SAFESIGHT
DRIVER SAFETY

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1. Introduction / Narrative

1.1 Project Background

Humans are unquestionably the smartest beings on the planet. From the dawn of time there have been nonstop innovations stemming from fire to the world around us today. However, with such innovation stem new challenges to overcome. Technological advancements have come to aid humanity to live a more efficient life and spark innovation. In recent decades, one particular invention came to fruition, the SmartPhone. The SmartPhone has made communication via the internet possible with the combination of the cell phone which came decades prior. Being such a monumental piece of technology, we as a species have become reliant on them, looking at notifications for communication or browsing the internet for necessary information all at our fingertips. With such amazing technology came one of our biggest flaws, distractions. As consumers of smartphones, we are all susceptible to having our attention diverted by applications designed for our amusement and to focus on areas of non-importance. Such distractions that stemmed from the smartphone are social media, messages and games. These distractions get in the way of everyday life as we know it, continuing to shorten the attention span of the average consumer. Whether it be in a classroom, at work, cooking dinner or even waiting at the doctor's office, the smartphone and its captivating applications have infiltrated our daily lives at a grand scale. One daily task that it has invaded is commuting.

One of the biggest hassles people face on a day to day basis, often even multiple times a day, is commuting in their vehicle. In this day and age a normal traffic stop at a red light makes the general population believe there is enough time to catch up with their friends and family on popular social media apps like Instagram and Facebook. As quickly as they may perceive their phone usage at the red light, drivers often feel in a state of comfort when driving, oftentimes not remembering specific events on the road and just recalling arriving at their destination. This state of comfort leads directly to a lack of importance perceived from the driver and then in turn the brain looks for its favorite source of dopamine: the smartphone and the endless applications it holds.

After spending some time in traffic and looking around at the other drivers at a stop, nearly all drivers are tinkering on their cell phone whether it's changing a song, sending a text or responding to an email. When the world's drivers are constantly distracted from the traffic around them, this directly leads to a higher cause of accidents between vehicles and a higher danger to pedestrians. The goal with this product is to reestablish attention and bring awareness back to safety on the roads. Alongside, big automobile manufacturers have made efforts to keep the driver engaged while on the road in latest models. Many of the automotive companies like Hyundai and Tesla for example are implementing new sensors in their cars to encourage drivers to drive as intended rather than cause unnecessary delays. Many of these sensors include forward collision warnings, lane departure warnings, lane centuring assistance, and adaptive cruise control. Even though these technologies are made for aiding in the safety of the roads, they do not address the lack of attention that is growing in our society.

What if there were a compact device, no larger than a standard transponder, designed specifically to help drivers maintain focus on the road? Hence, came the idea of **SafeSight**, a device that is able to track traffic light changes, when the car in front of you is leaving, and take photo documentation of a trip so that drivers can realize how distracted they can be when commuting.

1.2 Project Motivation / Current Commercial Technologies

The motivation of **SafeSight** is to develop a device that brings the attention of the driver back to the roads, aids lack of response times, and helps ensure safety on the roads for commuters. SafeSight is a tool that leverages the advancements of modern technology and combines the existing technology in a matter to bring the integrity and efficiency of the roads back to a higher level than that of the time prior to smartphones.

For SafeSight to truly live up to the ambition we have for it, the team has come together to develop it in a way that allows for ease of access and compatibility with modern technologies. For instance we have limited the size of this device to be the size of a transponder that many individuals already carry in their vehicle for toll purposes. The technology in the device is also compatible with applications to store data from a commute to a user’s profile in order to encourage better driving practices whenever the user returns on the road. According to a recent study, 3,047 fatal crashes were caused by distractions. This number alone accounts for 8% of all fatal crashes in the United States. In addition to these fatalities, there was a total of 362,415 people injured from distracted drivers. Now, not all of these distractions are caused by smartphones, but rather a vast majority of them are. For this project to really be effective, the device would combat any distraction, alerting the driver and reducing the number of fatalities we see from such a preventable occurrence.

As we mentioned earlier, there are some technologies that do in fact help ensure safety but they do not attack the distractions. Moreover, these technologies are only installed into vehicles as of late, leaving nearly a century of automotive engineering without safety features. Our goal is for this device to be able to be implemented on every single vehicle, offering a much more intuitive and updated experience for every make and model on the road today. SafeSight will make the commuting process much more efficient and in turn reduce accidents, commute times, and unexpected obstacles from distracted drivers.

