Exploration of a Provisional Design for the Future Autonomous Vehicle

by

Oluwatobi Olamide Lanre-Amos

Submitted to the
Department of Mechanical Engineering
in Partial Fulfillment of the Requirements for the Degree of
Bachelor of Science in Mechanical Engineering

at the
Massachusetts Institute of Technology

June 2015

© 2015 Massachusetts Institute of Technology. All rights reserved.

Signature redacted

Department of Mechanical Engineering
May 21, 2015

Certified by: ____________________________

Maria C. Yang
Associate Professor of Mechanical Engineering
Thesis Supervisor

Accepted by: ____________________________

Anette Hosoi
Professor of Mechanical Engineering
Undergraduate Officer
Exploration of a Possible Design for the Future Autonomous Vehicle

by

Oluwatobi Olamide Lanre-Amos

Submitted to the Department of Mechanical Engineering on May 21, 2015 in Partial Fulfillment of the Requirements for the Degree of Bachelor of Science in Mechanical Engineering

ABSTRACT

The goal of this thesis is to design a plausible fully automated vehicle that could be easily integrated into today’s society. There’s a unique opportunity to introduce large steps of innovation within the automobile industry thanks to rapidly improving self-driving technology, and the hardware that supports these capabilities should be more actively considered.

The design was made with three assumptions: the car is fully autonomous - assuming there are absolutely no components that allow the passenger to take full control of the car; the car is fully electric, and the car is designed for the high income professional as the target niche. The design was pursued in the perspective of introductory research, which included current automation efforts and the styles that best appeal to the target market. The front end, cabin, internal components and the potential infrastructure to support this technology are all considered.

Ultimately, the thesis shows the full design process; research and sketches of preliminary ideas are displayed and discussed, and it ends with fully rendered images of the final design.

Thesis Supervisor: Maria Yang
Title: Associate Professor of Mechanical Engineering
ACKNOWLEDGEMENTS

The author would like to thank Professor Maria Yang for her support and encouragement for the pursuit of this topic, as well as her guidance during the writing of this thesis.

The author would like to acknowledge the following faculty for their support during the writing of this thesis:

Brandy Baker
Heather Theberge
Ellen Ferrick
Sara Nelson
Cullen Buie
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract</td>
<td>2</td>
</tr>
<tr>
<td>Acknowledgements</td>
<td>3</td>
</tr>
<tr>
<td>List of Figures</td>
<td>5</td>
</tr>
<tr>
<td>Introduction</td>
<td>6</td>
</tr>
<tr>
<td>1.1 The Automation Race</td>
<td>6</td>
</tr>
<tr>
<td>1.2 The Styling</td>
<td>8</td>
</tr>
<tr>
<td>1.3 The Assumptions</td>
<td>10</td>
</tr>
<tr>
<td>Preliminary Ideas</td>
<td>12</td>
</tr>
<tr>
<td>2.1 Design Inspiration and Motivation</td>
<td>12</td>
</tr>
<tr>
<td>2.2 Preliminary Sketches</td>
<td>15</td>
</tr>
<tr>
<td>2.2.1 Front End</td>
<td>18</td>
</tr>
<tr>
<td>2.2.2 Cabin</td>
<td>20</td>
</tr>
<tr>
<td>2.3 Internal Components</td>
<td>24</td>
</tr>
<tr>
<td>2.4 Infrastructure</td>
<td>26</td>
</tr>
<tr>
<td>Final design</td>
<td>28</td>
</tr>
<tr>
<td>Future considerations</td>
<td>32</td>
</tr>
<tr>
<td>Sources</td>
<td>33</td>
</tr>
</tbody>
</table>
LIST OF FIGURES

