

MICHIGAN STATE UNIVERSITY

ECE 480 - Design Team 4 **Hot Strip Mill Centerline Tracking** **10/10/13**

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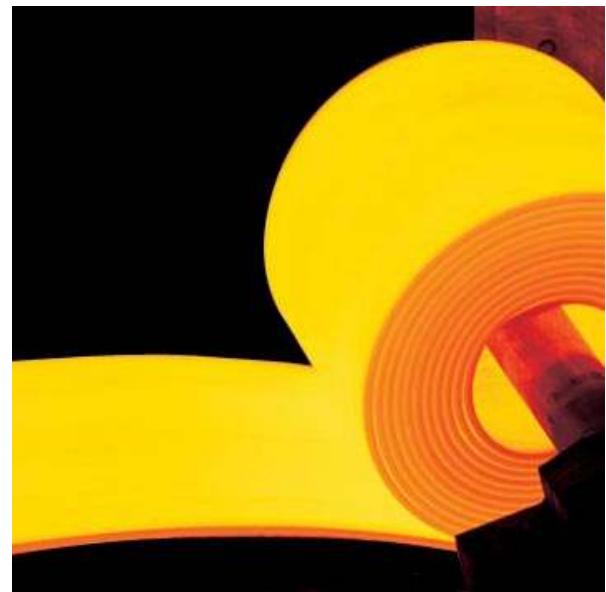
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Executive Summary

The finishing section of ArcelorMittal's steel hot strip mill passes a length of heated steel through seven high pressure rollers to flatten the steel into a long strip. Several issues, such as inconsistent temperatures and pressures can cause the steel length to bend. This bending can cause the steel to impact the guards on either side of the rollers, damaging equipment and stopping production. Currently, the curvature of the steel is monitored by an operator in the hot mill's control room. When the operator sees curvature in the strip, corrections are made and changes can be made to improve future strips. Steam, distance from the strip, and a low viewing angle make monitoring the shape of the strip difficult. Team four's design project entails a vision solution to display a more clear visual of the shape of the strip to the operator. Giving the operator a clear, live feed of the strip will allow for more accurate adjustments and will help to prevent production halts. Data obtained from the system could be used in control systems to produce straighter steel and reduce failures in the hot strip mill.

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Introduction

In the steel manufacturing process, after all raw materials have been melted down and turned into a slab of steel, it must be sent through a hot strip mill. In a hot strip mill, the slab width is reduced from 6-10 inches thickness into a strip of about .05 to .5 inch thickness. This strip of steel is rolled into a large coil and shipped to customers or other steel processing plants within the company. All defects that occur here will cause problems within future finishing processes, in addition to delivering a lower quality product to customers. A prominent issue occurring here is cambering. Cambering is an issue where a strip of steel can curve off its intended path. It is very difficult to keep the steel running straight through the mill during the hot milling process. It is common that the steel curves (camber) slightly during the process. It is critical to keep cambering under a reasonable threshold during the hot strip milling process. Cambering can be caused by many discrepancies such as differences in temperature throughout the steel and pressure being applied from the rollers. A uniform press is not always obtained. If camber becomes too extreme, the steel can cause a wreck in the mill. A wreck occurs when the steel runs off the line and production must be halted. There are guard rails to try and prevent this, but even when the steel hits the guard rails there is great potential for negative consequences. Sometimes when the steel contacts the guard rails it will curl and fold onto itself. This causes another issue called cobbling. When cobbling occurs it damages the rollers and they can no longer perform a uniform press on the steel. Consequently, when wrecks occur or the rollers are no longer usable this causes production to halt. The cost of downtime is approximately \$12,000 per hour. Therefore, it is critical to prevent production shutdown. Skilled staff can change rollers as quickly as seven minutes! It is still not desirable for cobbling to ruin the rollers because they are very expensive to repair and maintain.

Our customer needs a centerline tracking device to aid in minimizing and preventing camber. When the steel strip starts to curve, there must be a system in place to detect it fast and efficiently. Due to the large-scale operations of steel mills, total prevention of the problem is not feasible and would result in a huge amount of downtime. The scope of the project will not be designed to prevent the problem, rather detect and alert an operator of the curvature. When camber is detected, the roll operator (individual in charge of the hot rolling process) will be able to see the severity of the cambering and make pressure adjustments based on the data and visual aid. This ensures that the problem is not repeated and worsened in the next strip.

