Swerve

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1. Executive Summary:

Swerve is a cheap, small device that attaches to cars, thus saving businesses money, vehicles, and lives. Our team is dedicated to building an affordable, accessible, attractive product, which will support a variety of businesses and the city government to be as successful as possible.

Our product is an easy-to-install product which can be bought for $40, and has a $1 monthly service subscription. It sits on the bottom of one's vehicle, where it detects crashes and poor road conditions such as potholes and speed bumps. When these events occur, their location, time, and severity are uploaded to a cloud database where businesses such as Turo or Renty can verify damage caused by hitting potholes or crashes and use this information to quickly file insurance claims and/or report it to the city.

In addition to the value this provides to transportation businesses, we intend to build an extensive map of road conditions. This data is extraordinarily useful to cities such as the City of San Diego, which can then repair roads and discover important information regarding the condition of the city and how/when causes crashes, and their frequency and patterns. This data, once bought by the city, has the potential to dramatically increase road safety and improve public infrastructure while decreasing tax expenditure.

Unlike many of our competitors, our product is much cheaper and more accessible, while also being convenient. Competitors such as StanTheApp require users to manually log street conditions. Meanwhile, CityRover and Robotiz3d are expensive, and unnecessarily complex, making them inconvenient for businesses and individual consumers to use. We plan to fix that with our cheap device, which will have excellent support and will be continually updated and improved in order to personalize business needs. We will be targeting two market segments - the road maintenance market and the vehicle protection market, with current market values estimates of $23.39 billion and $146.01 billion and respective projected growth rates of 5.13% and 10.2%.

Our team is extraordinarily excited to bring this product to San Diego; our extensive software and hardware backgrounds, developed at UCSD have been combined to build a product which strives to support the city. We are striving to meet the expectations of companies such as Renty and the City of San Diego - and potentially MTS, which have shown interest in working with us by building a product which is easily accessible to all people and is ethically and sustainability focused to reduce emissions caused by poor road quality with a device that is environmentally conscious.

As we continue growing, we are excited and prepared to add additional features as we scale, including continuous vehicle tracking and other customizable and optional features. We look forward to your investment!

2. Company Synopsis:

About Us:

We are Swerve, a team focused on building hardware and software which attaches underneath a car and detects potholes and crashes, thus updating a database of these and a Google Map displaying them. We are a good fit for this project because our team combines a wide range of relevant skills and experiences essential to building an incredible product.

Adrian has expertise in Python (numpy, tensorflow, uvicorn), and HTML, bringing valuable capability to building the server ecosystem and building the webpage that Swerve runs on. Additionally, his valuable experience in Image Inpainting and computer vision allows our team additional flexibility in future extensions to our base project.

Eddie's background in computer science and full-stack web development, coupled with his proficiency in MySQL, database design, and AWS (Lambda, S3, EC2), ensures us to build a robust and scalable software database. His skills in Python, Java, and C have enabled him to implement the Google Maps Plugin which was necessary for Swerve to function.

Ethan, an electrical engineer, contributes his proficiency in Python, C++, HTML, Javascript, and SQL, as well as circuit design. His electrical engineering expertise along with his software experience allowed him to work on our phone application, which served as a liaison between our hardware and the server.

Henri, also an electrical engineer, specializes in embedded systems, CAD, and 3D printing, alongside Python and C++. His skills enabled him to build our core hardware and to develop the software which enabled it to run.

Together, our team's diverse hardware experience and strong software development skills, including web development and API usage, position us well to build the MVP. Additionally, all team members have driving experience, and two have access to cars, facilitating our success. Overall, our team is uniquely positioned to bring Swerve to market because our strong intra-team connections, wide array of skills, and emphasis on truly understanding the needs of our customers provide us with the drive, means, and vision to realize Swerve.

Team Weaknesses:

Our team will definitely need to hire people who can help us build this product at scale. We are not familiar with a lot of the practical elements of scaling a business to a factory level. Beyond this, we will also need to hire a lawyer to help us establish patents and ensure the legality of all of our promises and goals; we lack a lot of knowledge with actually establishing businesses and setting up all the necessary formalities (i.e. taxes, funds, etc.), so we would need an accountant as well. A lawyer would also be able to support us with negotiating with companies such as Waze.

In terms of building or conceptualizing the product, we may also want to hire an experienced software engineer and designer to look over our code and website, helping us ensure it would work at scale, and can support the loads we expect from it. Similarly, we would need to hire a security consultant in order to support us with ensuring that we have properly secured all of the information we collect properly.

Business Vision

Swerve is a product that saves money, cars, and lives for businesses and customers who need to be aware of what is occurring to their car and road conditions. We're different from competitors like StanTheApp and CityRover because our product is much cheaper and less intrusive. We will generate revenue via a one-time-staple fee and a subscription for access to data and support. We strive to be accessible to consumers and environmentally conscious.

3. Market Overview:

The global road maintenance market was valued at $14.91 billion in 2023 and is projected to hit a market valuation of $23.39 billion by 2032 with an annual growth of 5.13%. With the expansion of infrastructure, our roads are becoming increasingly important, with an estimated $500 billion spent every year on road maintenance. Swerve's capability to detect potholes accesses this market by collecting information on where road damage occurs and enabling faster repairs that reduce maintenance costs in the long run. Given that spending on preventive work is estimated to $6 to $10 for every dollar that would otherwise have been spent on major construction, early warning systems such as Swerve that provide organizations with the ability to detect road damage before it escalates has the potential to capture a large share of the market (Road Maintenance Market Size, Share & Growth [2032] (astuteanalytica.com). There lies especially strong market opportunities in areas with high traffic, as high throughput of cars and low road quality can quickly lead to large expenses. Luckily, Swerve functions best in these sorts of dynamics where large quantities of drivers are present to map and detect road damage. With this in mind, we plan to address the road surface inspection portion of the market, which places our addressable market at $376.1 million with predictions to reach $536.1 million by 2030 (Road Surface Inspection Systems Market, Report Size, Worth, Revenue, Growth, Industry Value, Share 2024 (valuates.com)). Since our solutions will offer lower-cost alternative to competitors but less in-depth mapping, we realize that our solution is not the ideal for all customers within this market such as those with the money or desire to pay for in-depth road mapping services . Therefore, we hope to capture 10% of this market, emphasizing on customers with a priority for low cost and rapid detection.

Along with accessing the road maintenance market, Swerve also touches on the vehicle protection market. The vehicle protection market is globally valued at $146.01 billion is projected to reach $288.3 billion by 2030, growing at a compound annual growth rate of 10.2% (Vehicle Protection Service Market Size & Share Analysis - Industry Research Report - Growth Trends (coherentmarketinsights.com) . With a market growing so rapidly, there is a large potential for financial gain. However, Swerve touches on a very

niche portion of this market by detecting potential incidents of hazard in your car, which is not currently done by many others. As a result, our specific target market is underdeveloped and there do not exist any statistics on its current valuation or projected growth. That being said, we do have the advantage of capturing the vast majority of this market, and we hope to capitalize on this to capture 40% of this market, given that there are some adjacent potential competitors such as built-in maintenance systems in newer vehicles.

4. Competitive Analysis:

Competitors:

StanTheApp:

StanTheApp is a free phone application which allows users to report a wide variety of road defects, such as potholes, to authorities. The app uses computer vision to identify the defect and its location. They are based in Great Britain and have approximately 6,000 images within their database.

Their competitive advantage is that they appear to be well established and are free, which makes their product very accessible. Additionally, they have a lot of information and their website and user experience appears to be very pleasant. Their biggest downfall, however, is that they are inconvenient to use; the user must manually take a photo or video, which is likely why they appear to have captured only a small proportion of their market.

CityRover:

CityRover uses AI cameras to detect and report a variety of infrastructure issues; it is similar to a dashcam, which then adds the data to the cloud. It can package this information into a work management system they have created for construction companies, directing them on how to efficiently do work. It is used in ~250 cities and has reported approximately 400,000 incidents.

Their competitive advantage is that they are working with their market really well; they know they are working with cities and repair work, and they've zeroed into it. Their website and infrastructure is very focused on repairing roads and reporting a wide variety of damage directly to the city, and then managing the repair process. Our advantage compared to them is that our device will be less intrusive, cheaper, and it will have a wider market, making the data collection more powerful and extensive. Their largest weaknesses seems to be that they have stringent requirements to work with, and appear to not have that large of a quantity of data.

