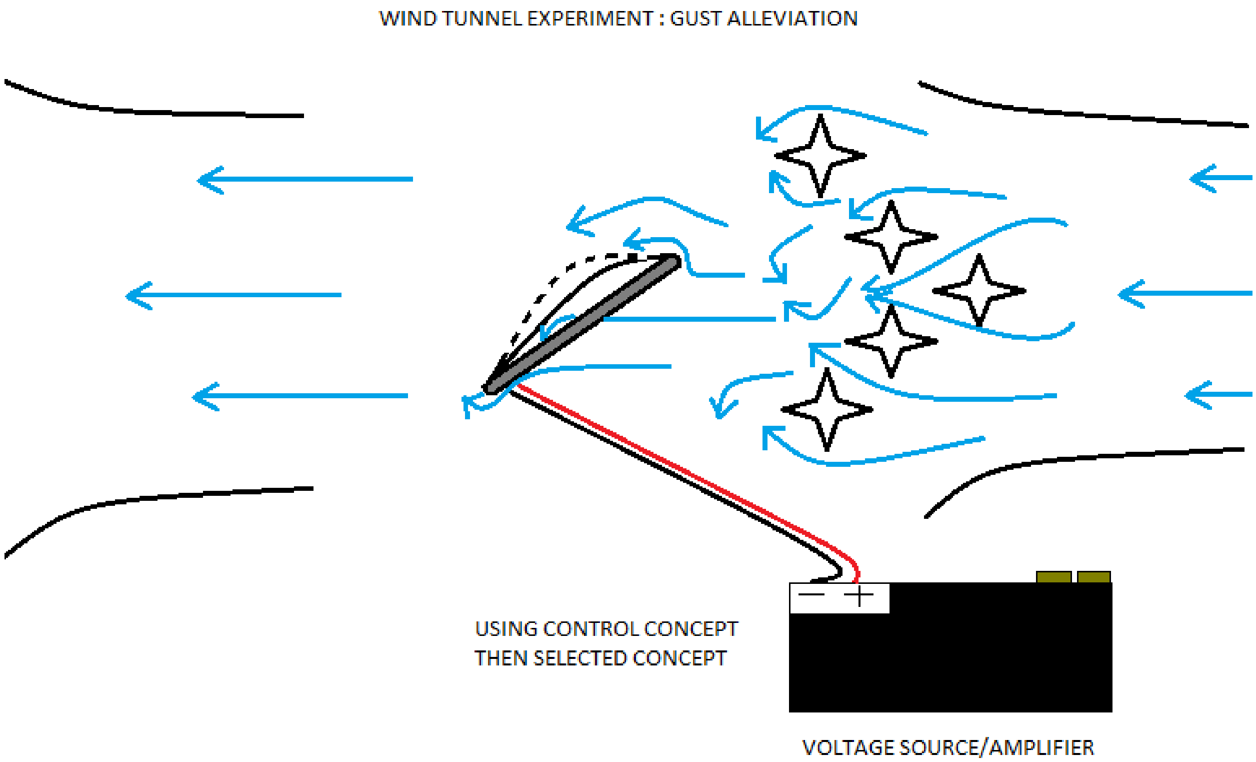



**Figure 6** - Wind Tunnel for Gust Alleviation

Figure 6 shows the third part of the experiment which is similar to the second part of the experiment however one thing will be changed. In order to observe how the wing reacts towards gust alleviation, a bluff blody will be placed in front of the wing in front of the incoming air flow. The bluff body simulator at Eglin is a large wall of rotating plates which simulate induced vorticies. This will be used in this experiment to generate the vortices supposedly generate by a bluff body. During this experiment, how the wing reacts to this imposed condition wil be recorded over time with and without applied voltage.

