Optimal Design
Adjustable Art Table

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Team 9
Bruce Bassi
Kristen Haldeman
Richard Sierra

Client Coordinator: Dr. Brooke Hallowell
Supervising Professor: Dr. John D. Enderle
Funding: National Science Foundation
Objective

What the Product Does

Basic Functions
This table will provide a smooth and steady surface for artists to work upon. Foremost, the table shall be safe so that nobody is injured. Once this is assured, the table should be able to adjust in height so that it could fit somebody in a wheelchair comfortably underneath it. This means that its clearance must be higher than the legs of someone in a wheelchair, the width must be wider than the wheels on the wheelchair, and the depth must be longer than the legs of someone sitting in the chair. The table will accommodate individuals in an oversized wheelchair. If the user is comfortably underneath the table, the table will be lowered so that the artist can be comfortable without feeling enclosed. While underneath the table, the user should have confidence that the table will not fall. When the artist feels inclined to leave the table, it would be easy to do so. The height adjustable art table could then be adjusted for the next user. The table shall be reliable enough to withstand many adjustments over many years without much upkeep, other than cleaning the surface. A height adjustment would be useful for the artists at Passion Works to be more comfortable while creating the art they enjoy.

How It Will Be Implemented
The table will be developed by purchasing the basic components, assembling them and then testing the prototype for safety. This will be done in three stages. Firstly, the tabletop will be purchased that has a size and finish that is appropriate for art purposes. The tabletop is an important piece in the table because it must have good durability since it will be used very often throughout the day. The laminate surface would also make for an easy clean up. Knowing the weight of the table will be important in determining the pressure required in the gas springs.

Most importantly, the device and its operations must be failsafe. The safety of the user is of utmost importance and will be a top concern. The safety latch is designed so that it only needs to be released in order to lower the table. In other words, if the safety latch is not touched, then the user will only be able to raise the table, by turning the handle. Therefore, the safety latch will be stopping the crank from turning, so this will be an important element in the table and will be given much attention. The texture, corners and edges of the tabletop must be specifically designed so that they are as safe as possible. To reiterate, the height adjustment mechanism must not cause harm to the user while in operation or while the table is being used. In short, the project will improve upon the past and existing tables and also satisfy the needs of those at Passion Works Studio.

Block Diagrams

Helper’s Perspective – Appendix I
The diagram is a basic schematic that represents how the user will interact with the table. In order to raise the table, one would press and hold the button, and turn the handle in the appropriate direction. To lower the table, the latch should be released, and the button should be pressed simultaneously, while turning the crank in the proper direction.
Design Process – Appendix II

The schematic represents the team’s plan of execution to implement the manufacturing of the height adjustable art table. As of now, the team is currently on the Design Process step.

Major Components

The following diagrams of the rear view and the side view of the tabletop show the dimensions of the table. As previously mentioned, the height, width and depth have to accommodate someone who may be in a wheelchair. Starting from the top, one should note that there are rounded corners of the tabletop. This will assure that nobody will hurt themselves when walking into the tabletop. The table will be adjusted by a gear mechanism located in the rear center of the table. For support, there will be two locking gas springs on the sides of the table, eight inches from the front and mounted to a base. The base will be wide enough to provide support, and will extend all the way around the sides and rear of the table to prevent it from tipping.

Rear View

The rear view below shows what the table would look like if someone was looking directly at the artist using the table. A rear view was chosen instead of a front view, so that the gear rack and the gear would be included. The front view would just have a smooth, rectangular table leg and would not denote a gear or a gear rack. The gear rack is shown by the shading on the table leg, as this is a direct view at the grooves on it. The handle can be turned in either direction so that the table is raised or lowered as desired. If the table should be raised, one would go about turning the handle clockwise, while pressing the gas spring release button. Should the table be lowered, the button should be pressed as usual and the safety latch must be removed while turning the handle counterclockwise. The gear is held in place by two support panels which will be welded onto the bottom half of the leg.
Figure 1: Rear View

