Contents

Background
Problem Statement
Solution
  Mechanical
    Areas of Interest
    Mounting Configuration
    Statics and Dynamics
    Focal Point of Dish
  Electrical
    Motors
    Sensors
  Software
    Controller
    SatPC32
    Serial Communication
    Interpolation
    Calibration Techniques
Subsystem Videos
Budget
Timeline
Remaining Tasks
Responsibilities
Special Thanks
Questions
Background - CubeSat

- CubeSat is 10cm x 10cm x 10cm (10cm ≈ 3.94 inches)
- Solar Powered
- Utilizes GPS and Celestial Navigation Techniques
- Transmits Information from Sensors
  - Camera, UV/IR Spectrometer, Electron Flux
Background – CubeSat

Lunar Lander
Rapid Prototype Models

Booster

3D Solid Model of CubeSat Structure
Background – Ground Station

- VTC developing CubeSat, transmits data
  - Continuing where previous groups have left off

- Have to follow CubeSat to receive data (2.4GHz)

- Existing 3-meter parabolic dish antenna

- Low orbit satellite revolves around Earth in minutes, seen for short time per orbit
Problem – Ground Station

- Track a low orbit satellite such as a CubeSat from horizon to horizon in as little as 30 seconds with an accuracy of ± 0.5°
  - 180° /30 seconds = 6° /sec

- Move a 3 meter satellite dish
  - 360° Azimuth (left/right)
  - 180° Elevation (up/down)

- Interface to PC running SatPC32 (Satellite Tracking Program)
Azimuth and Elevation

- **Azimuth**
  - A left to right angle measurement from a fixed point (north in navigation)

- **Elevation**
  - Angle between the flat plane and the object in the sky (satellite).
Solution

SatPC32

RS232

Micro-Controller

EL - Motor Controller

AZ - Motor Controller

Limit Switches

Position Encoders
Mechanical Areas of Interest

- Axis orientation (EL/AZ or AZ/EL)
- Weight of dish and Center of Mass
- Moment of Inertia of the dish
- Torque needed to spin/flip the Dish
Choosing a Solution:

- Two choices: Fork Mount and Equatorial mount
- Equatorial is accurate
- Fork is versatile
Axis Mounting Design

- **Equatorial Mount:**
  - The movement of the Azimuth (here the Declination Axis) makes an arc in the sky.
  - The Elevation (a) is set parallel to the earths axis of rotation.

This system is much more accurate than the Fork and needs a much less complicated control system.
Fork Mount

- Simple left-right/up/down characteristics
- Allows the dish to go over backwards if it needs to.
- Dish can track large range of orbit paths.

We chose this configuration because of the versatility in what we can track.
Final Proposed Design

- 180 degree EL Motion
- 360 degree AZ Motion
- Approx weight: 1100 lbs
Finite Element Analysis (FEA)

Fork design FEA

Tripod stand FEA
Motion Study in Solidworks
Elevation Axis

Simple shaft and Bearing setup

Azimuth Axis

Load bearing Thrust and Ball Bearing setup
Azimuth Axis

Load bearing Thrust and Ball Bearing setup
Bearing Manufacturing
Statics and Dynamics:

Key Points of Interest:

- **Center of Mass** - The mean location of all system masses.

- **Moment of Inertia** - A measure of an object's resistance to changes to its rotation. It is the inertia of a rotating body with respect to its rotation.

- **Dynamic Torque** - The torque encountered by a system that is not only in motion, but accelerating.

- **Static Torque** - The torque produced at constant velocity (rest or running).
This point is where we want our center of mass.
Forces and Foot Pounds

Having a balanced mass is very important in a motion system.

