Team: Kingpin

Project: Pin Deck Camera System

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1. Product Concept

The product concept describes the purpose, use, and intended user audience for the Pin Deck Camera System. The Pin Deck Camera System is a product that tracks the movement of a bowling ball as it traverses the area of a bowling lane where the pins are placed, known as the pin deck. Users of the Pin Deck Camera System will be able to view data gathered by the system from video footage captured as the ball moves through the high-speed camera's field of view.

1.1 Purpose and Use

The system will be activated through a user interface on a personal computer prior to the delivery of the ball down the lane. Once the system detects the ball entering the cameras field of view (FOV), it will begin to process the images received from the camera. From the captured images the system will calculate four individual pieces of information. The system will determine the entry angle of the ball when the first pin is struck and the exit angle when the ball leaves the pin deck. In addition to this, the system will determine the lane board number the ball is sitting on during contact of the first pin and just before exiting the pin deck. Finally the system must determine the average velocity and path of the ball and pins as the ball moves through the pin deck. The system will create a comma separated value file of the resulting data, which can then be analyzed by the user at a later time.

1.2 Intended Audience

The intended audience of the Pin Deck Camera System is the employees of the United States Bowling Congress (USBC). The resulting data provided by the system will be used by USBC engineers to study the effects of changing conditions on how the bowling ball moves through the bowling pins on the pin deck. To the best of Team Kingpins knowledge, this product will not be made available commercially to individuals or organizations.
Figure 1-1 provides a graphical overview of the main system components.
2. Product Description and Functional Overview

This section provides the reader with an overview of the Pin Deck Tracking System (PDTS). The primary operational aspects of the product, from the perspective of end users, maintainers and administrators, are defined here. The key features and functions found in the product, as well as critical user interactions and user interfaces are described in detail. These features are derived from specifications directly from our sponsor (USBC).

2.1 Features and Functions

The system shall be composed of a high-speed video camera that will be placed to observe the pin deck, and a lighting fixture to light the pin deck. The camera will be placed in such way that will be able to capture the video of the ball entering the pin deck to the ball exiting the pin deck. From the captured video, the system shall be able to calculate the speed, entry and exit angle, and entry and exit board. The system shall identify the entry and exit angle by using image processing techniques. The camera will be placed at the center of the bowling lane, which will provide a view similar to the point of view of the bowler. The camera will be connected, via Ethernet, to a PCI express card on the computer. The system shall only track the ball from the point the ball enters the FOV until the frame before the ball falls off the back of the pin deck.

Figure 2-1 Pin Deck Tracking Concept
2.2 External Inputs and Outputs

The functionality of the system is defined by a few key inputs and outputs. There will be several options for the user to select that will enable certain features, such as whether or not to save the video of the trial to the hard drive. The user will also control the system by inputting when the system should start to capture video and when the system should stop capturing video. Video capture is not to be confused with the start of video analysis which will occur after the ball enters the field of view. After inputting the options and starting the system, the user will wait while the images are captured and processed. After processing the images, the system will output five important data points. These include entry and exit board, entry and exit angle, and the speed of the ball. This data along with the additional data that the user has selected will be output from the system.

Table 2-1 System Inputs and Outputs

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Use</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Input:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start Capture</td>
<td>Starts the camera and begins capturing video.</td>
<td>The user will use this input when they are ready to be capturing video.</td>
</tr>
<tr>
<td>Calibrate</td>
<td>Calibrates the camera in order to provide the best possible estimates.</td>
<td>The user will use this input when they wish to calibrate the camera, such as when the camera is moved.</td>
</tr>
<tr>
<td>Filename</td>
<td>Sets the name of the output file.</td>
<td>The user will use this input when they decide which directory to output the data from the run.</td>
</tr>
<tr>
<td>Export Video File</td>
<td>This is a Boolean value describing whether the video for the run should be output to a file.</td>
<td>The user will set this input if they desire to output the video for the run to a file.</td>
</tr>
<tr>
<td>Export CSV File</td>
<td>This is a Boolean value describing whether the data for the run should be output to a file.</td>
<td>The user will set this input if they desire to output the data for the run to a file.</td>
</tr>
<tr>
<td>Video from Camera</td>
<td>Slow motion video of the ball hitting the pins will be input and then analyzed.</td>
<td>The video of the ball will be input to be analyzed so the data of the run can be printed or written to a file.</td>
</tr>
<tr>
<td><strong>Output:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Entry Angle</td>
<td>The entry angle will be the angle at which the ball hits the pins measured positive to the right of the center board and negative to the left.</td>
<td>The entry angle will be displayed to the user or written to a file.</td>
</tr>
</tbody>
</table>
2.3 Product Interfaces

Our product interface will be designed so the customer can control the important parts of the capturing process. For example, the user interface will have buttons that enable the user to specify when to start and stop the collection of video. Also, the interface will allow the user to specify the names of output files. Finally, the user interface will show important data from each run that can also be output to a comma separated value (CSV) file. While our product is not intended for the commercial use, the user interface design provided by our software is based purely on ease of use and functionality.

### 2.3.1 Interface Overview

The basic user interface will consist of a window with labeled buttons containing basic keywords intended to provide a quick understanding of the process accomplished by clicking the button.

<table>
<thead>
<tr>
<th>Feature</th>
<th>Description</th>
<th>Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exit Angle</td>
<td>The exit angle will be the angle at which the ball leaves the back of the pin deck.</td>
<td>The exit angle will be displayed to the user or written to a file.</td>
</tr>
<tr>
<td>Entry Board</td>
<td>The entry board will be the board which the ball is currently on when it first touches a pin.</td>
<td>The entry board will be displayed to the user or written to a file.</td>
</tr>
<tr>
<td>Exit Board</td>
<td>The exit board will be the board that the ball last touches before it leaves the back of the pin deck.</td>
<td>The exit board will be displayed to the user or written to a file.</td>
</tr>
<tr>
<td>Ball Speed</td>
<td>The ball speed across the pin deck will be measured.</td>
<td>The ball speed will be displayed to the user or written to a file.</td>
</tr>
<tr>
<td>Ball Path</td>
<td>The path of the ball from the point of entry to the point of exit will be tracked.</td>
<td>The ball path will be displayed to the user or written to a file.</td>
</tr>
<tr>
<td>Pin Movement</td>
<td>The paths of each of the pins will be measured after the ball hits the pins.</td>
<td>The pin movement for each pin will be displayed to the user or written to a file.</td>
</tr>
<tr>
<td>Calibration Notification</td>
<td>After the system has finished calibrating, the system will output a notification of the calibrations success or failure.</td>
<td>The user will be notified of the calibrations success or failure.</td>
</tr>
<tr>
<td>Progress Notification</td>
<td>During a capture or a saving event the current status will be output to the user.</td>
<td>This will display the progress of the current operation</td>
</tr>
<tr>
<td>Saved Video</td>
<td>Video of the ball as it moves through the pins.</td>
<td>If the saved video option is selected, the video will be saved to the disk and stored in a file.</td>
</tr>
</tbody>
</table>
The left side of the interface will be initial conditions, ball options, save options and a “Start Capture” key. On the right side of the interface will be the results of the capture after the image analysis is completed and the option to save the analyzed results.

