DELPHI REPORT: S.A.R.A.

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EDSGN 100, SECTION 022
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**Executive Summary**

The goal of this project is reducing the frequency of automobile accidents and allowing drivers to reach their destinations safely. To do this, we focused on turns where drivers have the potential to rollover or slide of the road. We created a system that would be integrated with the GPS in the vehicle to detect the speed of the driver and the sharpness of the turn. Using this information, the system would take appropriate action such as alerting the driver and controlling the brakes if necessary. Our design can be implemented into any car and can help save many lives.

**Problem Statement**

**Goal:** As a professional group of consulting engineers, one of our main goals is safety. Our desire is a world in which rollover accidents simply do not occur. We believe that these accidents do not need to happen and in fact be completely preventable with the use of technology that diminishes the impact of human error.

**Currently:** Modern day rollover detection systems only act once the roll is already occurring, deploying airbags and other safety systems in the vehicle. Any attempt made to control the vehicle is made after losing control. With electronic stability control systems, tire traction is controlled by sensing when the car is out of control (skidding) and correcting it accordingly.

**Path:** We will attempt to engineer a system that prevents rollover and loss of control around a turn before it occurs. With the use of proper engineering design, we will consider the global impact of our systems while fully addressing consumer needs. Our product will be discrete, but
will always be there for your safety. We understand the need for reliability at a lower price and will incorporate this idea fundamentally into our design.

**Background:**

The possibility of rollover in an automobile presents an obvious danger to anyone who travels in vehicles. When we first decided that we wanted to develop a system to minimize this danger, we conducted research on the topic. Our goal was to see what systems were already in vehicles to improve rollover safety and also, to understand the physics of rollover accidents so we knew exactly what we were dealing with.

To start off, we will introduce an alarming statistic about the seriousness of vehicle rollover. In 2010, 35% of all passenger vehicle fatalities occurred in rollover accidents (SaferCar). Of equal interest is that only 2.1% of the total passenger-vehicle accidents were actually rollover accidents (SaferCar). These two statistics put together a very important conclusion about rollovers. When rollovers occur, they are hardly ever going to be minor incidents. A rollover accident does not occur where there is no damage to either the vehicle or the car occupants. This is the driving force behind the development of this product.

One method which was designed to “deal” with these terrible accidents was developed in 2003. A patent was approved which included a system for early detection of rollover (Delphi). This system comprises of a sensor and a communication signal for airbags and other safety features to deploy. The idea behind the invention was that they wanted to prevent damage after rollover occurred, which is what we believe to be the wrong approach. However, we were able to use some principles developed here for the creation of our final product.
To our knowledge, the only system that is pro-active in preventing such accidents is electronic-stability control (ESC). Electronic stability control provides control of the vehicle after loss of tire traction occurs. This system has an active way of dealing with traction loss, activating a braking system to help the driver regain control of the vehicle. For the purposes of rollover prevention this system is not good enough, as vehicle rollover occurs with too much lateral acceleration to be reduced after traction loss.

**Customer Needs:**

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<th>AHP Matrix</th>
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<th>Ease of MFG</th>
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*Figure 1: AHP Matrix, displays a ranking of importance for our various customer needs.*

Our team analyzed various customer needs that seem like important requirements for our design. These needs were cost, ease of use, safety, ease of manufacturing, durability, reliability, efficiency and ergonomics. After discussing these needs, our team narrowed down these needs into the ones we found most important. These requirements were ergonomic, reliability, and safety, as seen in the AHP matrix. We want the driver to be able to experience a smooth ride. To
accomplish this our system will apply the brakes early enough to keep the driver safe and gradually so that the driver does not jerk forward with a sudden input of the brake system. Furthermore, we want our system to be reliable. If the system is not reliable, then there is a chance of endangering drivers who rely on the system. Our top priority, however, is safety. The main goal of this design is to avoid accidents and if we fail to keep drivers safe then our system has no purpose.
Concept Generation:

Figure 2: Concept selection diagram. The entirety of our considerations for this product, split into categories. Boxes in red were not chosen to be included in our final design.
The diagram on the previous page sums up our entire critical design process in the development of SARA. We knew that we wanted to develop a system that prevented rollovers, so we looked into three main categories for how that would work: energy and materials, driver interaction and vehicle interaction. In this analysis, we looked at various ways of collecting data (i.e. accelerometer vs. force sensor on wheels), how the system would actually sit in the car and also how the driver would be interfacing with the system.