The final design will incorporate a high-resolution camera integrated within a microcomputer. The microcomputer will be able to detect the edges of the steel and calculate a centerline. The centerline data will be stored and compared with future data. When the change in centerline crosses a threshold, an operator is alerted of the error and will make adjustments accordingly. The software will be user-friendly and compatible with what the operators use during their typical monitoring of the process.

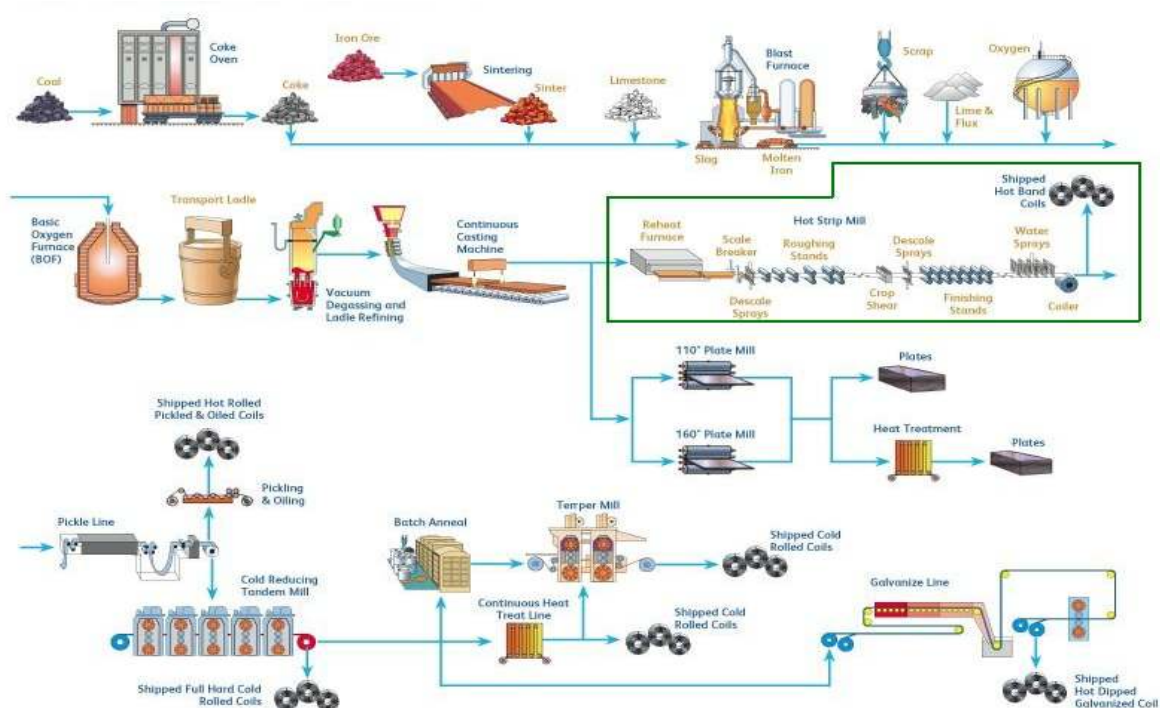


Figure 1: Process Flow, courtesy of ArcelorMittal
An overview of the entire steel process