Figure 2-2 Main Window Mockup

2.3.2 Button Behavior

2.3.2.1 “Start Capture”

Begins the capture process of initializing the high speed camera and recording the images to then be analyzed and displayed on the results window.

2.3.2.2 “End Capture”

 Stops the system capture process. Until this button is pressed, high speed video will continue to be recorded before analyzing the captured video.

2.3.2.3 “Calibrate”

Allows the camera to calibrate to markers on the pin deck, properly focus and perform any maintenance or automated cycles (including necessary power cycles of the equipment). Any technical errors will be displayed along with a “Calibration Failed” error.
2.3.2.4 “Recording Options”

*Filename* – Allows user to type a filename to save video and CSV files.

*Export Video File* – Check box to save the recorded video file when exported/saved.

*Export data as CSV* – Check box to save the recorded data file as a comma separated value.

2.3.2.5 “Save/Export”

Saves the selected files.
3. Customer Requirements

This section covers the requirements as specified by the sponsor (Emily Troutman, USBC). Each of the following requirements includes a priority level that represents the priority of the requirement. For example, requirements with a priority level of “1” need to be implemented in order for the project to be considered a success. The requirements as defined here are not to be altered unless it is first agreed upon by the whole group and the sponsor.

3.1 Entry Board

3.1.1 Description: The system shall provide the board number the ball is on just before the ball strikes the first pin.

3.1.2 Source: Emily Troutman (USBC Sponsor)

3.1.3 Constraints: Board measurement increments are restricted to half the width of a single board.

3.1.4 Standards: United States Customary Units of Measurement

3.1.5 Priority: 1 – Critical

3.2 Exit Board

3.2.1 Description: The system shall provide the board number the ball is on just before leaving the pin deck.

3.2.2 Source: Emily Troutman (USBC Sponsor)

3.2.3 Constraints: Board measurement increments are restricted to half the width of a single board.

3.2.4 Standards: United States Customary Units of Measurement.

3.2.5 Priority: 1 – Critical

3.3 Entry Angle
3.3.1 **Description:** The system shall provide the entry angle of the ball just before the ball strikes the first pin. Accuracy of angle must be within + - 1.0 degree.

3.3.2 **Source:** Emily Troutman (USBC Sponsor)

3.3.3 **Constraints:** Ball must hit one of the front seven pins.

3.3.4 **Standards:** United States Customary Units of Measurement

3.3.5 **Priority:** 1 - Critical

### Exit Angle

3.4.1 **Description:** The system shall provide the exit angle of the ball just before the ball falls off the pin deck. Accuracy of angle must be within + - 1.0 degree.

3.4.2 **Source:** Emily Troutman (USBC Sponsor)

3.4.3 **Constraints:** Ball must leave the pin deck on one of the numbered boards.

3.4.4 **Standards:** United States Customary Units of Measurement

3.4.5 **Priority:** 1 - Critical

### Ball Speed

3.5.1 **Description:** The system shall output the speed of the bowling ball at a given position on the pin deck. Accuracy of speed must be within 0.01 mph.

3.5.2 **Source:** Emily Troutman (USBC Sponsor)

3.5.3 **Constraints:** Measurement shall be accurate to within 0.01 mph.

3.5.4 **Standards:** The system shall use United States customary units of measurement.

3.5.5 **Priority:** 2 – High

### Ball Path

3.6.1 **Description:** The system shall output the position of the ball for every frame the ball is located on the pin deck. Accuracy of position must be within ¼ of an inch.

3.6.2 **Source:** Emily Troutman (USBC Sponsor)

3.6.3 **Constraints:** Measurement shall be accurate to within ¼ of an inch.

3.6.4 **Standards:** The system shall use United States customary units of measurement.
3.6.5 Priority: 2 – High

3.7 Pin Movement

3.7.1 Description: The system shall track the position of each pin while the ball is still on the pin deck represented by a pair of (x,y,z) coordinates.

3.7.2 Source: Emily Troutman (USBC Sponsor)

3.7.3 Constraints: Second camera will be necessary to determine pin position.

3.7.4 Standards: United States Customary Units of Measurement

3.7.5 Priority: 5 - Future

3.8 Camera Calibration

3.8.1 Description: The system shall have the ability to calibrate the camera.

3.8.2 Source: Emily Troutman (USBC Sponsor)

3.8.3 Constraints: None

3.8.4 Standards: United States Customary Units of Measurement

3.8.5 Priority: 1 - Critical

3.9 Data Output

3.9.1 Description: The system shall provide data output in a comma separated value file.

3.9.2 Source: Emily Troutman (USBC Sponsor)

3.9.3 Constraints: Image processing needs to be functional in order to provide numerical data items.

3.9.4 Standards: United States Customary Units of Measurement

3.9.5 Priority: 1 - Critical
4. Packaging Requirements

Due to the digital nature of the deliverable product, the software will not be packaged and simply delivered to the customer. The hardware used in this project is already on site and will not be in possession of team Kingpin, therefore it will be assembled on site as discussed below. Described below is the process to how the product will be delivered.

