P14542: Vertical XY Camera Rig

Detailed Design Review
Dec-10-13
Agenda

- **Team Introduction**
- Project Review
- Mechanical Designs
  - Vertical Traverse
  - Horizontal Traverse
  - Camera/Light Mounting
  - Rail System
- Wiring Diagrams
- GUI
- Safety Systems
- Risk Analysis
- Test Plan
- Bill of Materials
Team Introduction and Roles

<table>
<thead>
<tr>
<th>Member</th>
<th>Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dan Kearney</td>
<td>Electrical Engineer</td>
</tr>
<tr>
<td>Sam Brown</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>Brandon Stangman</td>
<td>Industrial &amp; Systems Engineer</td>
</tr>
<tr>
<td>Matt Misiaszek</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>Dan Jang</td>
<td>Electrical Engineer</td>
</tr>
<tr>
<td>Kyle Bradstreet</td>
<td>Mechanical Engineer</td>
</tr>
<tr>
<td>Zach Sostack</td>
<td>Mechanical Engineer</td>
</tr>
</tbody>
</table>
Agenda

- Team Introduction
- **Project Review**
- Mechanical Designs
  - Vertical Traverse
  - Horizontal Traverse
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Project Objective

- Create a rig that will move a camera, with lighting, vertically and horizontally to take tiled images of large permanently installed artwork
Functional Decomposition

- Processing Images
- Access Artwork
- Illuminating artwork
- Program Capture Sequence
- Capturing Images
### Customer Needs

<table>
<thead>
<tr>
<th>Customer Requirement #</th>
<th>Importance</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CR0</td>
<td>11</td>
<td>Cannot damage artwork</td>
</tr>
<tr>
<td>CR1</td>
<td>9</td>
<td>Move camera to positions required for composite images</td>
</tr>
<tr>
<td>CR2</td>
<td>9</td>
<td>Support weight of camera and lights</td>
</tr>
<tr>
<td>CR3</td>
<td>9</td>
<td>Fit through doors</td>
</tr>
<tr>
<td>CR4</td>
<td>9</td>
<td>Have capacity to image one particular large work</td>
</tr>
<tr>
<td>CR5</td>
<td>9</td>
<td>Incorporate means of mounting lights</td>
</tr>
<tr>
<td>CR6</td>
<td>9</td>
<td>Uniform Lighting</td>
</tr>
<tr>
<td>CR7</td>
<td>9</td>
<td>Require less than 15 Amps</td>
</tr>
<tr>
<td>CR8</td>
<td>9</td>
<td>Safe to operate for personnel</td>
</tr>
<tr>
<td>CR9</td>
<td>3</td>
<td>Easy to use</td>
</tr>
<tr>
<td>CR10</td>
<td>3</td>
<td>Minimal job-to-job reconfiguration</td>
</tr>
<tr>
<td>CR11</td>
<td>3</td>
<td>Connect to camera with standard tripod mount</td>
</tr>
<tr>
<td>CR12</td>
<td>3</td>
<td>Automated capture after initial setup</td>
</tr>
<tr>
<td>CR13</td>
<td>3</td>
<td>Minimal to no maintenance</td>
</tr>
<tr>
<td>CR14</td>
<td>3</td>
<td>Aesthetically Appealing</td>
</tr>
<tr>
<td>CR15</td>
<td>3</td>
<td>Flexible for large and small works</td>
</tr>
<tr>
<td>CR16</td>
<td>3</td>
<td>Flexible lighting setup</td>
</tr>
<tr>
<td>CR17</td>
<td>3</td>
<td>Can orient camera automatically</td>
</tr>
<tr>
<td>CR18</td>
<td>1</td>
<td>GUI</td>
</tr>
<tr>
<td>CR19</td>
<td>1</td>
<td>Compatible with stitching algorithm</td>
</tr>
<tr>
<td>CR20</td>
<td>3</td>
<td>Absorb vibrations from building floor</td>
</tr>
<tr>
<td>CR21</td>
<td>3</td>
<td>Maintain distance from camera to wall during vertical traverse</td>
</tr>
</tbody>
</table>
# Engineering Requirements