Side View

The side view depicts the depth of the table which could not be seen in the front view. The table was designed to have a depth of 30” which will give the artist enough room for somebody in a wheelchair to fit underneath. The table base will be designed to have a curvature in order to avoid sharp corners that could harm someone. The other side view, in Figure 3, shows the side view as if one were underneath the table and looking outward.
Figure 2: Side View
Mechanism Close Up

The previous figure shows what the gear would look like from the side of the table, looking outward, also looking through the gear support piece. The number of teeth on the gear, for this diagram, is arbitrary. Additionally, the shape of these teeth is not what will be used either. The figure provides a close up of how the gear and the gear rack would interact and also how the gear would be held together. The handle can be turned in either the clockwise or the
counterclockwise direction as denoted by the double headed arrow. The safety latch is connected
to the mounting plate to the side of the gear itself. The latch is spring loaded such that it will stay
in contact with the gear rack as the table is being raised. The safety latch must be removed from
the teeth so that the user could lower the table.

**Handle Dimensions**

The schematic for the handle was acquired from a source (see Appendix III – References). This
is a basic handle that serves as a way to increase the mechanical advantage of turning the gear.
The mechanical advantage comes about by having a handle which provides a bigger turning
radius and therefore a bigger moment about that point. The bottom portion of the handle slides
into the gear and the handle would stick out from the side of the table as depicted in Figure 1.

![Figure 4: Handle Dimensions](image)

**Three Dimensional View**

It should be noted that the three dimensional view depicted below is just a rough
schematic. This diagram gives a good idea of how all of the pieces will interact and this is why
they are included. It makes it clear that there are two gas springs near the front of the table that
support it. The table base extends around the sides and the back of the table to connect to the
square tubing. The table top is transparent so that the gear mechanism and components can be
seen.
Subunits of Design

Tabletop

The tabletop used in this design should be able to meet the specifications of the Passion Works artists as well as for anyone who would like to draw on it. The tabletop is going to weigh 28 pounds. This is a light weight when compared to other tabletops on the market. With having a lighter tabletop, it will be that much easier for the tabletop to be raised and lowered. The edges of the tabletop should be smooth to prevent injury to the user. The surface should also be very smooth, as it will be a drawing surface. The tabletop surface should also be easy to clean since some art materials may be spilled onto it. The tabletop used in this design will be from made by Safco. Its dimensions are 30 in. X 42 in. X 0.75 in. Since the width is 42 inches, this provides any user who is sitting in a wheelchair to have a comfortable full range of motion since
maximum wheelchair widths are 35 inches. The width of the tabletop should not be out anyone’s
drawing range while it is in use, otherwise this would be a waste of material. The depth of the
tabletop is 30 inches. This will provide plenty of arm extension for any user since the shoulder to
arm length of a person 6 feet 5 inches tall when fully extended is about 30 inches. The
dimensions of the tabletop can be seen in Figures 1 and 2, and a three-dimensional view of the
 tabletop can be seen in Figure 5.

Many of the artists who will be using the table at Passion Works will be in wheelchairs,
so it is very important that the table accommodates all wheelchair types. The standard
wheelchair is 26” wide and has a seat height of 21”. This standard width would accommodate
most of the wheelchairs on the market, but there are some exceptions that would require a larger
width for the table. There are wheelchairs made for the obese, which have widths of 35”.
Therefore, the width of the space between the bases must be at least 36”. This chair also has a
depth of 20”, so the shaft extending across the back of the table should be at least 20” from the
front of the table. The artist’s torso takes up anywhere from 5” to up to 15” of that depth, so
there would be plenty of leg room for the artist if the shaft is locate approximately 25” back as in
our design.