Balance \((R_0M = Rm)\)
Reduces driving torque that the motor has to produce.
Ballast Manufacturing

Simple shaft and Bearing setup
Dynamic Torque Curve (Elevation)

Max Torque needed = 8.7 ft lbs

EL Torque Data
Dynamic Torque Curve (Azimuth)

Max Torque Needed = 3.3 ft lbs

AZ Torque Graph
Focal Point

Focal point calculated to be 37.5 inches from vertex of dish with a tolerance within 0.150” – 0.300”
Focal Point

Transceiver Mount Must be Level
Electrical

120v AC

DC Motor PSU

5vDC PSU

Angular Position Sensors

Dish Heater

AZ Motor

EL Motor

AZ-PWM Motor Controller

EL-PWM Motor Controller

Micro

Signal

Serial

Indicator Light

AC Power

DC Power

30 min

Serial
Absolute Magnetic Shaft Encoder

- 1° step size = at least nine bit resolution
  - 2° = 512 steps
  - 360 deg/512 steps = .7 deg/step
- 6°/sec = 1 rpm
  - 180°/30sec=6°/sec=360°/60sec
- Magnetic shaft encoder
  - Max 15,000 rpm
  - Absolute position sensing
  - Small size, large operating temperature range
  - Analog output from 10-bit DAC
    - 1024 steps or .35°/step
Electrical – Motor Modeling
Electrical – Motor Modeling

Time Constant – 67ms
Software – PI Controller

Pole-Zero Diagram:

\[ G_s(s) = (PI) \left( \frac{1}{0.075(s + 13.3)} \right) \]

Z-Transform Equation:

\[ G_c(z) = \frac{7.4669z - 7}{z - 1} \]

Difference Equation:

\[ Y_c(n) = 7.4669X_c(n) - 7X_c(n-1) + Y_c(n-1) \]
Software – SatPC32: Video
<table>
<thead>
<tr>
<th>Time (sec)</th>
<th>Logic Placer</th>
<th>AZ Value</th>
<th>EL Value</th>
<th>Azimuth</th>
<th>Elevation</th>
<th>CR</th>
<th>Desired Track Time</th>
<th>Desired AZ Displacement</th>
<th>Desired EL Displacement</th>
<th>Divisor Value</th>
<th>AZ Increment Value</th>
<th>EL Increment Value</th>
<th>Be sure to copy ONLY AZ, EL AND CR fields into HyperTerm</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td></td>
<td>180 Sec</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8 Degrees/Divisor</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
<td>8</td>
<td>4</td>
<td>AZ008.0</td>
<td>EL004.0</td>
<td>0</td>
<td></td>
<td>360 Degrees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>AZ008.0</td>
<td>EL004.0</td>
<td>0</td>
<td></td>
<td>180 Degrees</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>AZ008.0</td>
<td>EL004.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>0</td>
<td>8</td>
<td>4</td>
<td>AZ008.0</td>
<td>EL004.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>1</td>
<td>16</td>
<td>8</td>
<td>AZ016.0</td>
<td>EL008.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>0</td>
<td>16</td>
<td>8</td>
<td>AZ016.0</td>
<td>EL008.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>0</td>
<td>16</td>
<td>8</td>
<td>AZ016.0</td>
<td>EL008.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>0</td>
<td>16</td>
<td>8</td>
<td>AZ016.0</td>
<td>EL008.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>24</td>
<td>12</td>
<td>AZ024.0</td>
<td>EL012.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>0</td>
<td>24</td>
<td>12</td>
<td>AZ024.0</td>
<td>EL012.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>0</td>
<td>24</td>
<td>12</td>
<td>AZ024.0</td>
<td>EL012.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>0</td>
<td>24</td>
<td>12</td>
<td>AZ024.0</td>
<td>EL012.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>32</td>
<td>16</td>
<td>AZ032.0</td>
<td>EL016.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>0</td>
<td>32</td>
<td>16</td>
<td>AZ032.0</td>
<td>EL016.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>0</td>
<td>32</td>
<td>16</td>
<td>AZ032.0</td>
<td>EL016.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>0</td>
<td>32</td>
<td>16</td>
<td>AZ032.0</td>
<td>EL016.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>17</td>
<td>1</td>
<td>40</td>
<td>20</td>
<td>AZ040.0</td>
<td>EL020.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>0</td>
<td>40</td>
<td>20</td>
<td>AZ040.0</td>
<td>EL020.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>19</td>
<td>0</td>
<td>40</td>
<td>20</td>
<td>AZ040.0</td>
<td>EL020.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>20</td>
<td>0</td>
<td>40</td>
<td>20</td>
<td>AZ040.0</td>
<td>EL020.0</td>
<td>0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Software – Serial Communication