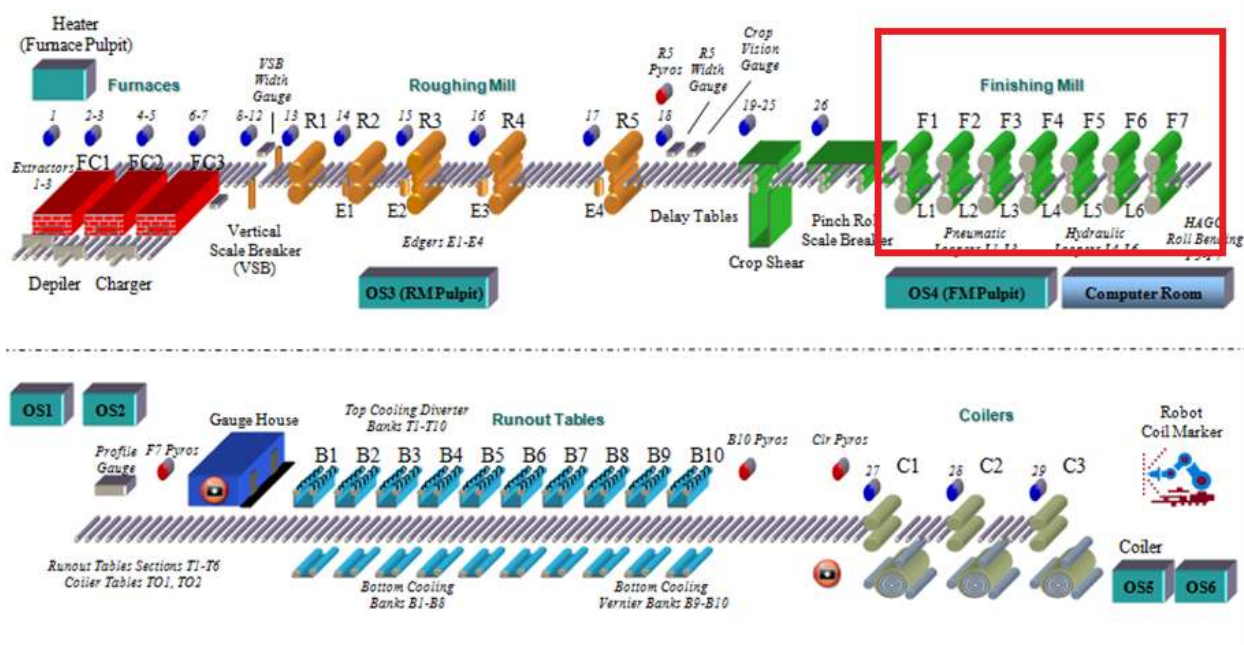


Figure 2: Hot Mill, courtesy of ArcelorMittal

Cambering becomes most apparent towards the end of the finishing mill. The focus of this project will be measuring the steel between the sixth and seventh finishing stands

Background

In a hot strip mill, cambering is a critical issue. Cambering can be dangerous for employees on the floor, it damages equipment, wastes steel, and complicates production processes down the line which cost time and resources to correct. The most critical event cambered strips of steel cause is a wreck. When cambering is server the steel strip will run off the steel mill line. When there is a wreck it takes considerable down time to get machines and personnel on the floor to clear the wreckage. A reduction of cambering ensures a higher quality product for customers and other steel processes within the company. Preventing cambering reduces collisions between the steel strip and the roller guards, increasing operational safety for employees and preventing equipment damage and downtime. Tracking the centerline of the steel strip and correcting cambering as it is occurring in the roughing mill is crucial to maximizing production. When cambering is quickly detected and addressed, control systems can adjust the left and right pressures of the rollers independently to help counter the curvature of the steel strip. The American Institute of Steel Construction's (AISC) Code of Standard Practice for Steel Buildings and Bridges states that 1/8 inch of cambering for each 10 feet of steel length is acceptable.

Various companies make vision and sensor systems to detect and aid in the management of camber. EMG Automation GmbH specializes in the automation of continuous production processes in the metal industry. A product they offer, called hotCAM, is a high speed camera designed to measure camber of steel strips in the hot milling process. Delta is another company that specializes in applications to the steel industry. Delta has a sensor called the CCD Array Sensor TSP, which is typically used in centerline tracking applications. It works by detecting light and dark area. The steel is hot and glowing which emits light, while the rest of the area being captured is darker. The sensor has a diode array that switches on for light areas and remains off for dark areas. The output of light to dark area is given as an analogue output voltage from 0-10V. Software can be utilized to track the centerline of the steel with this device. Hardware applications such as these sensors require software and complex control systems to fully utilize their capabilities.



Figure 3: Finishing Stands, courtesy of ArcelorMittal

Design Specifications

Power

Our solution will be directly wired to supply power, preferably a 120/240VAC source. Battery power would require constant maintenance due to non-stop facility operation. Realistically, power consumption will be minimal compared to the power consumption of the hot-rolling process and will not be a concern.

Communication

Ethernet, profibus, and wireless are all feasible solutions depending on where the customer would like the alarm system to be placed. For the scope of this project the device can be hard wired to a display for the data to be accessible for operators. If other communication options are more desirable changes could be made.

Resolution

The resolution of the camera the team uses needs to be enough to provide a clear picture for the operators of the steel strip and to clearly detect edges. The rate of sampling (frames per second) is critical to success. Higher rates of sampling provide a more accurate and faster detection, but require more data to be stored. A lowered sampling rate provides a lower cost and storage requirement, but reduces the accuracy of the process. The steel moves through the mill at a speed of up to 30mph so the system needs to be fast enough to monitor the change in shape of the steel at this speed.

Data Storage

The program we use should be able to write data of how far off the steel is from the centerline to compare to previous samples. It also needs to display the image and save it for analysis.

