Executive Summary
The objective is to identify an opportunity to improve human life through the use of the Internet of Things. After determining customer needs and doing preliminary research, the need is to increase driver safety and improve the quality of roadways. The technology we have developed is a 3-D Road Scanner. This device will be placed under the front bumper of a vehicle and will scan the depth of the road as the car drives. When there is a deviant in the street height, the sensor will send the data to a database for anyone to view. The goal is for construction companies to use this information to know which roads are in the most need of being fixed. This will improve street quality and in turn increase driver safety.
# 3-D Road Scanner

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1.0 Introduction
The objective of our design project is to identify an opportunity to incorporate the Internet of Things, IoT, into products or systems to benefit the quality of life. As Penn State students taking Engineering Design 100, AT&T has asked us to participate in their design project. For this endeavor, we have been asked to create something to either connect a house, car, or some sort of wearable device into our everyday lives.

1.1 Schedule
Our team’s first steps were to create a Gantt chart to help us stay on schedule throughout the entire design process. Our Gantt chart is displayed below for reference. By following the schedule, we are able to work at an effective pace to accomplish each task. Our group selected the connected car. We determined the need, gathered information, and researched our topic. Because of this we had to determine certain specifications that could only apply to our car. After that we were able to move onto brainstorming and were able to come up with a few good ideas. We determined our solution to the problem and evaluated it. We finally created a SolidWorks drawing of our device.

1.1a: Schedule

1.2 Internet of Things
The Internet of Things uses unique identifiers to connect animals, people, or devices and allows them to transfer information over the internet without using human-to-human or human-to-computer communication. Objects used in daily life could be given an identifier and in turn, can then be managed on a computer. This allows connection to occur from machine-to-machine and can connect any device with the identifier to a network. A modern day example of this is how IPHones connect to IPads with ICloud.
People are able to view anything they have saved to the iCloud on any iCloud enabled device through the use of machine-to-machine connection.

1.3 AT&T and the Project
AT&T is the sponsor of our design project. It is a well-known communications company that provides services to the United States and internationally. They have a large span of resources such as their 4G LTE network, wireless high speed Internet, as well as voice and cloud services. AT&T has participated in this design project before and they have come back to collect our student’s great ideas once again. Each section of Engineering Design has groups working to create the next big solution for AT&T to further develop. Each section selects one team to attend the fair, sponsored by AT&T, held in the Bryce Jordan Center for anyone to attend. There, attendees can see the amazing ideas thought of by our very own Penn State Engineering Design students.

For the project, we were able to choose between the categories of creating Digital Life (Connected Home), Connected Car, or Wearables. The Digital Life is focused on improving life in an individual’s home by connecting devices that are already present. This area can include helping the elderly in their homes and working with systems integration. Wearables are used to connect devices between one another. These help with our design performance and human needs assessment.

The category that our group ended up selecting was the Connected Car. AT&T has asked that we expand the use of the car beyond its normal use for transportation. Some problems they suggest we work on are to improve driver safety, productivity and infotainment. We must make sure to limit driver distraction while maximizing the experience. For example, some smart cars can now determine when you are getting too close to another vehicle and will apply the brakes for you if you cannot react quickly enough.

2.0 Project Background
To define the problem space, we first researched what the Internet of Things is. “The IoT connects uniquely identifiable objects throughout the world through the internet." Only after understanding this, did we begin designing our project.

Before choosing the connected car, we first researched Wearables and Digital Life. To decide our direction, we asked ourselves, “What do people need?” There is no exact answer because different demographics need different things. Our target audience is not exact but we decided to connect with people who will make IoT technology a part of their daily life. These are the people who will communicate with others throughout the world with their watch, their glasses or anything else imaginable. Ones that drive cars
that communicate directly with them. Ones who will own houses that will be nearly or completely automated.

The Wearables aspect seemed most appealing at first and that is where we began our research. Wearables today are very advanced and through thorough research, everything we could have imagined was either too advanced, as in unrealistic, or already invented. We moved onto houses and we had some good ideas that we did not want to rule out. Finally we came to cars, and after some research, we settled on a solid idea; a 3-D Road Scanner that maps the surface of the road within a quarter-inch.

2.1 Stakeholders
Although this will not be sold directly to the consumer, car manufacturers could add it to their new vehicles. AT&T will also hold stake as we could use their cell towers to send the information to a satellite that will, in turn, add it to the IoT and the interweb. Judd Communication will also have stock as they will build and finalize the sensor. We, the creators, will also claim stake as we created the product.

2.2 Customer Needs
To determine our customer needs we had to ask our stakeholders a series of questions. A list of our questions are placed below along with a chart of the responses.

2.2a: Survey

To make sure the consumer can conserve gas and protect their car by driving on smoother, safer roads, there will be an app that can see which roads are not as torn up as others. The Department of Transportation will also benefit from this device. With the department being able to see an accurate depiction of the entire roads surface, they can
better allocate funds to fix roads that are in desperate need of fixing before roads that aren’t as dire. Also, with them fixing roads in need, driver safety will increase because roads will be in better condition to drive on.

2.3 Proposed Technology
Through technology research, the cell phone towers sending the information to the IoT is most plausible for a few reasons. The biggest reason for not choosing Wi-Fi, Bluetooth, Ultra Wideband, Zig bee, or ISA100.11A is that the car may be moving at a high velocity, making it difficult to connect to these stationary wireless protocols. We chose to use UHF (Ultra High Frequencies) transmitters as it will be energy efficient and easily connectable to the phone towers of AT&T for transmitting the information.