1.3 Project Function

SafeSight will utilize computer vision to classify and make connections between the driver and their attention towards the road. Cameras will continuously monitor the driver and outside traffic signals to then alarm the driver if they are not paying attention to the road. For example, a driver is caught at an intersection waiting for the traffic signal to switch to green. They suffer from a short attention span and resort to their mobile device to pass the duration of the red light. This distraction prevents them from properly reacting to the traffic signal switching to green, causing unnecessary delays and inefficient flow of traffic. These attention infractions made by the user of the vehicle will be acted upon by a sound alarm and recorded by the Safe Sight device. Safe Sight, in a manner, will make its user's driving more efficient by increasing response time, reducing error when driving, and maintaining alertness to surroundings. SafeSight will actively track the user's performance on the road by documenting how many times the user committed an attention infraction. The device will communicate with the user by projecting an audio signal outside of a speaker connecting to the PCB. This audio signal will serve as a sensory reminder to get off the phone or divert attention back to the road. Additionally, the computer vision will be trained to classify if the driver in the vehicle is looking down while the vehicle is in motion, where the device can then register and act upon an attention infraction. Our team must design a system that is both lightweight and compact in order for the device to function as anticipated, but also there comes the hardware necessary to make these ambitions come true.

2. Project Objectives, Requirements, and Goals

2.1 Project Objectives

SafeSight will encompass a system that brings back driver integrity and safety to the traffic environment as a whole. With this comes an increase in efficiency from the traffic system as well, leading to reduced commute times with reductions in accidents and injuries caused on the roads. When a commute begins, the system should be started and acquire traffic data to give a numerical representation of a driver. From every traffic stop, lane merger, and cruising scenario, the SafeSight system will constantly provide feedback to keep the driver alert. This same system should also detect changes in a driver's performance, for example if a driver is appearing to swerve between lane lines, then the device will suggest taking a break due to restless sleeping habits. If the driver is taking longer than usual to respond to changes in a traffic light , the device will notify the driver to focus their attention back on the road. These behaviors can be recognized by the SafeSight system in order to properly assess the reason for the driver's lack of performance.

SafeSight should encompass a system that captures the current state of a driver and multiple sample points during a journey. This system will then process the world around the host vehicle and the data collected from the driver's performance to assess recommendations (if any) to the driver on how to be more safe and efficient on the roads. The system in itself should be able to detect pedestrians, change in traffic light patterns, stop signs, movement from the host vehicle, and distances from cars ahead with the help of computer vision algorithms. These algorithms will be tested through the hardware of the Raspberry Pi and the tests will be deemed successful if it efficiently identifies the change in traffic light colors where red = stop and green = go. The system should also correctly sound the auditory signal when the driver is idle for a longer than anticipated reaction time to a vehicle moving ahead of it. SafeSight should also be able to identify pedestrians crossing and offer a signal that the driver must come to a stop, this scenario is also expected at a stop sign.

SafeSight should encompass a system that knows when the driver should be ready to progress their journey or not. This will require for the system to be able to detect movement in the vehicle, notify the driver for longer than anticipated stop times.

All of the components of SafeSight should be modular, meaning that each component should have the ability to be individually tested prior to being integrated to the entire system. The components of SafeSight should be able to be assembled and should ***not*** be able to be disassembled quickly, as it needs to adhere to conditions of a moving vehicle and portable. The entire system should be able to fit on the windshield of a vehicle without obstructing the driver's view.

SafeSight is currently a self-funded project, and with that comes the ambition to make sure it is cost effective for someone to replicate themselves if another engineer found interest in doing so. For the lack of sponsorship, the team has an aim to make this device for under $300, so that each member does not contribute more than $100. In the scenario where significant changes are needed, the budget shall be adjusted accordingly.

2.2 Goals

- <u>Focus Lane Goals:</u>
    - Basic
        - Maintain drivers attention to the road at all times while the vehicle is in motion by setting off an alarm if the driver deviates their attention from the road. CV will be trained to classify if a driver is looking at the road or looking down (at their phone).
        - Analyze common traffic lights and alert the driver if they are not following them properly. Train CV to classify, depict the contours, and differentiate colors of common traffic lights.
    - Advanced
        - Develop an application that will pair with the device to pull driver data that is collected along trips. For example, an application on a user's phone will keep a tally and download pictures of attention infractions that the user makes.

