Introduction to Engineering Design

with Professional Development

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Final Report for

The Dynamic iSland

Version 1.9

Team Crush

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Executive Summary

After much concept development, debate, and matrix scoring, Team Crush came to the conclusion that it was best to move forward with the Dynamic iSland, an island that utilizes the wasted space inside an island to allow users to access their products easily without any stress of strain. After iterations of the Dynamic iSland were considered, the design seen to have the most promise in regards to human interface, time necessary to operate, cost, stability, and other properties was chosen to be the final design.

The first iteration of the final design, which was further developed and built, used a vertical and horizontal movement actuator system to move shelves from left to right and up and down. This system allowed the user to interface with shelves only one spot on their island, conserving the rest of the counter-space.

Basic final designs and operation specifications can be seen in Section 17, Appendix H: User Manual, which give a broad overview of the Dynamic iSland's design and user interface.

The Dynamic Island brings something new and innovative to the market, as seen by the lack of similar products with the same functionality on the market. This gives Team Crush and the Dynamic iSland a keen advantage in marketability and production.

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1 Introduction

Team Crush was faced with an objective; create an innovation revolving around a robotic, sustainability and alternative energy, or biometrics platform. After a few speed bumps, Team Crush chose the robotics platform and moved forward with the *Dynamic iSland*.

Team Crush's *Dynamic iSland* innovation came about when the team decided to take a step back and reconsider new ideas after arriving at a dead end with the initial concept of a water filtration system. The team decided to move forward with a dynamic cabinet system, which was considered to be under the umbrella of robotics. After a final brainstorming session, the team concluded that there is extra space in kitchen islands that is wasted. If one could utilize that space and create some sort of robotic shelving system, this would increase the storage space in one's kitchen, which a vast range of people could use. The *Dynamic iSland* was the team's solution to this problem.

2 Project Objectives & Scope

The items below constitute a list of the objectives and describe the scope of the *Dynamic iSland*.

- Brainstorm innovative and unique concepts for automated kitchen shelving/cabinets that are unlike current models
- Clearly identify a need for the proposed product
- Think of a possible market in which to potentially introduce the product where the concept would be positively received – In scope, this market will be created (not real) from intuition and experience for the purposes of the project.
- Come up with potential customer requirements based on the chosen market
- Use these customer requirements in order to create a fi nal design and assign metrics to the design of the product – In scope, these metrics are to be scaled down appropriately for prototype practicality considering the resources available
- Successfully build the proposed product in order to at least prove the concept of the design for future modification and consumer use – In scope, future modification and use would be beyond the Introduction to Engineering class and done on students' own terms or for another engineering design class.

2.1 Mission Statement

Team Crush's mission statement can be seen below in Figure 2.1.1, as it is broken down into categories to increase clarity.

Figure 2.1.1: Mission Statement

Goals	A device capable of operating quickly, quietly, and durably. Ease of installation into a home. Customizable dimensions to fit any kitchen.
Benefits	Prevent the need to bend over for access to appliances, and provide a modern augmentation to a popular kitchen feature.
Primary Markets	Physically impaired, independent elderly, and customers with back problems
Secondary Markets	Modernist consumers
Assumptions	Functional and safe design, easily adapted to any size kitchen, contains at least three shelving units.
Stakeholders	Contractors, architects, and installation company.

2.2 Customer Requirements

Customer Requirements were initially listed off using off using intuition and research. They were then translated in technical specifications and their corresponding target or range of values. The most important customer requirements were further researched and translated into technical specifications.

As seen below, customer requirements and technical specifications are listed in Table 2.2.1 in decreasing order of importance. In general, consumer customization and convenience were placed above anything else. This is because requirements like easy repair access are more applicable to repair people and the manufacturer. The customer requirements were decided on by considering what would cause the most frustration when using the product. By targeting those issues, customer satisfaction would be ensured as best as possible. While not all the customer requirements were included in the prototype that was built (such as button operation), it was only because of time and resource limitations; each one still holds its purpose and importance.

Table 2.2.1: Customer Requirements and Technical Specifications

Customer Requirement	Technical Specifications	Target Values/Range of Values
Standardized, yet customizable for most residential kitchen islands	The dynamic system can be applied without modifications that would interfere with the kitchen	48 in. (length) x 24 in. (width) x 36 in. (height), but appearance can vary based on customer specifications
Shelves visible for easy selection	At least one clear side panel	Opacity < 25%
Easy repair access	Panels on side of island able to be opened and/or removed	Panels at least half the length of the island
Long lasting/durable	Minimum of 5 years with uninterrupted operation	Operates without mechanical and software issues for at least 5000 uses
Easily operated	Straightforward interface	No more than 5 buttons
Easily powered	Can be plugged into standard household outlet	120V
Does not require bending over	Forklift system brings shelves level to countertop of island	Raises shelves 36 in. above ground

2.3 Technical Specifications

After the customer requirements were defined in Table 2.2.1, they were translated into technical specifications shown in the same table. Team Crush took general and broad demands and converted them into specifics for the product. Then, these specifications were turned into actual tangible values that Team Crush could work with to build the prototype. Although some of these target values might not have been achieved or attempted to be completed in the prototype, they were still considered to be significant aspects for a final product.

3 Assessment of Relevant Existing Technologies

Surprisingly, there were very few automated kitchen islands on the market. Figure 3.1 shows K7 Kitchen by Team 7. Although it was automated, the only automated part was the adjustable tabletop, which can be raised or lowered at the user's demand. This product was not quite the same as what Team Crush had envisioned. This supported our belief that Dynamic Island had the potential to be an innovation.

Figure 3.1: K7 Kitchen Island by Team 7

Table 3.1: Competitive Benchmarking

Competitive Product	Title/Description	Relation to this project
K7 Kitchen	Automated Kitchen Island (adjustable countertop)	A Kitchen Island with Automated Parts

During the patent search, Team Crush found a crane-type arcade game that utilized two axis actuators to control a crane. By having two actuators in two different axis, it could point to any spot in a two dimensional plane. This inspired the Horizontal Actuator and Vertical Actuator subsystems.

Table 3.2: Patent Research for Related Technologies

Patent Number	Title/Description	Relation to this project
US 20120228828 A1	Crane Game	Horizontal/Vertical Actuators

4 Professional and Societal Considerations

It is important to consider not only the technical implications but also the professional and societal implications of any project the team decided to undertake. The *Dynamic iSland* is not fundamentally different from any other piece of furniture found in many homes with two notable exceptions: it is powered, and it has moving parts. While it is necessary to power the device, it is ultimately not essential that this power be any particular standard. Team Crush's prototype will likely use the North American household plug standard for electricity, NEMA. The power supply uses an earthed NEMA 5-15 connection, while the Arduino uses a USB connection. For the prototype, these are both easily converted to any NEMA-compliant plug across North America. It would not be difficult to change the standard for international use, but as the prototype stands, the target consumer is decidedly North American.

It is also necessary to pay attention to the societal considerations of a piece of furniture with moving parts, especially across North American suburban households. These homes usually contain either children or pets; both will probably interact with the *Dynamic iSland*, be it intentional or not. It is feasible that a moving part would be able to harm a child or pet if unsupervised. However, the forces and torques in play are not sufficient enough to cause any more harm than accidentally shutting a door on one's finger. These dangers can be mitigated with common child safety precautions, such as child-safe buttons and motion sensors.