Robotiz3d:

Robotiz3D consists of large robot cars which drive around roads, identify potholes, and then repair them, themselves. The idea is that they are self-sufficient and will cut out the need for workers to manually go repair potholes, which is much more expensive and slow. It is based in UK and aims to be cheaper than current solutions, while also mapping where potholes are occurring.

Their competitive advantage is that they are fully self-sufficient and can carry out the full pothole repair service from start to finish. Additionally, they will save cities much more time than all the other existing solutions, including our proposed solution. With that said, their product doesn't appear to actually exist, and instead appears to be in early demo stages. Beyond this, the robot itself will likely be prohibitively expensive and its legality and safety on roads is questionable, and the company does not seem to have sorted out the details of how it will work yet.

Our Whitespace:

Our product has several large advantages which make it very competitive in this market by fulfilling the space our competitors have left. The three largest factors which make our product competitive is that it is cheap, simple to use, and flexible.

Our product is cost competitive; we intend to charge $40 for the product, which is cheaper than CarRover's and Robotiz3d's prices by a large margin. While it isn't free like StanTheApp, our product allows for automation of a process and allows for scaling, which theirs does not. Indeed, for businesses, our product carries several solutions, which StanTheApp doesn't, at a much cheaper cost than other companies which are focused on supporting businesses and the city and not only individual citizens. Our low cost is a large advantage for us as well, since it will be much easier to build large data networks and maps of potholes if we can mass-sell our product.

Additionally, due to the flexibility of our product, it is not only constrained to tracking potholes; it can also track crashes, damage to the vehicle, and the location of all of these, which our competitors do not do. Additionally, due to how our product is designed, we can easily add features and expand into having passive car tracking and more, which is something businesses want, which our competitors cannot do. Altogether, due to the flexibility of our product and that

we are not entrenched into any specific market, we are able to make our product attractive to many more consumers.

Lastly, our product is simple to use; it is very unobtrusive and only needs to be strapped to the bottom of one’s car. Once it's there, we hope to make it into something which the user does not need to worry about again. While we are currently using batteries to power it, we are hoping to find alternative solution, such as tapping into the car’s power (and also reading error codes from the car), or using larger, longer-lasting batteries. Meanwhile, StanTheApp requires users to take individual pictures of potholes themselves, and CarRover is a large dash cam-type object which sits on your windshield.

5. Customer Personas, Interviews, and Acquisition Plan:

Customer Personas, Interviews, Job Stories:

Customer Persona #1: Rental Companies:

Rental companies, both small businesses and large chains, have always had to deal with various problems resulting from potholes/hazards on the road and also from incidents causing damage to their rental cars. During our interviews with these rental companies, we were able to pinpoint their main pain points

Job-To-Be-Done: Rental companies want to be able to detect and store data about potential damage resulting from potholes or crashes. This information needs to be reliable and also automatically be reported to the rental company, not just to the user sitting in the car who's also connected to our product with their phone.

Job Stories:

- When someone driving a rental car gets into an incident that damages the car, I (the rental company) want to receive a notice immediately and also get all relevant information such as location, time, severity, etc.
- When a typical customer rents a car in a place they're unfamiliar with, I want to be able to provide them with mapping data or just general recommendations on where there might be hazards and how to avoid them.
- When a customer returns a rental vehicle outside of normal business hours, I want to be able to release their deposits and handle the return as soon as possible, but I also need to ensure that they haven't damaged the car before doing so.

Customer Journey: We approach rental companies and offer to install our product on their fleet of vehicles to help them deal with damage prevention and reporting for a fixed upfront cost. As the rental company uses our product, they will also pay us low monthly upkeep costs and come to us to replace/fix any devices that were damaged in incidents. In the case of chain rental companies, we would trial our product at one of their locations and assuming they see that our product saves them money in the long run, we will begin to install our products at more locations nationwide.

Linked Interviews:

Renty Interview.m4a

Enterprise Interview.m4a

Customer Persona #2: The City/UCSD:

The city is interested in the information we plan to provide to our customers, believing that it could genuinely have an impact on consistent and responsive road maintenance. So long as high risk areas are frequently updated with new information, we could work to build a long term relationship with city officials to uphold safe road conditions and to reduce the amount of financial drain on government bodies.

Job-To-Be-Done: The city wants information on the location of potholes to quickly eliminate road hazards and reduce the amount of individuals who would otherwise ask for compensation due to damages.

Job Stories:

- When dangerous potholes emerge in high traffic areas, I want quick access to each one's location, so that I may organize efforts to fix them before they cause further damage.
- When parts of the city suffer from neglected infrastructure, I want detailed information on where maintenance needs to be performed, so that I organize the necessary entities to initiate repairs.
- When I am initiating repairs, I want to be able to get them done as quickly as possible, so that I lose less money to poor logistics.
- When I am creating bills for city infrastructure, I want to minimize the amount of tax money spent, while maximizing the effects, so that voters are happy and will reelect me.

Customer Journey: The city is either approached by us directly or learns of the product through other cities implementing it in their road maintenance system. Our device is strategically attached to vehicles that either frequently travel through high traffic areas, neglected roads, or have routes that thoroughly and routinely cover the city's streets. Information is provided to the city, who begins to use it to quickly respond to road maintenance issues. Once the lifespan of

the product expires, the city may choose to purchase replacement hardware, and will continue to receive data on hazard locations regardless of their decision.

Linked Interviews:

OllieCantosCityCouncil.mp3

Customer Persona #3: Normal Driver Interviews:

Normal Drivers tended to be semi-interested in our product, with an average net promoter score of 4. While drivers did tend to think that potholes were an issue, they frequently were only willing to spend a limited amount of money on our product, and were unhappy that we may be potentially selling their data from a device they purchased. Based on our second interview, we found that customers seemed to be more interested in the crash detection and also a potential future feature of passively tracking the car.

Job-To-Be-Done: General drivers want to be aware of what is happening with their cars at all times and to increase their safety as much as possible.

Job Stories:

- When I am driving in unfamiliar areas or when it's raining, I want to receive real-time notifications about any detected potholes, so that I feel confident and safe on the road.
- When I am trying to plan a road trip, I want to be aware of where road incidents have occurred, so that I can save time and keep my vehicle in good shape.
- When I park my car for a long time, I want to be able to passively track its location, so that I can find it and will also be notified if it is stolen.
- When I hit a pothole and damage my car, I want to be notified that I can file a claim with the city, so that I am aware that I will not need to pay for the damages myself.
- When I hit a pothole and damage my car, I want to be able to quickly file a claim with the city, so that I can recuperate my money.
- When I am involved in a car crash, I want my emergency contacts to be notified, so that they can come and support me as quickly as possible.
- When my son or daughter is in a car crash, I want to know about it and its location as soon as possible, so that I can support them and make sure they are alive.

Customer Journey: A customer will see an advertisement of our product on social media and click on it, coming to our site and/or Amazon. There, they will be able to purchase our product, which will quickly arrive at their door. Once they open it, a small information booklet containing a summary of how to set it up in 8 simple steps will be the first thing they see. As they begin setting it up, they will discover that the device easily attaches to their cars and they will experience no issues while connecting to it. While using our map, they will be notified of any incidents that we monitor, and will be able to plan their trip according to these incidents. Ultimately, whenever they experience issues, they will be able to contact our support line for rapid assistance. Once the end of life of our product occurs, or their battery needs to be replaced, they will be able to easily remove the product, and will be able to find disposal/replacement instructions on our linked website. During this process, we will offer them a new, discounted, pothole detector hardware, and will regardless continue to give them access to the data we collect in order to increase customer satisfaction and retention.

Linked Interviews:

JD Russo Interview Video - 1715883767671.mp4

InterviewVaishParents.mp4

Customer Persona #4: Car Hobbyists:

Car hobbyists were very interested in the potential to detect potholes and speed bumps since the cost of damage is significantly higher for them since many of their cars are custom-built or heavily modified. Also, for many car hobbyists, the likelihood of car damage is much higher because they cars are often older or lower-clearance. Their current solution to avoiding potholes are memory, which they give a net promoter score of 4/10 because it is difficult when they drive to car meets and new locations to know ahead of time where speed bumps and potholes will be.