4.1 System Hardware Assembly

4.1.1 Description: The system’s hardware shall be assembled at the site of the sponsor.

4.1.2 Source: Emily Troutman (USBC Sponsor)

4.1.3 Constraints: Development of the product will partly need to be done away from USBC’s facilities.

4.1.4 Standards: None

4.1.5 Priority: 1 - Critical

4.2 Software Delivery

4.2.1 Description: The system software shall be delivered to our USBC sponsor on a USB memory stick.

4.2.2 Source: Team Kingpin

4.2.3 Constraints: Size of software must be within a reasonable range.

4.2.4 Standards: None

4.2.5 Priority: 1 - Critical

4.3 Software Installation

4.3.1 Description: The system software shall be delivered such that the customer can install it by themselves on a machine at their facility.

4.3.2 Source: Team Kingpin
4.3.3 **Constraints:** The machine on which the software is being installed must have enough resources (disk space) to install the software.

4.3.4 **Standards:** None

4.3.5 **Priority:** 1 – Critical

4.4 **User Manual**

4.4.1 **Description:** Along with the software, a PDF document containing the user manual shall be provided on the delivered USB device.

4.4.2 **Source:** Team Kingpin

4.4.3 **Constraints:** None.

4.4.4 **Standards:** None

4.4.5 **Priority:** 2 - High
5. Performance Requirements

This section covers the performance requirements for the system. The system will be held to certain performance requirements described here. The system calibration and processing times will be held to a certain constraint defined here.

5.1 Calibration Performance

5.1.1 Description: The system’s calibration module shall complete in an acceptable time frame.

5.1.2 Source: Team Kingpin

5.1.3 Constraints: None

5.1.4 Standards: None

5.1.5 Priority: 2 - High

5.2 Data Analysis Performance

5.2.1 Description: The systems data analysis module shall process images in an acceptable time frame.

5.2.2 Source: Team Kingpin

5.2.3 Constraints: None

5.2.4 Standards: None

5.2.5 Priority: 2 - High
6. Safety Requirements

This section covers the safety requirements of the deck tracking system. The safety of the user and all the equipment used in gathering data will be considered. The safety of both the expensive equipment and of the user will be ensured as the system will be operating around many quickly moving projectiles.

6.1 Camera Mounting

6.1.1 Description: The camera shall be mounted away from moving machine parts and in such a way that no harm or damage is caused to the camera by surrounding machinery, pin movement or ball movement.

6.1.2 Source: Team Kingpin

6.1.3 Constraints: Camera must have an unobstructed view of the pin deck.

6.1.4 Standards: None

6.1.5 Priority: 1 – Critical

6.2 Lighting Mounting

6.2.1 Description: Lighting shall be mounted so that it will not obstruct the functionality of any other device or machinery in the pin deck area creating opportunity for hardware damage.

6.2.2 Source: Team Kingpin

6.2.3 Constraints: Lighting must be provided for the camera in such a way that shadows and/or overexposed areas do not obstruct the view of the pin deck from the camera.

6.2.4 Standards: None

6.2.5 Priority: 1 – Critical

6.3 Cabling / wiring

6.3.1 Description: Cables and wires must be laid in a way to prevent the obstruction of the bowling lane, pin deck and any area trafficked by the user.

6.3.2 Source: Emily Troutman (USBC Sponsor)

6.3.3 Constraints: None.
6.3.4 Standards: Ethernet cable shall meet Ethernet Version 2 and IEEE 802.3 Physical Characteristics.

6.3.5 Priority: 1 – Critical

6.4 User Safety

6.4.1 Description: The system shall be built in a way to prevent the need of the user to interact with the system during the capture and analysis process to prevent harm to the user from moving machinery.

6.4.2 Source: Team Kingpin

6.4.3 Constraints: User interaction with the hardware may be necessary in some extreme cases.

6.4.4 Standards: None.

6.4.5 Priority: 4 - Low
7. Maintenance and Support Requirements

This section outlines the requirements for maintenance and support of the Pin Deck Camera System. All support is in the form of documentation that will assist in further development, maintenance or troubleshooting of problems.

7.1 Source Code

7.1.1 Description: Team Kingpin’s source code shall be well documented with comments and details to allow future teams to modify functionality, troubleshooting procedures, maintenance procedures, or upgrade the system.

7.1.2 Source: Team Kingpin

7.1.3 Constraints: None

7.1.4 Standards: Comments shall be written in American English.

7.1.5 Priority: 1 – Critical

7.2 Troubleshooting Instructions

7.2.1 Description: Team Kingpin shall provide documentation to assist in troubleshooting activities in the event that the system does not operate properly.

7.2.2 Source: Team Kingpin

7.2.3 Constraints: None

7.2.4 Standards: American English

7.2.5 Priority: 2 - High

7.3 System Maintenance

7.3.1 Description: Team Kingpin shall not provide maintenance to the system or source code after delivery of the system to the customer.

7.3.2 Source: Team Kingpin
7.3.3 Constraints: None
7.3.4 Standards: None
7.3.5 Priority: 1 – Critical

7.4 User Manual

7.4.1 Description: Team Kingpin shall provide a user manual which describes how the user should interact with the system’s interface as well as how to perform common operations with the software.

7.4.2 Source: Team Kingpin

7.4.3 Constraints: None

7.4.4 Standards: None

7.4.5 Priority: 1 – Critical

7.5 Training

7.5.1 Description: USBC personal shall be trained to use the Pin Deck Tracking System. They shall be trained to setup the system, interface with camera, exporting the data, and troubleshoot the system.

7.5.2 Source: Team Kingpin

7.5.3 Constraints: None

7.5.4 Standards: None

7.5.5 Priority: 1 – Critical
8. Other Requirements

This section specifies extra requirements for the deck tracking system that do not fit in the sections above. As our project will build on a part of a previous project, it will be important for us to maintain modularity of code as a future project might build on our work. The machine on which our software will be running, at USBC’s campus, is a Windows system. Therefore, our code must support running on the Windows operating system.

8.1 Windows OS Support

8.1.1 **Description:** The software Team Kingpin develops for the sponsor must be compatible with the Windows OS.

8.1.2 **Source:** Emily Troutman (USBC Sponsor)

8.1.3 **Constraints:** Some image processing libraries might not be compatible with Windows.

8.1.4 **Standards:** None

8.1.5 **Priority:** 1 - Critical

8.2 Code Modularity

8.2.1 **Description:** The code developed by Team Kingpin shall be modular in nature in order to support the extension of our code in possible future projects.

8.2.2 **Source:** Team Kingpin

8.2.3 **Constraints:** The amount of time to develop the product is short.

