Mobile Computer Cart

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Final Report

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Abstract

In today's technologically advancing world mobile work stations are needed to perform a variety of tasks, anywhere from transporting medical apparatuses to engineering testing equipment. Unfortunately the current products available for purchase are much too expensive and incapable of easily being transported outside. Dr. Srinivas Kosaraju is currently managing multiple student capstone teams at Northern Arizona University that require some sort of testing. A mobile testing work station is not currently available for students to test their designs. Dr. Kosaraju is requesting an inexpensive mobile computer cart capable of accommodate a data acquisition computer that can be taken easily outside the engineering building for outdoor experiments. With this in mind a team of undergraduate mechanical engineering students designed a mobile computer cart that can be used by the engineering department to preform experiments outside.

The team worked with Dr. Srinivas Kosaraju to verify that the design would meets the needs. The design must be fabricated to holding two adjustable wide screen monitors, a CPU, data acquisitioning equipment, and attachments to hold a keyboard and mouse. There must be enough storage space for user to keep additional cables, manuals and equipment. In addition, the design must be capable of being operated by one individual and cost under $500.00.

The two wheeled dolly style design was chosen for the final design based on relatively low cost, manufacturing capability, and its function. For this design square A36 square tubing was welded together to create a structurally sound frame. Sheet metal was then welded to the exterior to create an aesthetically pleasing and weather proof shell from the outside elements. A telescoping mechanism was manufactured to allow two monitors to be pulled out of the frame when in use. The exterior of the cart was painted blue to prevent corrosion to take place if the cart was left in the rain. During transportation the monitors can be easily placed back inside the structure and the cart is rolled around on two large inflatable rubber wheels. To ensure the cart is completely weather proof rubber weather stripping was used to seal any potential entry point for water. To further increase the carts capability window were installed on either side, which allows the operator to leave the testing equipment running while the monitors are in the closed position.

The design for the prototype took place over Fall of 2014 and the fabrication took place during Spring of 2015. The project was 100% manufactured by the students on the team in the Northern Arizona University machine shop.

1. Project Summary

Northern Arizona University Capstone instructor is looking for one mobile computer cart designed and fabricated by students. The team will work directly with the client Dr. Srinivas Kosaraju to verify if the design meets his needs. The primary objective of these carts is to accommodate a data acquisition

computer that can be taken easily outside the engineering building for outdoor experiments. Current available market designs are very expensive and are made to be used indoors only. The computer cart must be fabricated to carry a CPU, data acquisition equipment, two widescreen monitors, attachment to position keyboard and mouse at adjustable height. It must also have some storage space for user to keep additional cables, manuals of equipment. The design must not exceed the cost of $500.00.

2. The Problem Statement

This section will include all necessary problem formulation information such as needs and goals statements as well as project's objectives and constraints.

2.1. The Clients Need Statement

Dr. Srinivas Kosaraju's need statement is, "The current available mobile computer carts are too expensive and are not designed for outside use."

2.2. The Problem Definition

2.2.1. Goal Statement

The project goal is to design two mobile computer stations that are less expensive than available marketed products and can be operated in outside conditions.

2.2.2. Design Objectives

Team 12 determined the objectives based off the client's quantifiable expectation on how the computer cart should perform. These objectives will drive the design process and help the team formulate each part of the design in the future. The objective is as follows "Design two inexpensive mobile computer stations that can easily be taken outside to perform experiments, while resisting the outside elements. In addition the cart must hold dual monitors, CPU, testing equipment, reasonably sized, and be adjustable for different users." The following objectives are listed on (Table 1).

Table 1: Design Objectives

Objectives	Measurement Basis	Criteria	Units
1. Inexpensive	Cost for 2 prototype production	Cost	Dollars
2. Be able to hold CPU, Monitors, and testing equipment	The amount of the storage space	Volume	ft^3

3. Should be adjustable for multiple users	Able to change the height of the station	Height	ft
4. Should be easily maneuverable	Time it takes to transport inside and outside easily	Time	Minutes
5. Weather Resistant	Ability to resist weather conditions	Water accumulation	in
6. Reasonable size	Fit through a door and is light	Weight	lbs.
7. Remain functional after transported	Material not deformed after rolling outside	Material Strength	psi

2.2.3. Design Constraints

The design constraints are based off the permissible conditions of design features, the permissible range of the design and performance parameters our client tasked us with. There are multiple constraints our team needs to abide by in order to create two successful mobile computer station prototypes. The constraints are broken into two categories, which include yes-no constraints and one sided inequality constraints.

- Yes-No constraints
  - The mobile cart has to support two screen monitors.
  - The mobile computer cart has to hold a CPU, keyboard, and a mouse.
  - The mobile computer cart has to move through rough terrain.
  - The mobile computer cart must be easily transported with only one individual.
  - The mobile computer cart must be weather resistant.
- One-sided inequality constraints
  - The cost of each mobile computer cart must be less than $500.00.
  - The storage space must accommodate 2 ft^3.
  - The width of the cart must be less than 3 ft.
  - The height of the cart must be less than 7 ft.

3. Quality Function Development (QFD)

This section contains information describing the Quality Function Deployment (QFD) stage of the team's design process. This section includes engineering and customer requirements, benchmarking research, and the final QFD table that resulted in relating everything together. The QFD can be found on (Table 2) below.

Table 2 : QFD

		Engineering Requirements										**Bench Marks**	
		Yield Strength	Max Deflection	Weight	Time to transport	Force	Material thickness	Cost	Volume	Center of Gravity	Wheel Diameter	Deluxe Diagnostic Fusion Cart	Ergotron WorkFit-C
Customer Requirements	Holds Dual Monitors	X		X					X				O
	Aesthetics						X					O	O
	Inexpensive			X			X	X					
	Adjustable height	X				X		X				O	
	Storage space			X				X	X	X			
	Mouse and keyboard platform							X	X	X		O	O
	Hold CPU							X	X			O	O
	Portable				X	X				X	X	O	O
	Light weight			X			X	X	X	X	X	O	O
	Easy to transport			X	X	X		X			X	O	O
	Weather proof			X			X	X					
	Durable	X	X	X		X	X	X			X		
	Move through rough terrain	X	X				X	X		X	X		
	Units	psi	in	lbs.	min	lbs.	in	$	ft^3	ft	in		
								500 x2					
		Engineering Targets											

3.1 Customer Requirements

This section contains the requirements specified by the client. The client is going to be using this mobile computer cart when performing engineering tests therefore the prototype must meet all his requirements. The relationship to engineering requirements can be seen in (Table 2).

