Budget Proposal

for Autonomous Panda System

Sponsor: The Department of Electrical, Computer, Software & Systems Engineering at Embry Riddle Aeronautical University

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Funky Town Fancy Pandas Development Team

**Abstract:** The budget proposal and functional design is contained in this document in conjunction with the preliminary budget, justifications, and decisions for each of the major components.

# Revision History

|  |  |  |
| --- | --- | --- |
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| 0.1.0 | Sept. 28, 2014 | Initial draft of the document |
| 0.2.0 | Sept. 30, 2014 | Continuation of budget proposal |
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# Introduction

The introduction of this document defines the purpose, scope, and team information for the project.

## Purpose

The purpose of this document is to identify the preliminary budget for the Autonomous Panda System (APS). It is intended to provide the customers of the APS with justifications for major item decisions. These justifications include decision matrices, risk analysis and fulfillment of requirements.

## Scope

This document is intended to provide the customers of APS with a list of parts with justification and pricing information. In this list of parts, only major components have been considered. These major components are those with price above $20 [**citation**] and are essential to the early prototyping of the APS. This document also contains a high-level break down of the APS that provides an overview of the initial design of the system.

## Team Information

|  |  |
| --- | --- |
| **Name** | **Role** |
| Kurt Pedrosa | Team Leader/Scrum Master |
| Merissa Roth | Software Leader |
| Mary Luongo | Hardware Leader/Product Owner |
| Luis Bogran | Development Leader |
| Kok Peng Tan | Developer |

# Functional Decomposition System

## High-Level Architecture of System

## Decomposition of Vehicle Hardware Layer

## Decomposition of Communication Hardware Layer

# Requirements Traceability

## Microcontroller

|  |  |  |
| --- | --- | --- |
| **ID** | **Requirement Text** | **Fulfillment** |
|  |  |  |

## Sensors

|  |  |  |
| --- | --- | --- |
| **ID** | **Requirement Text** | **Fulfillment** |
| 4.1.3 | The APS shall monitor the red LED on the floor. |  |
| 4.1.5 | The APS shall follow the line on the floor. |  |
| 4.1.6 | The APS shall remain within the playing board. |  |
| 4.1.7.1 | The APS shall identify the game station. |  |
| 4.1.8 | The APS shall stop moving once the finish line is crossed. |  |
| 4.2.2 | The APS shall play with the Simon Carabiner for 15 seconds. |  |
| 4.2.3 | The APS shall rotate one (1) row of the Rubik’s Cube 180 degrees. |  |
| 4.2.8 | The APS shall pick up one (1) playing card from the stack of cards. |  |

## Motors

|  |  |  |
| --- | --- | --- |
| **ID** | **Requirement Text** | **Fulfillment** |
| 4.1.4 | The APS shall start moving when the red LED powers off. |  |
| 4.1.6 | The APS shall remain within the playing board. |  |
| 4.1.8 | The APS shall stop moving once the finish line is crossed. |  |

## Arm

|  |  |  |
| --- | --- | --- |
| **ID** | **Requirement Text** | **Fulfillment** |
| 4.2.1 | The APS shall press the middle button on the Simon Carabiner to start playing. |  |
| 4.2.2 | The APS shall play with the Simon Carabiner for 15 seconds. |  |
| 4.2.3 | The APS shall rotate one (1) row of the Rubik’s Cube 180 degrees. |  |
| 4.2.6 | The APS shall draw “IEEE” on the Etch-a-Sketch using the knobs located on the Etch-a-Sketch. |  |
| 4.2.8 | The APS shall pick up one (1) playing card from the stack of cards. |  |

## Frame

|  |  |  |
| --- | --- | --- |
| **ID** | **Requirement Text** | **Fulfillment** |
|  |  |  |

## Batteries

|  |  |  |
| --- | --- | --- |
| **ID** | **Requirement Text** | **Fulfillment** |
| 4.1.1 | The APS shall receive power from an independent, on-board, battery. |  |

# Budget Decision Matrices and Justifications

This section of the document contains the reasoning used during the selection of the major components. The use of decision matrices is main method for selecting all components to be used for the APS. These matrices show the important characteristic of the component and indexed each of them with a weighted score. The development team scored each characteristic of each component and the average score is then calculated. The total score is gathered and the item with the highest total score is then selected as the most desirable component for the system.