The surface of this tabletop will be that of laminated white melamine material. The inside
of the tabletop is made from a plastic fiber, which is compressed cross-linked polymer. The
melamine surface is made by mixing melamine powder with other substances, including an
aqueous formaldehyde solution. This solution forms a resin which is also known as an adhesive
which is added to the outside of the chip board. This resin is then processed further to make the
laminate surface for the tabletop. This laminate surface has many good qualities and advantages
which our clients will find in the tabletop surface. The melamine laminate surface is extremely
durable and resistant to heat. This surface is also scratch and moisture resistant. This increases
the lifetime of the tabletop over others since it will not get scratched up and soiled if water or
other liquids are accidentally spilled on it. With the surface being moisture resistant, this also
makes the tabletop very easy to clean. When looking into electrical conduction, the melamine
surface is electrically insulating. Electricity could not be conducted from one side of the surface
to another. This is just another extra safety feature that the melamine surface provides. With all
the properties of the tabletop taken into account, it is apparent that this tabletop will provide the
user with the maximal comfort as well as minimal maintenance.

**Height Adjustment Mechanism**

The adjustment mechanism for this design is a gear rack system, which relies on a handle to raise
and lower the tabletop. The rack will be mounted to the tabletop and fitted to move up and down
inside the square tubing. The gear shaft is mounted to the square tubing by two steel plates on
each side of the leg, so the shaft will run through each plate with the gear in the middle. This
supports and allows control of the gear while also allowing free movement of the rack into the
tubing.

The rack and gear move together by interlocking teeth. The gear is rotated by a handle, which in
turn causes linear movement of the rack. The setup is shown in the following figure.
The force, $F$, is applied to the rack, and in order to raise the rack up, the gear must be rotated to apply the forces, $A$ and $B$. In the design, $F$ is the downward force of the tabletop and applied load. The gear used for the table has a diameter of 2.4 inches, so the torque required would be:

$$T = F \times (2.4 \div 2) = 1.2F$$

The handle used for turning the shaft is 5” long, so the force needed to provide the necessary torque is found by:

$$F = 0.6F \div 5 = 0.24F$$

The gear has a diameter of 1.2 inches, so the circumference of the gear is:

$$C = 1.2\pi = 7.54\text{”}$$

With each turn of the gear, or handle, the rack moves a distance of 7.54 inches. So, each tooth on the rack corresponds to a length of:

$$L = 7.54 \div 48 = 0.157\text{”}$$

**Support Legs**

The support legs for the table are two locking gas springs. The springs are placed opposite each other near the front of the table, and the adjustment control is located at the rear of the table. In a gas spring, a piston is fitted inside a cylinder with nitrogen gas under a specified pressure. When a valve is opened, the piston is moved either up or down based on the external forces exerted on it. Standard gas springs will only lock in a position in the fully extended configuration, or if the external force is large enough in the fully retracted configuration. On the other hand, locking gas springs allow the spring to be adjusted to any length and locked in place. This is because a release lever is inserted in the cylinder; only when a control button is pushed does the release lever move to allow the piston to travel.
Both types of gas spring work based on the same physical principles. The force exerted by the gas through the piston rod is based on the surface area of the piston and the pressure of the gas.

\[ \text{Area} = (\pi \times \text{diameter}) \div 4 \]

\[ \text{Force} = \text{area} \times \text{pressure} \]

There are two main types of locking gas springs, elastic blocking and rigid blocking. Elastic blocking springs are filled only with nitrogen gas, and when locked will give a bit when external forces are applied. This creates a bounce effect on the spring such as in computer chairs, where a person is cushioned as they sit down. The rigid blocking springs resist all movement once locked, which is achieved by including a compartment of oil in the cylinder in addition to the nitrogen gas. The oil is not as easily compressed as the nitrogen gas, so when the external forces are applied the spring remains securely in place.

The locking gas spring used for the table is a rigid blocking gas spring from Easylift. The spring is rigid blocking in the push-in direction, meaning that it will resist moving under larger compressive forces. The configuration of the locking gas spring is important in determining the blocking type of the gas spring. In the rigid blocking in the push-in direction the oil is located between the piston and the end of the cylinder, and the nitrogen gas is located behind the piston and a floating piston. The floating piston separates the gas from the oil without making a rigid boundary. The piston is able to adjust as normal when unlocked, but when locked the oil is uncompressed, and there will be no movement. In rigid blocking in the pull-out direction, the floating piston is between the piston and the end of the cylinder and the gas is between the floating piston and the end of the cylinder. The oil is located between the floating piston and the piston, blocking the piston from being pulled out in the locked configuration. The configuration of the rigid blocking in compression gas spring is depicted in figure 7. For these locking gas springs the material of the piston, rod, and cylinder are steel, with zinc plated steel connecters. The oil is hydraulic oil and the release levers are made out of stainless steel.
Figure 7: Rigid Blocking in Compression Gas Spring (See Appendix III)

The locking gas springs used for the table have specific dimensions and force requirements to operate the table. The specifications for the spring are presented in Table 1.