5 System Concept Development and Selection

Team Crush's idea for a *Dynamic iSland* came from a general idea for an automated cabinet system. While brainstorming on how to create a dynamic cabinet system that would be more space efficient, a team member noted all the wasted space found in kitchen islands. This led the team in an entirely new direction to move forward with the *Dynamic iSland* innovation. Originally, the team had a number of ideas on how to design an island that allowed the user to bring shelves to the counter top of the island. The team knew it wanted to conserve the extra counterpace an island gives you, meaning the team could not utilize the entire top surface for shelving units.

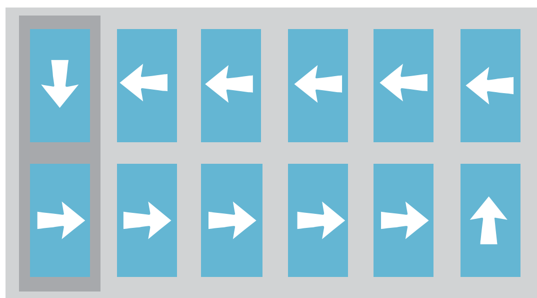

Figure 5.1: Conveyor Belt System, overhead view

The first idea the team considered was a conveyor belt system, as depicted above in Figure 5.1. The conveyor belt system would adopt circular motion that would unload shelves onto a fork, represented by the darker grey portion in the above figure. The forklift would then raise the desired shelves. This system would allow the user to lift two half-length selves at a time. The user interface for a system such as this was seen to be too complicated time consuming to be efficient enough for practical use. Both of these limitations would frustrate the user and deter them from purchasing such a product. This system was not used for those reasons.

Figure 5.2: Ferris Wheel System: Side View

Another system similar to the Ferris Wheel, seen above in Figure 5.2, was also considered. This system has shelves that are held by bars on a rotating frame. The frame would turn clockwise or counterclockwise to bring shelves where they would be lifted vertically to the surface of the island. This system, however, made horizontal and vertical movement convoluted and lacked efficiency. Due to these reasons, this idea was passed on as well.

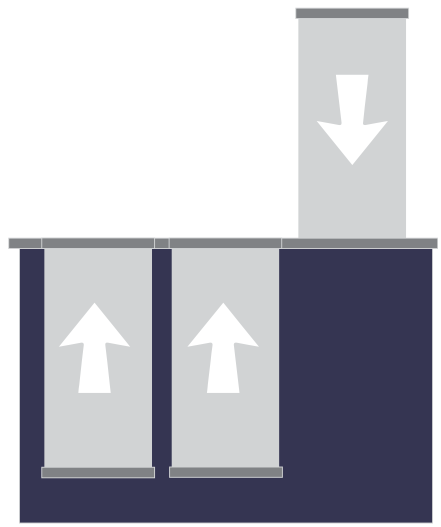

Figure 5.3: Multiple Shelving: Side View

The team quickly considered multiple shelving units at different locations in the island, as seen above in Figure 5.3. But this idea was overturned due to the amount of counter space it would take up – something the team wanted to avoid as to not disrupt other functions of an island.

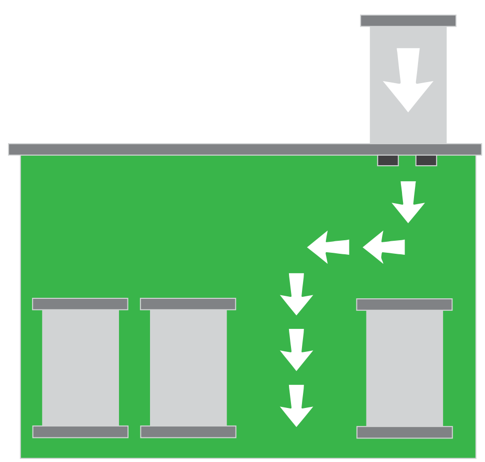

Figure 5.4: Final Design: Side View

The final design, in Figure 5.4, allowed the system to hold a number of shelves on lifts that were accessed by a horizontal fork system, which was then raised by a vertical system. This system allowed for shelves to pass over one another to reach the opening on the rightmost edge of the island. The top and bottom of each shelf would match the countertop material of the island to fit seamlessly, while the side panels of each shelf would mirror those used for an encasing of items a shelf. In addition, this system would have a user interface (not pictured here), where a one would be able to choose the shelf they wanted to access.

6 Subsystem Analysis and Design

Once the design was decided on, different parts were brainstormed and sectioned off to create subsystems to give every team member a task. The team decided it would be beneficial to have larger subsystems that broke down into sub-subsystems, allowing room for collaborative thinking and integration, yet not hindering ownership. It also allowed the team to have more evenly sized and logical subsystems. The first set of subsystem division is seen below in Figure 6.1.

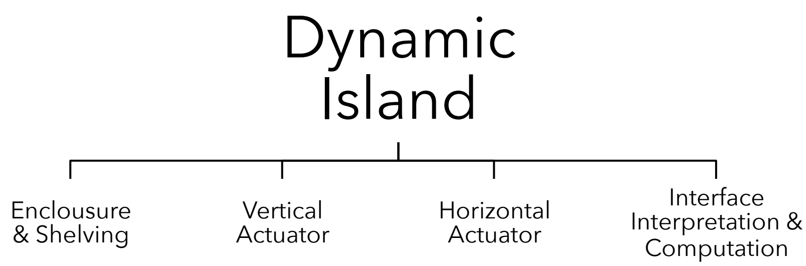

Figure 6.1: Master Subsystem Diagram

The subsystem breakdown was determined by the specific needs of the prototype. It was necessary for the system to provide horizontal and vertical movement, have an interface to run the system, and an enclosure to represent the island itself. After the project was broken down into four subsystems, the three more complicated systems were broken down into two-person tasks. The breakdown from master subsystems to personal systems is shown below in Figure 6.2.

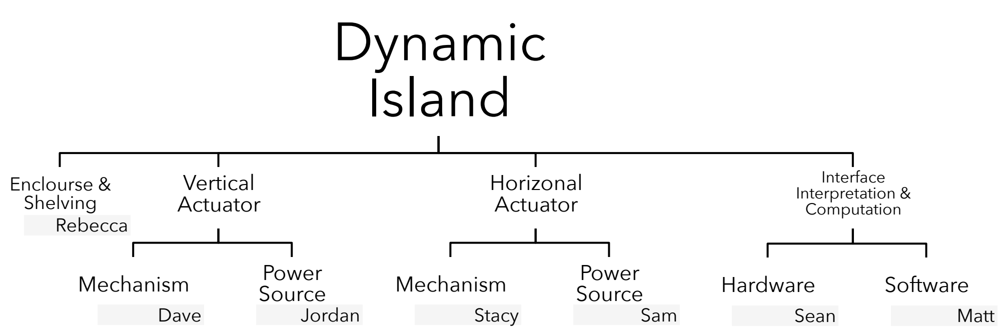

Figure 6.2: Personal Subsystem Diagram

When designing the overall prototype, keeping costs low was an important metric for Team Crush, as it usually is during the design process. Products are made with the intent to maximize profits whenever possible, whether that is done by using cheaper materials, better marketing strategies, unparalleled customer service for customer retention, etc. The need for low costs led the team to design in a cost-effective manner. Less expensive materials were used in place of unnecessary mechanical or electrical components that did not directly pertain to the mechanical innovation of the system.

