Optimization of the Welding Training Simulator

MECH 497- VALUE ENGINEERING PROJECT

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Executive Summary

Our client, 123 Certification Inc., builds portable welding simulators. They came to our Value Engineering group with the objective of designing a stationary simulator at a lower cost. We were tasked to fulfil these goals using the Value Engineering methodology.

To achieve our goals our main approach was to improve on basic components of the simulator. These components consist of the motion sensing system, display, casing, video glasses, and onboard computer. For each of these, we came up with multiple proposals to replace the current component. We evaluated each proposal according to the value engineering process.

We combined these proposals into scenarios; each scenario had a cost and merit corresponding to its proposals' evaluations. We analysed the scenarios based on overall cost, merit and feasibility. Most scenarios we developed were significantly less expensive than the current simulator; therefore we concluded that the scenario with the most merit would be our final scenario. Here are our proposed changes:

- Motion Sensing: Use magnetic motion sensing instead of an infrared camera. Replace the Polaris Vicra with Sixense's Razer Hydra.
- Display: Use a larger and more robust touch screen. Replace the ELO Intellitouch with a Samsung 32" LCD Touch Screen.
- Simulator Housing: Use a kiosk type casing instead of the current portable casing.
- Computer: Use a bare bones assembly instead of the current computer.
- Video Glasses: Replace the eMagin Z800 with Sony's HMZ-T1 headset.

Making these drastic changes to the current product would convert the simulator to a stationary design and increase its aptitude to a workshop environment. This scenario reduces the total cost of the components from $16 954 to $5 730, with a cost reduction of 66.2 %. While this is a large reduction in cost, we have not factored in the cost of assembly, software integration, and shipping.

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1. Introduction

1.1. Company Profile

123 Certification offers various professional services related to welding, but their primary business is training for welders. They operate in the small niche market of virtual reality and welding, where schools and companies demand a cheaper way to train welders. Most welding operations are dependent on the precise movements of the welder's hands and welding gun. The speed and orientation of the welding gun governs the quality of a weld. The skill of a welder is largely dependent on practice, which can be expensive if done using real materials. Thus, there is a demand for a welding simulator where the user's movements are projected into a virtual welding environment.

123 Certification has a broad scope for a small company; they both design and build welding simulators. They have developed their own software for the simulation, which creates the virtual welding environment. They also assemble the simulators from basic components, and ship the products to the clients. The simulators they currently build are of a portable design.

123 Certification has participated in the Value Engineering course here at McGill before and this year they came to McGill with a new goal: analyze the concept of a stationary welding simulator for a lower cost.

1.2. Current Product

The current product of interest is the ARC+ Virtual Welding Simulator. The user of this simulator uses a replica welding gun and mask. Motion sensing captures the movements of the mask, gun and secondary welding tool with very high precision. The simulation is visualized by the user via video glasses in the welding mask. There is also a touch screen that is used to set up a session, or used to review a simulation. A defining feature of the ARC+ is that it is portable and can be used in many environments.

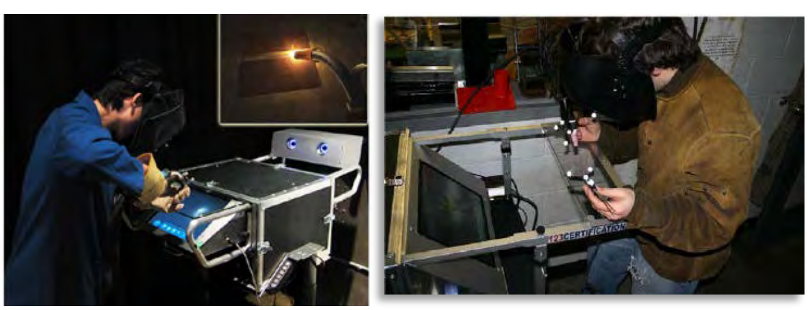


Figure 1. The ARC+ Virtual Welding Simulator

The motion sensing system is made up of an infrared (IR) camera and passive motion sensing spheres attached to the mask and tools. The motion sensing is very precise, due to the high quality of the IR camera. In fact, the same IR camera is often used for surgical applications, where precision is a matter of life and death!

123 Certification caters to a small market, which expect premium products and are prepared to pay for it. Thus, expensive, top of the line products are used to build the ARC+.

2. Organization Phase

123 Certification would like to build cheaper simulators. One proposed approach is to build stationary simulators instead of portable ones. The idea is that, in losing the portability feature, less cost would be focused on the structure, thus a less expensive simulator.

Our client is open to changing the components of the simulator. This includes the motion sensing system, video glasses, simulator housing and onboard computer. Our value engineering group focused on finding lower cost components, while still maintaining a high quality, to replace the current ones on the ARC+.

123 Certification specifically requested a larger display of at least 30 inches to replace the current touch screen. In addition to being larger, a desired (but not required) feature would be impact and scratch resistance. This is because the simulator may be used in a welding workshop, where wear and tear is inevitable.

2.1. Objectives

- Use the Value Engineering method to design a less expensive, stationary welding simulator

2.2. Goals

- Stationary Design
- Reduce cost by at least 20%

2.3. Scope

- Focus on the physical components of the product

2.4. Limits

- Do not focus on software, structural, or shipping issues

2.5. Study Constraints

- The motion sensing must track three independent objects with 6DOF
- Motion sensing must have precise motion tracking within a $1m^3$ volume
- The display must be at least 30 inches
- Attractive design

3. Information Phase

123 Certification provided all the relevant information for this project. Most importantly we were provided a bill of materials of the ARC+, which was vital for our goal of lowering the cost. Additionally, all the technical requirements were specified for the motion sensing and computer systems. Approximate dimensions were specified for the rest of the technical components.

We had the opportunity of visiting the 123 Certification offices during this phase. During this visit, we had the opportunity to use the ARC+ and perform a simulation. This visit helped put a physical perspective on the components we would be looking to change.

3.1. Technical Information

- System requirements of the onboard computer
- The bill of materials of the ARC+
- The detection system requirements (axis precision, repeatability, detection volume, frequency)
- Approximate dimensions of the components

3.2. Economical Information

- The bill of materials with a cost breakdown
- Reducing costs by designing a portable version of the welding simulator was a key objective

3.3. Social Information

- To be used in a workshop learning environment; ie. in industry or in a welding training school
- Permanent placement (not portable)
- Must be resilient to dust and debris
- Preferred if screen is impact and scratch resistant
- Aesthetics and a professional appearance is also required of the product design

4. Function Analysis Phase

Functional analysis is a crucial part of the value engineering methodology. We used a systematic approach to fully understand and explain all functions of the welding simulator in terms of usage instead of immediately searching for problems and their solutions.

A function is an action that the final product must accomplish in order to satisfy the needs of the client. If the simulator did not accomplish this function, it clearly would not satisfy the client's requirements. A function is most easily and clearly expressed in its simplest form; as an active verb and a measurable noun only. A function can either be basic (crucial action to be done by the product), secondary (required to support the basic function), or a constraint (limitations upheld by the client or defined by the application or technology).

4.1. Identifying Functions

In order to decide upon a list of functions, the team utilized three methods: *intuitive research*, *environment analysis*, and *sequential analysis.*

4.1.1. Intuitive Research

Intuitive research involved individual and team brainstorming of basic functions of the welding simulator. General discussion of the function ideas sparked further ideas amongst the team.

The following is a list of the relevant functions of the training simulator, as determined using the intuitive method:

- Detects motion
- Imitates welding
- Saves movements
- Captures motion
- Trains welders
- Instructs techniques
- Saves data
- Converts movements to signals
- Records movements
- Simulates in 3-D
- Senses hand motions
- Ensures reliability
- Interacts with user
- Displays instructions
- Accepts instructions
- Explains steps
- Displays interface
- Resists impact
- Conveys instructions
- Projects visually
- Accepts commands

4.1.2. Environment Analysis

Throughout the simulator's life cycle, the product is used and interacted between various users and environments. In this context, environmental interactions include:

- Trainee or welder
- An observer or instructor
- Maintenance and IT
- Training classroom or workshop setting

In this analysis, each of these entities were considered and relevant functions were determined. Functions that relate to all possible connections during its use were identified and discussed.

The following diagram depicts these interactions:

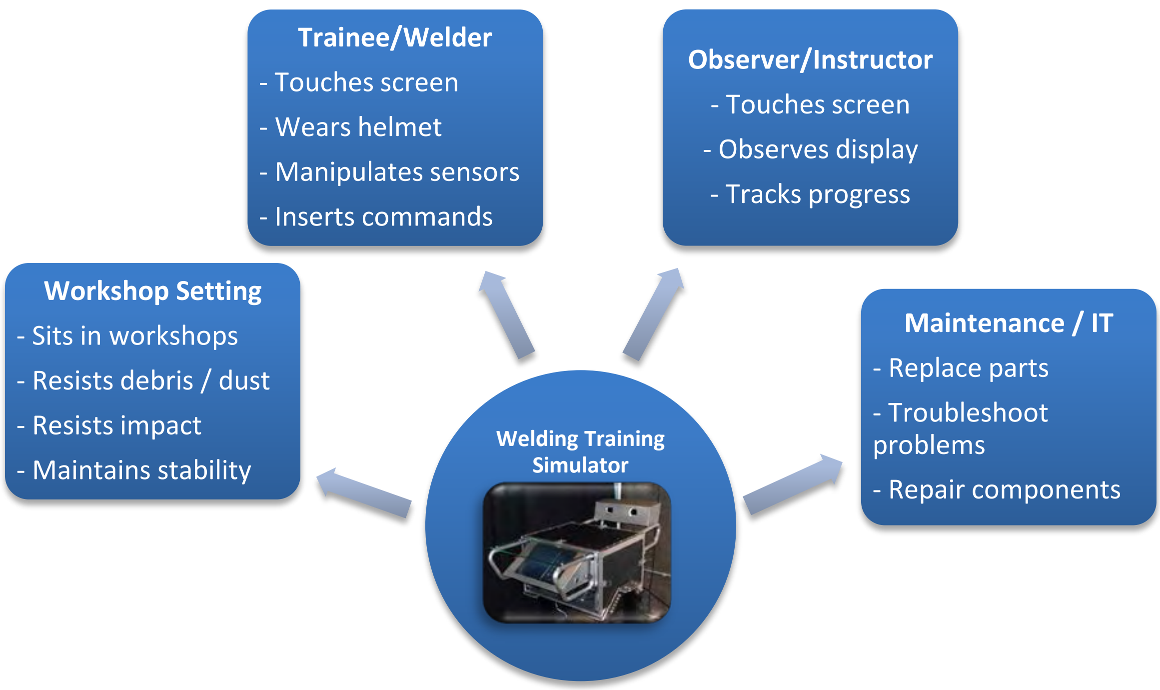


Figure 2. Environment Analysis Diagram

4.1.3. Sequential Analysis

To use this method, the team considered the entire life cycle process and use of the welding simulator, from the moment after purchase of the product to the end of its usable life. The sequence of its lifecycle is analyzed, and the various activities related to the use of the welding simulator are listed in a table of functions.

The following is a table of the sequence of activities of the simulator as functions:

Table 1. Sequential Analysis

Step	Sequence of Activities	Function Verb	Function Noun
1	Shipment	protect	parts
2	Installation	assemble	device
3	Initiation	begin	session
4	Interact with software	use	interface
5	Interact with simulator tools	conduct	immersive simulation
6	Instructor observation	assess display	trainee 3-d animation
7	Review training simulation	provide	feedback / replay
8	Evaluate trainee performance	study	welding evaluation
9	Turn off	end	session

4.2. Organizing Functions

At this point in the value engineering process, the team had a much better understanding of the welding simulator product and its functional purpose. Function analysis proved very useful in this regard. However, we were left with a jumble of many different functions that needed to be properly organized and hierarchized.

Figure 3. Sean and our Post-it, FAST Diagram

To begin functional organization, the group wrote down all the functions on moveable Post-Its and removed any redundancies. As a first iteration, the team divided the functions into four levels, from the most basic to the support functions as a means of prioritizing. After this rough iteration the functions were relatively evenly divided. From an examination of the basic functions, a primary mission of the product was determined:

Mission: "*Train a welding student in an attractive and cost-effective manner*."

The next iteration involved looking at each level and prioritizing functions, and switching a function's level if necessary. The basic function level should answer the question: "How does the simulator train students?"

With further discussion, the basic functions that answer this question were:

- Imitate welding
- Conduct training session
- Provide feedback
- Ensure reliability

Subsequent iterations of organizing the functions helped the team realized which functions were missing or redundant. Through the process, the functions were placed in hierarchized levels and checked to make sure they followed the "how-why" logic. From left to right, each ensuing function should explain how a basic function could be accomplished. From right to left, the basic function should give reason to why support functions were needed. The goal of each function and when they come into play was also discussed.

