Portable Balcony Crane

A Baccalaureate thesis submitted to the
School of Dynamic Systems
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

H. Tyler Vander Werf

April 2013

Thesis Advisor: Prof. Laura Caldwell
ACKNOWLEDGEMENTS

I would like to thank all of my family and friends for their support and motivation throughout my undergraduate career. I couldn’t have done it without them.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS ....................................................................................................................... II
TABLE OF CONTENTS ....................................................................................................................... II
LIST OF FIGURES .......................................................................................................................... III
LIST OF TABLES ............................................................................................................................ III
ABSTRACT ........................................................................................................................................... IV
INTRODUCTION .............................................................................................................................. 1
RESEARCH .......................................................................................................................................... 1
INTERVIEWS ....................................................................................................................................... 1
EXISTING PRODUCTS .................................................................................................................... 1
SURVEY .............................................................................................................................................. 3
PRODUCT OBJECTIVES .................................................................................................................. 4
CONCEPT DESIGNS AND SELECTION ......................................................................................... 5
90° SUPPORT CONCEPT .............................................................................................................. 5
30° SUPPORT CONCEPT .............................................................................................................. 6
30° SUPPORT CART CONCEPT ..................................................................................................... 7
WEIGHTED OBJECTIVES ............................................................................................................... 8
CALCULATIONS .............................................................................................................................. 8
FREE BODY DIAGRAMS AND CALCULATIONS ........................................................................... 9
ASSEMBLY DESIGN DETAILS ...................................................................................................... 13
FABRICATION ................................................................................................................................. 14
MACHINES USED ............................................................................................................................ 14
ASSEMBLY ........................................................................................................................................ 15
SCHEDULE ....................................................................................................................................... 16
BUDGET ............................................................................................................................................ 17
WORKS CITED ............................................................................................................................... 18
APPENDIX A - RESEARCH ........................................................................................................... 1
APPENDIX B - SURVEY ................................................................................................................. 1
APPENDIX C - QUALITY FUNCTION DEPLOYMENT (QFD) ......................................................... 1
APPENDIX D – PRODUCT OBJECTIVES ....................................................................................... 1
APPENDIX E – SCHEDULE .................................................................................................................. 1
APPENDIX F - BUDGET .......................................................................................................................... 1
APPENDIX G – PROPERTIES OF STEEL STRUCTURAL TUBING (HSS-SHAPES)
AND PROPERTIES OF STRUCTURAL STEELS .................................................................................. 1
APPENDIX H – BILL OF MATERIALS ..................................................................................................... 1

LIST OF FIGURES
Figure 1: Smart-Rig T1 Crane .................................................................................................................. 1
Figure 2: Small Indoor Rotation Crane Hoist ......................................................................................... 2
Figure 3: Boom Crane Pulley .................................................................................................................. 2
Figure 4: 90° Support Concept ............................................................................................................... 5
Figure 5: 30° Support Concept ............................................................................................................... 6
Figure 6: 30° Support Cart Concept ....................................................................................................... 7
Figure 7: Weighted Objectives .............................................................................................................. 8
Figure 8: FBD of Maximum Stress Point in Crane .................................................................................. 9
Figure 9: FBD of Cross Section ............................................................................................................. 10
Figure 10: FBD of Two Legs of the Base in Bending .......................................................................... 11
Figure 11: Bending and Moment Diagrams for Legs on Base .............................................................. 12
Figure 12: Complete Assembly ........................................................................................................... 13
Figure 13: Pictures of Fabrication Process .......................................................................................... 14
Figure 14: Four main parts of Portable Balcony Crane ....................................................................... 15
Figure 17: Schedule .............................................................................................................................. 16
Figure 18: Budget ................................................................................................................................. 17

LIST OF TABLES
Table 1: Survey Results ......................................................................................................................... 3
Table 2: Tip over Calculations .............................................................................................................. 8
ABSTRACT

Moving in and out of multiple story buildings is a bit of a hassle, especially when there are only tight stairwells that are next to impossible to fit furniture in. This balcony crane was designed to create an alternative to that long and hard process. By having a crane that fits on a balcony raise and lower furniture and other objects in and out of apartments and houses, people can focus on other important things, like enjoying their new home. This report shows the process that was used to design a prototype of a portable balcony crane. The prototype was fabricated and tested, and was able to meet the entire list of design criterion that was specified by consumers. It is lightweight, able to lift up to 300 lbs, and is able to be assembled and disassembled without the use of tools.
INTRODUCTION

Moving in and out of a multi-story building without an elevator can be very exhausting and difficult. The goal of this project is to design and build a fully functional prototype small crane that would fit on the balcony of a house or apartment to lift the objects that would otherwise have to be carried up the multiple floors.

RESEARCH

INTERVIEWS

Because this prototype is aimed toward moving in and out of buildings, a local moving business was contacted and an interview was conducted with Tim Armstrong (1) on thoughts he would have on the design of a small crane like this. Some key points that he suggested that should be addressed in the design were:

- Portability
- Easy to set up
- Easily operated between two people
- Be able to extend out and over balcony for clearances
- Had to handle up to 300 lb.

Mike Harlor (2), owner of a painting company and Columbus Fire Fighter was also contacted and asked questions about how he would use something like this. Some of his suggestions were similar to Tim’s but some of the others were:

- Find a proper way to secure it for safety
- Power options (battery vs. wall outlet)
- Tag line for safety

EXISTING PRODUCTS

The research conducted turned up three unique and interesting examples of what is out on the market right now.

The first crane is called the Smart-Rig T1 Crane (3) and is shown in Figure (1). It is typically used in industrial environments when a mid-sized crane is needed on different levels during construction.

![Smart-Rig T1 Crane](image)

Figure 1: Smart-Rig T1 Crane
Some key features in this design are:

- Small cranes utilize a light-weight pull-out manual boom.
- Utilizing pick and carry features for rigging, moving, transporting and traveling heavy objects.
- Adjustable, folding, versatile full power straddle crane is smaller and more affordable compared to expensive spider cranes, davit cranes, or crawler cranes.
- Light duty with articulating boom arm, able to work on rough terrain or indoors makes the Smart-Rig mini crane a full power portable lifting crane.

The second crane is actually called a Small Indoor Rotating Crane Hoist (4) and is shown in Figure (2). When installed against the ceiling and the upper floor, it can easily lift goods from ground floor to upper floors.