**Cost Analysis**

| Product | Cost |
| --- | --- |
| Carbon Grease | $26(2 tubs) |
| VHB4910 Tape | $56.64 for 2 rolls |
| Aluminum Frame | $72.40 for one sheet |
| Electrical Wire | $20 for 5 feet |
| | Total Cost: $175.04 |

**Figure 7** - Table Showing Cost Analysis Breakdown

Base on the setup of our experiment, and preliminary data we have come to the conclusion that we will be running through a fair amount of material. The material breakdown of the costs per material can be seen in Figure 7. So we assumed that carbon grease and vhb tape would need to be constantly renewed assuming the material fails from time to time. Taking this into consideration, we decided to purchase two tubs of carbon grease and two rolls of vhb tape which are each five yards long. All other costs like aluminum for the frame are considered with only one necessary iteration. From scratch, this experiment will incur a cost of under $200. However, this is assuming that none of the materials are already available. In reality this cost will decrease because the lab facilities already have some of these materials as well as the aluminum frame. One additional remark is that this cost does not include cost of existing equipment such as the voltage amplifiers or the wind tunnel, nor does it include travel costs. However, considering everything the costs will come well beneath the $2,000 limit.

## Future Plans

| ID | Task Name | Duration | Start | Finish |
|---|---|---|---|---|
| 1 | Code of Conduct | 4.5 days | Mon 9/12/1 | Fri 9/16/1 |
| 2 | 1st Advisor Visit | 0.5 days | Mon 9/26/1 | Mon 9/26/1 |
| 3 | Project Needs/ Scope | 5 days | Sat 10/1/1 | Thu 10/6/1 |
| 4 | Product Spec/Project Plan | 6 days | Thu 10/6/1 | Thu 10/13/1 |
| 5 | 2nd Advisor Visit | 0.5 days | Thu 10/13/1 | Thu 10/13/1 |
| 6 | Phone Meeting w/ Mentor | 4 days | Mon 10/17/1 | Thu 10/20/1 |
| 7 | Concept Gen. & Selection | 5 days | Fri 10/21/1 | Thu 10/27/1 |
| 8 | Present : Concept Design | 1 day | Thu 10/27/1 | Thu 10/27/1 |
| 9 | Benchtop Testing | 10 days | Fri 10/28/1 | Thu 11/10/1 |
| 10 | Eglin Tour / Meet Mentor | 1 day | Fri 11/4/1 | Fri 11/4/1 |
| 11 | Present:1st Dsgn Review | 1 day | Thu 11/17/1 | Thu 11/17/1 |
| 12 | Mentor reads Rough Draft | 6 days | Mon 11/28/1 | Mon 12/5/1 |
| 13 | Final Design Package | 6 days | Thu 12/1/1 | Thu 12/8/1 |
| 14 | Present : Final Design | 1 day | Thu 12/8/1 | Thu 12/8/1 |
| 15 | Order Materials | 2 days | Mon 12/12/1 | Tue 12/13/1 |

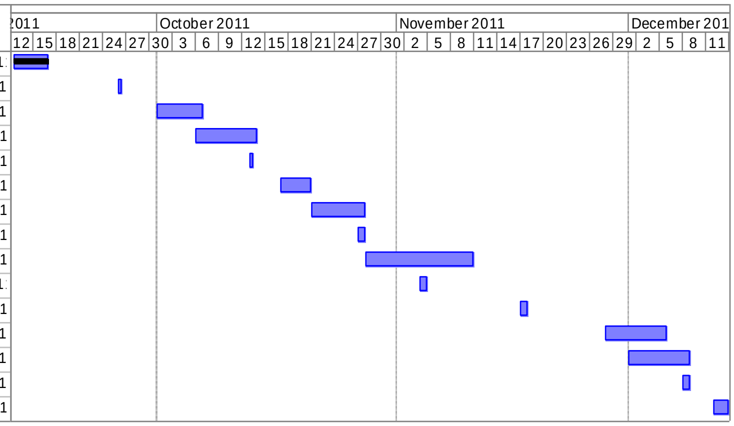



**Figure 8** - Table Showing Fall Semester 2011 Timeline

| ID | Task Name | Duration | Start |
|---|---|---|---|
| 1 | Receive Materials | 2 days | Fri 1/13/1 |
| 2 | Prototype Build | 5 days | Fri 1/20/1 |
| 3 | Prototype Testing | 6 days | Sat 1/28/1 |
| 4 | Data Analysis | 3 days | Mon 2/6/1 |
| 5 | 2nd Test(If Needed) | 4 days | Mon 2/13/1 |
| 6 | 2nd Data Analysis | 3 days | Fri 2/17/1 |
| 7 | Final Build | 4 days | Sat 2/25/1 |
| 8 | Final Testing & Analysis | 6 days | Sun 3/4/1 |
| 9 | Final Report & Presentation | 1 day | Wed 4/18/1 |