After this process, the following complete FAST diagram was assembled, in an effort to classify all functions in a logical manner:

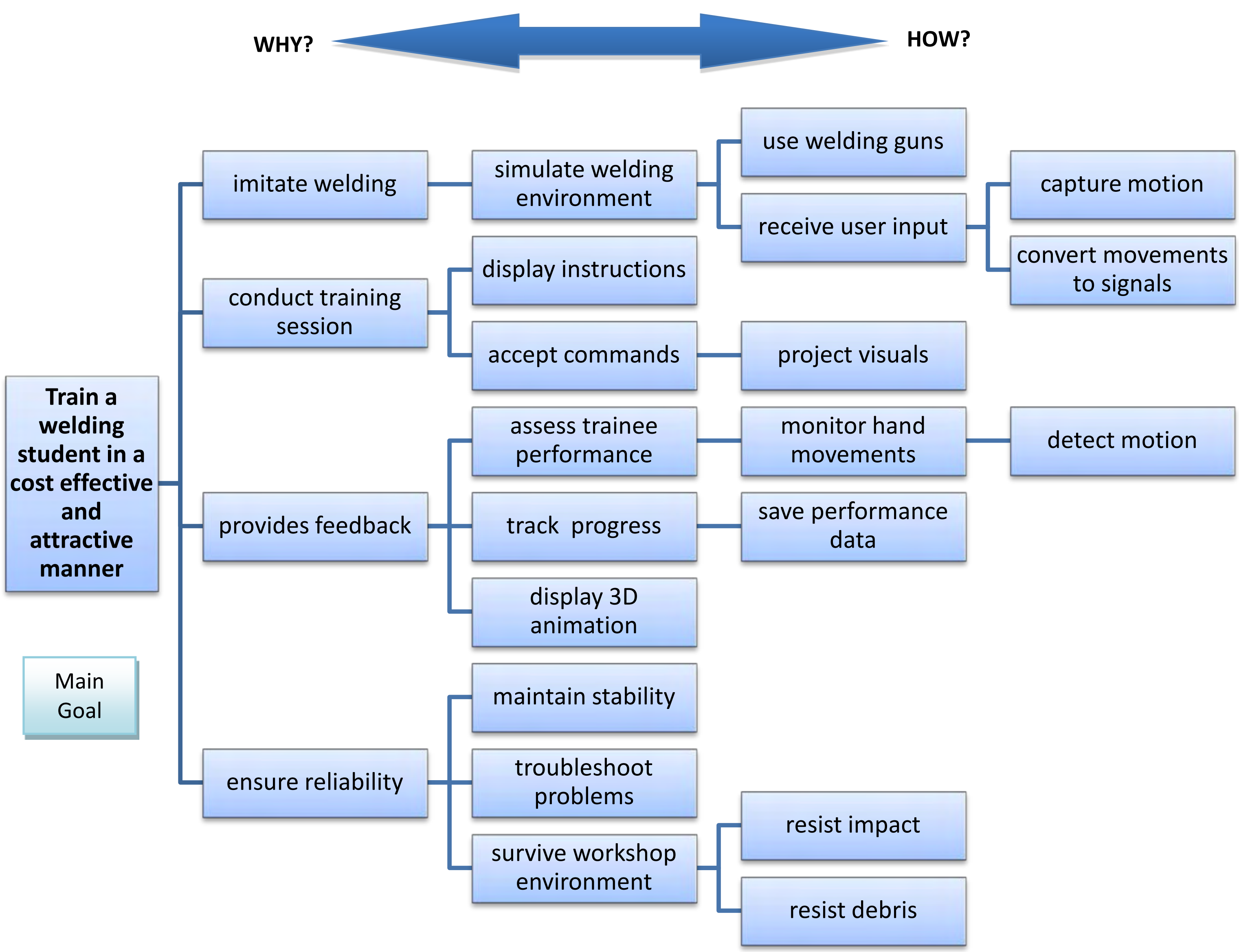


Figure 4. FAST Diagram

4.3. Characterizing Functions

With a logical schematic developed explaining all the functions of the welding simulator, the next step required characterizing the functions based on feedback and requirements from the client. An accumulation of the functions in the last levels of each branch gives a clear picture of all the variables needed to fulfill the client's needs. For each of these functions, the criteria, measurable level of satisfying the criteria, and flexibility of this level is decided upon in collaboration with the client. After discussion, the following table was formulated:

Table 2. Characterizing Functions

Function	Criteria	Level	Flexibility	Rank	Notes
resists impact	impact load	20lbs force	Minimum	2	Resistant to damage from dropping equipment
displays 3D animation	screen size	30 inches	Minimum	2	Must be easily viewed by an observer
uses welding gun	weight	10lbs	F0	1	Required equipment by client
detects motion	number of items to track	3	F0	1	Helmet & 2 welding torches
	tracking accuracy	max 0.5mm	Maximum		High tracking accuracy needed
converts movements to signal	out of scope				Company software developers responsible for this function
troubleshoot problems	out of scope				
maintains stability	oscillation of movement	0	F1	4	Stationary setup
resists debris/dust	motion sensor precision	No effect	F0	4	Sensors must not be affected by accumulation of dust
captures motion	sensor precision	0.5mm	Maximum	1	High precision needed for simulation
	durability				Durable solution required by client
	working area	$1m^3$	Minimum		Range needed for training
	# of sensors	3+	Minimum		Helmet & 2 welding torches
	degrees of freedom	6	F0		Complete motion must be tracked
receives user input	CPU time response	1.5GHz	F1	2	See appendix for details from client
	Precision	1mm	F1		High motion sensor precision tracking
Displays instructions	Screen brightness	High	F1	3	Must be easily viewed by an observer
	screen tilt angle	-	-		Must be easily viewed by an observer
	screen size	30in	minimum		Must be easily viewed by an observer
	surface finish	Smooth	F3		Left to team discretion
	attractiveness	High	Minimum		Attractive aesthetics required by client
	reflectivity	Low	F2		Must be easily viewed by an observer

5. Estimating Functions

Functional cost analysis is a very crucial step in the entire value engineering process. To estimate a function, a suggested monetary value is distributed to each finalized function. The weight on each function needs to be decided in the way so that the new cost distribution will consist with the interest of the client and can maximize client's satisfaction. The main object to conduct the functional cost analysis is to identify mismatches between function cost and function value. This can be achieved by comparing the actual cost of each function with its corresponding adjusted function value.

5.1. Actual Function Cost

The following table (Table 3) was created to study the actual cost of each function. We broke all components down into the functions they accomplish. Then we distributed the cost of each component to its functions based on what percentage of the components purpose is attributed to that function. At this point the total function cost can be determined by summing all the sub-costs of that function.

According to Table 3, the top expense is the Convert Movements to Signal function, which accounts for approximately 31% of the total value. In sharp contrast, the company has only invested $248.21 on the Troubleshoot Problems function, which is about 1% of the entire cost. Indeed, there is a fairly uneven cost distribution among functions.

Table 3. Actual Function Cost

Component	Resist Impact	Display 3D Animation	Simulate Physical Interactions	Detect Motion	Convert Movements to Signal	Troubleshoot Problems	Maintain stability	Resist Debris/ Dust	Receive User Input	Display Instructions
Camera				$4431.58	$4431.58			$984.80		
Touch Screen	$26.05	$104.19				$26.05		$26.05	$182.33	$156.28
Computer					$1099.44	$122.16				
Support	$754.49		$301.80				$980.84	$980.84		
Welding Accessories			$409.31						$136.44	
Video Glasses		$1259.30								$539.70
Others	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100
Shipping	$188.23									
Actual Function Cost	$880.54	$1463.49	$811.11	$4531.58	$5631.02	$248.21	$1080.84	$2091.69	$418.77	$795.98

5.2. Function Cost Analysis

To determine if the current cost distribution matches the company's focus, we prepared a value index table (Table 4) and compared the actual function cost with function worth. First, each function worth percentage was adjusted based on the company's preferences. To calculate the function worth in dollars, we simply multiplied each percentage with desired total product cost (a 20% reduction of current cost). Then the value index was calculated to find function cost vs. function worth ratio.

Having a value index of one means that the function cost is equal to the function worth and no re-allocation of funds is required. While if the value index is too big or too small, it indicates a large discrepancy between these two values.

In Table 4, the Resist Debris/Dust function has a value index of 5.76. That means that the actual spending is much greater than the expected value (indicated by three arrows down). On the other hand, the Receive User Input function has a value index as small as 0.19, which implies that more resources should be spent on this function (indicated by three arrows up). It seems that there are many discrepancies between the actual function cost and the function worth.

Table 4. Value Index

	Resist Impact	Display 3D Animation	Simulate Physical Interactions	Detect Motion	Convert Movements to Signal	Troubleshoot Problems	Maintain stability	Resist Debris/ Dust	Receive User Input	Display Instructions
Actual Function Cost ($)	880.54	1463.49	1220.41	4531.58	5631.02	248.21	1080.84	2091.68	418.76	795.98
Function Worth($)	1088.48	1814.14	1814.14	2902.63	1814.14	362.83	725.66	362.83	2176.97	1451.31
Value Index	0.81	0.81	0.45	1.56	3.10	0.68	1.49	5.76	0.26	0.55
Comparison	↑	↑	↑↑	↓	↓↓	↑	↓	↓↓↓	↑↑↑	↑↑

To visualize the differences between function worth and function cost we created two pie charts (Figure 5). The left pie chart shows the actual function cost for the ARC+, while the right pie chart presents a recommended function cost re-distribution.

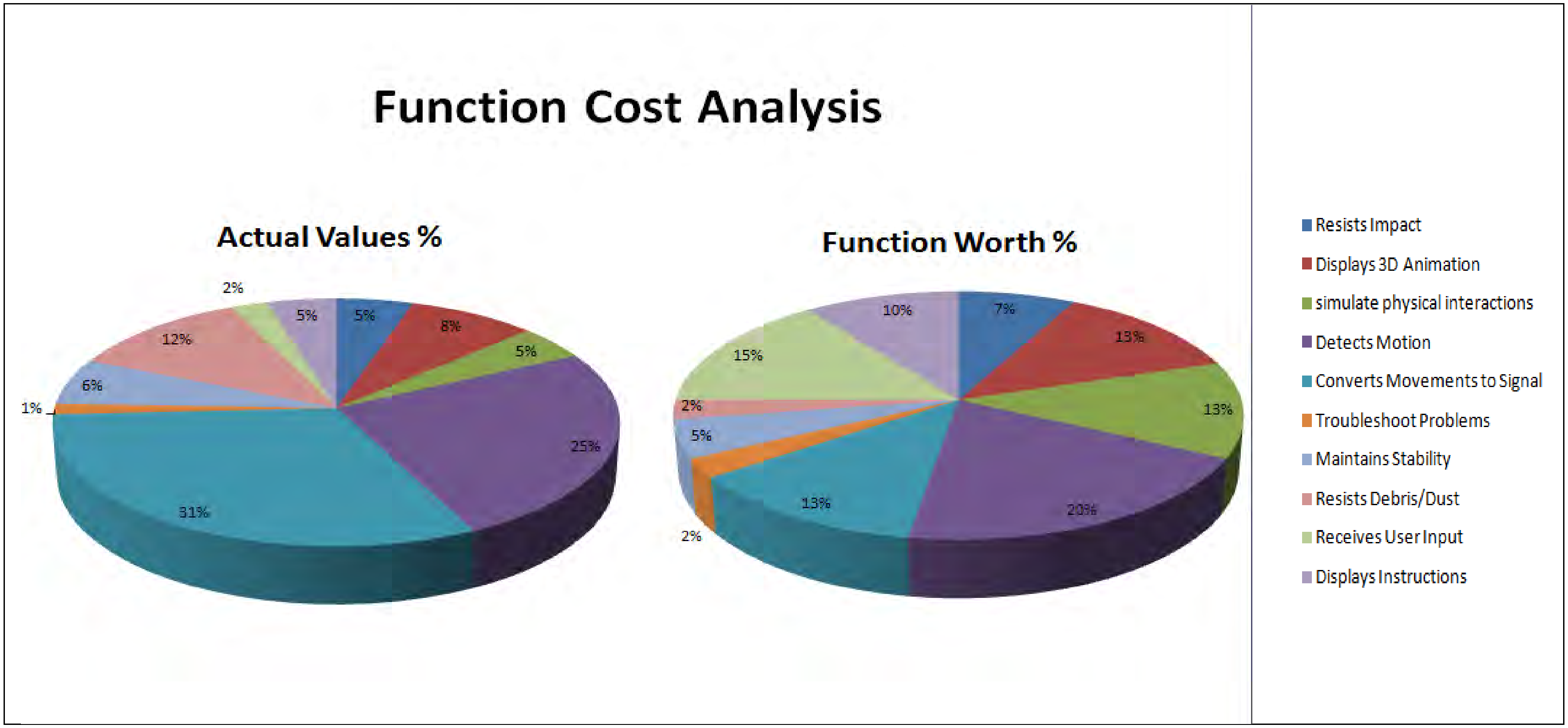


Figure 5. Function Cost Analysis

6. Creativity Phase

The completion of function analysis leads to the next phase of value engineering, which is the creativity phase. The main goal of this phase is to propose solutions for the functions in creative and innovative ways.

Potential solutions were found to fulfill each function task during this stage. When completing this phase we made sure to be open-minded and to pursue new ideas to accomplish each function. At this point there were absolutely no limitations, restrictions (such as product constraints), or concerns about product feasibility.

Each member of the team contributed with their own ideas. We combined the results and then evaluated all the advantages, drawbacks, and limitations of each idea. In Appendix A is a table listing all these ideas.

Figure 6. Creativity Phase

7. Evaluation Phase

Now in evaluating our proposals, we first used our intuition to eliminate some of the ideas from our brainstorming session that were obviously unsuitable for the purposes of this project. This process can be seen in Appendix A in the Suggested Proposal with Elimination table.

For the next step of the process, each member of the team scored all the remaining proposals (those highlighted in Appendix A) out of ten, based on our previous research. The scores of each proposal were averaged to give it its final score.