![Small Indoor Rotation Crane Hoist](image)

**Figure 2: Small Indoor Rotation Crane Hoist**

Some of the features include:

- Light weight
- With accessional support frame, it’s suitable for both indoor and outdoor hoisting
- Applicable for outdoor large projects when fixed with scaffolding

The third crane is a Boom Crane Pulley (5) and is shown in Figure (3). It is a general design that is used to lift heavy objects. This particular crane was made as a project on a “do-it-yourself” website.

![Boom Crane Pulley](image)

**Figure 3: Boom Crane Pulley**

Some of the features include:

- Low cost
- Attached to structure – very secure.
These three different cranes are basic examples of what is available for customers in today’s market. Some other manufacturers use these designs as a base and slightly chains different aspects of their design. There isn’t anything available to do what the balcony crane prototype is designed to do. Please refer to Appendix A for more information on research.

SURVEY

A survey of twenty random college students at the University of Cincinnati was conducted to try and get a broad idea of what a potential customer would want. The survey had the students rate what they thought were the most important things for the design of a balcony crane, along with rating the same criteria of products that are the current options on the market. The college students were also asked to circle the price range in which they’d be willing to purchase a crane like this on a scale from 1-5 (the importance of their satisfaction). The survey results are listed in Table (1) under Customer importance.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Customer importance</th>
<th>Designer’s Multiplier</th>
<th>Current Satisfaction</th>
<th>Planned Satisfaction</th>
<th>Improvement ratio</th>
<th>Modified Importance</th>
<th>Relative weight</th>
<th>Relative weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost</td>
<td>4.2</td>
<td>1.0</td>
<td>1.9</td>
<td>4</td>
<td>2.1</td>
<td>8.8</td>
<td>0.17</td>
<td>17%</td>
</tr>
<tr>
<td>Safety</td>
<td>4.8</td>
<td>1.0</td>
<td>3.0</td>
<td>4</td>
<td>1.3</td>
<td>6.4</td>
<td>0.12</td>
<td>12%</td>
</tr>
<tr>
<td>Reliability</td>
<td>4.8</td>
<td>1.0</td>
<td>4.2</td>
<td>5</td>
<td>1.2</td>
<td>5.7</td>
<td>0.11</td>
<td>11%</td>
</tr>
<tr>
<td>Manuverability</td>
<td>3.5</td>
<td>1.1</td>
<td>2.7</td>
<td>4</td>
<td>1.5</td>
<td>5.7</td>
<td>0.11</td>
<td>11%</td>
</tr>
<tr>
<td>Capacity</td>
<td>4.9</td>
<td>1.0</td>
<td>4.9</td>
<td>5</td>
<td>1.0</td>
<td>5.0</td>
<td>0.09</td>
<td>9%</td>
</tr>
<tr>
<td>Adjustability</td>
<td>4.4</td>
<td>1.0</td>
<td>3.6</td>
<td>4</td>
<td>1.1</td>
<td>4.9</td>
<td>0.09</td>
<td>9%</td>
</tr>
<tr>
<td>Operational Speed</td>
<td>3.3</td>
<td>1.2</td>
<td>3.3</td>
<td>4</td>
<td>1.2</td>
<td>4.8</td>
<td>0.09</td>
<td>9%</td>
</tr>
<tr>
<td>Ease of use</td>
<td>4.1</td>
<td>1.0</td>
<td>3.8</td>
<td>4</td>
<td>1.1</td>
<td>4.3</td>
<td>0.08</td>
<td>8%</td>
</tr>
<tr>
<td>Durability</td>
<td>3.8</td>
<td>1.0</td>
<td>3.9</td>
<td>4</td>
<td>1.0</td>
<td>3.9</td>
<td>0.07</td>
<td>7%</td>
</tr>
<tr>
<td>Operational Range</td>
<td>3.5</td>
<td>1.0</td>
<td>3.8</td>
<td>4</td>
<td>1.1</td>
<td>3.7</td>
<td>0.07</td>
<td>7%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>53.2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Table 1: Survey Results

From the survey results, a QFD was used to produce product objectives. The designer also added input to get the weight where it needed to be to plan what objectives were the most important.

Please refer to Appendix B for more information on the survey.
Please refer to Appendix C to view the QFD chart.
PRODUCT OBJECTIVES

The product objectives are the objectives that make up the proof of design for this project, and are the goals that are set in order to make sure the project is successful. The main criteria are the criteria defined in the survey and QFD, but the product objects go further and define the main points of these criteria. Each objected is organized from the highest relative weight to the lowest. The product objectives are as follows:

1. Cost 17%
   a. Less than $600 for the prototype.

2. Safety 12%
   a. Must have tag line
   b. Use material and design factor(s) consistent with loading conditions
   c. Must have emergency stop
   d. System will provide brake to maintain control of load
   e. System will be balanced to prevent tip over

3. Maneuverability 11%
   a. Able to fit through sliding glass doors and on balconies assembled
   b. Wheels/Casters will require no more than 50 lbs.
   c. Two steps to adjust the arm height

4. Reliability 11%
   a. Design factor consistent with loading conditions in expected use
   b. Rust-resistant material selection or surface finish
   c. Purchased parts will have a life cycle of at least 5 years

5. Adjustability 9%
   a. Able to alter linear extension of swing arm with a range of 1 foot
   b. Able to alter the height of the extension arm 1 foot

6. Capacity 9%
   a. Able to lift 300 lbs.
   b. Tip-over calculation

7. Operational Speed 9%
   a. Able to raise and lower object at controlled speed between 0.5 ft./sec and 10 ft./sec.

8. Ease of Use 8%
   a. Controls comparable to similar mini cranes on the market
   b. Will be able to be lifted by two people (50th percentile male)
c. Size of module one will be 3 ft. x 1 ft. x 1 ft.
d. Size of module two will be 3 ft. x 3 ft. x 1 ft.
e. Will have quick disconnect with cable connected pins
f. Will collapse in 3 steps without tools
g. Should assemble in 10 minutes

9. Durability
   a. See Reliability

10. Operational Range
    a. Has to be able to lift items up at a maximum distance of 40 feet

Please refer to Appendix D for more information on the product objectives.