8.2.4 **Standards:** None

8.2.5 **Priority:** 3 - Medium

8.3 Team Galaxy Interface Integration

8.3.1 **Description:** Team Kingpin shall integrate the system’s graphical user interface with Team Galaxy’s graphical user interface.
8.3.2 **Source:** Emily Troutman (USBC Sponsor)

8.3.3 **Constraints:** Contingent on the completion of Team Galaxy’s GUI.

8.3.4 **Standards:** None

8.3.5 **Priority:** 5 - Future

---

**8.4 Light Placement**

8.4.1 **Description:** Lighting shall be mounted in such a way as to limit the amount of shadows on the pin deck while the system is running.

8.4.2 **Source:** Emily Troutman (USBC Sponsor)

8.4.3 **Constraints:** Must adhere to previously stated safety requirements

8.4.4 **Standards:** None

8.4.5 **Priority:** 2 – High

---

**8.5 Camera Placement**

8.5.1 **Description:** Camera shall be placed in such a way as to provide a clear view of the pin deck and the contents contained therein with minimal to no obstructions.

8.5.2 **Source:** Emily Troutman (USBC Sponsor)

8.5.3 **Constraints:** Must adhere to previously stated safety requirements

8.5.4 **Standards:** None

8.5.5 **Priority:** 2 – High

---

**8.6 Cabling Requirements**

8.6.1 **Description:** Standard category 5 cable shall be used to connect the Camera and computer via a PCI express card

8.6.2 **Source:** Emily Troutman (USBC)

8.6.3 **Constraints:** Must adhere to previously stated safety requirements
8.6.4 Standards: Category 5 data cable must be used

8.6.5 Priority: 2 – High

8.7 Leftover Pins

8.7.1 Description: The system shall output the pins that are left after the ball has cleared the pin deck.

8.7.2 Source: Emily Troutman (USBC)

8.7.3 Constraints: Pins are not uniquely identifiable except for their position

8.7.4 Standards: None.

8.7.5 Priority: 4 – Low
9. Acceptance Criteria

Our acceptance criteria is based on our customer requirements. The final product will be a simple graphical user interface that can calibrate the hardware, begin a recording or capture process of a bowling ball moving through the pin deck and allow the user to save any data collected by the system. The system shall provide the entry angle and board and the exit angle and board once analysis has been performed on the recorded video. The user must then be able to save the data from the analysis into a CSV file that can be opened in a spreadsheet editor. Only critical requirements provided by the project sponsor will be used as acceptance criteria which are listed below.

9.1 Provide Entry Board

9.1.1 **System will provide the entry board:** Requirement 3.1 Entry Board: the system must provide the board number the ball was on just before making contact with the first pin the ball hits.

9.1.2 **Verification Procedure:** The customer will see the “Entry Board” result box populate with the determined board number. The determined board number will then be verified by manually extracting the board from the video and comparing the two results.

9.2 Provide Exit Board

9.2.1 **System will provide the exit angle:** Requirement 3.2 Exit Board: the system must provide the board number the ball was on just before the ball falls off the back end of the pin deck.

9.2.1 **Verification Procedure:** The customer will see the “Exit Board” result box populate with the determined board number. The determined board number will then be verified by manually extracting the board from the video and comparing the two results.

9.3 Provide Entry Angle

9.3.1 **System will provide the entry angle:** Requirement 3.3 Entry Angle: the system must provide the angle from the center of the lane that the ball was traveling just before contact with one of the front seven pins.

9.3.2 **Verification Procedure:** The customer will see the “Entry Angle” result box populate with the determined angle. The determined entry angle will then be verified by manually extracting the entry angle from the video and comparing the two results.
9.4 Provide Exit Angle

9.4.1 System will provide the exit angle: Requirement 3.4 Exit Angle: the system must provide the angle from the center of the lane that the ball was traveling just before falling off the back end of the pin deck.

9.4.2 Verification Procedure: The customer will see the “Exit Angle” result box populate with the determined angle. The determined exit angle will then be verified by manually extracting the board from the video and comparing the two results.

9.5 Data Output

9.5.1 System will produce a comma separated value file: The CSV file will contain the data results of the high speed video analysis that can then be analyzed further by the customer.

9.5.2 Verification Procedure: File will be imported into Microsoft excel to verify the correct data has been written to the file.

9.6 Camera Calibration

9.6.1 System shall have the ability to calibrate the camera: An option will be provided in the user interface that will calibrate the camera to facilitate accurate estimations of position, speed, and ball path.

9.6.2 Verification Procedure: The calculated measurements from the markers on the pin deck will be compared to the actual measurements of the pin deck to ensure accuracy.
10. Use Cases

The use case section describes how the intended user interacts with the system. There are two sets of related use cases for the Pin Deck Camera System. The video capture set is how the user interacts with the video capturing system, which also initiates the image processing and required calculations. The user can start and stop the video capture and save a current video to the hard drive. The data file set is how the user interacts with the resulting data files. The user can create, save and open data files that are a result of data obtained from the image processing.

10.1 Start Video Capture

10.1.1 Scenario: The USBC employee uses the system to start the video capture.

10.1.2 Actor(s): USBC user

10.1.3 TUCBW: The user clicks the start video capture button.

10.1.4 TUCEW: The system displays a message that the video is being captured.

10.2 End Video Capture

10.2.1 Scenario: The USBC employee uses the system to stop the video capture.

10.2.2 Actor(s): USBC user

10.2.3 TUCBW: The user clicks the stop video capture button.

10.2.4 TUCEW: The system displays a message that the video has been captured.

10.3 Save Video

10.3.1 Scenario: The USBC employee uses the system to save the video to the hard drive.

10.3.2 Actor(s): USBC user

10.3.3 TUCBW: The user clicks the save video button.

10.3.4 TUCEW: The system displays a message that the video has been saved.
10.4 Save Data File

10.4.1 Scenario: The USBC employee uses the system to save a data file.

10.4.2 Actor(s): USBC user

10.4.3 TUCBW: The user clicks the save data file button.

10.4.4 TUCEW: The system displays a message that the data file has been saved.

10.5 Open Data File

10.5.1 Scenario: The USBC employee uses the system to open a data file.

10.5.2 Actor(s): USBC user

10.5.3 TUCBW: The user clicks the open data file button.

10.5.4 TUCEW: The system displays a message that the data file has been opened.
Pin Deck Camera System

Data File

Save File

Open File

User
11. Feasibility Assessment

In this section, we will attempt to define the feasibility of completing the product we have defined in this document. We will use the following six areas to determine the probability of successfully completing this project on time: scope analysis, research completed/remaining; technical analysis; cost analysis, resource analysis; and schedule analysis. In the scope analysis, we will determine if the scope of our project is feasible given the amount of time allotted to complete the project. We will analyze the technical aspects of our project in the research and technical analysis sections. Finally, we will determine if the project can be completed on time by analyzing resources and schedule.

