Preliminary Design Review

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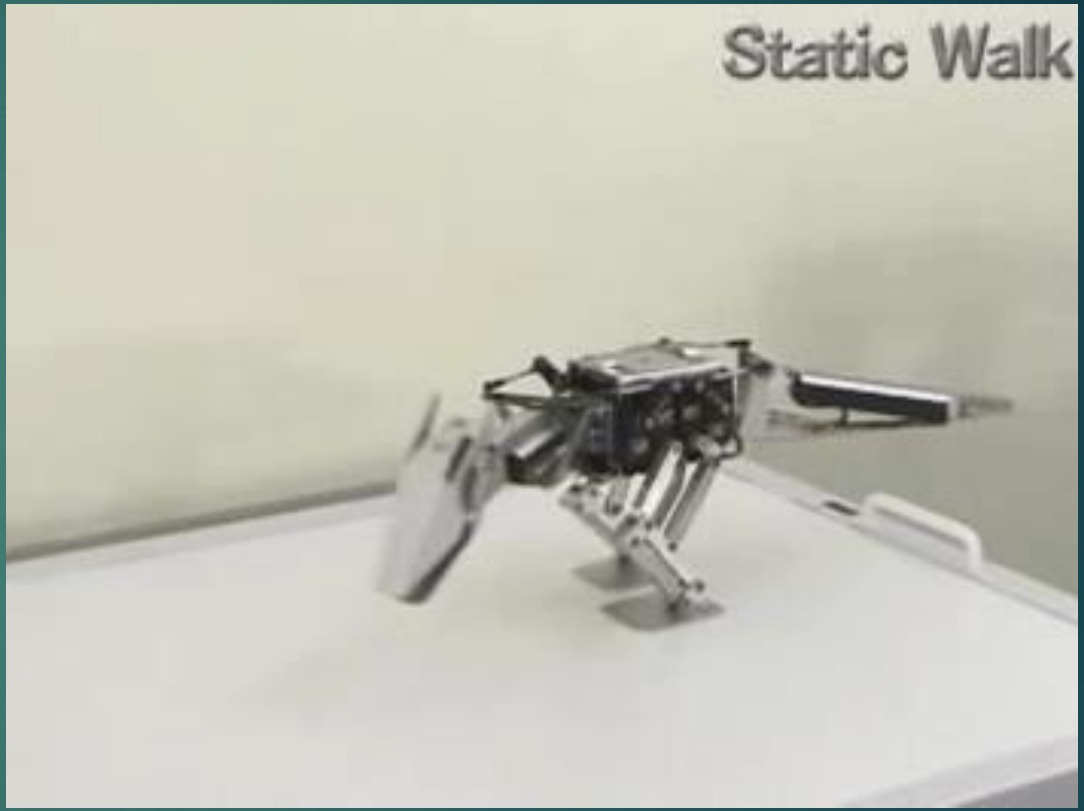
Program Objectives/Mission Profile

The Fall 2016 Velociraptor is inspired by the biped Titrus-III robot developed by the Tokyo Institute of Technology. The Fall 2016 Velociraptor is the third generation biped robot and we're expanding from previous semester's design.

Mission Profile

- The Fall 2016 Velociraptor is the 3rd Generation biped robot
- Inspired by the Titrus III by the Tokyo Institute of Technology
- Participate in the Game: Save the Human
  - Walk
  - Balance itself on an incline
- 3DoT board incorporated to the design



Program Objectives

Customer's Expectation

1. Utilize the 3DoT Board as our microcontroller
2. Use the Arxterra Control Panel by using tele robotic communication
3. Motors instead of Servos

Design Innovation

Creativity Exercise:

- Balance
- Feet Design
- Walking Linkages

Balance:

- Animatronic Tail
- Planar Manipulation

Feet Design:

- Materials under feet
- Human-Like Walking

Walking Linkages:

- Jansen’s Linkages
- UCI Linkages

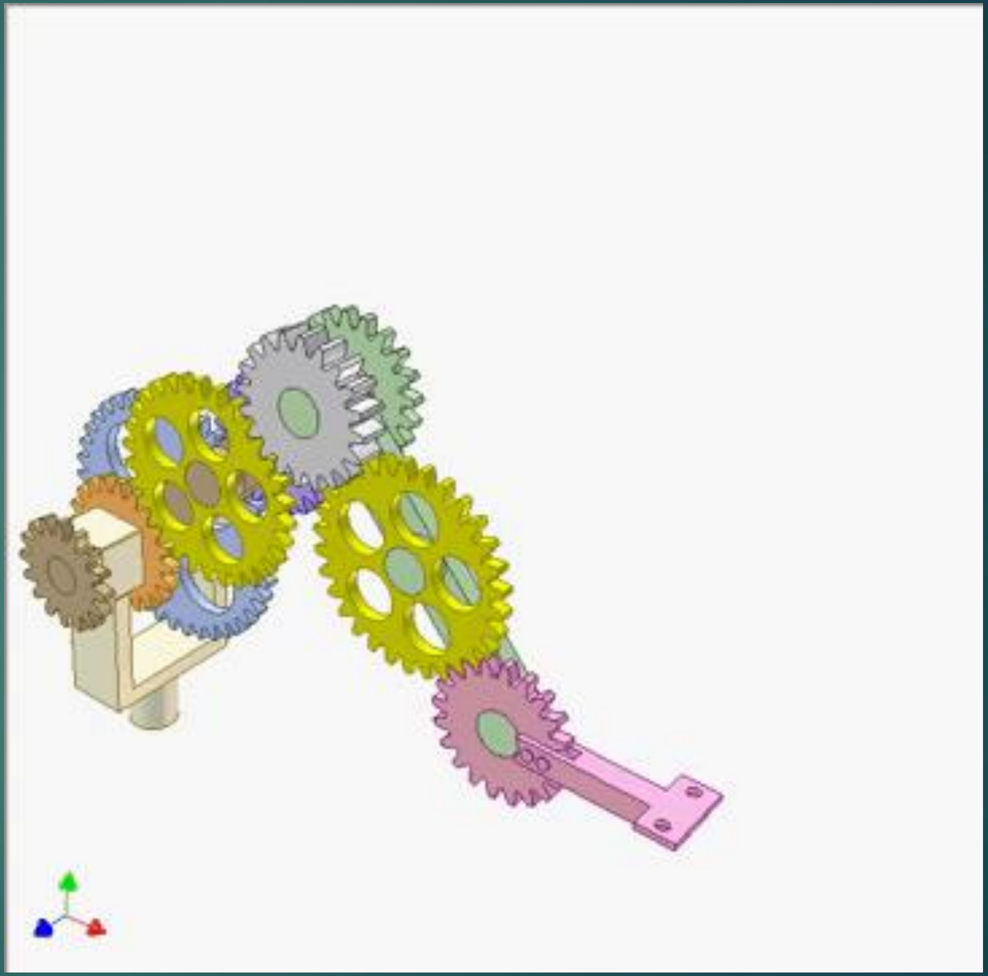
Animatronic Tail

1. Balancing capability
2. Able to shift the center of mass (left, right, up, or down)

Animatronic Tail (Other options)

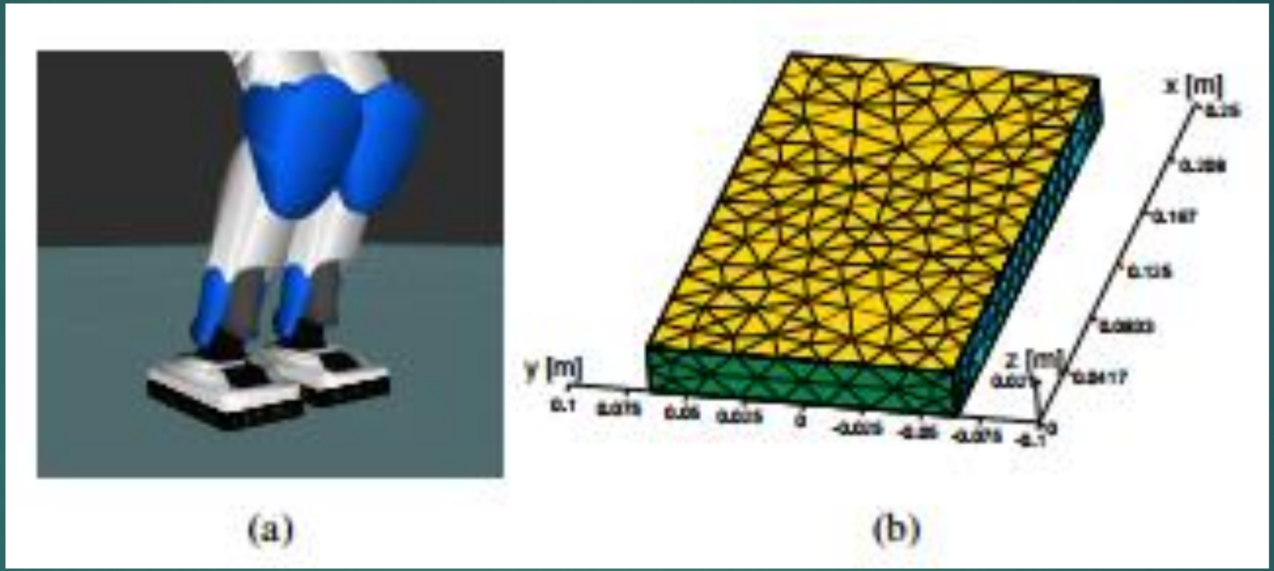
Planar Manipulation

- Have a mechanical design along certain axis for balance
- Rotate the gears to manipulate the head and tail to get (left, right, up, and down)
- Simple design