Then, according to their scores, each of the proposals was ranked. The top proposals for each function were then researched thoroughly and fully developed. Below is a table containing these top proposals:

Table 5. Proposal Rankings

Receives user input	Rank	Resists debris	Rank
Projection on the wall	3	Drawers system	3
Finger touch	1	Metal casing	2
Infrared grid detection	2	Plastic casing	1
Displays instructions	**Rank**	**Displays 3d animation**	**Rank**
Touch screen	1	Video Glasses	1
Adjustable display	5	Projector	3
Projector	4	2 masks for monitor	4
LED Colour display	3	OLED peripheral vision screen in helmet	2
OLED peripheral vision screen in helmet	2	**Detects motions**	**Rank**
Maintains stability	**Rank**	Camera	5
Vibration absorbers	5	Magnetic motion sensor	1
Projection on to the wall	2	Infrared	2
Truncated Cone	1	Accelerometers	4
Curved base (ie. Mac)	4	Gyroscopes	3
Wide base, thinning	3	**Converts movements to signals**	**Rank**
Resists impact	**Rank**	Computer	1
Welding station separate from the monitor (detachable)	4	**Troubleshoot problems**	**Rank**
Hinged lid on the monitor	3	Standardization of parts	2
Protective glass over screen	2	User-friendly assembly	1
Impact-resistance screen	1	Ventilation	5
Simulate physical interactions	**Rank**	Heat sensors to detect and avoid overheating	4
Haptic control (touch vibration on screen, ie. Like new cell phones)	1	Crash reports and error log files sent to the company	2
Vibrations to simulate welding / identify errors to the user	2		

8. Development Phase – Proposals

8.1. Head Mounted Displays

Proposal 1: i-Trek 3D PC

Current Situation:

eMagin Z800 3DVisor

The eMagin is a high end product that satisfies the requirement of displaying the simulation to the user. It is a pair of OLED screens attached a head mountable frame, like glasses and is attached to a welding mask. This product is very expensive compared to similar lower end models, at a price of $1799. This cost could be significantly reduced by using a different model of video glasses.
It should be noted that the eMagin has built in head tracking, but this feature is not being used in the end product/simulation. The head tracking feature in the eMagin is an unneeded cost.

eMagin Specifications:
Price: $1799
2 OLED Displays - 16.7 Million Colors
Viewing Equivalent - 105" diagonal movie screen at 12 feet
view angle - 40 degrees
head tracking - 360 degrees, >60 degrees vertical
Aspect ratio - 4x3
Resolution - SVGA - 800x600 triad pixels per display (1.44 megapixels)
Power Supply - USB or 5V DC regulated

Proposal Description

i-Trek 3D PC

http://www.vrealities.com/i-trek3dpc.html

Figure 7. I-Trek 3D

The i-Trek model is essentially the same as the eMagin, but with slightly lower specifications, and no built in head tracking (though head tracking attachments are available).

Specifications:
Price: $700 approx.
Resolution: 800x600
Virtual Image Size: 90" at 10'
Field of View: 35 degrees
Color: 24-bit True color (16.7 million colors)
Input Signal: NTSC/PAL Video, VGA
Modes: 2D and 3D Stereoscopic, supports NVIDIA stereo drivers
Control Functions: Brightness, Contrast, Sharpness, Color and Volume
IPD Adjustments: None Required
Eye Relief: 25MM
Audio: Full Stereo - Integrated Earbud Speakers
Power Consumption: 6V

Discussion
Advantages:

1. Much lower cost (savings of approx $1100 per unit)

Disadvantages:

1. Lower field of view (from 40 degrees to 35 degrees)

Implementation:
To replace the eMagin. The i-Trek would fit inside the welding mask, just like the eMagin.

Cost Summary
Current cost: $1799
Savings: approx $1100

Proposal 2: WRAP 1200VR

Current Situation:

eMagin Z800 3DVisor

The eMagin is a high end product that satisfies the requirement of displaying the simulation to the user. It is a pair of OLED screens attached a head mountable frame, like glasses and is attached to a welding mask. This product is very expensive compared to similar lower end models, at a price of $1799. This cost could be significantly reduced by using a different model of video glasses.

It should be noted that the eMagin has built in head tracking, but this feature is not being used in the end product/simulation. The head tracking feature in the eMagin is an unneeded cost.

eMagin Specifications:
Price: $1799
2 OLED Displays - 16.7 Million Colors
Viewing Equivalent - 105" diagonal movie screen at 12 feet
view angle - 40 degrees
head tracking - 360 degrees, >60 degrees vertical
Aspect ratio - 4x3
Resolution - SVGA - 800x600 triad pixels per display (1.44 megapixels)
Power Supply - USB or 5V DC regulated

Proposal Description

Vuzix Wrap 1200VR

http://www.vuzix.com/consumer/products_wrap_1200vr.html#specifications

Figure 8. Vuzix Wrap 1200VR

The Vuzix model is essentially the same as the eMagin, but with slightly lower specifications, and no built in head tracking.

Specifications: Price: $600 approx. 75-inch virtual screen as viewed from ten feet (approximately 3 m) 16:9 widescreen aspect ratio Twin high-resolution 852 x 480 LCD displays Supports display resolutions of: • 640 x 480 (VGA) • 800 x 600 (SVGA) • 1024 x 768 (XGA) • 1280 x 720 (720p) 60Hz progressive scan update rate 35-degree diagonal field of view 24-bit true color (16 million colors) Weighs approximately three ounces Independent left and right eye focal adjustment Supports side-by-side 3D video for PC gaming Connects to PC VGA or DVI port & USB2.0 ports Head tracker with drift compensation VR Manager software (digital download)
Discussion Advantages: 1. Much lower cost (savings of approx $1200 per unit) Disadvantages: 1. Lower field of view (from 40 degrees to 35 degrees) Implementation: To replace the eMagin. The Wrap 1200VR would fit inside the welding mask, just like the eMagin. Cost Summary Current cost: $1799 Savings: approx $1100

Proposal 3: Sony HMZ-T1

Current Situation:

eMagin Z800 3DVisor

The eMagin is a high end product that satisfies the requirement of displaying the simulation to the user. It is a pair of OLED screens attached a head mountable frame, like glasses and is attached to a welding mask. This product is very expensive compared to similar lower end models, at a price of $1799. This cost could be significantly reduced by using a different model of video glasses.
It should be noted that the eMagin has built in head tracking, but this feature is not being used in the end product/simulation. The head tracking feature in the eMagin is an unneeded cost.

eMagin Specifications:
Price: $1799
2 OLED Displays - 16.7 Million Colors
Viewing Equivalent - 105" diagonal movie screen at 12 feet
view angle - 40 degrees
head tracking - 360 degrees, >60 degrees vertical
Aspect ratio - 4x3
Resolution - SVGA - 800x600 triad pixels per display (1.44 megapixels)
Power Supply - USB or 5V DC regulated

Proposal Description

Sony HMZ-T1

http://www.sony.co.uk/product/head-mounted-display/hmz-t1#pageType=ProductBenefits

Figure 9. Sony HMZ-T1

The Sony HMZ-T1 is similar to the eMagin, but with higher technical specifications and lower cost. The resolution is much higher in the Sony model, and the the angle of view is also larger. The cost of the Sony HMZ-T1 is approx two thirds the price of the eMagin. Unfortunately the product is not yet available in North America, it is expected to be available this November (2011). Specifications: Price: $800 Pixels: 1280 x 720 View Angle: 45 degrees (approx.) 5.1ch Virtual Surround Input and HDMI input: One line Mass: 420g (approx.) Power Supply Voltage: 100V Power Consumption: 15 W
Discussion Advantages: 1. Lower cost (savings of approx $1000 per unit) 2. Higher Resolution 3. Larger angle of view Disadvantages: 1. Product is not yet available in N. America. Implementation: To replace the eMagin. The HMZ-T1 would fit inside the welding mask, just like the eMagin. Cost Summary Current cost: $1799 Savings: approx $524

8.2. Motion Sensor Tracking

Proposal 1: Six Degrees of Freedom Inertial Sensor

Current Situation:

Polaris Vicras (IR Optical Tracking System)

The Polaris Vicras tracks the 3-dimensional motion of passive markers strategically placed on the welding equipment and helmet. These markers are removable and can be used universally on any welding equipment. The IR camera can follow the motion of these markers with high accuracy, although the range and visibility is limited. The cost of this solution is exceedingly high.

Proposal Description

Analog Devices ADIS16362 *i*Sensor®

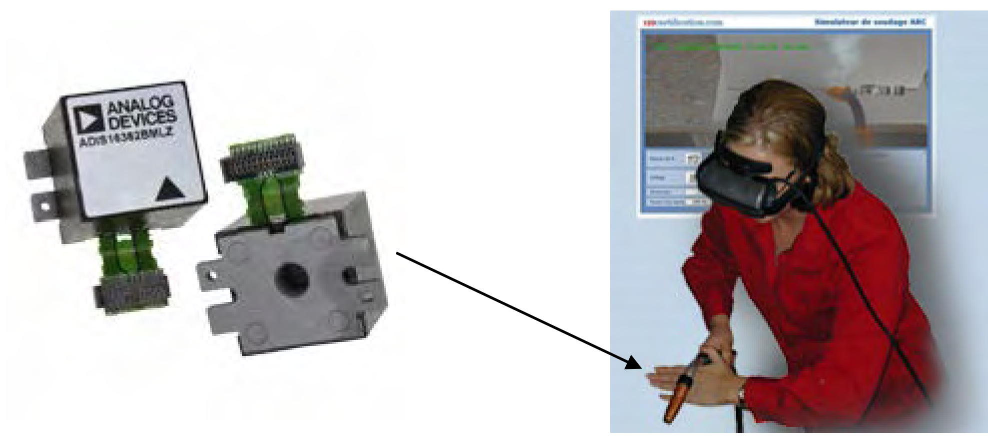


Figure 10. iSensor Integration in Welding Equipment

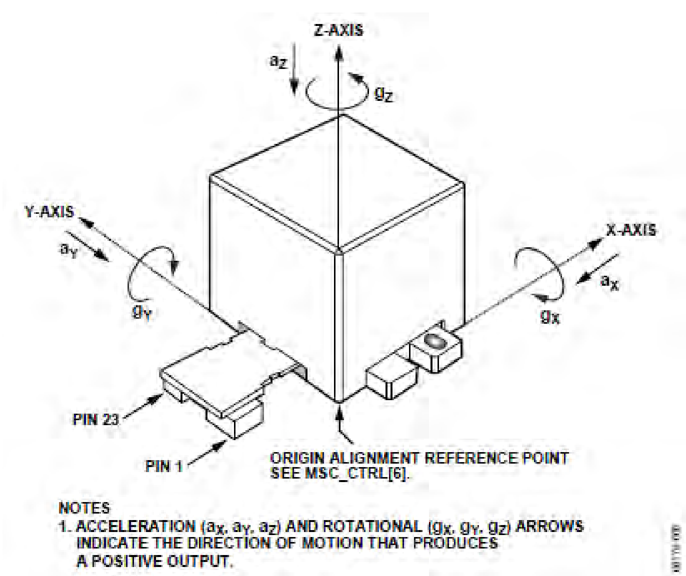


Figure 11. iSensor schematic

The ADIS16362 *i*Sensor® is an inertial motion tracking system that includes a triaxis gyroscope and triaxis accelerometer which allows it to be capable of detecting motion in six degrees of freedom. The technology is highly sensitive with tight orthogonal alignment of <0.05° and a sensitivity of 0.0125°/s/LSB. The sensitivity, bias, and axial alignment are factory calibrated.

The gyroscope is capable of measuring full 360° rotational motion (angular rate) about all three axes. The accelerometer detects various aspects of motion, including translational movement (position and orientation), tilt sensing, and vibration sensing. These sensors effectively capture the required motions that must be measured during a welding training simulation.

Detailed specifications can be found on *Analog Device*'s web site (http://www.analog.com/en/mems-sensors/inertial-sensors/adis16362/products/product.html).

Each sensor module's dimensions are 23mm x 23mm x 23mm, which gives it a compact design that can easily be integrated with the welding equipment and/or the helmet for complete motion capture. All motions during training or interface selection can be tracked using these sensors only.

Discussion

Advantages:

1. Small, non-obstructive and compact device easily integrated with welding equipment and helmet
2. 6 degrees of freedom motion tracker satisfies all motion detection requirements for the training simulator, and does not require any secondary sensors.
3. High sensitivity and accuracy
4. Motion testing and calibration is completed in factory assembly, reducing set-up time.
5. A flexible connector interface allows for freedom of mounting and assembly on equipment.

Disadvantages:

1. Relatively high cost per module, with up to 3 modules required for full motion tracking
2. Designed for excessively high accuracy and unnecessarily capable of withstanding high force/impact and large range of operating external temperatures.
3. Requires compatibility with training software and program coding

Implementation:

3 module sensors are required to capture the motion of two pieces of welding equipment and the helmet. These sensors can be mounted on each piece of equipment at locations vital to the training simulator's accuracy (ie. Edge of welding torch).

The existing training software must be made compatible with the sensor technology.

Cost Summary

Current cost: $9847.95

Proposal sensor cost: $516.06x3 = $1548.18

Savings: $8299.77 or about 84%

Proposal 2: Markerless Optic Motion Capture

Current Situation:

Polaris Vicras (IR Optical Tracking System)

The Polaris Vicras tracks the 3-dimensional motion of passive markers strategically placed on the welding equipment and helmet. These markers are removable and can be used universally on any welding equipment. The IR camera can follow the motion of these markers with high accuracy, although the range and visibility is limited. The cost of this solution is exceedingly high.