- Transmitted Format
  - AZ360.0 EL180.0

- Serial Transmit Rate
  - 1 Data point/Second

Flowchart:
- SatPC32
  - Has A or E been received?
    - No
    - Has Z or L been received?
      - No
      - Yes
        - Store AZ and EL Accordingly
      - Yes
        - Yes
          - Store AZ and EL Accordingly
void check_serial(void) {
    CALLcheck_serial = 0;
    switch(Serial_State) {

        case 3:

            if (Serial_Error == ERR_OK) {
                if (Buffer_In == 'A') {
                    // Look for 'A'
                    Serial_State = 4;
                }
            } else {
                Serial_State = 3;
            }

        break;
    }
}
if (store_serial_AZ==1){

    store_serial_AZ=0;

    for (i=NumPos-1; i>0; i--){
        Serial_AZ[i]=Serial_AZ[i-1];
    }

    /*Pull Float from Incomming, put into Serial_AZ[0]*/
    Serial_AZ[0]=0;
    Serial_AZ[0]=(float)(
        ((Incomming[0]-48)*100) + //convert from ASCII to decimal, 100's place
        ((Incomming[1]-48)*10) + //convert from ASCII to decimal, 10's place
        ((Incomming[2]-48)*1) + //convert from ASCII to decimal, 1's place
        //Incomming[3] = decimal point
        ((Incomming[4]-48)*.1) + //convert from ASCII to decimal, .1's place
        ((Incomming[5]-48)*.01)+0.48)); //convert from ASCII to decimal, .01's place
    /*Pull Float from Incomming, put into Serial_AZ[0]*/

    //ADD TO THE TIMER ARRAY TOO
    for (i=NumPos-1; i>0; i--){
        Serial_AZ_TIME[i]=Serial_AZ_TIME[i-1];
    }
    Clock_Error=Clock_GetTimeMS(&current_time);
    Serial_AZ_TIME[0]=(((float)(current_time))/1000);
    //ADD TO THE TIMER ARRAY TOO

    CALLcheck interpolate=1; // Start Interpolating
    Serial_State = 3
Software Serial Interpolation
void interpolate_serial(void){

switch(interpolate_state){

case 0:

if (Serial_AZ[1] > 0){
    dP = (Serial_AZ[0] - Serial_AZ[1]) * 0.1f;    //DEFINE CHANGE IN UNIT TIME HERE
    interpolate_out = dP + Serial_AZ[0];
    interpolate_state = 1;
} else interpolate_state = 0;
break;

case 2:

interpolate_clock_GetTimeMS(&interpolate_time);
if (interpolate_time >= INTDELAY){
    interpolate_time = 0;
    interpolate_clock_Reset();
    interpolate_count--;
    interpolate_out = dP + interpolate_out;
    interpolate_state = 1;
} else interpolate_state = 2;
break;
}
Calibration Techniques – True AZ and EL

- **Azimuth**
  - Align one leg of tripod to true north

- **Elevation**
  - Inclinometer (Shown here)
Calibration Techniques - Repeatability

- Mount laser on transceiver location
- Point to given spot and record location
- Attempt to recreate position
- Adjust accordingly
Subsystem Videos