Job-To-Be-Done: Car hobbyists want to know where potholes and speed bumps are so that they can avoid damaging their cars that they have invested in.

Job Stories:

- When I am driving to a car meet, I want to know where potholes are so that I can prevent my car from being damaged.

- When I hit a pothole, I want to track where the damage occurred so that I can remember to avoid that road.
- When my car is in an accident, I want emergency services to be notified so that they can help my injuries.

Customer Journey: A classic car fan will see our product at a car meet and an existing customer will tell them about this new product that helps them avoid potholes to protect their cool car. The potential customer will look up Swerve online and be surprised at its low cost and decide that it is a good investment. The customer will then purchase the product which quickly ships to them and provides clear instructions on how to simply mount the product and set up their account. The customer will mount the Swerve hardware and set up their account within 10 minutes, and then regularly check the app to successfully avoid potholes and speed bumps. The customer will continue going to car shows and spreading the word of their positive experience with Swerve. When the Swerve product breaks after years of use, the customer will decide that the product is cheap enough to buy another one, thereby creating a cycle of usage.

Linked Interviews:

Jarett Smith Interview - 1715884442330.mp4

Customer Acquisition Plan:

Depending on our customer persona, we intend to acquire them in different ways. We see 3 primary customer ‘segments’ or ‘markets’ that our product will target. Our foremost is businesses, such as Lyft, MTS, Uber, Turo, and car rental companies. Second, we have the city and map applications. Finally, we have general drivers.

We intend to acquire businesses such as Lyft, MTS, Uber, Turo, and car rental companies by specializing our product so that it best serves their needs. We intend to add car tracking and optimize our system so that they get notified if a car crash or other car incident occurs. In order to acquire businesses such as this, we intend to first do more interviews with them to best accommodate them and introduce features which are customized to their needs. Next, we intend to offer a pilot program to these companies and give them a few devices for free, so that

we can collect feedback and give them the opportunity to use and enjoy our product. Finally, we will discuss with their procurement departments to establish a deal. Once we have all of this in place, we will offer customized training and support for using our product while also offering metrics and data showing that our product is useful. Altogether, we will entice businesses with free trials and then slowly develop an agreement with them, while providing support to keep them as loyal customers.

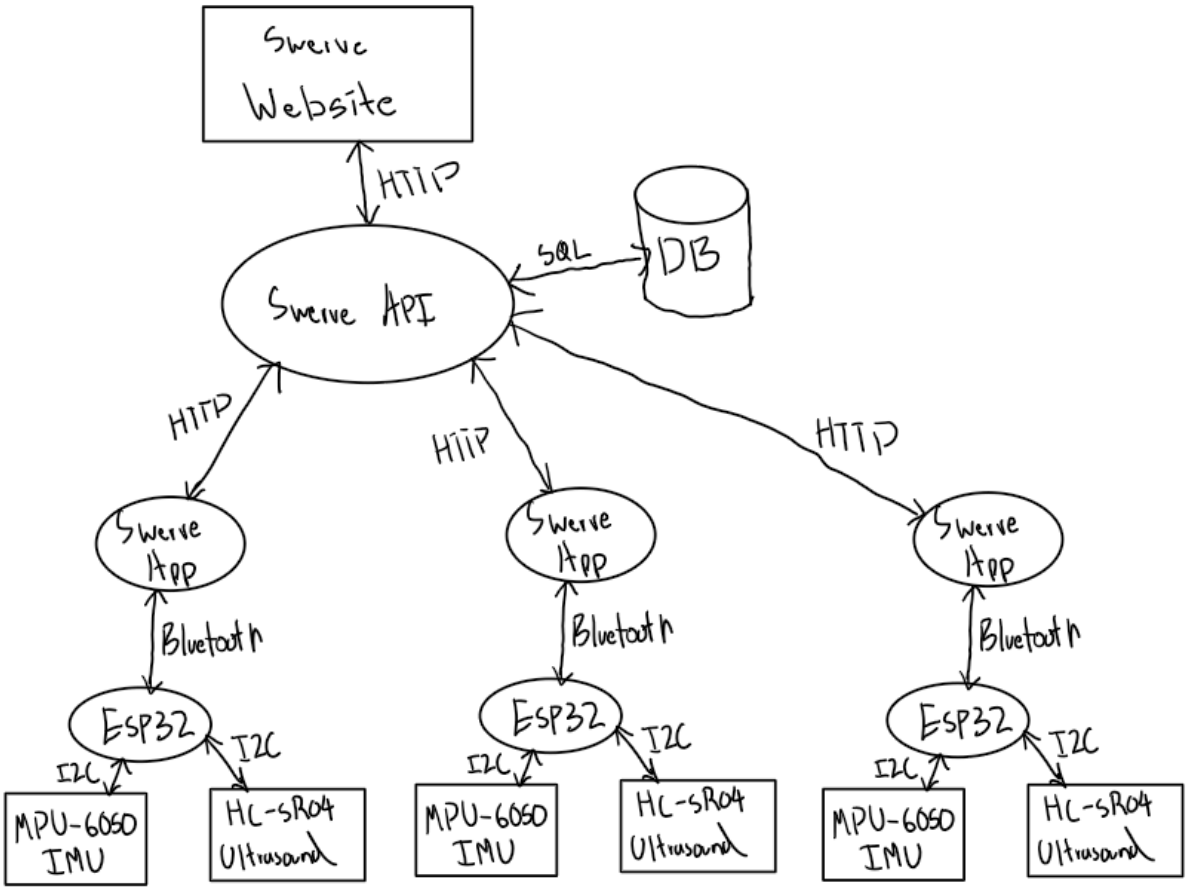
Beyond this, our acquisition plan for the city and map applications is to wait until we have collected data from our other partners. After collecting comprehensive data from our initial partners, we will analyze and package this data into actionable visuals. We will then target city governments and map application companies like Google and Waze, highlighting the benefits of our data for road maintenance, traffic management, and enhanced routing. Through targeted outreach, customized proposals, and negotiations, we aim to establish long-term partnerships, offering continuous data updates and additional insights.

Finally, we intend to also make our product accessible for general consumers and drivers. We are planning to introduce different versions of our product to best address consumer needs, such as car tracking and crash notifications. In response to feedback, we will shift our marketing strategy to emphasize these popular features over pothole detection. Additionally, we may reduce costs or simplify the product to enhance its appeal and affordability. To further support customer acquisition, we will launch targeted marketing campaigns highlighting key features and benefits, using social media and influencers to reach a broader audience. We will also introduce promotions and incentives, such as discounts, referral programs, and free trials, to attract new customers and encourage word-of-mouth.

6. Product Details and Design:

Technical Design:

Our product can be broken down into 4 distinct components: the sensor, the app, the API, and the website.

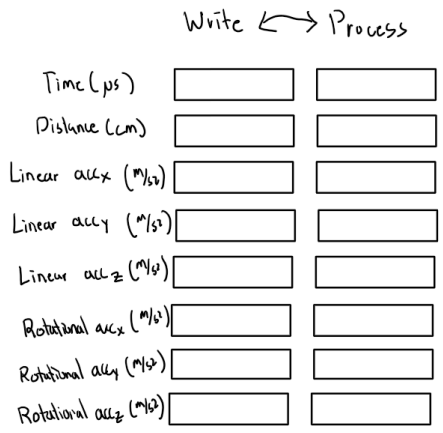


Connection Map

Hardware Design

Our hardware component consists of an ESP-32 connected to an MPU-6050 IMU for accelerometer and gyroscope readings, and a HC-SR04 ultrasonic sensor for distance readings, which all communicate with each other via I2C protocol.

The ESP-32 operates using 2 separate sets of writing and processing buffers with 8 buffers in each set with 100 samples per buffer that store each respective reading and regularly sample and store the results in the corresponding index in the buffer. When the buffer is full, the set of buffers used for processing and writing are swapped, allowing the ESP-32 to start a secondary task that processes the processing buffer while still capturing the sensor values in the writing buffer.