## Microcontroller

The microcontrollers considered and descriptions of the decision process are described in the following content. The process was tailored to provide the APS with the optimal microcontroller to control all the subsystems.

### Items Under Consideration

The following items were considered as the microcontroller used to operate the subsystems of the APS. All of the items have been characterized on **table x** by item identification name (Item ID), vendor, and a description.

|  |  |  |
| --- | --- | --- |
| Item ID | Vendor | Description |
| Arduino Due | Amazon | A microcontroller based on the ARM Cortex-M3 chip. Contains 54 general purpose input/output (GPIO) pins. It run at a clock speed of 84 MHz. Contains 96 KB of RAM and 512 KB of Flash memory. It is a popular microcontroller for novice and expert developers. |
| Raspberry Pi Modle B+ | Amazon | A microcontroller with a Broadcom BCM2835 chipset, Micro SD storage, and 40 GPIO pins. Contains 512 MB of RAM (Random Access Memory) and a processor speed of 700 MHz. It has gain popularity between the novice and experience developers. |
| UDOO Quad | Udoo | A microcontroller based on a ARM Cortex-A9 chip with a clock speed of 1GHz. On-board integration with the Arduino Due Cortex-M3 chip set. It contains 76 fully available GPIO pins, and two Micro USB storage slots. It is not a popular microprocessor within the developer community but has promising features that may satisfied most novice and expert developers. |
| BeagleBone Black | Amazon |  |

### Decision Matrix

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Name** | **Price** | **Speed** | **RAM** | **Memory** | **GPIO** | **OS/IDE** | **Ease of use** |
| Arduino Due | $40.22 | 84 MHz | 96 kB | 512 kB | 54 (12 PWM) | Arduino IDE |  |
| Raspberry Pi Model B+ | $38.89 | 700 MHz | 512 MB | SD Card | 40 | Linux |  |
| UDOO Quad | $135 | 1 GHz | 1 GB | SD Card/SATA | 76 | Linux/Aduino IDE |  |
| BeagleBone Black | $65.90 | 1 GHz | 512 MB | 4 GB | 65 | Linux |  |
|  |  |  |  |  |  |  |  |
| **Name** | **Price** | **Speed** | **RAM** | **Memory** | **GPIO** | **OS/IDE** | **Ease of use** |
| Arduino Due | 8 | 2 | 2 | 5 | 8 | 6 | 9 |
| Raspberry Pi Model B+ | 9 | 5 | 5 | 9 | 7 | 8 | 9 |
| UDOO Quad | 3 | 8 | 8 | 10 | 9 | 10 | 5 |
| BeagleBone Black | 5 | 8 | 5 | 7 | 8 | 8 | 7 |
|  |  |  |  |  |  |  |  |
| **Weighted** | 0.2 | 0.2 | 0.1 | 0.25 | 0.1 | 0.1 | 0.05 |
|  |  |  |  |  |  |  |  |
| **Name** | **Price** | **Speed** | **RAM** | **Memory** | **GPIO** | **OS/IDE** | **Ease of use** | **Total** |
| Arduino Due | 1.6 | 0.4 | 0.2 | 1.25 | 0.8 | 0.6 | 0.45 | 5.3 |
| Raspberry Pi Model B+ | 1.8 | 1 | 0.5 | 2.25 | 0.7 | 0.8 | 0.45 | 7.5 |
| UDOO Quad | 0.6 | 1.6 | 0.8 | 2.5 | 0.9 | 1 | 0.25 | 7.65 |
| BeagleBone Black | 1 | 1.6 | 0.5 | 1.75 | 0.8 | 0.8 | 0.35 | 6.8 |