1. Holds dual monitors: The mobile computer cart must be able to hold two computer monitors that operate in parallel.
2. Aesthetics: The mobile computer station must be aesthetically pleasing.
3. Inexpensive: Each station must cost up to $500.
4. Adjustable Height: The monitor's height must adjust for users of different height.
5. Storage Space: There must be enough storage space for engineering test equipment.
6. Mouse and Keyboard platform: A platform should be provided for a mouse and keyboard.
7. Hold CPU: There should be a compartment to put a CPU.
8. Portable: The station must be able to move from one location to another.
9. Light Weight: The station must be light enough to be operated by one person.
10. Easy to transport: The station must move in and out of a building with ease.
11. Weather resistant: The station should not be affected by rainy weather.
12. Durable: The station must be able to withstand bumps and other outside elements.
13. Move through rough terrain: The station should be able to move through grass, rocks, dirt, and uneven terrain.

3.2 Engineering Requirements

The engineering requirements were created based on taking the customer requirements and finding how they would be analyzed. Each requirement has a mathematical unit associated with it letting us translate the customer requirements into units of measurement. The engineering requirements will be used later on when the design and testing takes place. The only exact values known for the requirements are in the cost category, which is $500 per cart. The rest will be specified later on in the process. All engineering requirements can be seen on (Table 2).

3.3 Benchmarking

This section contains two different mobile computer carts that are currently out on the market. Both carts have some design components our client is looking for, but neither fully meets the customer requirements. This is represented in (Table 2).

3.3.1 Deluxe Diagnostic Fusion Cart

The Deluxe Diagnostic Fusion Cart is a mobile computer cart sold by Versa Tables for $459.00. Although this would meet the cost criteria, other aspects would not qualify. The cart only holds one monitor and a space for a CPU. There would be no space for testing equipment and other storage room. The wheels would hinder the cart from moving around outside with ease. All the electronics are exposed to the outside elements as well, making it not weather resistant. Although this mobile computer cart has some of the client's requirements, all are not met.

3.3.2 Ergotron WorkFit-C

The Ergotron WorkFit-C is a mobile computer cart sold by CompSource for $854.99. Its features include dual monitor attachments, a CPU holder, a platform for a mouse and keyboard, and a platform to write on. It also includes four small wheels that allow it to move when pushed. Additional features include 25" total height adjustment, a small footprint and advanced cable management. This particular cart also does not meet all the customer requirements specified. The cost is out of budget and it is not weather proof. The smaller wheels would also hinder it from moving through rough terrain.

3.4 QFD Results

After relating all customer and engineering requirements, the QFD concluded that the most important area of focus will be on the cost, material thickness, and weight. Based on the QFD, these need to be part of the main focus when designing the cart. Research needs to be done to find out the most cost effective way of designing the cart. By doing this the cost will stay below $500.00 per cart. The weight comes in to play when any customer requirement needs to be added to the cart. If material is added, it obviously will add some sort of weight. The QFD shows that the existing products will not meet all the clients' expectations and proves the necessity for students to create a new design. Although some areas need more attention than others, every customer requirement needs to be analyzed in order to have a successful product. All results can be seen in (Table 2).

4. State of the Art (SOTA)

When designing a new product it is essential to research existing designs and products that are already developed. By researching different books and journals, it allows your product to reach its full potential. It also cuts down on wasted time trying to re-invent the wheel, when you could have taken already existing products and improved on them. The following section is a summary of relevant State of the Art (SOTA) compiled in the efforts of designing components for the mobile computer station.

4.1 Mobile storage and computer cart patent

The mobile storage and computer cart patent has a wheeled base on the bottom. On top of that is a lockable storage area with drawers and then a mounting location for a computer. This design contains many of the desired objectives for the project. It contains a storage area that is completely enclosed and it has mounting for a computer. The design is lacking in some areas, the location where the computer goes is not weatherproof so the computer could be easily damaged by the elements. The wheels on the base do not appear to be large enough to handle outdoor travel and they do not appear to have any locking mechanism to prevent the cart from rolling if left on an incline. This patent can be seen in (Figure 1) of the appendix.

4.2 Engineering Mechanics Statics

The design of the cart is going to need to be able to handle many stresses and strains because of the computer, the monitors, and the desire for it to be able to travel through rough terrain. An engineering statics book contains many useful equations and data about designs and how forces from different directions affect them. The information contained in this book will be helpful in calculating the strength of the design and simulating the stresses it will endure.

4.3 Wheel design

The patent illustrates the structure of an axel rod, brackets, and caster wheel that allow the wheels to swivel. The axle rod will be mounted to the base. The Fabricated brackets swivel to adapt to the swivel cavities providing an accurate disposition of the wheels. This patent wheel structure should provide smooth rotating wheels to ease the cart movement.

4.4 Breaking System

The patent illustrates a braking system which can be activated by foot pressure to hold shopping cart from rolling downhill while unloading the cart. The way this braking system work is by an activated wedge pressing on the cart wheels and not released unless the wedge is pulled. This patent could benefit our project to keep the mobile cart from rolling downhill when conducting an experiment.

4.5 Large Monitor computer cart

This patent talks about the design of a mobile flat panel monitor and a computer cart. The cart has a wheeled base, a support structure coupled to and extending above the base, a shelf coupled to the support structure above the base for supporting a computer, and a bracket coupled to the support structure above the shelf. This support structure is adapted to have mounted to it a flat-panel monitor. This patent helps us

with the structure of our mobile cart where we intend to add a wheeled base and a support structure for the monitors.

4.6 Multiple Wheel bases

This patent talks about a multi-wheeled base for a mobile cart that includes one or more swiveling, optionally locking, caster wheels and one or more non-swiveling traction wheels. This design improves the maneuverability of the cart by making it easier to steer and stop. The traction wheels may be manually engaged, which may be operated by a cam and lever. The traction wheels may be automatically engaged, operated by a motor and a threaded shaft or activated by a motion-sensitive sensor and an on/off electrical switch or button. The traction wheels are preferably in contact with the floor when the mobile cart is moving and rise above the surface of the floor when the cart is stationary. This patent helps us with improving the maneuverability of the mobile cart as it describes a working design of the multi-wheeled base and the functions of each of its parts with their benefits to the base structure.

5. Concept Generations

Each member of the mobile computer cart team generated two full cart designs in the efforts of eventually deciding on two final products that will be used. The following section is describing the ten different designs Team 12 created for the project.