Buffer Layout

When the processing task detects a sudden change in acceleration, it flags it as a potential pothole and opens a Bluetooth connection with the app and serializes the buffers and sends the data to the phone to be parsed back into buffer form and then classified.

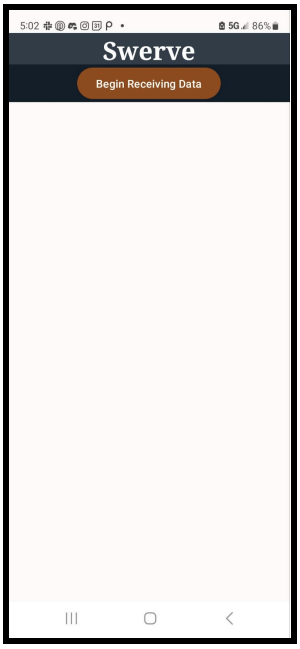
By minimizing the processing done on the ESP-32, we are able to achieve a faster sampling rate and increase the processing speed to reduce the latency between pothole occurrence and pothole detection and increase the precision of our measurements.

Our hardware is powered by a small USB-compatible battery pack for easy recharging, and is housed in a 3D-printed enclosure with cutouts for the ultrasound sensor. The device is easily attached to the bottom of a user’s vehicle using 3M double-sided tape.

Swerve Enclosure

App Design

Our Android app's purpose is to function as a geolocator and communication gateway between the ESP-32 and our API. Therefore, it has a very simple UI, and the majority of its tasks occur in the background, allowing it to connect to the ESP-32 over bluetooth, receive and process the sensor data transmitted from the ESP-32, and then make a POST request to the Swerve API to add a geotagged incident.



Swerve App Display

Our background process consists of 3 tasks: receiving bluetooth data, classifying the incident, and notifying the Swerve API.

To receive the Bluetooth data, we establish a Bluetooth connection with the phone then read in the incoming bytes and convert them to strings, with each packet delimited by “BGD\n” to indicate the start of a potential incident and “END\n” to indicate the end thereof. We then split the buffers using newlines between the contents of the sample buffers to get the appropriate acceleration, distance, and time values.

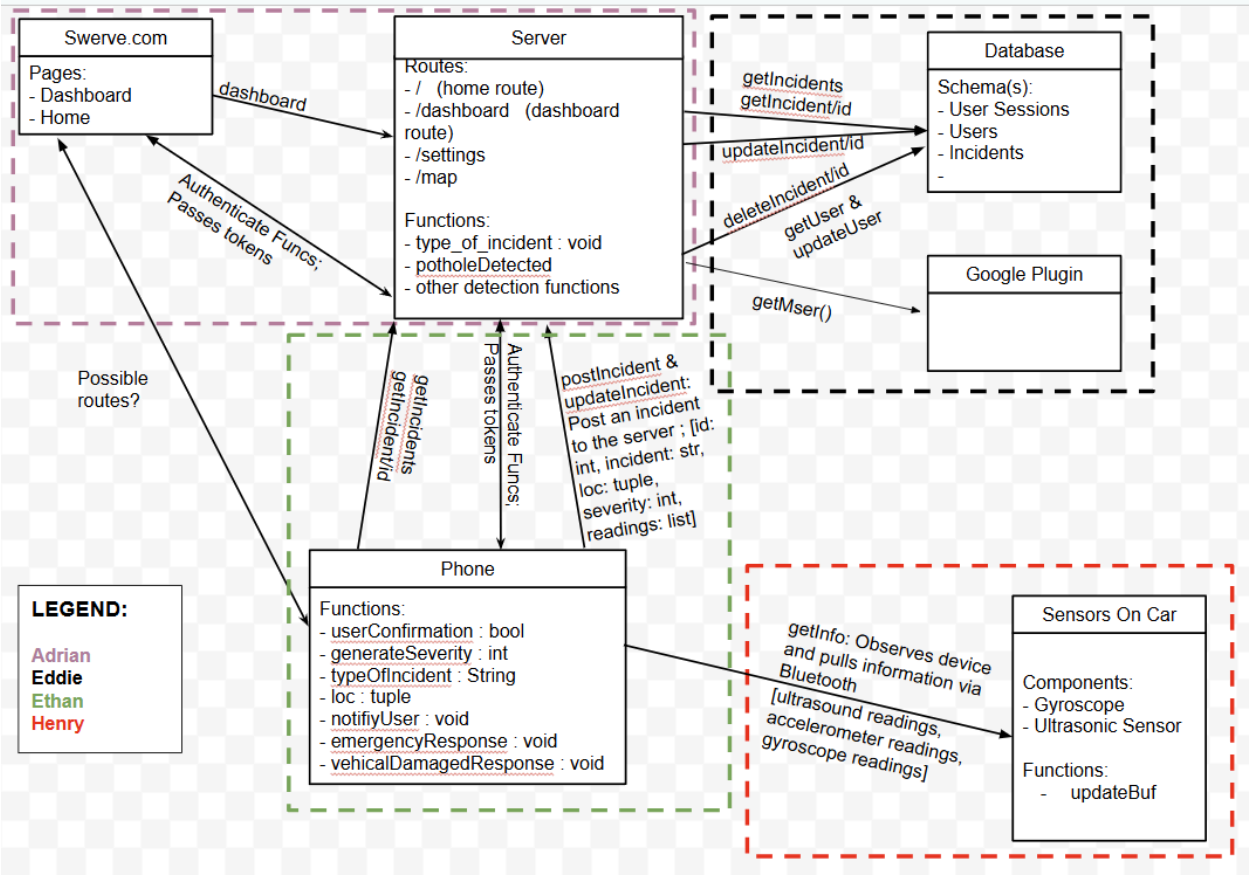
Once we have received the Bluetooth data, we use a simple heuristic to compute the peaks of the acceleration and sensor data, and we classify the incident. Potholes are classified by a negative peak in linear acceleration of z-axis followed by positive peak or increase in distance followed by decrease in distance. Speedbumps are classified by a positive peak in linear z-axis followed by negative peak or decrease or increase in distance followed by decrease in distance. Crashes are classified by a severe change in linear x and y axis or severe changes in any rotational acceleration axis. In the case that no severe changes are observed, the incident is deemed a “No incident”, and no data is transmitted to the API. In this process, we also extract the length and depth of the pothole or speed bump using the peak width.

After classifying the incident data, we convert the information to JSON format and make a POST request to the Swerve API's addIncident route.