Click Film
<table>
<thead>
<tr>
<th>Item/Description</th>
<th>Quantity</th>
<th>Price Per</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>High-Speed Cast Iron Mounted STL Ball Bearing Square-Flange Mount, for 1-1/4&quot; Shaft Diameter</td>
<td>2</td>
<td>$103.82</td>
<td>$207.64</td>
</tr>
<tr>
<td>Extra-Grip Two Piece Clamp-on Shaft Collar 1-1/4&quot; Bore, 2-1/2&quot; Outside Diameter, 5/8&quot; Width</td>
<td>2</td>
<td>$9.69</td>
<td>$19.38</td>
</tr>
<tr>
<td>Partially Keyed Steel Drive Shaft 1-1/4&quot; OD, 1/4&quot; Keyway Width, 36&quot; Length</td>
<td>1</td>
<td>$60.26</td>
<td>$60.26</td>
</tr>
<tr>
<td>E52100 Alloy Steel Ball 1&quot; Diameter, Grade 25</td>
<td>5</td>
<td>$13.05</td>
<td>$65.25</td>
</tr>
<tr>
<td>One-Piece Steel Thrust Ball Bearing for 1-1/4&quot; Shaft Diameter, 2-11/32&quot; OD, Shielded</td>
<td>1</td>
<td>$22.35</td>
<td>$22.35</td>
</tr>
<tr>
<td>Mounting Flange One-Piece Shaft Collars 1-1/4&quot; Bore, 2-1/4&quot; Collar OD, 1&quot; Overall Width</td>
<td>1</td>
<td>$43.98</td>
<td>$43.98</td>
</tr>
<tr>
<td>Cast Iron Base-Mounted Babbitt-Lined Bearing Solid, for 2&quot; Shaft Diameter</td>
<td>2</td>
<td>$82.60</td>
<td>$165.20</td>
</tr>
<tr>
<td>Two-Piece Clamp-on Shaft Collar Steel, 2&quot; Bore, 3&quot; Outside Diameter, 11/16&quot; Width</td>
<td>4</td>
<td>$11.32</td>
<td>$45.28</td>
</tr>
<tr>
<td>Fully Keyed 1045 Steel Drive Shaft 2&quot; OD, 1/2&quot; Keyway Width, 48&quot; Length</td>
<td>1</td>
<td>$146.06</td>
<td>$146.06</td>
</tr>
<tr>
<td>Steel Needle-Roller Bearing Double Sealed for 3/4&quot; Shaft Dia, 1&quot; OD, 3/4&quot; Width</td>
<td>2</td>
<td>$10.34</td>
<td>$20.68</td>
</tr>
<tr>
<td>Hardened Precision Steel Shaft 3/4&quot; Diameter, 12&quot; Length</td>
<td>1</td>
<td>$9.60</td>
<td>$9.60</td>
</tr>
<tr>
<td>Black Polyurethane Sheet 1/4&quot; Thick, 12&quot; X 12&quot;, 90A Durometer</td>
<td>1</td>
<td>$5.99</td>
<td>$5.99</td>
</tr>
<tr>
<td>Step-Up Clamp-on Shaft Adapter 5/8&quot; Bore, 7/8&quot; Shaft Outside Diameter</td>
<td>1</td>
<td>$54.91</td>
<td>$54.91</td>
</tr>
<tr>
<td>Two-Piece Clamp-on Shaft Coupling Steel, with Keyway, 3/4&quot; X 5/8&quot; Bore, 1-1/2&quot; OD</td>
<td>1</td>
<td>$82.12</td>
<td>$82.12</td>
</tr>
<tr>
<td>Fully Keyed 1045 Steel Drive Shaft 3/4&quot; OD, 3/16&quot; Keyway Width, 3&quot; Length</td>
<td>1</td>
<td>$8.48</td>
<td>$8.48</td>
</tr>
<tr>
<td>Extra-Grip Two Piece Clamp-on Shaft Collar 1&quot; Bore, 2-1/4&quot; Outside Diameter, 5/8&quot; Width</td>
<td>1</td>
<td>$9.13</td>
<td>$9.13</td>
</tr>
<tr>