In red are concepts that did not get through into the final design. These were either ideas that were not as cost effective, were ineffective completely, or caused some other problem. For example, to have the system run off of external solar panels is sort of unrealistic and incorporates a new complication in our system which is power generation and transportation. Also, to bring in a solar panel would mean practically two separate products, because it would require considerations regarding questions of if the power should also be used to power other things in the car. A great idea, but an impractical one for the scope of the project.

Overall, the concept generation tree is the reflecting point of our entire operation and contains a very good overview of the process. The exercise of actually creating this tree is one that promotes the right kind of thinking about your product and was key in our development. We believe that this tree is a great control point for the view of the engineering process behind SARA.
## Concept Selection:

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<th>Ease of Use .123</th>
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As we were narrowing down options for the design of our project, we created a design selection matrix in order to score our potential concepts against each other. In the design selection matrix, we had three distinct designs that could potentially serve the purpose for our project. The first design, the Central Sensor Braking System, consisted of a sensor or bundle of sensors located near the center of the vehicle to measure changes in force on the vehicle from one location. With one set of sensors in the center of the car, less sensors could be used to achieve the same result thus lowering the production cost. Our second design, the Wheel Sensor Braking System, consisted of four sensors or bundles of sensors with one bundle located on each of the four wheels or shocks/springs. This design would be able to measure the forces on each of the four wheels to accurately determine where and how the force is distributed. However, having four times the amount of sensors on the vehicle would greatly increase the production cost and
increases the amount of potential maintenance. The third design, the GPS Braking System, consisted of a device integrated into the existing GPS device of the car in order to accurately determine when a turn is approaching and the speed that is appropriate for the turn. The GPS system, unlike the sensors will be able to determine whether or not the car needs to slow down and will be able to warn the driver before the car automatically decelerates the vehicle. However, the GPS system will not be reliable on all roads as there are many roads that are not marked or recognized on current GPS databases. The sensors on the other hand, are reliable on all roads no matter if they are recognized by GPS or not but they do not react until the turn is initiated. On the design selection matrix above, the Central Sensor Braking System and the Wheel Sensor Braking System scored the same with a score of 3.878 while the GPS Braking System came in first with a score of 4.158. After completing the matrix, we reviewed our designs and realized that the optimal design incorporated both the GPS system as well as the central sensor system. We came to this conclusion because the GPS system would be available on most roads and it would provide for a more ergonomic deceleration as it would detect the danger earlier. Also the GPS system would provide an earlier warning to the driver and would not necessarily have to active the deceleration if the driver could react in time. The central sensor system would be incorporated as more of a backup or fail safe system. This would activate once the turn is initiated and would slow down the vehicle once a certain calibrated threshold is activated. These sensors would be reliable on all roads and would not rely on GPS signal to protect the vehicle making them available even if GPS signal was weak or interrupted. With both of these systems at work, once danger is detected a signal would be sent to the driver as an audio and visual alert to alert the driver of the danger and inform the driver that the vehicle is automatically decelerating. When designing this, it became evident that a system is needed to detect road
conditions as different conditions affect braking ability differently. Therefore we included a feature that would be integrated into the car's existing thermometer or weather system to detect potential conditions such as rain, snow, or ice. If one of these conditions was evident or possible, the system would automatically lower the threshold at which the system activates and slow the driver at a lower speed, at an earlier time, and with softer braking to avoid loss of traction. It was also evident to us that all drivers would not desire this feature. As a result of this, we determined that the system would be active when the car is started and running but would provide a button on the dashboard that would allow the driver to turn off the system if he/she so chooses to do so. After taking into consideration every aspect that became apparent to us, we decided that this design met the design criteria better than any other design by keeping the driver safe, having a reliable system with built-in fail-safes and backups, and being ergonomically friendly with a smooth as possible deceleration.
**Systems Diagram:**