Figure 1: The current Google self-driving car

Figure 2: Renderings of the Mercedes Benz F 015

Figure 3: Tesla Model S with front trunk opened

Figure 4: Series of cars through a 127 year period

Figure 5: Automated vehicle idea boards

Figure 6: Sketch of the Alpha Romeo 8C

Figure 7: Sketch of the 2013 Lincoln MKS

Figure 8: Sketch of the Tesla Model S

Figure 9: Preliminary sketches for the front end of the car

Figure 10: Second level sketches and detailed focuses

Figure 11: Exterior and interior of the Maybach 62

Figure 12: General interior sketches

Figure 13: Schematic of a battery electric vehicle (BEV) powertrain

Figure 14: Overhead concept sketches of the laser camera mounting

Figure 15: Brief sketch design of the parking dock

Figure 16: Sketches of different views of the final design

Figure 17: Section views of the final design

Figure 17: Series of renderings of the final design
CHAPTER 1

INTRODUCTION

The auto industry has been evolving rapidly along with the technology boom. Since around 2000, car companies have been pushed by consumers to deliver new and improved capabilities to drivers: an increase in number and sophistication of embedded technologies and improved gas efficiency, high-end design in low-end cars and hybridization, and now a push to make a car drive on its own. It is as if the age old question of the "horseless carriage" has been reintroduced into the 21st century, except now we are asking, can we make a "driverless car"?

This thesis showcases my research in identifying characteristics that could be useful for implementing driverless technology, as well as my work in designing a potential design concept to market to the passenger of the future. Most of my work is done under the assumption that the necessary policies and procedures would be implemented in order to best support this growing field of technology within the social and political sectors. As such, I will not be discussing in depth the social implications of the technology; instead, I will focus on features such as form, visibility, and interior that could support this rapidly growing development.

I will begin with background research on what is currently being done within the automation efforts. I will then discuss the current designs for fully automated vehicles before outlining the assumptions I take on in pursuing my own design.
1.1 THE AUTOMATION RACE

Automation is already being introduced in new cars through the integration of small features: intelligent cruise control, safety mechanisms, auto merge in the Tesla Model S, and self-parking in the BMWi3 EV, just to name a few examples. This gradual installation is an effective method of technology familiarization - the more the public is used to a car completing simple maneuvers on its own, the easier it will be to introduce a fully automated car.

This process, while necessary, is slow. However, it has not kept the industry from dreaming about full automation; if anything, it has only fueled the auto race, as consumers are gradually becoming more and more interested in self-driving capabilities. The shift has not only inspired car companies, but other sectors of the market are finding it irresistible to add their own capabilities. Software companies Google and Apple have been leading the race towards a car that can drive itself at speeds that exceed 25 miles per hour (Plaugic 15). Google has even designed a mini car of its own (Fig. 1) to show off its software that is now commonly seen driving through the Bay Area, an operator at the wheel but not driving.

Figure 1: The current Google self-driving car, outfitted with its overhead laser camera, can only go 25 miles per hour (as of December 2014) Source: Inman
Even NVIDIA, a company that is known for pioneering visual computing and computer graphics, has been boasting of its own role in the automation race. It recently released Drive PX, a constantly learning platform for self-driving cars, while partnering with companies like Audi and Tesla. It was announced during this press release that NVIDIA would sell Drive PX for any company to buy and automate their existing vehicles (Johnson 2015).

All of the progress made by what would be considered third-party companies has put a lot of pressure on existing car companies, as they are being pushed not only by consumers, but by unforeseen competitors, or rather (in some cases) allies. Delphi Automotive, Mercedes Benz, and Audi all have models that have been testing automated features, and there are rumors that the upcoming Tesla Model D may raise the ante in the number and sophistication of its self-driving capabilities (Howard 2015). The progress to these steps have been rapidly growing over the tech boom, and it can be argued that we now have all the technology we need in order to make what was once a sci-fi concept into a reality.

1.2 THE STYLING

Despite the admirable and public progress on a software level, very few companies have released any details on the aesthetics of such a car that the public can look forward to once the technology arrives. Whether it is due to disinterest or privacy, the lack of designs has not kept people from wondering what the car will look like once the technology is so advanced that it is considered dangerous for humans to be driving on major highways. One car company has taken the lead in developing a design for the car of the future; Figure 2 shows the Mercedes Benz F 015 that debuted in March of this year, showing off the research car with the year 2030 in mind.
Figure 2: Renderings of the exterior (left) and interior (right) of the Mercedes Benz F 015. Not included in the image is a steering wheel and pedals on the right side. Source: Howard; Ziegler (respectively).