API Design

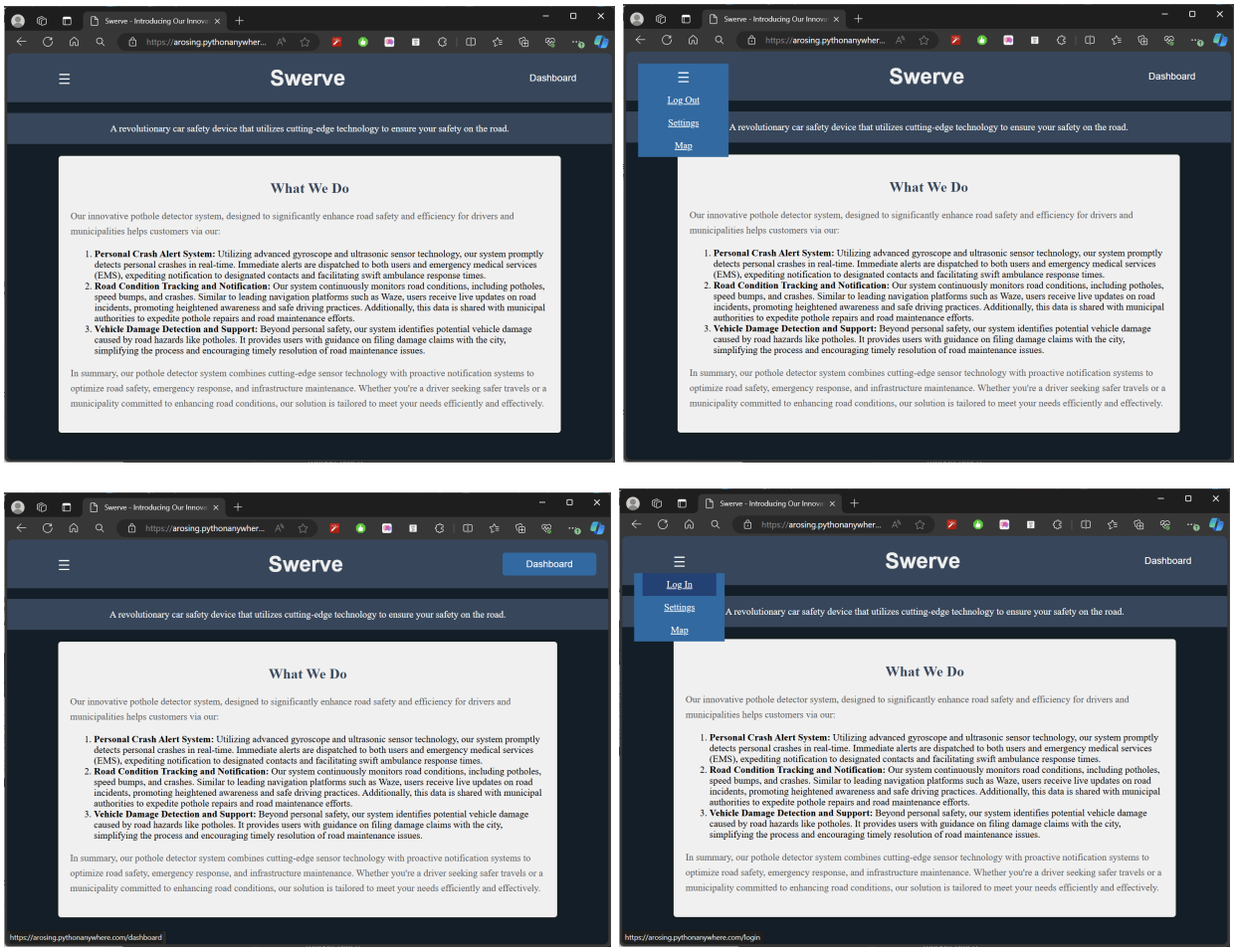
Our API was designed to be simple to use and well documented. It is designed to communicate primarily with the phone as a liaison between the server and the hardware, but occasionally it communicates with the database.

The API manages two tasks; tracking users and tracking incidents. It can add an incident, modify an incident, delete an incident, update an incident, and return an incident. Similarly, it can do all of this with the user. For each of the API calls, it will pull from our AWS database and format the information as needed for the action. Further documentation of our code API can be found at: [Swerve Github.]



Website Design

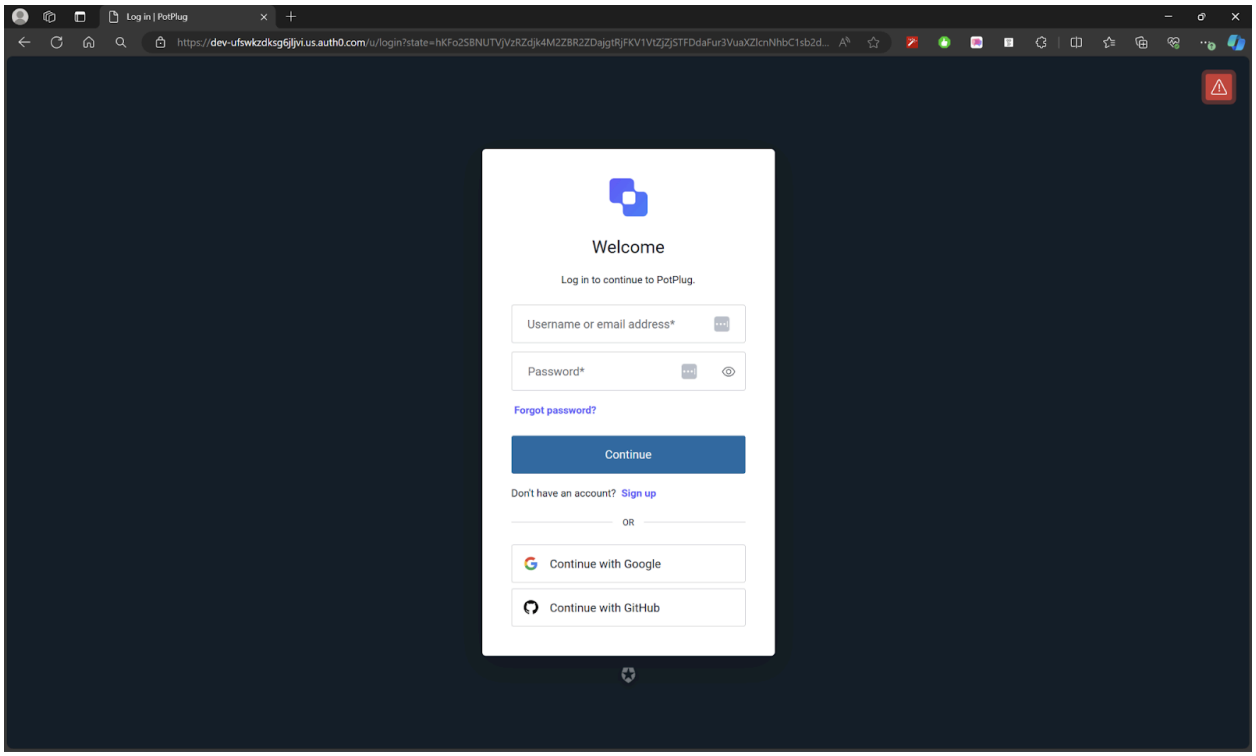
Our website was designed to use low cognitive load by making use of a flow that users would tend to be used to. Like many other websites, our homepage consists of a summary of our product, and has a typical menu flow, with buttons being highlighted to show that they are being selected:



Above Our Homepage Can Be Seen; It Conforms to Typical Website Design

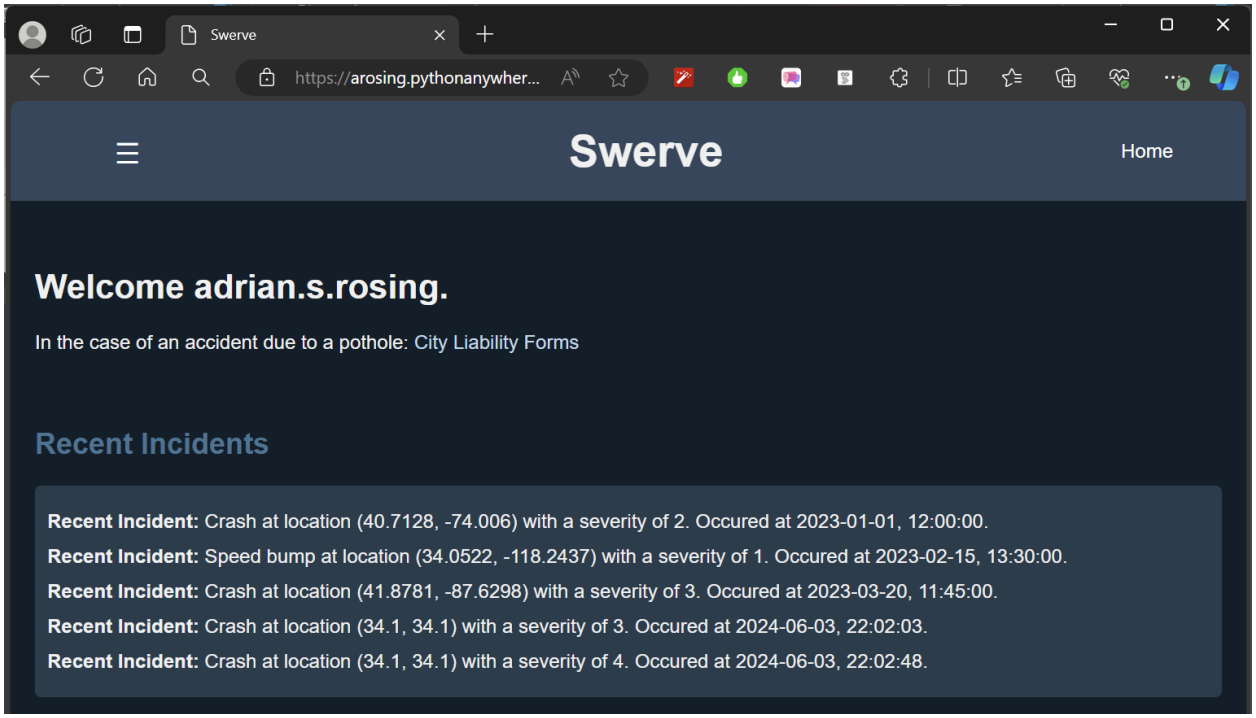
As our product is not designed to be accessible to everyone, but only to paying users, we do block everything besides our homepage behind 3rd party authentication. In order to simplify the process, creating an account automatically occurs as soon as the user attempts to access anything which would require an account. Due to this being our MVP, we currently allow anyone

to access our website once they create a free account, but we intend to only allow certain users to have full access once our product is on the market. We are currently using auth0 as our authenticator:



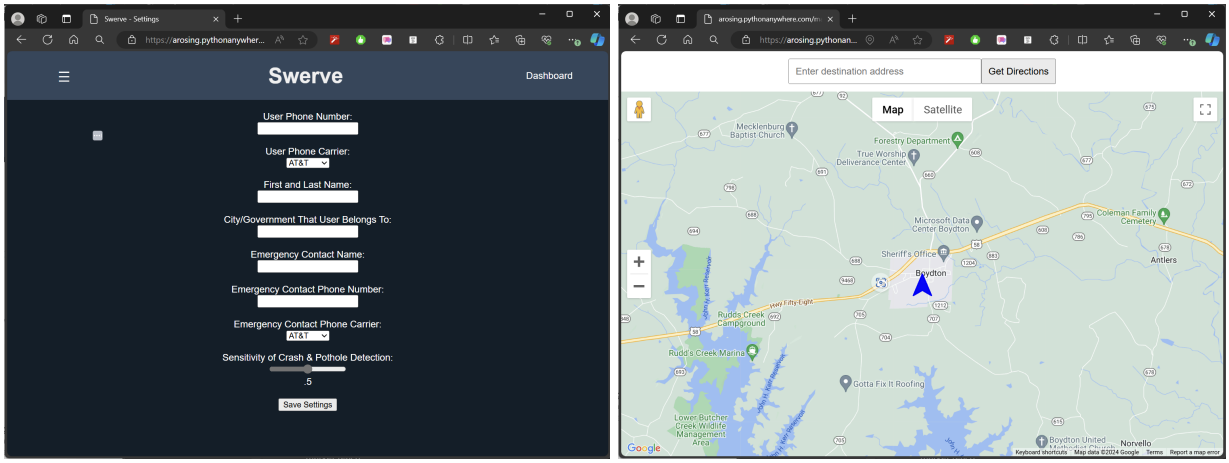
Our Authenticator, Which Allows Google Sign-In and GitHub Sign-In

Once signed in, users are greeted with the dashboard, where they can see the latest incidents listed:



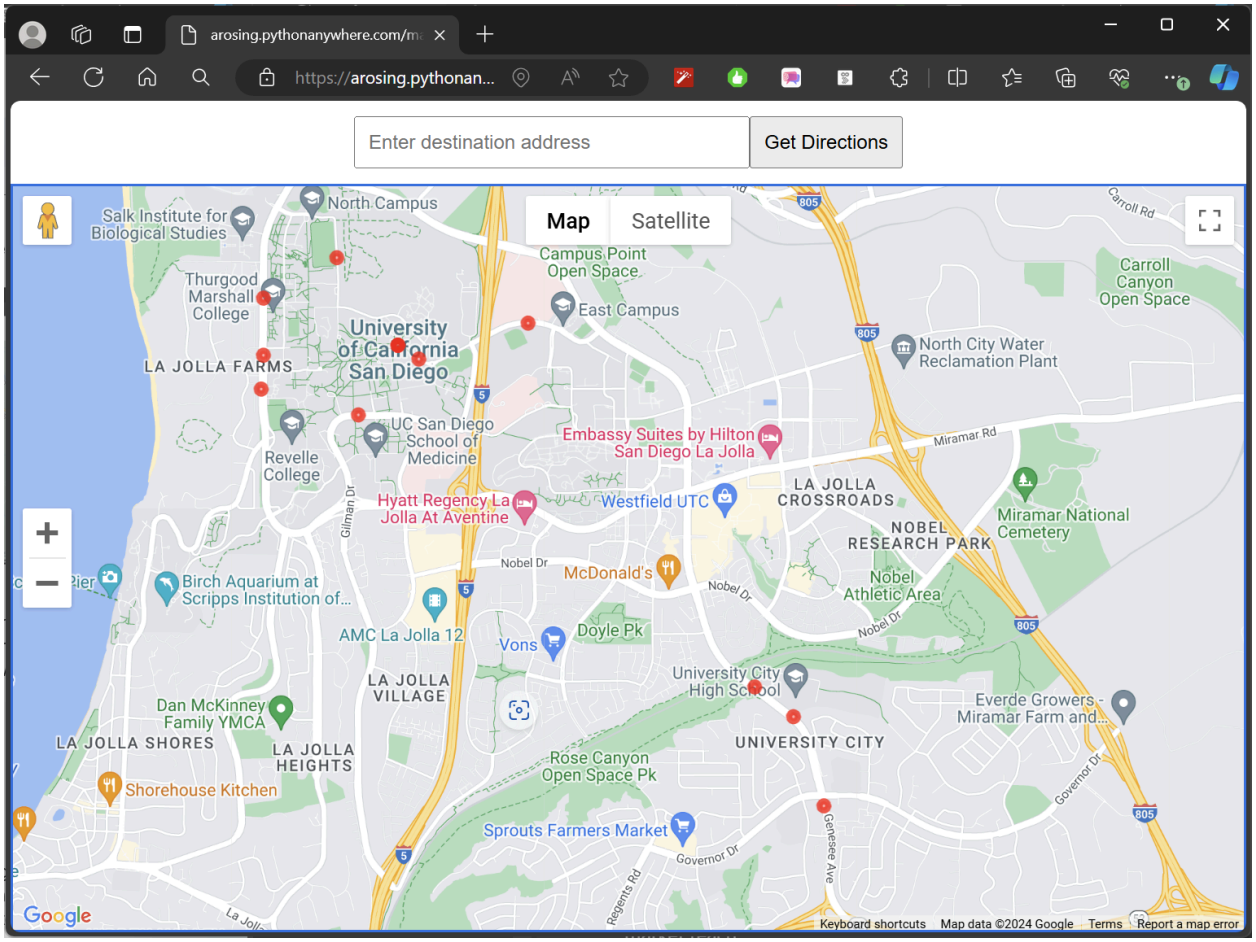
The Dashboard

From there, they have the option to adjust their device's settings via the setting page, or to go directly to the map which displays pothole data:



Our Settings Page (Left) & Map (Right)

Our intention is to ultimately integrate the map into Google Maps or Waze, but currently we are using our own map in order to display the data. Users can get directions relative to their own address, and will be able to see potholes marked in red on the map, as shown below:



Map Displaying Potholes in Red

Overall, we are trying to keep our product as simple as possible, by making the website easy to navigate. Our ultimate goal is to make the website be something that is optional for users to use, and to make it as convenient and helpful as possible. Currently we are striving to do this by keeping the website simple and making use of pre-existing patterns of development. As we continue to work on this project, we hope to improve these features and to make using our product as streamlined of a process as possible.

KANO:

Must-Haves:

Our product has several necessary features to be competitive in our space, including pothole and speed bump detection. As all of our competitors track this data and share it to the cities in

order to repair the roads, these are all features that we need to incorporate in order to be competitive in this space.

Competitive Features:

In addition to the must-have features, our product is competitive with its low cost and high accessibility, making it an attractive option for a wider range of users. Furthermore, we link directly to tire repair forms, streamlining the process for users to repair their vehicles via city funds, which is something that most are unaware of. While these features may not be the most exciting to customers, they provide value by enhancing convenience and affordability.