6.1 *Enclosure & Shelving*

When it came to the enclosure and shelving, the desired size of the design was based off current islands sold at stores such as Home Depot or Lowes. Most typical kitchen islands are approximately 2 ft. (width) by 4 ft. (length) by 3 ft. (height) but are often made customized to the customer's specifications. This variability in size led the team to take the most standard, pre-existing kitchen island as the base size. After doing this and other appropriate research, Team Crush concluded that the dimensions of the prototype were not going to be to scale and that the final design would not utilize the same materials a typical island would.

Figure 6.1.1: Enclosure Framework (Unpainted)

Team Crush wanted their innovation to be as close to a scale model as possible but realized the pitfalls in designing a scale model. Certain mechanical pieces were not able to be sized down perfectly along with the body. The model size

Team Crush chose was 1 ft. (width) by 2 ft. (length) by 2 ft. (height) inside dimensions for the frame, as can be seen in Figure 6.1.1.

Along with the size of the prototype being altered to aid the design and testing process, the materials used for the enclosure and shelving were altered as well. A typical island is made of wood with a granite or ceramic countertop – this was not needed for the prototype. Team Crush was more interested in making a working mechanical prototype, rather than an aesthetically pleasing one due to the nature of the class and the unnecessary costs that would be incurred by creating an island with a granite countertop and extra finishes. This design choice allowed the team to utilize a simpler model. Team Crush decided that a wooden frame with clear acrylic walls way the best choice, enclosing everything yet allowing others to see the mechanics of the system. After researching, it was deduced that acrylic walls were too expensive and were not beneficial enough to the overall system to bear the cost. Attempts to have the clear acrylic walls donated were unsuccessful.

For the shelving, a number of design choices were considered. Team Crush found it best to utilize a four-walled system where the sidewalls matched the wood paneling of the island, while the top and bottom "walls" matched the countertop. This allowed the prototype to look cohesive whether the shelves were all enclosed in the system or lifted for access. For the scale model, however, this system was not used because of the space inside the model. The shelves were made out of a 5 mm think panel with dimensions of 5 in. (length) by 9 in. (width). The material chosen was based on its cost and accessibility. In final models though, customers could change their shelf dimensions based on their needs however. The outside dimensions of the prototype became 10 in (length) by 18 in (width). Unexpected constraints became apparent and the team saw it best to have flat shelves in order to accommodate changing the mechanics.


Figure 6.1.2: Enclosure Lifts

Lastly, it was necessary for the shelves to be on lifts inside the system to allow the fork to grab and move them. The lifts, which are seen above Figure 6.1.2, were made as wide as possible, while providing room for the forklift to fit. When deciding on the number of shelves to have in the prototype, Team Crush was not able to have the model hold as many as planned, again due to the nature in which the island was scaled down.

6.2 *Vertical Actuator: Mechanisms*

The goal of this subsystem was to allow the horizontal actuator to travel vertically. In order to achieve this goal, Team Crush considered two different options. The first one was a pulley system that would hook the two ends of the horizontal actuators onto two loops of pulley. These two pulleys would be operated by motors in order achieve vertical motion. However, the problem with this system was that the motor would have to be turned on at all times in order to keep the actuator stationary.

The other solution was to use motor-controlled, retractable chains to achieve vertical motion. Again, this solution had the same issue as the pulley system with heavy loading.

The final solution was to use two 2 ft., ¾" threaded rods as a linear actuator. It was decided that a thread pitch of 5 instead of 10 or 12 should be used to allow faster motion. The principle behind this system is that there are two ¾" nuts flush against the sides of the horizontal actuator, which the threaded rods go through. When the threaded rods spin, the nuts also try to spin. However, the nuts are flush against the horizontal actuator, which is locked in place by the two threaded rods. Therefore, the nuts start traveling up or down the rods. In turn, this allows the horizontal actuator to achieve vertical motion.

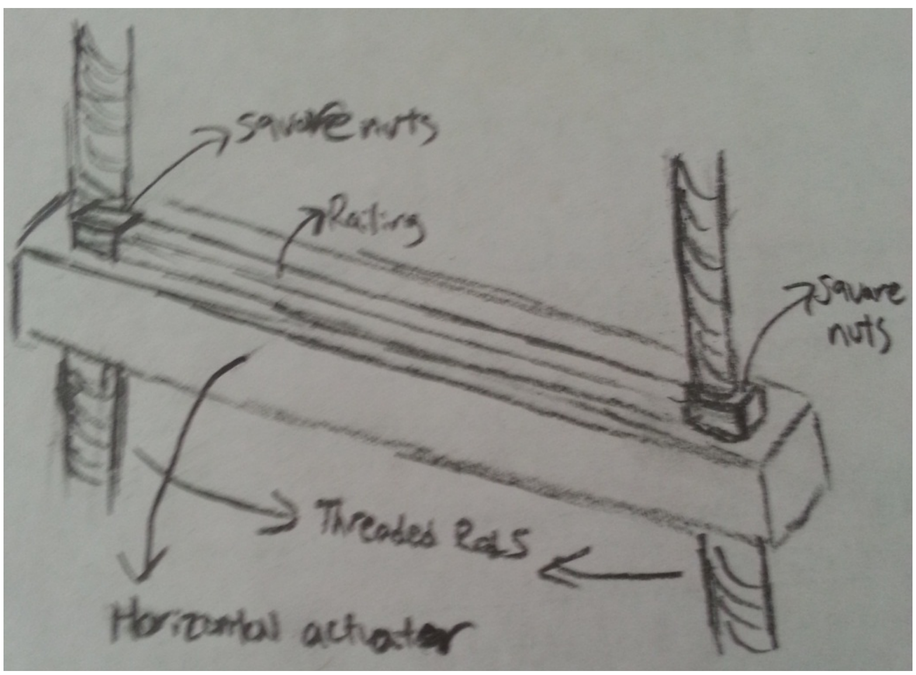

Figure 6.2.1: Vertical Mechanics

As shown in Table 6.2.1, these were each given a score of 1, 0, or -1 in different categories. These scores were added up to find which is better out of the three. Threaded rod system came out as the clear winning out of the three

One of the major problems the team encountered was friction. The less friction the system had, the easier the motor could actuate the system. Team Crush decided to use ¾" thrust bearings at the bottom of the rod since thrust bearings do well when a load is put on it perpendicular to its face. On the contrary, the top of the rod only had friction on the sides. Therefore, ball bearings would have been a perfect choice. However, despite Team Crush's best efforts, ball bearings with a boar diameter of ¾" could not be found. Instead, the team used 1" long, 1" outer diameter, ¾" inner diameter, PVC tube in order to reduce friction. This created considerably less friction than wood on steel.

Another problem the team had was that the two threaded rods must be coordinated at all times. If not, this will cause the horizontal actuator to tilt and the rods to warp. Therefore, the two rods were connected by a #35 chain and two sprockets so that only one of the rods has to be powered by a single motor.