11.1 Scope Analysis

The scope of work for all critical requirements is reasonable, and prototyping of these by the deadline date appears feasible. This assessment is based on our research, discussions with our sponsor, technical skills that our team members are confident of, and analysis of previous CSE Senior Design project that incorporated similar components and concepts as ours. We expect that two requirements will comprise the bulk of the work scope. The bulk of the work will come from research and using image processing to fulfill our five most important requirements. Our five biggest requirements are as follows:

Customer Requirement 3.1 – The system shall provide the board number the ball is on just before the ball strikes the first pin.

Customer Requirement 3.2 – The system shall provide the board number the ball is on just after the ball leaves the pin deck.

Customer Requirement 3.3 – The system shall provide the entry angle of the ball just before the ball strikes the first pin.

Customer Requirement 3.4 – The system shall provide the exit angle of the ball just after the ball leaves the pin deck.

Customer Requirement 3.5 – The system shall output the speed of the bowling ball at a given position on the bowling lane.

Based on research done for high speed camera interface, camera SDK, image processing, team’s skills in both hardware and software, it has been determined that the bulk of the project is very feasible. Since the critical and high level requirements make up over 90% of the overall requirements for the product, it
has been decided that the overall project can be completed as specified. Using schedule analysis it can be determined that the project shall be completed in timely fashion.

The requirements that are classified as future requirements are beyond the scope of this project are not considered in this section.

### 11.2 Research

Our team is in a unique position as far as research is concerned. There is a project closely related to ours (Team Galaxy) which is being developed as we are beginning documentation on ours. Therefore, our first research duty was to speak with their team and have them explain their project and provide us any advice that they saw fit. They provided some key information about the sponsor, the machines with which we might work, and how they are interfacing with the cameras that they were provided by the sponsor.

There is a large amount of technical research that our team needs to do in order to possess the skills necessary to implement this project. We need to begin researching image processing. Currently, our team, as a whole, has very little knowledge on image processing. Our plan is to get advice from professors and to find books to gather knowledge on the subject. We have discussed image processing with one professor at this point, who suggested that we begin by researching OpenCV. Therefore, researching this library will be a top priority moving forward.

Another technical area our group must research is interfacing with the Phantom Miro eX2, which is the slow motion camera provided to us by our sponsor. We have received the SDK from the camera manufacturer. At this point, it is necessary for our group to begin researching the SDK and how to use it. We will need to find out what languages the SDK supports. Additionally, we will need to learn how to use the API provided by the SDK. However if it is not powerful enough for our needs, we will need to research how to write our own code to interface with the camera. However, the probability of this happening is very low.

### 11.3 Technical Analysis

This project includes the use of a high speed camera and the analysis of the images and video captured by it. Our team has a small amount of experience with computer vision which will be necessary in the analysis of the captured videos and images. In using the camera, we will need to find various documentation for the specific hardware involved (i.e. SDK and API documentation). Our knowledge on the specifics of bowling such as terminology will be supplemented by the USBC representatives. Our team is well versed in the coding languages required to complete this project and there will be few to no coding language issues within the project timeline. We have many tools available to us to provide communication and organization within our team as well as development environments such as Visual Studio and Eclipse to aid us in writing the code required for the project.
We feel that if we are to run into any problem requiring the attainment of new knowledge, we will be able to sit down as a group and/or individuals to quickly and efficiently resolve the problem with research and hands on experience. On a technical level we feel very confident we will accomplish our goals within this project.

### 11.4 Cost Analysis

The United States Bowling Congress shall cover the cost of the cameras, cable, PCI express card, Terminal Computer. Our sponsor is ready to buy all the parts, camera system, and terminal computer as per the project requirement. The sponsor has made sure that we will get all parts as our specification. Based on initial cost analysis budget should not be the problem for this project. Tables 11-1 and 11-2 show the projected costs for high-speed camera system.

Table 11-1: Phantom Miro eX2 Cost

<table>
<thead>
<tr>
<th>Camera</th>
<th>Quantity</th>
<th>Single Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phantom Miro eX2</td>
<td>1</td>
<td>$2,300</td>
<td>$2,300</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>2,300</strong></td>
</tr>
</tbody>
</table>

Table 11-2: Projected Costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Quantity</th>
<th>Single Cost</th>
<th>Total Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>CAT5 Cable 500ft</td>
<td>1</td>
<td>$43</td>
<td>$43</td>
</tr>
<tr>
<td>Pack 100 RJ45 Plugs</td>
<td>1</td>
<td>$4</td>
<td>$4</td>
</tr>
<tr>
<td>GigE Card PCIe AdLink GIE64+</td>
<td>1</td>
<td>$320</td>
<td>$320</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$367</strong></td>
</tr>
</tbody>
</table>

### 11.5 Resource Analysis

Team Kingpin is made up of two Computer Engineering students, one Computer Science student, and one Software engineering student. Therefore, we seem to have a good balance of knowledge in most areas. We possess a diverse array of technical skills as a team. For instance, every member of our group feels comfortable working with C, or C++. Although our group is comfortable with more than the two aforementioned languages, we feel that knowledge of these two languages will be most useful in implementing the project. One final technical skill our team possesses is the dealing with hardware because we have two Computer Engineering students who took Embedded Systems I and II. In addition, three out of four group members have taken the Robotics course at UTA.

In addition to the technical skills above, each team member has a specific set of skills that will help the project get finished correctly and in a timely manner. There are persons within our group who possess the management and planning skills that will help the project stay on track. Others have industry
experience that will help us avoid common pitfalls that occur in practice. Together the group has the ability to work diligently to get work finished on time.