CONCEPT DESIGNS AND SELECTION

90° SUPPORT CONCEPT

The first concept shown in Figure (4) shows a mobile base that would be either square or triangular. This base is mounted on casters for mobility. The support components for the base and arm are made up of two different sizes of square steel tubing. This larger square tube is welded in a “L” shape and supported with another square tube at a 45 degree angle. Both the main support and the arm are adjustable, and would telescope in and out of the “L” square pipe.
A pulley is attached on the outer-most point of the arm. This is where the wire drops down to lift the object. That wire goes from the outer-most part of the arm to another pulley placed on the “L” square pipe. The wire follows that pulley down and into/through the main support square tube. The wire then connects to a winch, which is centered below the main support tube, and would be anchored down to the base of the crane.

An alternate pulley system design is also shown in Figure (4). In this design, the pulleys are below the arm and “L” tube, and the wire doesn’t go inside the tubes at all. The second pulley is placed in the 45 degree support tube that is attached to the “L” tube. This offsets the winch from the center of the base.

**30° SUPPORT CONCEPT**

![30° Support Concept Diagram]

Figure 5: 30° Support Concept

For the second concept, refer to Figure (5). This concept also includes use of a square or triangular base mounted on casters. Two key differences for this concept are the winch is mounted on the “T” connection piece instead of mounted on the base, as well as the adjustable arm set at a 30
degree angle. From this position, the wire travels over the far arm pulley to be attached to the object being lifted. Besides the winches primary objective of reeling in the wire to lift the object, it would also serve a secondary objective by acting as a counter weight to balance the crane out when lifting objects.

30° SUPPORT CART CONCEPT

Figure 6: 30° Support Cart Concept

The 30° Support Cart Concept is shown in Figure (6). It uses a cart base that counterweights can be place on to prevent tip over of the crane. Five gallon water buckets filled with water are used for counter-weights due to the portability when empty and the weight of the water when full. The main support that is connected to the base is detachable. The “T” connection is shown in this concept due to its ease of use. The winch that was used in previous sketches is replaced in this sketch with a hand crank. The hand crank provides the same function with less weight to increase portability and to avoid situations where there is no power source available to the operator of the crane.
WEIGHTED OBJECTIVES

From this weighted objectives table, the 30° Support Cart Concept is the highest ranked option based on the relative weights of the objectives, and therefore best option to go with.

CALCULATIONS

To find the maximum stress that the main support of the crane undergoes, the moment at that point was used. The size of the square tubing along with the material of the tubing factored into what the design of the prototype. The crane has to be strong enough to withstand the forces acting on it without tipping over or failing, but also has to be light enough to be easy to disassemble and carry. For material properties refer to Appendix G.

The above table, Table 2: shows the tip over calculations that were completed based on a 300 lb weight and an arm over-hang of 23 inches. The helped determine how many 5-gallon buckets of water were going to be needed in order to provide enough counter weight so that the crane didn’t tip over.
**FREE BODY DIAGRAMS AND CALCULATIONS**

Figure 8: FBD of Maximum Stress Point in Crane

Figure (8) shows the free body diagram used to calculate the highest stress point for the crane prototype.

### Moment at Point A for Max Stress Point

\[
\Sigma M_A = 0 \\
\Sigma M_A = M_A - 300 \text{ lb} \times 26 \text{ in} \\
M_A = 7800 \text{ in lb}
\]

### Stress at Point A for 1 ½” x 1 ½” x 3/16” Square Steel Tubing

\[
\sigma = \frac{M}{S} + \frac{P}{A}
\]

\[
\sigma = \frac{7800 \text{ in lb}}{0.314 \text{ in}^3} + \frac{300 \text{ lb}}{0.840 \text{ in}^2}
\]

\[
\sigma = 25200 \text{ psi} = 25.2 \text{ ksi}
\]
Factor of Safety in Max Stress Point

\[ FS = \frac{\text{Material Strength}}{\text{Design Load}} \]

\[ FS = \frac{46 \text{ ksi}}{25.2 \text{ ksi}} \]

\[ FS = 1.83 \]

---

Figure 9: FBD of Cross Section

Figure (9) is the FBD of the cross piece that the main support is mounted to.

Polar Section Modulus at Point A

\[ Z_p = 2t (a - t) (b - t) \]

\[ Z_p = 2(0.1875 \text{ in}) \times (2.0 \text{ in} - 0.1875 \text{ in})(2.0 \text{ in} - 0.1875 \text{ in}) \]

\[ Z_p = 1.232 \text{ in}^3 \]

Torsion at Point A

\[ \tau = \frac{T}{Z_p} \]

\[ \tau = \frac{7800 \text{ in lb}}{1.232 \text{ in}^3} \]

\[ \tau = 6331.5 \text{ psi} = 6.331 \text{ ksi} \]
Stress at Point A for 1 ½” x 1 ½” x 3/16” Square Steel Tubing

\[ \sigma = \frac{M}{S} + \tau \]
\[ \sigma = \frac{7800 \ \text{in} \ \text{lb}}{0.640 \ \text{in}^3} + 6331.5 \ \text{psi} \]
\[ \sigma = 13174 \ \text{psi} = 13.17 \ \text{ksi} \]

Maximum Shear Stress at Point A for 1 ½” x 1 ½” x 3/16” Square Steel Tubing

\[ \tau_{\text{max}} = \sqrt{\left(\frac{\sigma}{2}\right)^2 + \left(\tau\right)^2} \]
\[ \tau_{\text{max}} = \sqrt{\left(\frac{13174 \ \text{psi}}{2}\right)^2 + (6331.5 \ \text{psi})^2} \]
\[ \tau_{\text{max}} = 9136.4 \ \text{psi} = 9.13 \ \text{ksi} \]

Factor of Safety of Cross Section

\[ FS = \frac{\text{Material Strength}}{\text{Design Load}} \]
\[ FS = \frac{46 \ \text{ksi}}{13.17 \ \text{ksi}} \]
\[ FS = 3.49 \]

Figure 10: FBD of Two Legs of the Base in Bending

Figure (10) is the FBD of the bending that will occur in the two sides of the base that the casters are mounted to. Figure (11) shows the bending and moment diagram of the two base sides as well.
Force on Front Wheel
\[ \Sigma M_{W2} = 0 \]
\[ \Sigma M_{W2} = -W_1 (36 \text{ in}) + 150 \text{ lb (30 in)} + 140.5 \text{ lb (12 in)} \]
\[ W_1 = 171.8 \text{ lb} \]