5.1. Design #1

Design #1 is designed for optimal desk and storage space. The storage section is split into three sections where you can fit a printer, a CPU, and materials used for data testing. The middle section has shelving that is easily accessible allowing the user to get the material he needs quickly and efficiently. The two sections around it are made out of plexiglass. The thought behind using the plexiglass is so that the user can easily see what is going on with the CPU or printer while being weatherproof. The storage will be connected to a rectangle frame where it will be bolted and secured. The desk section has a lot of room so you can spread out all the necessary materials that you need without shuffling through items. Depending on the user's height, you have the feature of raising or lowering the desk to make it accessible to everyone. The keyboard is attached to the bottom of the desk where you can slide it in and out for easy access while keeping it protected from the weather. The desk will be mounted to the main vertical pole in the middle of the design, which will make the final product sturdy. The monitor mounts allow you to swivel the monitor to a certain angle of your choice, making it easier to take data without the glare on the screen. Since this design consists of four wheels, there will be a handle on the right side of the cart where you can pull or push it with ease.

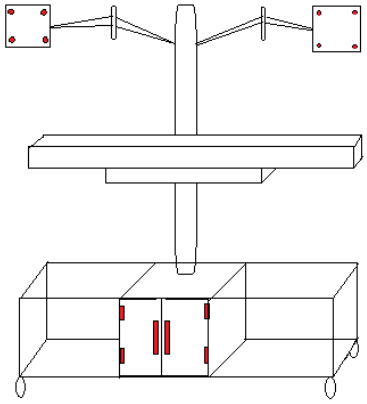

Figure 1: Design #1

5.2. Design #2

Design #2 is designed around the waterproof and maneuverability aspects of our client's need. It will function the same way a stroller works with two large wheels in the rear and one large wheel in the front. Each wheel will have individual axles, helping cut down on the overall weight. The three points of contact will give the cart more stability when traveling to different destinations, while the large wheels help it climb over rough terrain. In addition there will be a handle attached to the back so that the cart can be pulled or pushed. The shape is modeled around a cylindrical garbage bin standing roughly 4 feet high and 3 feet in diameter. Two doors will be attached to the front panel, allowing for easy access to the CPU and experimental equipment. The computer monitors and keyboard adjust up and down the center poles. For weather proofing and ease of transportation, the monitors and keyboard will move inside the cylinder. Once in the appropriate position, the lid can be closed and locked. By doing this, the center of gravity is lower making it easier to push the cart. The cart will have a metal interior shell, giving it structural rigidity while transporting. Some sort of thin material will be used for the walls, cutting down on weight. Design #2 can be seen below in (Figure 2).

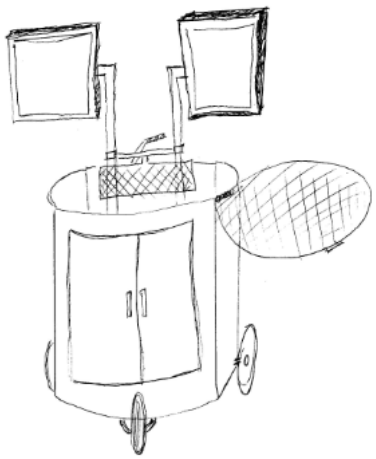

Figure 2: Design #2

5.3. Design #3

Design #3 is a triangular shaped cart with a canopy for weather protection. The canopy on this cart will provide an umbrella over the whole cart and the person using the computer. It will protect from sun and moisture directly above but will have limited coverage for weather coming from the side. The post holding the canopy is also what the monitors are mounted to. The monitors are adjustable up and down and can spin around to be seen from any angle. The top of the cart allows space for a mouse, keyboard and a limited amount of workspace. The side of the cart is a door that opens to allow access to the storage inside. The storage includes a specific place for the CPU and cords, as well as general storage space. The design contains three wheels, one at the monitor point and two at the keyboard side. The wheel in the front swivels to allow for easier maneuverability. The two on the rear are connected with an axle and do not pivot. Above them is a handle mounted to the side to allow for easy movement of the cart.

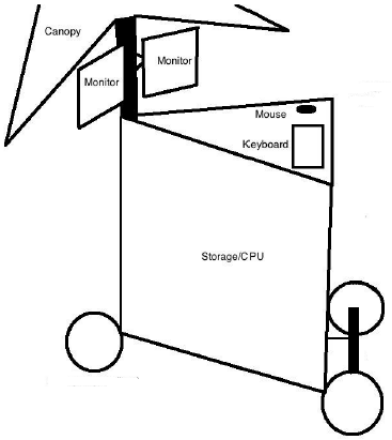

Figure 3: Design #3

5.4. Design #4

Design #4 will have garden rubber wheels that are used in garden carts with the same pulling mechanism, where a rod is attached to the wheels shaft to direct the wheels and pull the cart. The garden wagon frame could be made or bought. The wheels from a garden wagon will be able to withstand rough terrain. The wheels will be attached to an aluminum cabinet with a garage-like door to have the electronics protected when needed and for storage purposes. The garage door can be opened and closed manually. The cabinet will be designed from the inside then welding aluminum plates to the three sides. Inside the cabinet there will be a storage space, a space for the CPU, keyboard, and adjustable monitors. There will be a large storage space that can be shelved and designed to meet the client's needs. The keyboard will be retractable for ease of use. The cart should be easily moved by one person because of the wagon mechanism and should fit through a door easily.

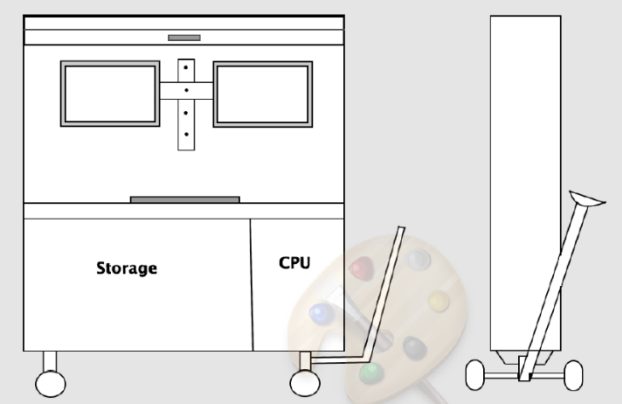

Figure 4: Design #4

5.5. Design #5

Design #5 will be sectioned into three different parts; the storage, a desk, and monitor mounts. The storage is circular in shape giving the design a unique attribute. Shelves will be installed in the storage section where you can put a backpack, pencils, etc. The storage unit will be sitting and bolted on a circular frame. Since the storage is split into two sections, the right side will consist of just the CPU while the left will be for personal needs and data testing materials. The design will allow the CPU to be protected during harsh and wet weather. The desk section will have the keyboard on it with enough room to take notes on. The desk will be held up by two carefully placed poles, which connect the storage and the desk together. The monitor mounts will allow the user to adjust it to any desired height and angle providing maximum comfort. The mounts will be bolted and secured to the desk keeping the monitors safe during transportation. Since this design consists of only two wheels, there will be a handle at the back

of the desk that will allow the user to tip the desk backwards and pull it to the desired location, just like a furniture dolly.