Exciters:

Our product's primary feature which excites our customers is our emergency contact and crash detection, which can automatically alert your emergency contact in the event of an accident, thereby enhancing user safety. Additionally, in the future we would like to implement passive car tracking capabilities, which offer users the ability to monitor their vehicle's location in real-time, providing added security and convenience. These innovative features set our product apart and our users showed much interest in them during our interview.

Iterations of Product:

We initially began as ChordChampion, working on music, but we decided to pivot from that idea to pothole tracking on roads. Our team name was PotPlug and we were primarily working on making potholes in a Waze-like manner for generic consumers. However, as we did several interviews, we discovered that most normal car-owners were not interested in buying a hardware device which tracked potholes, but did not actively detect them and give prior warnings for new potholes. We discovered that users were more interested in the potential for crash detection, tracking the car, and the end data.

Due to this, we began to move away from having pothole tracking as our core feature, and we also began to adjust to target a more specialized business market. We reached out to Lyft, Uber, Turo, Hertz, San Diego Car Rentals, MTS, the City of San Diego, and UCSD to talk to them, and began working on features we figured would be more interesting to them, such as

being notified of when their car/bus crashed. Additionally, we intend to still sell pothole data to the City of San Diego in order to make repairing the city's streets a more streamlined and cheap process..

Altogether, our product has pivoted from being focused on generic drivers and only tracking potholes, to having several features that track a car and damage done to it, while mapping road conditions for the city. In future iterations of this product, we would like to add passive car tracking, make our device directly connect to the internet (without a phone), and find a better power source.

RATs:

We have several risky assumptions. The first is that we will be able to accurately map out data collected from the ultrasonic sensor and from our gyroscope, when moving at a high speed, such as when driving. We are currently experiencing issues with bandwidth and our buffers overflowing when we sample at speeds above 35 mph. Additionally, our accuracy of detection falls greatly, so we currently have a very risky assumption that the accuracy we have, or will be able to have, without computer vision will be sufficient.

An additional risky assumption we have is that we can categorize fewer things than computer vision, and only potholes which drivers drive over or hit. Despite this, we are assuming that our low cost, our low maintenance, and our wide set of features will compensate for this holdback. However, the city may want to be able to track more than the few things we are able to track with our cheaper device, in order to make use of the flexibility that computer vision provides.

Lastly, one of our largest risky assumptions is to think people will buy our device and allow us to collect (and sell) pothole data that they are essentially collecting for us. While we do provide other features and use this data to better the city, during several of our interviews, customers were unhappy that we would be making use of the data that they were working on, so we are risking our market with general drivers by doing this (although businesses did not seem to mind as much).

7. Revenue and Economic Model:

Business Model & CAC/LTV:

We will be business to business, business to customer, and business to government. Our primary business model, however, will be business to business, followed by business to government.

Businesses:

In order to acquire a business, we estimate our customer acquisition cost to consist of advertising costs, the cost of giving ~20 demo products, and operational overhead. Initially advertising will be primarily done by us, reaching out directly to large businesses. Assuming that it takes about 100 hours worth of work for one of our representatives to agree to a deal with a business, which at a rate of $30 an hour, we estimate will be $3,000 in costs. Additionally, in order to give 20 promotional devices, at a cost of production of $19.90 per device, this yields $398 in costs for the free devices. Finally, for the operational costs for 5 years, we estimate that we will need to pay for support and manufacturing, which will be $240,000 per year and we will need to pay for the product materials, yielding a total cost of $1.2 million over the course of 5 years. Assuming that we are working with 10 total businesses/governments, we can estimate that the operational cost per business for 5 years will be $120,000. Thus, altogether the customer acquisition cost for businesses over the course of 5 years (how long we estimate our product to survive), we expect it to be $123,400.

Meanwhile we expect our lifetime value from a business with ~100,000 cars (The Rental Car Industry), which buys 10,000 of our units to be: we will charge $40 a product, which means our profit will be $20.10 per product up front. Additionally, we will charge a $100,000 maintenance and upkeep fee yearly for the entire business a year, in order to be able to provide personalized support and representatives to the businesses. Over the course of our product's 5 year life cycle, we estimate that we will generate $201,000 in initial profit. Beyond this, we anticipate to generate $500,000 over the next five years in operational costs. Overall, subtracting out the $123,400 in customer acquisition and maintenance costs for 5 years, we see a customer lifetime value of $577,600 per business.

Governments:

As we are selling pre-existing data to governments, we estimate the customer acquisition cost will be much lower. We estimate 100 hours of work to reach an agreement with the city, which at a rate of $30 an hour, we estimate will be $3,000 in costs. Finally, we estimate our operational costs per year with the government to be approximately $60,000 a year, in order to employ a support agent to serve as a liaison with them. Thus altogether for a year, our customer acquisition cost is $63,000.

Meanwhile, we expect the government to work with us as long as we continue to produce data, so we will calculate our lifetime value as a yearly profit. Since the city spends $46.4 million on pavement management, they intend to spend up to $213 million annually in the future. As we expect we will be able to drastically reduce the tracking and management of potholes, we hope to achieve a contract worth $1.5 million a year. Thus, from the city we expect a $1.4 million profit yearly.

General Customers:

While general customers will not be our primary market, we will still try to market to them in order to generate more data for the city. We estimate our customer acquisition cost to consist of advertising, promotional, and operational costs. Overall, our advertising cost per customer will be primarily spent on social media. We estimate that only 1% of clicks will translate into purchases, based on the 1% rule. Assuming that instagram ads cost approximately $.4 to $.7 per click, we estimate that capturing a customer via advertising will cost on average $65. Meanwhile, for promotional costs, we will have discounts to only charge $1 a month maintenance fee for server expenses and support expenses. Finally, operational costs per customer, assuming we have 50,000 customers will be approximately $5 a year per customer. Thus, over the course of $5 years, we estimate that our customer acquisition cost will be $65 for promotion and $30 for support, yielding a total customer acquisition cost of $65.

Meanwhile our lifetime value from a customer, assuming 5 years of product usage, will be $20.10 in initial profits, along with $60 in revenue for our maintenance subscription. Altogether, that means we will generate $80.10 per customer in revenue, altogether meaning that we have a $15.10 profit per customer over the course of 5 years.

Costs:

Item	Cost	Category	Cost Type
ESP 32	$9	Product materials	Variable (per unit)
Ultrasonic Sensor	$4.50	Product materials	Variable (per unit)
GY-522 MPU-6050 Accelerometer and Gyroscope	$3.30	Product materials	Variable (per unit)
Power Regulator	$1.80	Product materials	Variable (per unit)
4 x M2 x 8mm Screws	$0.30	Product materials	Variable (per unit)
Solder, heat shrink, 3D printer filament, wiring	$1	Product materials	Variable (per unit)
LulzBot TAZ Workhorse+ 3D Printer	$2,995	Manufacturing	Fixed
Screwdrivers	$5	Manufacturing	Fixed
Weller Soldering Station	$120	Manufacturing	Fixed
Manufacturing wages and benefits cost for 3 employees	$240,000 ($80,000 x 3)	Labor	Variable (annual and will increase as production scale increases)
IT Staff for 5 employees	$250,000 ($50,000 x 5)	Labor	Variable (annual and will increase as

			production scale increases)
Web Hosting - PythonAnywhere	$60	Hosting	Variable (annually; will increase as our market grows)
AWS Database	$10	Hosting	Variable (monthly and will increase with user count, but not linearly)
Host App on Google Store	$25	Hosting	Fixed

Thus, each unit will be $19.90 to produce. Additionally, there will be a $3,120 initial cost of starting up the business in order to be able to manufacture the product. Finally, we will initially have an annual operational expense of $490,095 a year, which we do expect to increase as we scale.

Scalability:

We believe that our product is extraordinarily scalable due to the high demand by governments for the data that we can provide. As we grow, we intend to begin using our own hardware instead of relying on ESP32s. This transition will allow us to perfect the hardware, improving reliability and performance, while also making it cheaper to produce, allowing us a greater profit.

Similarly, our modular design enhances scalability, allowing us to easily integrate new features and updates. This makes it easier to adapt to evolving market needs and technological advancements. As we can make old cars 'smart' with our technology, we have a vast market which allows our product to be competitive and scalable.