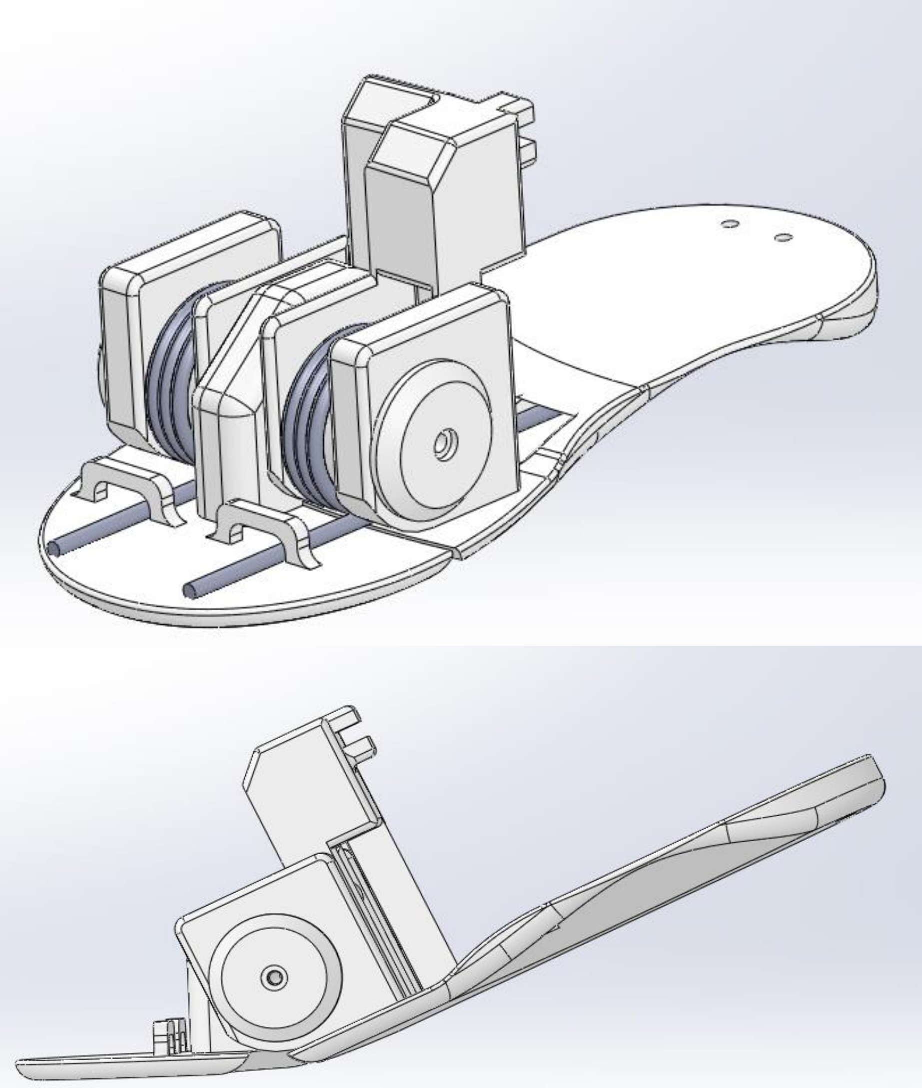
Foot Design

- Grip tape
- Rubber
- Mesh



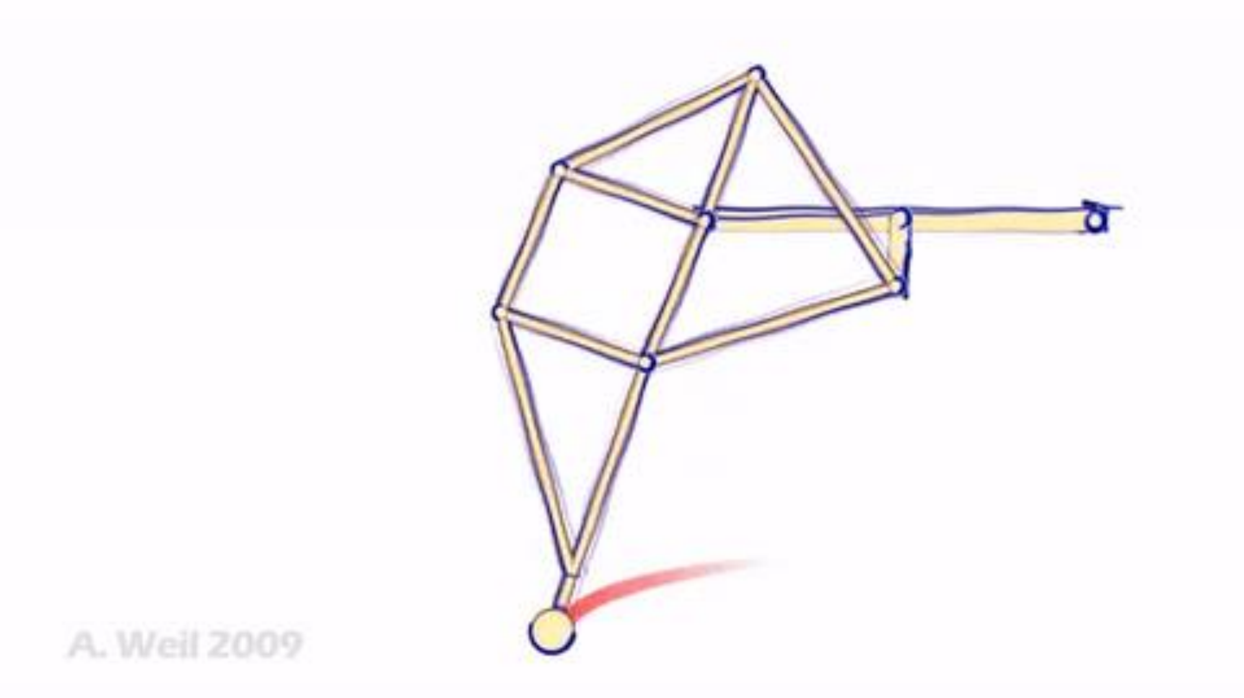
Foot Design

- Kinesiology-Based Robot Foot Design for Human-Like Walking
- Enhance Performance and stability



Jansen's Linkage

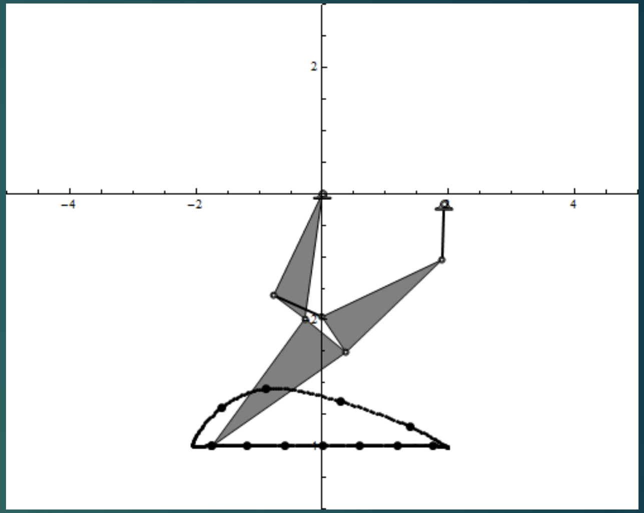
- Theo Jansen's *Strandbeest*
- Models Humanoid Gait Motion
- Actuation on Single Joint

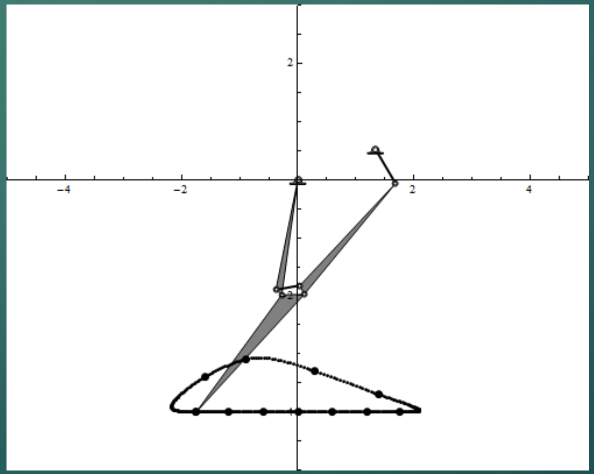


Walking Linkages

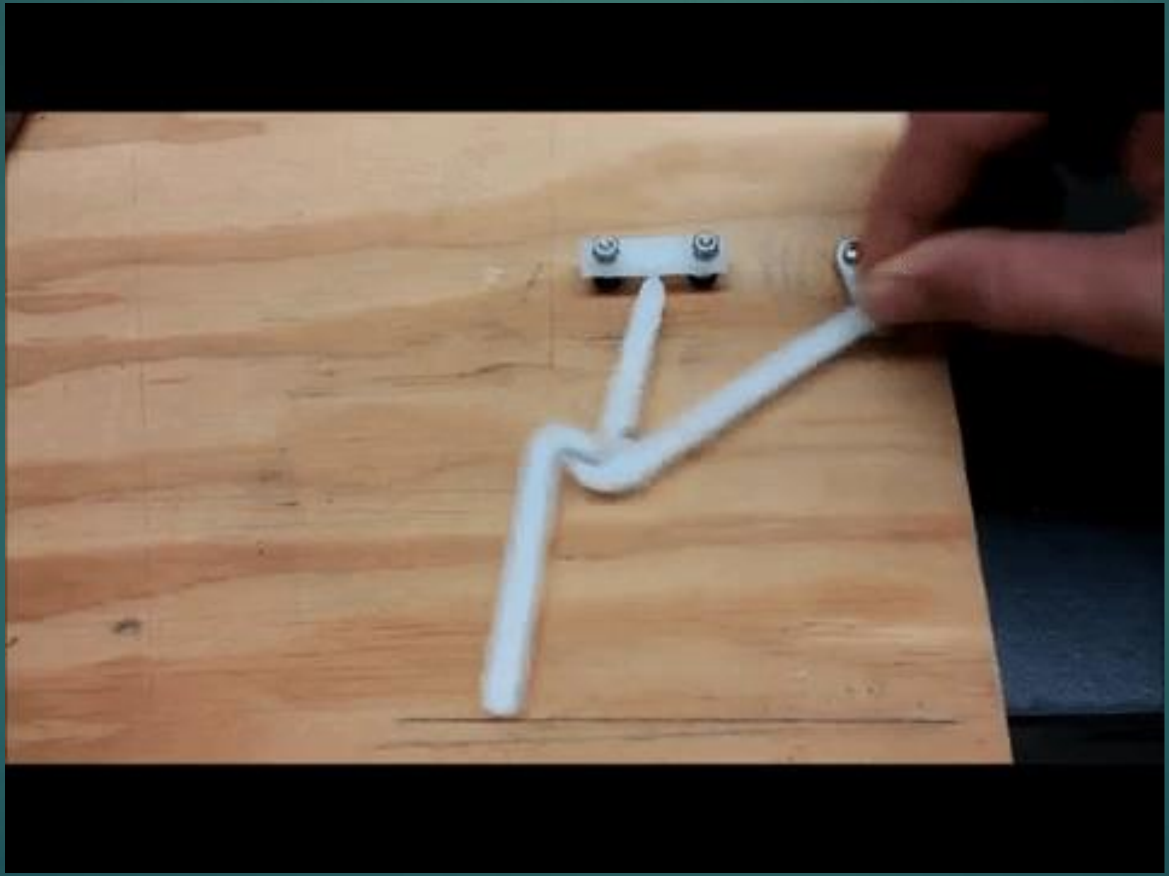
- “Each are single degree-of-freedom and would be driven by a single crank rotating at constant angular velocity.“

  -Mark Plecnik (UCI Professor)