The responses, while positive, are hesitant. Chris Ziegler aptly says in his review in The Verge of the research vehicle, “The F 015 doesn’t really communicate ‘beautiful’ through its design – at least not by any present day standard. But it definitely communicates ‘future.’”. On the one hand, it’s exciting – many people are thrilled to see that someone is really taking this challenge head-on; it makes the possibilities more real. However, it may be a little off from the mark. The difficulty of finding the aesthetic entryway onto the highways probably one of the reasons why there are no other companies openly researching the looks the self-driving car may require.

In my opinion, they miss the mark because there are many areas that are being overlooked; it is not just about creating the car of the future, but creating a vehicle for the passenger of the future. This is a once-in-a-century opportunity to create innovation in a space that has been so standard for so long, which is why I have pursued looking into designing a different concept of the fully autonomous vehicle. I will not only looking at aesthetics, but also other infrastructural components (particularly in regards to charging) that will help the vehicle assimilate easily into society.
1.3 THE ASSUMPTIONS

Where design is concerned, there are many directions one could go. Even in today's auto market, the design varies widely from mini vans, to luxury vehicles, to sports cars - the transition from the horseless carriage to the internal combustion engine allowed designers to evolve the cabin and functionality of the car to fit a very diverse range of consumers over the past century. I believe this variety in design and functionality will only exponentially grow with the increasing confidence in a car's ability to drive itself, and the consumer's adjustment from driver to passenger. However, for this specific design I decided to rely on three basic assumptions:

1. The car is fully autonomous
2. The car is completely electric
3. The car is designed for the high income consumer

The assumption of a fully automated vehicle implies that there are no human-driving components; the car is fully capable of reacting to any external situation, and (at the point of implementation) it may also be connected to a network that connects all self-driving cars on the road. This adjustment takes away many of the modern car's components (steering wheel, ignition, acceleration pedals, etc.) and makes room for new interface capabilities that would have once been considered distracting to the driver.

The second assumption removes even more of the components required in a modern car, relying on the technologies that companies like Tesla have proven to be not only viable but desirable improvements to the gas powered engine, and even the hybrid vehicles. The minimized internal components gives a lot more room for innovation, as proved by the Tesla S and the front trunk, or "frunk" as shown in Figure 3.
Figure 3: Tesla Model S with front trunk, or “frunk,” opened. Due to minimal components required, a lot more space is available for storage and the cabin. Source: Green Lifestyle

The final assumption concerns the market niche that would determine most of the design and functionality choices for the car. Most new technologies have found success in marketing in a top-down approach: more affluent consumers are more willing to put money down to invest in a new, and arguably unnecessary, technology. What drives them to purchase these technologies (the first few generations of Apple technology, the Tesla cars, etc.) is not only the pressure to stay at the front of a rapidly changing tech space, but also the effort to impress business partners or passersby with physical statements of the social standing.

These observations and theories led me to focus on designing a self-driving, fully electric vehicle that is a hybrid between a luxury model and a sports car. The luxury model, of course, is to seamlessly introduce the car within the existing market without it being too much of a "sci-fi" shock. It must provide the riding experience that is akin to perhaps a first class plane or train ride, thus it carries the comfort and aesthetic appeal of a luxury vehicle. The sports car design is mostly due to the fact that I see this car as a two-seater; after all, there is no more reason for four seats for a business associate who often drives alone or with one other individual - there is no driver.
CHAPTER 2

PRELIMINARY IDEAS

To explore where the industry could move forward in the realm of automated vehicles, I first went backwards, to the transition between the carriage and the car - what kind of components are inherently necessary to this mode of transportation? What kind of considerations were made when introducing this new technology to the mainstream user? I then looked at modern cars - what kind of design is already accepted and can be adjusted to fit the new wave of technology? What kind of experience would be most appealing for the target market? This section will provide the answers to these questions in more detail.

2.1 DESIGN INSPIRATION AND MOTIVATION

History proved to be a useful source of information, as the previous large transition in personal transportation relied on several concepts that are still relevant today. For instance, the integration of the new technology hinged primarily on the gradual digression from the box form of the carriage to the rounded form of the more modern car.
Starting from the beginning did not necessarily aid in finding specific design elements to use for the self-driving car. However, the research did show how the range of the first fleet of motor vehicles were narrowed down, as many models that were quite innovative still never entered the market in a broad scale. While one may say that the increased pace in technological innovation makes it easier to adapt to a rather “forward” design, there seems to be wisdom in looking at the modern designs and what is appealing in order to best integrate a technology that is already rather foreign, as is evidenced by the mixed responses to the Mercedes Benz F 015.

