Payload Stabilization System

Team 517

April 2, 2019

Team Introductions

FAMU-FSU College of Engineering

Ariel Mathias
Team Lead &
Controls Engineer

Junyi Wang
Mathematician

John Bryant
Programmer

Tristan Kirby
CAD Engineer

Anthony Wyrick
Systems Engineer

Sponsor & Academic Advisor

Thank you to our sponsor, Northrop Grumman, for their contributions to the project. We're grateful for their support of engineering pursuits at FAMU-FSU College of Engineering.

Thank you to our academic advisor, Dr. Camilo Ordonez, for his knowledge and expertise on the project.

Ariel Mathias

Objective

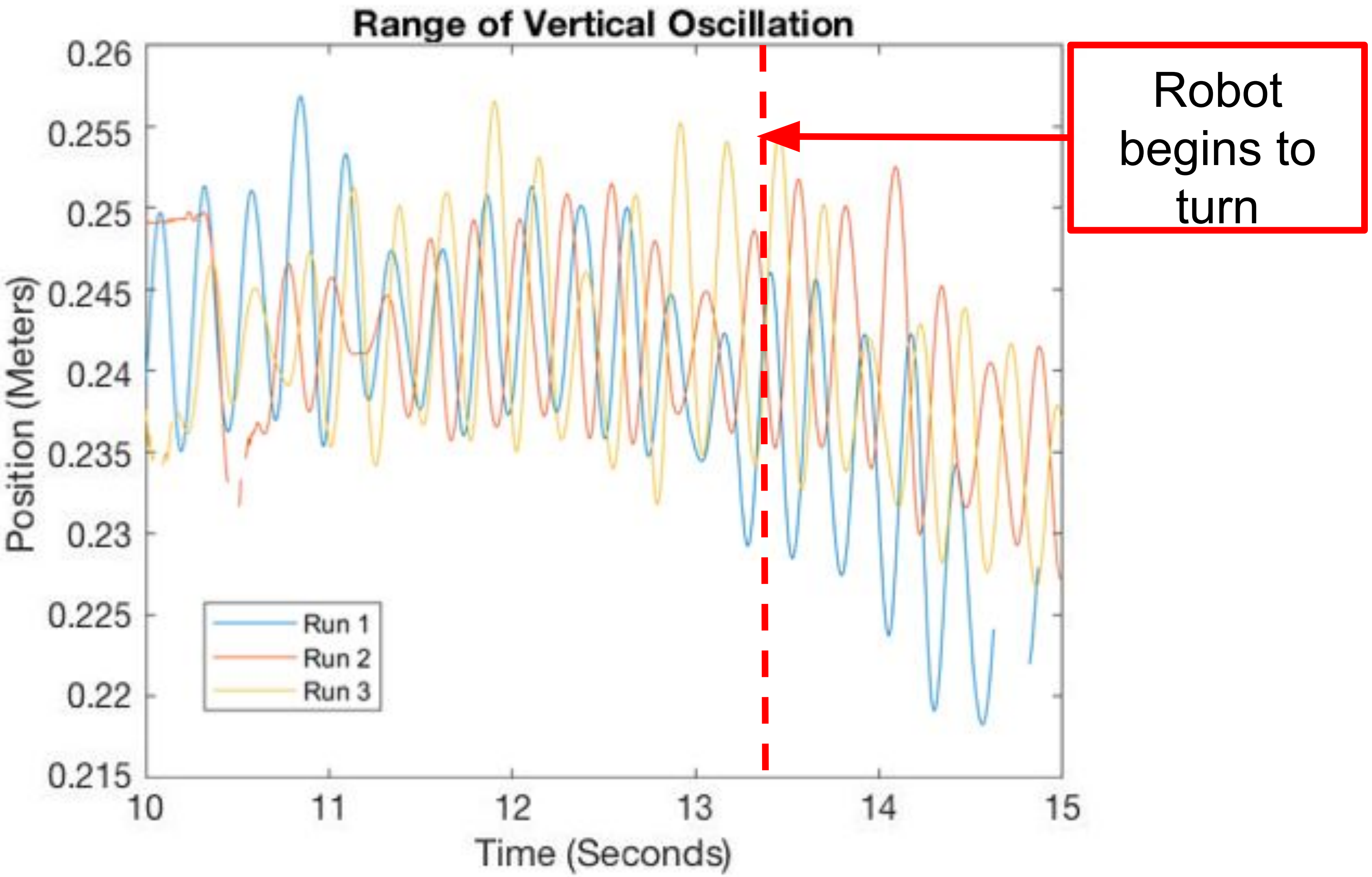
Build a system that stabilizes the payload of legged robots

Ariel Mathias

Minitaur in Motion

Ariel Mathias

Baseline Data



Project Background

Ariel Mathias

Customer Needs

- Improved system for payload stabilization
- Provide better return data
- Utilize a pre-existing robot as a baseline for data
- Reduce the levels of oscillation in the feedback of a system that occur at the center of the robot's mass