To scan the road, the scanner will be similar to the Judd Communication Depth Sensor where it has a resolution of 3mm and is accurate within a centimeter. However, the sensor will be a bar under the front bumper that sends a pulse to scans the road within the width of the car. The receiver will be farther back on the car’s underside. That is where the information will be gathered and sent to the towers. It uses ultrasonic waves at a speed of 50 kilohertz (50,000 cycles/minute).

To know which roads the car is sending the information from, the car will also need to be connected with GPS to map roads coherently and accurately.

3.0 Project Objectives
The project needed to be designed in a way that the device could connect to the IoT and increase the quality of living. The following specifications and objectives will help to enhance the prospective device to its highest capabilities.

3.1 Preliminary Specifications
● Creates safer driving environment
● Not distracting
● Eases travel
● Can reduce accidents

3.2 Technical Specifications
● Must be able to connect to a network and transmit data
● Must detect depth up to the nearest centimeter
● Must run off a car battery
● Must fit on the front bumper
● Must be no bigger than a foot cubed
4.0 Conceptual Designs

Our idea is a three dimensional road mapper where sensors on cars can identify potholes. These cars would then alert the city hall to have maintenance constructed on each road. Based on how often a pothole is driven over and how deep it is will determine the urgency of the city’s maintenance to fix the problem. The way this system works is by placing a sensor that scans the area underneath the vehicle on the bottom of every car’s bumper. If the depth is greater than the specified height from the bottom of the wheel to the sensor, then the pothole is reported. All of the information will be stored in a database for anyone to access. The goal is for construction crews to be able to view the information in order to know which roads need to be fixed.

4.1 Ideas

Our ideas we developed before coming up with our actual design included a mixing and matching between different scanning methods and several communication techniques. These included radar with Bluetooth, infrared with ultra high frequency, and sonar with Wi-Fi, and then our actual idea of sonar with ultra high frequency. Later in this report, we demonstrate how and why this combination is the most appropriate.

4.2 Research & Analysis

We used concept screenings to take each idea we developed to determine which would be the most ideal for this product. We researched each method to find its pros and cons and compared them to the other techniques to decide which was the best option. You can view each of these concept matrices below.

<table>
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<tr>
<th>SELECTION CRITERIA</th>
<th>CONCEPT VARIANTS</th>
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<tbody>
<tr>
<td></td>
<td>Radar</td>
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<tr>
<td>Detects Depth Within 1 Centimeter</td>
<td>-</td>
</tr>
<tr>
<td>Can Run Off of Car Battery</td>
<td>+</td>
</tr>
<tr>
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<tr>
<td>Availability</td>
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<tr>
<td>RANK</td>
<td>3</td>
</tr>
<tr>
<td>CONTINUE?</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 4.2a: Type of Sensor
### 4.3 Concept Selection

As you can see by the tables above, the best combination in terms of scanning, communication, and location is sonar, ultra high frequency, and underneath the front bumper. Thus, these are the methods our group shall go forward with.

### 5.0 Detailed Design

The Road Scanner is a long rod-like structure located on the underside of the car, near the front bumper, with a pad attached to it (figure 5.0d). The dimensions of the device will vary by vehicle, but are generalized in figure 5.0c.

#### 5.1 Rod

Inside the rod-like structure is the ultrasonic transmitter. The transmitter's frequency is 20kHz which is a high enough frequency to accurately depict the road’s surface, even when the car travels at high speeds. The outer-covering of the rod is a durable polycarbonate that allows the ping to travel through without disrupting the transmission. The outer-covering is nearly frictionless so that dirt and other contaminates do not stick
to the surface of the rod. To make the outer-covering frictionless, we will cover it in a carbon coating that was developed by Argonne.

5.2 Receiver Pad
The pad is a receiver as wide as the beam that translates the sonar echo into code. It will also be frictionless to prevent dirt from sticking to it. The receiver will be able to connect to the speedometer of the car so that it can synchronize the timing of the ping with speed of the car so that speed does not affect the scanning and mapping ability.

5.3 Transmitter
After the data is collected by the receiver, it is sent to a microcomputer that, along with the data from the GPS telling the cars location, translates the data again so that it can be transmitted to a cell tower using the Ultra-High Frequency waves that cell phones use.

5.4 Final Design
After it is sent to the tower, a server collects all the data. The data will be translated so that the 3-dimensional representation of the road can be viewed either on an app or a web page. From here, there will be software that will automatically detect defects in the road so that mapping and GPS applications can understand which roads are best suited for driving. The whole device runs off the car's battery, and needs little energy, as to not affect the car.

5.4a: Sensor Top Isometric View
5.4b: Sensor Bottom Isometric View

5.4c: Sensor Multiview
5.4d: Underside of Car with Sensor Attached

5.4e: Flow Chart
6.0 Conclusions
AT&T asked for a product that incorporates the IoT in either a wearable, car, or house that makes the customer’s life easier or safer. Through surveying our audience and doing countless hours of research, we were able to determine the need was to improve our roads and increase driver safety. The 3-D Road Scanner was our solution that satisfied both goals. We defined our specifications and were able to select the use of Ultra High Frequency and sonar and that the device should be placed under the front bumper. The sensor works by collecting information on variants in the road’s height while the car is in motion and then sending that to a database. This is connected to the IoT and allows the general public to view the present road conditions in order to plan for safer trips. Another goal is that construction crews can view the information gathered. This will help them to determine which roads are in the most need of being corrected. With the roads in better conditions, there will be fewer accidents and driver safety will increase.

7.0 References