    - Stretch
        - Create a pre-collision alarm for the driver to notify them of imminent danger on the roadway. Utilize CV in a fast paced environment to depict the speed of incoming objects relative to the vehicle. Then, make a decision to alert the driver to react if they have not been responsive to their surroundings.
- <u>MCU Goals:</u>
    - Basic
        - Using an established UART connection with the raspberry pi. Receive inputs from the computer vision indicating attention infractions and send an output signal to a speaker connected to the PCB board to alarm the driver.
        - Read register values from the inertial sensor to dictate whether the car is in motion or at a stop.
    - Advanced
        - Implement interrupt service routines to have the MCU operate in a low-power mode to conserve energy. MCU will be interrupted by an attention infraction and then alarm the driver of the vehicle by outputting an alarm signal to a speaker.
- <u>Raspberry Pi Goals:</u>
    - <u>Basic</u>
        - Establish connectivity with all components of the final product: PCB and cameras.
        - Train CV and analyze/stream video at 15-30 frames per second
    - <u>Advanced</u>
        - Take pictures using the cameras and stream video to the application for it to be accessed by the user.

2.3 Requirement Specifications and Constraints

The previous sections in this report have described the ambitions and concepts encompassing SafeSight. In order to bring these ambitions into fruition, there are a certain amount of required specifications we must adhere to both hardware and software based. These requirements are what the SafeSight team believes are necessary to bring the project to its fullest potential. Let these requirements serve as a meeting ground for the members of this team and the advisors to all understand the goals and aspirations for what this project will be able to accomplish.

Initially, the first constraint that comes to mind with a compact mounted design is power. How will we power a raspberry pi computer and MCU executing real-time processing tasks including computer vision? Well, first we need to calculate roughly how much power in watts per hour will our execution of safesight require. Below are the average power requirements for the raspberry pi and ESP32 running at various demands.

Raspberry Pi 4 B

Pi State	Power Consumption
Idle	540 mA (2.7 W)
`ab -n 100 -c 10` (uncached)	1010 mA (5.1 W)
400% CPU load (`stress --cpu 4`)	1280 mA (6.4 W)

ESP-32 MCU

Power mode	Description			Power Consumption
Active (RF working)	Wi-Fi Tx packet			Please refer to Table 5-4 for details.
	Wi-Fi/BT Tx packet			
	Wi-Fi/BT Rx and listening			
Modem-sleep	The CPU is powered up.	240 MHz *	Dual-core chip(s)	30 mA ~ 68 mA
			Single-core chip(s)	N/A
		160 MHz *	Dual-core chip(s)	27 mA ~ 44 mA
			Single-core chip(s)	27 mA ~ 34 mA
		Normal speed: 80 MHz	Dual-core chip(s)	20 mA ~ 31 mA
			Single-core chip(s)	20 mA ~ 25 mA
Light-sleep	-			0.8 mA
Deep-sleep	The ULP coprocessor is powered up.			150 μA
	ULP sensor-monitored pattern			100 μA @1% duty
	RTC timer + RTC memory			10 μA
Hibernation	RTC timer only			5 μA
Power off	CHIP_PU is set to low level, the chip is powered down.			1 μA

Table 5-4. Current Consumption Depending on RF Modes

Work Mode	Min	Typ	Max	Unit
Transmit 802.11b, DSSS 1 Mbps, POUT = +19.5 dBm	—	240	—	mA
Transmit 802.11g, OFDM 54 Mbps, POUT = +16 dBm	—	190	—	mA
Transmit 802.11n, OFDM MCS7, POUT = +14 dBm	—	180	—	mA
Receive 802.11b/g/n	—	95 ~ 100	—	mA
Transmit BT/BLE, POUT = 0 dBm	—	130	—	mA
Receive BT/BLE	—	95 ~ 100	—	mA

We need to choose the values that assume we are running every component in its most energy demanding mode so that when we choose our power source, all processes will be properly powered to assure performance of all components. Using the formulas below we can calculate our most demanding average power in watts per hour.

$$Average\ Power\ Consumption(Watts\ Per\ Hour)\ =\ V(Voltage)\ *\ I(Current\ in\ mAh)$$

$$Total\ Power\ Supply\ (Watts)/\ Average\ Power\ Consumption\ (Watts\ per\ Hour)\ =\ Operational\ Hours$$

The values chosen for our raspberry pi will be 5V and 1280mA, demanding 6.4 watts per hour. Additionally, our ESP-32 will demand 3.3V and 240mA which makes about 0.8 watts per hour. Finally, we can calculate our average power consumption and operational hours. If Battery powered, we will assume a 5V 10000mAh battery.