Below is our systems diagram. This is a flow chart which really displays the data into the system, the processing by the system and system outputs. The car travels around a turn relaying speed data, weather data and other signals to SARA. SARA will then interpret the data and compare it to a calculated threshold value. When the threshold value is met, the system will then do all things in the output section of the diagram. Braking occurs, slowing you down and you are simultaneously notified that SARA is activated by visual and audible alerts.
3D Model/Prototype:

In the above image, a SolidWorks model depicts the basic interface and components of the product. In the image, the communication signals are transmitted to the S.A.R.A. device containing sensors and computer systems where they are interpreted. If danger is evident, a signal is sent through the wires to alert the driver with visual and audio signals. At this time, a signal is also sent to the existing ABS system where the commands to apply the brakes are sent to the brakes to decelerate the vehicle and prevent loss of control or an accident.
Concept of Operational Scenarios:

We believe our product has very practical uses, it is meant to actively prevent roll-over by applying a breaking force and also involves taking and interpreting signals from sensors. To provide an understanding of how the system works, it would be best if we provided scenarios where this product would be used.

*Figure 5: Mid-Sized Sedan (low COM) vs. SUV (high COM). 2nd row images display vehicles without SARA. 3rd row images show onset of braking after threshold has been reached in the SARA system. (see below)*
Detailed Description:

These scenarios were developed to show how S.A.R.A. would work in your vehicle. In Figure 1, your vehicle is taking a turn much over legal speeds and is in danger of rolling. S.A.R.A. detects this by checking if the lateral acceleration (translated into a force) has met the threshold value or not (see Figure 2). When it has met the threshold value, your car will automatically break for you. Because the system is constantly looking at signs of rollover, even

Figure 6: Describes the implementation of a threshold for breaking onset. Shows difference between high-COM vehicles and low-COM vehicles.
at very high speeds, we believe that you will be safe from possible rollover because the system will be tripped earlier into the curve.

The question then arises, how would we deal with poor weather? Intuitively, you can imagine that rolling or sliding would occur more easily when the road is wet, icy, or is covered in snow. The solution for this would be to provide connection with weather reports, where if the conditions were known to be at all hazardous, the threshold value would be reduced. If your threshold value translated into 45 miles per hour around a curve in an SUV on a regular day, the value would be lowered to 30 mph on a day that had less than desired conditions. This value may be low but, with driving conditions and considering safety, the driver should be restricted to reduced speed anyways.

**Delphi Cost and Feasibility:**

In regards to the costs of this product and its feasibility for production, this product is relatively low priced for its potentially immense benefits. Based on our calculations taking into account all factors of research, production, and the distribution chain, this product will be available to the customer at around $319.14 and will cost Delphi $53.19 per unit assuming 20,000 units are sold. To get this number we calculated production costs, Non-Recurring Engineering costs, and also assembly and labor costs. To calculate the Production costs, we based our price on a similar product, the MyGeoTab GO6 device that is a telematics system that can be installed into a vehicle to record and transmit information about the vehicle. This device consists of circuits and computer systems similar to what we would need so we decided to use this price range for our calculations. This device had a retail price of $47.00 so we put an estimate of our device of $50.00 to make calculations simpler. After a few simple calculations, our cost of manufacture came out to be $21.37. We also estimated how long it would take to
research and design a final working product to suit this need. We estimated it would take a team of three engineers roughly three months to complete. We decided it would require a computer engineer, an electrical engineer, and a mechanical engineer to design this product each at $28,800 per month. The total for engineering costs is $86,400 and an additional $300,000 to add the subsystem into car production. For the total Non-Recurring Engineering costs, we calculated this estimate to be $19.32 per unit sold. The assembly would take roughly a half hour at $25.00/hour which adds $12.50 per unit. Added up these costs come to $53.19 for Delphi to sell this product, $106.38 for the car manufacturer, and $319.14 for the customer.