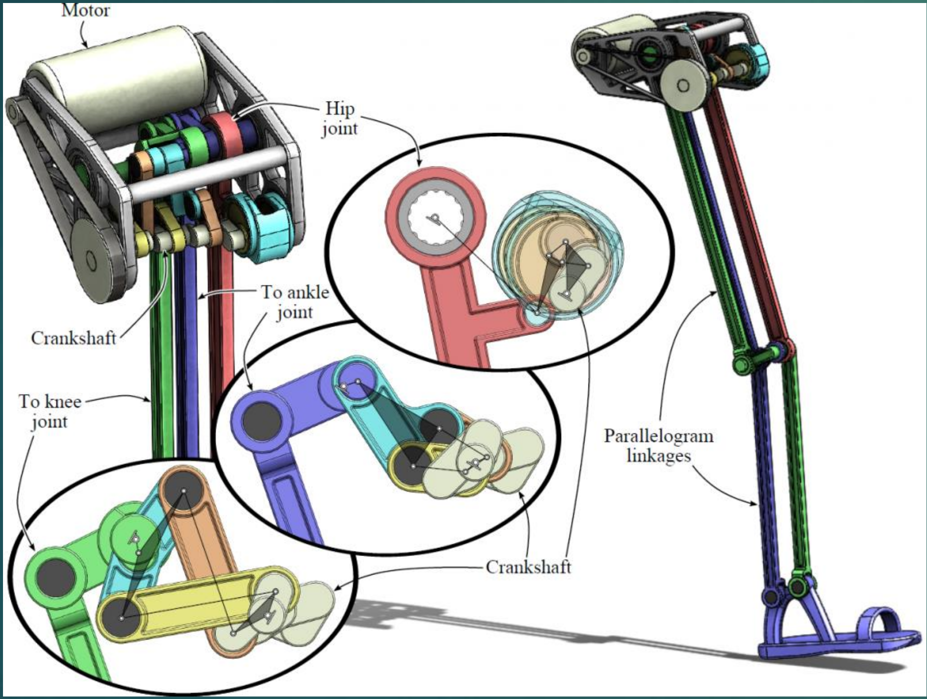


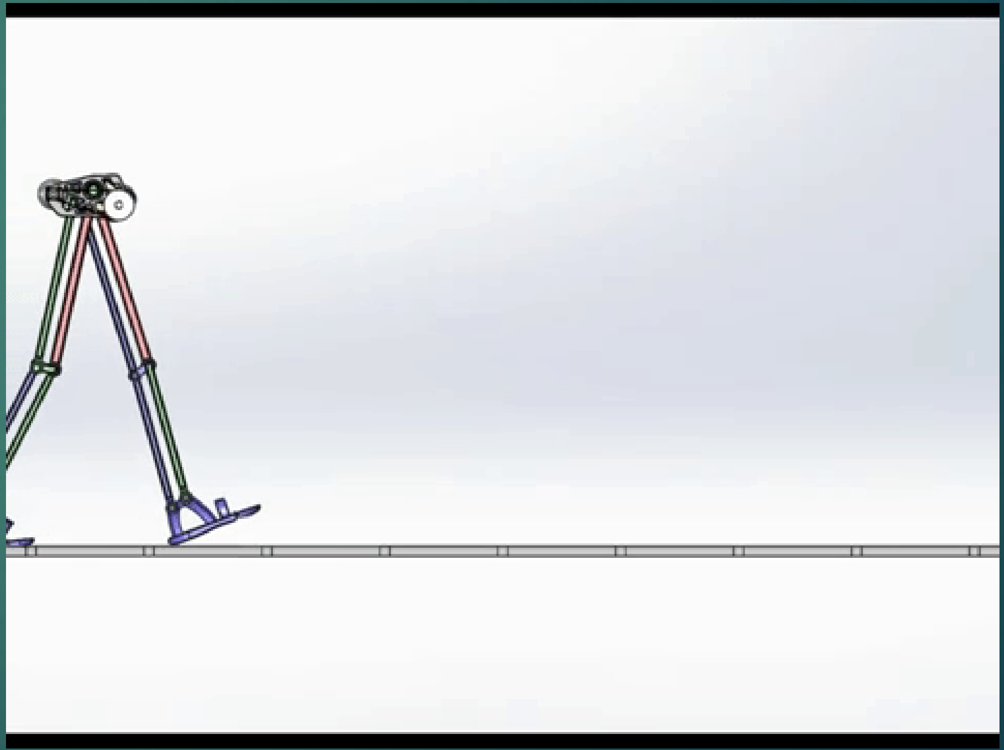


Prototype of Six-bar Compliant Leg Module



Human Gait Motion





Requirements & Verification

Level 1 Program Requirements

CSULB Fall 2016 Velociraptor …

1. Shall cost no more than $400.00 [1] [2]
2. Shall participate in the **Game: Save the Human** provided by the Game Committee and the customer [3]
3. Shall demonstrate its capabilities on the final day of school, **Wednesday, December 14, 2016** [4]

August 31, 2016

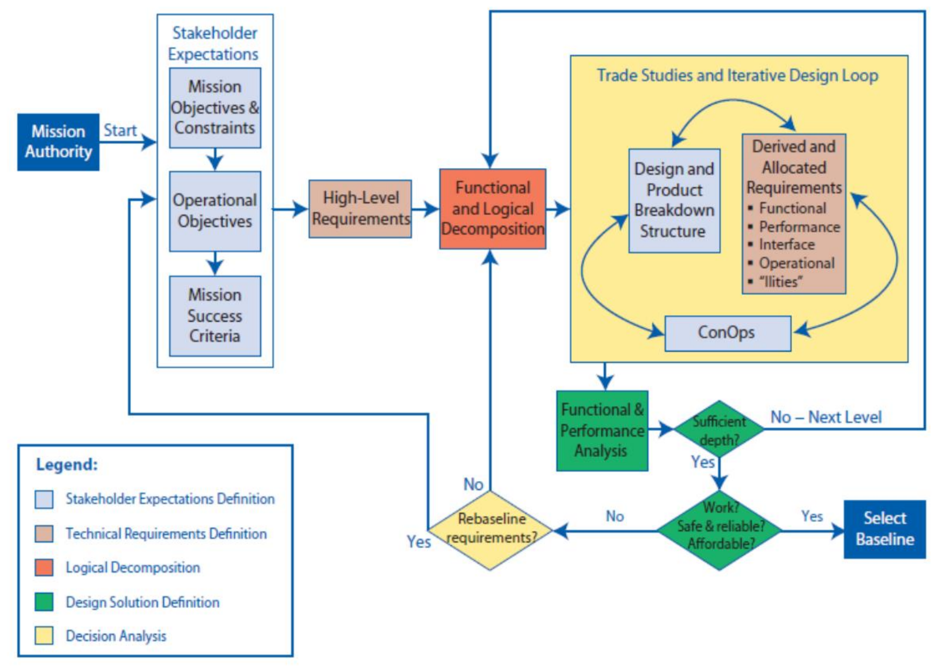


Figure 1 Systems Engineering Design Method

Level 1 Program Requirements Resources

[1] Khoivu0814. (2016). Retrieved September 21, 2016, from http://www.arxterra.com/spring-2016-velociraptor-preliminary-project-plan/

[2] Plaulsible. (2015). Retrieved September 23, 2016, from http://www.arxterra.com/fall-2015-microbiped-preliminary-project-plan/

[3] Paul Ahumada. (2016). Retrieved October 05, 2016, from http://arxterra.com/fall-2016-game-save-the-human/

[4] Time, B. C. (n.d.). Final Exam Fall 2016 Schedule Charts. Retrieved September 21, 2016,from http://web.csulb.edu/depts/enrollment/registration/final_exam/fall_chart.html

Level 1 System Requirements

The CSULB Fall 2016 Velociraptor shall…

1. Resemble a Theropoda Dinosaur [1]
2. Statically walk [2]
3. Dynamically walk [2]
4. Use Bluetooth to communicate with the Arxterra Control Panel [3]
5. Use a 3DoT board with a custom i2C shield [3]
6. Navigate through the game terrain provided by the game committee [4]

Level 1 System Requirements (Continued)

The CSULB Fall 2016 Velociraptor shall navigate through the game terrain provided by the game committee shall…

1. Utilize a foot design capable of traction of all surfaces [4]
2. Navigate on uneven surface height no larger than 0.5 cm [4]
3. Use a battery to sufficiently power the biped robot for the duration of the game [4]

Level 1 References

[1] Theropod dinosaurs - Google Search. (n.d.). Retrieved September 23, 2016, from https://www.google.com/search?q=Theropod dinosaurs

[2] Robotics/Types of Robots/Walkers. Retrieved October 05, 2016, from https://en.wikibooks.org/wiki/Robotics/Types_of_Robots/Walkers

[3] 3DoT. (n.d.). Retrieved October 05, 2016, from http://www.arxterra.com/3dot/

[4] Paul Ahumada. (2016). Retrieved October 05, 2016, from http://arxterra.com/fall-2016-game-save-the-human/

Level 2 requirements

1. The velociraptor shall have two feet to support a mass of the robot which shall not exceed 900 grams.
2. The velociraptor shall implement a control system [PID] that should shift the center of gravity along the axis of the legs (left and right). The center of gravity shall be controlled by two servo that c ontrols both head and tail.
3. The acceleration of the Velociraptor head and tail movement shall not exceed [to be calculated in m/s^2] to avoid the velociraptor tipping point, and falling down.
4. The velociraptor shall have a threaded rod be placed horizontally with respect to head and tail. The length of the threaded rod [to be determine cm], and thickness [to be determine mm] to ensure it fits in the body. The threaded rod shall move along the axis of the head, tail, and body to shift the center of gravity.
5. The velociraptor shall utilize DC motors [to be determine] for continuous static and dynamic movement.
6. The velociraptor shall shift the center of gravity over the leg while statically walking. The center of gravity shall be within a region of stability of [to be calculated] mm from the center of the foot.