Table 6.2.1: Vertical Mechanics Design Matrix

	Pulley	**Chain**	**Threaded Rods**
Practicality	-1	0	1
Safety	-1	-1	1
Cost	-1	0	0
Originality	0	0	1
Durability	0	1	1
Ease of Use	1	1	0
Total	-2	1	4
Rank	2	3	1

6.3 *Vertical Actuator: Power Source*

The vertical actuators required a system of power transmission that was capable of turning the vertical threaded rods simultaneously and at a fast enough rate to raise the shelf system in less than the 20 second goal. The full scale design was limited to a 20lb load on each shelf, meaning the scaled version would only need to carry a load of 5lbs.

The first calculation was finding how much torque is needed to lift the assembly. The equation was dependent on a few known variables of the design, such as thread pitch (5 threads/inch) and maximum shelf weight (5 lbs). There were, however, many variables that were not known. For example, it was difficult to know how much the horizontal locomotors assembly would weigh as well as how much friction the motor would have to overcome. These values were estimated during the initial calculations, in order to get an idea of what the torque would have to be. After the torque values were finalized and reviewed, a friction factor of %10 and a factor of safety of 2 was placed on the design. The following equation was used to find torque:

$$\tau = \left(\frac{F \cdot d}{2\pi}\right) \cdot C_{fr} \cdot FS$$

Where F is the overall load on the rod, d is the thread height, C_{fr} is the friction factor and FS is the factor of safety. The final calculated torque was **366.6 g-cm**.

In order to get the shelf to the top of the island in less than 20 seconds, a second calculation was needed to find the minimum angular velocity of the motor. This equation was used for the calculation.

$$\omega = \frac{h \cdot c}{t}$$

Where h is height, c is thread pitch, and t is time. The final calculated angular velocity was **360 RPM**.

The next objective was deciding on a motor. Since the device is supplied with 120V wall current, electric motors were the easiest choice for driving power because they can be directly attached to the power supply. Deliberation arose on which type of electric motor to use. There were three options available: a DC motor, a gearhead motor, and a stepper motor. Each had their own advantages and disadvantages:

- A regular DC motor is able to achieve high revolutions per minute, meaning it can raise the shelves faster, but many of the models within the budget range lacked the appropriate torque needed to overcome the weight and friction of the system.
- The gearhead motors researched had the right amount of torque but they were not capable of the RPM needed for the vertical actuation. They are also hard to use in our application because of the inability to exactly measure how much the motor has spun.
- Stepper motors were the third consideration for the power source. They offer the ability to track the exact angular displacement in degrees, which was important for the computation team. The challenge though, was finding a motor that satisfied the desired values of torque and revolutions per minute.

The final decision was to use a stepper motor because of the key advantage of quantifiable rotational steps. In searching for capable motors, it was discovered that stepper motors are described by a different set of parameters than DC motors. Instead of RPM, the motor speed had to be calculated by dividing the pulses per second by the pulses per revolution. Although difficult to find, the team was able to purchase a motor with sufficient properties. Figure 6.3.1, supplied by the distributor, helped in assuring the motor had the appropriate specifications:

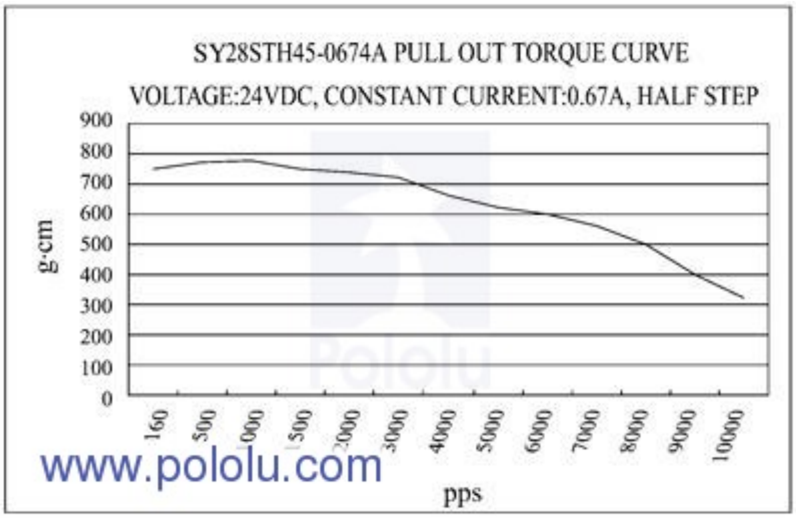

Figure 6.3.1: Torque vs. Pulse Rate Diagram for Vertical Stepper Motor

The curve relates supplied torque, in g-cm, as a function of pulses per second (pps.) The motor needed to run at 360 rpm which equates to 1200 pps, and that translated to a torque of approximately 750 g-cm.

The next issue was transmitting power to the vertical rods. The motor had to be attached in such a way that it did not impede the motion of the rest of the device and was capable of transmitting its rotation to the threaded rod. The best position was found to be parallel and on top of the horizontal edges of the enclosure, between the two rods. Angled miter gears allowed the motor to rotate on a plane orthogonal to the rods. Since the bore diameter of the angle gears was ¾" and the axle diameter of the motor is 5mm a custom aluminum hub was milled from extra stock and tapped with a torque screw to prevent slippage between the axle and the bore. Figure 6.3.2 is a rough schematic of the entire power transmission system. The motor is on the right, attached to the horizontal beam, the meshing gears illustrate how the motor rotates the threaded rod.

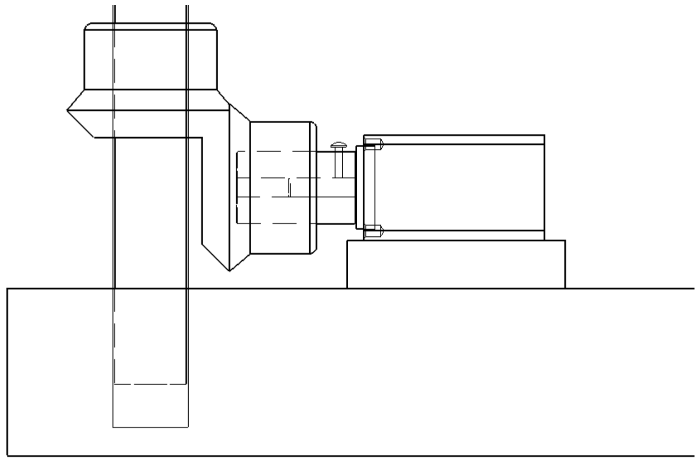

Figure 6.3.2: Technical Drawing of Vertical Power System

After assembly, and during testing, it was found that the friction in the vertical lift system was too much for the motor to overcome, even though the motors torque was greater than the initial specification, it was not enough to overcome the resistance of the metal rod and its components.