Force on Back Wheel
\[ \Sigma F_y = 0 \]
\[ \Sigma F_y = 171.8 \text{ lb} - 150 \text{ lb} - 140.5 \text{ lb} + W_2 \]
\[ W_2 = 118.7 \text{ lb} \]

Max stress on base side 1 \( \frac{1}{2}'' \) x 1 \( \frac{1}{2}'' \) x 3/16'' Square Steel Tubing
\[ \sigma = \frac{M}{S} + \frac{P}{A} \]
\[ \sigma = \frac{1021 \text{ in lb}}{0.314 \text{ in}^3} + \frac{171 \text{ lb}}{0.840 \text{ in}^2} \]
\[ \sigma = 3455.2 \text{ psi} = 3.45 \text{ ksi} \]

Factor of Base Sides
\[ FS = \frac{\text{Material Strength}}{\text{Design Load}} \]
\[ FS = \frac{46 \text{ ksi}}{3.45 \text{ ksi}} \]
\[ FS = 12.2 \]

Figure 11: Bending and Moment Diagrams for Legs on Base
ASSEMBLY DESIGN DETAILS

The components of the assembly are designed to perform in the outside environment. It is designed to have detachable parts that can be connected together with relative ease on site with no tools.

Pulley tip and T connection piece made from 2”x2”x3/16” A500 Grade B structural square steel tubing.

Arm, Main Support, and base made from 1.5”x1.5”x3/16” A500 Grade B structural square steel tubing.

(4) 3” casters mounted to base for mobility.

(8) 5-gallon plastic buckets used as counter-weights.

Bucket system for bucket support.

Hand Brake Winch

Removable Handle

2” pulley for cable to go around to lift object.

Figure 12: Complete Assembly
FABRICATION

Figure (13) shows a couple snap shots of the different processes used to complete this project, followed by a list of the actual machines used in some of the pictures.

Figure 13: Pictures of Fabrication Process

MACHINES USED
- Vertical Bandsaw
- Drill Press
- Grinder
- MIG Welder
- Ring Roller
- Lathe
- 20 Ton Hydraulic Press
- Punch Press
- Tap
- Oxy-Acetylene Torch
ASSEMBLY

Below is a brief description of the processes that were involved in the assembly of the four main parts of the Portable Balcony Crane Please reference figure (14).

Figure 14: Four main parts of Portable Balcony Crane

- **Base**
  - Cut pieces to length using vertical bandsaw.
  - Cut out caster plates, punch holes for casters, and bend to shape.
  - Prepare and weld pieces together.
  - Attach casters.
  - Weld plate for arm and pegs for bucket system and handle in place.

- **Arm**
  - Cut pieces to length using vertical bandsaw.
  - Drill out holes for adjustment pins.
  - Weld pieces together.
  - Attach hand brake winch and pulley.

- **Handle**
  - Cut pieces to length using pipe cutter.
  - Bend conduit to form radius.
  - Drill hitch pin hole.
  - Weld back plate fork and cross handle in place.

- **Bucket System**
  - Cut pieces to length using hacksaw.
  - Form circles with material to go around buckets with a ring roller.
  - Drill the hitch pin holes in support conduit.
  - Weld on support conduit to rings and weld rings together.
SCHEDULE

A weekly schedule was generated to make sure the project was kept on pace to complete.

<table>
<thead>
<tr>
<th>Task</th>
<th>Proposed Dates</th>
<th>Actual Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design lift arm system</td>
<td>Nov. 28, 2012</td>
<td>Dec. 13, 2012</td>
</tr>
<tr>
<td>Assembly</td>
<td>Feb. 27, 2013</td>
<td>Mar. 30, 2013</td>
</tr>
<tr>
<td>Final testing</td>
<td>Mar. 27, 2013</td>
<td>Apr. 2, 2013</td>
</tr>
<tr>
<td>Advisor demonstration</td>
<td>Mar. 29, 2013</td>
<td>Apr. 3, 2013</td>
</tr>
<tr>
<td>Faculty demonstration</td>
<td>Apr. 5, 2013</td>
<td>Apr. 4, 2013</td>
</tr>
<tr>
<td>Spring oral presentation</td>
<td>Apr. 12, 2013</td>
<td>Apr. 17, 2013</td>
</tr>
</tbody>
</table>

Figure 15: Schedule

Please refer to Appendix E for more information on the schedule.
**BUDGET**

My proposed budget to design a prototype is $600.00. Based on the changes that were made during the design process, the total bill is under budget.

<table>
<thead>
<tr>
<th>Materials, Components, or Labor</th>
<th>Forecasted Amount</th>
<th>Actual Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame (at $7.00/ft.)</td>
<td>$200.00</td>
<td>$132.06</td>
</tr>
<tr>
<td>Cable</td>
<td>$50.00</td>
<td>$56.04</td>
</tr>
<tr>
<td>Hand Crank</td>
<td>$100.00</td>
<td>$82.45</td>
</tr>
<tr>
<td>Casters</td>
<td>$50.00</td>
<td>$71.92</td>
</tr>
<tr>
<td>Pulley</td>
<td>$10.00</td>
<td>$6.66</td>
</tr>
<tr>
<td>Misc. Services/Parts/Delivery</td>
<td>$180.00</td>
<td>$131.82</td>
</tr>
<tr>
<td>Total</td>
<td>$590.00</td>
<td>$480.95</td>
</tr>
</tbody>
</table>

Figure 16: Budget

Please refer to Appendix F for more detail on the budget.
WORKS CITED

3. Smart-Rig Cranes. Smart-Rig Cranes. [Online] [Cited: 09 13th, 2012.]
   http://www.instructables.com/id/Boom-Crane-Pulley/?ALLSTEPS.
APPENDIX A - RESEARCH

Interview with Tim Armstrong. Move Cheap Cincinnati Movers. 4316 Mt. Carmel-Tobasco Rd. Cincinnati, OH 45244 09/13/2012
Felt that my project was a great idea.
Some features that he thought were important included: portability, easy to set up, easily operated between two people, be able to extend out and over balcony for clearances, had to handle up to 300 lb.
Did not know of any currently existing devices.

