Budget Proposal

for Autonomous Panda System

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

Released: October 7, 2014

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

|  |  |  |
| --- | --- | --- |
| **Version** | **Date** | **Description** |
| 0.1.0 | Sept. 28, 2014 | Initial draft of the document |
| 0.2.0 | Sept. 30, 2014 | Continuation of budget proposal |
| 0.3.0 | Oct. 1, 2014 | Formatting |
| 0.4.0 | Oct. 2, 2014 | Continuation of budget proposal |

Table of Contents

[Revision History 2](#_Toc399974138)

[1. Introduction 5](#_Toc399974139)

[1.1 Purpose 5](#_Toc399974140)

[1.2 Scope 5](#_Toc399974141)

[1.3 Team Information 5](#_Toc399974142)

[2. Functional Decomposition System 6](#_Toc399974143)

[2.1 High-Level Architecture of System 6](#_Toc399974144)

[2.2 Decomposition of Vehicle Hardware Layer 6](#_Toc399974145)

[2.3 Decomposition of Communication Hardware Layer 6](#_Toc399974146)

[3. Requirements Traceability 7](#_Toc399974147)

[3.1 Microcontroller 7](#_Toc399974148)

[3.2 Sensors 7](#_Toc399974149)

[3.3 Motors 7](#_Toc399974150)

[3.4 Arm 7](#_Toc399974151)

[3.5 Frame 7](#_Toc399974152)

[3.6 Batteries 8](#_Toc399974153)

[4. Budget Decision Matrices and Justifications 9](#_Toc399974154)

[4.1 Microcontroller 9](#_Toc399974155)

[4.1.1 Items Under Consideration 9](#_Toc399974156)

[4.1.2 Decision Matrix 9](#_Toc399974157)

[4.1.3 Justification 9](#_Toc399974158)

[4.2 Sensors 10](#_Toc399974159)

[4.2.1 Items Under Consideration 10](#_Toc399974160)

[4.2.2 Decision Matrix 10](#_Toc399974161)

[4.2.3 Justification 10](#_Toc399974162)

[4.3 Motors 11](#_Toc399974163)

[4.3.1 Items Under Consideration 11](#_Toc399974164)

[4.3.2 Decision Matrix 11](#_Toc399974165)

[4.3.3 Justification 11](#_Toc399974166)

[4.4 Arm 12](#_Toc399974167)

[4.4.1 Items Under Consideration 12](#_Toc399974168)

[4.4.2 Decision Matrix 12](#_Toc399974169)

[4.4.3 Justification 12](#_Toc399974170)

[4.5 Wheels 13](#_Toc399974171)

[4.5.1 Items Under Consideration 13](#_Toc399974172)

[4.5.2 Decision Matrix 13](#_Toc399974173)

[4.5.3 Justification 13](#_Toc399974174)

[4.6 Frame 14](#_Toc399974175)

[4.6.1 Items Under Consideration 14](#_Toc399974176)

[4.6.2 Decision Matrix 14](#_Toc399974177)

[4.6.3 Justification 14](#_Toc399974178)

[4.7 Batteries 15](#_Toc399974179)

[4.7.1 Items Under Consideration 15](#_Toc399974180)

[4.7.2 Decision Matrix 15](#_Toc399974181)

[4.7.3 Justification 15](#_Toc399974182)

[5. Risk Analysis 16](#_Toc399974183)

[5.1 Microcontroller 16](#_Toc399974184)

[5.2 Sensors 16](#_Toc399974185)

[5.3 Motors 16](#_Toc399974186)

[5.4 Arm 16](#_Toc399974187)

[5.5 Wheels 16](#_Toc399974188)

[5.6 Frame 16](#_Toc399974189)

[5.7 Batteries 16](#_Toc399974190)

[6. Total System Budget 17](#_Toc399974191)

[Glossary 18](#_Toc399974192)

[Acronyms & Abbreviations 19](#_Toc399974193)

[References 20](#_Toc399974194)

# 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 Uno | Amazon | A microcontroller board based on the ATmega328. It contains 14 digital I/O pins, with 6 of them providing pulse width modulation (PWM) output. It has a 5V operating voltage with input voltage recommendation between 7V and 12V. |
| Raspberry Pi Modle B+ | Amazon |  |
| UDOO Quad | Udoo |  |
| BeagleBone Black | Amazon |  |

### Decision Matrix

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **Name** | **Price** | **Speed** | **RAM** | **Memory** | **GPIO** | **OS/IDE** | **Ease of use** |
| Arduino Uno | $40.22 | 84 MHz | 96 kB | 512 kB | 54 (12 PWM) | Arduino IDE |  |
| Raspberry Pi Modle 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 Uno | 8 | 2 | 2 | 5 | 8 | 6 | 9 |
| Raspberry Pi Modle 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 Uno | 1.6 | 0.4 | 0.2 | 1.25 | 0.8 | 0.6 | 0.45 | 5.3 |
| Raspberry Pi Modle 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 and quantitative methods and it is shown with the reasoning behind these methods.

### Items Under Consideration

The following items were considered as different choices for the wheels for the APS. The table includes items from Amazon, SparkFun, and Vex Robotics. The data for these items was found at each of these vendors.

### Decision Matrix

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Price |  | Cost | Availability | Weight | Load Rating | Holonomic | Extra gear | Total |
|  | Weight | 0.2 | 0.2 | 0.15 | 0.1 | 0.25 | 0.1 | 1 |
| 24.99 (per two) | Omni (4 in.) | 6 | 9 | 9 | 9 | 9 | 1 |  |
| 59.99 (per four) | Mecanum (4 in.) | 1 | 9 | 6 | 9 | 9 | 9 |  |
| 6.95 (per two) | Wheel (42 x 19 mm) | 9 | 9 | 1 | 1 | 1 | 1 |  |
| Per each |  |  |  |  |  |  |  |  |
| 12.5 | Omni | 1.2 | 1.8 | 1.35 | 0.9 | 2.25 | 0.1 | 7.6 |
| 14.99 | Mecanum | 0.2 | 1.8 | 0.9 | 0.9 | 2.25 | 0.9 | 6.95 |
| 3.48 | Wheel (42 x 19 mm) | 1.8 | 1.8 | 0.15 | 0.1 | 0.25 | 0.1 | 4.2 |

### Justification

## Frame

### Items Under Consideration

### Decision Matrix

### Justification

## Batteries

### Items Under Consideration

### Decision Matrix

### Justification

# Risk Analysis

## Microcontroller

## Sensors

## Motors

## Arm

## Wheels

## Frame

## Batteries

# 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