The primary objective of this project is to design and produce an aftermarket system that will be able to detect the speed and distance of a vehicle directly ahead of the adaptive cruise control equipped vehicle (ACCEV) and automatically adjust the speed of the ACCEV to maintain a minimum separation. This will be accomplished using radar, vehicle BUS interconnect, and control software. Relevant information and controls will be displayed on a LCD touch screen. A prototype system will be designed for the Dodge Stratus. The project has been determined to be feasible in scope, schedule, and cost, and will be completed by the appointed deadline of May 5, 2007. We estimate that we will be able to sell our system for approximately $1,850, and sell approximately 7,500 units in our first year.
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1.1 Project Introduction

1.1.1 The Team

Team 3: Calvin Cruise (TCC) is composed of 5 senior electrical engineering students at Calvin College.

From left to right: Erik Barton, Nate Barker, Nate Sportel, Bryan Bandstra, Chris Vonk

1.1.2 Project Description

The Calvin Cruise team is working to create an Adaptive Cruise Control (ACC) system. It is being designed to detect a vehicle from 150 meters away and to find the other vehicles speed. The system will then slow the ACC equipped vehicle down to the other vehicles speed using only throttle control. The system will also maintain a distance per the 3 second rule or user entered distance. Once the other vehicle moves out of the lane, speeds up, or the ACC equipped vehicle changes lanes the system will speed the ACC equipped vehicle back up to the pre-set cruise speed.

The system is activated when a person engages their vehicles original cruise control and then presses “Turn ACC On” button on the LCD touch screen. The system will also display information such as distance to the other vehicle, the other vehicles speed, and the speed differential on the LCD touch screen. The system will sound an audible alarm and display a warning message on the LCD touch screen if a dangerous speed differential is detected, such as 15 mph, so that the driver may be notified and
manually take corrective action. This is done only if the system will be unable to slow the ACC equipped vehicle within the distance allowance.

### 1.2 Calvin Engineering Educational Outcomes

It has been the Goal of the Calvin Engineering program to achieve certain Educational outcomes for its students. Calvin has achieved these outcomes and it is very apparent in the senior design projects. The following shows how Team 3: Calvin Cruise, has used these outcomes in its design of an adaptive cruise control system.

#### 1.2.1 Mathematical & Technical Sciences

As with the majority of engineering projects, Math and science is the base of TCC’s project. The adaptive cruise control system requires the design to determine which cruise control action should be taken and when. When the ACC system is active, it constantly monitors the speed and distance of forward vehicles and compares it to the speed of the equipped vehicle. Then, using the preset following distance calculated from the speed of the equipped vehicle, the system determines whether or not the equipped vehicle will be able to stay outside that calculated following distance. If the equipped vehicle is beyond the following distance and the vehicle is traveling below the speed the cruise control was set at, the system will slowly increase the speed of the vehicle up to the point of the set cruise speed to allow the equipped vehicle to maintain the calculated following distance at maximum speed allowed. If the set cruise speed of the vehicle is such that the equipped vehicle will stay beyond the following distance the system will take no action, even if the distance between the vehicles is increasing. If the speed of the equipped vehicle is such that the vehicle will be encroaching upon the calculated following distance, the system slows the speed down until the vehicle can maintain the calculated following distance.

To reach a target speed smoothly requires feedback looping that allows the speed of the vehicle to fall into a calculated goal “following speed” without the system having to accelerate and decelerate the vehicle multiple times to reach that goal following speed. The ACC system will also know the maximum deceleration of the vehicle, and if the design determines that with the maximum deceleration is not great enough to slow the equipped vehicle down in time, the system will turn the cruise control off and activate both and audible and visual alarm from the screen.

To design a system which accomplishes the above tasks, TCC needed a basic understanding of the principles behind the logic. They also needed to know how to write the necessary VHDL and C code, do circuit analysis, and apply logic. TCC also needed VHDL as the basis for their design to interface between the software and the outside world, namely the vehicle, radar, and user. They used the C code
to write the software that will perform the mathematical calculation, as well as compare and respond to
the situation. Circuit design was needed for analog to digital and digital to analog control needed to read
the cruise control button presses from the steering column as well as recreating the voltages on the
wires for the system to simulate button pushes.

TCC also had to learn many new things. They had to analyze the current circuitry already in the
vehicle, learn the protocols for J-1850 and Medium Speed CAN bus’ for the vehicle and radar, and learn
how to use the neoVI which was used to connect to the two types of buses simultaneously.

This newfound knowledge also had to be applied to the business plan portion of the design.
Accounting practices were used to create a financial plan for a simulated company that TCC
represented, and evaluate the product with it. A sales pitch and a brochure were also created to
“advertise” the ACC system product.

Overall, a large base of mathematical and technical knowledge was needed to be able to apply
techniques used in the ACC system project. Calvin provided TCC not only with the knowledge needed in
particular areas, but also the ability to learn quickly to apply new ideas and techniques.

1.2.2 Data Analysis
TCC implemented data analysis in the formation of their project. The ability to design and conduct
experiments as well as analyze and interpret data to extract meaning was demonstrated within the
group through various avenues. The ability to design and conduct experiments can be seen through the
following experiments conducted by the team.