Another observation is the functional requirements of the new design; as the styles changed, the focus was still on the cabin and the placement of internal components and storage. These considerations changed more or less depending on the target market (soccer mom’s require more cabin space than joyriders, etc), and so I then turned to the target market to see what kind of elements are crucial to this particular niche.

Figure 5 shows a few idea boards I designed from pictures of items typically associated with the target consumer. Note that it is not just cars, but also items such as watches and suits, as
well as first class passenger experiences, that all have information about what kind of design addresses what is already seen as desirable.

Figure 5: Automated vehicle idea board - an accumulation of photos of items associated with the target consumer in order to find inspiration for designs that would fit well within the market. Source (individual images): Assorted (Pinterest)
The first of the three boards focuses on interior and surroundings. What kind of environment would one normally find the business consumer? There are many references to different passenger experiences that define the current expectations. The second board focuses on the current automobiles (mostly luxury) that is associated with the target market. Later I find specific test cases, but it is helpful to see a conglomeration of images that show the similarities that would be required in a driverless car—no matter the innovation. And finally, the third board is an assortment of items and gadgets that are on the target market’s person. In creating a car of the future, what items will make the consumer want to add this innovation to their collection?

It goes beyond aesthetics and details, however. The boards also display the importance of functional precision, elegance, and practicality that is directly associated with the myriad of professional items. Paying attention to these concepts, as well as holding onto lessons from the past, leads to a list of requirements for a credible design that could begin a new era of transportation:

1. The design must have a professional environment;
2. The design must be able to stand out as an innovative vehicle, yet retain the elegance of a luxury car; and finally,
3. The design must have features that add functional value to the consumer.

2.2 PRELIMINARY SKETCHES

Before I began sketching my own ideas, I tried to put on the mind of an industrial designer by sketching existing models. By studying certain cars by not only observing different models but also drawing them, I was able to ask and answer many more specific questions about design: What lines repeat themselves? Which forms are considered sporty as opposed to
common-place, and what profiles catch the eye? These and many other questions were
considered as I proceeded through these case studies.

The models I focused on in particular were the Alpha Romeo 8C (Fig. 6), the 2013
Lincoln MKS (Fig. 7), and the Tesla Model S (Fig. 8). These models were selected from the
three categories I was looking at (sports, luxury, and fully electric respectively), and as such I
found a variety of details that shed light on the possibilities for my design.

*Figure 6: Sketch of the Alpha Romeo 8C*
Figure 7: Sketch of the 2013 Lincoln MKS
Figure 8: Sketch of the Tesla Model S

Certain observations from these test cases did not surprise me, such as the streamlined curves from the front to the middle of the car, and the aspect ratio of the different sections of the car (front, cabin, back). It was interesting to see how low the chassis would sit over the wheels in sports cars, and how the distance between the wheels and the extreme ends varied depending on the model. There were some elements that I had not noticed before, such as the range in designs.
for the headlights and the universally long front extension. In designing the car, I broke down the parts and looked to optimize the design of each component separately. Following is the implementation of these observations in my own sketches.

2.2.1 FRONT END

The difference between a luxury car and a sports car is grand, given that luxury vehicles prefer a more minimalistic design of streamlines, where sports cars often have extra features that give the car more personality. In addition, the front end (the section from the front extremity to the dashboard of the vehicle) is the primary differentiating factor between cars, sporting different details and profiles that make it unique; it is also one of the first things one observes about the car. Because of the variety of existing possibilities, I saw much room for creativity, and the research pointed me in a direction that I decided to follow.