Level 2 Requirement (continued)

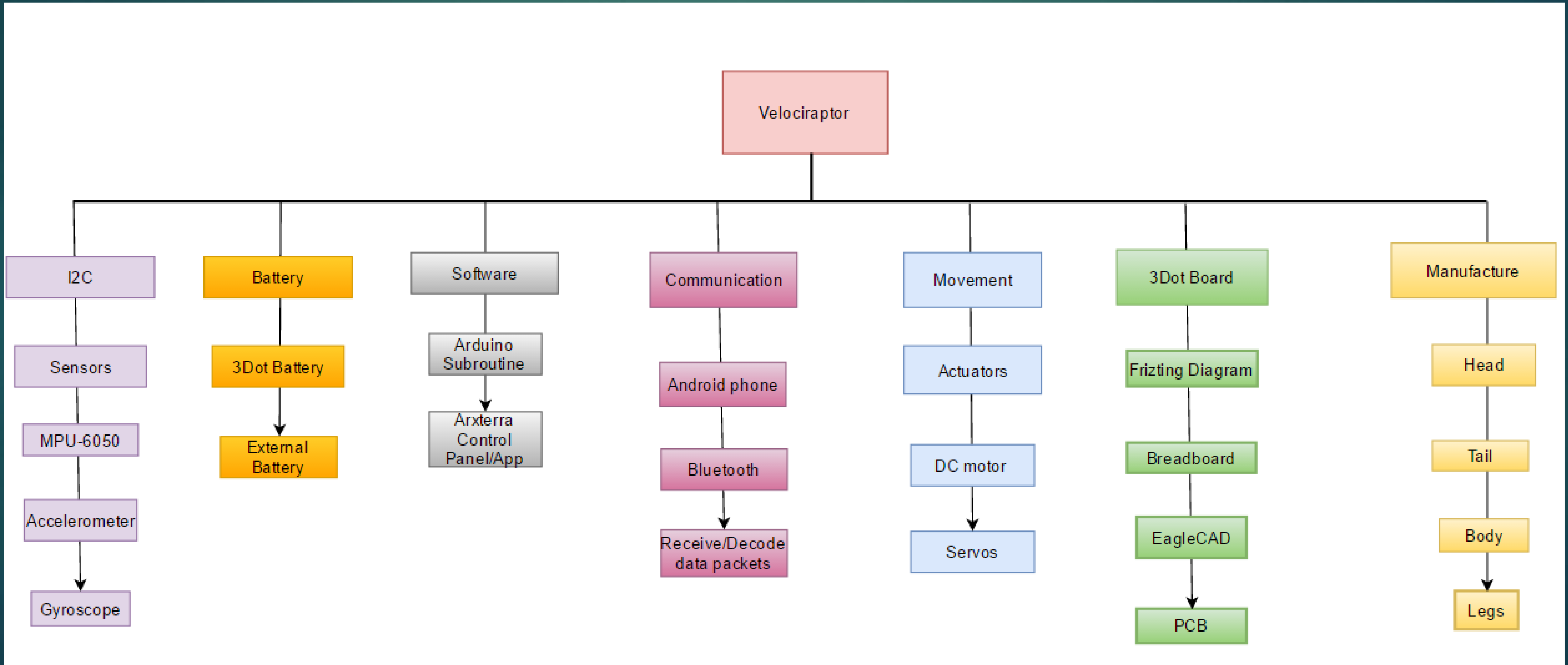
1. The velociraptor shall use a gyroscope which tracks X, Y, and Z angles and transmit input data to the MCU.
2. The velociraptor shall implement an accelerometer which tracks acceleration in the X, Y, and Z planes.
    1. The Velociraptor shall implement an IMU MPU-6050 to communicate with the I2C at a frequency rate of [to be determined] Hz. The MPU-6050 will collect input data and implement that into the control system.
3. The velociraptor shall utilize HC-06 Bluetooth to communicate with the Arxterra control panel at a maximum range of 12 feet.
4. The Velociraptor shall implement a motor controller [to be determined what kind] on the motor shield that communicates to the I2C at the frequency rate [to be calculated] Hz.
5. The velociraptor shall utilize the two servos for the head and tail through the 3DoT board.
6. The velociraptor shall use 2 batteries to power the 3DoT Board and motor shield.

Level 2 requirement continue..

1. The Velociraptor shall be able to continuously operate in game arena for minimum one hour.
2. The IMU shall send input data to the control system when encountering uneven surfaces, inclines, and declines.
3. The model of the foot [to be decided] design shall have a surface area of [to be calculated] in order to provide stability and not put stress on movement.
4. The material for the traction of foot [to be determined] shall provide enough friction on all surfaces [study to be shown] of game terrain to prevent raptor from falling over.
5. The Velociraptor shall be able to turn left or right from 0 – 360 degrees, standing on foot while not walking.

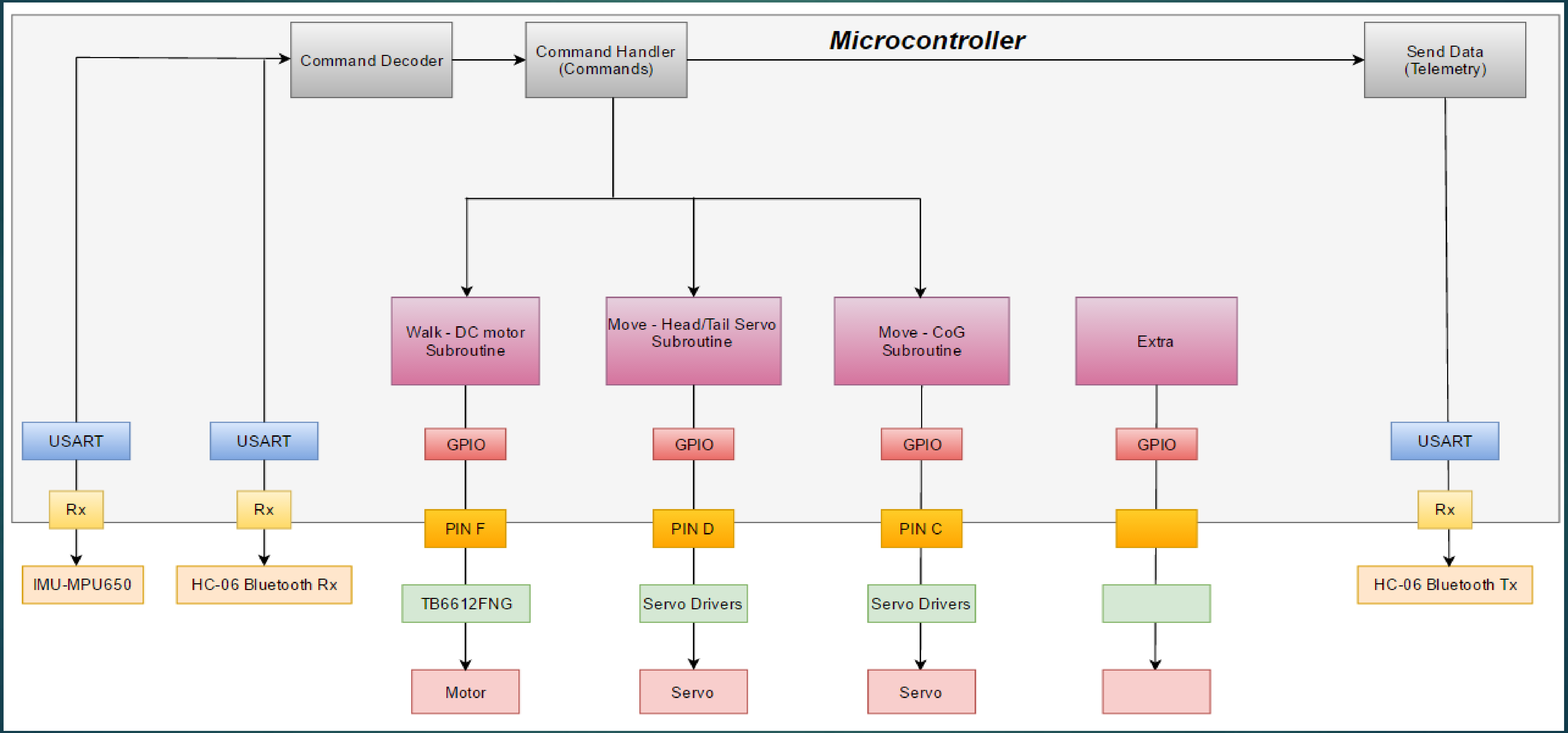
Product Breakdown Structure

- The structural of the project.



Software Design

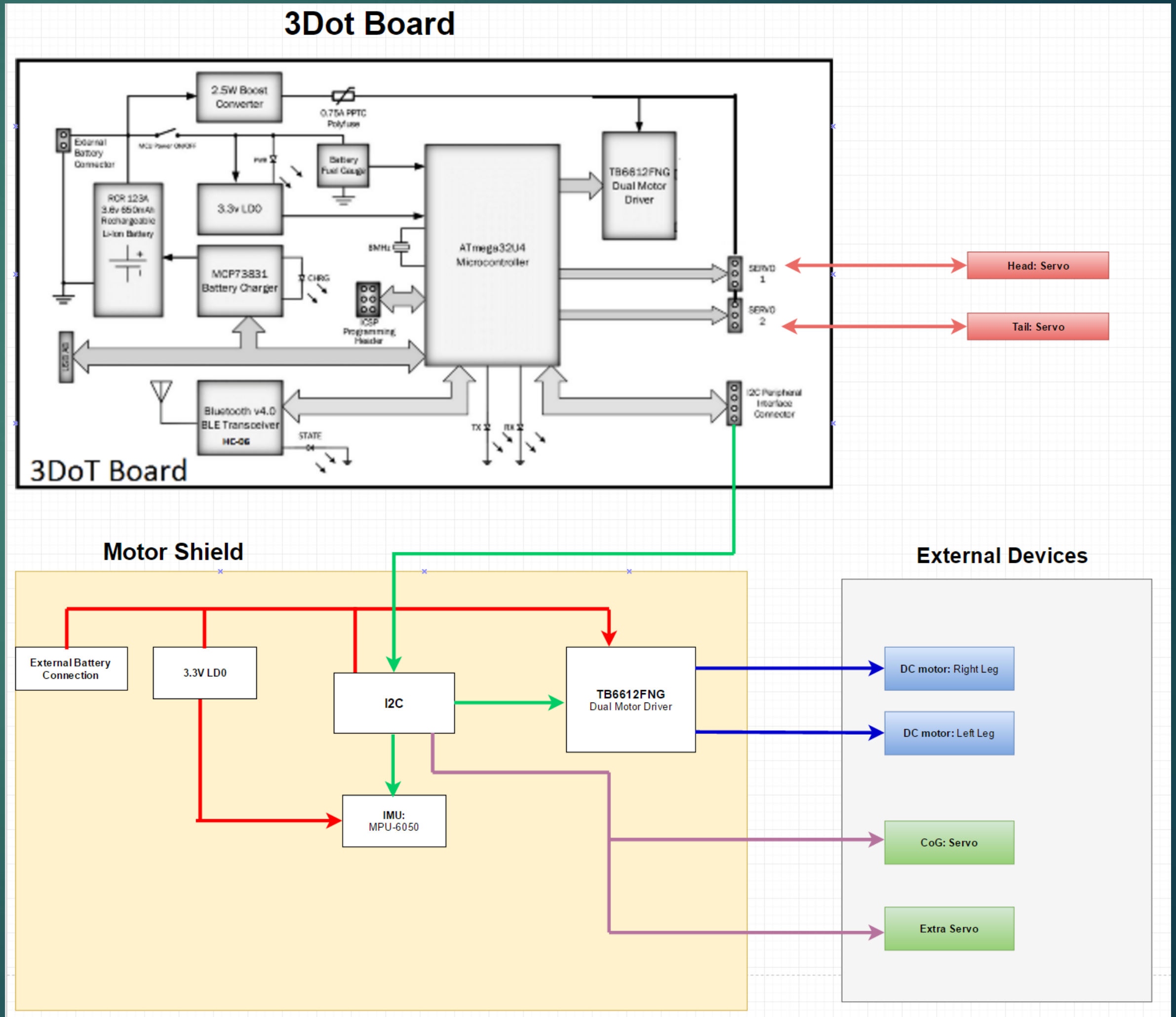
Software Block Diagram



Electronic System Design

System Block Diagram

- The 3rd servo will added through the I2C bus.



