Clemson University
Critical Design Review
Mission Overview
Mission Overview (A)

- To evaluate the structural integrity and kinematic characteristics of spring-type soft body robot
- We aim to be able describe critical differences between the operation of a soft body robot while on the ground compared to operation during flight
Mission Overview: Mission Objectives

1. Develop a fully functioning soft body robot (single section)
2. Develop a measurement technique that utilizes the measurements available
3. Develop a full analysis of how the soft body robot operates under different stresses
Mission Overview (B)

• To allow local students with the opportunity to build a functional payload that integrates with the main payload

• A 3D map of the launch portrayed through google maps
Mission Overview: Mission Objectives

1. Develop small lesson plans that integrate into the preexisting curriculum

2. Develop a fully functioning payload with students that works both on the ground and the rocket
Theory and Concepts

• Image correlation
• GPS mapping
• Mechanics of materials
• Application and manipulation of soft body robotics
Success Criteria

• Minimum Success Criteria:
  – GPS SSEO system works on ground
  – Video is captured during launch and reentry

• Comprehensive Success Criteria:
  – GPS SSEO is able to map entire launch and reentry
  – Video captured provides distinguishable data that can be processed and analyzed
Functional & Design Requirements:

• Design Requirements:
  1. Final system includes fully functioning soft body robot and one Arduino capable of mapping the launch and reentry of the rocket in 3D.
  2. The soft body robot (SBR) has two functioning motors, a mounted camera, a power supply to both the motors and the camera tracking system, eight stainless steel springs that connect the body of the robot to the mounted camera
  3. All components are protected against launch conditions (heat shield on Arduino; electronics are sealed in place to combat high vibration forces)

• Functional Requirements
  1. The SBR is structurally stable in both zero and high G forces
  2. Camera and motors receive power
  3. Memory storage in capable of recording video file for the duration of the flight
## Example Functional Requirements:

<table>
<thead>
<tr>
<th>REQUIREMENT</th>
<th>VERIFICATION METHOD</th>
<th>DESCRIPTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Camera points towards center</td>
<td>Demonstration</td>
<td>The original position will be set while on the ground, this process can verified before loading</td>
</tr>
<tr>
<td>The soft robot stays pointed on center</td>
<td>Analysis</td>
<td>Bitmapping allows for the position of the robot to be know at all times during flight</td>
</tr>
<tr>
<td>GPS is successfully integrated and connected to the ground</td>
<td>Test</td>
<td>Connection to GPS will be made before integration to insure reliability</td>
</tr>
<tr>
<td>Hardware is capable of storing a large image file</td>
<td>Inspection</td>
<td>This specs of the device will be available to insure size</td>
</tr>
</tbody>
</table>
System Overview
System Definitions

- Small Satellite Education Outreach (S.S.E.O.)

- Soft Robotic Analysis (S.R.A.)
System Level Block Diagram

Full System

- Power Supply Unit (PSU)
- Research System
- Outreach System
De-Scopes and Off-Ramps

• Accuracy of the motor
• Slack development
• Precision of control
  – Feedback delay
  – M.A. of input power to output moment on upper body (measurement section)
Subsystem Design
Small Satellite Education Outreach (S.S.E.O.)
Subsystem Design Section

• SSEO originated from the idea that we wanted to use the opportunities we have been given to create opportunities for others
• Arduino’s were chosen as our main hardware component due to the low cost, amount of background experience and ease of use
Research for this portion was minimal; however due to the amount of open source projects available online, research was preformed to determine the best way to meet the goals of this program.