Lastly, since we control both our hardware and software, we will be able to improve data accuracy and enhance overall user experience as we scale. This would solidify our market

position. Overall, our design is very scalable, and scaling up our business would greatly benefit our business, enabling us to increase our profit margin.

8. Traction to Date:

What works right now?

Our hardware is able to flag potential incidents (potholes, speed bumps, and crashes) in real-time based on sudden impulses and transmit buffers containing sensor samples for the relevant time period to the app via Bluetooth for further signal processing to classify each signal.

Our phone app is capable of communicating with both our hardware and our server, facilitating the flow of data between the two. Most of the app's functionality is restricted to background processes, with most of the consumer interaction with our product occurring through our website. Currently, the app serves to receive data from our sensors, categorizing that data into different incident types, and reporting an incident to both the user and our servers if one is detected.

Our server has all of the necessary APIs in order to retrieve incidents, display them, add them, track users, add users, and update users. In addition to this, our server hosts our website, authenticates users, and displays a map with potholes on it. Overall, our website works well, has its own domain, and is very accessible to consumers, carrying a low cognitive load by making use of typical design choices. Additionally, we have City Liability Forms linked to the webpage for general users to access, which is something that came up in our interviews.

Our database is live on AWS and the rest of our software is able to communicate with it to do a variety of things. These include reporting potholes and incidents, looking up nearby hazards to a user given a geo location (for the purpose of displaying on a map for navigation), and storing user data so that the app and website can work as intended.

Progress with customers:

Currently, we have the city and Renty, the car rental agency, excited about our product; they showed interest in the information we generate and our ability to track crashes respectively. Going forward, we would like to interview more businesses and begin to specialize our product to best complement their needs. If we are able to deliver on our goals, it is likely that we will be able to have both of these organizations partner with us, which would be monumental for our team.

In addition to this, we are currently talking to MTS regarding our product. They have shown some interest in it, but have not had time to schedule a formal interview yet. We are very excited to meet with them in the upcoming weeks in order to see if our product will meet their needs and if they would be interested in working with us going forward. Assuming we can work together with MTS and Renty, as well as potentially partnering with other groups (such as Turo), we will be able to generate a lot of the data that we need in order to be successful and to work with the city, and potentially Google and Waze.

As for general consumers, we would like to continue exploring their needs and wants, and our team would like to ultimately build several ‘series’ of this product, with different series being focused at different markets and with different capabilities. We would like to build a driver-focused product which will act as a passive car tracker and will protect people who experience car crashes, to save lives.

To Do:

We are hoping to continue doing interviews and build a larger customer base, while also attaining greater interest in our product. With a greater number of interviews, we are hoping to refine our features and add additional features that customers would like in our next iterations of our MVP.

Beyond this, we would like to ultimately remove the phone app from our product; we would like to have our hardware communicate directly to the server by integrating a sim card or something similar which would allow us to connect to the internet. We intend to do this to simplify our product and make its user experience better, while also increasing accessibility for people who cannot afford nice phones, or the data which would be consumed by our product.

Our hardware can also be further compacted and simplified; this is something which we are striving to work on. We currently have issues with battery life and so we would like to make our device more efficient. We are currently examining using larger battery packs or potentially using the car’s battery directly.
We would also like to improve our classification algorithm to better distinguish between potholes, speed bumps, and crashes. Ideally, we would want to have enough data gathered to

perform some sort of machine learning to create better classification metrics, and also allow people to give feedback on whether our classifications are correct to help further verify and train our classification system.

Additionally, we would like to improve our website, making it more accessible for the color blind and also improving its flow, so that it contains more information more compactly. We would like to add a support page and FAQ to our webpage.

Lastly, we need to incorporate our company and improve the hardware so that it tracks potholes and speed bumps more accurately. We will need to examine the legal aspects of our product as well, and finalize all of the logistics before considering scaling up our business.

9. Project Review:

In our project, we worked hard to implement a hardware component which can detect crashes, speedbumps, and potholes by making use of a gyroscope and ultrasonic sensor along with an ESP-32 in order to collect, process, and transmit that data. This data is then sent by bluetooth to our phone app, which makes use of kotlin to forward location data and incident data to our python server, which logs it to an AWS server and displays it on https://arosing.pythonanywhere.com, which also contains a map which only authenticated users can access. This map displays locations of potholes and users can use it on their phones to navigate.

While working through this, we experienced several problems; the largest was with interviews. We struggled to get interviews from businesses, and many of our interviews with typical drivers were lackluster and showed they were not interested in our product. We learned that getting interviews with businesses takes weeks, or even months, after reaching out to a wide variety of businesses, such as Turo, Lyft, Uber, MTS, UCSD, and more. Beyond this, we experienced difficulties with the implementation of our hardware; we consistently experienced issues when trying to map data and recognize potholes due to a combination of ultrasonic sampling limitations, buffer limitations, and bandwidth limitations. Beyond this, we had several issues with the phone application and implementing it in such a way that it connected to both our hardware and the server at the same time.

Despite this, we ultimately saw several large successes while working on this project. These included discovering Python Anywhere functioned as a free domain hosting service, with several powerful capabilities. On top of this, our web hosting, API, Flask app, Auth0 authentication, and basic hardware capabilities were relatively quickly finished and were very powerful tools, which could be used in production as well.

Overall, we learned a lot while working on this project, including essential skills which could carry over to any other product we decided to build. Working on this project and developing a pothole detector was very informative and we learned a lot regarding the development process, getting interviews, and using popular APIs and products.

10. Ethical Sustainability:

Sustainability:

Our product will have some sustainability issues, at least initially. As our product is attached to a car, uses batteries, and also has circuitry in it, it would constitute hazardous waste and would also require special disposal. We are hoping to use as few heavy metals and toxic materials as possible, by simplifying our product before it comes to production.

With that said, we are currently trying to make sure that our product is as energy efficient as possible, so that the batteries rarely need to be changed (thus producing less waste). Additionally, we intend to make sure that the Swerve hardware device is attached well to the car, so that it won't fall off and create hazardous waste, which could also damage cars. Lastly, we will ensure we follow all regulations with labeling our materials and describing how to dispose of the product.

Ethical Concerns:

Our product has several ethical concerns which we plan to work through. The first of these is the fact that our product takes customer location information and also contains a lot of other private customer information. We intend to be very careful with this data and not publish it anywhere. The only data we will publish or share will be the locations of potholes - and this data will not be associated with any specific customers. Any data will be very carefully processed and we will not collect anything which is not absolutely necessary.

Along with this, since our product will be purchased online, and may have components which are subscription based, we need to be concerned with keeping our customers' private billing information as secure as possible, to prevent their credit card information from being leaked. Properly handling payment information in a secure manner will be highly important to us in creating the final product and service. We will ensure that we properly handle data encryption, as well as secure payment authorization on our end. We also have an ethical and legal responsibility to also be transparent with our users as to how we might use their data if we utilize/track metrics in our application.

Lastly, ethical concerns may arise from how our product is produced, and where it is produced. We intend to have our product be produced at least currently in America, and we intend to uphold all pertinent labor standards, by providing accurate pay, keeping financial records of all transactions, and giving workers breaks. We will source materials from factories that we have thoroughly researched and do not use child labor or other unethical practices.

Accessibility:

We are working to make our product accessible via several different methods. First, we are trying to make it as easy as possible for users to attach it to cars, so that anyone, regardless of who they are, is able to use our product's hardware. We are currently trying to do this by making our product be non-intrusive and very simple to attach to the bottom of the car. Additionally, we are attempting to design it to be energy efficient, so that users will rarely need to lay down under their car in order to be able to use it. We would also like to ultimately come up with a solution for attaching this so that users who cannot crawl under a car would be able to easily attach it, but as of now we do not have a solution for this.

Additionally, we are working to make this product extremely cheap for users so that they are able to afford it, even if they are of lower income. As part of this, we are trying to move away from using phones as a data liaison, since we want to avoid using a lot of data, which is expensive for people who do not have unlimited plans. In order to do this, we would like to ultimately make the device connect to the internet directly.

Lastly, we are trying to make this product accessible by lowering cognitive load when users use the software portion of the product. We are trying to make the website function in a way that they would expect it to function. Additionally, one of the things we are working on is making the website more readable for the color blind, and also for the elderly and/or those who cannot see well.