### Justification

## Sensors

### Items Under Consideration

### Decision Matrix

|  |  |  |
| --- | --- | --- |
|  |  | |
| **Product** | | **Availability** | | **Price** | **OS/IDE** | **FPS** | **Resolution** |  |
| Pixy Cam | | Available | | $0 | Arduino/C | 50 | (640 x 400) |  |
| CMUcam4 Robot Vision | | Buy it | | $116.24 | Arduino/C | 30 | VGA (640 x 840) |  |
| Raspberry Pi | | Buy it | | $29.95 | Raspberry Pi | 30 | 1080 p HD |  |
| Minoru 3D webcam | | Buy it | | $37.99 | openCV | 30 | 320 x 240 |  |
|  | |  | |  |  |  |  |  |
| **Product Weighted** | | **Availability** | | **Price** | **OS** | **FPS** | **Resolution** |  |
| Pixy Cam | | 10 | | 10 | 9 | 8 | 6 |  |
| CMucam4 Robot Vision | | 5 | | 5 | 9 | 6 | 7 |  |
| Raspberry Pi | | 5 | | 8 | 6 | 6 | 9 |  |
| Minoru 3D webcam | | 5 | | 7 | 6 | 6 | 4 |  |
|  | |  | |  |  |  |  |  |
| **Weighted** | | 0.1 | | 0.2 | 0.2 | 0.25 | 0.25 |  |
|  | |  | |  |  |  |  |  |
| **Product** | | **Availability** | | **Price** | **OS/IDE** | **FPS** | **Resolution** | **Total** |
| Pixy Cam | | 1 | | 2.00 | 1.8 | 2 | 1.5 | 8.30 |
| CMucam4 Robot Vision | | 0.5 | | 1 | 1.8 | 1.5 | 1.75 | 6.55 |
| Raspberry Pi | | 0.5 | | 1.6 | 1.2 | 1.5 | 2.25 | 7.05 |
| Minoru 3D webcam | | 0.5 | | 1.4 | 1.2 | 1.5 | 1 | 5.60 |

### Justification

## Motors

The following tables and justifications compose a description of the decision-making process that was used to select a motor for the APS. This process includes analytical and quantitative methods as well as reasoning behind these methods documented.

### Items Under Consideration

The following items were considered as possible motors for the APS. Each item in this section has a corresponding item ID (part number or product number) and vendor which has been compiled.

|  |  |  |
| --- | --- | --- |
| Motors | ID | Vendor |
| Standard Gearmotor | ROB-12399 | Sparkfun |
| Preicision Gearmotor | ROB-12497 | Sparkfun |
| 154:1 Metal Gearmotor 20Dx44Lmm | Pololu item #: 1109 | Pololu |
| 100:1 Metal Gearmotor 37Dx57L mm | Pololu item #: 1106 | Pololu |

### Decision Matrix

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Motors** | **Price** | **Voltage-Max** | **RPM** | **Stall Torque** | **Stall Current** | **Weight** |
| Standard Gearmotor | $24.95 | 12V | 101 | 32.2 N-cm | 0.5 A | 119.07 g |
| Preicision Gearmotor | $34.95 | 12V | 90 | 98.01 N-cm | 1 A | 240.97 g |
| 154:1 Metal Gearmotor 20Dx44Lmm | $19.95 | 6V | 90 | 84.73 N-cm | 3.3 A | 32.6 g |
| 100:1 Metal Gearmotor 37Dx57L mm | $24.95 | 12V | 100 | 155.35 N-cm | 5 A | 201.28 g |
|  |  |  |  |  |  |  |
| **Motors** | **Price** | **Voltage-Max** | **RPM** | **Stall Torque** | **Stall Current** | **Weight** |
| Standard Gearmotor | 4 | 4 | 5.61 | 2.9 | 9.1 | 5.6 |
| Preicision Gearmotor | 1 | 4 | 5.00 | 6.7 | 8.2 | 1.0 |
| 154:1 Metal Gearmotor 20Dx44Lmm | 5 | 8 | 5.00 | 5.9 | 4.1 | 8.8 |
| 100:1 Metal Gearmotor 37Dx57L mm | 4 | 4 | 5.56 | 10.0 | 1.0 | 2.5 |
|  |  |  |  |  |  |  |
| **Weighted** | 0.15 | 0.1 | 0.05 | 0.35 | 0.3 | 0.05 |
|  |  |  |  |  |  |  |
| **Motors** | **Price** | **Voltage-Max** | **RPM** | **Stall Torque** | **Stall Current** | **Weight** | **Total** |
| Standard Gearmotor | 0.60 | 0.40 | 0.30 | 1.05 | 2.70 | 0.30 | 5.35 |
| Preicision Gearmotor | 0.15 | 0.40 | 0.25 | 2.45 | 2.40 | 0.05 | 5.70 |
| 154:1 Metal Gearmotor 20Dx44Lmm | 0.75 | 0.80 | 0.25 | 2.10 | 1.20 | 0.45 | 5.55 |
| 100:1 Metal Gearmotor 37Dx57L mm | 0.60 | 0.40 | 0.30 | 3.50 | 0.30 | 0.10 | 5.20 |