Interface Definitions

- Complete interface matrix
- The pin mapping data was collected directly from the Arduino website.

Arduino Leonardo pin mapping table			Details	
PIN #	Pin Name	Mapped Pin Name		
1	PE6 (INT.6/AIN0)	Digital pin 7		
2	Uvcc	5V		
3	D -	RD -		
4	D +	RD +		
5	UGnd	UGND		
6	Ucap	UCAP		
7	VUSB	Vbus		
8	(SS/PCINT0) PB0	RXLED		
9	(PCINT1/SCLK) PB1	SCK		
10	(PD1/PCINT2/MOSI) PB2	MOSI		
11	(PD0/PCINT3/MISO) PB3	MISO		
12	(PCINT7/0C0A/0C1C/#RTS) PB7	Digital pin 11 (PWM)		
13	RESET	RESET		
14	Vcc	5 +	Power	
15	GND	GND	Ground	
16	XTAL2	XTAL2		
17	XTAL1	XTAL1		
18	(OC0B/SCL/INT0) PD0	Digital pin 3 (SCL) (PWM)	I2C PC9685 (SCL)	(SCL1) IMU sensor
19	(SDA/INT1) PD1	Digital pin 2 (SDA)	I2C PC9685 (SDA)	(SDA1) IMU sensor
20	(RX D1/AIN1/INT2) PD2	Digital pin 0 (RX)	Bluetooth Receiver	
21	(TXD1/INT3) PD3	Digital pin 1 (TX)	Bluetooth Transmitter	
22	(XCK1/#CTS) PD5	TXLED		
23	GND1	GND		
24	AVCC	AVCC		
25	(ICP1/ADC8) PD4	Digital pin 4	Head & Tail servo	
26	(T1/#0C4D/ADC9) PD6	Digital pin 12		
27	(T0/0C4D/ADC10) PD7	Digital Pin (PWM)		
28	(ADC11/PCINT4) PB4	Digital pin 8		
29	(PCINT/OC1A/#0C4B/ADC12) PB5	Digital Pin 9 (PWM)		
30	(PCINT6/0C1B/OC4B/ADC13) PB6	Digital Pin (PWM)		
31	(OC3A/#0C4A) PC6	Digital Pin 5 (PWM)	CoG servo	
32	(ICP3/CLK0/)0C4A) PC7	Digital Pin 13 (PWM)		
33	(#HWB) PE2	HWB		
34	Vcc1	5V		
35	GND2	GND		
36	(ADC7/TDI) PF7	Analog In 0	DC motor Left Leg	
37	(ADC6/TD0) PF6	Analog In 1	DC motor Right Leg	
38	(ADC5/TMS) PF5	Analog In 2		
39	(ADC4/TCK) PF4	Analog In 3		
40	(ADC1) PF1	Analog In 4		
41	(ADC0) PF0	Analog In 5		
42	AREF	AEF		
43	GND3	GND		
44	AVCC1	AVCC		

Interface Definitions

Simplify Interface Matrix, “3Dot Board”

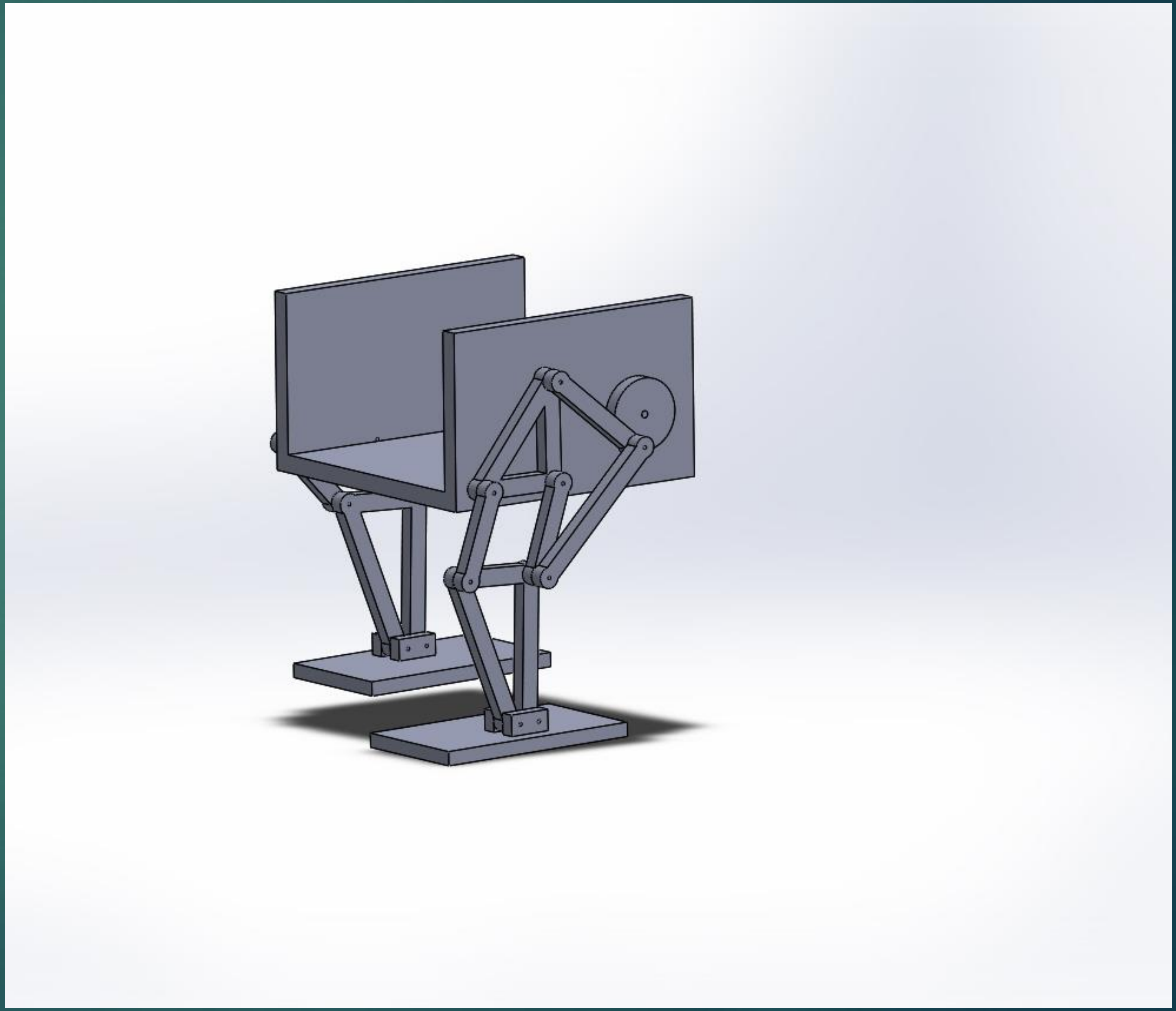
- This interface matrix is map to the 3 Dot board.
- The third servo is to be map to an I2C pin.

Interface Matrix

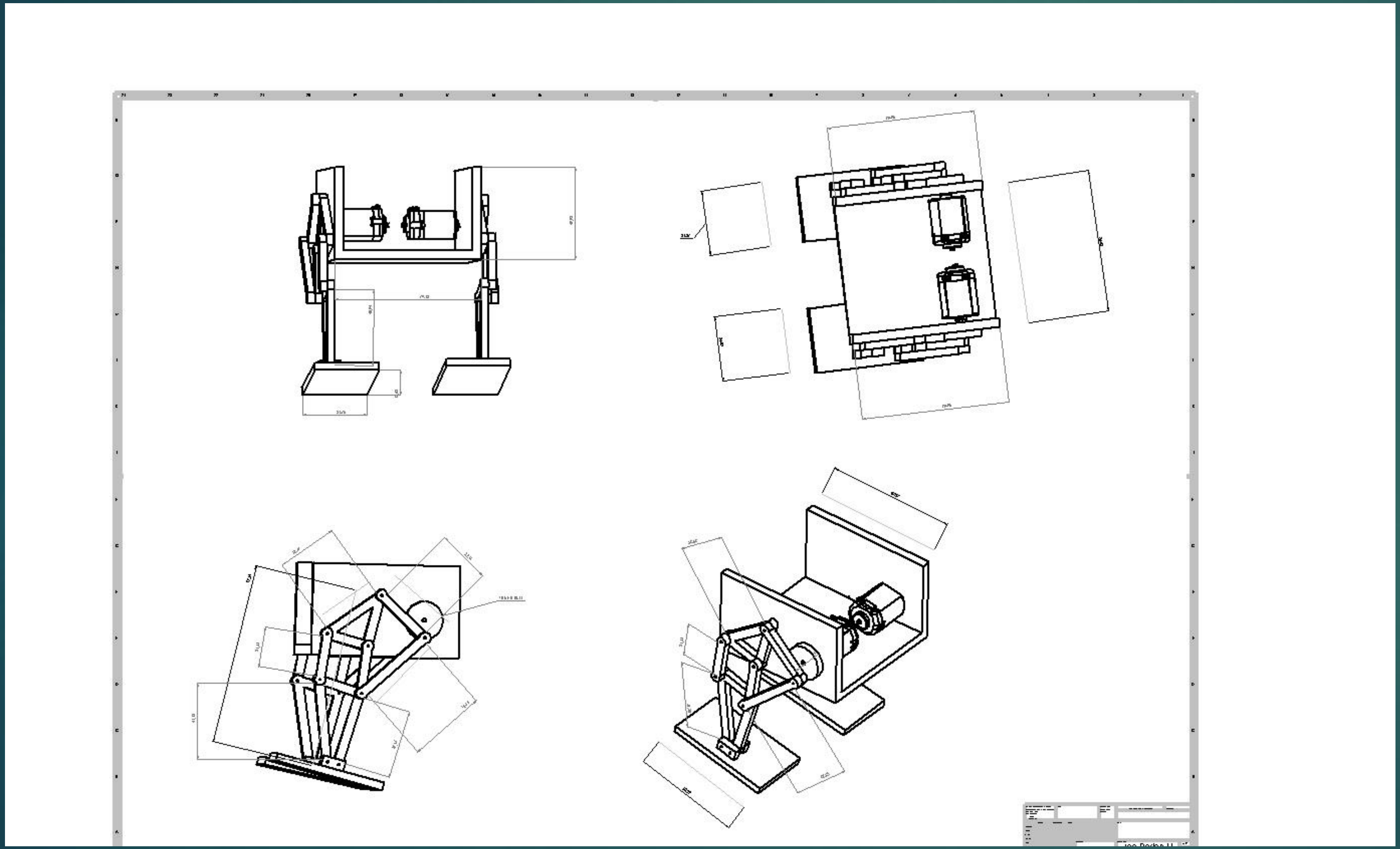
Pin #	3Dot Board	Bluetooth HC-06	IMU - MPU6050	PCA9685	GM6-1	GM6-2	HS-6	HS-645MG-2	HS-645MG-26	battery 1	baterry 2	Boost Convert	LDO
1	5V											5V	
2	3V3	3V3	3V3	3V3			3V3	3V3	3V3			3V3	3V3 OUT
3	RX	RX											
4	TX	TX											
5	I2C (SCL)		SCL	SCL									
6	I2C (SDA)		SDA	SDA									
7	Motor 1A				IN JP2-P2								
8	Motor 1B				OUT JP2-P1								
7	Motor 2A					IN JP3-P2							
8	Motor 2B					OUT JP3-P1							
10	Servo 1						IN JP7-3						
11	Servo 2							IN S1-3					
12	Servo 3								PWM				
13										3V7	3V7		3V7 IN
14													
15	GND	GND	GND	GND			GND	GND	GND	GND	GND	GND	