<table>
<thead>
<tr>
<th>Requirement Number</th>
<th>Importance</th>
<th>Source</th>
<th>Specification Metric</th>
<th>Units</th>
<th>Marginal Value</th>
<th>Ideal Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER0</td>
<td>9</td>
<td>CR1, CR4, CR10, CR14</td>
<td>Overall range</td>
<td>ft</td>
<td>25' Lateral x 18 High</td>
<td>&gt; 25 Lateral x &gt;18 High</td>
</tr>
<tr>
<td>ER1</td>
<td>9</td>
<td>CR2, CR16</td>
<td>Weight capacity</td>
<td>lbs</td>
<td>200</td>
<td>250</td>
</tr>
<tr>
<td>ER2</td>
<td>9</td>
<td>CR11</td>
<td>Camera mounting</td>
<td>Boolean</td>
<td>Has rigid tripod mount</td>
<td>Active tripod mounts</td>
</tr>
<tr>
<td>ER3</td>
<td>9</td>
<td>CR6, CR16, CR19</td>
<td>Light mounting and range of motion</td>
<td>DOF</td>
<td>fixed light positions 0 degrees of freedom</td>
<td>3 degrees of freedom</td>
</tr>
<tr>
<td>ER4</td>
<td>9</td>
<td>CR1,CR4, CR12</td>
<td>Camera field of view outside of rig</td>
<td>ft</td>
<td>1.5</td>
<td>&gt;1.5</td>
</tr>
<tr>
<td>ER5</td>
<td>9</td>
<td>CR1, CR12</td>
<td>Traverse range without user reconfiguration</td>
<td>ft</td>
<td>25 lateral x 18 height</td>
<td>&gt;25 x &gt;18</td>
</tr>
<tr>
<td>ER6</td>
<td>9</td>
<td>CR3</td>
<td>Package Size</td>
<td>in</td>
<td>32 x 82</td>
<td>Smaller</td>
</tr>
<tr>
<td>ER7</td>
<td>3</td>
<td>CR9, CR10, CR13</td>
<td>Number of steps to use</td>
<td>Steps</td>
<td>As few as feasible</td>
<td></td>
</tr>
<tr>
<td>ER8</td>
<td>3</td>
<td>CR17, CR18, CR15</td>
<td>Range of motion of camera mount</td>
<td>DOF</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>ER9</td>
<td>9</td>
<td>CR7</td>
<td>Power Consumption</td>
<td>Amps</td>
<td>&lt;15</td>
<td></td>
</tr>
<tr>
<td>ER10</td>
<td>3</td>
<td>CR5</td>
<td>Setup Time</td>
<td>hr</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>ER11</td>
<td>3</td>
<td>CR10</td>
<td>Maintenance interval</td>
<td>hr</td>
<td>40</td>
<td>Inf</td>
</tr>
<tr>
<td>ER12</td>
<td>9</td>
<td>CR0, CR2, CR8</td>
<td>Moment applied to tip-over</td>
<td>lb-ft</td>
<td>250</td>
<td>&gt;250</td>
</tr>
<tr>
<td>ER13</td>
<td>3</td>
<td>CR20</td>
<td>Peak to peak displacement</td>
<td>in.</td>
<td>.1&quot;</td>
<td>0</td>
</tr>
<tr>
<td>ER14</td>
<td>3</td>
<td>CR21</td>
<td>Displacement of camera during vertical traverse</td>
<td>in.</td>
<td>2&quot;</td>
<td>&lt;2&quot;</td>
</tr>
<tr>
<td>ER15</td>
<td>3</td>
<td>CR1</td>
<td>Traverse increment &amp; backlash</td>
<td>in.</td>
<td>+/- 0.5&quot;</td>
<td></td>
</tr>
</tbody>
</table>
Agenda

● Team Introduction
● Project Review
● Mechanical Designs
  ○ *Vertical Traverse*
  ○ Horizontal Traverse
  ○ Camera/Light Mounting
  ○ Rail System
● Wiring Diagrams
● GUI
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● Bill of Materials
Vertical Traverse

Genie SLA-20 material lift

Dual Staged Mast
SLA-20 Mast On Custom Base

Base to suit needs for automation and equipment mounting.