Total Power Supply = 5*10 = 50 Watts **Average Power Consumption** = 7.2 Watts/Hour

Operational Hours = 50/7.2 = 7 Hours

Now that we have documentation on the requirements and performance of powering our product, we can conclude that a battery powered method of power delivery will not provide convenient usage of the product for the user due to frequent recharges needed from driving, roughly every 7 hours. However, our solution to this is to use the 12V charger port in the vehicle with a voltage converter circuit to properly power the device with no worry of any recharge.The wired design will drop our product in size and weight. Furthermore, Most car charger ports run 12V with a 10A fuse which provides 120 Watts of power! This is more than enough power that our device needs and will be the power source tapped into by our Safe Sight product.

2.4 Engineering Specifications

Specifications for each of the project’s subsystems are listed below:

<u>Model Specifications:</u>

- The device cannot be bigger than 8.5 inches x 7 inches to abide by federal highway safety regulations
- Should weigh less than 900 grams

<u>MCU Specifications:</u>

- Should power on the rest of the system when the 12V source is connected to the device
- Amplifies the excitatory signal from the raspberry pi and inertial sensor to the pcb speaker’s requirement of 50-100mV RMS.
- Properly transmits the excitatory signals from both the CV (raspberry pi) and the sensor around the rest of the system with the base UART rate of 5 Mbps.

- Maintains a connection to the user's device that is housing the software via bluetooth from 1.5KB/s to 10KB/s.

RaspberryPi Specifications:

- Properly utilizes the CV algorithms to identify traffic distances and changes at a processing power of 2.4GHz.
- Captures and stores the instances when a driver is distracted via Image Signal Processor and transmits the data to the mcu.
- Executes the two cameras on their respective CV algorithms with no computational overlap with dual 4k display output.

CV Algorithm:

- Identifies the change in traffic conditions such as a moving vehicle, distance, and light changes.
    - Color detection through color thresholding
    - Distance calculation from size change analysis
- Facial recognition to detect when the driver is not looking straight ahead at the road, OpenCV.

Inertial Sensor Specification:

- Detect when the host vehicle has reached a net velocity of 0.
- Detects when the host vehicle has begun movement, immediately signaling the end of an excitatory signal to the MCU when inertia >0.

Software Specifications:

- Should be able to power on immediately when plugged into the 12V source.

Table 2.4.1 Hardware Component Specifications

Component(s)	**Parameter**	**Specification**
Application	Distraction tracking / Live camera feed	Tracks number of distractions and shows live camera feeds
Cameras, raspberry Pi, sensors	Car, light and motion detection	CV algorithms for color thresholding, size change analysis, and face orientation recognition.
Mini adafruit speaker	Beep sound/Action Delay	102dB +/- 3dB , 600Hz to 10kHz
Power	cigarette lighter adapter	12V
Led	To show what light is being detected	1-2 Lumens
Microcontroller ESP 32	Performs calculations and communicates with Pi.	Data transfer >= 5Mbs

	Transmits data to the application host device.	
IC (integrated circuit)	Non-inverting Operational Amplifier to perform message signal amplification.	Gain of range from 50-100mV

Table 2.4.2 *Tentative* **Bill of Materials**

Component	Quantity	Unit Cost	Total
Adafruit BNO055 (Inertial Sensor)	1	$35	
Raspberry Pi v5	1	$90	
Raspberry Pi HQ Camera	1	$50	
Micro SD	1	$12.00	
Raspberry Pi camera	1	$35	
LED	1	$3	
Voltage Regulators	1	$5	
ATMega 328P (MCU)	1	$3	
PCB Board	1	$30	
PCB Speaker	1	$2	
Signal Amp I.C	1	$4	$269

2.5 System Diagram and Visualization

In an effort to bring our ideas to fruition we have drafted a visual representation of both the hardware and software of the system as a whole. These diagrams highlight not only the flow of our system but also references the engineers who are taking responsibility for overseeing the specific components in the system. All of the engineers who are working on Safesight will make equal contributions on all systems and their subsystems, however in an effort to diversify the workload and abide by the constraint of time, assignments to specific areas were made.