An additional aspect I considered in the design process is the concept of the passenger experience (PX). As mentioned previously, this is a unique opportunity to redefine what it means to be a passenger, and what one expects. So for the user as a passenger as well as a consumer, what designs could be implemented on the front end to benefit them?
Besides comfort, accessibility and control over their environment, one part of the new transportation experience that will be emphasized with this design is visibility. Now that the user doesn't have to focus on the road ahead at all times, it is important to give them the opportunity to look out the window and see what is going on around the vehicle; as one can tell a corporate office by its view, the same is true of a corporate vehicle. Maximizing external visibility is what prompted me to play with different contours and profiles, trying to see which combination would increase visibility along the lines of my design research.
2.2.2 CABIN

The cabin defines the PX overall, which is why it is one of the more crucial elements considered in this design. As cars nowadays cater more and more towards the user, one of the most prevalent design challenges is to satisfy the consumer's desire for more space, while still having enough room for the internal components, and keeping the car as a whole as compact and streamlined as possible. Since the concept car presented is assumed to be fully electric, there is less space necessary to house internal components (as compared to a hybrid or combustion engine vehicle), thus most of those issues turn out to be easily addressed.

One of the main sources of inspiration for what the new PX should be like is the Maybach 62, an ultraluxury sedan that ceased manufacturing in 2013 shown below in Figure 11 (Edmunds). While it did not quite match the standards the industry required for price point, it
certainly astounded the world with its focus on the passenger, creating an experience that may have simply been ahead of its time.

![Maybach 62 Exterior and Interior](image)

*Figure 11: Exterior (left) and interior (right) of the Maybach 62. Source: Edmunds*

Ironically enough, Maybach was a Mercedes Benz model that attempted to bring the chauffer-driven cars from the 1920-40’s period into the modern world. Many saw the interior design and high-performance hardware as “excessive;” however, there are certain elements that were meant to cater towards the market intended, such as the Business Package: it converts the vehicle into an executive office, sporting “a duel-port wireless Internet router, Bluetooth capability and a multipurpose read storage area” (Edmunds).

While credible, the PX of the future should not simply be an office on wheels. It is true that it is necessary to have the capabilities to be productive while on the go, but what should be emphasized is the ability to interact with other passengers in the car without fear of safety. So with the high quality interior of the Maybach 62 in mind, I made a few adjustments. Figure 12 shows some sketches of the allotted space within the car itself and what it could be used for.
There are some key features that are specific to this design, revolving around comfort, viewing, storage, and entertainment. Comfort is seen, not only in the seating itself, but in their versatility. There is room to sit up and to lounge, with plenty of leg room left over. What is not shown is an adjustment to the rails the seats rest on – the final design would no doubt have the...
chairs only on one rail rather than two in order to have the seat not only move forward and
backward, but pivot as well. The seats can then turn to face each other, or even face the back,
where the back panel can be lifted to reveal two extra seats in the case of accommodating more
passengers.

The need for maximum viewing continues within the cabin, so the profile of the car is
shifted such that the windows are not restricted to the doors as it is on normal cars. The windows
extend up and over along the top of the car, and from there in the frame the doors open and close.
While this makes it so the windows of the doors are not retractable, the lead windows above the
tires are, allowing the passengers fresh air when necessary.

In addition to adopting the front trunk concept, the back panel (when closed) allows an
extra space behind the seats to store smaller items out of the way. There is also a storage area in
the front beneath the screen (between the two speakers). This can simply be shelving, or convert
to an optional feature of a mini fridge.

There is a lot of potential for the implementation of entertainment within the space. I took
a risk and decided to use the headboard space (that reaches over the front wheels and the front
storage area) as a resting dock for a large-screen TV. The screen can be raised and lowered on
command, and is connected to the Smart Table that rests between the two seats.

The Smart Table addresses the user’s communication with the car. Where would it be
best to send in information about destination, or other PX preferences? And in what manner
would it be most intuitive for the passenger?

As seen in the idea boards, the target market mostly interacts in that manner with a smart
phone, or with a self-service kiosk. One is a personal responsibility, the other is readily available;
in a self-driving car, it would be feasible to simply send your destination to the car through your
phone, but as for making quick adjustments to the PX and setting preferences, as well as being about to communicate with the car while driving, something readily available has to be present. That was what led me to the idea of the smart table.

Right at the passenger's side, the Smart Table is essentially a smart phone interface, but geared primarily to the car's functions. Calls, web, and other productivity tools could be accessed and synced with the passengers' phone. From the ideas that I had considered, it seems to be the most unobtrusive and intuitive interface that can provide not only entertainment and functionality, but also a sense of control in an environment that can control itself.