Knee braces, stabilizers will be adopted from SLA-20,
## Mast Specs

<table>
<thead>
<tr>
<th></th>
<th>Custom Dual Mast</th>
<th>Stock SLA-20</th>
<th>Implemented SLA-20</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Vertical Range</strong></td>
<td>19' - 2&quot;</td>
<td>19' - 6&quot;</td>
<td>19' - 6&quot;</td>
</tr>
<tr>
<td><strong>Package Height</strong></td>
<td>5' - 5&quot;</td>
<td>6' - 2&quot;</td>
<td>6' - 2&quot;</td>
</tr>
<tr>
<td>(Above Base)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Width (w/ stabilizers)</strong></td>
<td>34&quot;</td>
<td>31.5&quot; (73&quot;)</td>
<td>32&quot; (~73&quot;)</td>
</tr>
<tr>
<td><strong>Weight</strong></td>
<td>200 lb</td>
<td>~200 lb</td>
<td>~200 lb</td>
</tr>
<tr>
<td><strong>Payload</strong></td>
<td>100 lb (36&quot; LC)</td>
<td>350 lb (42&quot; LC)</td>
<td>350 lb (42&quot; LC)</td>
</tr>
<tr>
<td><strong>Crank Force</strong></td>
<td>Unknown</td>
<td>20-25 ft-lb</td>
<td>20 - 25 ft-lb</td>
</tr>
<tr>
<td></td>
<td></td>
<td>240 lb at full extension</td>
<td>240 lb at full extension</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td>&gt;2,600 USD (matl. only, no motor, drive line, or winch)</td>
<td>2,810 USD (preferred pricing, freight included)</td>
<td>3,400 USD (motor, driveline, mounting plates included)</td>
</tr>
</tbody>
</table>
Motorized Winch

- **Gearmotor**
  - McMaster P/N: 59825K52
  - Power: ¼ Hp
  - Torque: 125 in-lbs

- **Gear Train**
  - ANSI 40 chain
  - 1:2.44 gear reduction ratio
  - Can be disengaged

- **Max measured winch torque of 300 in-lbs**
Adjustable Stop
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  - **Horizontal Traverse**
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Horizontal Traverse
Horizontal Traverse
Mast Support Rail - Picks up mast load via mounting plate - 4” x 4” x 0.25” A500 Steel Tube. SF = 15
Mast Support Rail - Picks up mast load via mounting plate - 4” x 4” x 0.25” A500 Steel Tube. SF = 15

Type: Von Mises Stress
Unit: ksi
12/9/2013, 8:05:43 PM

Max: 1.478 ksi
Min: 0.027 ksi
Frame - SF = 9.4
Axle - 1” AISI keyed shaft. 49.5” Wheel track. 22” Wheel. SF = 13.6
Axle - 1” AISI keyed shaft. 49.5” Wheel track. 22” Wheel. SF = 13.6
Wheels - 6” OD V-Groove 6061 Aluminum. SF = 15.
Wheels - 6” OD V-Groove 6061 Aluminum. SF = 15.
Belly Pan - 0.25 Thick 6061 Aluminum Plate. SF = 15. 200 lb distributed load
Bearings

Cast Iron mounted steel roller bearing
- 3,150 lb dynamic load rating
- 5,600 rpm maximum
- Maintenance free, USDA H1 solid polymer-polyethylene grease
Driveline

Chain
- AISI 40
- ½” Pitch
- 437 lb Work Load

Driving Gear
- 9 Hardened Teeth

Driven Gear
- 18 Hardened Teeth
Motor - Right Angle Worm Gearmotor

1/17 Hp
90 Vdc; 0.9 A
Speed: 42 rpm
Torque: 22 in-lb

Sizing Calculation

Desired cart velocity = 180 in/min = 3 in/s = 0.25 ft/s

Time to accelerate = 1 sec → Acceleration = 0.25 ft/s²

Wheel Diameter = 6 in → Wheel circumference = 18.85 in

Wheel Speed = 9.5 rpm = 1 rad/s

Rolling Resistance = 0.005 * 1000 lb = 5 lb

Mechanical efficiency = 0.90

Cart weight = 1000 lb Cart Mass = 31.081 slug

Force = (31.081 slug * 0.25 ft/s² + 5 lb) / 0.90 = 14.2 lb

Drive Torque = 14.2 lb * 3 in = 42.6 in-lb = 3.5 ft-lb

Power = 3.5 ft-lb * 1 rad/s = 3.4 ft-lb/s = 0.006 hp
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Camera & Lighting Assembly
Camera Pan & Tilt

Servo City MPT2100-DS
- Smoothly operate cameras up to 40 lbs.
- System weighs 11 lbs
- Toothed Kevlar belts provide quiet operation and have a lifetime warranty.
Motor Torque Analysis

- Camera exerts a torque of 18 in-lb at a 3” moment arm.
- Gear ratio of the camera system is 3:1
- Force applied on the 3” diameter gear can be calculated by $F = \frac{T}{D}$ ($F=12$ lbs).
- The gear attached to our motor will see a max torque of 6 in-lb (96 oz-in).
- Selected motor has a stall torque 2.6 times greater.
Camera Pan & Tilt Motors

Pololu Gearmotor

- Stall Torque 250 oz-in
- 131.25:1 metal gearbox
- 37Dx57L mm with 64 CPR Encoder (high resolution)
- Mounts directly to purchased pan & tilt system.