Interview with Mike Harlor: Firefighter of 10 years, Just Paint It! Owner and Professional Painter for 15 years. 4754 Glencross Ct. Grove City, OH 43123
Felt that my project could be useful in many different ways.
Some features that he thought were important included: portability, has to support a high amount of weight, has to find a proper way to secure it for safety, power options as in battery vs. wall outlet, and should have a tag line for windy days.
Possible current designs could include a window washer like system for heavy and secure lifting.
Smart-Rig Cranes

The Smart-Rig T1 portable mini crane is made to lift, drop, drag, pull, tug, transport, carry, stack, move, hold and set loads and heavy materials in any situation in interior or exterior of buildings. Small enough to fit inside a residential doorway, elevator, narrow aisle, hallway or back of a truck, this vertical lifting mini crane allows rigging in tight spaces. Dual batteries allow mobility and easy transport. Electric 120v winch option available. Industries that use small floor cranes and portable hydraulic floor cranes include HVAC, pipe, steel, ports, military, oil refineries, warehouses, marinas, manufacturers/fabricators, water plants, glass, glazing, shipping yards, film/tv/theatre rigging & production, concrete removal, plumbing, factories, airlines, utility companies, disaster deployment operations, aluminum installation, farms, sewage, window installation, mining, AAC concrete installation, cement, petrol exploration, railroad, and many more. Unlike material lifters from beneath, the mini crane lifts from above via cable and winch.

- Small cranes utilize a light-weight pull-out manual boom.
- Utilizing pick and carry features for rigging, moving, transporting and traveling heavy objects.
- Adjustable, folding, versatile full power straddle crane is smaller and more affordable compared to expensive spider cranes, davit cranes, or crawler cranes.
- Light duty with articulating boom arm, able to work on rough terrain or indoors makes the Smart-Rig mini crane a full power portable lifting crane.

Used in industrial environments when a mid-sized crane is needed on different levels during construction. This design is way too big, and definitely too heavy to carry up floors without using an elevator to get it up. That defeats the purpose of the idea for this design.

Price not available

http://www.smartriganes.com/
09/13/2012
This new indoor hoist is light weight. When installed against the ceiling and the upper floor, it can easily lift goods from ground floor to upper floors. For higher buildings with no elevator it would be tiring to move heavy or wide materials inside, but with our hoists it becomes much easier, you can directly lift materials inside the building through windows. With accessional support frame, it’s suitable for both indoor and outdoor hoisting, and also applicable for outdoor large projects when fixed with scaffolding.

Price not available

- Well designed
- Not automated
- Requires a ceiling over the balcony to work
- Swing-arm is not adjustable and only has one degree of freedom.

Figure 2

09/13/2012
Moving into a new house with nice new hardwood floors is hard enough. But if you need to climb not, one but *two* skinny staircases to get to the living room, moving in is simply a nightmare. Grills, couches, TVs, fridges, etc. are a pain to lift as it is, let alone attempting to traverse stairs. So instead of performing move-in gymnastics while breaking our backs, I decided to simplify things by building our own boom-crane pulley system.

So the basic idea is that this is a 3-story house with roof deck. The living room is on the third floor, and has a balcony. The crane is mounted to the floor of the roof deck (the 'fourth' floor). This will allow us to pull things from the street level up to the third floor balcony. So the boom crane is saving us from having to bring things up two flights of stairs.

---

**Boom Crane Pulley**

http://www.instructables.com/id/Boom-Crane-Pulley/?ALLSTEPS

09/13/2012

Stationary and requires drilling in order to anchor the pulley system in place
- Not portable

Cost:~$200
APPENDIX B - SURVEY

BALCONY CRANE
CUSTOMER SURVEY

The purpose of this survey is to get a consumer's view on the features that would be most and least important for a balcony crane product. The idea behind the balcony crane is to make moving small furniture in and out of multi-story structures a lot easier and efficient when no elevator is available. Please take a moment to rate the following features mentioned below.

How important is each feature to you for the design of a new balcony crane?
Please circle the appropriate answer.  
1 = low importance  
5 = high importance  

<table>
<thead>
<tr>
<th>Feature</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>N/A</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(4)</td>
<td>5(16)</td>
<td>N/A</td>
<td>4.8</td>
</tr>
<tr>
<td>Low Cost</td>
<td>1</td>
<td>2</td>
<td>3(2)</td>
<td>4(13)</td>
<td>5(5)</td>
<td>N/A</td>
<td>4.2</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(18)</td>
<td>5(2)</td>
<td>N/A</td>
<td>4.1</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>1</td>
<td>2</td>
<td>3(13)</td>
<td>4(4)</td>
<td>5(3)</td>
<td>N/A</td>
<td>3.5</td>
</tr>
<tr>
<td>Durability</td>
<td>1</td>
<td>2</td>
<td>3(9)</td>
<td>4(7)</td>
<td>5(4)</td>
<td>N/A</td>
<td>3.8</td>
</tr>
<tr>
<td>Reliability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(5)</td>
<td>5(15)</td>
<td>N/A</td>
<td>4.8</td>
</tr>
<tr>
<td>Adjustability</td>
<td>1</td>
<td>2(1)</td>
<td>3(2)</td>
<td>4(6)</td>
<td>5(11)</td>
<td>N/A</td>
<td>4.4</td>
</tr>
<tr>
<td>Capacity</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(3)</td>
<td>5(17)</td>
<td>N/A</td>
<td>4.9</td>
</tr>
<tr>
<td>Operational Speed</td>
<td>1(1)</td>
<td>2(4)</td>
<td>3(7)</td>
<td>4(4)</td>
<td>5(4)</td>
<td>N/A</td>
<td>3.3</td>
</tr>
<tr>
<td>Operational Range</td>
<td>1</td>
<td>2</td>
<td>3(11)</td>
<td>4(8)</td>
<td>5(1)</td>
<td>N/A</td>
<td>3.5</td>
</tr>
</tbody>
</table>

How satisfied are you with the current options on the market similar to a new balcony crane?
Please circle the appropriate answer.  
1 = very **UN**satisfied  
5 = very satisfied  