Table 2.5.1 Software Block Diagram

Table 2.5.2 Software Block Diagram(2)

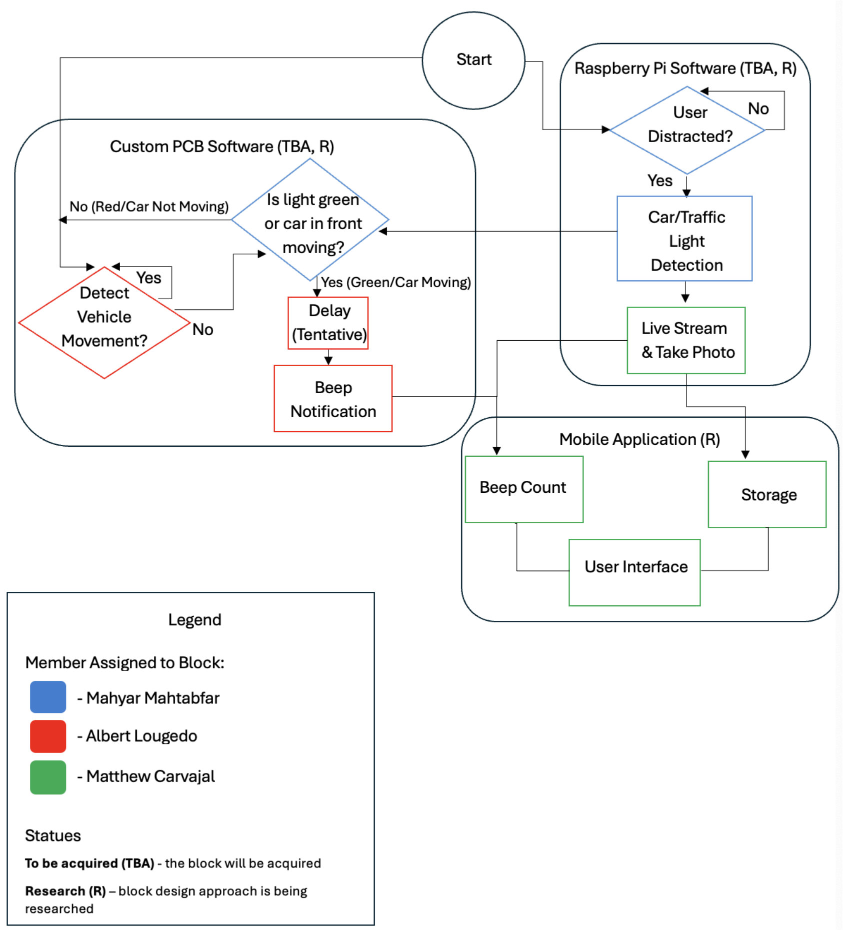
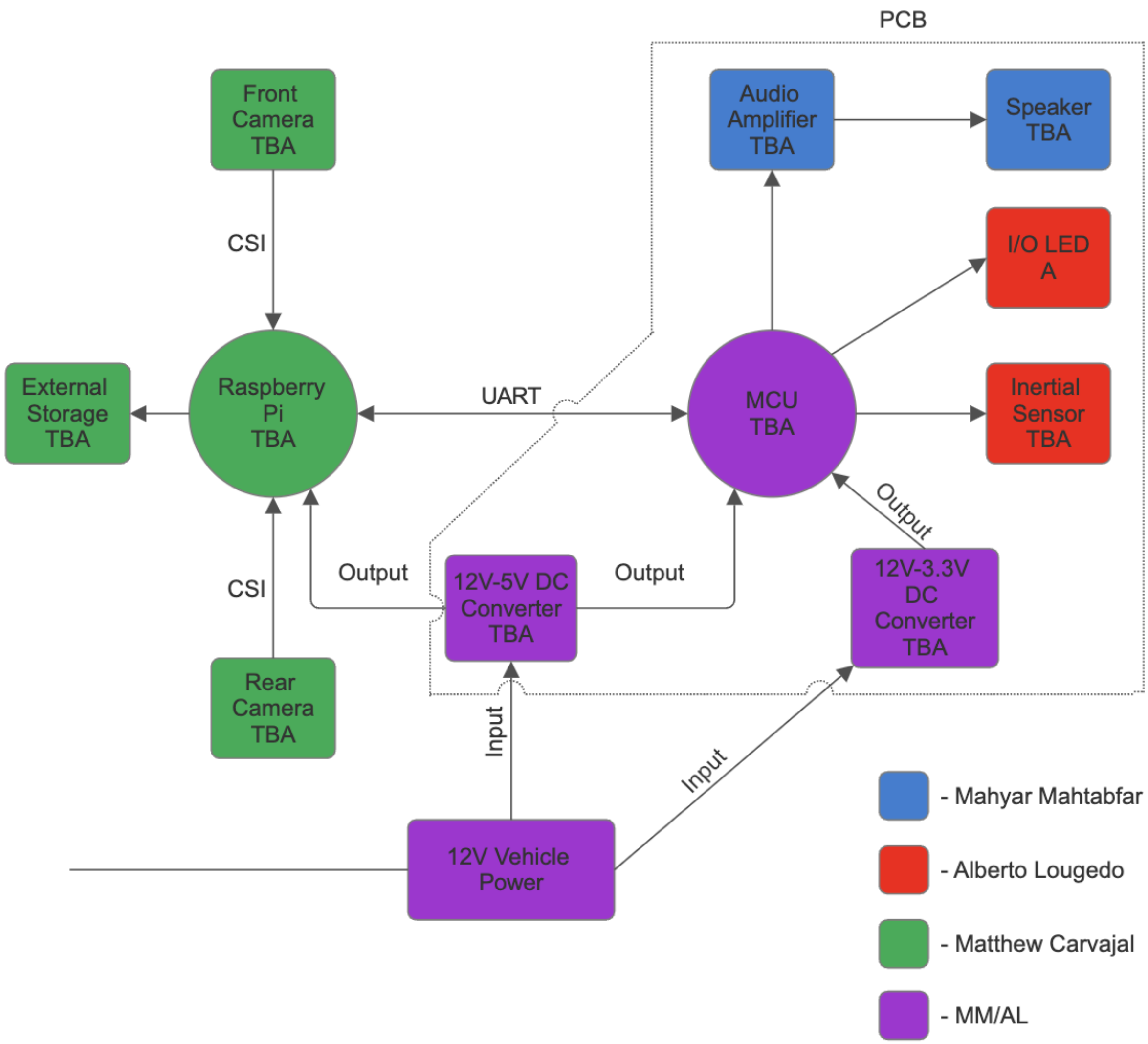
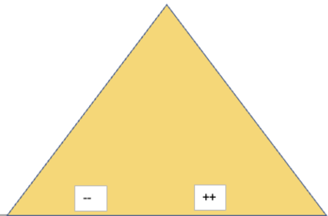