### Justification

The following describes the process used in obtaining the scores for the various categories used to rate the motors under consideration in the decision matrix. The data for the motors under consideration was obtained from (sparkfun) and (pololu)

Price

The score for the price was obtained by normalizing the price and multiplying the normalized valued by the maximum score of 9 and adding 1. The weighted value of the price category is 15%. The equation below is an example to show how the price score is produced.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| ROB-12399 |  | 4 |
| ROB-12497 |  | 1 |
| Pololu item #: 1109 |  | 5 |
| Pololu item #: 1106 |  | 4 |

Voltage

The voltage category scores the voltage levels required of the APS for the motors. As the maximum operating voltage of all the items are either 6 V or 12 V, they are given a score of 4 for 12 V as it requires more voltage from the APS and they are given a score of 8 for the 6 V requirement. This category is given a 10% weighted value.

RPM

The rpm category scores the rpm of the motors. The motors chosen were from around the 90 rpm range so as to determine the differences in the torque of the different motors. This was done as the motors for each item can come in many different rpm but the torque would change scaling reasonably with the change in rpm. The score for this is determined by dividing the rpm value by 90 and multiplying by 5 as 90 rpm was the arbitrary choice. As this was an arbitrary choice, the weighted value of the score is 5%.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| ROB-12399 |  | 6 |
| ROB-12497 |  | 5 |
| Pololu item #: 1109 |  | 5 |
| Pololu item #: 1106 |  | 6 |

Stall Torque

The stall torque category scores the stall torque of the APS. This determines the amount of load that the APS can move. If the weight of the APS is above the limit, the motor will stall. The equation to determine the stall torque wass derived by calculating the normalized stall torque values multiplied by 9 and subtracting that from 10. As this determines the load that the APS can carry it is given a weight of 35%

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| ROB-12399 |  | 3 |
| ROB-12497 |  | 7 |
| Pololu item #: 1109 |  | 6 |
| Pololu item #: 1106 |  | 10 |

Stall Current

The stall current category scores the maximum current the APS needs to supply the motors, when they in a stall state. The equation used to determine the scores was derived by normalizing the stall current values multiplying them by 9 and adding 1. The weighted value of this category is 30% as it can affect other systems if the current is too high.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| ROB-12399 |  | 9 |
| ROB-12497 |  | 8 |
| Pololu item #: 1109 |  | 4 |
| Pololu item #: 1106 |  | 1 |

Weight

The weight category determines the weight of each of the different motors. The scores for this category is determined by normalizing the weights of the motors multiplied by 9 and adding 1. The weighted value of this category is 5%.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| ROB-12399 |  | 9 |
| ROB-12497 |  | 1 |
| Pololu item #: 1109 |  | 9 |
| Pololu item #: 1106 |  | 3 |