<table>
<thead>
<tr>
<th>Feature</th>
<th>1</th>
<th>2(2)</th>
<th>3(17)</th>
<th>4</th>
<th>5(1)</th>
<th>N/A</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>1(5)</td>
<td>2(13)</td>
<td>3(1)</td>
<td>4(1)</td>
<td>5</td>
<td>N/A</td>
<td>3.0</td>
</tr>
<tr>
<td>Low Cost</td>
<td>1</td>
<td>2</td>
<td>3(8)</td>
<td>4(9)</td>
<td>5(3)</td>
<td>N/A</td>
<td>1.9</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>1(1)</td>
<td>2(9)</td>
<td>3(7)</td>
<td>4(2)</td>
<td>5(1)</td>
<td>N/A</td>
<td>2.7</td>
</tr>
<tr>
<td>Maneuverability</td>
<td>1</td>
<td>2</td>
<td>3(4)</td>
<td>4(14)</td>
<td>5(2)</td>
<td>N/A</td>
<td>3.9</td>
</tr>
<tr>
<td>Durability</td>
<td>1</td>
<td>2(1)</td>
<td>3(2)</td>
<td>4(10)</td>
<td>5(7)</td>
<td>N/A</td>
<td>4.2</td>
</tr>
<tr>
<td>Reliability</td>
<td>1</td>
<td>2(1)</td>
<td>3(9)</td>
<td>4(7)</td>
<td>5(3)</td>
<td>N/A</td>
<td>3.6</td>
</tr>
<tr>
<td>Adjustability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(2)</td>
<td>5(18)</td>
<td>N/A</td>
<td>4.9</td>
</tr>
<tr>
<td>Capacity</td>
<td>1(3)</td>
<td>2(4)</td>
<td>3(1)</td>
<td>4(8)</td>
<td>5(4)</td>
<td>N/A</td>
<td>3.3</td>
</tr>
<tr>
<td>Operational Speed</td>
<td>1</td>
<td>2(1)</td>
<td>3(7)</td>
<td>4(7)</td>
<td>5(5)</td>
<td>N/A</td>
<td>3.8</td>
</tr>
</tbody>
</table>
### APPENDIX C - QUALITY FUNCTION DEPLOYMENT (QFD)

#### H. Tyler Vander Werf
Balcony Crane

9 = Strong
3 = Moderate
1 = Weak

<table>
<thead>
<tr>
<th>Feature</th>
<th>Size of Crane (Assembled)</th>
<th>Size of Crane (Dis-assem.)</th>
<th>Weight</th>
<th>Speed</th>
<th>Torque</th>
<th>Power</th>
<th>Battery Life</th>
<th>Degrees of Articulation</th>
<th>Distance</th>
<th>Controls</th>
<th>Material</th>
<th>Customer importance</th>
<th>Designer's Multiplier</th>
<th>Current Satisfaction</th>
<th>Planned Satisfaction</th>
<th>Improvement ratio</th>
<th>Modified Importance</th>
<th>Relative weight</th>
<th>Relative weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>9</td>
<td>4.8</td>
<td>1.0</td>
<td>3.0</td>
<td>4</td>
<td>1.3</td>
<td>6.4</td>
<td>0.12</td>
<td>12%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cost</td>
<td>3</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>4.2</td>
<td>1.0</td>
<td>1.9</td>
<td>4</td>
<td>2.1</td>
<td>8.8</td>
<td>0.17</td>
<td>17%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ease of Use</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>3.1</td>
<td>4.1</td>
<td>1.0</td>
<td>3.8</td>
<td>4</td>
<td>1.1</td>
<td>4.3</td>
<td>0.08</td>
<td>8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maneuverability</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>3.5</td>
<td>2.7</td>
<td>4.1</td>
<td>2.7</td>
<td>4</td>
<td>1.5</td>
<td>5.7</td>
<td>0.11</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Durability</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3.8</td>
<td>1.0</td>
<td>3.9</td>
<td>4</td>
<td>1.0</td>
<td>3.9</td>
<td>0.07</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reliability</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>4.8</td>
<td>1.0</td>
<td>4.2</td>
<td>5</td>
<td>1.2</td>
<td>5.7</td>
<td>0.11</td>
<td>11%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjustability</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>1</td>
<td>4.4</td>
<td>1.0</td>
<td>3.6</td>
<td>4</td>
<td>1.1</td>
<td>4.9</td>
<td>0.09</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacity</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>9</td>
<td>4.9</td>
<td>1.0</td>
<td>4.9</td>
<td>5</td>
<td>1.0</td>
<td>5.0</td>
<td>0.09</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Speed</td>
<td>9</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3.3</td>
<td>3.3</td>
<td>1.2</td>
<td>3.3</td>
<td>4</td>
<td>1.2</td>
<td>4.8</td>
<td>0.09</td>
<td>9%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Operational Range</td>
<td>3</td>
<td>1</td>
<td>9</td>
<td>9</td>
<td>3.5</td>
<td>3.8</td>
<td>4</td>
<td>3.8</td>
<td>1.1</td>
<td>3.7</td>
<td>4</td>
<td>1.1</td>
<td>3.7</td>
<td>0.07</td>
<td>7%</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abs. importance</td>
<td>2.13</td>
<td>1.65</td>
<td>2.27</td>
<td>2.21</td>
<td>2.28</td>
<td>2.28</td>
<td>1.68</td>
<td>3.17</td>
<td>3.27</td>
<td>1.27</td>
<td>6.35</td>
<td>28.6</td>
<td>53.2</td>
<td>1.0</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rel. importance</td>
<td>0.07</td>
<td>0.06</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.08</td>
<td>0.11</td>
<td>0.11</td>
<td>0.04</td>
<td>0.04</td>
<td>0.22</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Appendix C1
APPENDIX D – PRODUCT OBJECTIVES

The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project was met.