6.4 *Horizontal Actuator: Mechanisms*

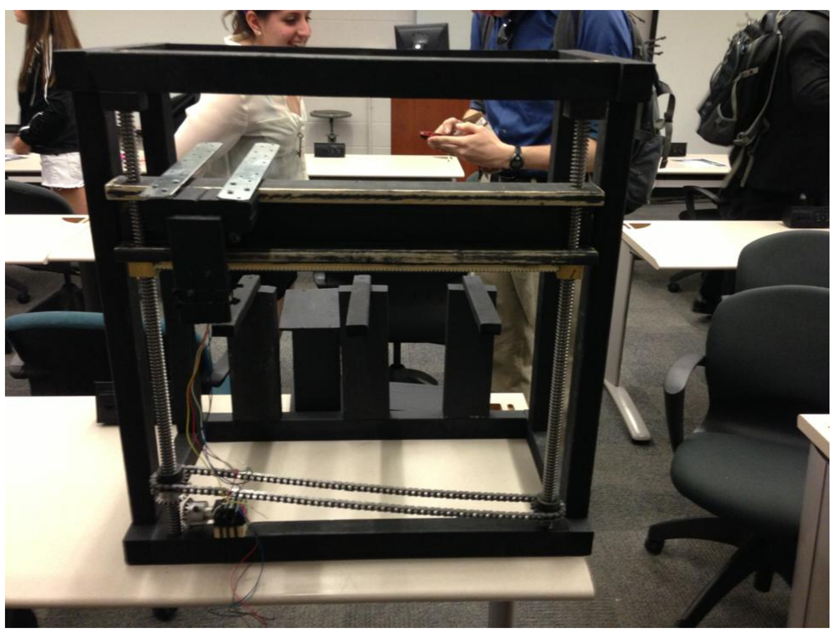

Figure 6.4.1: Overall Island System

Design Methodology

For the lateral movement of the forks three different systems were considered. One idea was to use to a HTD (High Torque Drive) timing belt and pulley system that would be attached to a pair of forks. The belt system would be powered by a motor. This system was not used because it was not cost efficient.

The second idea considered was to use a chain system. Each end of the chain would be attached to the outside edges of each fork. This system was not practical because the horizontal actuator would not be stationary. Using a chain system, it would be difficult to avoid interference with the vertical actuator subsystem.

The third idea was to rotate a wheel against a beam where friction would propel the forks horizontally. However, it was difficult to make sure the system would have enough friction to move the forks and shelves. It was finally decided to trade the wheel for a rack and pinion system. This system ranked the highest in the Initial Ideas Decision Matrix due to its high practicality, low cost, and durability.

Rack and Pinion Subsystem

Once the general idea of the subsystem was accepted, the design of the smaller elements of the system were discussed and analyzed. There were three material options to select from for the rack and pinion: steel plain, machined nylon, and molded nylon. Steel was not used due to its higher cost and greater weight. The choice was between machined or molded nylon. The manufacturer of the rack and pinion suggested using a molded nylon gear and rack since its application was not heavy duty.

To work together, the gear and rack must have the same pitch and pressure angle (the angle between contact points of meshing teeth). A gear's pitch is the number of teeth divided by the pitch diameter. Fewer teeth per inch means teeth are larger and therefore stronger; for the proposed objective of the system, a 16-pitch gear with 12 teeth was selected.

Once the rack and pinion system design was selected, the team needed to figure out a way to connect the forks to the motor and rack and pinion system. The design would have to prevent the weight of the forks and shelves from being placed on the motor. It was decided that the rack and pinion system would be attached to the bottom of a u-channel and the forks would slide on top. The team looked into different types of metal u-channels since metal would be durable and have a lower friction coefficient. The design needed to avoid sources of friction in order to harness the most power from the motor. After brainstorming and visiting Home Depot in order to get a visual representation of the proposed ideas, it was decided to use wood to make the u-channel. The basic idea was to have a slider piece that would slide inside the U-channel and on top it would be attached to the forks, and the motor would also be attached to the slider.

Lastly, the team had to design the slider piece. The slider would have to be lightweight and relatively frictionless in order to be able to slide along the beam easily. Several designs were brought together and after ruling out a metal box-like slider and a design that used the same mechanism as cabinet drawers, the slider was designed out of wood with two wheels that would allow the slider to move across the u-channel. The forks would be attached directly above the slider, and the motor would be attached near the bottom of the slider.

Not much thought went into the design of the forks. The forks needed to be strong enough to support at least 5 lbs. Two metal brackets were used for the forks. Plastic sliders were purchased and placed between the forks and beam.

Figure 6.4.2: Horizontal Actuator Forks

Table 6.4.3: Horizontal Mechanics Design Matrix

	HTD Belt & Pulley	**Chain**	**Rack & Pinion**
Practicality	1	-1	1
Safety	1	0	1
Cost	-1	0	1
Scope	0	-1	0
Originality	0	0	0
Durability	1	1	1
Ease of Use	1	-1	1
Total	3	-2	5
Rank	2	3	1

6.5 *Horizontal Actuator: Power Source*

Together with the u-channel and rack and pinion system, the function of this sub-subsystem was to provide the actual power for the slider to move the shelves horizontally. The main variable that had to be determined before deciding on the optimal motor was the driving torque. In order to calculate this, the coefficient of static friction for wood, the weight of a loaded shelf plus the slider (estimated to be 5 lbs. for the prototype), and the radius of the gear were all taken into account (Engineering Toolbox). The motor would have to provide a torque greater than the one calculated. Please see the calculation below.

$$\tau_{\mathrm{motor}} > \mu_{\mathrm{static}} F_{\mathrm{gravity}} r > (.5)(5\mathrm{lb})(.75\mathrm{in}) > 1.88\mathrm{lb}-\mathrm{in}$$

The torque of the motor had to be greater than 1.88 lb.-in. For a specific manufacturer, the chosen motor provided 2.75 lb.-in of torque; it was the closest to 1.88 lb.-in without going under. The motor was a unipolar/bipolar stepper motor rated for 4 V and 1.2 A. It also output 4.8 W of power.

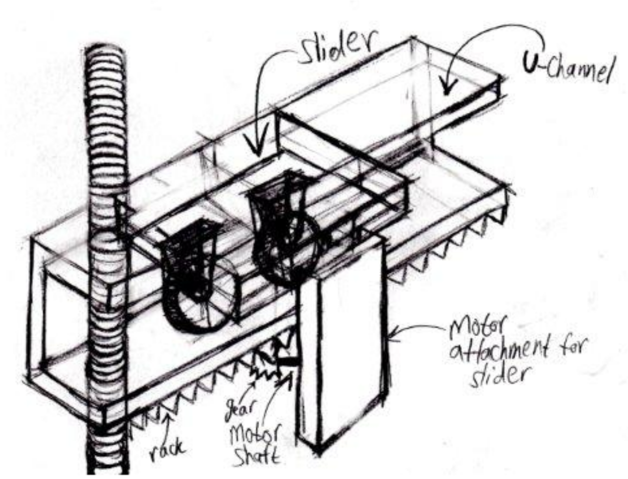

Figure 6.5.1: Sketch of Horizontal Actuator Subsystem

As seen in Figure 6.5.1: Sketch of Horizontal Actuator Subsystem, the motor was attached to the vertical piece of wood on the back of the slider. It was secured using zip-ties and super glue. The motor was tested for operational status with the software/hardware subsystem team before the entire horizontal assembly was incorporated into the whole prototype.

6.6 *Interface Interpretation & Computation: Hardware*

The *Dynamic iSland* uses two motors to affect all actuators: a vertical bipolar stepper motor and a horizontal unipolar stepper motor. A stepper motor is a type of motor that can travel in discrete "steps," allowing for fine-tuned control of the motor's position. Specifically, the SY42STH47-1206A was used for the horizontal drive, while the SY28STH45-0674A was used for the vertical drive.