## Arm

### Items Under Consideration

### Decision Matrix

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Product** | **Claw Size** | **Weight** | **Price** | **DOF** | **Controlled** |  |
| OWI-535 Robotic Arm Edge | 2-3 in. | 1.45 lbs. | $44.29 | 5 | RC |  | |
| Stacker 2WD Mobile Robot | 4.25 in. | 3 lbs. | $142.78 | 2 | RC or autonomous |  | |
| AX-12 Dual Robotic Gripper | 9 in. | 2 lbs. | $69.00 | 6 | Autonomous |  | |
| AL5D Arm Hardware Only - Kit | 1.3 in. | .6 lbs. | $143.88 | 4 | Autonomous |  | |
|  |  |  |  |  |  |  | |
| **Product Weight** | **Claw Size** | **Weight** | **Price** | **DOF** | **Controlled** |  | |
| OWI-535 Robotic Arm Edge | 4 | 9 | 10 | 8 | 1 |  | |
| Stacker 2WD Mobile Robot | 7 | 5 | 4 | 3 | 7 |  | |
| AX-12 Dual Robotic Gripper | 10 | 6 | 9 | 9 | 9 |  | |
| AL5D Arm Hardware Only - Kit | 2 | 9 | 4 | 6 | 9 |  | |
|  |  |  |  |  |  |  | |
| **Weighted** | 0.25 | 0.15 | 0.15 | 0.25 | 0.2 |  | |
|  |  |  |  |  |  |  | |
| **Product Total** | **Claw Size** | **Weight** | **Price** | **DOF** | **Controlled** | **Total** | |
| OWI-535 Robotic Arm Edge | 1 | 1.35 | 1.5 | 2 | 0.2 | 6.05 | |
| Stacker 2WD Mobile Robot | 1.75 | 0.75 | 0.6 | 0.75 | 1.4 | 5.25 | |
| AX-12 Dual Robotic Gripper | 2.5 | 0.9 | 1.35 | 2.25 | 1.8 | 8.8 | |
| AL5D Arm Hardware Only - Kit | 0.5 | 1.35 | 0.6 | 1.5 | 1.8 | 5.75 | |

### Justification

## Wheels

The following tables and justifications give a description of the decision-making process that was used to select wheels for the APS. The process included analytical, qualitative, and quantitative methods and it is shown with the reasoning behind these methods.

### Items Under Consideration

The items in **Table 1** were considered as different choices for the wheels for the APS. The table includes items from Amazon, SparkFun, and Vex Robotics.

Table 1: Wheels under consideration for the APS

|  |  |  |
| --- | --- | --- |
| **Wheels** | **Part number** | **Vendor** |
| Vex Robotics Omni (4 in.) | 217-2584 | Amazon |
| Vex Robotics Mecanum (4 in.) | 217-3644, Right (217-3645, Left) | Amazon |
| Fingertech Mecanum (4 in.) | ROB-11578 | SparkFun |
| Pololu Wheels (42 x 19 mm) | ROB-0889 | SparkFun |

### Decision Matrix

The following tables create the quantitative reasons for the wheels chosen for the APS. **Table 2** contains the description matrix which shows the price, weight, load rating, and holonomic ability for each wheel under consideration.

Table 2: The Description Matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Wheels** | **Price** | **Weight (lbs.)** | **Load Rating (lbs.)** | **Holonomic** |
| Vex Robotics Omni | $12.50 | 0.42 | 200 | Yes |
| Vex Robotics Mecanum | $15.00 | 0.55 | 200 | Yes |
| Fingertech Mecanum | $18.75 | 0.1325 | 30 | Yes |
| Pololu Wheels | $3.50 | 0.08 | Not Found | No |

**Table 3** contains the weighted values for each characteristic of the wheels. The scores of the characteristics were multiplied with these values to get the final decision values.

Table 3: The Weighted Value Matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Weighted Values** | 0.25 | 0.25 | 0.2 | 0.3 |

**Table 4** contains point values for each characteristic as driven by the quantitative and qualitative reasons set forth in the justification. The point values ranged from one to nine. One is the least desired amount of a characteristic and nine is the most desired amount of a characteristic.

Table 4: The Point Value Matrix

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Wheels** | **Price** | **Weight** | **Load Rating** | **Holonomic** |
| Vex Robotics Omni | 4 | 7 | 9 | 9 |
| Vex Robotics Mecanum | 3 | 9 | 9 | 9 |
| Fingertech Mecanum | 1 | 2 | 5 | 9 |
| Pololu Wheels | 8 | 1 | 1 | 1 |

**Table 5** contains the final decision matrix for the wheels with the choice of wheels highlighted. The scores of each characteristic from **Table 4** were multiplied with the weighted values of each characteristic in **Table 3** to get the final points.