Proposal Description

Optic Motion Capture with Camera

Microsoft Kinect Software Development Kit

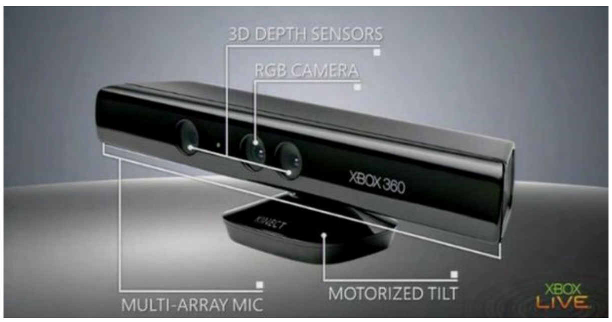


Figure 12. Microsoft Kinect Hardware

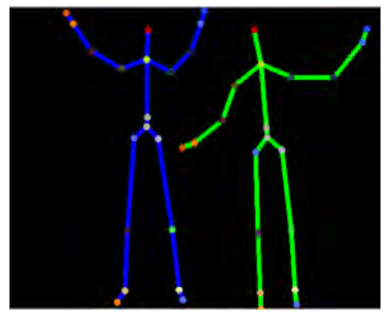


Figure 13. Kinect Skeletal Motion Tracking

Optic motion capture is a rapidly evolving technology. The Microsoft Kinect is a state-of-the-art camera system originally designed for video gaming applications. It is capable of accurately and consistently tracking skeletal motion by sensing colours and depth.

Components of the Kinect include a colour VGA motion camera (640 x 480 pixel resolution), a depth camera (640 x 480 pixels), voice microphone, speaker, and tilt motor for sensor adjustment. The following are a list of the camera's capabilities:

Field of view:

- Horizontal field of view- 57 degrees
- Vertical field of view- 43 degrees
- Physical tilt range- (-27 degrees to +27 degrees)
- Depth sensor range- 1.2 m to 3.5 m

Data Streams:

- 320×240 16-bit depth @ 30 frames/sec
- 640×480 32-bit colour@ 30 frames/sec
- 16-bit audio @ 16 kHz

The existing Software Development Kit currently supplied for free by Microsoft allows developers to build their own code to use the hardware for applications other than gaming. The coding and be altered to detect motion of bodies or equipment and react accordingly. This software is at the moment available for only non-commercial uses, although it is anticipated that a commercial version will be available soon. The camera is to be installed on a surface or kiosk in full view of the training student. It will capture all movements of the student, including interface interaction and during the welding simulation. Other people or objects could also be sensed, if desired.

Discussion

Advantages:

1. All-in-one user interaction with the camera by movement, including pointing to indicate interface selection, and welding training movements.
2. No obstructive markers required
3. Significantly reduced cost compared to present IR camera solution.
4. Camera has potential to be used for a large variety of interactions and uses, that could help improve and develop functionality of the welding simulator.
5. Adjustable camera with tilt
6. Free and available software development kit allows for cheap and easily coding for specification training application.

Disadvantages:

1. At present, only the non-commerical software development kit is available. This limits the proposal to research, development, and testing until Microsoft release a commercial license.
2. Relatively low camera resolution
3. Camera is originally designed to track skeletal motion of the body. Further programming is needed in order to track the motion of welding equipment.
4. Observers or other irrelevant objects may interfere with the accuracy or reliability of the camera's function. Further research is required to ensure this is not a problem during practical use.

Implementation:

Initial research, development, and testing is required using the free SDK. The camera can be installed in a kiosk with ability to capture all necessary movement during the welding simulation. It is recommended that a vertical non-interactive LCD screen is used for this proposal for intuitive interaction between the student user and the training system.

Cost Summary

Current cost: $9847.95

Proposal cost: Kinect Hardware $149.99

Software Development Kit free (*Note: Commercial license cost not yet available)

Savings: To be determined.

Proposal 3: Sixense Magnetic Motion Tracking

Current Situation:

Polaris Vicras (IR Optical Tracking System)

The Polaris Vicras tracks the 3-dimensional motion of passive markers strategically placed on the welding equipment and helmet. These markers are removable and can be used universally on any welding equipment. The IR camera can follow the motion of these markers with high accuracy, although the range and visibility is limited. The cost of this solution is exceedingly high.

Proposal Description

Sixense Razer Hydra Motion-Sensing Controller

Figure 14. Integrate Razer Technology Hydra in Welding Equipment

The Razer Hydra detects motion by tracking the movement of electromagnetic sensors with respect to a main hub. It is capable of tracking six degrees of freedom with a precision of 1mm and 1°. The hardware within the handheld gaming controllers can be integrated in the welding equipment and the welding helmet, allowing for up to four sensors to be used at any given time. No line of sight is required, and so tracking can never be interfered with. The magnetic sensors have up to 12' range, well within the requirements of the client. The technology has a low latency feedback of 60Hz.

Discussion

Advantages:

1. High precision, non-interfering sensors; solves most problems with current solution
2. Very low cost
3. Wide range
4. Low latency

Disadvantages:

1. Not as precise as other motion sensor technologies

Cost Summary
Current cost: $140.00
Savings: $9660.00

Proposal 4: Six Degrees of Freedom Optical Tracking Camera

Current Situation:

Polaris Vicras (IR Optical Tracking System)

The Polaris Vicras tracks the 3-dimensional motion of passive markers strategically placed on the welding equipment and helmet. These markers are removable and can be used universally on any welding equipment. The IR camera can follow the motion of these markers with high accuracy, although the range and visibility is limited. The cost of this solution is exceedingly high.

Proposal Description

V120:Duo tracking system

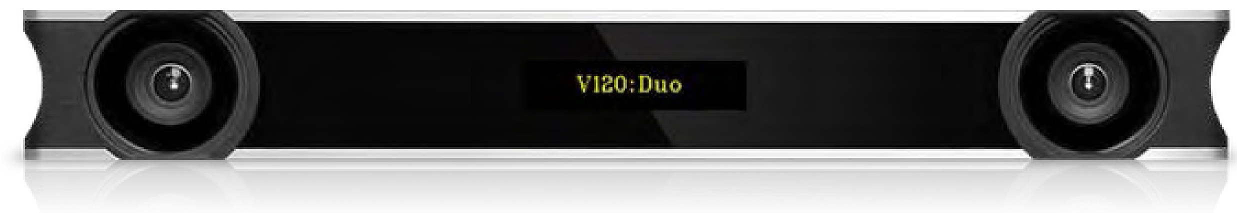


Figure 15. V120:Duo IR Camera

The V120:Duo tracking system is an optical motion tracking system which is capable of detecting motion in six degrees of freedom. It has a 120FPS frame rate, capable of tracking markers down to sub-millimeter movements. It weighs only 0.6kg.

Discussion

Advantages:

1. 6 degrees of freedom motion tracker satisfies all motion detection requirements for the training simulator, and does not require any secondary sensors.
2. High sensitivity and accuracy.
3. Motion testing and calibration is completed in factory assembly, reducing set-up time.
4. One simple input/output jack needed to plug into to begin tracking movement.
5. Durable and highly portable.
6. Much lower cost than current system.
7. Similar to current system so much less re-engineering of software required and easy to set up in simulator.
8. Capable of recording tracking data for later playback.

Disadvantages:

1. Still uses camera lenses, which have limitations in field of view (58 degrees) and can be affected by gathering of dust.

Implementation: Same as current implementation (needs to be placed in casing or kiosk at an appropriate height to see user). Only requires slight re-engineering of software.   Cost Summary Current cost: $9847.95 Proposal sensor cost: $1899 Savings: $7948.95 or about 80%

8.3. Displays

Proposal 1: Interactive Projector

Current Situation:

IntelliTouch Surface Wave Touchscreen

A 17" touchscreen interface is primarily used to display instructions, the interactive interface, the actual welding environment and the training results of a welding session. These surface wave screens are scratch-resistant with a glass surface and high resolution display.

Proposal Description

IN3900 Series Interactive Projector

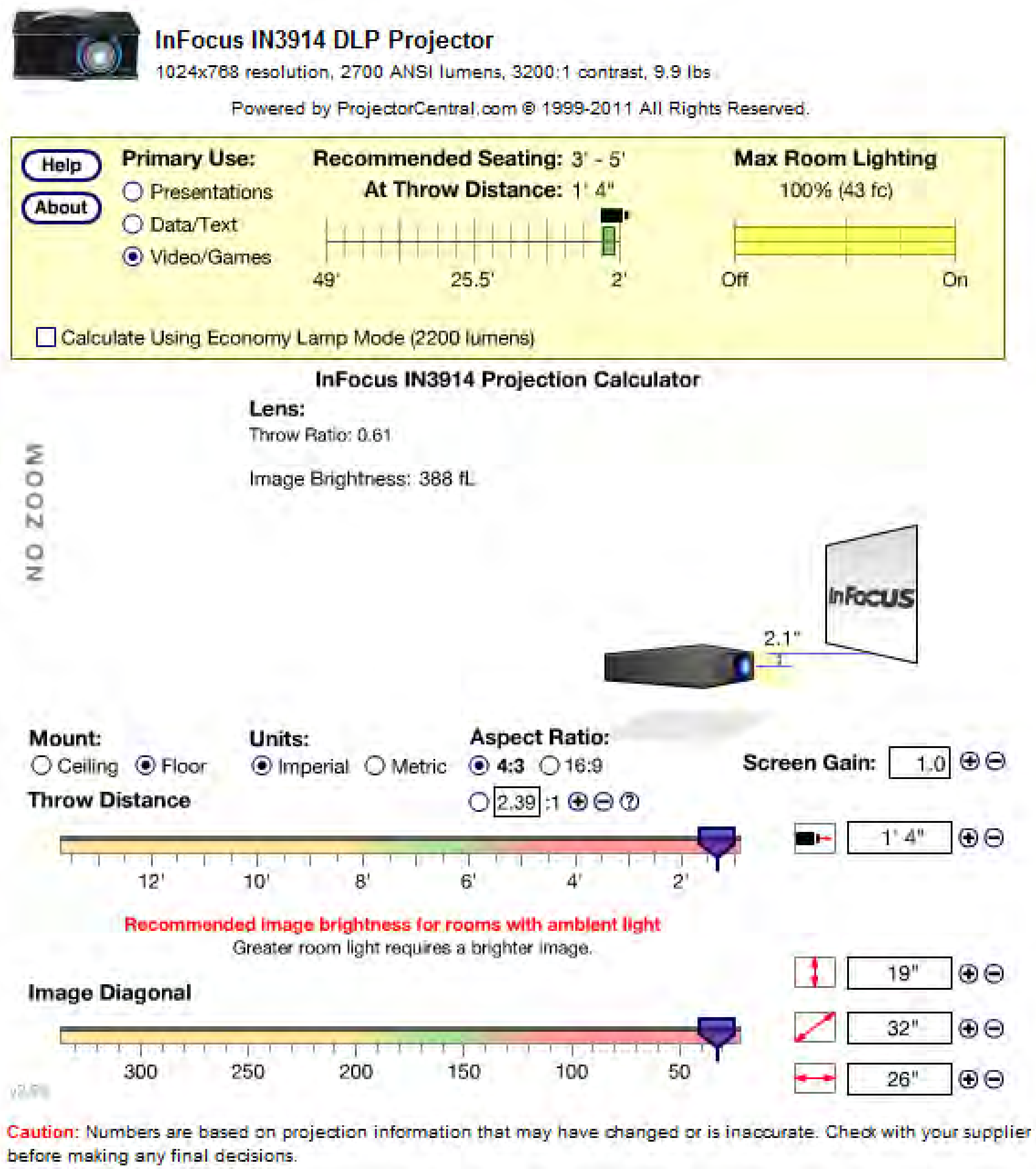
Figure 16. Interactive Projector

Projector

Wand

The interactive projector is an effective technology that presents large-size displays while requiring a short throw distance. All images, selection pages, or animations used for the training simulator can be clearly displayed with this technology. The interactive interface does not require touch or any direct physical interaction by the student or observer. The "wand" is a pointer-like device that is used to make selections on the screen. This wand (or its working internal components) can be integrated into the training equipment, requiring only said equipment to interact fully with the training system.

The projector is easily installed in a small storage kiosk and is displayed on a white wall or small projector screen that is at least 32" in size. The following data from InFocus describes the required approximate throw distances, ambient lighting, and resolution for this size:



The computer hardware can easily be connected to the projector using a USB port or through a wireless LAN connection. 20-watt stereo speakers are integrated so that sounds related to interface selections or welding simulations can be heard by the student and observers.

The following are further specifications of the product (see IN3914):

	IN3914	IN3916
Resolution (native)	XGA 1024 × 768	WXGA 1280 × 800
LiteBoard Wand	Standard	
Brightness	2700 lumens	
Connections (Input)	VGA × 2, Composite, RCA audio, 3.5 mm (mic), 3.5 mm (audio)	
		HDMI 1.3, USB (for display), USB (for wireless LAN or USB thumb drive), LAN
Connections (Output)	Monitor out: VGA, Variable audio out: 3.5 mm, Power out: 5V × 2 amp (for accessories)	
		Wireless-ready Port via USB for 802.11b/g dongle
Control	RS232, USB mini-B	RS232, USB mini-B, LAN (RJ-45)
Aspect ratio (native)	4:3	16:10
Throw ratio	0.61:1	0.52:1
Image size (width)	48.4 - 106.3" (1.23 - 2.7 m)	56.7 - 124.8" (1.44 - 3.17 m)
Image offset	7.5 %	2.5 %
Power consumption	280 watts (Eco Mode); 330 watts (Bright); ‹ 1 watt (Standby)	300 watts (Eco Mode); 350 watts (Bright); ‹ 1 watt (Standby)
Audio	20 w (2 × 10 w), voice and multimedia modes	
Warranty	5 Years	
Standard accessories	VGA cable, Remote control, Wand Kit (includes LiteBoard Wand, wand dock, power charger and USB cables), WizTeach InFocus Edition software	

Discussion

Advantages:

1. All-in-one user interaction with the training simulator. The student can use the same welding equipment to either make selections on the screen or to weld, simplifying user interaction and reducing the risk of accidents or misplacement of the equipment.
2. No fragile touch sensitive components.
3. Short throw distance and bright/clear display at adjustable sizes. The display can easily be viewed from a distance, by the student or by observers.
4. Integrated sound system.
5. Lower cost than shatter-proof LCD touchscreens at 32”.