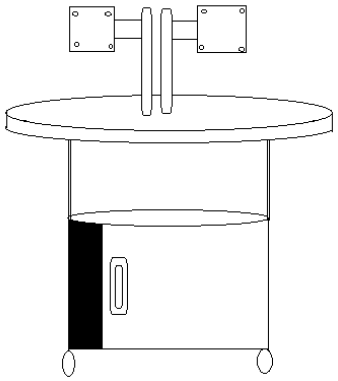

Figure 5: Design #5

5.6. Design #6

Design #6 will have rubber gate wheels with suspension to ease maneuvering. The suspension could be designed or bought online. The cart will have four wheels that will be mounted to an aluminum cabinet. The aluminum cabinet will have the storage space and the CPU. The storage space can be modified depending on client needs. A bar will be mounted to the top of the aluminum cabinet to hold up the keyboard and the two monitors. The bar will be adjustable to go up and down to adjust the height of both the monitors and the keyboard. If needed, the design can be modified to have the keyboard and screen rotate. Furthermore, the box will have hooks to attach a plastic cover to cover the monitors and keyboard when needed. The cover will be transparent to allow for seeing the monitors while covered. There is also a handle on each side to pull the cart easily.

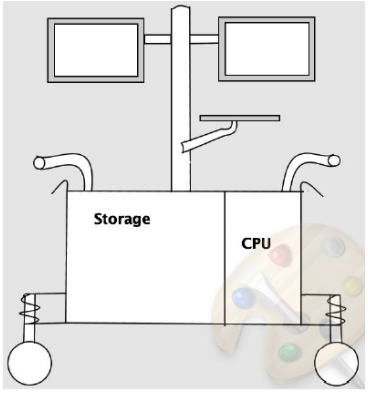

Figure 6: Design #6

5.7. Design #7

Design #7 is generated around the weight, weather proof, and maneuverability aspects of the client's needs. This design will resemble a dolly that can be moved by one individual. Two large wheels will be attached to the back end, allowing for it to be tilted around the axle and pulled to the desired destination. The long handle on the back allows for two hands to be used, which gives the operator more stability. Once at the destination, the cart will be tilted forward and rest on two adjustable legs in the front to keep it level. The cart will consist of a metal frame in the shape of a rectangle. Sheet metal will then be welded on the outside for weather proofing. A single door in the front gives access to the CPU, adjustable shelving, and experimental equipment. The dual monitors and keyboard will adjust up and down the center pole, allowing for multiple users. When the cart needs to be transported the monitors and keyboard slide down into the component and the top lid is slid shut. The same lid can be used as a table that has extending arms for support. A plastic window will be incorporated on the side wall so the monitors can be seen when the lid is shut. The overall size of the rectangle will be 4 feet tall by 2.5 feet wide. Design #7 can be seen in (Figure 7) below.

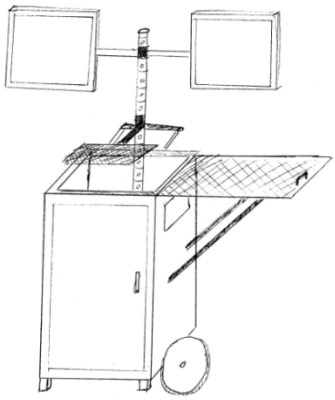

Figure 7: Design #7

5.8. Design #8

In this concept design, there is a column on both sides of the cart. Both columns are on top of a bar connecting two tires on each side of the cart. Each one of the two monitors will be attached to one column with a few inches in between the two monitors when placed in the vertical position. Both the CPU and the storage space will be placed between the second and the third horizontal bars in the middle between the three columns. A horizontal bar will be placed between the two columns to hold the keyboard stand and any other equipment needed by the client. This horizontal bar will be held by the third column that rises from the middle of the lower horizontal bar between the CPU and the storage space. The third and middle column can also rise higher to hold a circular umbrella cover to provide extra protection to the monitors

and top parts of the cart. For easy moving of the cart, there will be a handle attached to each of the two sides of the cart. The cart moves using four medium sized wheels placed on each corner to allow for maximum stability.

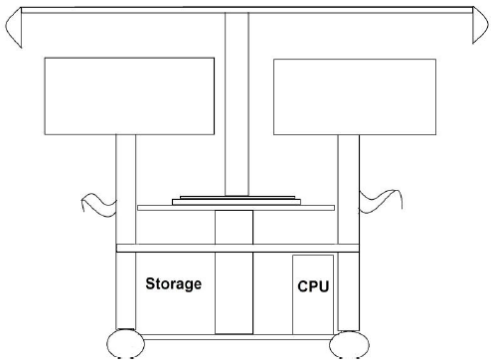

Figure 8: Design #8

5.9. Design #9

Design #9 is a completely enclosed, completely waterproof cabinet on wheels. The outer shell will be sealed so that no water can get inside. The top portion of the front is a door that will swing up and be held up by hydraulic arms. This will give shade and weather protection while working on the computer. The inside of the top portion will have a large platform to hold a mouse, a keyboard, and give ample space to work on. Two monitors will mount side by side at the back and will have height adjustable stands. The bottom portion of the cart will have doors that open and will be split into two sections. One section will be designed specifically to hold a CPU. The other side will be a storage area that will have the option of adjustable shelving. The design will have four wheels mounted to the bottom of the cart. Two of the wheels will have swiveling capabilities to aid in maneuvering the cart. The other two will be fixed to add stability. The wheels will have a braking system that can be activated when the cart is not in motion to prevent it from rolling away.

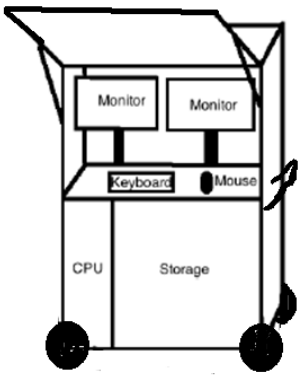

Figure 9: Design #9

5.10. Design #10

In this concept design, there are two sidebars connecting the tires on each side. A horizontal base will be placed on top of two sidebars that will be the base for the cart. The CPU will be held on top of this horizontal base. A second horizontal shelf will be placed between two sides of the cart on top of the CPU space. This will allow for a large storage space above this second horizontal shelf that will be able to hold multiple medium sized pieces of equipment as needed by the client. Between the two sides and on the top, there will be a horizontal base holding the keyboard and serving as the working table for the client. From this base, a middle column rises holding the attachment of the two screen monitors. Both screen monitors can be adjusted up or down to allow for better positioning for the client. This cart has four medium sized wheels attached to the four corners of the cart to allow for a good stability when rolling indoors or outdoors.