One major area of concern is that our team is clearly not yet skilled enough in image processing to be able to successfully complete this project. A few of the group members have a small amount of experience in image processing from taking the Robotics course. However, this minute amount of knowledge will not nearly be enough. As noted in the sections above, we will need to research this topic.

We all feel strongly that, despite our lack of knowledge in the topics noted above, we have the abilities to learn new languages and concepts quickly. Therefore, we believe that our group will be able to do the necessary research in order to develop the skills required to implement the project.

11.6 Schedule Analysis

In this section, three methods were used to estimate the duration of the project schedule. The first method used is COCOMO II followed by Function Point Analysis and finally a Ballpark estimate. The best possible schedules from all three are summarized in Table 11-13 at the end of the section.

11.6.1 COCOMO II Software Cost Estimation

In order to derive a scheduling estimate in COCOMO II it is necessary to estimate the source lines of code needed to complete a project. In Table 11-3, lines of code are given for each major module that will be used in the project. High and low counts are given for each module in order to provide a range for the schedule.

Table 11-3 SLOC Rough Estimation

<table>
<thead>
<tr>
<th>Module</th>
<th>SLOC Low</th>
<th>SLOC High</th>
</tr>
</thead>
<tbody>
<tr>
<td>GUI &amp; GUI Integration</td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>Image Input</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>Image Processing</td>
<td>2500</td>
<td>5000</td>
</tr>
<tr>
<td>Camera Calibration</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td>Output Calculations</td>
<td>1000</td>
<td>2000</td>
</tr>
<tr>
<td><strong>Total SLOC</strong></td>
<td><strong>6000</strong></td>
<td><strong>12000</strong></td>
</tr>
</tbody>
</table>

There are five scale drivers used in calculating the schedule estimation. The rating values given in table 11-4 are arrived at from averaging the results from related features in COCOMO 81, as well as from the Costar™ estimation software. Three of the five scale drivers are set to nominal while two are set to low to accurately reflect the lack of process maturity and the Precededness, or the lack of experience with image processing, of Team Kingpin.
Table 11-4 Scale Driver Ratings for Team Kingpin

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Scale Factor</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>PREC</td>
<td>Precededness</td>
<td>Low</td>
</tr>
<tr>
<td>FLEX</td>
<td>Development Flexibility</td>
<td>Nominal</td>
</tr>
<tr>
<td>RESL</td>
<td>Architecture/Risk Resolution</td>
<td>Nominal</td>
</tr>
<tr>
<td>TEAM</td>
<td>Team Cohesion</td>
<td>Nominal</td>
</tr>
<tr>
<td>PMAT</td>
<td>Process Maturity</td>
<td>Low</td>
</tr>
</tbody>
</table>

Similar to the scale drivers explained above, there are seventeen cost drivers that rate a variety of factors that are characteristics of personnel, product, platform, and project. The rating values found in table 11-5 were determined from definitions provided on the COCOMO website as well as from the Costar™ estimation software. The rating values are believed to be accurate for Team Kingpin and the Pin Deck Tracking System project.

Table 11-5 Cost Driver Ratings for Team Kingpin and Pin Deck Tracking System

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Cost Driver</th>
<th>Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Personnel Factors</strong></td>
<td></td>
</tr>
<tr>
<td>ACAP</td>
<td>Analyst Capability</td>
<td>Nominal</td>
</tr>
<tr>
<td>APEX</td>
<td>Applications Experience</td>
<td>Very Low</td>
</tr>
<tr>
<td>PCAP</td>
<td>Programmer Capability</td>
<td>Nominal</td>
</tr>
<tr>
<td>PCON</td>
<td>Personnel Continuity</td>
<td>Very High</td>
</tr>
<tr>
<td>PLEX</td>
<td>Platform Experience</td>
<td>High</td>
</tr>
<tr>
<td>LTEX</td>
<td>Language and Tool Experience</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td><strong>Product Factors</strong></td>
<td></td>
</tr>
<tr>
<td>RELY</td>
<td>Required Software Reliability</td>
<td>Low</td>
</tr>
<tr>
<td>DATA</td>
<td>Database Size</td>
<td>Low</td>
</tr>
<tr>
<td>CPLX</td>
<td>Software Product Complexity</td>
<td>High</td>
</tr>
<tr>
<td>RUSE</td>
<td>Required Reusability</td>
<td>Low</td>
</tr>
<tr>
<td>DOCU</td>
<td>Documentation Match to Life-Cycle Needs</td>
<td>Nominal</td>
</tr>
<tr>
<td></td>
<td><strong>Platform Factors</strong></td>
<td></td>
</tr>
<tr>
<td>TIME</td>
<td>Execution Time Constraint</td>
<td>Nominal</td>
</tr>
<tr>
<td>STOR</td>
<td>Main Storage Constraint</td>
<td>Nominal</td>
</tr>
<tr>
<td>PVOL</td>
<td>Platform Volatility</td>
<td>Low</td>
</tr>
<tr>
<td></td>
<td><strong>Project Factors</strong></td>
<td></td>
</tr>
<tr>
<td>TOOL</td>
<td>Use of Software Tools</td>
<td>Nominal</td>
</tr>
<tr>
<td>SCED</td>
<td>Required Development Schedule</td>
<td>Very Low</td>
</tr>
<tr>
<td>SITE</td>
<td>Multisite Development</td>
<td>High</td>
</tr>
</tbody>
</table>
The equations in table 11-6 are used to estimate the effort, schedule and staffing in COCOMO II. The equations use four variables, listed in table 11-6, to determine the estimations. KSLOC is the thousands of lines of code estimated for the project. EAF is an effort adjustment factor value derived from the cost drivers. E and SE are values derived from the scale drivers. All values with the exception of KSLOC were calculated using the Costar™ estimation software. Since the person month in COCOMO is defined as 152 hours, which is considered full time, it is necessary to adjust the resulting effort value to compensate for the part-time nature of the project. This is accomplished by multiplying the calculated full-time effort by the ratio of full-time to part-time hours per person-month. The part-time hours per person month is assumed to be 80, dividing the full-time hours of 152 by this value results in a ratio of 1.9.