Disadvantages:

1. Requires a white wall or projector screen to display information. Not all training centers will necessarily have either of these resources available within the classroom. A projector screen included in shipment package may be unattractive, inconvenient, or appear unprofessional for some clients.
2. Requires a support kiosk or desk.
3. Requires a minimal throw distance, which may not be available for some clients.
4. Interface selection with the “wand” or welding equipment may not feel intuitive to some users. Touchscreens that require physical touching or interaction may be easier to use.
5. More costly than present display solution (although change in size should be taken into consideration).

Implementation:
A kiosk is required to support the projector device. This kiosk can be used to contain the projector, the computer hardware, and to store the welding equipment. The kiosk should also be design to protect the projector while it is not in use, and shield it from dust and debris.

A projector screen or white wall in the classroom would be necessary. Inclusion of a screen in the package could be optional, depending on the needs and available resources of the client.

The “wand” can be used as a separate device to make selections with the simulators interface. Alternatively, the electrical components of the want could be installed into the welding equipment so that all interaction with the simulator will be done with the equipment.

Cost Summary
Current display cost: $520.93
Projector Cost: US $1099.00 ≈ CAN $1109.51
Savings: -$588.58 or -211%

Proposal 2: Touch Screen ELO Intellitouch 32" Display
Current Situation: *Touch Screen ELO Intellitouch 10.2''* The current design uses a 10" touch screen panel. The Intellitouch panel is scratch resistant and situated on the portable simulator at an approximately 30 degree angle.
Proposal Description Exact same as current situation, but bigger screen.
Discussion Advantages: 1. Bigger screen (fills 30'' size requirement). Disadvantages: 1. Higher cost. Implementation: Exact same implementation, but casing needs to be designed to fit bigger screen. Cost Summary Current cost: $520.93 Proposal cost: $1700 Savings: -$1179.07 or -226%

Proposal 3: Samsung 32" LED HDTV

Current Situation:

Touch Screen ELO Intellitouch 10.2’’

The current design uses a 10” touch screen panel. The Intellitouch panel is scratch resistant and situated on the portable simulator at an approximately 30 degree angle.

Proposal Description

Figure 17. Samsung LED HDTV

Specifications:

Video	**Screen Size**	32"
	Resolution	1366 x 768
	Picture Engine	HyperReal Engine
	Dynamic Contrast Ratio	Mega Contrast
	Wide Colour Enhancer Plus	Wide Color Enhancer Plus
	Clear Motion Rate	60CMR
Audio	**Dolby**	Dolby Digital Plus / Dolby Pulse
	SRS	SRS TheaterSound
	dts 2.0 + Digital Out	Yes
	Sound Output (RMS)	10 W x 2
	Speaker Type	Down Firing + Full Range
Feature	**ConnectShare™ (USB2.0)**	Movie (Photo : JPEG, Music: MP3 / WMA, M MKV)
	Anynet+ (HDMI-CEC)	Yes
	Auto Channel Search	Yes

	OSD language	English, French, Spanish
	Auto Volume Leveller	Yes
	Auto Power Off	Yes
	Clock & on/off timer	Yes
	Sleep timer	Yes
	Game mode	Yes
	Picture-in-Picture	1 Tuner PIP
System	**DTV Reception (ATSC)**	ATSC
	DTV Tuner Built-in	Yes
Input & Output	**HDMI**	4
	USB	1
	Component In (Y/Pb/Pr)	1
	Composite In (AV)	1 (Common Use for Component Y)
	Digital Audio Out (Optical)	1
	PC In (D-sub)	1
	RF In (Terrestrial/Cable Input)	1
	RF In (Satelite Input)	No
	Headphone	No
	PC Audio In (Mini Jack)	1
	DVI Audio In (Mini Jack)	1 (Common Use for PC Audio in)
	Audio Out L-R (Mini Jack)	1
Design	**Design**	ToC
	Bezel Type	Normal
	Slim Type	Ultra Slim
	Front Colour	Dark Grey
	Stand Type	Square
Eco	**Eco Mark**	Energy Star 5.1
Power	**Power Supply**	AC110 ~ 120 V 60 Hz
	Power Consumption (Stand-by)	Under 0.3 W
Dimension	**Package Size (WxHxD)**	984 x 560 x 120 mm
	Set Size (WxHxD) with Stand	763.6 x 527.1 x 222.7 mm
	Set Size (WxHxD) without Stand	763.6 x 463.1 x 29.9 mm
Weight	**Package weight**	10.8 kg / 23.8 lb

	Set weight with stand	9 kg / 19.84 lb
	Set weight without stand	7 kg / 15.43 lb
Accessory	**Ultra Slim Wall Mount Support (sold separately)**	Yes
	Vesa Wall Mount Support (sold separately)	Yes (200 x 200)
	Remote Controller Model	TM1050
	Slim Gender Cable	1 Component (AV share)
	Power Cable	Yes
	E-Manual	Yes
	User Manual	Yes

Discussion

Advantages:

1. Bigger screen (fills 30'' size requirement).
2. Lower cost.
3. Superior quality screen (much higher contrast ratio).
4. Low weight.

Disadvantages:

1. Not scratch resistant.
2. Not anti-glare
3. Requires separate method of input.

Implementation:

The screen would have to be placed at an angle such that it is easily viewable (it has a 178 degree viewing angle). As well, we would need to include a separate method for the user to input information. This would most likely be a remote control that the user could hold and point at the screen to input information.

Cost Summary

Current cost: $520.93

Proposal cost: $445.99

Savings: $74.94 or 14%

Proposal 4: Samsung 32" Touch Screen LCD Display

Current Situation:

Touch Screen ELO Intellitouch 10.2''

The current design uses a 10" touch screen panel. The Intellitouch panel is scratch resistant and situated on the portable simulator at an approximately 30 degree angle.

Proposal Description

Figure 18. Samsung Touch Screen LCD Display

32'' touch screen LCD display. It has built in speakers, a computer, and a heat-regulating fan. It's glare free, scratch resistant, and shatter-proof.

Table #. Samsung Touch Screen Specifications

Panel	**Diagonal Size**	32"
	Type	S-PVA (B-DID)
	Resolution	1366 x 768 (16 : 9)
	Pixel Pitch(mm)	0.51075 (H) x 0.51075 (W)
	Active Display Area(mm)	697.6845 (H) x 392.256 (V)
	Brightness(Typ.)	450 cd/m²
	Contrast Ratio	3500 : 01 : 00
	Viewing Angle(H/V)	178 / 178
	Response Time(G-to-G)	8 ms
	Display Colours	8 bit - 16.7 M
	Colour Gamut	72%
Display	**Dynamic C/R**	4000 : 01 : 00
	H-Scanning Frequency	30 kHz ~ 81 kHz

	V-Scanning Frequency	56 Hz ~ 85 Hz	
	Maximum Pixel Frequency	148.5 MHz	
Connectivity	**Input**	**RGB**	Analog D-SUB, DVI-D, Display Port
		Video	CVBS, HDMI1, HDMI2, Component (D-sub 15 pin)
		Audio	RCA (L / R), Stereo mini Jack
	Output	**Audio**	Stereo mini Jack
		Power Out	5 V (for SBB)
	External Control	RJ45, RS232C (in / out)	
	External Sensor	USB B type (touch screen)	
Power	**Type**	Internal	
	Power Supply	AC 100 - 240 V ~ (+ / - 10%), 50 / 60 Hz	
	Power Consumption	**On Mode**	220 W (max) / 177 W (typ)
		Sleep Mode	less than 5 W
		Off Mode	less than 5 W
Mechanical Spec	**Dimension (mm)**	**Set**	780.0 x 482.0 x 116.3 mm
		Package	890 x 590 x 256 mm
	Weight (kg)	**Set**	20.8 kg
		Package	23.9 kg
	VESA Mount	200 x 200 mm	
	Protection Glass	Yes	
	Stand Type	Foot Stand (optional)	
	Media Player Option Type	Internal	
Operation	**Operating temperature:**	10ºC ~ 40ºC	
	Humidity	10 ~ 80%	
Feature	**Key**	All-in-one Touchscreen	
	Special	Embedded Touch (IR), Lamp Error Detection, Brightness Sensor, Anti Retention, Temperatu Built in Speaker (5 W + 5 W), Plug and Play (DDC2B), PIP / PBP, Video Wall (10 x 10), Pivo Scheduling, MagicInfo S / W, Smart F / W update, Windows embedded 2009	
Certification	**Safety**	UL (USA) : UL 60950-1 CSA (Canada) : CSA C22.2 No. 60950-1 TUV (Germany) : EN60950-1 NEMKO (Norway) : EN60950-1 KC (Korea) : K60950-1 CCC (China) : GB 4943-2001 PSB (Singapore) : IEC60950-1 GOST (Russia) : IEC60950-1, EN55022 SIQ (Slovenia) : IEC60950-1, EN55022 PCBC (Poland) : IEC60590-1, EN55022 NOM (Mexico) : NOM-019-SCFI-1993 IRAM (Argentina) : IEC60950-1 SASO (Saudi Arabia) : IEC60950-1	

	EMC	FCC (USA) FCC Part 15, Subpart B class A CE (Europe) EN55022, EN55024 VCCI (Japan) V-3 (CISPR22) KCC (Korea) : KN22, KN24 BSMI (Taiwan) : CNS13438 (CISPR22) C-Tick (Australia) : AS/NZS3548 (CISPR22) CCC (China) : GB 9254-2008, GB 17625.1-2003	
Accessories	**Included**	Quick Setup Guide, Warranty Card, Application CD, D-Sub cable, Power Cord, Remote Con	
	Optional	**Mount**	WMTL4001D
Media Player	**CPU**	Athlon X2 Dual-Core	
	N/B	AMD	
	S/B	AMD	
	GPU	AMD	
	FDM/HDD	HDD 40 GB	
	Memory	DDR3 1 GB	
	Ethernet	Marvell 88E8055 Gigabit LAN	
	Connectivity	**USB**	3 EA
		Output	RGB OUT, Magicinfo OUT (digital)
		Others	LAN RJ45

Discussion

Advantages:

1. Bigger screen (fills 30’’ size requirement).
2. Shatter-proof as opposed to just scratch resistant.

Disadvantages:

1. Higher cost.

Implementation:

Screen can be placed at almost any angle on simulator due to being anti-glare and shatter-proof (not worried about trainee dropping welding instruments onto it).

Cost Summary

Current cost: $520.93

Proposal cost: $2658

Savings: -$2137.07 or -410%

8.4. Welding gun improvement leading to an optimization of the simulated environment

Proposal 1: Addition of Haptic interface on the welding gun

Current Situation:

No feedback

Without feedback from the welding gun, user can practically go through the virtual welding piece with the welding gun and feel no resistance. This takes away the credibility of the welding session.

Proposal Description

PHANTOM Omni® Haptic Device

http://www.sensable.com/haptic-phantom-omni.htm

Figure 19. Haptic Device

Haptic interface allows us to build an object with tactile feedback in virtual space. Such devices are in use in gaming industries and especially in training surgeons. It acts as a useful tool in teaching palpatory diagnosis-"detection of medical problems via touch." Futuristic researches involving this technology include researches by the Department of Education and National Institute of Health on providing feedback from prosthetic limb to the amputee and by University of Tokyo to add haptic feedback to holographic projections. The haptic feedback allows users to interact with the virtual object and receive tactile response as if the object were real.

There are many different levels of devices. Aside from wheels with 1 degree of freedom and joystick with 2 for gaming purposes, high-end haptic devices give up to 7 degrees of freedom.

Specifications

Price: $1000 approx.

Discussion

Advantages:

1. The welding gun will have its own six degree-of-freedom positional sensing thus eliminating the cost of attaching a separate sensor on the welding equipment
2. The welding gun will be attached to device thus eliminating risk of dropping the welding equipment and the need for a separate store-away hooks

Disadvantages:

1. Smaller work space
2. Higher pricing

Implementation:

1. Removable stylus for end-user customization (ie to a welding gun)

Cost Summary

Current cost: $0

Savings: approx ($1000)

Proposal 2: Addition of small vibrating DC motor with 8 bit microprocessor

Current Situation:

No feedback

Without feedback from the welding gun, user can practically go through the virtual welding piece with the welding gun and feel no resistance. This takes away the credibility of the welding session.

Proposal Description

Cell Phone Vibrating DC Motor

http://www.cs-tele.com/mobile-phone-spare-parts/vibrator.htm

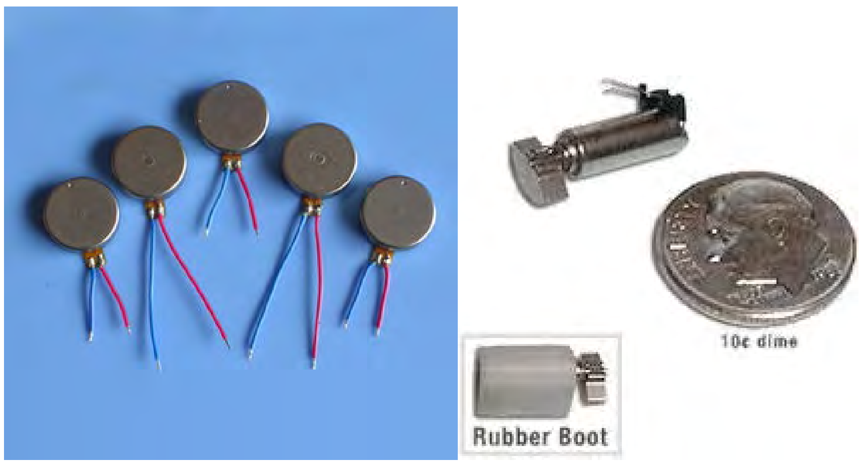


Figure 20. Vibrating DC Motors

Similar to Haptic interface of 1 degrees, by addition of simple small motor with weight offset- used in cell phones- provide feedback to user by vibrating the welding gun at mistakes made or at weld start and finish.