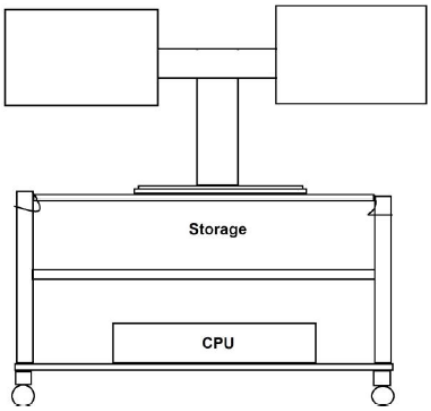

Figure 10: Design #10

6. Concept Selection

After the ten design ideas were created and shared, they were then evaluated using the decision matrices shown in (Table 1) and (Table 2). The matrices dove in to the constraints and objectives of the project to score each of the designs and help determine which ones would be the best solution to the problem. Decision Matrix 1 evaluated the cost, ease of manufacturing, and the aesthetics of each design. Decision Matrix 2 evaluated how weather proof the design was as well as the durability, adjustability, maneuverability, storage space, weight, and size. Once the designs were evaluated, the scores were added and the top two designs are being taken to the next step in the design process.

Table 3: Decision Matrix 1

Decision Matrix # 1				
Concepts	**Criteria**			**Score**
	Cost	Ease to manufacture	Aesthetics	
Design #1	6.8	7.4	7.4	21.6
Design #2	4.8	6.8	6.6	18.2
Design #3	6	5.8	6.2	18
Design #4	4.8	6.6	7	18.4
Design #5	6	6	7.4	19.4
Design #6	5.8	6.4	6.2	18.4
Design #7	6.4	5.4	8.2	20
Design #8	7.4	7	6.2	20.6
Design #9	6.6	5	7.6	19.2
Design #10	8.2	8.4	6	22.6
			10 = High , 1 = Low	

- **Cost**: The project was given a cost limit of $500. All of the concepts are expected to be at or below this amount but the designs were graded on how much they were going to cost to build.
- **Ease to manufacture**: With limited funds and limited manufacturing capabilities, it is important to have a design that can be built within reasonable means. This criterion grades how easy it will be to actually build the design.
- **Aesthetics**: In order for a product to be marketable, it needs to be something that the customer wants to look at and is not an eye sore. The designs were graded based on how pleasing to the eye that each of the designs will be.

Table 4: Decision Matrix 2

Decision Matrix # 2									
Concepts	**Criteria**							**Score**	**Total**: Matrix 1 and 2
	Weather Proof	Durability	Overall Adjustability	Storage Space	Maneuverability Inside / Outside	Weight	Overall Size		
Design #1	1	5.4	9	8.4	5.6	6.8	6.4	42.6	64.2
Design #2	9.4	8.8	4	7.8	6.6	4.8	5.8	47.2	65.4
Design #3	5.4	6	5	5	7.2	7.2	6.8	42.6	60.6
Design #4	9	8	5.2	9	6	4.2	5.4	46.8	65.2
Design #5	1	5.6	7	6.8	5.6	6.6	6.6	39.2	58.6
Design #6	2.2	6.2	7.4	7.6	6.6	6.2	6.6	42.8	61.2
Design #7	7.6	7.6	9.2	6.6	9	7.8	8.8	56.6	**76.6**
Design #8	4.8	5.6	4.8	5.8	5.4	7	5.8	39.2	59.8
Design #9	7.6	7.2	8.8	6.4	8.4	7.2	7.4	53	**72.2**
Design #10	0.8	5.4	4	6.6	5.4	7.6	6.8	36.6	59.2
							10 = High , 1 = Low		

- **Weather proof**: One of the design requirements is that the cart needs to be able to go outside and withstand some weather when experiments are being performed outside. The cart needs to be able to withstand a reasonable amount of weather so that it can still be used even if the weather is not perfect.
- **Durability**: The cart needs to be able to be used outside in areas where the terrain is not smooth and flat. The design needs to be able to withstand a reasonable amount of rough terrain travel and still perform as desired.
- **Overall Adjustability**: More than one person will be using the cart and therefore the cart needs to have a certain level of adjustability to accommodate multiple users. The designs were graded on the overall adjustability including the monitors, the keyboard/mouse, and the work platform.
- **Storage Space**: One design requirement was that the cart needed to have at least 2 ft^3 of storage space. All of the designs are expected to contain at least the minimum amount of storage. This criterion grades the designs on how much storage they offer.
- **Maneuverability inside/outside**: The cart needs to be able to be transported by one person with a limited amount of effort. The carts were graded on how easily they could be transported inside and outside by a single person.
- **Weight**: A lighter cart will generally be easier to transport and easier to maneuver. The carts were graded on how much they would weigh in comparison to the other carts assuming the carts were all made of the same material.

- **Overall size**: The size of the cart is also related to ease of transport and maneuverability. A design requirement was that the cart had to be able to fit through an average sized door so that it could be transported outside and easily through a building. The carts were graded on their overall size.
- **Score**: The score shows the sum of the criteria for each decision matrix.
- **Total**: The total is the sum of the scores from Decision Matrices 1 and 2. The top two designs from each member's matrices are highlighted to display what designs scored highest.

7. Final Design Selection

Based on our client's needs, two different mobile computer carts will be designed and fabricated. The two final design choices were based off the final averaged scores of Decision Matrices 1 and 2. The following is the top two designs selected from the decision matrices.

7.1 Design #7: Two Wheel Dolly

The design with the highest score in the decision matrix was design #7. Based on the two wheeled feature and compact look, it will be called the two wheel dolly style cart. One of the main deciding factors in this design was its high score in overall size, maneuverability, adjustability, and weather proofing ability. The overall size will stand about 4 feet tall when the cart is in transport mode, meaning everything is inside the compartment. It also allows for the cart to be stored inside and fit through doors with ease. The maneuverability came into play with the large wheels seen in (Figure 14) and handle on the back seen in (Figure 11). The two large wheels will allow for one person to transport it without assistance. The handle will provide a steady support to rest your hands while transporting as well. Another big factor in the decision is the unique adjustability for the monitors, keyboard, and lid. The monitors and keyboard move up and down the center pole, which will make the cart suitable for multiple users. Each monitor will be attached to the pole by the rotating arm seen in (Figure 12). The lid will retract outwards giving the operator a table to perform various tasks on. Furthermore, this design will be protected from the outside elements because of its unique ability to store everything inside the compartment. Once the lid is closed, all six sides are protected by sheet metal. Lastly, the cart will have a stable metal frame as seen in (Figure 13), which everything will be built around.