<td>Steel Ball Bearing--ABEC-1 Dbl Sealed Bearing NO. R16 for 1&quot; Shaft Dia, 2&quot; OD</td>
<td>1</td>
<td>$11.36</td>
<td>$11.36</td>
</tr>
<tr>
<td>Threaded Stem Caster W/Total Lock, 5&quot; X 1-1/4&quot; Rubber Whl, 1/2&quot;-13 Stem</td>
<td>3</td>
<td>$20.25</td>
<td>$60.75</td>
</tr>
<tr>
<td>Type 416 Stainless Steel Key Stock 3/16&quot; X 3/16&quot;, 12&quot; Length</td>
<td>1</td>
<td>$11.20</td>
<td>$11.20</td>
</tr>
<tr>
<td>5/8 inch needle bearings</td>
<td>2</td>
<td>$2.76</td>
<td>$5.52</td>
</tr>
<tr>
<td>7/8 needle bearing</td>
<td>1</td>
<td>$2.83</td>
<td>$2.83</td>
</tr>
<tr>
<td>7/8 keyed shaft (3/16 keyway) 9&quot; length</td>
<td>1</td>
<td>$20.82</td>
<td>$20.82</td>
</tr>
<tr>
<td>3/4 needle bearing</td>
<td>1</td>
<td>$2.83</td>
<td>$2.83</td>
</tr>
<tr>
<td>3/4 inch diameter keyed shaft (3/16 keyway) 9&quot; length</td>
<td>1</td>
<td>$15.16</td>
<td>$15.16</td>
</tr>
<tr>
<td>1.25x3x3/8&quot; Roller Flat Sealed Track Roller</td>
<td>3</td>
<td>$23.43</td>
<td>$70.29</td>
</tr>
<tr>
<td>Two-Piece Clamp-on Shaft Collar Steel, 1-1/4&quot; Bore, 2-1/16&quot; OD, 1/2&quot; Width</td>
<td>2</td>
<td>$5.17</td>
<td>$10.34</td>
</tr>
<tr>
<td>Dayton DC Motor (50 RPM)</td>
<td>1</td>
<td>$347.23</td>
<td>$347.23</td>
</tr>
<tr>
<td>Dayton DC Motor (94 RPM)</td>
<td>1</td>
<td>$347.23</td>
<td>$347.23</td>
</tr>
<tr>
<td>2&quot;x2&quot;x3/16&quot;x 24' Square Tubing</td>
<td>3</td>
<td>$82.00</td>
<td>$246.00</td>
</tr>
<tr>
<td>2&quot;x2&quot;x 5&quot; Plate</td>
<td>3</td>
<td>$75.00</td>
<td>$225.00</td>
</tr>
<tr>
<td>6&quot;x2&quot;x3/16&quot; x12' Rect. Tube</td>
<td>1</td>
<td>$105.00</td>
<td>$105.00</td>
</tr>
<tr>
<td>8&quot;x 8&quot; x 1/4&quot; Plate</td>
<td>5</td>
<td>$9.50</td>
<td>$47.50</td>
</tr>
<tr>
<td>Waterjet Cutting for Brackets and Mounts</td>
<td>1</td>
<td>$230.00</td>
<td>$230.00</td>
</tr>
<tr>
<td>Waterjet Cutting for Gears for Encoders</td>
<td>1</td>
<td>$51.95</td>
<td>$51.95</td>
</tr>
<tr>
<td>Vinal Coated Nylon Tarp (Black)</td>
<td>3</td>
<td>$58.50</td>
<td>$175.50</td>
</tr>
<tr>
<td>Vinal Adhesive</td>
<td>1</td>
<td>$18.75</td>
<td>$18.75</td>
</tr>
<tr>
<td>CASE,RACKMNT,19,,.88.1mmX250mm</td>
<td>1</td>
<td>$51.95</td>
<td>$51.95</td>
</tr>
<tr>
<td>Woods 59007 Decora Style 30-15-10-5 Minute Preset Wall Switch Timer, White, 30-Minute</td>
<td>1</td>
<td>$13.39</td>
<td>$13.39</td>
</tr>
<tr>
<td>CA-MIC3-SH-NC 3-Pin Micro / Unterminated Shielded Cable (20ft)</td>
<td>2</td>
<td>$26.30</td>
<td>$52.60</td>
</tr>
<tr>
<td>MA3 Miniature Absolute Magnetic Shaft Encoder</td>
<td>4</td>
<td>$45.40</td>
<td>$225.55</td>
</tr>
</tbody>
</table>