Table 2.5.3 Hardware Block Diagram



One consideration when designing the project is the needs of the customer. In an effort to take these needs into the design process we have to analyze the tradeoffs of our vision with that of the customer, thus a house of quality visuals was made. In the house of quality we utilized a numerical representation to represent the correlation we deemed fit for the technical specifications and the requirements made by the customer. At the roof of the house is our correlation of the technical specifications to each other. This portion demonstrates the tradeoffs we had to acknowledge outside of the customer's needs.

2.5.4 House of Quality



House Of Quality

		Minimize or Maximize	Max	Min	Min	Min	Min	Min	Min	Min
		Technical Specifications (How)	Attention Infraction Accuracy	Weight	Cost	Latency	Power Consumption	Temperature	Size	Start-up Time
	Customer Requirements (What)	**Importance**	1	2	3	4	5	6	7	8
1	Size	5	1	9	3	1	5	1	9	1
2	Weight	2	1	9	3	1	5	1	9	1
3	Cost	3	1	2	9	1	2	1	5	2
4	Ease of Use	5	9	1	1	9	1	1	3	9
5	Power Consumption	1	3	1	1	1	9	9	1	3
6	Latency	5	9	1	1	9	1	1	1	4
		Target	< %90	< 32 Ounces	< $300	< 5ms	< 7.2 Watts per Hour	< 45 Celcius	< 8.5 in X 7 in	< 10 Seconds
		Importance	24	23	18	22	23	14	28	20

Correlations:
++ Strong Positive
+ Positive
- - Strong Negative
- Negative

Relationships:
Strong= 9
Medium= 3
Weak= 1

Guidelines for using the House of Quality also known as QFD (Quality Function Deployment)

1. Identify Customer Requirements (What)

2. Rate the importance of each requirement, 1 = least important and 5 = most important

3. Identify how the product will satisfy the customer (i.e list Technical Specifications)

4. Identify relationship between technical descriptors and customer need (Strong=9, Medium=3, and low=1)

5. Evaluate which direction the Technical Specifications should go to make the customer happy (max or min)

6. Set up targets for Technical Specifications at the bottom

7. Evaluate competing products or services. The question to be answered here is: How well do competing products meet customer wants? This activity is completely based on research. (1 = worst and 5 = best)

8. Determine the desirable technical attributes. In this step, our performance and the competitor's performance are determined and compared