Now the real question is if the customer feels $319.14 is an acceptable price for this product. Our target customers are first Delphi, then car manufacturers, then high end car owners, and eventually the everyday average driver. First, as this product becomes more available and is more widely accepted, the cost will go down greatly. Also relative to a new car, this is a very small, almost negligible cost in the big picture. Most importantly this product will prevent possible accidents which are expensive and also save lives which we all know is an almost priceless value. Based on the fact that it could potentially save lives alone, this product should automatically be implemented in all vehicles. However, people need more concrete evidence to spend this money on a product. As this product costs $319.14 to the customer and it has the potential to prevent accidents of all severities, when will the product cost break even and start saving money? Since almost every accident even the smallest fender bender costs over three hundred dollars to make right (repair costs, insurance, non-monetary factors such as guilt or stress), one avoided accident due to this product is likely to save the driver more than just the cost of this product.
Even though this product is a lifesaver, it should not be mandated by law but rather an encouraged option. When things are mandated by law, they tend to be viewed negatively and disrespected. We want our customers to use this product because it keeps them safe not because they are lawfully mandated to. This product is similar to the traction control feature as it is a preventative form of this same feature. Following the idea of being proactive instead of being reactive, traction control aids a car after it loses control while we aim to prevent that loss of control in the first place. I feel our product should be an option like the existing traction control where customers can choose whether or not they want to utilize it. As far as the adoption by automakers, I do not this product will incur any privacy or cultural issues. While this system may get complaints that it is not effective in extreme situations, this product, like all others, has limits. If exceeded it can be rendered less than helpful which if documented properly cannot punish the automaker.

**Life Cycle Assessment:**

The design of the turning sensor involves the use of wiring and computer systems enclosed in a plastic housing. These materials will be created by the auto part suppliers. Then it will be assembled into the car by the car manufacturers. This is when it will be integrated with the GPS and braking systems of each type of car. The cars will then be sold to be driven on the roads. Our design is very energy efficient, so it will only use a small fraction of energy from the car to detect and alert drivers of the possibility of a rollover or sliding off the road.
Conclusions:

Rollover accidents account for 35% of all passenger vehicle fatalities. The danger is very real, as just one incidence of reckless driving can lead to a rollover accident and multiple fatalities. We have designed a product which offers to minimize the human error in these situations. We believe with the proper implementation of a system which accurately monitors conditions leading to traction loss and rollovers, while actively decelerating the vehicle in dangerous situations, we can reduce or prevent fatalities resulting from these situations. This is why we designed SARA.

An advantage of our system over any system in place already is the idea of being proactive rather than reactive. Other systems offer protection after the vehicle has already lost control, namely electronic stability control and pre-releasing side air bags, while we hope to prevent these situations from ever happening. We aim to prevent all fatalities, but we acknowledge that our product would be ineffective at controlling vehicles moving at unreasonably high speeds or with erratic drivers.

The implementation of this product should be a standard in all vehicles. The possibilities for traction loss and rollover are too high to ignore. From here, we are hoping that this design will make it to the desks of Delphi where it will be considered for production or is at least researched. The impact of a product like this must be considered heavily so that money can be saved and safety can be upheld.

Our team has advanced as engineers throughout this design process. We have learned how to approach a project with many different perspectives. We now understand how to identify design criteria and customer needs to objectively assess the quality of potential designs. The
greatest aspect of our project was effective team work and without it we would have not been able to work with such quality and success.
References


2.) “Electronic Stability Control”, Wikipedia, the free encyclopedia, last edited Mar 2014

Wiki Citations: (ESC)


3.) “Fatalities”, http://www.safercar.gov/Vehicle+Shoppers/Rollover/Fatalities, NHTSA(gov’t org), Dec 2014 (SaferCar)