Table 5: The Decision Matrix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **Wheels** | **Price** | **Weight** | **Load Rating** | **Holonomic** | **Total** |
| Vex Robotics Omni | 1 | 1.75 | 1.8 | 2.7 | 7.25 |
| Vex Robotics Mecanu | 0.75 | 2.25 | 1.8 | 2.7 | 7.5 |
| Fingertech Mecanum | 0.25 | 0.5 | 1 | 2.7 | 4.45 |
| Pololu Wheels | 2 | 0.25 | 0.2 | 0.3 | 2.75 |

### Justification

The process for the decision making is described in the next paragraphs. The data for these items was found at the websites of Amazon, SparkFun, and Vex Robotics. The wheels were judged based on price, weight, load rating, and the wheels’ holonomic ability.

**Price**

The Price was valued at 25% of the decision. The wheels are being sold by the vendors in multiple pack styles. The Vex Robotics Omni (4 in.) wheels are being sold for $24.99 for a two pack. The Vex Robotics Mecanum (4 in.) wheels are being sold for $59.99 for a four pack. The Fingertech Mecanum (4 in.) wheels are being sold for $74.95 for a four pack. The Pololu Wheel (42 x 19 mm.) wheels are being sold for $6.95 for a two pack. Therefore, for the decision matrix the price was, first, divided by the number of items sold to find the price per each item. The prices were then normalized comparing each price to the greatest price. The normalized prices were multiplied by nine and added to one as shown in **Table 6**.

Table 6: Calculation of the price scores

|  |  |  |
| --- | --- | --- |
| **Item** | **Calculation** | **Score** |
| Vex Robotics Omni |  | 4 |
| Vex Robotics Mecanum |  | 3 |
| Fingertech Mecanum |  | 1 |
| Pololu Wheels |  | 8 |

**Weight**

The weight was valued at 25% of the decision. The APS has a maximum weight limit of 50 lbs. and therefore the weight of each wheel was important in choosing the wheels for the APS. The wheels should not be too light to hold the APS; consequently the point values were reversed to have the heavier wheels to be rated higher than the low weight wheels. **Table 7** shows the calculation used to find the score for the weight of each type of wheel. The weight of each type of wheel was normalized to the greatest weight. The score was multiplied by nine and added to one. The final score was subtracted from ten to yield the heavier wheels having a higher rating.

Table 7: Calculation of the weight point scores

|  |  |  |
| --- | --- | --- |
| **Item** | **Calculation** | **Score** |
| Vex Robotics Omni |  | 7 |
| Vex Robotics Mecanum |  | 9 |
| Fingertech Mecanum |  | 2 |
| Pololu Wheels |  | 1 |

**Load Rating**

The APS has a maximum weight limit of 50 lbs., thus the load rating was valued at 20% of the decision. Two types of wheels had equivalent load ratings (200 lbs.) and had the point value of nine as they had the best rating value. One wheel type, Pololu Wheels (42 x 19 mm), had no load rating available for it so it has the lowest value possible of one. This left the Fingertech Mecanum as the lowest rated value, but larger than the unknown value. Consequently, the value for the Fingertech Mecanum was given as the mid-range value, five.

**Holonomic**

Each wheel type was judged whether it had any holonomic ability or not. Each wheel was given either a nine, for yes, or an one, for a no. To minimize the complexity of the robotic arm it was decided to utilize wheels that had holonomic abilities. Therefore, holonomic ability has a value of 30% for the decision matrix.

## Frame

### Items Under Consideration

### Decision Matrix

### Justification

## Batteries

The following tables and justifications compose a description of the decision-making process that was used to select the batteries that will be used for the APS. This process includes analytical and quantitative methods as well as reasoning behind these methods documented.