Environmental Tolerance

The hot strip mill is a very harsh environment for electrical equipment. Any hardware used needs to be able to withstand high temperatures and may call for a cooling system or a shielding enclosure. The steel strips are 800-1300 degrees Celsius. The maximum range of most production monitoring cameras is around 8 meters. Also, high pressure water is sprayed onto the steel in the roughing mill. If sensors are used near the roughing mill they need to be waterproof and debris resistant.

Function Analysis System Technique (FAST) Diagram

In order to fully visualize the scope of the project, a FAST diagram was created; defining all of the functions the design is to entail. The diagram begins with the primary function of the design project: tracking centerline. From the primary function branches a few paths that detail all secondary functions that describe how the project's primary function will be achieved. The FAST diagram is as follows:

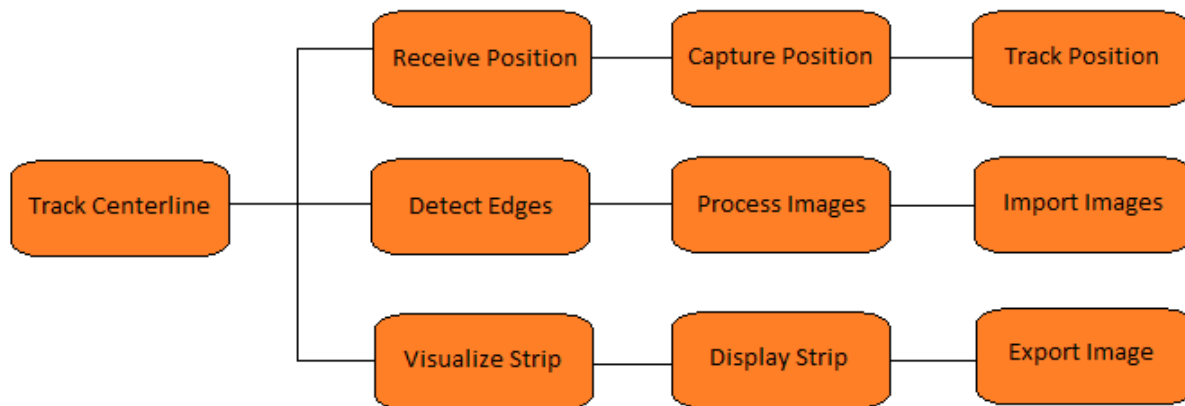


Figure 4: FAST diagram

The three functions at the ends of the branches on the far right indicate that three major components need to be integrated into one system for our design to be realized. These three components are:

- Vision capturing device (camera, sensor) to track the position
- Processing device (laptop, microcontroller) to import and process images
- Display (monitor, alarm) to output images to for visualization

Conceptual Designs

Design 1: Centerline Tracking Production Monitor

One design solution is to use hotCAM for camber and position measurement. This device is manufactured and sold by an European company called EMG Automation. This device would be mounted above the line in the hot strip mill and is able to record and delivers an image of the camber to the operator's room. The hotCAM could be installed on any of the stands to provide continuous centerline measurement to feed into control systems for corrections. The most critical position for a hotCAM would be at the sixth finishing stand where cambering is most server. It is ideal to have multiple cameras throughout the line since the position of the steel strip changes as it goes through each finishing stand. Once the hotCAM detects the change in position of the steel strip, hotCAM records the image and the data can be used by control systems to make real time fine tune adjustments. The image is then sent to the operator's room where operator will be able to make more course adjustment on the rolling force to keep the strip in the middle of the line.

This design is good due to its high accuracy, thermal resistance, and ease of assembly. The downside of the Centerline Tracking Production Monitor is the cost. High-end production monitors are well outside of the team's budget. Additionally, there is little engineering innovation to be done because this system was built to track centerline and there is little left to add to it