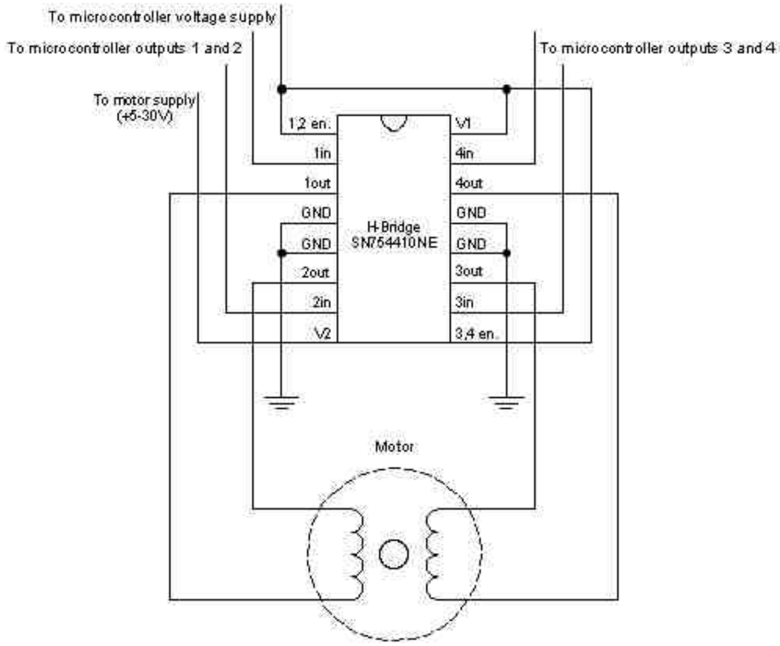

Figure 6.6.1: Unipolar Stepper Motor

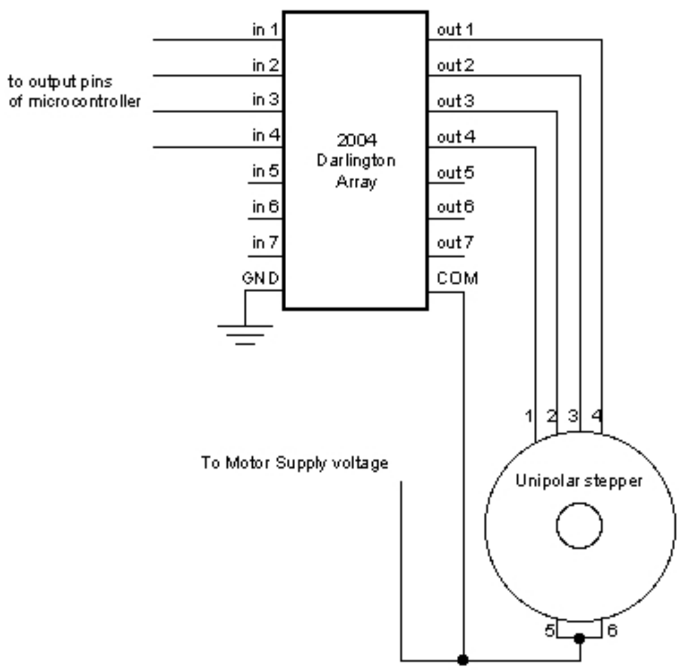

Figure 6.6.2: Bipolar Stepper Motor

While all stepper motors can be controlled down to individual and small steps, not every type of stepper motor uses the same control scheme. Each motor required a different control circuit depending on its use. Unipolar motors are motors that have a central power source or “center tap,” which is always pulled high. Power always flows into this tap (or these taps, in the case of six-wire motors), hence the name “unipolar.” Bipolar motors are motors that have only the four wires, and power must be supplied from each terminal in turn. In other words, each coil must be powered and flow both ways or from two poles, hence the term “bipolar.” As a result, the control circuits for each are very different. While a unipolar motor can simply use an array of Darlington transistors (transistors “daisy-chained” to supply additional current amplification and act as a digital switch), a bipolar motor requires an H-bridge configuration in order to power it properly. The circuitry configurations used for both types of motors can be seen in Figure 6.6.1. Due to the differing control circuits, both motors are controlled by the same pulse train configuration from the Arduino controller.

6.7 *Interface Interpretation & Computation: Software*

The software side of system control contains all of the coding responsible for moving the shelves in the order required by the user. Code written in the C programming language handles the motion of the shelves, ensuring that they move smoothly and in the desired pattern. This system could not be fully implemented because of problems with other subsystems. As a result, the resources of this subsystem were focused on the readying and preparing of the locomotion subsystems

7 Results and Discussion

7.1 *Results*

The development of the kitchen island ultimately resulted in failure. Unaccounted friction in the vertical motion system meant that the motor that was used was not strong enough to spin the threaded rods, much less lift a payload. A stronger motor may have been able to lift the required weight. Alternatively, multiple motors of lower power could be used voiding the need for a connecting chain, but necessitating modification to motor control to ensure synchronous operation.

The horizontal locomotion system operated successfully. It was able to move shelves across the length of the wooden housing. However, the motion was not as smooth as initially intended due to the friction between the surface of the forklift and the u-channel. The testing results can be seen below in Table 7.1.1. If possible, the team would look to reduce the size and weight of this system to allow for more storage space in the cabinet as well as increase the functionality of the vertical system.

Table 7.1.1: Horizontal Motion Speed Testing

Units of Seconds	**Test 1**	**Test 2**	**Test 3**	**AVG**
Horizontal 3.3 V	18 seconds	16 seconds	17 seconds	17 seconds
Horizontal 5 V	15 seconds	14 seconds	15 seconds	14.67 seconds
Horizontal 12 V	14 seconds	14 seconds	13 seconds	13.67 seconds

The motor purchased for vertical use was unfortunately not powerful enough for its intended use, as seen through the qualitative data given in Table 7.1.2. For future prototypes and the final model, a much more powerful motor would have to be purchased to ensure that the system would work properly and effectively.

Table 7.1.2: Vertical Motion Speed Testing

Units of Seconds	
Vertical 3.3 V	Not sufficient to turn gear
Vertical 5 V	Not sufficient to turn gear from standstill, rotation achieved after slight push
Vertical 12 V	Turned gear when detached from rods, not sufficient to turn rods
Vertical 24 V	Same as 12 V but caused overheating and then malfunctioning of servo after a few seconds of use

The cabinet enclosure was constructed successfully for the purposes of demonstration but was not completed to the specifications of the original design due to monetary and time restrictions. Walls made of wood or clear plastic would have been added to the system to close it off, with one side having swinging doors to allow for a different method of access to any items stored in the cabinet.

The control system of the kitchen island was moderately successful. Its implementation was limited by the level of completion of the other subsystems. A power source for the cabinet was created and the proper circuitry and code were created allowing the motors to be controlled to the specifications anticipated. However, because both locomotion systems did not work, the full control algorithm could not be implemented. In addition, the team was unable to implement any sort of user interface due to time restrictions. Given time, three push buttons would have been wired to the Arduino and located on the counter-top. Pressing any of the buttons would bring the corresponding shelf to the surface of the unit.

7.2 *Significant Technical Accomplishments*

The *Dynamic iSland* is a synthesis of several pre-existing technologies: gear drives, Arduino & control circuits, and a frame. This project is significant in that it causes these parts to effectively work together to solve a problem. There are no other products on the market like the *Dynamic iSland*. While there are shelving units that have moving parts, none are as small or as easy to install as this. This project solves a host of problems for the customer, and it does so easier, simpler, and with less space than any other product in existence now.