Mechanical Design

Complete 3D Model

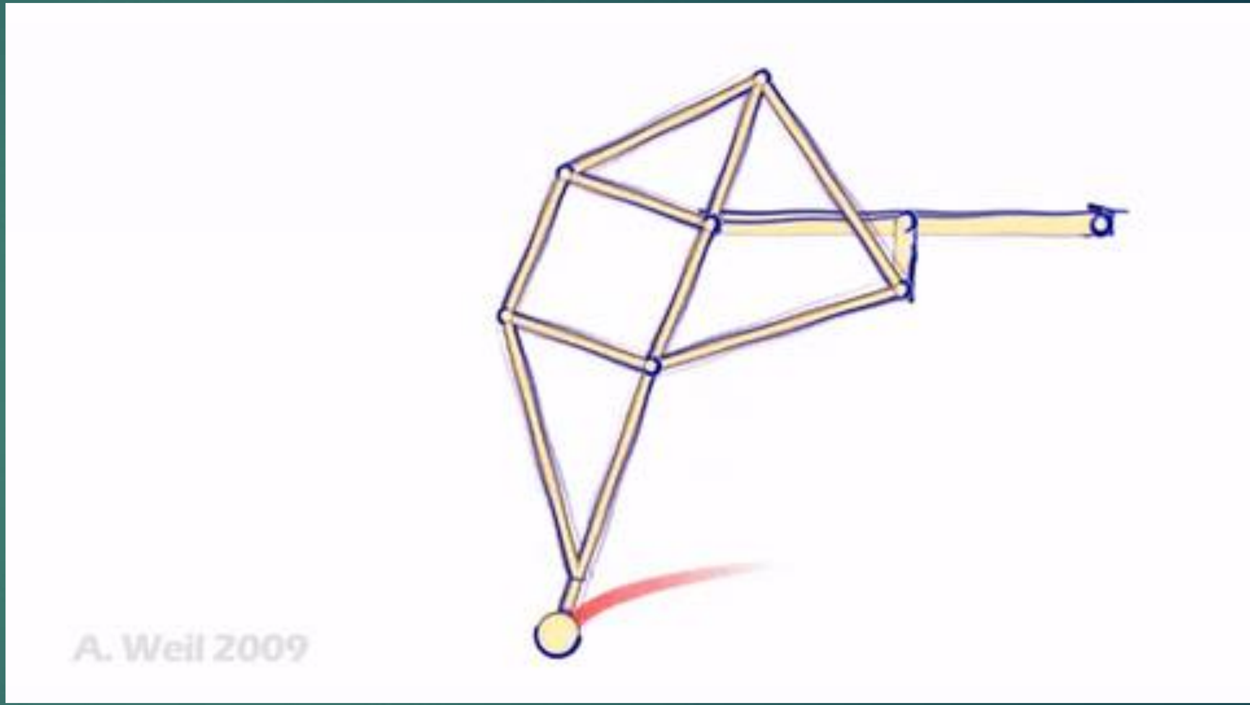


Measurements



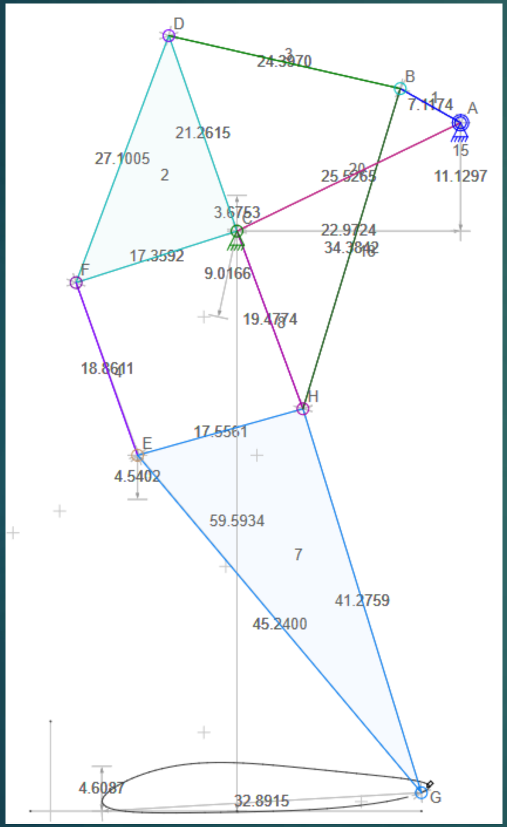
Leg Design: Theo Jansen's Linkage

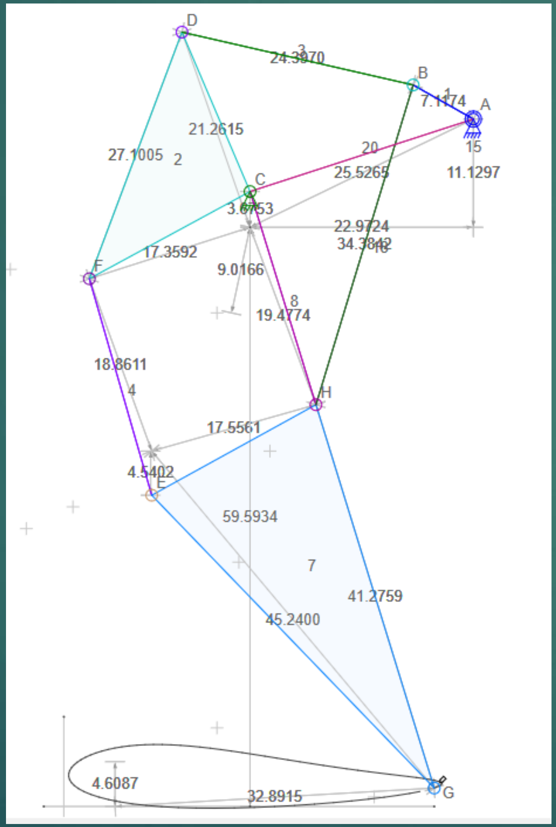
- Eight-Bar Mechanism
- Single rotation crank
- Smooth walking motion