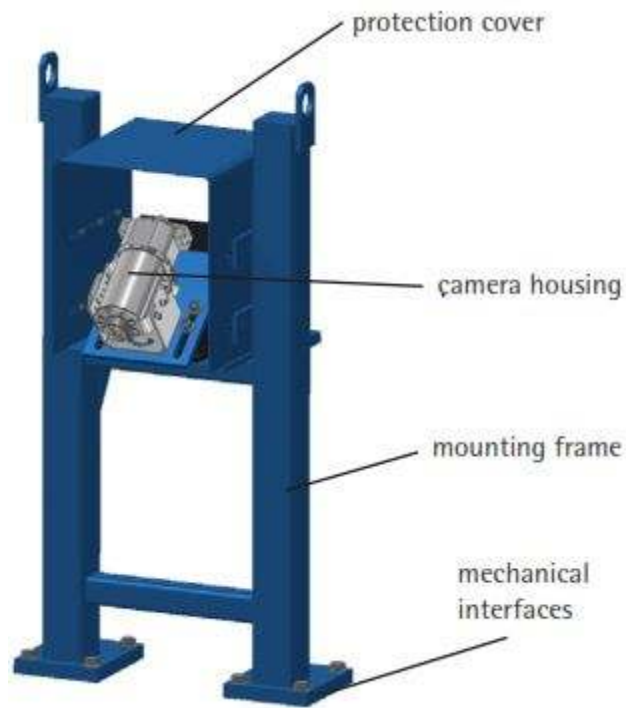


Figure 5: hotCAM, courtesy of EMG Automation

Design 2: Laser Strip Edge Detection

In the second design, multiple lasers could be mounted on each side of the line in the finishing stands. When the steel strip begins to camber, different sensors would trip. The microcontroller would then be set to high. Then software interfaced with the microcontroller will output a visual image of the strip, and this is how the operator will know steel strip began to camber. However, there are some downsides with this solution. For instance, the accuracy of the visual representation is highly dependent on the number of lasers installed by each side. Consequently, this design option will be expensive. Additionally, environmental factors such as debris and steam will interfere with the laser. As a result, the lasers may not even detect when the steel strip begins to camber.

This design is considerably cheaper than the Centerline Tracking Production Monitor; however it includes a significant drop in accuracy. The range of the laser sensors is much less than that of a high-end camera, placing the sensors very close to the hot steel strip. Melting sensors would be difficult to avoid and would require an extensive heat removal process and shielding.



Figure 6: Fiber Optic Laser Sensor

Proposed Design Solution

Our final design consists of a hi-definition webcam connected via USB to a Beaglebone Black microcomputer with processing help from a DSP (Digital Signal Processor). The Beaglebone will be using Linux Ubuntu as an operating system, where we will be able to process the data received from a DSP chip. We have decided to use a DSP in order to reduce the load on our microcomputer. The DSP is specifically designed to process signals. By transmitting the image matrix to the DSP, it can properly detect contrasting areas to locate the edges of the strip. After the edges are located, a series of algorithms calculate the centerline data. The centerline data is sent back to be stored on the Beaglebone, where it will be anticipating the next location of the centerline. Using the centerline data, we can properly determine if cambering has occurred.

Using AISC's standard for cambering, our product will be able to alert an operator when the centerline has crossed a certain threshold. At this point, the operator must make adjustments to the rollers so that the problem is not replicated in the next strip.

Our webcam will be able to take pictures at a resolution of 1080p and a speed of 30 frames per second. If the team only uses the Beaglebone microcomputer to process image data, it would cause a serious bottleneck to the system. It may not be able to process the data fast enough. Instead, the Beaglebone microcomputer acts as a midway point between the image and centerline data. We chose Beaglebone over other microcomputers because of the processing speed, along with ease of setup. The Beaglebone will be constantly receiving and transmitting data, and it is important to keep all of this processing up to our camera's rate of 30 frames per second. Hence the need for a dsp chip to reduce the processing burden on the Beaglebone microcomputer.



Figure 7: Camera and Beaglebone Black

Feasibility Matrix

To decide which of the preliminary designs will be implemented, a feasibility matrix was constructed. The matrix analyses each design with respect to the project's key factors (Cost, Environmental Tolerance, Resolution, and Processing Speed). The designs are given a rating in each category from one to five with five being the most feasible. The matrix is shown below:

Design	Centerline Tracking Production Monitor	Laser Strip Edge Detection	BeagleBone Black Controller and Camera
Estimated Cost	0	2	5
Environment al Tolerance	4	2	2
Imaging Resolution	4	1	4
Processing Speed	3	4	3
Averaged Scores	2.75	2.25	3.5 Most Feasible

Table 1: Feasibility Matrix

The results of the Feasibility Matrix show that the BeagleBone Black Controller wand Camera is the most feasible system and has been chosen to be the final design.

Project Management

The table below describes the role of each member in the team. However, these roles will not forbid other members from assisting each other. They are meant for smooth functioning of the team to meet deadlines of the project. All members will contribute to the project equally and are to ensure that the other member's tasks are completed for any particular deadline. The team shares responsibilities for all deliverables as a whole.