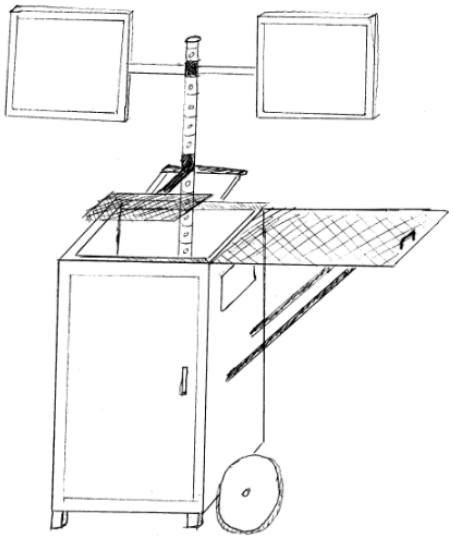

Figure 11 : Final Design 1

Figure 12 : Monitor Mounting System

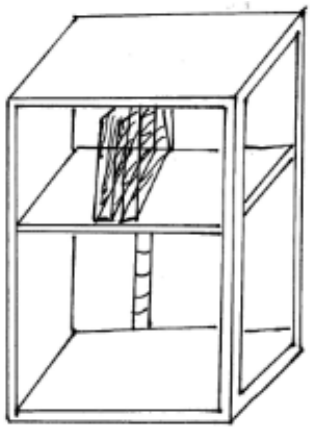

Figure 13 : Final Design 1 Frame

Figure 14 : Wheels for Final Design 1

7.2 Design #9: Four Wheel Cart

The runner up design in the decision matrix was design #9. It has four wheels and a basic rectangular cart shell and is therefore referred to as the Four Wheel Cart. The high scores for this design were its aesthetics, its weather proof design, its adjustability, and overall maneuverability. The approximate dimensions for this design will be 6 feet tall, 4 feet wide, and 2 feet deep. The cart will be split into two main sections. The top section will contain two monitors, the keyboard, mouse, and a platform to provide a work space. The bottom section will be split into smaller sections with one specifically for the CPU and the others for miscellaneous storage. The wheels will be a large diameter caster with two that swivel and two that are stationary (Figure 15). The swivel wheels will increase maneuverability while the fixed wheels will add stability. The door for the top section will swing upwards and be held open by 2 hydraulic arms seen in (Figure 16). This will keep it out of the way when in use and provide shade and protection from weather for the monitors and the user. The front of the door will contain a plexiglass window to allow for the monitors to be seen if the door is closed. The complete enclosure allows for an aesthetically pleasing look with no exposed cords and the shell can be painted to increase the overall look. The monitors will be adjustable within the enclosure to provide better viewing options for different users.

Figure 15 : Caster Wheel

Figure 16 : Hydraulic Arms

8. Concept Generations

8.1 Two Wheeled Dolly Style

The two wheeled dolly style cart is designed to be completely portable and weather proof. It incorporates telescopic tubing which will allow the dual monitors to extrude out of the cart when the operator wants to perform experiments. The design consists of an interior frame created from steel square tubing, while sheet metal lines the exterior. All the experimental components, monitors, keyboard, and CPU can be stored inside. The walls will consist of two Plexiglas windows to allow for the operator to watch the monitors when the cart sits in a closed position. Further description of the design and analysis is presented below.

8.1.1. CAD / Drawings

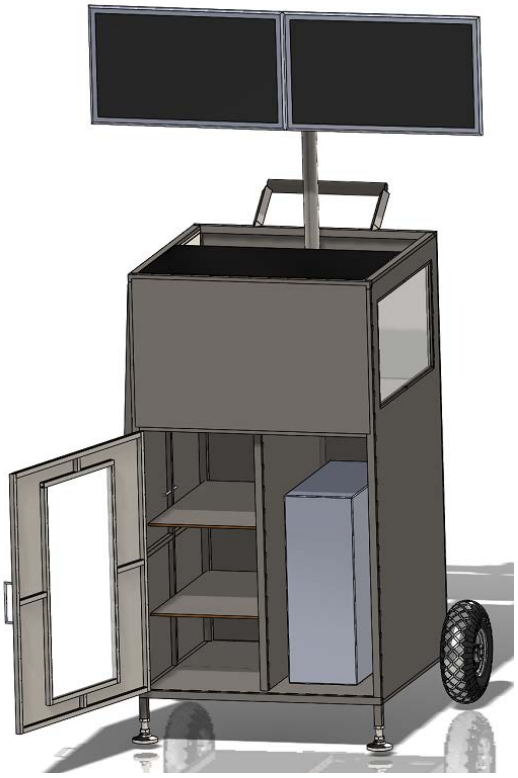

Figure 17 : Cart Design 1

The CAD drawings below are an accurate representation of the design for the two wheeled model. The inner framing of the cart consists of 0.75'' x 0.065'' A513 hot rolled steel square tubing. This frame will give the cart its main structure and stay together during transportation. To prevent the outside elements from damaging any of the interior components, 0.03'' thick steel sheet metal will be welded to the frame. The monitor mounts will be mounted to telescopic tubing with holes drilled at every inch. A pin can be inserted into these holes to position the monitors at the preferred height. There will be two 10'' wheels that will allow for the cart to be leaned back and pushed around. The cart will be 24'' x 24'' x 48'', which will allow for plenty of storage space. The 48'' height is a comfortable position to place your hands and maneuver the cart around. The three Plexiglas windows are made from UV resistant and scratch resistant polycarbonate. This will allow for the operator to look inside when the unit is closed.