2.3 INTERNAL COMPONENTS

A battery electric vehicle (BEV) has a very simple internal architecture, as it requires relatively few components as shown below in Figure 13. There was not too much consideration as to the placement of these components, besides certain general observations: for example, the battery would be placed in the back of the car (rather than the bottom center as it is for Tesla) simply for easy charging and use of the space available. For the first iteration of the vehicle, it would have only one motor on the front axle, and the transmission on the back axle. The computer would be placed in the front, below the screen and behind the small storage space in the front.
There are also components required for the self-driving function of the car, such as the overhead laser camera, the radar cameras on the front and back, the traffic light camera, and the GPS. Most of these components are discreet, and can be readily integrated into the existing design (as they had been in the first Google Prius). The overhead laser camera, on the other hand, does require an extra step of design to integrate it into the current model.

One of the benefits of having windows essentially surrounding the cabin is not only for user viewing, but for computer viewing as well. With the design shown in Figure 14, the car will be able to see everything from the top of the vehicle within a streamlined extruding housing. The addition is not disruptive to the overall aesthetic, and creates a type of signature that shows the outside viewer that this is a self-driving car.
Figure 14: Some overhead concept sketches of what mounting the laser camera would be like. Note: Little about the glass’ effect on the laser’s ability to take in information is currently known, and may change the overall design.

2.4 INFRASTRUCTURE

In considering a design for the car, it’s necessary to also look at what is needed for implementation within society. Such a process was seen before, such as when the horse-less carriage was gradually integrated into everyday items: speed limits, traffic lights, parking spots, etc. Considering the additions required, at least at a product rather than policy level, is necessary for understanding the validity of the technology. Most of what is necessary already exists, which is why it’s possible to phase in automated features into modern cars. However, there are certain adjustments I focused on that, if made, would improve the functionality of the car itself, as well as further integrate it easily within society.

The one concept I investigated as part of my research is charging. The biggest downside to a fully electric vehicle is the fact that as of right now, an average battery charge lasts approximately a hundred miles before it needs to recharge. This makes them less than practical beyond everyday usage, and even then under discretion. While Tesla has started making
charging stations more readily available, there needs to be a method that is more intuitive to the
car itself, not just the passenger.

The idea is based off of a parking space block, the white divider that keeps a car from
traveling beyond the boundary of the parking space. Ordinarily, it would be a normal parking
block. But in the case of a self-driving car, it would also serve as a charging dock when
activated. A general design is shown in Figure 15.

![Figure 15: Brief sketch design of the parking dock. Features to note: the retracting panel on the back of the car, and the indicator on the dock that shows the charging state of the car.]

The idea is that, while self-parking, the car would continue backward into the
space until it engages with the dock. This can double not only for convenience but for a
second layer of security, as the car will not disengage until the main passenger unlocks it
from the charger.
CHAPTER 3

FINAL DESIGN

In this section, what follows is a series of sketches, images, and renderings of the final design. Commentary is dispersed throughout the images.

Figure 16: Sketches of different views of the final design. Note the overhead laser mounting, the large windows enveloping the sides, and the sloped front end, the top of which serves as a lid for the front trunk.
Figure 17: Section views of the final design to prep for the final CAD drawings and renderings.
Figure 18 follows, which is a series of renderings from the front, side, and back of the final design. Also included is a rendering of three models in different colors.
FUTURE CONSIDERATIONS

Many people (most famously Google engineers) believe that the fully automated vehicle is right around the corner. For the most part, they are right — at this pace, only a few years will bring vast improvements to the software capabilities that a car needs to drive itself. As far as hardware is concerned, there may be some difficulties in the social arena to have a vehicle where it is nigh impossible for the passenger to take over for the car, and it may seem risky to make a car almost as much glass as it is metal. But, like the software improvements, the appropriate hardware and manufacturing techniques may also be just around the corner.

A car like the one proposed is designed to be easily integrated into society. Even the charging dock (which is designed based on convenience) can be slowly introduced first through private, then through public sectors. It is not considered to be the best, nor even the most practical design based on the constraints and design goals (i.e. safety is an issue not thoroughly assessed in this design); rather, it is a possible design that could lead the way to future innovation as the technology progresses.
SOURCES


