TABLE OF CONTENTS

General Overview

ID #	Tasks	Days	Start	Finish	Start Week	Finish Week	Assignments
MSD II - P13029 - JUMPING ROBOT TIGER (AIR MUSLCES)						
1	**Muscle Testing and Development**	**20**	**4-Mar-2013**	**24-Mar-2013**	**1**	**5**	
1.1	Orifice Size Testing	6	4-Mar-2013	10-Mar-2013	1	1	Andrew Pace
1.2	Wall Thickness Testing	6	11-Mar-2013	17-Mar-2013	2	2	Andrew Pace
1.3	Decision on Prototype Muscle	6	18-Mar-2013	24-Mar-2013	3	3	Group
1.4	Testing Spring Return/Landing	13	11-Mar-2013	24-Mar-2013	2	3	Sean Mosier, Andrew Pace
1.5	Air Supply Development	34	4-Mar-2013	7-Apr-2013	1	5	Group
2	**Theoretical Analysis (MatLab)**	**20**	**4-Mar-2013**	**24-Mar-2013**	**1**	**3**	
2.1	Finish Simulations	20	4-Mar-2013	24-Mar-2013	1	3	Jeff Manicone, Sean Mosier
2.2	Incorporate Test Data	13	11-Mar-2013	24-Mar-2013	2	3	Jeff Manicone, Sean Mosier, Andrew Pace, Trevor Crandell
2.3	Final Evaluation	6	18-Mar-2013	24-Mar-2013	3	3	Group
3	**Prototype Build**	**20**	**4-Mar-2013**	**24-Mar-2013**	**1**	**3**	
3.1	Order Parts for Prototype	6	4-Mar-2013	10-Mar-2013	1	1	Trevor Crandell, Andrew Pace
3.2	Machine Parts	6	11-Mar-2013	17-Mar-2013	2	2	Trevor Crandell, Andrew Pace
3.3	Assemble Prototype	13	11-Mar-2013	24-Mar-2013	2	3	Trevor Crandell, Andrew Pace
4	**Prototype Testing**	**48**	**25-Mar-2013**	**12-May-2013**	**4**	**10**	
4.1	Theoretical Based Testing	27	25-Mar-2013	21-Apr-2013	4	7	Group
4.2	Purely Experimental Testing	27	25-Mar-2013	21-Apr-2013	4	7	Group
4.3	Final Adjustments	20	22-Apr-2013	12-May-2013	8	10	Group
5	**Arduino Testing**	**69**	**4-Mar-2013**	**12-May-2013**	**1**	**10**	
5.1	Basic Program for Testing	27	4-Mar-2013	31-Mar-2013	1	4	Phil Brown
5.2	Program for Final Product	27	8-Apr-2013	5-May-2013	6	9	Phil Brown
5.3	Precise Solenoid Timing	27	8-Apr-2013	5-May-2013	6	9	Group

1. Muscle Testing and Development

1.1 Orifice Size Testing

The outcomes of this test will allow us to understand the effects of orifice size on fill rate, muscle contraction time, and force profile produced. We will use this test to choose a final muscle inner diameter.

- Open up the steel pressure chamber to incorporate a 3/8" opening
- Varying the size of the orifice leading up to the muscle (solenoid opening, 1/4", 3/8")
- Holding the muscle tested constant and only changing tubing/ solenoid connected to it
- Looking visually for changes in fill time
- Accelerometer will be used to calculate the force the muscle exerts ($F = m*a$)

1.2 Wall Thickness Testing

Wall thickness testing will help us determine the wall thickness we will use on all muscles. After deciding on an inner diameter from orifice testing, we will hold the inner diameter constant and test three different wall thicknesses. This will allow us to determine the final muscles types to be used on the tiger.

- Varying the wall thickness of the tube
- Looking for fill time changes, force changes, deflections
- Accelerometer to determine forces of various tube thicknesses
- Using best option from orifice testing based on best contraction time

1.3 Decision on Prototype Muscle

From the previous sections we will have figured out finalized muscles to be used on the prototype. We can test the muscles in parallel to determine how many to use.

- Attaching best muscles we found from wall thickness and orifice testing to full prototype
- Testing different positions of air muscles on prototype as well as multiple muscles per limb
- Testing if it's possible to use self-contained steel tank given our design
- Adjust project scope accordingly
- Test electronics portion

1.4 Testing Spring Return and Landing

- Test springs with spring constants found from simulation
- If unsuccessful, modify anchor points as necessary
- Implement shock absorbing springs between at front leg knee joint
- Test and modify if necessary racquetball feet

1.5 Air Supply Development

The air supply will be developed in parallel with the air muscle testing. At the end of the air supply development time a decision will be made by the group. Testing will go as follows.

- Test and acquire legitimate proof of higher air flow rate requirements for adequate muscle function and tiger jumping.
- From test data, decide on a proper outlet orifice size for the air supply.
- Explore options for air tank with required specifications.
    - Volume
    - Pressure
    - Outlet Orifice
    - Weight
    - Price
- If any of the on board options look promising, order and test the part.
- If no on board options look feasible, consider un-mounted solutions.

On the last week of our scheduled allotted time for this section of our development we will meet as a group and discuss our progress. Depending on the situation we will make a team decision about which option to proceed with. This may include re-scoping our project and customer needs.

2. Theoretical Analysis

2.1 Finish Simulations

This portion of the test will finalize the matlab simulations and leave them ready for realistic force calculations for later testing.