Table 1: Gas Spring Specifications (See Appendix III)

<table>
<thead>
<tr>
<th>Stroke Length</th>
<th>Diameters of Rod/Piston</th>
<th>Length of Gas Spring (Fully Extended)</th>
<th>Blocking Force</th>
</tr>
</thead>
<tbody>
<tr>
<td>350 mm (13.78 in)</td>
<td>10/22 mm (0.4/0.87 in)</td>
<td>927 mm (36.5 in)</td>
<td>12000 N (~2,700 lbs)</td>
</tr>
</tbody>
</table>

The stroke length of the gas spring is the distance the spring can travel. The project specifications require that the table be able to travel between 27” and at least 40” off the floor, so the required stroke length is only 13”. The stroke length of this gas spring allows for a little under an inch more travel, providing a larger range of adjustment than required. Each gas spring will be calibrated to exert a force equal to half the weight of the tabletop. This is enough to hold the table steady when the locking mechanism is released. When the release lever is locked into place the table will resist moving under applied forces, and maintain a stable surface for the user.
to complete art projects on. The blocking force of the locking gas spring corresponds to the amount of force that the gas spring can hold while locked without failing. This gas spring can withstand approximately 2,700 pounds, so the table itself can withstand approximately 5,400 pounds. This permits the user to store heavy objects on the table when not in use, and also ensures that the support legs will not fail if a heavy person sits on the tabletop.

In order to adjust the table the locking mechanisms must first be disabled. The mechanisms are controlled by a parallel hydraulic release system, which uses water to connect the control system to the springs. The hydraulic release system is the best system for operating the locking mechanism of the gas springs because of the ease of use. In other operating systems the mechanism is based around a lever or a handle requiring the user to exert force to operate it. The hydraulic release is based on a single button, which requires very little force from the user and is easily manipulated while adjusting the table. The table requires two gas springs as supports, so adjusting both at the same time would be difficult with other release systems. The hydraulic release system is the only system that can be configured into a parallel release. The parallel hydraulic release system allows for the integration of the controls for each gas spring into one control. The controls for both gas springs would be controlled by a single button, allowing one person to operate both with one hand. This also ensures that both gas springs are operated at the same time, taking away the risks of unequal adjustments and an uneven surface. Since hydraulic release systems are attached to the gas springs with hoses, the control can be attached to any location on the table. The release systems based on levers have limited range, and wouldn’t be able to be put in the most optimal location. The parallel release system is depicted in the following figure.

![Figure 8: Parallel Hydraulic Release System (See Appendix III)](image)

The release is going to be located on the rear of the table so that the button can be pressed and the handle turned at the same time. The hoses are going to run up the support legs and along the bottom of the tabletop, meeting in the back center of the table.
The safety of the users and bystanders is of utmost importance when dealing with a device such as this. The table is designed so that when it is locked in place, the pneumatics will stay in the same exact position as long as the button is not pressed. So that the button is not pushed accidentally, it will have a safety cover that must be opened so that the button is accessible. If the safety latch remains closed, then the button cannot be accessed and therefore the pneumatics will not be moved.

**Forces on Table/Joint Reactions**

The main concern with the table is that it must be stable enough for the artist to work on it. The table can be placed under many different forces and it must resist tipping and breaking. Tipping could occur when large forces are placed on the edges of the table, such as someone sitting on the edge. The external forces acting on the table are depicted in Figure 9.