37D mm metal gearmotor with 64 CPR encoder.
Pan & Tilt Mounting Surface

Nodes: 4081
Elements: 2005
Type: Displacement
Unit: in

1.443e-004 Max
1.155e-004
3.66e-005
5.773e-005
2.887e-005
0 Min
Linear Motion

- 80/20 Linear Motion slides with manual mechanical brake
- High strength low friction bearing pads for smooth motion
- Self Lubricating bearing pad.
Linear Motion FEA - SF=15

Type: Displacement
Unit: in

1.204e-005 Max
9.63e-006
7.222e-006
4.815e-006
2.407e-006
0 Min
Lighting Frame Hinge FEA

- Combined loading both bending and torsion included on the bracket due to the lighting angles.
- Approximately a 200 in-lb moment, SF=10
Method of Joints - Truss Analysis
Vertical Lighting Assembly

- 1x1 T-Slotted Aluminum Extrusions
- Simplified model of the framing used in FEA model
- Light weight structure weight = 4.75 lbs
- Cross Sectional Area = 0.44 in$^2$
Vertical Lighting FEA - SF=15
Horizontal Lighting FEA - SF=15

Nodes: 2424
Elements: 854
Type: Displacement
Unit: in

8.897e-004 Max
7.118e-004
5.338e-004
3.559e-004
1.779e-004
0 Min
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Rail System

- V-groove track system
- Track lengths: 6’, 3’, and 1’
- Vertex to vertex: 4’1.5”
- Manual leveling feet
Other Track Configurations

1' track piece

3' track piece
Track FEA

- Max deflection: 0.003 in
- Lowest F.O.S.: 5.67
Leveling feet

Foot Block

Foot
Track Ends

Female End

Male End
Track Assembled
Agenda

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- **Wiring Diagrams**
- GUI
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Electrical System - Top
Electrical System - Top
Electrical System - Top

Start sequence → User Input maximum height → Is vertical traverse at starting point?
  Yes: Read sensor’s distance → Compare values to max
  No: Move vertical traverse to starting point

Sensor’s value less or equal to max?
  Yes: Sensor’s value match?
    Yes: Allow for next stage
    No: Alert user to check setup.
  No: End

Move vertical traverse to starting point → Sensor’s value match?
  Yes: Allow for next stage
  No: Alert user to check setup.
Electrical System - Base
Agenda

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GUI

package gui;

import java.awt.Graphics2D;
import java.awt.image.*;
import javax.imageio.*;

import java.io.*;

public class Stitcher {

    // assumes that tiles will be square and
    // that tiles will be put together in a square format
    public static BufferedImage stitch (String[] tiles, int size) throws IOException {
        // find out necessary info to initialize new image
        int rows = (int) Math.sqrt(tiles.length);
        System.out.println(rows + " rows");
        BufferedImage result = new BufferedImage(size * rows, size * rows, 1);
        Graphics2D graphics = result.createGraphics();

        // loop through each tile & stitch
        for (int i = 0; i < tiles.length; i++) {
            System.out.println("Stitching tile number " + i);
            BufferedImage buffer = null;
            try {
                buffer = ImageIO.read(new File(tiles[i]));
                System.out.println("Reading " + tiles[i]);
            } catch (IOException e) {System.out.println("Error reading " + tiles[i]);}
            System.out.println(buffer == null);
            graphics.drawImage(buffer, null, (i % rows) * size,
                (int) Math.floor(i / rows) * size);
            buffer = null;
        }
        File output = new File("result.jpg");
        ImageIO.write(result, "jpg", output);
        return result;
    }
}
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Safety Systems

- Manual kill-switches
  - 2 total
- System limit switches
  - 10 total
- Hard stops
  - Each end of the rail
- Ultrasonic proximity sensor
  - 6 total
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- **Risk Analysis**
- Test Plan
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## Risk Analysis