8 Conclusions

The Dynamic iSland was conceived by Team Crush to help consumers add functionality to their home's kitchen, especially disabled users who cannot reach the lower storage. It utilizes space under the countertop; space normally wasted by a standard kitchen island.

Four different systems of dynamic shelves were initially proposed and voted on in a concept selection matrix. The benefit of having so many options was the opportunity to choose a design that the group was passionate about. The Dynamic iSland was easily divided into seven challenging subsystems that complemented the teams skill set, and provided priceless experience with design and development.

Even though it did not function to full expectations, the prototype was a profound first step. Further improvements and development would be made before going to market. An increased focus on safety, aesthetics and variability would be addressed in the future. This product represents the future of our kitchens and a step forward in machines helping humans.

9 References

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10 Appendix A: Customer Requirements and Technical Specifications

Table 11.1: Customer Requirements and Technical Specifications

Metric No.	Metric	Importance	Units	Target Value
1	Elevation of shelves from ground	5	Ft	36
2	Unit manufacturing cost	5	US$	< 400
3	The error range of safety proximity sensors	5	mm	<10
4	North American Furniture Test	5	Binary	Pass
5	Durability	4	Cycle	> 5000
6	Volts needed to operate	4	volts	120
7	Maximum time for one cycle	4	S	< 20
8	Maximum load on each shelf	4	lb	> 40
9	Shelf Size	4	List	9 in (length) x 20 in (width) x 16 in (height)
10	Number of Shelves	4	No.	5
11	Island Size	3	List	48 in (length) x 24 in (width) x 36 in (height)
12	Percentage of accessible panel	3	List	Half of the side of island
13	Number of transparent sides	2	No.	> 1
14	Number of buttons for interface	1	Buttons	< 5
15	Time to disassemble/ assemble for maintenance	1	s	< 300

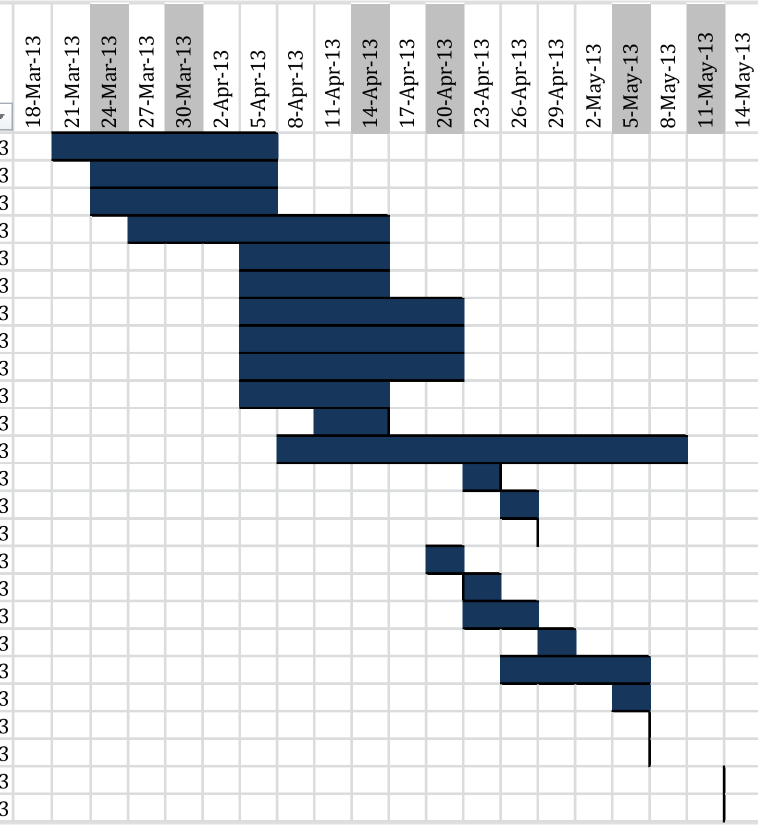
11 Appendix B: Gantt Chart

The Gantt Chart was a basic frame for the team's deadlines and time parameters. It was seen more beneficial to use the Gantt Chart for overall dates and deadlines, while delegating more specific tasks in the meetings as they came up. Team Crush's Gantt Chart can be seen in Chart GC.1 on the following page. The team set tasks during weekly meetings and pairs delegated their specific tasks on their own, holding one another accountable for what was necessary to complete their subsystems. Progress was monitored by the entire team, checking in at least once a week to monitor progress.

The Gantt Chart, however, was not as successful as some team members had wished. Deadlines were missed and many tasks were pushed back as conflicts arose, whether they were personal or design issues. Had the team had more time to work on the innovation and get to know one another's work ethics, the Gantt Chart would have been more easily followed and utilized.

Other methods of organization and planning were used such as calendars visually dictating deadlines and constant reminders sent out by team members.

Project Name	Status	Owner	Start	End
Design Enclosure & Shelving Systems	100%	Rebecca	3/20/2013	4/5/2013
Decide on Vertical Actuator Style	100%	Jordan & Dave	3/23/2013	4/5/2013
Design Horizontal Locomotors	100%	Stacy & Sam	3/24/2013	4/5/2013
Purchase Materials for Personal Subsystems	100%	Individual Basis	3/26/2013	4/15/2013
Decide on Hardware Interface	100%	Sean	4/5/2013	4/15/2013
Decide on Software Interface	100%	Matt	4/5/2013	4/15/2013
Build and Test Personal Subsystems	100%	Group	4/5/2013	4/21/2013
Design & Build Actuator	100%	Jordan & Dave	4/5/2013	4/20/2013
Build Locomotors	100%	Jordan & Dave	4/5/2013	4/20/2013
Build Enclosure & Shelving Systems	100%	Rebecca	4/5/2013	4/15/2013
Collaborate Hardware & Software	100%	Matt & Sean	4/10/2013	4/16/2013
Work on Final Memo	100%	Group	4/8/2013	5/8/2013
Finish Prototype (Assemble)	100%	Group	4/20/2013	4/20/2013
Test Prototype	100%	Group	4/21/2013	4/23/2013
Account and Compensate for Errors	100%	Individual Basis	4/22/2013	4/25/2013
Remedy Any Issues Found After Testing	100%	Individual Basis	4/23/2013	4/26/2013
Finish PowerPoint Presentation	100%	Group	4/25/2013	5/5/2013
Re-Test	100%	Group	4/26/2013	4/26/2013
Complete Finishing Touches on Prototype	100%	Group	4/27/2013	4/28/2013
Prototype Demonstration	100%	Group	4/29/2013	4/29/2013
Practice for Presentation	100%	Group	5/5/2013	5/5/2013
Complete Finishing Touches on Final Memo	100%	Group	5/6/2013	5/6/2013
Final Presentation	100%	Group	5/7/2013	5/7/2013
Email Report Into Professor (At Latest)	100%	Rebecca	5/10/2013	5/10/2013
Celebrate Completion!	100%	Group	5/10/2013	5/10/2013