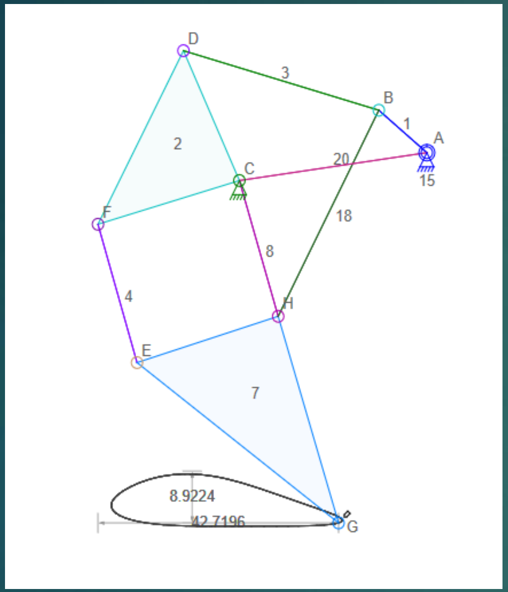
Design and Unique Tasks

Leg Design: Initial Idea

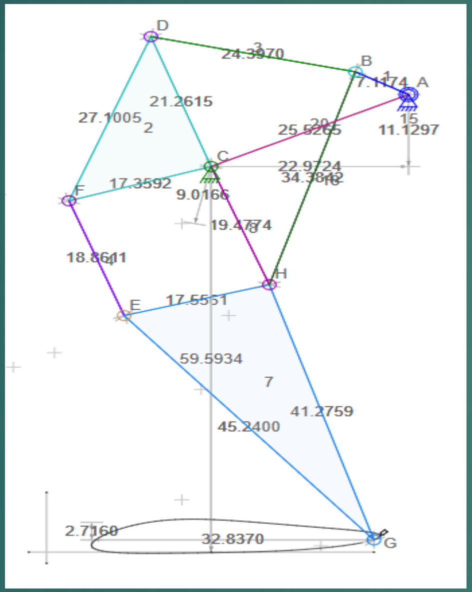




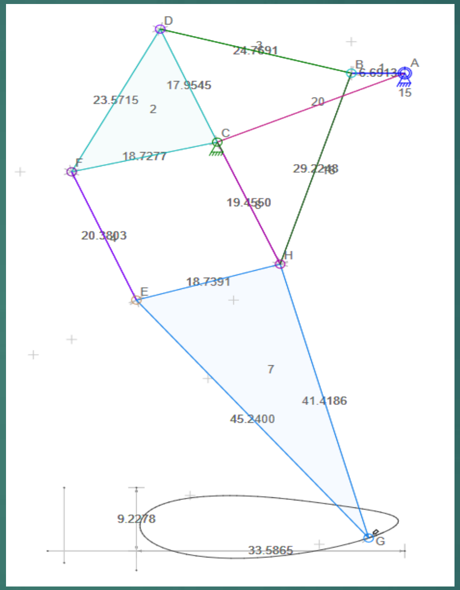
Leg Design: Current Design



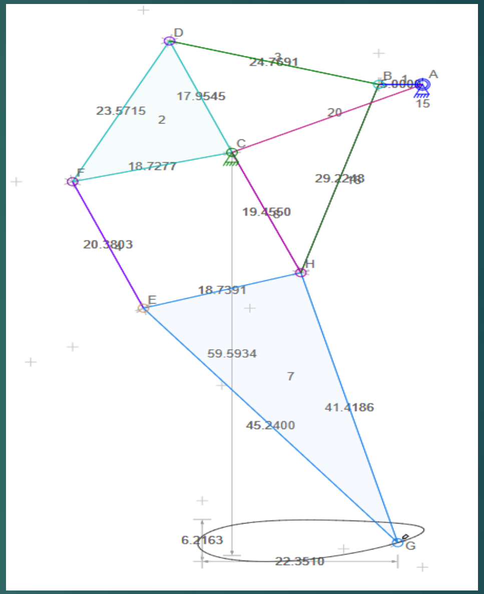
Jansen's Linkage



Leg Design v1.0

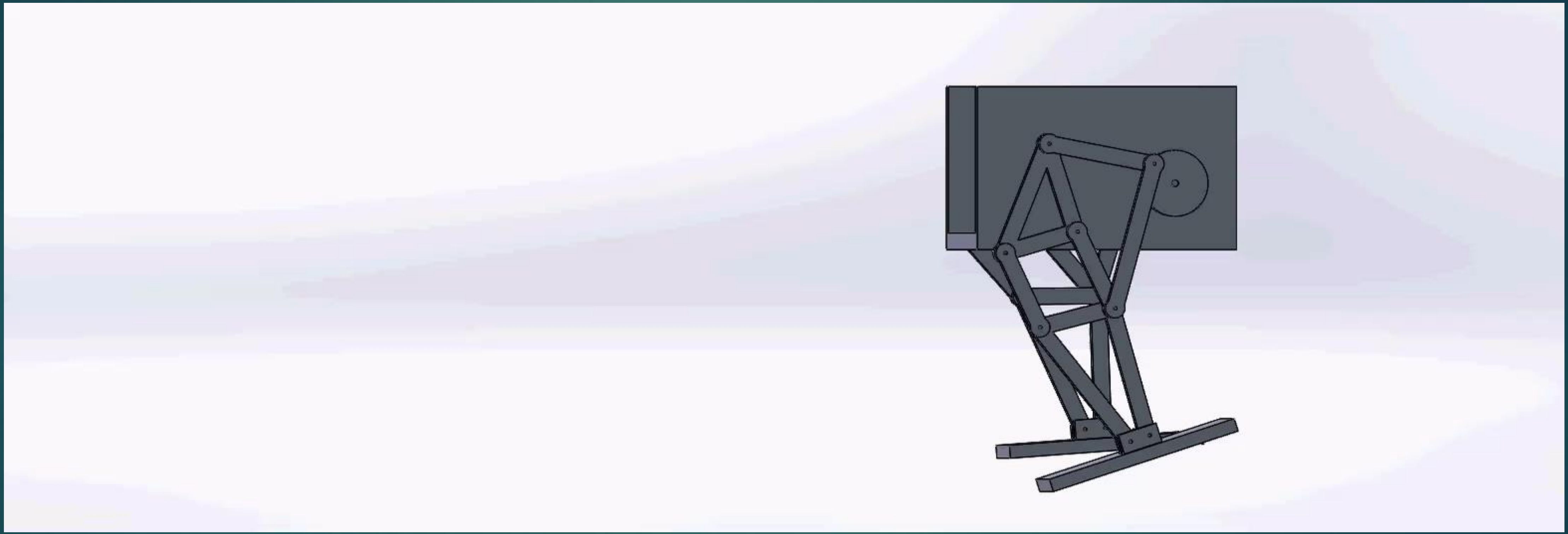


Leg Design v1.3



Leg Design v1.6

3D Model Simulation



Torque Calculations for DC Motors

Requirement: The velociraptor shall have two feet to support the full mass of the robot of 900 grams.

- Mass of the robot ~ 1kg
- Force(gravity) = Mass*g = 1kg*9.8m/s^2 = 9.8 N
- Radius of turn shaft for legs = 7mm
- Force of friction = μ*Force(gravity) = 0.5*9.8N = 4.9N
- Force(Total) = 9.8N + 4.9N = 14.7N
- Torque = 0.007m*14.7N = 0.1029 Nm = 14.6 oz-in

Speed Calculation

- Area of the terrain = 12ft x 5ft
- Time of game = 1hr
- 60ft/hr = 12 inches/min
- The velociraptor moves about 0.5 inches/step
- In order for the velociraptor to be able to navigate the entire arena, it should move at a speed of 24 steps/min = 24rpm

DC Motor Trade off Study

Requirement: The velociraptor shall have two feet to support the full mass of the robot of 900 grams.

Motor	Voltage (Volts)	Speed (RPM)	Torque (Oz-in)	Current (mA)	Weight (grams)	Price	Reference
Gear Motor 8 by Solarbotics	5	70	43	57.6 (670 stall)	32	$5.75	[1]
Gear Motor 9 by Solarbotics	5	66	43	73.2 (670 stall)	34.1	$5.25	[2]

Motor References

- [1] http://www.robotshop.com/en/solarbotics-gm8-gear-motor-8-offset.html
- [2] http://www.robotshop.com/en/solarbotics-gm9-gear-motor-9.html

Servo Calculations

- Mass of head = Mass of Tail = 150g
- Force (gravity) = (0.150 kg)*(9.8 m/s^2) = 0.0153 N
- Radius = 6 cm
- Torque = (0.0153N)*(0.06m) = 0.000918 Nm = 0.13 oz-in

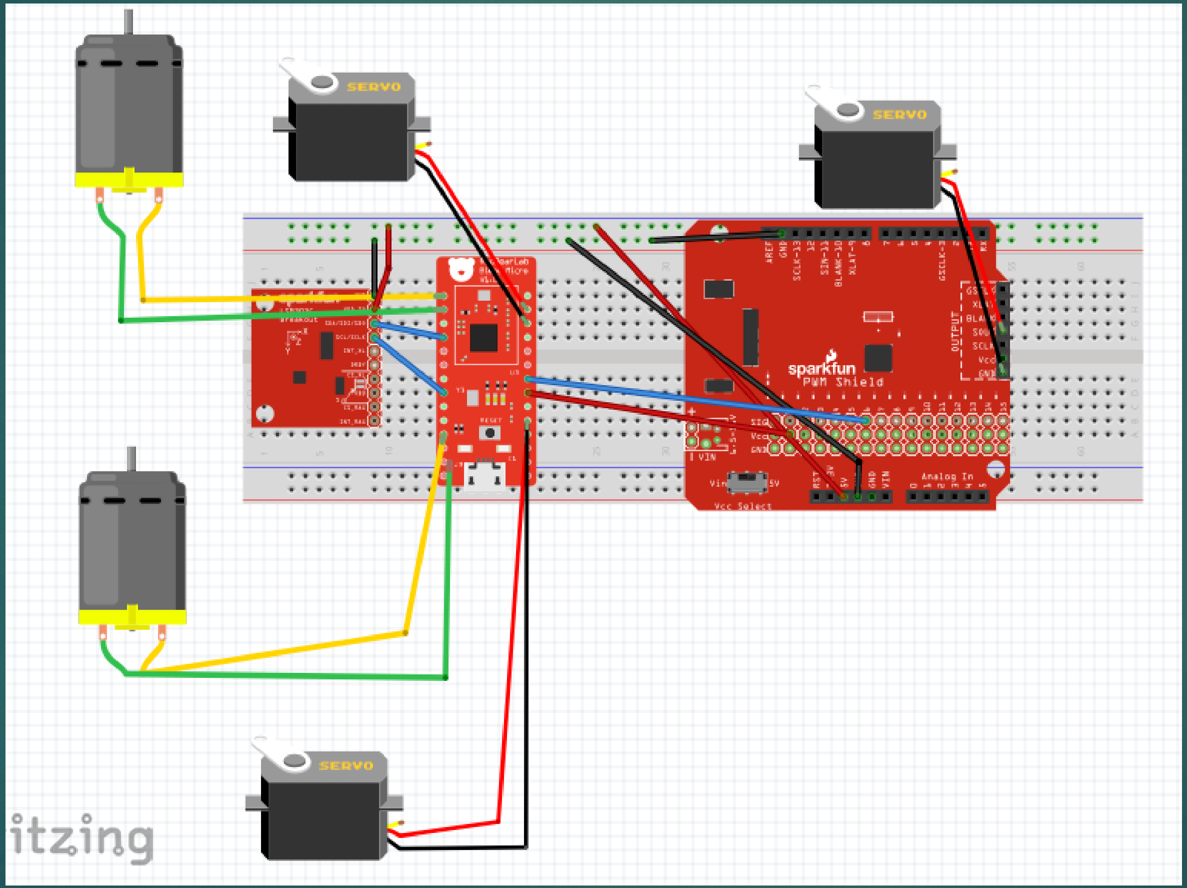
Servo Motors Requirement:

Servo	Torque (oz-in)	Weight (grams)	Speed (sec/60°)	Price	Reference
HS-422 Servo Motor	57	45.5	0.16	$9.69	[1]
HS-645MG Servo Motor	133	55.2	0.20	$28.59	[2]
HS-485HB Servo Motor	72	45	0.20	$14.99	[3]