Personnel Roles

Bryan Blancke	Non-Technical Role: Team Management Oversees the operation of the project. Responsible for ensuring all members work together efficiently. Manages methods and systems for effective team communication and information sharing. Ensures quality of work. Cohesively coordinates team members and their individual responsibilities to meet deadlines of the project. Technical Role: Demonstration Bench Design Design and Build Demonstration Bench in collaboration with the ECE shop to demonstrate the significance of the design project. Acquire materials to simulate hot strip mill operations and integrate the team project into the system to show how it will perform in industry. A video of the demonstration must be recorded to show on design day.
Mark Heller	Non-Technical Role: Document Preparation Responsible for ensuring each deliverable has all of the necessary information, such as final proposal and final report. Maintain document standards and organization. Technical Role: Functionality and Testing Define standards of functionality of all hardware. Includes stressing the system to invoke failures as well as altering the design to overcome these failures. System must perform smoothly under stress for pre-determined amount of time in order to be considered functional.
Daniel Kim	Non-Technical Role: Presentation Preparation Coordinates oral communication for team presentation and preparation of the poster for the design day. Technical Role: Hardware Specialist Responsible for acquiring camera/sensor and testing the

	functionality of the equipment. Assess the feasibility of the equipment for the project.
Jeremy Martin	Non-Technical Role: Web Design Coordinates ordering parts and ensures the cleanliness of the lab. Schedules lab meeting times and coordinates build phases of the project. Technical Role: Software integration Establish electronic communication with equipment via Ethernet. Creation of Demonstration Bench Human Machine Interface and data collection scheme. Responsible for maintaining a standard in code work for ease of comprehension.

Project Management Plan



Figure 8: Gantt Chart

The team's project requires seven critical steps in order to bring the project to its completion. The first step of the project is to conduct the preliminary research required to understand the problem and potential solutions for centerline tracking in the hot strip mill. After researching potential equipment and the software that applies to this project the next step will be to use this information in constructing a proposal and deciding on the optimal design solution. Once the team concurs on the most feasible design solutions derived from the research phase, the team will proceed with the third step of ordering the equipment. While equipment is being shipped the team will continue to work on the tasks outside of the critical path.

Once the equipment arrives the team will move into the design phase of the project. The fourth step towards completing the hot strip mill center line tracking project is to test the equipment that was ordered. The team needs to confirm the equipment will be able to perform as expected from the research phases of the project. It is important to start this step immediately after obtaining the equipment to ensure it meets the team's needs and will work as expected. If any components do

not satisfy the team's expectation it may be necessary to order other equipment. The team may also discover the need for additional equipment during this process. That is why the team must assess the functionality of the hardware as soon as possible. The delay of ordering extra equipment if the first order was not enough will add extra downtime and could significantly affect the completion date of the project.

After verifying the equipment functionality the team will begin prototyping. In this phase of the design the team will interface the equipment with the software. The BeagleBone microcontroller and the Logitech camera need to be connected. Once the hardware is functioning together and the programming interface with the controller is complete, the team will move into the testing and programming step. During the sixth step, the programming and testing the design will be done. This is the bulk of the work required to make the project functional. Therefore, this is the longest phase of the project. This will allow time for coding, debugging and fine tuning of the design. The extra time for the phase is also needed because the team has the least experience in the programming required for this project. The team will need to spend time learning how to use the programming language and to bring software skills up to the technical level required to complete the project.

The final phase of the project will be designing a test bench. The test bench will be used on design day to demonstrate that the project can visually detect the center line of a curved object. Once the project is functioning and the test bench is completed, the team will verify the project performs as needed for design day. This will conclude the centerline tracking project.

Project Cost

The team has been funded with \$500. The majority of the budget will be spent on purchasing a camera and the Beaglebone black microcontroller. Initially, purchasing a state of the art camera was being considered, but that will go over team's budget. Consequently, it is more feasible to purchase a cheaper, yet high quality camera. Peripheral hardware such as cables and power supplies will not put significant strain on the budget. The cost of building a test setup to demonstrate the project will be around \$50 and only cheap building materials will be required.

Component	Price
BeagleBone Black Microcomputer	\$45.00
Logitech C920 Camera	\$75.00
HDMI Cable	\$7.00
USB Cable	\$7.00
5VDC 2.5A Power Supply	\$10.00
BeagleBone Enclosure	\$20.00
Demonstration Bench Materials	\$50.00
Total Estimated Project Cost	\$214.00

Table 2: Budget

The estimated cost of the project is \$214, which is well below the budget cap, and will allow for possible expansion in both materials and hardware capabilities if need be.

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