**Total**

$3326.47
## Ground Station Timeline (Rev 1.05)

### Mechanical

<table>
<thead>
<tr>
<th>Design</th>
<th>Week 1</th>
<th>Week 2</th>
<th>Week 3</th>
<th>Week 4</th>
<th>Week 5</th>
<th>Week 6</th>
<th>Week 7</th>
<th>Week 8</th>
<th>Week 9</th>
<th>Week 10</th>
<th>Week 11</th>
<th>Week 12</th>
<th>Week 13</th>
<th>Week 14</th>
<th>Week 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>Space (Rooftop) Requirements</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Physical Characteristics</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Torque Requirements</td>
<td></td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fork Mount</td>
<td></td>
<td></td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Balast</td>
<td></td>
<td></td>
<td></td>
<td>Y</td>
<td>Y</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Small Scale Test</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gears</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sensor Mounts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Motor Selection and Mounts</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preliminary Budget</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Construct

| Move to Building                    | Y      |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Small Scale Test                    |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Fork Mount                          |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Balast                              |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Ballast Support on Cone Dish        |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Elevation Shaft (Tape to 1” for gear) |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Water Jet Parts (Tape and Fitting)  |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Misc Machining (Keyways, shafts)    |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Gears                               |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Sensor Mounts                       |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Motor Mounts                        |        |        | Y      |        |        |        |        |        |        |         |         |         |         |         |         |
| Final Assembly                      |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| El Shaft Mounted on Fork            |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| 1” Groove on AZ Bearing Setup       |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Tripod Legs                         |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Tripod Assembly                     |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |

### Electrical

| Power Supply                        | Y      |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Sensors                             |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Motor Controller                     |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Microcontroller                      |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| RS232 Communication                 |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |

### Software

| SatPC32 Research                     | Y      | Y      |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Serial Communication Test            |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Serial Code                          |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Encoder Code                         | N      |        | Y      | Y      |        |        |        |        |        |         |         |         |         |         |         |
| Motor Controller Code                 |        |        | N      | N      | Y      |        |        |        |        |         |         |         |         |         |         |
| Interpolation Code                    |        |        | Y      | Y      | Y      | Y      | Y      | Y      | Y      | Y        |         |         |         |         |         |

### Misc

| Group Meeting                        | Y      | Y      | Y      | Y      |        |        |        |        |        |         |         |         |         |         |         |
| Brandon Meeting                      |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Presentation                         |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| Calibrate                            |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |
| System Tests                         |        |        |        |        |        |        |        |        |        |         |         |         |         |         |         |

### Milestones

<p>| | | | | | | | | | | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
</table>
Remaining Tasks

- Mechanical
  - Weatherization
  - Calibration
- Electrical
  - Hardware User Interface Box
- Software
  - Further (Redundant) Control Algorithm Testing
Areas of Responsibility

- **Hodge (300+ Hours)**
  - CAD and FEA
  - Torque Calculations/Measurements
  - Ballast Implementation
  - Motor Specifications

- **Lyford (300+ Hours)**
  - Sensors and Electrical
  - Fork Design w/ Motors
  - Drive Mechanisms and Implementation
  - Material Manager / Budget

- **Schreiber (300+ Hours)**
  - Project Manager
  - Mechanical Analysis and FEA
  - Interpolation Implementation
  - Communications
  - Motor Controllers
Special Thanks

**Vermont Technical College Staff**
- John Kidder - Use of Catamount Building Space
- Bryan Carroll - Use of Catamount Building Space
- Carl Wolf - FEA, General Project Guidance
- Andre St. Denis - Software Support, General Project Guidance
- John Murphy - Controller Development, Software and Hardware Support
- Ingred Van-Steamburg - Ordering Parts, Budget Allocation, Financial Assistance
- Preston Allen - Supplying Tools and Machinery, Assembly and Construction Assistance
- Joan Richmond-Hall - Materials Safety Precautions
- Roger Howes - CNC Support
- Mike Wright - Machine Shop Assistance
- Scott Sabol - Green Structural Building Analysis
- Sam Colwell - LCD Software Support

**Vermont Technical College Students**
- Aaron Minard - Briefing from previous years
- Ben (Student in Design Comm. Class) - Solidworks Models of Motors

**Outside Vermont Technical College**
- David Durgin of Mainly Metals - Water-jet parts
- K BeBee Plumbing - Supplying Free Material
- Vermont Wireform - CNC/Machine Shop and Machine Time
- Mark Schreiber of Granite City Electric - Delivering Material, Providing Dish Heater
Questions?
Join us at the Catamount building for a live demonstration

- From VTC, Continue down Rte.66
- Take a Left at the Aadco Medical sign (VTC’s logo also on the sign)
- Enter the door by the garage door with VTC’s logo

We will be leaving in 15 minutes