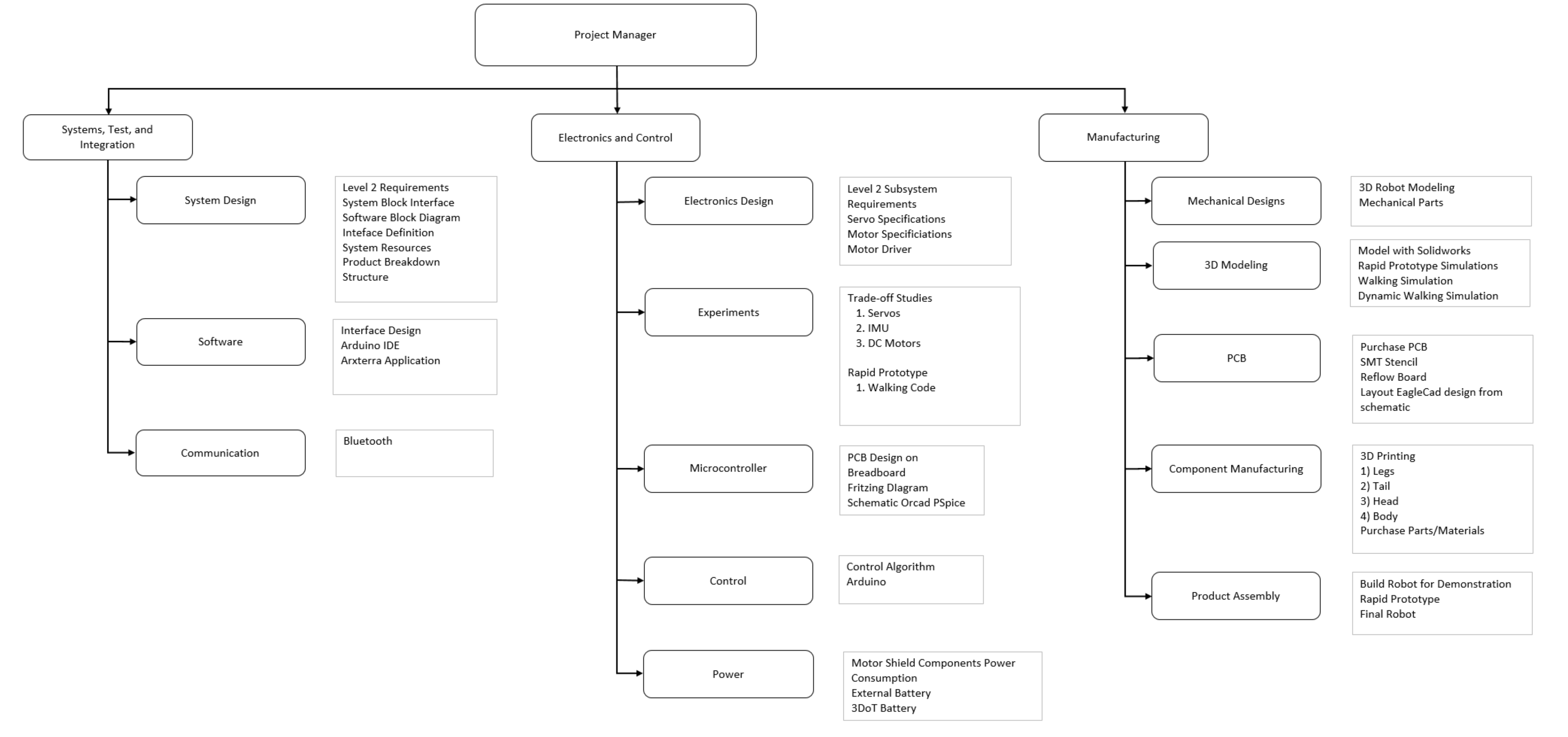
Servo references

- [1] http://www.robotshop.com/en/hitec-hs422-servo-motor.html
- [2] http://www.robotshop.com/en/hitec-hs645mg-servo-motor.html
- [3] http://www.robotshop.com/en/hitec-hs-485hb-servo-motor.html

Fritzing



Work Breakdown Structure



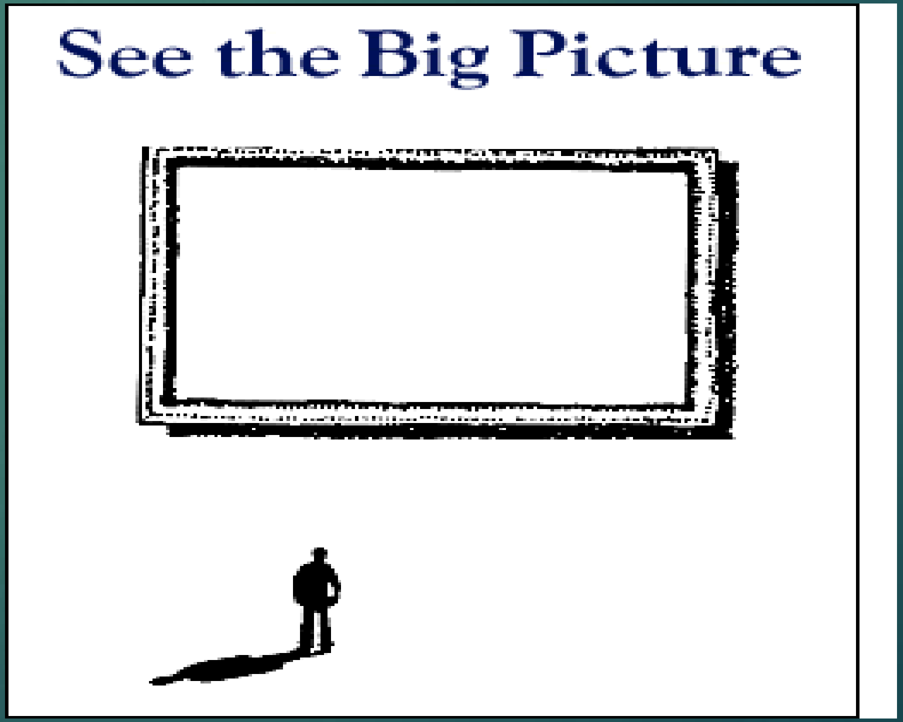
Project Schedule

Project Status

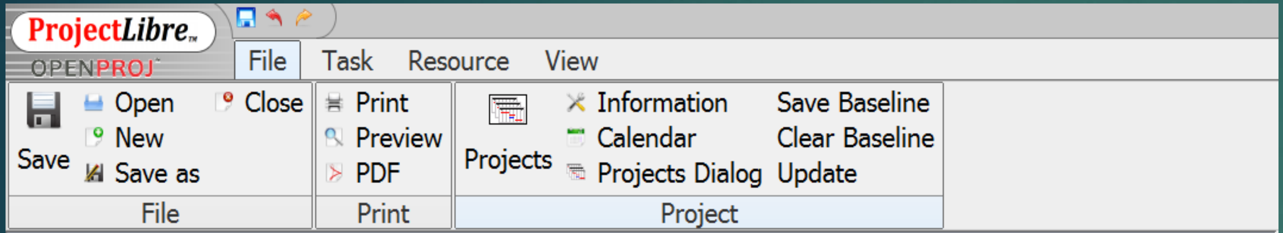
Challenges:

- Tests/Experiment
- 3D Modeling
- Simulation
- Trade Off Studies
- CDR Presentation

1. Top Level Schedule
2. System and Subsystem Level Tasks



Top Level Schedule



		Name	Duration	Start	Finish
1		⊞Project Milestones	80 days?	8/24/16 8:00 AM	12/14/16 8:00 AM
20		⊟Project	76 days?	8/31/16 8:00 AM	12/14/16 5:00 PM
21	✔	⊞Project Planning	6 days?	9/7/16 8:00 AM	9/14/16 5:00 PM
24		⊞Level 1 Requirements	33 days?	8/31/16 8:00 AM	10/14/16 5:00 PM
29		⊞Design Documentation	61 days?	9/14/16 8:00 AM	12/7/16 5:00 PM
36		⊞System	35 days?	9/8/16 8:00 AM	10/26/16 5:00 PM
48		⊟Subsystem	59 days?	9/23/16 8:00 AM	12/14/16 5:00 PM
49		⊞Electronic Design	9 days?	9/23/16 8:00 AM	10/5/16 5:00 PM
55		⊞Mechanical Design	14 days?	9/23/16 8:00 AM	10/12/16 5:00 PM
59		⊟Experiements	24 days?	9/23/16 8:00 AM	10/26/16 5:00 PM
60		⊞Trade-Off Studies	10 days?	9/23/16 8:00 AM	10/6/16 5:00 PM
65		⊞Rapid Prototyping	24 days?	9/23/16 8:00 AM	10/26/16 5:00 PM
68		⊞3D Model	11 days?	9/28/16 8:00 AM	10/12/16 5:00 PM
73		⊞Preliminary Design	10 days?	9/28/16 8:00 AM	10/11/16 5:00 PM
78		⊞Critical Design	10 days?	10/27/16 8:00 AM	11/9/16 5:00 PM
82		⊞3D-Printing	10 days?	10/12/16 8:00 AM	10/25/16 5:00 PM
87		⊞Assembly	36 days?	10/26/16 8:00 AM	12/14/16 5:00 PM
90		⊞Purchase components	16 days?	11/10/16 8:00 AM	12/1/16 5:00 PM
93		⊞Demonstration	36 days?	10/26/16 8:00 AM	12/14/16 5:00 PM

System and Subsystem Level Tasks

System Engineer (Hal Vongsahom)

- Learn C++ programming language for the 3DoT board
- Generate system resource report (Mass, Power, Cost)
- Continue refining level 2 system requirements
- Verification and Validation test plan

Electronic & Controls (Taylor Farr)

- Research servo, motor specification and conduct a trade off study
- Research power subsystem requirements
- Generate Fritzing diagram
- Circuit schematic in Eagle CAD

System and Subsystem Level Tasks (continued)

Manufacturing & Design Engineer (Aaron Choi)

- Complete the 3D Model of the Velociraptor on Solidworks
- Simulate the walking movement on Solidworks
- Coordinate with E&C for PCB design

Burn Down and Project Percent Completion

Power report

- All the data was collected from the manufacture website except for the 3Dot board. Data for 3Dot was collected from measurement of last semester.
- The servo and DC motor will consume the most Amps.

Power Report

Resource	Quantity	Minimum Current Draw (mA)	Maximum Current Draw (mA)	Measured Current Usage (mA)	uncertainty (%)	Margin(±mA)	
Servos (HS-645MG)	3	18.2	1350		25%	270	
Accelormeter/Gyroscope (MPU6050)	1	0.115	3.9		20%	0.2	
I2C (PCA-9685)	1	6	10		20%	5	
3Dot Board	1	20	200		20%	40	
DC motor (RM2)	2	155	900		25%	200	
Project Allocation							4000 mAh
Total Margin							515.2 mA
Total Expected Current Consumption							2463.9 mA
Contingency							2051.3 mA

Mass Report

- The weight of the frame will weigh the most.
- The second contributor to weight are the three servos.

Mass Report							
Resource	Quantity	Indidvidual Weight (g)	Expected Weight (g)	Actually Weight (g)	uncertainty (%)	Margin(±g)	(g)
Servos (HS-645MG)	3	55	165		25%	20	
Accelormeter/Gyroscope (MPU6050)	1	3	8.5		15%	5	
I2C (PCA-9685)	1	5.5	5.5		20%	5	
3Dot Board	1	15	15		5%	5	
DC motor (GM6)	2	18	36		20%	20	
Battery (CR123A/16340/2000mA)	2	8.5	17		20%	20	
Frame (body, head, tail,legs)	1	450.9	450.9		25%	50	
Threaded Rod		50	50		15%	10	
Project Allocation							900
Total Margin							155
Total Expected Weight							747.9
Contingency							307.1

Cost Report

- The most expensive item will be the frame.
- The prototype will cost as much as the frame.
- The 3 servo is the 3rd expensive component.

Cost Report

Resource	Quantity	Expected Cost ($)	Actual Cost ($)	Uncertaintty (%)	Margin(±$)	($)	Source
Servos (HS-645MG)	3	45		25%	8		Robotshop.com
Accelormeter/Gyroscope (MPU6050)	1	4		20%	6		Newegg.com
I2C (PCA-9685)	1	15		25%	6		Adafruit.com
3Dot Board	1	Included	Included	0%			G. Hill
DC motor (GM6)	2	5.75		25%	8		Polulu.com
Battery (CR123A/16340/2000mA)	2	16		20%	10		Ebay.com
PCB Printing		40		25%			Arxterra.com
Prototype	1	47		25%	10		Arxterra.com
Frame (body, head, tail)	1	47		25%	10		Arxterra.com
Threaded rod	1	5		25%	5		Grainger.com
Project Allocation						400	
Total Margin						63	
Total Expected Cost						224.75	
Contingency						238.25	

Resource Report Resources

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