1. Cost 17%
   a. Less than $600 for the prototype.

2. Safety 12%
   a. Must have tag line
   b. Use material and design factor(s) consistent with loading conditions
   c. Must have emergency stop
   d. System will provide brake to maintain control of load
   e. System will be balanced to prevent tip over

3. Maneuverability 11%
   a. Able to fit through sliding glass doors and on balconies assembled
   b. Wheels/Casters will require no more than 50 lbs.
   c. Two steps to adjust the arm height

4. Reliability 11%
   a. Design factor consistent with loading conditions in expected use
   b. Rust-resistant material selection or surface finish
   c. Purchased parts will have a life cycle of at least 5 years

5. Adjustability 9%
   a. Able to alter linear extension of swing arm with a range of 1 foot
   b. Able to alter the height of the extension arm 1 foot

6. Capacity 9%
   a. Able to lift 300 lbs.
   b. Tip-over calculation

7. Operational Speed 9%
   a. Able to raise and lower object at controlled speed between 0.5 ft./sec and 10 ft./sec.

8. Ease of Use 8%
   a. Controls comparable to similar mini cranes on the market
   b. Will be able to be lifted by two people (50th percentile male)
   c. Size of module one will be 3 ft. x 1 ft. x 1 ft.
   d. Size of module two will be 3 ft. x 3 ft. x 1 ft.
   e. Will have quick disconnect with cable connected pins
   f. Will collapse in 3 steps without tools
   g. Should assemble in 10 minutes
9. Durability 7%
   a. See Reliability

10. Operational Range 7%
    a. Has to be able to lift items up at a maximum distance of 40 feet
## APPENDIX E – SCHEDULE

<table>
<thead>
<tr>
<th>Task</th>
<th>Proposed Dates</th>
<th>Actual Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design lift arm system</td>
<td>Nov. 28, 2012</td>
<td>Dec. 13, 2012</td>
</tr>
<tr>
<td>Assembly</td>
<td>Feb. 27, 2013</td>
<td>Mar. 30, 2013</td>
</tr>
<tr>
<td>Final testing</td>
<td>Mar. 27, 2013</td>
<td>Apr. 2, 2013</td>
</tr>
<tr>
<td>Advisor demonstration</td>
<td>Mar. 29, 2013</td>
<td>Apr. 3, 2013</td>
</tr>
<tr>
<td>Faculty demonstration</td>
<td>Apr. 5, 2013</td>
<td>Apr. 4, 2013</td>
</tr>
<tr>
<td>Spring oral presentation</td>
<td>Apr. 12, 2013</td>
<td>Apr. 17, 2013</td>
</tr>
</tbody>
</table>
# APPENDIX F - BUDGET

<table>
<thead>
<tr>
<th>Materials, Components, or Labor</th>
<th>Forecasted Amount</th>
<th>Actual Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame (at $7.00/ft.)</td>
<td>$200.00</td>
<td>$132.06</td>
</tr>
<tr>
<td>Cable</td>
<td>$50.00</td>
<td>$56.04</td>
</tr>
<tr>
<td>Hand Crank</td>
<td>$100.00</td>
<td>$82.45</td>
</tr>
<tr>
<td>Casters</td>
<td>$50.00</td>
<td>$71.92</td>
</tr>
<tr>
<td>Pulley</td>
<td>$10.00</td>
<td>$6.66</td>
</tr>
<tr>
<td>Misc. Services/Parts/Delivery</td>
<td>$180.00</td>
<td>$131.82</td>
</tr>
<tr>
<td>Total</td>
<td>$590.00</td>
<td>$480.95</td>
</tr>
</tbody>
</table>
APPENDIX G – PROPERTIES OF STEEL STRUCTURAL TUBING (HSS-SHAPE) AND PROPERTIES OF STRUCTURAL STEELS

Properties of steel structural tubing (HSS-shapes) US Customary units.

<table>
<thead>
<tr>
<th>Nominal Size</th>
<th>Weight per Foot</th>
<th>Wall Thickness</th>
<th>b/t</th>
<th>h/t</th>
<th>Cross Sectional Area</th>
<th>I</th>
<th>S</th>
<th>r</th>
<th>Z</th>
<th>Torsional Stiffness Constant</th>
<th>Torsional Shear Constant</th>
<th>Surface Area Per Foot</th>
</tr>
</thead>
<tbody>
<tr>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>lb.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>in.</td>
<td>ft.²</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.25</td>
<td>5.41</td>
<td>0.233</td>
<td>5.6</td>
<td>5.6</td>
<td>1.51</td>
<td>0.745</td>
<td>0.745</td>
<td>0.703</td>
<td>0.964</td>
<td>1.31</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.1875</td>
<td>4.32</td>
<td>0.174</td>
<td>8.5</td>
<td>8.5</td>
<td>1.19</td>
<td>0.64</td>
<td>0.64</td>
<td>0.732</td>
<td>0.797</td>
<td>1.09</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>0.125</td>
<td>3.05</td>
<td>0.116</td>
<td>14.2</td>
<td>14.2</td>
<td>0.84</td>
<td>0.486</td>
<td>0.486</td>
<td>0.761</td>
<td>0.584</td>
<td>0.796</td>
</tr>
<tr>
<td>1.75</td>
<td>1.75</td>
<td>0.1875</td>
<td>3.68</td>
<td>0.174</td>
<td>7.1</td>
<td>7.1</td>
<td>1.02</td>
<td>0.405</td>
<td>0.462</td>
<td>0.63</td>
<td>0.585</td>
<td>0.699</td>
</tr>
<tr>
<td>1.625</td>
<td>1.625</td>
<td>0.1875</td>
<td>3.36</td>
<td>0.174</td>
<td>6.3</td>
<td>6.3</td>
<td>0.93</td>
<td>0.312</td>
<td>0.384</td>
<td>0.579</td>
<td>0.491</td>
<td>0.544</td>
</tr>
<tr>
<td>1.625</td>
<td>1.625</td>
<td>0.125</td>
<td>2.42</td>
<td>0.116</td>
<td>11</td>
<td>11</td>
<td>0.67</td>
<td>0.246</td>
<td>0.302</td>
<td>0.608</td>
<td>0.37</td>
<td>0.41</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>0.1875</td>
<td>3.04</td>
<td>0.174</td>
<td>5.6</td>
<td>5.6</td>
<td>0.84</td>
<td>0.235</td>
<td>0.314</td>
<td>0.528</td>
<td>0.406</td>
<td>0.414</td>
</tr>
<tr>
<td>1.5</td>
<td>1.5</td>
<td>0.125</td>
<td>2.2</td>
<td>0.116</td>
<td>9.9</td>
<td>9.9</td>
<td>0.61</td>
<td>0.188</td>
<td>0.251</td>
<td>0.556</td>
<td>0.309</td>
<td>0.316</td>
</tr>
<tr>
<td>1.25</td>
<td>1.25</td>
<td>0.1875</td>
<td>2.4</td>
<td>0.174</td>
<td>4.2</td>
<td>4.2</td>
<td>0.67</td>
<td>0.121</td>
<td>0.194</td>
<td>0.425</td>
<td>0.259</td>
<td>0.218</td>
</tr>
<tr>
<td>1.25</td>
<td>1.25</td>
<td>0.125</td>
<td>1.78</td>
<td>0.116</td>
<td>7.8</td>
<td>7.8</td>
<td>0.49</td>
<td>0.101</td>
<td>0.162</td>
<td>0.454</td>
<td>0.204</td>
<td>0.174</td>
</tr>
</tbody>
</table>