The first experiment needed was to try and reverse engineer different signals that were
displayed on the J1850 vehicle BUS. Key signals were sought after to extract their meaning such as
vehicle speed, cruise control status, and ignition messages. The experiment was conducted by
connected a hardware piece called the neoVI to the cars onboard computer through a J1850 connection
jack. Once the neoVI was connected and powered to the vehicles onboard computer, messages were
read from the cars computer via a program on a laptop called Vehicle Spy. The messages were sent
every couple milliseconds in a random assortment. In order to make assessments about the data
coming off of the bus a test plan was created to run through the various cycles of the vehicle status. The
first status was that of turning on and off the vehicle in order to determine an ignition status message.
Messages were collected in unison with a stop watch using precise timing to tell when the car was
turned on and off.
The next experiment of the bunch was used to determine was a 0 to 25 mph speed test in which time the car was accelerated a constant rate and throughout the experiment the speed was read at set time intervals in order to isolate the speed messages on the J1850 bus.

After testing the speed messages on the J1850 the team then moved onto determining the Cruise control on/off message. For this experiment the cruise control was turned on and off at set intervals of time 10 times. The idea was to be able to isolate the on / off signals on the vehicle bus out of all of the messages on the bus by looking at the specified times within the saved off log in order to determine the cruise on / off signal.

Once the cruise on / off test was completed the test of the cruise control buttons was recorded. The vehicle was brought up to speed and the cruise “cancel” button as well as the cruise control “set” button were turned on and of 10 times. The Cruise control “Resume” button was also tested in the same manner. The next test that followed from the previous test was that of the cruise control “on”, “set”, “cancel”, “resume”, “off” test. This succession of button presses was repeated twice and the times at which these buttons were pressed were also recorded so that the logs collected by vehicle spy at these exact times to look for signals that would stand out.

The two remaining tests included recorded the “on”, “set”, “accelerate x 5” to determine the accelerate message on the bus. Also, the “on”, “set”, “coast x 5”, “resume / cancel” combination.

Once all of the tests and logs were compiled it was off to the computer to look at the logs to try and analyze the data to extract meaning from the data collected. The logs that were created for the different tests had a built in time stamp that was correlated with the onboard stop watch time for the certain events. This approach of looking at critical times to try and analyze signals was useful in the interpretation and isolation of the different messages that were on the bus.

The program “Microsoft Excel” was used to look at the logs and apply strategic filters in order to look at the data in a more efficient manner. After conducting the experiments TCC was able to successfully reverse engineer the messages to find a general pattern for the speed messages as well as the cruise messages. It was found through testing and verified through an outside contact that the cruise control messages were not on the bus as was expected. TCC found out through a contact that the messages themselves were actually voltage encoded and were on a separate system than the rest of the vehicle information. TCC did however find that the speed messages were on the bus through experimentation. The HEX value of the ID address was determined to be 0x10. The only thing the team
needed was to figure out what the exact conversion factor was used to convert the digital bits to a speed in mph. Thankfully a contact proved useful and helped us with a conversion rate of 1/128 kph for every bit registered on the two byte encoded 0x10 signal for the speed message. This saved extra experimentation and analysis for the project.

### 1.2.3 System & Process Design

Calvin College’s Engineering Department requires all students to take a year-long project study called Senior Design. The goal of taking a course focusing completely on accomplishing a task is to give students a taste of what projects for real companies will feel like. The Senior Design goes about accomplishing these tasks by requiring students to take on a very challenging and lengthy project. Engineering students demonstrate many skills taught by the engineering department throughout the four year education of the engineering curriculum. One of these skills is the ability to design a system, component, or process to meet desired needs. The following paragraphs will describe how TCC displayed this ability and skill while doing the adaptive cruise control project.

The adaptive cruise control project is a project where TCC created a controller unit to lower and raise the cruise control speed based on a range detecting unit, specifically a radar unit. In order to accomplish this goal the team actually created a prototype that would be installed on a real car. Because safety is a concern as well as the protection of the large investment of an automobile, this had to be a careful process as well as a very deliberate system to assure the safety of those testing the unit on the automobile.

The abilities demonstrated in the process of creating this prototype cannot all be listed here, but the main and most useful skills are described below. Calvin College Engineering Department has the view that engineers should have very good communication skills as well as technical skills. Because so many credit hours are spent doing technical courses, Calvin has integrated writing and communication programs into the engineering curriculum. Just about every engineering course requires at least one formal report written from the many lab exercises per semester. The writing is then reviewed either by a professor or an industrial consultant and then given back with comments and suggestions so the students can revise their reports and create a very elegant report that can be understood by most in scientific professions. The skill of writing and communication was so critical in senior design. TCC needed it especially for the Project Proposal and Feasibility Report, however, good communication skills were important and beneficial in everyday things like writing e-mails to mentors and industrial experts who were crucial for the attaining of information necessary for the design of the project. Communication skills are invaluable and useful far beyond this college course.
Another skill was a familiarity with the tools, languages and parts used in the project prototype. The first example would be a mastery of the VHDL language. The students attain an introduction to VHDL in Engineering 304 and a much more focused look at the language during the interim course Engineering W82. Using this hardware description language allowed us to build three separate electronic components that were needed in the design. Just one example was a unit telling the controller how to send messages through the RS232 port. This particular port was necessary to sending and receiving messages to the Radar unit. Besides VHDL, another beneficial language to know was C. C code is a software language that was used to program the microcontroller. Engineers take 2 courses in C++ which was helpful, but some members of the team also had much more experience with C and software by doing internships, another aspect of the engineering program that is pushed extremely hard. Lastly, the microcontroller was made on a DE2 board by using a NIOS II processor. This particular processor and development board was used heavily in Engineering 325 and Engineering W82. Needless to say, the team has a lot of knowledge and experience using the board. This experience was probably the most important because the processor and controller is the heart and soul of the adaptive cruise control.