### Items Under Consideration

The following items were considered as possible batteries for the APS each item in this section has a corresponding item ID (part number or product number) and vendor which has been compiled.

|  |  |  |
| --- | --- | --- |
| Motors | ID | vendor |
| Polymer Lithium Ion Battery-2000mAh | PRT-08483 | Sparkfun |
| Polymer Lithium Ion Battery-2200mAh 7.4V | PRT-11856 | Sparkfun |
| Turnigy 2200mAh 3S 20C Lipo Pack | T2200.3S.20 | Hobbyking |
| Turnigy 2200mAh 3S 25C Lipo Pack | T2200.3S.25 | Hobbyking |
| Turnigy 2200mAh 3S 30C Lipo Pack | T2200.3S.30 | Hobbyking |

### Decision Matrix

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Motors | Price | Capacity | Discharge Rate | Voltage | Weight |
| Polymer Lithium Ion Battery-2000mAh | $12.95 | 2000 mAh | 2 C | 3.7 V | 36.00 g |
| Polymer Lithium Ion Battery-2200mAh 7.4V | $13.95 | 2200 mAh | 30 C | 7.4 V | 206.00 g |
| Turnigy 2200mAh 3S 20C Lipo Pack | $8.50 | 2200 mAh | 20 C | 11.1 V | 188.00 g |
| Turnigy 2200mAh 3S 25C Lipo Pack | $10.60 | 2200 mAh | 25 C | 11.1 V | 188.00 g |
| Turnigy 2200mAh 3S 30C Lipo Pack | $13.50 | 2200 mAh | 30 C | 11.1 V | 197.00 g |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Motors | **Price** | **Capacity** | **Discharge rate** | **Voltage** | **Weight** |
| Polymer Lithium Ion Battery-2000mAh | 1.65 | 4 | 1.60 | 4.00 | 8.43 |
| Polymer Lithium Ion Battery-2200mAh 7.4V | 1.00 | 5 | 10.00 | 7.00 | 1.00 |
| Turnigy 2200mAh 3S 20C Lipo Pack | 4.52 | 5 | 7.00 | 10.00 | 1.79 |
| Turnigy 2200mAh 3S 25C Lipo Pack | 3.16 | 5 | 8.50 | 10.00 | 1.79 |
| Turnigy 2200mAh 3S 30C Lipo Pack | 1.29 | 5 | 10.00 | 10.00 | 1.39 |

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Weighted | 0.15 | 0.25 | 0.3 | 0.25 | 0.05 |

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Motors | Price | Capacity | Discharge Rate | Voltage | Weight | Total |
| Polymer Lithium Ion Battery-2000mAh | 0.3 | 1 | 0.6 | 1 | 0.4 | 3.30 |
| Polymer Lithium Ion Battery-2200mAh 7.4V | 0.15 | 1.25 | 3 | 1.75 | 0.05 | 6.20 |
| Turnigy 2200mAh 3S 20C Lipo Pack | 0.75 | 1.25 | 2.1 | 2.5 | 0.1 | 6.70 |
| Turnigy 2200mAh 3S 25C Lipo Pack | 0.45 | 1.25 | 2.7 | 2.5 | 0.1 | 7.00 |
| Turnigy 2200mAh 3S 30C Lipo Pack | 0.15 | 1.25 | 3 | 2.5 | 0.05 | 6.95 |

### Justification

The following describes the process used in obtaining the scores for the various categories used to rate the batteries under consideration in the decision matrix. The data for the batteries under consideration was obtained from (sparkfun) and (hobbyking).

Price

The score for the price was obtained by normalizing the price and multiplying the normalized valued by the maximum score of 9 and adding 1. The weighted value of the price category was 15%.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| PRT-08483 |  | 2 |
| PRT-11856 |  | 1 |
| T2200.3S.20 |  | 5 |
| T2200.3S.25 |  | 3 |
| T2200.3S.30 |  | 3 |

Capacity

The capacity category scores the different capacities of the batteries. As the capacities of the batteries do not vary much, 2200 mAh for 4 of the batteries under consideration and the last one at 2000 mAh. A score of 5 was given to the 2200 mAh batteries and a score of 4 was given to the battery with 2000 mAh. As the capacity determines the capacity of the battery, it was given a weighted score of 25%.