Properties of Structural Steels

<table>
<thead>
<tr>
<th>Material ASTM no.</th>
<th>Products</th>
<th>Ultimate strength, Su</th>
<th>Yield strength, Sy</th>
<th>Percent elongation in 2 in</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ksi</td>
<td>Mpa</td>
<td>ksi</td>
</tr>
<tr>
<td>A500 Cold-formed</td>
<td>Round, grade B</td>
<td>58</td>
<td>400</td>
<td>42</td>
</tr>
<tr>
<td>structural tubing</td>
<td>Round, grade C</td>
<td>62</td>
<td>427</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Shaped, grade B</td>
<td>58</td>
<td>400</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Shaped, grade C</td>
<td>62</td>
<td>427</td>
<td>50</td>
</tr>
</tbody>
</table>

Note: Sections highlighted in orange are the selections used in the design.

Appendix H1
<table>
<thead>
<tr>
<th>Line</th>
<th>Qty</th>
<th>UOM</th>
<th>Item Number</th>
<th>Item Description</th>
<th>Supplier</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12</td>
<td>Ft</td>
<td></td>
<td>2&quot;x2&quot;x3/16&quot; Square A500 Grade B Structural Steel Tubing</td>
<td>David Hirshberg Steel</td>
</tr>
<tr>
<td>2</td>
<td>24</td>
<td>Ft</td>
<td></td>
<td>1 1/2&quot;x1 1/2&quot;x3/16&quot; Square A500 Grade B Structural Steel Tubing</td>
<td>David Hirshberg Steel</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>Ft</td>
<td></td>
<td>1&quot; A500 Grade B Structural Round Steel Tubing</td>
<td>David Hirshberg Steel</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>Ea</td>
<td>3308T53</td>
<td>Wire Rope with Hook for Winch, 3/16&quot; Diameter, 50 Foot Length</td>
<td>McMaster-Carr</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>Ft</td>
<td>101543</td>
<td>1/2&quot; Conduit</td>
<td>Home Depot</td>
</tr>
<tr>
<td>6</td>
<td>10</td>
<td>Ft</td>
<td>101568</td>
<td>1&quot; Conduit</td>
<td>Home Depot</td>
</tr>
<tr>
<td>7</td>
<td>6</td>
<td>Ft</td>
<td></td>
<td>2&quot; Wide x 1/4&quot; Thick AISI 1020 Steel</td>
<td>David Hirshberg Steel</td>
</tr>
<tr>
<td>8</td>
<td>6</td>
<td>Ft</td>
<td></td>
<td>2&quot; Wide x 3/16&quot; Thick AISI 1020 Steel</td>
<td>David Hirshberg Steel</td>
</tr>
<tr>
<td>9</td>
<td>6</td>
<td>Ft</td>
<td></td>
<td>4&quot; Wide x 3/16&quot; Thick AISI 1020 Steel</td>
<td>David Hirshberg Steel</td>
</tr>
<tr>
<td>10</td>
<td>1</td>
<td>Ea</td>
<td>DL-14914</td>
<td>Hand Brake Winch</td>
<td>GME Supply</td>
</tr>
<tr>
<td>11</td>
<td>2</td>
<td>Ea</td>
<td>27075T72</td>
<td>Caster, Swivel, 4&quot; x 1-3/8&quot; Rubber Wheel</td>
<td>McMaster-Carr</td>
</tr>
<tr>
<td>12</td>
<td>2</td>
<td>Ea</td>
<td>27075T73</td>
<td>Caster, Rigid, 4&quot; x 1-3/8&quot; Rubber Wheel</td>
<td>McMaster-Carr</td>
</tr>
<tr>
<td>13</td>
<td>1</td>
<td>Ea</td>
<td>3099T34</td>
<td>Steel Pulley for Wire Rope, Mounted Pulley, for 3/16&quot; Rope Diameter</td>
<td>McMaster-Carr</td>
</tr>
<tr>
<td>14</td>
<td>19</td>
<td>Ea</td>
<td></td>
<td>5/16&quot; x 1&quot; Full Threaded Bolt, Galvanized.</td>
<td>Ace Hardware</td>
</tr>
<tr>
<td>15</td>
<td>38</td>
<td>Ea</td>
<td></td>
<td>5/16&quot; Flat Washer, Galvanized.</td>
<td>Ace Hardware</td>
</tr>
<tr>
<td>16</td>
<td>19</td>
<td>Ea</td>
<td></td>
<td>5/16&quot; Nut, Galvanized.</td>
<td>Ace Hardware</td>
</tr>
<tr>
<td>17</td>
<td>4</td>
<td>Ea</td>
<td></td>
<td>1/2&quot; x 2&quot; Full Threaded Bolt, Galvanized.</td>
<td>The Home Depot</td>
</tr>
<tr>
<td>18</td>
<td>8</td>
<td>Ea</td>
<td></td>
<td>1/2&quot; Flat Washer, Galvanized.</td>
<td>The Home Depot</td>
</tr>
<tr>
<td>19</td>
<td>4</td>
<td>Ea</td>
<td></td>
<td>1/2&quot; Nut, Galvanized.</td>
<td>The Home Depot</td>
</tr>
<tr>
<td>20</td>
<td>4</td>
<td>Ea</td>
<td></td>
<td>1/2&quot; Wing Nut, Galvanized.</td>
<td>The Home Depot</td>
</tr>
<tr>
<td>21</td>
<td>5</td>
<td>Ea</td>
<td>43788</td>
<td>1/2 in. Zinc-Plated Hitch Pin Clip</td>
<td>The Home Depot</td>
</tr>
</tbody>
</table>

Appendix H1