Specifications

Cost : $7.95 (+ processor = $10)

Discussion

Advantages:

1. The user will get vibration feedback, thus educating the trainee's touch senses instead of just his/her vision.
2. We can apply vibration feedback not just when he/she goes near the welding piece but also when he/she makes mistakes to alert the trainee.

Disadvantages:

1. None

Implementation:

1. Incorporate the small motor and processor into the welding gun
2. Basic programming

Cost Summary

Current cost: $0

Savings: ($36) [$18 x 2 welding equipment]

8.5. Computer Hardware

Proposal 1: Cost reduction of computing system by "barebone" assembly

Current Situation:

Barebone assembly of different components including Shuttle XPC SH55J2

Proposal Description

Barebone assembly of different components

Figure 21. Barebones Hardware

While the computer accomplishes all the given specifications cost is reduced by assembling the parts ourselves and using the stable kiosk model for casing.

Specifications
PROCESSOR: AMD Athlon II X2 255 Regor (3.1GHz 2 x 1MB L2 Cache Socket AM3 65W Dual-Core Desktop Processor ADX255OCGMBOX)[$62.99]
(*http://www.newegg.ca/Product/Product.aspx?Item=N82E16819103896*)
HARD DRIVE: Western Digital VelociRaptor WD1500HLFS 150GB 10000 RPM 16MB Cache SATA 3.0Gb/s 3.5" Internal Hard Drive -Bare Drive [$199.99]
(*http://www.newegg.ca/Product/Product.aspx?Item=N82E16822136296*)
M/B : GIGABYTE GA-78LMT-S2P (AM3+ AMD 760G Micro ATX AMD Motherboard) [$59.99]
Memory : Crucial 4GB (2 x 2GB) 240-Pin DDR3 SDRAM DDR3 1333 (PC3 10600) Dual Channel Kit Desktop Memory Model CT2KIT25664BA1339 [$26.99]
(*http://www.newegg.ca/Product/Product.aspx?Item=N82E16813128504&Tpk=GIGABYTE%20GA-78LMT-S2P*)
Power Supply: 500W TFX atx power supply
(http://www.imexbb.com/500w-tfx-atx-power-supply-10717371.htm)

Understanding that compared with the equivalent Intel i-series processors, AMD processors lack durability and may be of lower performance rating, we recommend AMD processor because it offers reasonable pricing compared to its overpriced Intel equivalents.
As for the Mother Board (M/B) we recommend GIGABYTE's model for its durability and since it also has integrated Radeon Graphic card, which further reduces our cost of purchasing a separate graphic card.
We've recommended a dual channel RAM because compared with equivalent single channel memory; we gain a faster response time.

A TFX power supply was chosen on the basis that we will not have enough space for a regular power supply within the kiosk, and thus we have to reduce the size of the power supply. TFX models are usually compact, and upon searching for one with enough power the above choice was deemed worthy.
When ordering parts, we recommend ordering from a single “source” for less shipping costs and less companies to deal with when some parts are missing and or broken.

Discussion

Advantages:

1. Highly customizable
2. Lower cost

Disadvantages:

1. Must purchase different parts separately, requires man power (researching, placing order, assembly)

Implementation:

1. Directly install in the kiosk

Cost Summary
Current cost: $1221.60
Savings: approx. $800

Proposal 2: Shuttle

Current Situation:

Barebone assembly of different components including Shuttle XPC SH55J2

Proposal Description

Shuttle SH67H3

http://global.shuttle.com/news/productsSpec?productId=1477

Figure 22. Shuttle

Instead of purchasing different components as separate cards and having to deal with manual connections. Shuttle incorporates the Motherboard and power supply into a case that is only 1/3 the size of a regular desktop (323(L) x 208(W) x 196(H) mm). It is the same form factor as the current solution and this is just an upgrade of the shuttle.

Specifications

Processor: Supports Intel next generation Core i7, Core i5 and Core i3 processor LGA1155 socket 95w max

Graphics: Onboard graphics function: Intel® HD Graphics integrated in CPU

Memory: DDR3 1333 MHz support RAM Socket * 4, Dual channels support (MAX 32GB)

Audio: Realtek ALC888 7.1 channel High Definition Audio

Integrated Cooling Engine 2(I.C.E.2)

Discussion

Advantages:

1. Lighter shipping weight
2. Simplified assembly
3. Space efficient
4. Customizable

Disadvantages:

1. Higher Cost
2. Less customizable because everything is already installed in its own casing.

Implementation:

A drawer or cabinet can be made in the Kiosk to accommodate.

Cost Summary

Current cost: $1221.60

Savings: none

Proposal 3: Integrated one board solution

Current Situation:
Barebone assembly of different components

Proposal Description
Single Board Computer (SBC)
http://www.ieiworld.com/files/product/0B290414126746092628/catalog/en-US/IMB-H610.pdf
http://www.ieiworld.com/product_groups/industrial/content.aspx?keyword=IMB-H610&gid=00001000010000000001&cid=08141335426152039799&id=0B290414126746092628#

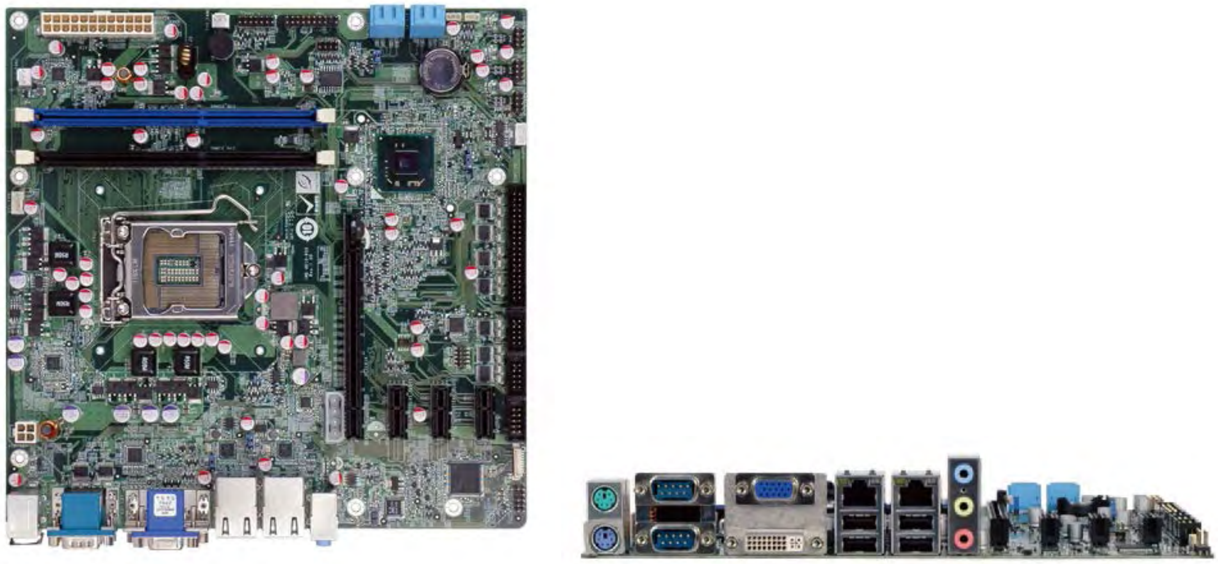


Figure 23. Integrated board

Instead of purchasing different components as separate cards and having to deal with manual connections, all the chips and cards may be mounted directly on a single motherboard (240mm by 240mm). The SBC supports all necessary components of a computer minus the power supply.

Specifications
Manufacturer: IEI (www.ieiworld.com)
Canadian distributor: *Nu Horizons Electronics*

Motherboard: Micro ATX(IMB-H610-R10) [$250-450 approx*]
Processor:

1. Intel® Core™ i3-2100T Dual Core 2.5GHz [$120 approx]
2. Intel® Core™ i5-2500T Quad core 2.3GHz [$220 approx]
3. Intel® Core™ i5-2390T Dual Core 2.7 GHz) [$200 approx]

Memory: Two 240-pin 1333/1066 MHz dual-channel unbuffered DDR3 SDRAM DIMMs [$40 approx]
Graphics: Intel® HD Graphics 2000/3000 (included with CPU)

Dual Ports USB cable with bracket
RS-422/485 cable, 200mm
SATA power cable
Quad ports RS-232 cable w/bracket, 400/400/400/400MM
20-pin Infi neon TPM module, software management tool, fi rmware V3.17
LGA1155/LGA1156 cooler kit, 1U chassis compatible, 45W
*Please note that the board *PN : IMB-H610-R10* are new actual prices will be released at the end of December 2011.

Discussion

Advantages:

3. Lighter shipping weight
4. Simplified assembly
5. Smaller work space

Disadvantages:

2. Costly
3. Difficult to customize and to upgrade
4. Need to downgrade the current CPU(Intel Core i5-760) to comply with the motherboard
5. Relatively new technology and not many solutions are available at the current moment

Implementation:

2. Directly install in the kiosk

Cost Summary

Current cost: $1221.60

Savings: approx. ($200)

8.6. Support & Kiosk Enclosure

Proposal 1: PC Defender Kiosk

Current Situation:

Self designed metal casing

The current aluminum casing is a complex integrated structure with low attractiveness. It contains many customized parts which require high manufacturing cost, long assembly time, and expansive labour. Also, the height and the angle of the monitor frame are designed to be adjustable. However, the additional portability adds very limited effect to the product performance while significantly increases the overall complexity as well as the cost. In addition, due to the small size of the touch monitor, trainer will have difficulty to obtain a clear view during the training session.

Proposal Description:

PC Defender

Shown with optional folding keyboard tray. Fixed keyboard tray is standard.

Figure 24. PC Defender Kiosk

One of the most popular products provided by PC enclosures. It is a great computer casing which is designed to be dust tight and waterproof. The enclosure includes steel case, a plastic window, a mounting arm for an LDC monitor, a built-in fan and filter system, and an external keyboard and mouse tray. The entire casing can be mounted on a wall.

Dimensions:

- 24''W x 30''H x 10''D
- 15''-24'' LCD Monitor

Materials Available:

- Powder Coated Steel
- Stainless Steel

NEMA Rating:

- 4,4X,12

Discussion:

Advantages:

1. attractive looking
2. water, dust and tamper proof
3. great space saver (can be mounted on the wall)
4. easily opened steel case, ease of maintenance
5. external tray can be used as a supporting piece where trainees can rest their arms during welding

Disadvantages:
1. screen size smaller than 30’’
2. cannot replace the plastic window with a touch screen

Implementation:
Detailed product drawing and specifications are required to make sure the inner space is large enough to contain all other necessary components. Additional accessories need to be added, such as hooks for holding the welding guns and hamlet. This is recommended that IR motion sensor is used for this proposal.

Cost Summary:
Current cost: $3017.96
Proposal cost: $1450

Proposal 2: Custom Touch Kiosk

Current Situation:

Self designed metal casing

The current aluminum casing is a complex integrated structure with low attractiveness. It contains many customized parts which require high manufacturing cost, long assembly time, and expansive labour. Also, the height and the angle of the monitor frame are designed to be adjustable. However, the additional portability adds very limited effect to the product performance while significantly increases the overall complexity as well as the cost. In addition, due to the small size of the touch monitor, trainer will have difficulty to obtain a clear view during the training session.

Proposal Description:

32'' Touch Kiosk(FRB-3004)

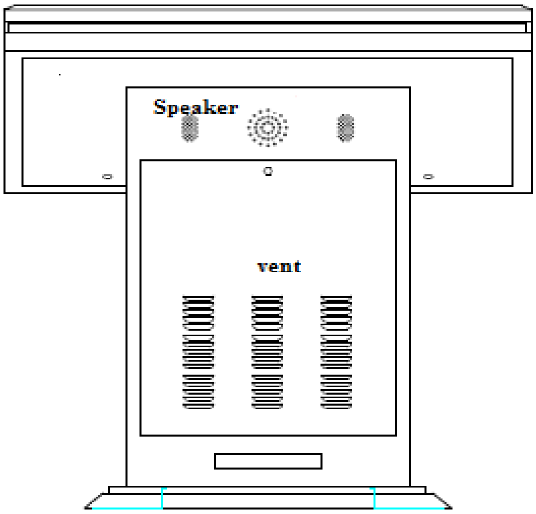


Figure 25. Kiosk FRB-3004

Forstec Co., Ltd. Offers beautiful large touch screen kiosks. These kiosks are able to integrate 32'' touch screen and custom computer components. The overall structure is very stationary. The back of each kiosk FRB-3004 has two built-in speakers and three columns of vent panels.

- Durable steel frame, powder coated steel back covers
- Security locks
- Internal fans for ventilation
- Moisture proof, anti-rust, anti-acid, static free

Discussion:

Advantages:

1. aesthetic
2. stationary
3. allows full customization of interior components (PC parts)
4. kiosk has enough inner space for all computer parts (confirmed with company engineers)
5. 32'' touch screen satisfies and excesses the minimum screen requirement

Disadvantages:
1. The kiosk originally comes with 32’’ Samsung monitor and IR touch screen. Modification of the screen frame is required in order to fit the custom screen to the kiosk.

Implantations:
Screen fitting is a big concern and the ease of the adaptation varies from case to case. Additional accessories need to be added, such as hooks for holding the welding guns and hamlet It is recommended that IR motion sensor is used for this proposal.

Cost Summary:
Current cost: $3017.96
Proposal cost: $1200

Additional Information:
An alternative solution is to use the standard monitor and touch screen provided by the company to eliminate modification and fitting problem. The total cost of the kiosk + the 32’’ Samsung monitor + IR touch screen is USD $1773.