12 Appendix C: Expense Report

Table 12.1: Project Expenses

Item	Quantity	Unit Price	Subtotal	Tax & Shippin g
Rack & Pinion	1	$20.96	$20.96	$4.83
Stepper motor #1200	1	$19.95	$19.95	$15.95
Stepper motor #1206	1	$19.95	$19.95	$8.95
Roller Chain	1	$13.13	$13.13	
Sprocket	2	$15.71	$31.42	
Angle Gears	2	$27.64	$55.28	
Threaded Rod	2	$15.38	$30.76	
Square Nut	2	$11.81	$23.62	
2 in. x 4 in. x 96 in. Kiln Dried Hem Fir Prem Stud	3	$2.58 + Tax	$8.36	--
5.0 mm x 2 ft. x 4 ft. Moisture Resistant Underlayment Handy Panel	1	$6.25 + Tax	$6.75	--
Forks	2	$2.82	$5.64	
Steel thrust ball	2	$2.25	$4.50	$4.83
Misc.			~$10.00	
Subtotals			$250.32	$34.56
Final Total				**$284.88**

A discrepancy in the cost of the prototype and the actual product exists. However, for the final product, the island itself would definitely cause the corporation and the customer to incur additional costs. For this reason, the pricing set forth here (except for the pieces used for the frame) shows the price of the mechanisms needed inside the island itself, not the entire cost. This price also does not take into consideration items Team Crush had to buy excess of due to the nature of products or the scale down in price that would occur when purchasing multiples of these items.

13 Appendix D: Statement of Work

Purpose: The *Dynamic iSland* was developed to effectively use the space inside of a kitchen island while also increasing ease of access to the contents

Scope of Work: This describes roughly the work that must be done in detail and specifies the hardware and software involved and the exact nature of the work to be done.

The team must:

Write a project proposal

- Build an enclosure for the subsystems
- Build horizontal and vertical locomotion systems
- Create software and circuitry to operate the locomotion systems
- Present the prototype
- Write a report detailing the development of the project

Location of Work: The majority of the work is to be performed in the IED shop with reports and presentations being created in various meeting places on campus

Period of Performance: Class times from March 20th to May 5th are dedicated to working on the project in addition to various meetings in the shop to work on the project. Smaller meetings may occur between members of specific subsystems as required.

Deliverables Schedule: See Gantt chart

Acceptance Criteria: The *Dynamic iSland* has been constructed to the best of the team's ability following the engineering guidelines outlined in class

14 Appendix E: User Manual

Please see the following pages for a complete user manual, (3 Pages).

DYNAMIC iSLAND

USER MANUAL

A TEAM CRUSH Product

Using the Interface

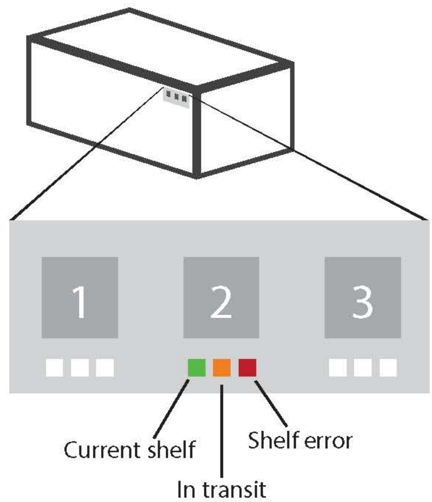
Selecting a shelf:

To select a shelf to bring to the top of the island simply press the button with the corresponding number. on the control panel (located under the lip of the countertop.)

The island will then exchange the current shelf with the new one. Once the shelf comes to rest, its status light will be green, indicating it is the current shelf.

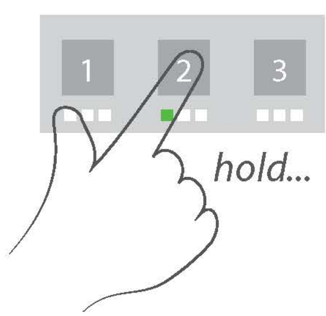
while a shelf is moving, its status light will be orange.

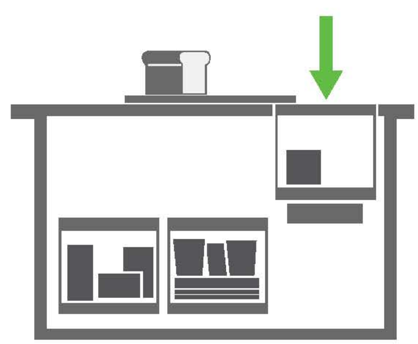
If the shelf encounters a problem during motion, a red status light will appear and the island will stop moving.



Clearing the surface:

To clear the surface of your island, press and hold the button of the current shelf (indicated by the green light), this will retract the shelf into the island and leave a flush and clean surface to prepare your food.





Phone: 518-342-6463
E-mail: customerservice@teamcrush.com

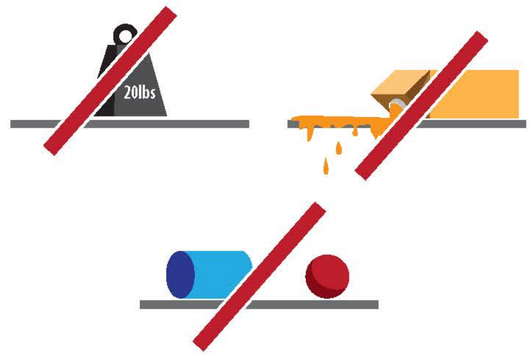
TEAM CRUSH
1999 Burdett Ave., Troy, NY, 12180

Safety and Maintenence

Precautions:

In order for your Dynamic iSland to continue to work properly, avoid the following:

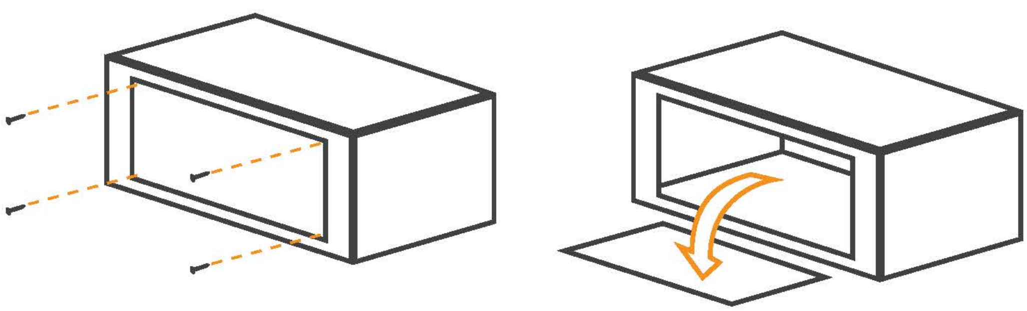
- Overloading shelves (nothing over 20 lbs / 9kg)
- Round or insecure items
- Large spills
- Leaving objects in the way of operation



The Dynamic Island comes with a safety sensor system ensuring that your fingers and shelved items don't get jammed on their way down. The safety sensor system checks for any fallen items or poorly placed appendages and halts movements if these items are found to be in its way when closing.

Accessing the shelves:

In case of spills, drops, or other issues with the shelving in your unit, the Dynamic Island's back panel can be taken off to access such items. Just unscrew the four corner screws and carefully pull the panel off.*



*If physically incapable of lifting heavy boards and materials, please contact someone physically able or one of our representatives for a Dynamic Island Mechanic.