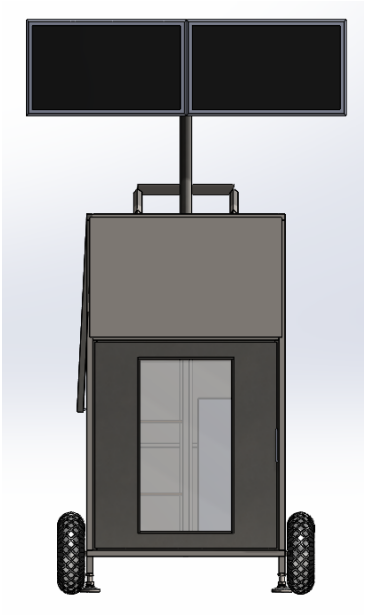

Figure 18 : Cart Design (Front)

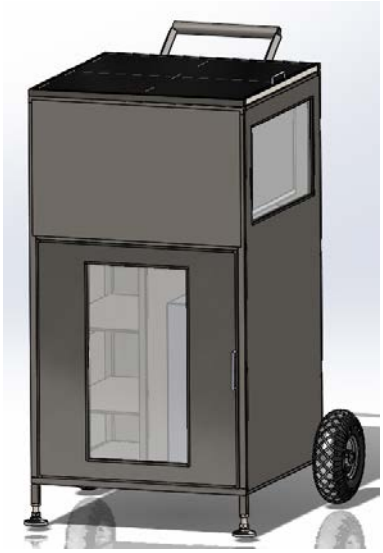

Figure 19 : Cart Design 1 (Closed View)

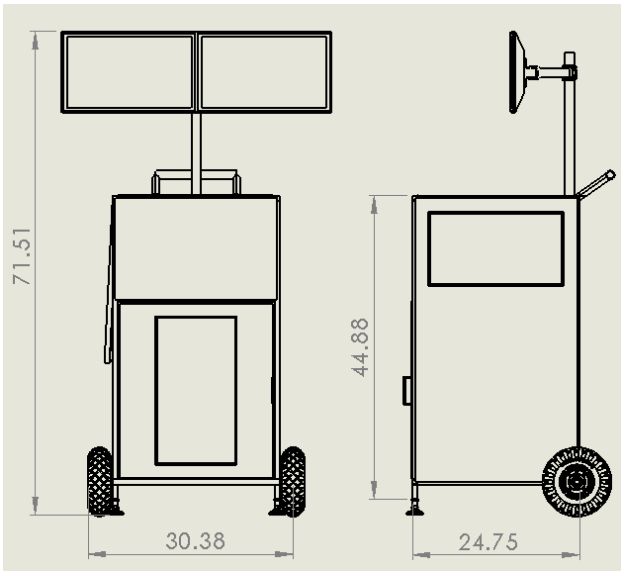

Figure 20 : Design 1 Dimensions 1

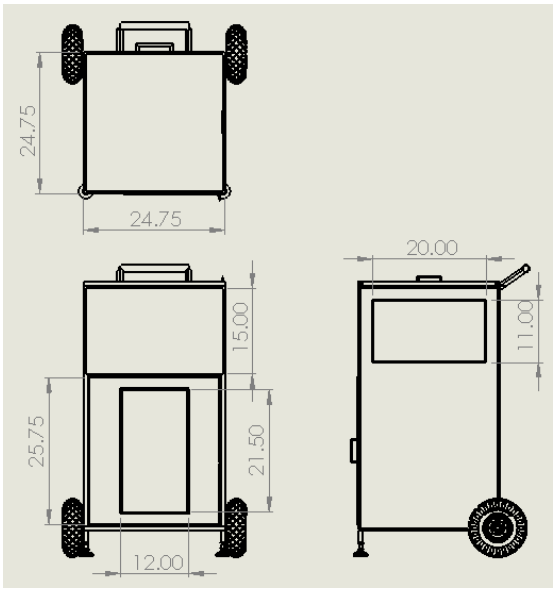

Figure 21 : Design 1 Dimensions 2

8.1.2 Bill of Materials

One of the client's constraints consisted of keeping the carts under a $500.00 budget. To accommodate this request, multiple companies were investigated to find the most amount of material we could purchase for the least amount of money. These companies included Online Metals, McMaster-Carr, Amazon, and Home Depot. The final bill of materials came a little over the initial budget. Extra additions and improvements were made to make the cart efficient and visually pleasing. A bill of materials can be seen below in (Table 5). The total calculated cost for the cart was estimated to be $540.23. Unfortunately the cost came in over budget, but it was significantly less than the cost of any mobile computer cart that is available on the market today.

Table 5 : Bill of Materials

Parts	QTY.	Cost [$]
0.75" x 8' square tubing	6	78.68
0.5" x 8' square tubing	7	49.49
Sheet metal	6	106.02
Plexiglass	2	52.07
Telescoping tubing	1	42.69
Hinges	3	6.68
Monitor mount	1	43.99
Latches / Camlocks	2	14.98
Aluminum plate	1	29.75
Paint	9	38.50
Wheels	2	49.59
Padding	2	13.29
Window siding	3	14.52
Total:		$540.23

9. Manufacturing Process

The large component to the mobile computer cart project consists of manufacturing the design together into one functioning component. This involves a lot of hands-on work assembling the ordered parts together in the Northern Arizona University machine shop. Over winter break, the frame section of the cart was about 90% assembled, taking about 40 hours of time. Measuring, cutting, welding, grinding, and sanding are just some of the components that have gone into the assembly process so far.

Manufacturing the cart ourselves allows us to keep cost down and spend more on parts. The beginning stages of the manufacturing process can be seen in the figures below.

9.1 Frame

The frame structure of the cart is designed to support the outside welded sheet metal, protect the equipment, and support the weight of the cart. The frame is made out of steel square tubing. The square tubing dimension cuts were based on the Solidworks assembly. The edges and burrs were further grounded down and sanded so it could be easily welded together. The smooth edges and burrs provide a resistance to contaminations, including rust or oil, that otherwise will weaken the welds. (Figure 22) and (Figure 23) represent the tubing being laid up on a welding table in preparation to be welded together. Levels and squares were used to get the desired dimensions for each of the tubing members. The frame was also clamped down to the table to make sure no warping occurred due to the intense heat. Welding tacks were first put down and then each section was welded. After welding the frame sections with protruding, weld beads were grounded down. The frame was all MIG welded in the NAU machine shop. The next step to finish up the frame is to attach the front support legs to the cart.

Figure 22: Welding Table

Figure 23: Frame with members welded

9.1. Sheet metal

(Figure 24) represents the process of welding the sheet metal onto the computer cart frame. The sheet metal was clamped down to the welding table the same way the frame was. The sheet metal was initially tacked down at multiple stops to prevent warping of the metal that might occur due to the heat. It was very important to allow time for the metal to cool enough before continuing. Care was taken to prevent the welds to burn through the time metal, which would create holes. Once welds were applied around the entire surface edges, the metal was grounded down to a smooth finish.

Figure 24 : Welding sheet metal

(Figure 25) shows the cart with all the sheet metal walls welded to the frame. The next step is to weld the sheet metal shelves. The shelves will be dimensioned to meet the client need of the storage space.