9. Evaluation of Scenarios (Cost vs. Merit)

In this section we will consider all possible combinations of proposals in order to construct and evaluate scenarios and find the best solution. For this purpose we created an excel sheet algorithm. This extensive Excel spreadsheet can be found in Appendices C and D.

First, we assigned a "weight" out of ten to each criterion according to its importance and flexibility. For example, the motion sensor must track 6DOF, and this criterion is critical to the final product. Therefore, the criterion *Degrees of Freedom for Motion* is assigned a weight value of ten.

Second, we assigned a "score" out of ten to each proposal for each criterion depending on how much that proposal satisfies that criterion. For example, the *Razer Hydra* satisfies the criterion *Degrees of Freedom for Motion* completely, and therefore is assigned a score of ten.

Third, we multiplied the criteria "weights" with its associated proposal "scores". Then the products were summed to gain the merit of each proposal.

Finally, we identified all feasible combinations of the proposals to construct scenarios. This is done by choosing one proposal from each function and combining them. Then the merit and costs of the proposals included in each scenario are summed to result in the final cost and merit of each scenario.

1) Each criterion is numbered: $i = 1, 2, 3, \dots, 14$.
   Then let $Criterion\ weight = CW_i$ each value of *'i'* indicates a different criterion.

2) Each proposal under one function is numbered: $j = 1,2,3 \dots$, up to the total number of proposals satisfying one function.
   Then proposal scores are values in a matrix of *i* rows and *j* columns:

   $Proposal\ Score = PS_{ij}$

3) Then merit of each proposal is $Proposal\ Merit = PM_j = \sum_{i=1}^{14} CW_i * PS_{ij}$

4) Finally, each scenario is numbered, *k*. Also say, each function is numbered, *h.*
   Then scenarios are combination of proposals $\text{Scenarios Merit} = \mathrm{S}_k = \sum_{h=1}^{6} \left(PM_j\right)_h$

Below is the Cost versus Merit graph displaying all feasible scenarios. Indicated as a red dot is the best merit scenario, the bottom straight line points to the scenario with the best merit to cost ratio and the slope of the top line indicates the worst merit to cost ratio.

Figure 26. Cost vs. Merit Graph

*NOTE: We could not perform any payback period, return on investment, or other financial analysis on our scenarios. This is because each unit is sold at a different cost and we do not have access to revenue information. As well, we do not know the development costs as these are out of the scope of our project.**

10. Final Scenario

10.1. Recommended Proposal

After completing all the analysis of the value engineering process, we arrived at a decision to propose scenario 13. Although it does not have the best merit to cost ratio, it does have the best merit out of any proposal. Considering the great reduction in cost that we have already achieved in all our proposed scenarios, we did not deem it worthy to sacrifice more merit for a greater reduction in cost. The scenarios with the best merit to cost ratio used a projector to display the visuals. Although this is a feasible solution, we felt it much more practical to use a solution with a touch screen. This way the product is not required to be placed close to a white wall nor does it need a projector screen, and there is no risk of a keystoned or blurry image. Here we will outline the key components we have chosen for the final design.

10.1.1. Head Mounted Display

The welder performing the simulation wears a welding helmet with 3D glasses underneath. The glasses currently being used perform the task well and we determined that an appropriate portion of cost is being spent on them. Despite this, through our research process, we were able to find a product that uses the same technology, but with added quality and reduced cost. This is to be expected as costs decrease and quality increases with the advancement of technology. This means that technology has advanced to the point where an upgrade in product was necessary. Therefore, our proposed scenario includes Sony HMZ-T1 video glasses. They are priced at $800, which is a 55% reduction in cost from the original glasses. As well, they provide a larger angle of view and increased resolution. Overall, better quality for less cost made this a simple decision for us.

Figure 27. Sony HMZ-T1

10.1.2. Motion Detection

One of the primary functions of the ARC+ is to detect the movement of the welder. Based on our function-cost analysis we identified a mismatch in function cost and worth and therefore set it as a goal to reduce the cost. We have succeeded in doing this and then some. We chose to use the Sixense Tracking Technology - Razer Hydra to fulfill this requirement. It uses magnetic motion tracking to track up to four independent sensors with six degrees-of-freedom. It has high precision (precise to 1mm and 1degree), a twelve foot diameter sensing range, and low latency (60Hz).

Figure 28. Razer Hydra

One of the main advantages of using this product is that it eliminates some of the limitations of IR camera motion tracking. Most notably, it does not lose track of a sensor when another sensors approaches it. The cost of this product is a measly $140, which pales in comparison to the $9848 price tag of the current system, the Polaris Vicra. Clearly, by using a solution that costs less than 1.5% of the current component, we have succeeded in greatly reducing the cost. We understand that it will take resources to implement and develop the software to integrate this solution. Despite these foreseeable costs and obstacles, we strongly believe the added quality and reduction in unit cost makes the change worthwhile.

An added feature we also have decided to include is vibration response. This will be integrated into the welding tools and in the event of a mistake during the simulation, the tools will provide feedback to the user. We feel that this improves the overall simulation experience and is worth the added cost.

10.1.3. Display

Vital to the effective training of a welder is being able to review the previous simulation session as well as allowing an instructor to watch the session as it is completed. To achieve this, we have decided to stay with the current concept of using a touch screen, though with improved specifications and added features. The design will use a 32'' Samsung touch screen. It has a high contrast ratio, large viewing angle, easy connectivity, and is completely shatter-proof. It also includes a built in computer, which is not necessary as of now, but may have its uses in the future.

Figure 29. Razer Hydra

One important benefit of this screen is that t allows a spectator (i.e. instructor) to easily view the session being conducted, by being so large, bright, and anti-glare. The other key feature that makes this particular screen attractive to us is its shatterproof feature. This ensures the durability and longevity of the product. A recurring risk with the current product is that a user may accidentally drop the heavy welding equipment on the screen, thereby shattering it. This renders the entire simulator ineffective and requires the replacement of the screen. Replacing the screen is quite complex especially if the client is located far away, as many of 123 Certification's clients are. With this new screen, there is no concern of this occurring and it adds to the overall quality of the product.

With all these added benefits comes, as expected, an increase in cost of the product. However, we had determined, while doing the function-cost analysis, that a higher percentage of cost should be allocated on this function. Thus, upgrading the screen, and therefore increasing its cost, is clearly justified by the increase in functionality.

10.1.4. Simulator Housing

The origin of this project arrived from the demand to build a stationary simulator as opposed to the current portable one. As a team, we wanted to ensure that it was very stable and aesthetically pleasing. These desires were derived from 123 Certification's preferences and demands. This led us to choose a very simple, kiosk design. The kiosk we are using includes in it the touch screen and the computer. With only the touch screen, which is a very beautiful, high quality device, and the actual housing visible, it ensures a very streamlined and sleek look. The kiosk is made of steel and is powder coated black. We have included three hooks on the side of the kiosk to provide for convenience of holding the welding tools and helmet when not in use.

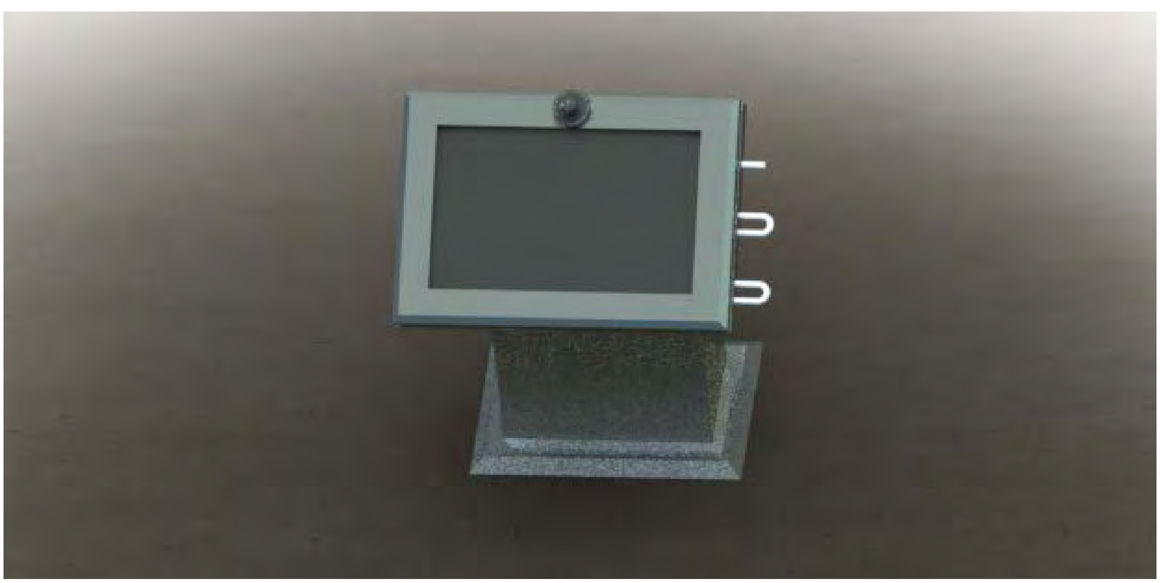


Figure 30. Razer Hydra

Adding to the benefit of our choice of kiosk is the option to integrate the computer parts directly into the housing. This allows us to reduce the computer costs by only purchasing the components and not having to worry about the casing and integration. It also provides the convenience of customizing the components to the requirements. Having been provided all the specific computer component requirements by 123 Certification, we simply chose those components and can provide them to the kiosk company for integration. This again contributes to a very streamlined product that appears clean and attractive to any user.

10.2. Cost Breakdown

Table 7. Cost Breakdown

Current Design		**New Proposal**	
Component	**Cost ($)**	**Component**	**Cost ($)**
Polaris Vicra	9,848.00	Razer Hydra	140
Touch Screen ELO Intellitouch	521	Samsung Touch Screen	2658
eMagin Z800 3D Visor HMD	1799	Sony HMZ-T1 Video Glasses	800
N/A		Vibration of Tools	36
Computer	1222	Computer - Assembled Components	350
Portable Housing Support	3018	Kiosk	1200
Welding Accessories	546	Welding Accessories	546
Total Cost of Components	**16,954**	**Total Cost of Components**	**5730**

As you can see, we greatly reduced the cost of the components of the simulator. Our total reduction in cost is 66%. At the same time, we believe that we also increased the quality and appearance of the product.

11. Implementation Plan

We believe our proposal will help 123 Certification continue along the great path it has already set out for itself. Our design is in line with the company's goals and desires; namely to create a higher quality product, at a lower price, that satisfies the demand of the consumers in the virtual welding industry. The industry appears to prefer a product that is stationary and cost effective so that is what we have proposed. We believe implementing our design will further the company's culture of providing an excellent product at a reasonable price.

An important point to stress once again is that implementing our design requires work on integration and developing of software. Switching to a motion detection system using a completely different technology will clearly require a lot of software changes. The costs and amount of time needed for these developments is unknown to us and out of the scope of this project. Despite this, we can foresee them being significant and therefore it is important to understand this risk and added cost. To our team, this risk seems miniscule compared to the improvements these changes allow. We have included all the research and work we have done in this report so that the company may see the indisputable evidence that led us to our decision. Hopefully, once they have read this report they will see no other choice but to implement our proposal.

12. Final Recommendation

Through the Value Engineering process we arrived at our final scenario. This arose from a few main discoveries. One is that the company is using a motion detection system that is far too cost consuming. It was clear to us from the start that this needs to be. We recommend a magnetic sensor system so that it improves two aspects at once: the cost, which is now greatly reduced, and the issue of losing sensors when they come close to each other.

The other main goal of this value engineering exercise was to move from the current portable design of the simulator to a stationary design. We recommend using a simple kiosk design to accomplish this. Not only is this much more aesthetically pleasing and simple than the current solution, it also reduces the cost. The kiosk we have chosen will reduce the cost of the housing by approximately 60% and enables us to reduce the cost of the computer by approximately 70%. That helps contribute to the staggering reduction in cost of the overall design.

These are our main recommendations, which are highlighted by the final design we are proposing.

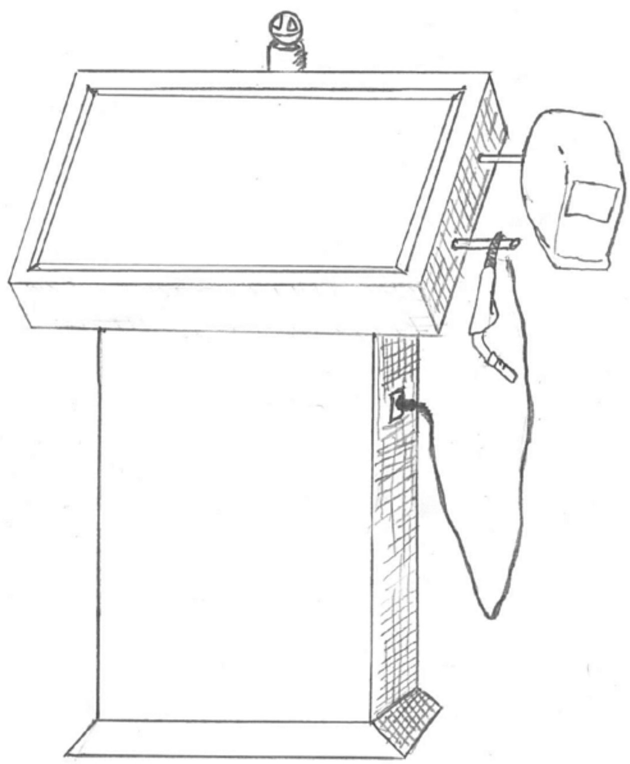


Figure 31. Final Recommended Solution for Welding Simulator

13. Conclusion

The Value Engineering methodology proved to be a useful and effective tool in order to create a new stationary concept design for 123 Certification's welding simulator. To fully understand the problem, our team consulted with the company representative to understand the context, requirements, constraints, and budget of the simulator. Through function analysis and brainstorming, the complete functions welding simulator were understood and various proposals were discussed. Cost and worth analyses allowed the team to focus on particular aspects of the present design that required improvement, most notably the components that received user input (screen) and that converted movements to signals (motion detection technology). The proposals were evaluated by their feasibility, cost, and merit, in order to decide upon a final solution that would satisfy the client.