The last ability that is so extremely important to any project is team work and time management. The work load in the engineering program is very intense. Obviously, this project was a lot of work. However, this is what engineers are used to after four years in the program, so the adjustment was not really that hard. The team was ready for the many hours put into the project because of the work load. This work ethic created by the demands of the engineering project will be invaluable to any employer. Also, the engineers in the senior design course were required to work in teams. For some students this may have been a challenge or an adjustment, however, for students at Calvin its feels like just another project. Just about all large projects at Calvin are team oriented. TCC was used to working in teams and was good at it. The members knew when to take lead in something and they also knew exactly what was expected. There were no weak links or people not holding up their part of the project.

The ability to create a prototype to meet demands required many skills and TCC had all of the necessary skills to get the job done. These skills were grown from the professors and learning they received at Calvin College.

1.2.4 Effective Communication

One of the educational outcomes of the engineering program at Calvin College is the ability to communicate truthfully and effectively. Calvin College has made communication a central focus of not
just the engineering program but the overall curriculum as well. Under the category of “Core Competencies” (Calvin College, 2007), the Registrar’s office includes written and oral rhetoric. These are required classes for all students who wish to graduate from Calvin College. As a result of this integration TCC has included these principles both inadvertently and intentionally.

To this end, TCC has strived to communicate truthfully and effectively. For example, the primary deliverable of ENGR 339 (Senior Design – fall semester) was the creation of a “Project Proposal and Feasibility Study”. This massive document was the summary of an entire semester of work and it included everything from a discussion of design norms to project requirements to explanations of design decisions. TCC met the challenge of this document by providing the document well-written and on time as requested.

Another requirement of the Senior Design class is four mid-semester status update presentations. These are six to ten minutes in length, and are presented to the entire senior design class, with each team member required to present at least once. The goal of these presentations is not just to keep the rest of the class reasonably updated on current project progress or to practice for the final presentation on senior design night, but to also allow each team member to have experience speaking in front of a large gathering of people. Since this is a cross-discipline gathering it also forces the team members to practice speaking in front of people who may not be fully knowledgeable in different concentration specific concepts and terminology. TCC feels that its presentations are more effective when the entire audience is able to easily engage the subject being presented. TCC has strived to meet this challenge by deliberately reducing the technical emphasis of the presentations to a bare minimum, instead presenting only basic concepts understandable with the broad engineering base that each student has received in their first two years in the engineering program.

Another important aspect of the communication curriculum is the ability to communicate truthfully. Through the Senior Design class especially, it has been impressed on TCC that communicating truthfully does not just involve writing and speaking, but the entire package of communication that an individual is able to offer. It is not enough to merely say and write the correct and truthful thing, but to also live the Truth that is presented in the Bible. In this case this departmental requirement is redundant with both the mission of Calvin College and the calling of Jesus Christ.

TCC has strived to exemplify truthful communication through a variety of means. First, TCC has made it their policy to not be dishonest with different vendors, suppliers, and other contacts. For example, TCC has not misrepresented themselves and their intentions or made promises of (nonexistent) future orders. Second, TCC has made the effort to document and cite sources of data and
other information that has been used throughout the process of this project. Third, TCC has done their best to avoid misrepresenting both the status of the project and the project itself to their advisor, classmates, or others.

1.2.5 The Global Footprint of Engineering

Along with the other crucial educational outcomes that every Engineering education should provide, is the idea of stewardship. Calvin’s Engineering program makes sure to hold true to the Reformed Christian world view, and thus teaches each student to be aware of the “Design Norms” for any project they encounter in their careers. One of these design norms is “Stewardship”.

Reformed Christian engineers are called to be wise stewards of all that is given to them. It is with this principle in mind that the Christian engineer must ask: is this technology utilizing and promoting the proper use of natural and synthetic resources? The engineer must consider the outputs of the system, and whether those outputs will have any negative effects (short-term and/or long-term) on the surrounding environment.

This is certainly an applicable design norm for the ACC system. It is commonly known that the more a vehicle’s speed is controlled the higher the fuel economy of that vehicle. In fact just by using cruise control the fuel economy of a vehicle is improved by an average of about seven percent. Since the ACC system controls the speed variations due to impeding traffic, it is the goal of TCC to improve the fuel economy of the equipped vehicle even more. This would be a wise use of resources.