Figure 25: Front and side view of the cart with the sheet metal welded

Attaching the wheels correctly on the cart was one of the most crucial parts of the project. To accomplish this, an axle was welded on the bottom back corner of the cart. To ensure that the axles are even on both sides, a small pair of angle square tubing was made with a hole in the middle of it with the diameter of the axle for a perfect fit. A final hole was made at the end of the axle for a pin to go through which allows for easy removal and installation of the wheel. Multiple tests were done to make sure that the cart met the standards. Initial tests of usability were done in the machine shop by maneuvering the cart around tables, tight spaces, and especially doors. By attaching the wheels, the cart felt tremendously lighter that it was easily maneuverable and it fit through single doors.

Figure 26 : Wheels

9.2. Monitor mount

Designing the monitor mount was a very challenging part during the build. The first telescoping tube which was welded at the base of the cart had to be perfectly centered in order to provide balance to the monitors. The second tube which was smaller in cross sectional area fit perfectly inside of the first tube which allowed the user to determine how high the monitors would sit by placing a pin shown in (Figure 27). The monitor mount was welded onto the telescoping tubing for easy monitor attachment. Multiple tests were done before the welding the telescoping tube to ensure that the monitors fit inside of the cart facing towards the user. The design of the monitor mount allows for a single user to lift the monitors and place the pin inside of it. (Figure 28) shows the telescoping tubing and how it attaches to the monitors.

Figure 27: Telescoping Pin

Figure 28: Telescoping attachment

9.3. NAU Logo

To establish the cart as property of Northern Arizona University, it was decided to attach the NAU logo to the cart. In order to accomplish this, a logo was designed using Solidworks. It was designed to allow for a CNC machine to cut out the logo and leave it as one piece. The design put four holes in exact

positions so that the logo could be bolted to the frame of the cart. After that, a program was coded in MasterCam to prepare for the CNC machine. A blank slab of 1/8 inch aluminum was used and the final logo was created and ready for installation.

Figure 29: NAU logo

9.5 Paint

The next step in manufacturing the mobile computer cart consisted in preparing it for paint. In preparation, the cart had to be completely free of high weld spots. This was accomplished by grinding and sanding various parts of the sheet metal. A body filler called Bondo was then used to smooth out any low spots and inconsistences produced through manufacturing. Once the Bondo dried, it was sanded down to be even with the sheet metal. The cart was then completely wiped down and cleaned to make sure the paint would stick to the metal. One coat of blue and gray paint was applied to the cart then lightly sanded. Two more coats of each color were then applied, followed by a clear coat. The cart was painted for aesthetic reasons and to prevent the metal from rusting due to outside elements. The process can be seen below in (Figures 30) and (Figure 31).

Figure 30: Sanding

Figure 31: First paint coat

9.6 Windows

The next challenge in the manufacturing process was to install the windows in the cart. The windows are made out of impact resistant polycarbonate. The plastic is 1/8'' thick and was cut using a vertical band saw at a high RPM to reduce the chance of the plastic cracking. It was then inserted into aluminum framing and bolted to the cart. This allows the window to be replaced just in case it is somehow damaged.

Lastly, a clear epoxy was applied to any gaps to create a water tight seal. The window installation can be seen in (Figure 32) below.

Figure 32: Window frame

10. Final Product

The final produce turned out to be a functioning mobile computer cart prototype that can be easily maneuvered outside to preform experiments. It includes a dual monitor mount that is attached to adjustable telescoping tubing. This allows the user to pull the monitors out into a comfortable position, which is held in place by a steel pin. Padding covers the bottom the monitor compartment to keep the monitors protected. A lid sits atop the cart and can be latched down to eliminate water from entering. The cart rests on two 16'' wheels, which allows it to roll over rough terrain easily. The back of the cart has a handle which is used to hold onto when maneuvering the cart. The lower compartment is split into two sections that separate engineering equipment from the CPU. An adjustable shelf is also located in the lower storage area. To eliminate people from opening the cart, two camlocks are used to keep the door and lid locked. The windows on both sides face the monitors and the users can observe the monitors in the closed position. The final design can be seen in (Figure 33, Figure 34, Figure 35, and Figure 36) below.

Figure 33: Final design

Figure 34: Side view

Figure 35: Inside storage

Figure 36 : Top storage

11. Testing

11.1 Testing Environment

When evaluating the objectives, it is necessary to have an ambiguous description of the testing environment. The goal of this environment is to test multiple aspects of our design to conclude whether or not we have met all the project's objectives. In terms of the mobile computer station, the test will be an outside field test, which is where our product is meant to operate. The following analyses will be completed during this test:

1. The client must be able to role the mobile computer cart outside with no assistance required
    a. Fit through door
    b. Weight
    c. Maneuverability
    d. Time it takes to transport
2. The computer station must move over multiple terrains
    a. Rocky, grass, dirt
3. The computer station must role outside and function properly once stationary
4. Testing components must remain undamaged during transportation
5. There must be no water accumulation inside storage compartment
    a. Simulate rain
6. Must be adjustable once in outside environment
    a. Test any adjustable components once at destination

11.2 Testing Results

The testing was performed at various locations around the NAU campus. The cart performed as well as expected in all areas and therefore met all of the design criteria that had been set. A single person pushed the cart through an average exterior door without touching the doorframe. The overall weight of the cart, including the CPU and monitors, was 135 lbs. The cart was taken by one person through a building and out a door to an exterior testing site to insure ease of maneuverability. The time taken to get the cart out to the testing area was only slightly higher than the time to walk to the area. The cart was maneuvered over grass, loose dirt, rocks, and concrete. It was maneuvered up and down a 40^{o} dirt slope. After transporting the cart over the various terrains, the contents were checked to insure that no damage had occurred and that it was all functioning properly. All contents were undamaged and functioned as desired. The cart underwent a rain simulation and no water was found in the interior. All adjustable components were tested and functioning properly after the terrain testing. The monitors were raised, set to

the maximum height, and ready for use all in less than one minute. The maximum height for the monitors is 71 inches from the ground. The force needed to pull the monitors in the up position is 20 lbs. (Figure 37) below shows the cart being pulled up a dirt slop.

Figure 37: Testing

12. Conclusion

The team produced a mobile computer cart that met the client's needs and constraints which can be used by future engineering students in various classes. The mobile computer cart works as an effective transportation device for experimental and computer equipment. The computer cart is easily maneuverable inside and outside by one individual, which make taking data inside and outside very easy. The final cost came in $40.23 over the requested budget, but was significantly less than current mobile cart on the market. The group feels that the overall concept is sufficient enough but improvement can be done to eventually be marketed.

13. References

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