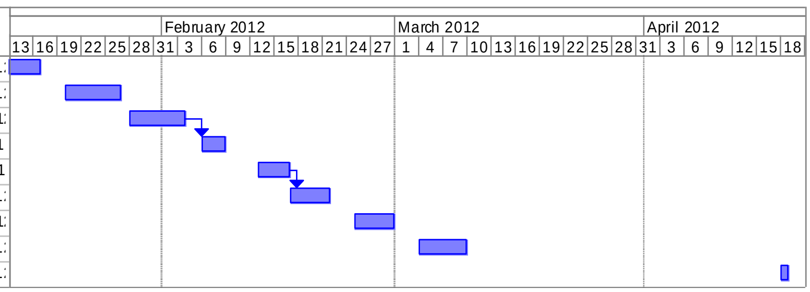



**Figure 9** - Table Showing Spring Semester 2012 Timeline

Next semester begins the assembly of the prototype along with experimentation. We will begin experimentation in early March through the wind tunnel located near Eglin Air Force Base, REEF. The spring semester will involve much iteration of experiments to cover all the aspects we want to measure. During the experimentation process, we will take diligent notes as to our experiment to assure nothing goes wrong. Considering we are limited to use on the wind tunnel, we need to make sure everything we do is right. We only have the capability to rent the wind tunnel for a short period of time and that is it. The experimental setup will look like Figure 1, with 2 high-speed cameras for visual image correlation. The sting balance will record forces as well as moments experienced by our wing.

Throughout the experimentation process we will be contacting both our mentor Dr. Dickinson and our advisor Dr. Oates. They will guide us in the proper steps to take in analyzing our data as well as understanding it. When assembling all relevant and useful data, we will get in touch with Dr. Dickinson to assure that our data is both accurate and crucial to his standards. Our goal is to achieve the needs of our clients and Dr. Dickinson can make sure we are headed in the correct direction.

**Figure 10** – This is the wind tunnel set-up that will be used for testing, which is

located just outside of Eglin Air Force Base.

The spring semester entails a very methodical process in order to achieve our goal, satisfying the client. This methodical process starts with bench top testing throughout the beginning of the semester. This test will give us a preliminary look at the behavior of our membrane. Some data we could collect includes frequency of the membrane. The frequency is crucial considering it was one of the major concerns expressed by the client. The client specifically asked for the membrane to achieve a stable frequency mode.

**Conclusion**

At the end of Fall Semester 2011, it appears that we are ready for experimentation. Based on preliminary data, for example dielectric breakdown of vhb tape, we have determined that the design where the pre-strain is varied would be the ideal choice for further research under these circumstances. By running with the design of varying the pre-strain, we believe that it may be possible to increase deformation and thusly the behavior of the system's response to applied voltage and induced conditions. The cost for this fairly new branch of research appears to be fairly reasonable considering our estimated cost of $200 is only a fraction of our allotted budget of $2,000 and also considering some of the materials are already available to us without monetary consequence. This leave an incredibly wide margin for travel costs which should also be minimal. The team's only drawback at this point is appropriately defining the system by governing equations as well as the need to invest time in understanding certain Finite Element Methods for analyzing the system as this is essential to properly understanding the system's behavior. However, despite these circumstances we believe that the design of the experiment for what our client is asking us to observe is sound and ready for execution.

## Works Cited

Dielectric Elastomer Graph, : http://www.bimat.org/polImage.cfm?doc_id=704&Size_Code=Doc.

Modeling Dielectric Elastomer Actuators, Wissler 2007, http://www.empa.ch/plugin/template/empa/*/78910).

Group 5: 2010-2011 Senior Design, http://eng.fsu.edu/me/senior_design/2011/team5/ .