Final project was based on the project done by aiaaocrocketry.org
Subsystem Design Section

- SSEO will use:
  - an Arduino Uno
  - GPS receiver
  - Xbee RF downlink

- The project was designed to send the information back to a remote PC to show the location of the rocket in real time however our data will be stored and accessed after splashdown.
Subsystem Design Section

• SSEO will allow Clemson Students to work along side Elementary school students familiar with basic coding and physic concepts, to fully construct an Arduino based system that will track the path of the rocket for the duration of the flight.
Soft Robotic Analysis (S.R.A.)
Subsystem Design Section

• SRA is a research based payload
• The aim SRA is to develop a correlation between the behavior of spring-type soft robotics when stationary on the ground and during high G acceleration
• The soft robot being used during this experiment is classified as a spring-type
Subsystem Design Section

• Spring-type soft robots fit the functionality and requirements of the goal of the project
• The spring-type robot operates through a series of strings under tension connected at multiple points through out the arm

Subsystem Design Section

- The final design is based on a soft robot design made and tested by another independent project.

- Comprised of stainless steel springs and two motors in charge of actuating the top of the soft robot in reference to the base.
Subsystem Design Section

• Time and research has previously been put into the actuation and analysis of spring-type soft robotics on the ground; undergoing only a constant downward gravitational force

• Due to the fact SRA will undergo a non-uniform acceleration forces of various magnitudes several problems are introduced to the overall design and analysis
Subsystem Design Section

• The analysis will employ a measurement technique that utilizes a camera and a single image placed on an inverted hemisphere

• The internal forces will be calculated on the ground after splash down using image correlation and predetermined equations that are defined for the set material
Subsystem Design – Weight Budget

- Over estimate of weight of final payload is as follows
- The weight budget includes both SSEO and SRA components
- Possibility of weight reduction if actuation process is scrapped

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raspberry Pi Zero w/ camera</td>
<td>0.044</td>
</tr>
<tr>
<td>Stepper Motors x2</td>
<td>1.250</td>
</tr>
<tr>
<td>Plastic disks x2</td>
<td>2.000</td>
</tr>
<tr>
<td>Canister</td>
<td>6.700</td>
</tr>
<tr>
<td>Spring Steel</td>
<td>3.000</td>
</tr>
<tr>
<td>Viewing disk</td>
<td>3.000</td>
</tr>
<tr>
<td>LiPo Batteries x4</td>
<td>0.316</td>
</tr>
<tr>
<td>Outreach Sensor Payload</td>
<td>3.000</td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td><strong>19.310</strong></td>
</tr>
</tbody>
</table>
# Clemson University - Power Budget

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Voltage (V)</th>
<th>Max Current (A)</th>
<th>Time On (min)</th>
<th>Watts</th>
<th>Ah</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raspberry Pi Zero w/ Camera Operating</td>
<td>5.0</td>
<td>0.24</td>
<td>60</td>
<td>1.20</td>
<td>0.24</td>
</tr>
<tr>
<td>Stepper Motors x2</td>
<td>2.8</td>
<td>3.40</td>
<td>60</td>
<td>9.52</td>
<td>3.40</td>
</tr>
<tr>
<td>LED x4</td>
<td>3.6</td>
<td>0.02</td>
<td>60</td>
<td>0.07</td>
<td>0.02</td>
</tr>
</tbody>
</table>

| Total                                        | 3.66        |                 |               | 10.79 | 3.66|

| LiPo 3200mAh battery pack x4                | Total Power Capacity: 4, Time On: 60 | | | 8.00 |
| Over (+)/Under (-)                          | 4.34        |                 |               |       |     |

| # of Flights Margin                        | 0.3         |                 |               |       |     |
Manufacturing Plan

Name of Presenter
Mechanical Elements

- There are two elements that need to be manufactured:
  - The two End Caps of the robot system
  - The Springs for the robot system

- What needs to be procured?
- Present a plan/schedule to get it done in time for testing.
  - Don’t forget margin!