Take off

- Implement more accurate tiger model
  - Replace joint torques with forces located at the end of the overhang
- Event detection to remove normal force 2
- Event detection on angle 1 (hold at -45 degrees)
- Event detection on angle 2(hold at 45 degrees)
- Event detection on angle 3 (hold at 135 degrees)
- Event detection to remove normal force 1

Free flight

- Check notation for compatibility
- Feed take off outputs into free flight initial conditions
- Fix damping coefficient and replace with more realistic hard stops
- Overhang can be compensated for with adjustable centers of mass

2.2 Incorporate Test Data

We will use the accelerometer data to find a correlation between force and time for our selected muscles. We will use this data to input realistic forces into the matlab simulations.

- Input forces as functions of time
- Find dimensions and masses for realistic muscle forces to achieve desired jump

2.3 Final Evaluation

At this point in the test phase we are left with three possible outcomes. These outcomes are explained below. This will also be the point where we either have results from the simulation or cease working on them.

Outcome 1 – The matlab codes are finished and working correctly. The simulations incorporate realistic muscle forces and show a successful jump. In this case the prototype will use initial conditions (lengths, muscle locations, etc) as predicted by the simulation.

Outcome 2 – The matlab codes are finished and working correctly. The simulations incorporate realistic muscle forces and do not predict a successful jump. In this case we

need to test the prototype using similar setups to the wooden tiger. If the jump is not successful project re-scoping needs to be considered (reducing weight, removing tank, shortening leg).

Outcome 3 – The matlab code is producing unsuccessful results. At this point all work on simulations should cease. Prototype will use initial setups based on the wooden tiger and initial lengths based on proportionality.

3. Prototype Build

3.1 Order Parts for Prototype

Once parts are ordered and shipped we can begin prototype construction.

- Send in order
- Check that all parts are come in as ordered
- If parts are missing or were not properly accounted for initially, order additional parts

3.2 Machine Parts

All body segments of 80/20 and aluminum bar leg segments need to be machined to design specifications.

- Make up detailed drawings for each part
- Machine leg links
- Machine 80/20 parts

3.3 Assemble Prototype

Prototype assembly depends on the outcome of a few factors.

Outcome 1 – Matlab simulations produce results. These results would consist of moments and starting angles of the legs to produce the proper jumping dynamics for our tiger. The numbers from the simulation would be followed on the actual model to give us proper sized lever arms.

Outcome 2 – Matlab doesn't yield results. Prototype would be assembled arbitrarily to the default designed positions.

4. Prototype Testing

4.1 Theoretical Based Testing

If Matlab simulations produce results, this testing method will be used.

- Copy required moments from simulation onto prototype by adjusting lever arms.
- Anchor muscles properly to produce stretched fit when at rest.
- Test fire prototype and record results.
- If jump is unsuccessful analyze results to understand error.
- Return to theoretical model. Find and follow trend that corrects error.
- Test fire prototype and record results. Repeat steps as necessary.

4.2 Purely Experimental Testing

If Matlab simulation does not produce results, this testing method will be used.

- Start prototype out at the default designed positions as shown in the 3D model and detailed drawings.
- Anchor muscles properly to produce stretched fit when at rest.
- Test fire prototype and record results.
- If jump is unsuccessful analyze results to understand error. Link error in jump to one of the following(theoretical model may show trends to help link error):
    - Starting angles
    - Muscle anchor points(improper stretch)
    - Lever arm length
    - Stopping points
    - Spring return strength
    - Spring return anchor points
- Adjust decided upon culprit.
- Test fire prototype and record results.
- Analyze results to understand trends in errors.
- Repeat steps as necessary.

4.3 Final Adjustments

Once a jump is successfully tested it can be assumed that it will not be perfectly aesthetic or possibly even function imperfectly. Final adjustments will be needed to make the jump behave perfectly.

5. Software Development

5.1 Basic Program for Testing

The basic program for the test platform will include accelerometer data logging. This is most likely to be done with the aid or full use of an Arduino and DAQ from National Instruments. The Data will provide a good quantitative analysis of the air muscles and will help provide valuable data that will aid in the final design of the robot. This program will also fire the solenoids at required intervals or at user inputs.

Arduino functionality:

- Output solenoid fire signal
- Output Debug data and possibly sensor data
    - Sensor data would require formatting into CSV or TDV
- Input from Sensors
- Input from user
    - If this input is not available from a GUI the use of buttons or automated code will be implemented

DAQ National Instruments:

- Output data from accelerometer
- Direct input into Matlab or Labview for data analysis
- Input could possibly be used to control the solenoids and prototype.
    - This requires a tether to be used as there is no on board data storage.

5.2 Program Final Product

The final product will be an Arduino package that is stand-alone and will allow for data communication and/or storage. This will control the robot via solenoids and possible collect some telemetry data from an onboard. The use of a DAQ will be discontinued, as it does not allow for wireless communication, which will be required.

Arduino functionality:

- Input from user in the form of a jump command
    - Transmitted wirelessly
- Input from sensors stored onboard or sent wirelessly for storage remotely
- Output to solenoids
- Output of wireless communication
- Some form of Gui

5.3 Precise Solenoid Timing

With the implementation of the final Arduino program Solenoid timing will be vital to control the movement of the Tiger robot. The timing will be acquired through further testing of the robot prototype and the theoretical data generated on the dynamics of the robot.

Solenoid firing control:

- The Arduino will store the timing require and upon initiation will loop through and fire the muscles in order.
- The solenoids fire with a delay between 10-25ms and return in about the same about of time.