![Figure 9: Free Body Diagram of Entire Table](image)

In this, the force $M_{TT}$ is the mass of the table top and the forces $M_L$ and $M_{SL}$ are the masses of the adjusting leg and safety legs respectively. $F$ is the load applied to the table. In order to tip the table the moment about point A must be positive, with the positive moment being defined as one that would cause a counter-clockwise rotation. The moment about point A is found using:

$$\sum M = F(0) - M_{TT}(15) - 2M_{SL}(8) - M_L(25).$$

Since this cannot be positive for any mass values, the table can never tip. This is due to the fact that the base of the table extends all the way to the edge of the tabletop, so no load could ever cause rotation around that point.

Even though the table will never tip, the loads applied will cause reactions in the joints between the legs and the tabletop and the legs and the base. For a load placed at the front of the table, as in Figure 9, the free body diagram of the tabletop will be as shown in Figure 10.
The forces on the tabletop can be described by equations for the vertical forces and for the moments about lines through different forces.

\[ \sum F_y = 0 = A + B + C - F - M_{TT} \]

\[ A + B + C = F + M_{TT} \]

\[ \sum M_1 = 0 = F(8) - M_{TT}(7) + A(17) \]

\[ A = (7M_{TT} - 8F) / (17) \]

\[ \sum M_2 = 0 = B(19) - C(19) \]

\[ B = C \]

\[ A + 2B = F + M_{TT} \]

\[ B = (25F + 10M_{TT}) / (34) = C \]

The reaction forces at B and C are only equal if the load F is centered on the table. If the load is large enough, greater than \((7/8)M_{TT}\), then the lifting leg does not hold any of the load. Instead it has a negative force that holds the table down and doesn’t allow rotation. This does not mean that the lifting leg will never experience large reaction forces. If someone were to sit on the rear of the table directly over the lifting leg, as in Figure 11, then there will be considerable forces in the leg and the joints.
\[ \sum M_1 = 0 = 17A - 17F - 7M_{TT} \]

\[ A = F + (7/17)M_{TT} \]

\[ \sum M_2 = 0 = 19B - 19C \]

\[ B = C \]

\[ A + 2B = F + M_{TT} \]

\[ B = (5/17)M_{TT} = C \]

For this scenario there is very little force applied to the support legs and the load is carried almost entirely by the lifting leg. For the maximum load of 300 lbs, the lifting leg needs to have a strong enough locking mechanism so that it can support a total load of 311.5 lbs.

In the case where the load is directly over one of the support legs, the maximum possible vertical reaction for the leg is experienced. Since the load is not centered the support legs do not have equal reactions. For this scenario, the load is assumed to be concentrated directly over support leg C as in Figure 12.

\[ \text{Figure 12: Free Body Diagram of the Tabletop} \]
\[
\sum M_1 = 0 = 17A - 7M_{TT}
\]

\[A = (7/17)M_{TT}\]

\[
\sum M_2 = 0 = 19A + 38B - 19M_{TT}
\]

\[B = (5/17)M_{TT}\]

\[A + B + C = F + M_{TT}\]

\[C = F + M_{TT} - (5/17)M_{TT} - (7/17)M_{TT}\]

\[C = F + (5/17)M_{TT}\]

Since the support legs are locking gas springs they will be able to hold approximately 2700 lbs while locked. So, with a maximum force of 300 lbs the legs will have no problem supporting the applied forces.

Horizontal forces can be applied to the table when moving it or by leaning on it, so the table needs to be reinforced in all directions. If a horizontal force is applied to the front of the table as if Figure 13, it will be distributed among all the legs.

![Figure 13: Free Body Diagram of the Tabletop](image)
\[ A + B + C = F \]

\[ \sum M_2 = 0 = 19B - 19C + 19F \]

\[ C = B + F \]

\[ \sum M_1 = 0 = 19A + 38C - 38F \]

\[ A = 2F - 2C = 2F - 2(B + F) = -2B \]

The exact values of the reactions cannot be solved for, but it is safest to assume that all of the force is resisted by C. So, the reactions at A and B are equal to 0. This is the best method because it shows that the maximum necessary reactions are equal to the maximum applied force. So, all legs will be supported in such a way to oppose the maximum horizontal force in all directions. It can be assumed that the maximum horizontal force applied to the table will be around 100 lbs.