Discharge Rate

The discharge rate, C rating, of the batteries scores the discharge relative to the battery capacity, a 100 mAh capacity at a 5 C rate will have a total capacity of 500 mA. The equation to determine the score was derived by normalizing the C rating multiplied by 9 and subtracting that from 10. As the discharge rate determines the total capacity of the battery, it was given a weighted score of 30%.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| PRT-08483 |  | 2 |
| PRT-11856 |  | 1 |
| T2200.3S.20 |  | 5 |
| T2200.3S.25 |  | 3 |
| T2200.3S.30 |  | 3 |

Voltage

The voltage category scores the voltage output of the battery. This determines the normalized voltage output of the battery. The equation to determine the score for the voltage was to normalize the voltage multiply by 9 and subtract that from 10 to get the score. The weighted value of this category is 25%.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| PRT-08483 |  | 4 |
| PRT-11856 |  | 7 |
| T2200.3S.20 |  | 10 |
| T2200.3S.25 |  | 10 |
| T2200.3S.30 |  | 10 |

Weight

The weight category determines the weight of each of the different motors. The scores for this category is determined by normalizing the weights of the motors multiplied by 9 and adding 1. The weighted value of this category is 5%.

|  |  |  |
| --- | --- | --- |
| Item | Calculation | Score |
| PRT-08483 |  | 8 |
| PRT-11856 |  | 1 |
| T2200.3S.20 |  | 2 |
| T2200.3S.25 |  | 2 |
| T2200.3S.30 |  | 1 |

# Risk Analysis

Each component has an amount of risk in its use on the APS. This section details some risks associated with each component used as part of the APS. The quantitative value of each risk was determined by personal experience and research of each component. The chance that the risk could occur is rated in a range of one to nine. One is the least likely for that risk to occur and nine being the most likely to occur. The severity of each is risk is rated in the same scale of one to nine; one being the least severe and nine is the most severe.

## Microcontroller

**Table 8** details the risks associated with the microcontrollers.

Table 8: Risks and alleviations associated with the Microcontrollers

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
|  |  |  |  |
|  |  |  |  |

## Sensors

**Table 9** details the risks associated with the sensors.

Table 9: Risks and alleviations associated with the Sensors

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
|  |  |  |  |
|  |  |  |  |

## Motors

**Table 10** details the risks associated with the motors.

Table 10: Risks and alleviations associated with the Motors

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
|  |  |  |  |
|  |  |  |  |

## Arm

**Table 11** details the risks associated with the arms.

Table 11: Risks and alleviations associated with the Arm

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
|  |  |  |  |
|  |  |  |  |

## Wheels

**Table 12** details the risks associated with the wheels.

Table 12: Risks and alleviations associated with the Wheels

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
| Damage to the wheels |  |  |  |
| Loss of a wheel |  |  |  |
|  |  |  |  |

## Frame

**Table 13** details the risks associated with the frames.

Table 13: Risks and alleviations associated with the Frame

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
|  |  |  |  |
|  |  |  |  |

## Batteries

**Table 14** details the risks associated with the batteries.

Table 14: Risks and alleviations associated with the Batteries

|  |  |  |  |
| --- | --- | --- | --- |
| **Risk** | **Probability** | **Severity** | **Risk Mitigation** |
|  |  |  |  |
|  |  |  |  |

# Total System Budget

# Glossary

# Acronyms & Abbreviations

|  |  |
| --- | --- |
| **Entry** | **Expanded Phrase** |
| FTFP | Funky Town Fancy Pandas |
| DOF | Degrees of Freedom |
| APS | Autonomous Panda System |
| LED | Light-emitted Diode |
| IEEE |  |
|  |  |

# References

Arduino Uno

<http://arduino.cc/en/Main/arduinoBoardUno>

Raspbarry Pi

<http://www.raspberrypi.org/products/model-b/>

UDOO

<http://shop.udoo.org/usa/product/udoo-quad.html>

Vex Robotics. Mecanum Wheels [Online]. Available: http://www.vexrobotics.com/vexpro/wheels-and-hubs/mecanum-wheels.html

Vex Robotics. Omni Wheels [Online]. Available: http://www.vexrobotics.com/vexpro/wheels-and-hubs/omni-wheels.html

SparkFun. Mecanum Wheels - 4 pack [Online]. Available: https://www.sparkfun.com/products/11578

SparkFun. Wheel 42x19mm [Online]. Available: https://www.sparkfun.com/products/8899

Fingertech. FingerTech Mecanum Wheels (Set of 4) [Online]. Available: http://www.fingertechrobotics.com/proddetail.php?prod=ft-mecanum-set-v2