Table 11-6 Estimation Equations

<table>
<thead>
<tr>
<th></th>
<th>Equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort</td>
<td>$(2.94 \times \text{EAF} \times (\text{KSLOC})^E) \times 1.9$</td>
</tr>
<tr>
<td>Duration</td>
<td>$3.67 \times \text{(Effort)}^{SE}$</td>
</tr>
<tr>
<td>Staffing</td>
<td>$\text{Effort}/\text{Duration}$</td>
</tr>
</tbody>
</table>

Table 11-7 Effort and Schedule Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSLOC</td>
<td>6 - 12</td>
</tr>
<tr>
<td>EAF</td>
<td>0.6094</td>
</tr>
<tr>
<td>E</td>
<td>1.1277</td>
</tr>
<tr>
<td>SE</td>
<td>0.3235</td>
</tr>
</tbody>
</table>

The following tables, 11-8 and 11-9, use the equations and variables described above to calculate the effort, duration, and staffing for the Pin Deck Tracking System project. Table 11-8 shows the low and high estimates for the nominal schedule in COCOMO II. Both estimated durations for the nominal schedule require more time than what is available to complete the project. In addition, the nominal schedule estimates do not utilize all of the resources available for the project. Given these two shortfalls in the nominal schedule estimate, it was necessary to use schedule compression in COCOMO II. As shown in table 11-9, an additional multiplier of 1.43 is used in the effort equation. The nominal schedule duration is then compressed by 75% and the staffing is calculated from the two new values. This brings the schedule estimation much closer to what is required for this project. However, the average SLOC is still too large to complete the project in the time allowed making it necessary to keep this number as low as possible. In order to do so, it will be necessary to designate a number of the customer requirements that are of a low priority as future items in order to complete the project on schedule.
Table 11-8 Nominal Schedule Calculations

<table>
<thead>
<tr>
<th>Calculation</th>
<th>Low Estimate</th>
<th>High Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort =</td>
<td>(2.94 * 0.6094 * 6^1.1277) * 1.9</td>
<td>(2.94 * 0.6094 * 12^1.1277) * 1.9</td>
</tr>
<tr>
<td></td>
<td><strong>19.76 Person-Months</strong></td>
<td><strong>41.35 Person-Months</strong></td>
</tr>
<tr>
<td>Duration =</td>
<td>3.67 * (19.76)^0.3235</td>
<td>3.67 * (41.35)^0.3235</td>
</tr>
<tr>
<td></td>
<td><strong>9.29 Months</strong></td>
<td><strong>11.68 Months</strong></td>
</tr>
<tr>
<td>Average Staffing =</td>
<td>19.76/9.29</td>
<td>41.35/11.68</td>
</tr>
<tr>
<td></td>
<td><strong>2.13 People</strong></td>
<td><strong>3.54 People</strong></td>
</tr>
</tbody>
</table>

Table 11-9 Accelerated Schedule Calculations

<table>
<thead>
<tr>
<th>Equation</th>
<th>Low Estimate</th>
<th>High Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effort =</td>
<td>(2.94 * (0.6094 * 1.43) * 6^1.1277) * 1.9</td>
<td>2.94 * (0.6094 * 1.43) * 12^1.1277) * 1.9</td>
</tr>
<tr>
<td></td>
<td><strong>28.26 Person-Months</strong></td>
<td><strong>59.14 Person-Months</strong></td>
</tr>
<tr>
<td>Duration =</td>
<td>9.29 * 0.75</td>
<td>11.68 * 0.75</td>
</tr>
<tr>
<td></td>
<td><strong>6.96 Months</strong></td>
<td><strong>8.76 Months</strong></td>
</tr>
<tr>
<td>Average Staffing =</td>
<td>28.26/6.96</td>
<td>59.14/8.76</td>
</tr>
<tr>
<td></td>
<td><strong>4.06 People</strong></td>
<td><strong>6.75 People</strong></td>
</tr>
</tbody>
</table>

11.6.2 Function Point Analysis

We are using Function Point Analysis to estimate the project, managing change of scope, measuring productivity, and communicating functional requirements. The function point total is determined on the basis of the number and complexity of the five components of Function Points. The list below shows the components of Pin Deck Tracking System Project.

**Internal Logical Files**

- None

**External Interface Files**

- Images from Camera (High)

**External Inputs**

- Start Capture (Medium)
- Stop Capture (Medium)
- Calibrate (High)
- Filename (Low)
Export Video File (Low)
Export CSV File (Low)
Video from Camera (High)

External Outputs

- Entry Angle (High)
- Exit Angle (High)
- Entry Board (Medium)
- Exit Board (Medium)
- Ball Speed (High)
- Ball Path (High)
- Calibration Success (Low)
- Pin movement (High)

External Inquiries

- Retrieve previous data from disk (Low)

By using Function Points, we can easily calculate the functionality and normalize the results of different parts on the product. The Function Points are calculated from the following formula:

\[ FP = \text{count}_{total} \times [0.65 + 0.01 \times \sum F_i] \]

Where:

- \( FP \): Function Points
- \( \text{count}_{total} \): A sum of the following measurement parameters:
  - Number of User inputs × Input Weight Value
  - Number of User outputs × Input Weight Value
  - Number of User Inquiries × Inquiry Weight Value
  - Number of Files × File Weight Value
  - Number of External Interfaces × External Interface Weight Value

In addition to the five functional components described above there are two adjustment factors that need to be considered in Function Point Analysis.

**Functional Complexity** - The first adjustment factor considers the Functional Complexity for each unique function. Functional Complexity is determined based on the combination of data groupings and data elements of a particular function. The number of data elements and unique groupings are counted and compared to a complexity matrix that will rate the function as low, average or high complexity.
**Value Adjustment Factor** - The Unadjusted Function Point count is multiplied by the second adjustment factor called the Value Adjustment Factor. This factor considers the system’s technical and operational characteristics and is calculated by answering 14 questions. The factors are listed below:

Table 11-10: Jones First Order Influence Factor

<table>
<thead>
<tr>
<th>Category</th>
<th>Influence (0-5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Communication</td>
<td>5</td>
</tr>
<tr>
<td>Distributed Processing</td>
<td>1</td>
</tr>
<tr>
<td>Performance</td>
<td>3</td>
</tr>
<tr>
<td>Heavily Used Configuration</td>
<td>3</td>
</tr>
<tr>
<td>Transaction Rate</td>
<td>4</td>
</tr>
<tr>
<td>Online Data Entry</td>
<td>1</td>
</tr>
<tr>
<td>End-user Efficiency</td>
<td>2</td>
</tr>
<tr>
<td>Online Update</td>
<td>1</td>
</tr>
<tr>
<td>Complex Processing</td>
<td>5</td>
</tr>
<tr>
<td>Re-usability</td>
<td>3</td>
</tr>
<tr>
<td>Installation Ease</td>
<td>3</td>
</tr>
<tr>
<td>Operational Ease</td>
<td>3</td>
</tr>
<tr>
<td>Multiple Sites</td>
<td>0</td>
</tr>
<tr>
<td>Facilitate Change</td>
<td>3</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>37</strong></td>
</tr>
</tbody>
</table>

**Value Adjustment Factor**: $0.65 + 0.37 = 1.02$

Using the Value Adjustment Factor from above, we can then obtain our Adjusted Function Points Total to make our estimates. Below is table for Function Point Analysis.