<table>
<thead>
<tr>
<th>Risk Item</th>
<th>Effect</th>
<th>Cause</th>
<th>L</th>
<th>S</th>
<th>I</th>
<th>Action To Minimize</th>
<th>Owner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mast Cable Failure</td>
<td>Damage to Equipment, Damage to Rig</td>
<td>Cable damage or fatigue</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Regularly inspect cable for fraying or other damage</td>
<td>Matt Misiaszek</td>
</tr>
<tr>
<td>Lift motor failure</td>
<td>Rig must be manually operated</td>
<td>Faulty or undersized motor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Allow manual operation, properly size motor</td>
<td>Matt Misiaszek</td>
</tr>
<tr>
<td>Lift sprocket/chain failure</td>
<td>Rig must be manually operated</td>
<td>Faulty or undersized chain</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Allow manual operation, properly size chain/sprocket</td>
<td>Matt Misiaszek</td>
</tr>
<tr>
<td>Outrigger not raised</td>
<td>Collision with stop or wall</td>
<td>Operator error</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Outrigger position switch</td>
<td>Matt Misiaszek</td>
</tr>
<tr>
<td>Horizontal Motor Failure</td>
<td>Horizontal traverse inoperable</td>
<td>Faulty or undersized motor</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Properly size motor</td>
<td>Sam Brown</td>
</tr>
<tr>
<td>Structural Failure in frame</td>
<td>Damage to surrounding, equipment or user, rig in operable</td>
<td>Weld fails</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Inspection interval</td>
<td>Sam Brown</td>
</tr>
<tr>
<td>Track Failure</td>
<td>Rig tipover</td>
<td>Weld fails</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>Inspection interval</td>
<td>Zach Sostack</td>
</tr>
<tr>
<td>Keyway failure in wheel</td>
<td>Rig inoperable</td>
<td>Fatigue from rotating and reversing load</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td>Inspection interval, design with high safety factor</td>
<td>Sam Brown</td>
</tr>
<tr>
<td>Sprocket or chain failure</td>
<td>Rig inoperaable</td>
<td>Faulty or undersized chain</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>Allow manual operation, properly size chain/sprocket</td>
<td>Sam Brown</td>
</tr>
<tr>
<td>Bearing Failure</td>
<td>Rig inoperable</td>
<td>Undersized out of axis loading</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>Size bearing with high safety factor</td>
<td>Sam Brown</td>
</tr>
<tr>
<td>Failure in the Lighting Frame</td>
<td>Damage to Equipment</td>
<td>Vibrations from vertical traverse</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Increase frame size</td>
<td>Kyle Bradstreet</td>
</tr>
<tr>
<td>Camera begins turning motors when set at a position</td>
<td>Out of focus pictures</td>
<td>Motor slipping</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Implement DC Braking circuitry</td>
<td>Kyle Bradstreet</td>
</tr>
<tr>
<td>Lighting Frame loosening</td>
<td>Cause the Lights to swing while in use</td>
<td>Damage equipment</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>Regularly inspect framing assembly, ensure system is properly locked</td>
<td>Kyle Bradstreet</td>
</tr>
</tbody>
</table>
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# Test Plan