The support legs in the front of the table do not have any external forces applied to them, so the reactions between the legs and the tabletop are equal to the reactions at the base of the table. So, the base must be supported in the same manner as the tabletop. The lifting leg has a more complicated design than the supporting legs, but it should still transfer the forces to the base equally.

When lifting the table, the support legs will apply constant force while the gear rack lifts the table. The most likely setup for the pressure of each of the gas springs will be half of the mass of the tabletop. With this setup the two support legs will be able to hold the tabletop steady when engaged, and minimal force will be necessary to raise the rack.

![Diagram](image)

*Figure 14: Free Body Diagram of the Tabletop*
\[ B = C = 0.5M_{TT} \]

\[ \sum F_y = 0 = A + B + C - M_{TT} \]

\[ A + 2(0.5M_{TT}) - M_{TT} = 0 \]

\[ A = 0 \]

The force A is the force required to hold the tabletop in place when the gas springs are engaged. To raise the tabletop, force A must be larger than 0. Very little force is required from the user to raise the table. For example, if 5 lbs were required to move the rack up and down smoothly the actual applied force in the handle is much lower. The diameter of the gear is 2.4” and the force of 5 lbs would be applied along the edge of the gear. So, the torque required to produce 5 lbs of force on the edge of the gear can be directly related to the force required on the 5” handle.

\[ T = F \times r \]

\[ T = 5 \times (2.4 \div 2) = 6\text{lbs} \times \text{in} \]

\[ F_{\text{Handle}} = T \div (r_{\text{Handle}}) = 6 \div 5 = 1.2\text{lbs} \]

The forces from the gas springs make raising the table very simple, but there are problems associated with them. If the control for the gas springs were accidentally engaged the front end of the table would no longer be completely stable. If the table is unloaded at the time, the only consequence would be a moment in the lifting leg as shown in Figure 15.

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**Figure 15: Free Body Diagram of the Tabletop**
\( B = C = 0.5M_{TT} \)

\( A = 0 \)

\[ M_A = (17)(0.5M_{TT}) + (17)(0.5M_{TT}) - (10)(M_{TT}) \]

\[ M_A = 17M_{TT} - 10M_{TT} = 7M_{TT} \]

If the table was loaded when the gas springs were engaged, the extra force could put the table in jeopardy of lowering in the front legs. If the force was at the front of the table, the moment will be much larger than when the table was unloaded.

![Figure 16: Free Body Diagram of the Tabletop](image)

\( B = C = 0.5M_{TT} \)

\[ \sum F_y = 0 = 2(0.5M_{TT}) - M_{TT} - F + A \]

\( A = F \)

\[ \sum M_y = 0 = 25F + 10M_{TT} - 2(0.5M_{TT})(17) + M_A \]

\[ M_A = -(25F - 7M_{TT}) \]

The moment reaction at A is in the opposite direction, holding the table up instead of keeping it from rising as it was in the unloaded situation. If the load was directly over the lifting leg, the moments would be different as well.
This moment is the same as when the table was unloaded. The lifting leg needs to be able to resist a maxim moment of $25F - 7M_{TT}$. This is necessary to ensure that the table does not break and that anyone sitting on the table or sitting underneath it will be injured.

**Safety Latch**

When the table is stationary, there will be an extra piece to ensure that the gear and shaft do not rotate and allow the table to lower on its own.
In this, the latch is positioned in the groove between teeth and attached to the leg by a spring. When the table is raised, the latch is dragged out of position by the next tooth, and then placed in the next groove by the spring. When the table is to be lowered, the latch must be removed. When the table is held steady, the shaft holds the rack in place and keeps the gear from rotating.

\[
\text{Figure 19: Forces Acting on Safety Latch}
\]

The force, \( F \), is the force on the rack. Therefore, the bar will need to be strong enough to withstand the maximum forces applied to the table. It has been assumed that the maximum possible force applied to the table will be 311.5 pounds, so the joint where the latch is connected to the leg and the latch itself must be able to withstand that force. When this is in use there will be less force on the gears. The overall forces on the table base and joints should be the same as when it is not in use, but the height will be kept constant without force being applied to the handle.