SLIDE COUNT: Your Discretion
Mechanical Elements: End Caps

- End Caps are to be made of easy-to-mill plastic
- A sheet of 1/8” HDPE (High Density Polyethylene) plastic will be procured
- The sheet will be sawn into two end cap blanks
- The blanks will have the necessary holes drilled according to the schematic
Mechanical Elements: Springs

• Springs are to be made from 301 Stainless Steel strips
• The 301 steel will be procured in a 1/16” sheet
• The sheet will be milled into strips using a mill

• All mechanical systems will be implemented early in the Spring semester
Electrical Elements

• Several Electrical systems need to be designed:
  – The motor driver circuit
  – The machine vision circuit
  – The power system
  – The outreach sensor payload
Electrical Elements: Motor Driver

- The motor driver circuit is a simple one
- The two motors are connected to separate analog pins on the Raspberry Pi
- The Raspberry Pi is used to drive the motors as needed
Electrical Elements: Machine Vision

- The machine vision circuit is also fairly simple
- The camera situated on the arm of the robot will have a wire run to the Raspberry Pi
- The Raspberry Pi has a dedicated camera port, and the camera input is run to this
Electrical Elements: Power System

- The power circuit consists of four LiPo batteries connected in parallel
- These batteries are routed to the Raspberry Pi and Arduino Voltage In pins
- Power for other circuit components is then routed from the Raspberry Pi as needed
Electrical Elements: Outreach Sensor

- The outreach sensor payload is a separate system based on an Arduino and an accelerometer.
- The Arduino takes input from the accelerometer through one of its dedicated I2C ports.

- Since the electrical systems are not particularly complicated, they will be created as soon as the parts are in, which will be early in the spring semester.
- There should only be 1 or 2 iterations needed to develop the system and work out any bugs.
Software Elements

• There is a number of software blocks that must be designed:
  – Machine Vision System
  – Sensor System
  – Motor Driver System
Software Elements: Machine Vision System

• The Machine Vision System is likely the most complicated part of the software
  – The system will be using the OpenCV vision system
  – The System will track a point that corresponds to the center of the robot’s movement. As the robot moves relative to the point due to external forces, the system will note the movement and actuate the motors to pull the robot back to center.
Software Elements: Sensor System

• The sensor system is part of the outreach payload. Sensor data will be read in from the accelerometer via I2C and stored in the onboard storage.
Software Elements: Motor Driver System

- The motor driver system will take the input from the vision system, determine if the system needs to be corrected along an axis, and perform the correction.
- The system will perform in an iterative way. Every time a small step is taken, the system will decide if another step is necessary.
Testing Plan

Name of Presenter
Electrical Testing

- Each electrical system will be tested in the following blocks, lowest block first:
  - Research Payload
    - Machine Vision
      - Camera
      - Proper Tracking
    - Motor Driver
      - Movement
      - Proper Step Size
    - Power System
  - Outreach Payload
    - Sensor Input
    - Proper Data Storage
Software Testing

- Software will be tested based on these functional blocks:
  - Machine Vision Block
    - Camera Input
    - Proper Point Recognition
  - Sensor Block
    - I2C System Behaving Properly
    - Storage Behaving Properly
  - Motor Driver Block
    - Motors Responding Correctly to Input
    - Motors Taking Proper Number of Steps
System Level Testing

- A number of systems level tests must be performed:
  - Fit Test
  - Robotic Movement Free From Obstruction
  - Electrical systems Connected Properly, No Shorts
  - All Systems Oriented Properly
  - All Systems Powered Properly

All tests will be performed on a running basis, as subsystems are completed.
User Guide Compliance
### Requirement Compliance