### P14542: Vertical XY Camera Rig - Test Plan

<table>
<thead>
<tr>
<th>Requirement Number</th>
<th>Source</th>
<th>Specification Metric</th>
<th>Units</th>
<th>Test</th>
</tr>
</thead>
<tbody>
<tr>
<td>ER0</td>
<td>CR1, CR4, CR10, CR14</td>
<td>Overall range</td>
<td>ft</td>
<td>Fully extend lift vertically measuring with tape measure and put all tracking together and traverse horizontally</td>
</tr>
<tr>
<td>ER1</td>
<td>CR2, CR16</td>
<td>Weight capacity</td>
<td>lbs</td>
<td>Extend rig to xy limits with desired payload</td>
</tr>
<tr>
<td>ER2</td>
<td>CR11</td>
<td>Camera mounting</td>
<td>Boolean</td>
<td>The camera mount can actively move</td>
</tr>
<tr>
<td>ER3</td>
<td>CR6, CR16, CR19</td>
<td>Light mounting and range of motion</td>
<td>DOF</td>
<td>Mount desired lighting and traversing in xy plane</td>
</tr>
<tr>
<td>ER4</td>
<td>CR1, CR4, CR12</td>
<td>Camera field of view outside of rig</td>
<td>ft</td>
<td>Extend camera to farthest point forward, capture image, measure the field of view</td>
</tr>
<tr>
<td>ER5</td>
<td>CR1, CR12</td>
<td>Traverse range without user reconfiguration</td>
<td>ft</td>
<td>Setup system for 25'x18' and record any necessary user intervention</td>
</tr>
<tr>
<td>ER6</td>
<td>CR3</td>
<td>Package Size</td>
<td>in</td>
<td>Measure broken down traveling size</td>
</tr>
<tr>
<td>ER7</td>
<td>CR9, CR10, CR13</td>
<td>Number of steps to use</td>
<td>Steps</td>
<td>Count all the steps involved in capturing image</td>
</tr>
<tr>
<td>ER8</td>
<td>CR17, CR18, CR15</td>
<td>Range of motion of camera mount</td>
<td>DOF</td>
<td>Measure displacement of pitch and yaw</td>
</tr>
<tr>
<td>ER9</td>
<td>CR7</td>
<td>Power Consumption</td>
<td>Amps</td>
<td>Hook rig up to multi meter to measure current drawn</td>
</tr>
<tr>
<td>ER10</td>
<td>CR5</td>
<td>Setup Time</td>
<td>hr</td>
<td>Time setup times taking into account learning curves</td>
</tr>
<tr>
<td>ER11</td>
<td>CR10</td>
<td>Maintenance interval</td>
<td>hr</td>
<td>Use manufacturer recommendations</td>
</tr>
<tr>
<td>ER12</td>
<td>CR0, CR2, CR8</td>
<td>Moment applied to tip-over</td>
<td>Ib-ft</td>
<td>Apply a measured moment until integrity of rig stability faults</td>
</tr>
<tr>
<td>ER13</td>
<td>CR20</td>
<td>Peak to peak displacement</td>
<td>in</td>
<td>Use sonar sensor to measure distance at bottom then traverse to maximum vertical and measure distance from wall again</td>
</tr>
<tr>
<td>ER14</td>
<td>CR21</td>
<td>Displacement of camera during vertical traverse</td>
<td>in</td>
<td>Use sonar sensor to measure distance at bottom then traverse to maximum vertical and measure distance from wall again</td>
</tr>
<tr>
<td>ER15</td>
<td>CR1</td>
<td>Traverse increment &amp; backlash</td>
<td>in</td>
<td>Mark initial position, command movement, measure distance traversed, command same negative movement, measure distance from initial position</td>
</tr>
</tbody>
</table>
Agenda

● Team Introduction
● Project Review
● Mechanical Designs
  ○ Vertical Traverse
  ○ Horizontal Traverse
  ○ Camera/Light Mounting
  ○ Rail System
● Wiring Diagrams
● GUI
● Safety Systems
● Risk Analysis
● Test Plan
● **Bill of Materials**
Bill of Materials

- The BOM is broken down by each subsystem
- These prices don’t include the cost of shipping
- Only long lead time item is the material lift

<table>
<thead>
<tr>
<th>Track Piece</th>
<th>Cost/Piece</th>
<th>Quantity</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>6' Track</td>
<td>$157.65</td>
<td>4</td>
<td>$630.60</td>
</tr>
<tr>
<td>3' Track</td>
<td>$108.57</td>
<td>1</td>
<td>$108.57</td>
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<tr>
<td>1' Track</td>
<td>$48.38</td>
<td>2</td>
<td>$96.76</td>
</tr>
<tr>
<td>Male End</td>
<td>$60.46</td>
<td>1</td>
<td>$60.46</td>
</tr>
<tr>
<td>Female End</td>
<td>$73.89</td>
<td>1</td>
<td>$73.89</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$970.28</strong></td>
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</table>

<table>
<thead>
<tr>
<th>Subsystem</th>
<th>Cost</th>
<th>Longest Lead Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical Traverse</td>
<td>$3,317.91</td>
<td>7 weeks</td>
</tr>
<tr>
<td>Horizontal Traverse</td>
<td>$2,213.19</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>Camera/Light Mounting</td>
<td>$1,824.10</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>Rail System</td>
<td>$966.69</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td>Electrical Components</td>
<td>$1,105.17</td>
<td>1-2 weeks</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$9,427.06</strong></td>
<td></td>
</tr>
</tbody>
</table>

Complete BOM
Questions?