**Table Base**

The base is a very important component to the design of our art table. The base will be the basis for the strength and stability of the table. The base which will be integrated in this table design will be made out of a 6061-T6 aluminum flat bar. This bar will run along the sides as well as the entire back side of the table under the base. This bar will be oriented under the tabletop on the left and right sides of it. It will run the full thirty inches so that it is the same length as the tabletop. Another piece of the bar will be placed between the insides of these bars on the sides of the table. This bar will run the entire length of the back of the table. This will cause the base to run along the entire length of the tabletop when viewed from the back. This flat rectangular bar will add extra stability to the base. A figure of one of the flat bars which will be used for one of the sides of the base can be seen below.
This aluminum in general is lighter than most other metals such as steel, or brass. Aluminum is also very versatile and is very machinable. In the construction of this table, the base may have to be cut and fabricated in order to ensure certain parts of the table function properly. Aluminum is a great metal to do this with since it can be riveted, welded, brazed, or resin bonded. This metal has greater tensile strengths when compared to other metals. Aluminum also needs no protective coatings applied to it. The aluminum flat bar already comes finished. When looking into the costs for this design, aluminum is relatively less expensive when compared to other metals such as stainless steel. The only area where stainless steel would be more adequate to use would be the higher corrosion resistance it has over aluminum. This higher corrosion resistance would only be needed of the table were to be used outside where weather elements would increase the rate of corrosion. Since this table will be used indoors, the degree of resistance to corrosion of aluminum is negligible.
### Table 2: Budget

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<tr>
<th>Part</th>
<th>Manufacturer</th>
<th>Quantity</th>
<th>Total Costs (inc shipping)</th>
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<td>Tabletop</td>
<td>Officemax</td>
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<td>Steel spur gear</td>
<td>MSC Industrial Supplies</td>
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<td>2ft Steel gear rack</td>
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<td>Online Metals</td>
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<td>8ft 6061-T6 ¾ x 3 in aluminum flat bar</td>
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<td>Locking Gas Spring</td>
<td>Easylift Springs</td>
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<td>Miscellaneous Screws, bolts, mounts etc</td>
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<td>Total</td>
<td></td>
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<td><strong>$617.27</strong></td>
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Appendix I: Block Diagram for User

1. **User Reaction:** Themselves Under the Table
   - **Is the table comfortable for the user?**
     - Yes
     - **Start Art Project**
     - **No**
     - **Does the table need to be raised?**
       - Yes
       - Press and Hold Button and Lift Table in the Appropriate Position
       - **No**
       - **Hold Safety Latch in the Released Position**

2. **Helper’s Perspective**
   - **Is height of table high enough for user to fit underneath comfortably?**
     - Yes
     - **Start Art Project**
     - **No**
     - **Does the table need to be raised?**
       - Yes
       - Press and Hold Button and Lift Table in the Appropriate Position
       - **No**
       - **Hold Safety Latch in the Released Position**
Appendix II: Block Diagram for Design Process

1. Design Process
2. Table Top Manufacturing
3. Table Base Manufacturing
4. Can a Wheelchair Fit Underneath?
   - Yes: Attach Gear Rack and Gas Springs To Base and Table
   - No: Redo Base Width to Accommodate Wheelchair
5. Does the Table Adjust Between 27" and at least 40"?
   - Yes: Attach Gears and Handle
   - No: Find Where Instability is Caused and Adjust
6. Is Table Stable?
   - Yes: Table is Complete, Work on Instructions and Finishing Touches
   - No: Redo Base Width to Accommodate Wheelchair
Appendix III: References

1. Figure 4 was adapted from the following website:
   http://www.closet-masters.com/Ergonomics_SF/Height_adjustable_tables/Free_standing_ATSSpecifications.htm

2. The diagrams and the table of specifications for the gas springs were taken from:

Appendix IV: Acknowledgements

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