Table 11-11: Function Point Analysis

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Low Complexity</th>
<th>Medium Complexity</th>
<th>High Complexity</th>
<th>Function Point Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inputs</td>
<td>3x3</td>
<td>2x4</td>
<td>2x6</td>
<td>29</td>
</tr>
<tr>
<td>Outputs</td>
<td>1x4</td>
<td>2x5</td>
<td>5x7</td>
<td>49</td>
</tr>
<tr>
<td>Inquiries</td>
<td>1x3</td>
<td>0x4</td>
<td>0x6</td>
<td>3</td>
</tr>
<tr>
<td>Logical Internal Files</td>
<td>0x7</td>
<td>0x10</td>
<td>0x15</td>
<td>0</td>
</tr>
<tr>
<td>External Interface Files</td>
<td>0x5</td>
<td>0x7</td>
<td>1x10</td>
<td>10</td>
</tr>
<tr>
<td><strong>Unadjusted Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>91</strong></td>
</tr>
<tr>
<td><strong>Adjustment Factor</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>1.02</strong></td>
</tr>
<tr>
<td><strong>Adjusted Function Point Total</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>92.82</strong></td>
</tr>
</tbody>
</table>
Adjusted Function Points: $0.94 \times 76 = 92.82$

Jones First-order Estimation

In order to estimate the number of calendar months, we used the coefficients for systems software. Then we used the rule-of-thumb equation to calculate the number of man-months necessary to complete the project. We then decided that each of us could work around 20 hour a week which is 50% of the average 40 hour work week. Using this estimate, we calculated the man months to complete the project.

Table 11-12: Jones First-order Estimation

<table>
<thead>
<tr>
<th></th>
<th>Best Case</th>
<th>Average Case</th>
<th>Worst Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>0.43</td>
<td>0.45</td>
<td>0.48</td>
</tr>
<tr>
<td>Function Point Raised to Power</td>
<td>$92.82^{0.43}$</td>
<td>$92.82^{0.45}$</td>
<td>$92.82^{0.48}$</td>
</tr>
<tr>
<td>Calendar Month</td>
<td>7.016</td>
<td>7.681</td>
<td>8.8</td>
</tr>
<tr>
<td>Man Months</td>
<td>12.791</td>
<td>16.784</td>
<td>25.24</td>
</tr>
<tr>
<td>Man Months for 4 Person Team</td>
<td>3.198</td>
<td>4.196</td>
<td>6.31</td>
</tr>
<tr>
<td>20 hour work week</td>
<td>4.797</td>
<td>6.294</td>
<td>9.465</td>
</tr>
</tbody>
</table>

11.6.3 Ballpark Schedule Estimation

Using the Table 8-9 Efficiency Schedules from McConnell’s Rapid Development text and an average approximation of 10,000 lines of code for the Pin Deck Tracking System project, the most efficient schedule is given at 8 months. The estimated number of man months required is 24 months. This allows for 3 resources to be devoted to the project.

11.6.4 Estimation Comparisons and Conclusion

Table 11-13 compares the results of the estimated schedules using the previous outlined methods. Values in the table are the average case for each method.

Table 11-13 Comparison of Estimation Method Results

<table>
<thead>
<tr>
<th>Method</th>
<th>Schedule</th>
<th>Effort</th>
<th>Staffing</th>
</tr>
</thead>
<tbody>
<tr>
<td>COCOMO II (Efficient)</td>
<td>7 Months</td>
<td>23 Man Months</td>
<td>4 People</td>
</tr>
<tr>
<td>Function Point</td>
<td>6 Months</td>
<td>17 Man Months</td>
<td>4 People</td>
</tr>
<tr>
<td>Ballpark (Efficient)</td>
<td>8 Months</td>
<td>24 Man Months</td>
<td>3 People</td>
</tr>
</tbody>
</table>
In conclusion, given an accelerated schedule, the scheduling methods seem to indicate that the Pin Deck Tracking System project should be achievable within a time frame of just over six months. However, in order to accomplish the goals within six months, it will be necessary to trim specified requirements to only “must have” requirements as indicated by the project sponsor. This would result in the need to relegate requirements 3.7 (pin movement) and 8.3 (Team Galaxy project BOLTS integration) to items to be implemented in the future.
12. Future Items

This section includes the future requirements that team purposed during the team meeting. The sponsor wanted us to have some additional features but could not be done due constraints of time, technology, complexity, and feasibility issues. Future items are listed based on the priority level of the all the requirements team kingpin came up in the earlier section.

12.1 3.7 - Pin Movement Tracking

12.1.1 **Description:** The system shall track path of each pin in the pin deck after ball makes initial contact.

12.1.2 **Source:** Emily Troutman (USBC Sponsor)

12.1.3 **Constraints:** Due to complexity and lack of technical knowledge of tracking each pin in pin deck will take long time. Due to time constraint we will not be able to implement above requirement.

12.1.4 **Standards:** None

12.1.5 **Priority:** 5 – future

12.2 8.3 - Team Galaxy Interface Integration

12.2.1 **Description:** Team Kingpin shall integrate our system’s graphical user interface with Team Galaxy’s graphical user interface by modifying source code to provide a single point of control for the two systems.

12.2.2 **Source:** Emily Troutman (USBC Sponsor)

12.2.3 **Constraints:** Contingent on the completion of Team Galaxy’s GUI.

12.2.4 **Standards:** None

12.2.5 **Priority:** 5 - Future