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Status/Reason (if needed)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Center of gravity in 1&quot; mid-can?</td>
<td></td>
</tr>
<tr>
<td>Contained in can</td>
<td></td>
</tr>
<tr>
<td>Connected to can by 4/5 bulkheads on top and bottom only</td>
<td></td>
</tr>
<tr>
<td>Mass at 20±0.2lbs</td>
<td></td>
</tr>
<tr>
<td>Shared canister clearance</td>
<td></td>
</tr>
<tr>
<td>No voltage on the can</td>
<td></td>
</tr>
<tr>
<td>Activation wires at least 4 ft</td>
<td></td>
</tr>
<tr>
<td>Activation wire at least 24 gauge</td>
<td></td>
</tr>
<tr>
<td>Early Activation: current &lt; 1 A</td>
<td></td>
</tr>
<tr>
<td>T-0 Activation: current &lt; .1 A</td>
<td></td>
</tr>
<tr>
<td>Battery Type</td>
<td></td>
</tr>
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Project Management Plan
Schedule (week of…)

- **Before ... 01.07.19:**
  - All cad files finalized
  - All requirements are double checked and finalized

- **01.14.19:**
  - First lesson with SSEO
  - First meeting with new team, sub teams made, meeting times for duration of the semester set
  - Meet with advisors and finalize specs, place orders

- **01.21.19:**
  - Production started for both SRA and SSEO
  - Second lesson with SSEO
  - Provide update and check to make sure we are on track if no presentation is to be made
## Budget

<table>
<thead>
<tr>
<th>ITEM</th>
<th>COST</th>
<th>NUMBER</th>
<th>TOTAL, NO TAX</th>
<th>TOTAL+7% TAX</th>
<th>LINK</th>
</tr>
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<tbody>
<tr>
<td>Teensy 3.6 Microcontroller</td>
<td>29.25</td>
<td>5</td>
<td>146.25</td>
<td>156.4875</td>
<td><a href="https://www.alliedelec.com/rasp">Link</a></td>
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<tr>
<td>Raspberry Pi</td>
<td>35</td>
<td>2</td>
<td>70</td>
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<tr>
<td>Triple Axis Accelerometer Board</td>
<td>10.49</td>
<td>4</td>
<td>41.96</td>
<td>44.8972</td>
<td><a href="https://www.sparkfun.com/products">Link</a></td>
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<tr>
<td>Solderless Breadboard</td>
<td>5.9</td>
<td>4</td>
<td>23.6</td>
<td>25.252</td>
<td><a href="https://www.amazon.com/B8400-010E/dp">Link</a></td>
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<tr>
<td>Breadboard Wires</td>
<td>1.95</td>
<td>4</td>
<td>7.8</td>
<td>8.346</td>
<td><a href="https://www.adafruit.com/product">Link</a></td>
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<tr>
<td>301 Stainless Steel Spring Strips</td>
<td>25</td>
<td>8</td>
<td>200</td>
<td>214</td>
<td><a href="https://www.precisionsteel.com/">Link</a></td>
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<tr>
<td>Stepper Motor</td>
<td>16.95</td>
<td>4</td>
<td>67.8</td>
<td>72.546</td>
<td><a href="https://www.pololu.com/products">Link</a></td>
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<tr>
<td>High Tension Nylon String</td>
<td>15</td>
<td>4</td>
<td>60</td>
<td>64.2</td>
<td><a href="https://www.robotshop.com/en/aa">Link</a></td>
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<tr>
<td>Aluminum Disks</td>
<td>15</td>
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<td>60</td>
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<td><a href="https://www.robotshop.com/en/aa">Link</a></td>
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<tr>
<td>Camera</td>
<td>65</td>
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<tr>
<td>Remaining Deposit</td>
<td>6000</td>
<td>2</td>
<td>6000</td>
<td>6000</td>
<td></td>
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<tr>
<td>Travel Costs for 4 People</td>
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<td>2</td>
<td>2500</td>
<td>2500</td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL:</strong></td>
<td></td>
<td></td>
<td><strong>9307.41</strong></td>
<td><strong>9958.9287</strong></td>
<td></td>
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Team Availability Matrix – SPRING 2015

To be determined during the week of 01.14.19
Project Summary

- Issues with precision of motor control
- Establish the use of matrix multiplication to compute the image correlation
- Finalize CAD files
- Finalize system is inside system requirements