The recommended final solution includes a number of improvements, most notably:

- A total 66% reduction in cost, excluding extraneous costs such as taxes and shipping
- Higher visibility and quality viewing screen
- Improvement video glasses technology
- A stable stationary kiosk with integrated components
- Magnetic motion sensing technology with improved reliability

The Value Engineering team is confident that the proposed solution adheres to all requirements of 123 Certification Inc., and will in term be a cost effective product for their customers.

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15. Appendices

Appendix A – Suggested Proposal with Elimination

Received User Input	Ok	Reasons to Eliminate
Big buttons projected on the wall		
Foam has indentation marks (memory / sensory foam)	X	Not understood
Voice control		
Wii remote-like		
Recognize body shapes (Kinect)	X	Not accurate enough for application.
Finger touch		
Keyboard and mouse input		
Playstation move		
Razer Hyrdra		
Switch inputs (binary)	X	Too simple for interaction.
Joystick and arcade buttons		
Infrared grid detection		
Blowing air as input (handicap device)	X	Too costly. Interferes with welding training.
Vibration recognition	X	?
Heart rate monitors	X	Not feasible
Monkey understands signals	X	Too costly, training is too costly!
Brain images CATSCAN	X	Too costly, not feasible.
Piezoelectric device to detect forces		
Temperature change sensors		
String-pulling detection system	X	No implementation.
Radar	X	Not feasible

Display Instructions	OK	Reasons to Eliminate
Touch screen		
Non-interactive screen		
Infrared	X	Out of scope.
High or low resolution		
3-D screen	X	Unnecessary added cost.
IMAX	X	Not feasible.
Multiple screens		
Adjustable display		
Vacuum tube screen (old screen)	X	Not feasible, unnecessary.
Projector		
Print-out	X	Not efficient or environmentally friendly.

Hologram	X	Technology does not exist
E-book reader screen (black pigment; change in polarity)	X	Require colour screens.
LED Colour display		
Audio instructions		
OLED		
OLED peripheral vision screen in helmet		
No screens: 2 helmets for user and observer		
Monitor on user's mask	X	Not feasible.

Maintain Stability	OK	Reason to Eliminate
System hangs from the ceiling	X	Not feasible, difficult to set up.
Vibration absorbers		
Corner of two walls (pyramid)	X	Limited accessibility and use.
Suction cups	X	Unreliable and limited.
Foam mold	X	?
Vacuum area (no air)	X	Not feasible, expensive.
Pull out wall/shelf/closet system	X	Requires renovation, large cost.
Wall interface (panels)		
Truss structure		
360 dome (IMAX)	X	Expensive, overkill.
Tripod	X	Takes too much spaces.
4-legged structure		
Wall (projection on to the wall, no need for support)		
Truncated Cone		
Monkey holding screen that has been frozen with liquid nitrogen	X	NO
Curved base (ie. Mac)		
Wide base, thinning	X	Too much material, inefficient shape
Cylinder		
Hollow support		

Resists Debris	OK	Reasons to Eliminate
System enclosed in a bubble	X	Not feasible, difficulkt to operate.
Curtains	X	Not effective.
Drawers system		
Change work environment (not in workshop)	X	Out of scope; requirement.
Waterproof casing	X	Out of scope.
Dust proof	X	Requires ventilation system to avoid overheating
Umbrella	X	Not relevant.

Metal casing		
Plastic casing		
Built-in air purifier	X	Too expensive.
Magnetic levitation	X	Too expensive, not feasible, does not exist.
Air blower	X	Not feasible, requires too much energy.

Resists Impact	OK	Reasons to Eliminate
Welding gear hung on strings	X	Limits motion
Welding station separate from the monitor (detachable)		
Bubble	X	Not feasible.
Screen placed on vibration absorbers	X	Not effective
Air flow from the screens (air hockey)	X	Doesn't protect from impact.
Magnetic repulsion against metallic debris (Tina)	X	Not feasible.
Hinged lid on the monitor		
Protective glass over screen		
Scratch-free screen		

Displays 3D Animation	OK	Reasons to Eliminate
Projector		
2 masks for monitor		
Hologram	X	Not possible.
Projector dome	X	Not feasible.
OLED peripheral vision screen in helmet		

Simulate Physical Interactions	OK	Reasons to Eliminate
Wand (Playstation 3 Move)	X	Not precise enough.
Hand sensors without equipment	X	Does not simulate welding properly.
Heat reading (IR)	X	Irrelevant.
Real welding equipment with screen interaction (no immersive environment)	X	Not desired by client.
Heat lamp (Simulates heat from welding)		
Haptic control (touch vibration on screen, ie. Like new cell phones)		
Vibrations to simulate welding / identify errors to the user		
Lighting control (sparks)		

Welding smells (fumes)	X	Not feasible.

Detects Motions	**OK**	**Reasons to Eliminate**
Camera		
Magnetic motion sensor		
Infrared		
Heat detection	X	Not reliable.
Radar (electromagnetic waves)	X	Too expensive, not precise enough.
Sonar	X	Not precise enough.
Interaction with the screen only	X	Does not simulate welding.
Accelerometers		
Gyroscopes		
Sensors in a headband (Atari Mindlink)	X	Unnecessary.
Track eye movement		
Tomagraphic detector	X	Not relevant.

Converts Movements to Signals	**OK**	**Reasons to Eliminate**
Computer		
Digital acquisition system		
Analog to digital		

Troubleshoot problems	**OK**	**Reasons to Eliminate**
Door to access computer components		
Standardization of parts		
Industry standard parts		
High factor of safety		
User-friendly assembly		
Modular assembly		
Extendable structures (telescopic)	X	Unnecessary
Emergency contact information on the casing	X	Irrelevant.
Emergency stop or shutdown button		
Access to power button of the screen	X	Unnecessary
Easily accessible ports		
Equipment holders on base		
Ventilation		
Heat sensors to detect and avoid overheating		
Crash reports and error log files sent to the company		

Appendix B – Proposal Scores

Receives user input	Score
Projection on the wall	6
Voice control	4.2
Remote Control	4.4
Finger touch	9.8
Keyboard and mouse input	4
Playstation move	4.4
Joystick and arcade buttons	4.4
Infrared grid detection	8
Piezoelectric device to detect forces	4.8
Temperature change sensors	1.8
Displays instructions	**Score**
Touch screen	9.8
Non-interactive screen	5.2
Multiple screens	3.4
Adjustable display	6
Projector	6.6
LED Colour display	7
Audio instructions	3.8
OLED	3.2
OLED peripheral vision screen in helmet	6.6
No screens: 2 helmets for user and observer	1.8
Maintains stability	**Score**
Vibration absorbers	5.8
Wall interface (panels)	5
Truss structure	4.8
4-legged structure	5.4
Wall (projection on to the wall, no need for support)	6.8
Truncated Cone	8
Curved base (ie. Mac)	6.2
Wide base, thinning	6.6
Hollow support	4

Resists debris	Score
Drawers system	8
Metal casing	9
Plastic casing	9.4
Resists impact	**Score**
Welding station separate from the monitor (detachable)	7.8
Hinged lid on the monitor	7.6
Protective glass over screen	9
impact-resistance screen	9.6
Displays 3d animation	**Score**
Video glasses	10
Projector	8.6
2 video glasses for monitor	7.8
OLED peripheral vision screen in helmet	9.8
Simulate physical interactions	**Score**
Heat lamp (heat from welding)	7.2
Haptic control (touch vibration on screen, ie. Like new cell phones)	10
Vibrations to simulate welding / identify errors to the user	9
Lighting control (sparks)	6.2
Detects motions	**Score**
Camera	6.8
Magnetic motion sensor	10
Infrared	8.2
Accelerometers	7
Gyroscopes	7.2
Track eye movement	5.2
Converts movements to signals	**Score**
Computer	10
Digital acquisition system	9
Analog to digital	8

Troubleshoot problems	Score
Door to access computer components	4.2
Standardization of parts	6.6
High factor of safety	1.6
User-friendly assembly	7.8
Modular assembly	5.2
Emergency stop or shutdown button	4.2
Easily accessible ports	5.2
Equipment holders on base	3.6
Ventilation	5.4
Heat sensors to detect and avoid overheating	5.6
Crash reports and error log files sent to the company	6.6

Appendix C – Cost / Merit Analysis of Proposals

	Criteria (From Cost Analysis Excel, Characterizing Functions)														Total Weight of Proposals	Cost of Proposals
	Impact Loads	Screen Size	Mass	# of Items to Track	Tracking Precision	Stability of Product	Dust Resistant	Sensor Working Area	Degrees of Freedom	CPU Time Response	Display Quality	Visibility of Display	Screen Reflectivity	Attractiveness		
Weight of Each Criteria:	7	8	3	10	8.5	3	2	4	10	5	6.5	8	4	8.5		
Proposals	**Weight of Proposals**														**TOTAL**	**COST**
Motion Sensors																
6DOF iSensor (x3)			10	10	10		10	10	10					9	451.5	$ 1,548.18
Razer Hydra			10	10	10		10	10	10					9	451.5	$ 140.00
IR Camera			6	10	9.5		5	9.5	10					7.5	410.5	$ 1,899.00
Microsoft Kinect w/ 6DOF iSensor (x2)			6	10	8		5	9.5	10					6.5	389.25	$ 1,172.12
															0	
Displays Instructions															0	
Samsung Touch	10	9.5	4.5				9				7.5	8.5	9	10	415.25	$ 2,658.00
Intelitouch	5	9.5	4.5				9				7	8.5	8	9	364.5	$ 1,700.00
Projector	8	10	10				5				7	10	8.5	6	386.5	$ 1,100.00
IR Touch w/ Regular Screen	3	9.5	7.5				9				10	8.5	9	10	391.5	$ 1,846.00
Regular Screen	3	9.5	8				9				10	8.5	9	10	393	$ 446.00
															0	
3D Visuals															0	
3D Glasses														8	68	$ 700.00
Sony HMZ-T1 Video Glasses														10	85	$ 800.00
															0	
Simulate Physical Enviroment															0	
Haptic Response														6	51	$ 20,450.00
Vibration when mistake made														9	76.5	$ 36.00
															0	
Computer															0	
Commercial PC										10					50	N/A
Integrated CPU										10					50	$ 2,500.00
Home Built PC										10					50	$ 350.00
															0	
Resists Debris/Resists Impact/Body															0	
Vib Abs (x4)						9								7	86.5	$ 35.00
Kiosk	8		5			10	9							9	195.5	$ 1,200.00
Industrial Made Cabinet	8		5			9	8							7	173.5	$ 595.00
No Kiosk	3		10			1	1							3	81.5	$ 200.00

Appendix D – Cost / Merit Analysis of Scenarios

Scenarios

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
Proposals																															
Motion Sensors																															
6DOF iSensor (x3)	1	1	1	1	1	1	1	1																							
Razer Hydra													1	1	1	1													1	1	1
IR Camera																	1	1	1	1	1	1	1	1							
Microsoft Kinect w/ 6DOF iSensor (x2)									1	1	1	1													1	1	1	1			
Displays Instructions																															
Samsung Touch	1				1				1				1				1				1				1				1		
Intelitouch		1				1				1				1				1				1				1				1	
Projector			1				1				1				1				1				1				1				1
IR Touch w/ Regular Screen				1				1				1				1				1				1				1			
Regular Screen																															
3D Visuals																															
3D Glasses	1	1	1	1					1	1	1	1					1	1	1	1									1	1	1
Sony HMZ-T1 Video Glasses					1	1	1	1					1	1	1	1					1	1	1	1	1	1	1	1			
Simulate Physical Enviroment																															
Haptic Response																															
Vibration when mistake	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Computer																															
Commercial PC																															
Integrated CPU																															
Home Built PC	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Resists Debris/Resists Impact/Body																															
Vib Abs (x4)																															
Kiosk	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1		1	1	1	
Industrial Made Cabinet			1				1				1				1				1				1				1				1
No Kiosk																															
Total Weight of Scen	1256.75	1206	1206	1233	1273.75	1223	1223	1250	1194.5	1143.75	1143.75	1170.75	1273.75	1223	1223	1250	1215.75	1165	1165	1192	1232.75	1182	1182	1209	1211.5	1160.75	1160.75	1187.75	1256.75	1206	1206
Total Cost of Scenari	$ 6,492.18	$ 5,534.18	$ 4,329.18	$ 5,680.18	$ 6,592.18	$ 5,634.18	$ 4,429.18	$ 5,780.18	$ 6,116.12	$ 5,158.12	$ 3,953.12	$ 5,304.12	$ 5,184.00	$4,226.00	$ 3,021.00	$4,372.00	$6,843.00	$ 5,885.00	$4,680.00	$ 6,031.00	$6,943.00	$ 5,985.00	$4,780.00	$ 6,131.00	$ 6,216.12	$ 5,258.12	$ 4,053.12	$ 5,404.12	$5,084.00	$ 4,126.00	$ 2,921.00
	5.165848	4.588872	3.589701	4.606796	5.175411	4.606852	3.62157	4.624144	5.120234	4.509832	3.45628	4.530532	4.069872	3.455437	2.470155	3.4976	5.628624	5.051502	4.017167	5.059564	5.632123	5.063452	4.043993	5.071133	5.130929	4.529933	3.491811	4.54988	4.045355	3.421227	2.422056