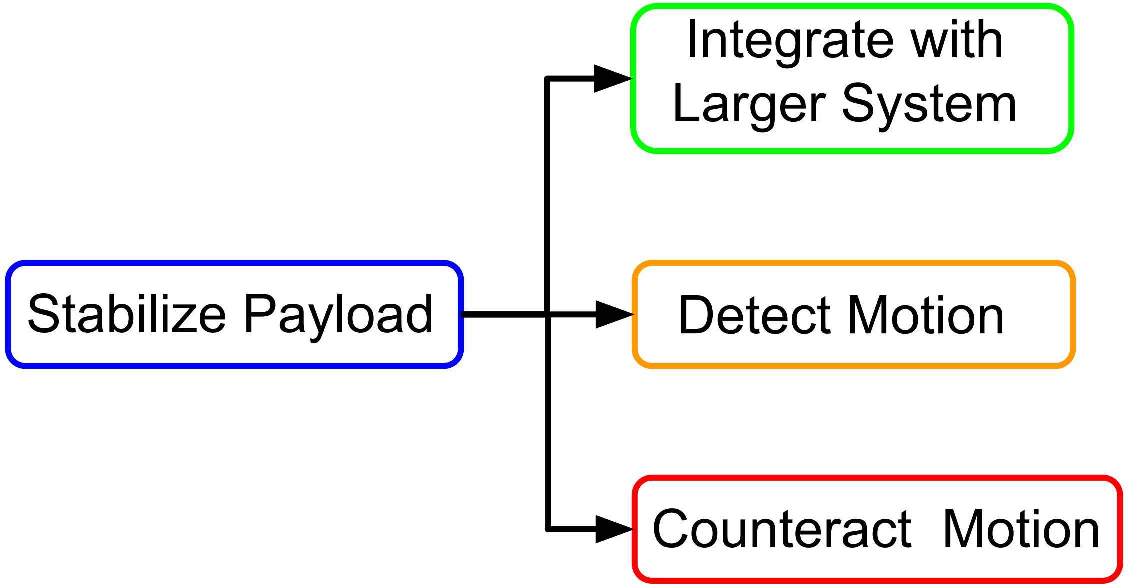
Ariel Mathias

Functional Decomposition

Stabilize Payload

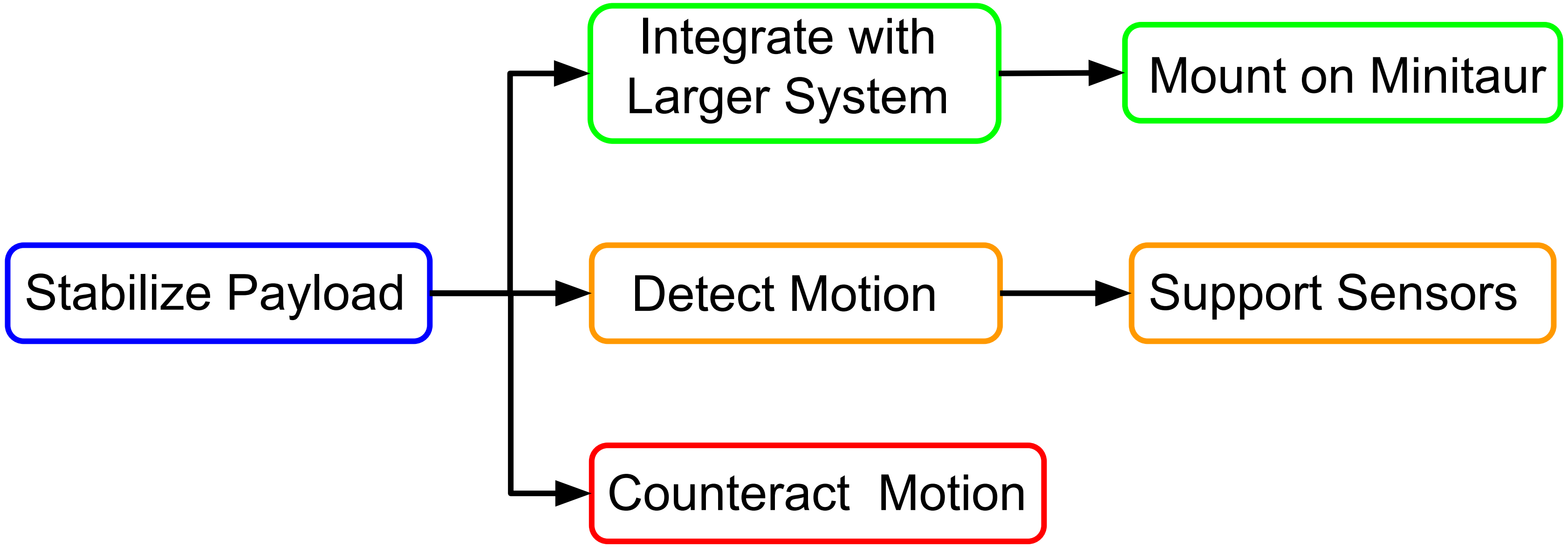
Ariel Mathias

Functional Decomposition



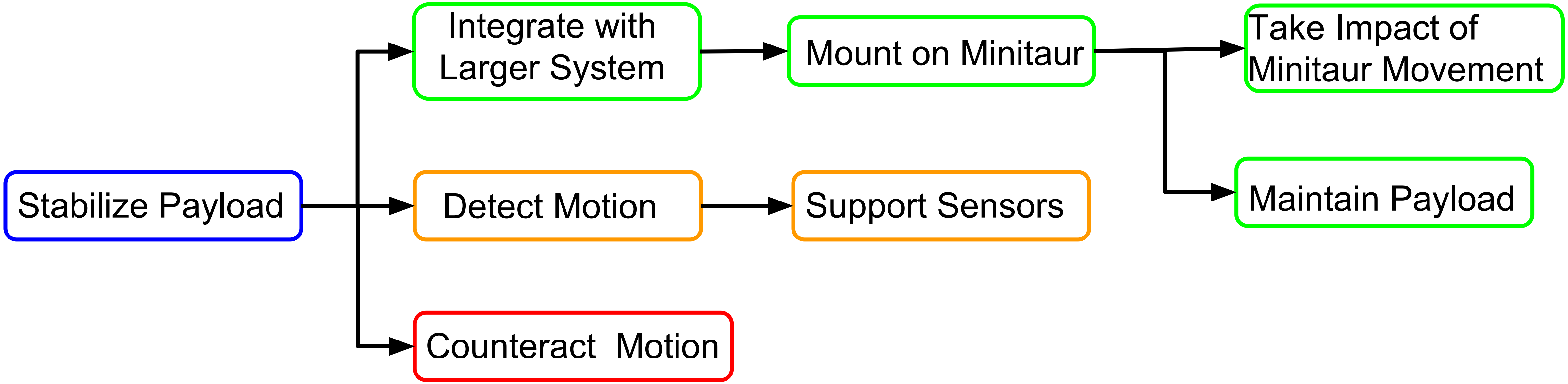
Ariel Mathias

Functional Decomposition



Ariel Mathias

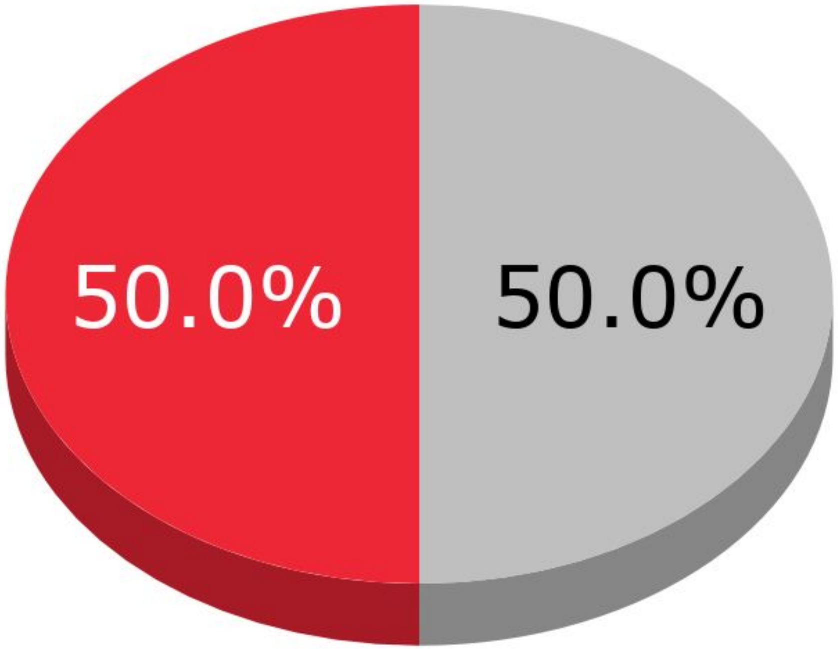
Functional Decomposition



Ariel Mathias

Targets and Metrics

Minimum Correction Factor



Maximum System Weight

Ariel Mathias

Concepts

Tristan Kirby

Concept Generation

	Concept 1
Description	4 servo motors to correct x,y,z and angle
Pros	fast, effective
Cons	heavy

Tristan Kirby

Concept Generation

	Concept 1	Concept 2
Description	4 servo motors to correct x,y,z and angle	telescoping linkage to adjust y position
Pros	fast, effective	simple, lightweight
Cons	heavy	limited effectiveness

Tristan Kirby

Concept Generation

	Concept 1	Concept 2	Concept 3
Description	4 servo motors to correct x,y,z and angle	telescoping linkage to adjust y position	linear actuators for 2 degrees of correction
Pros	fast, effective	simple, lightweight	lightweight
Cons	heavy	limited effectiveness	slow

Tristan Kirby

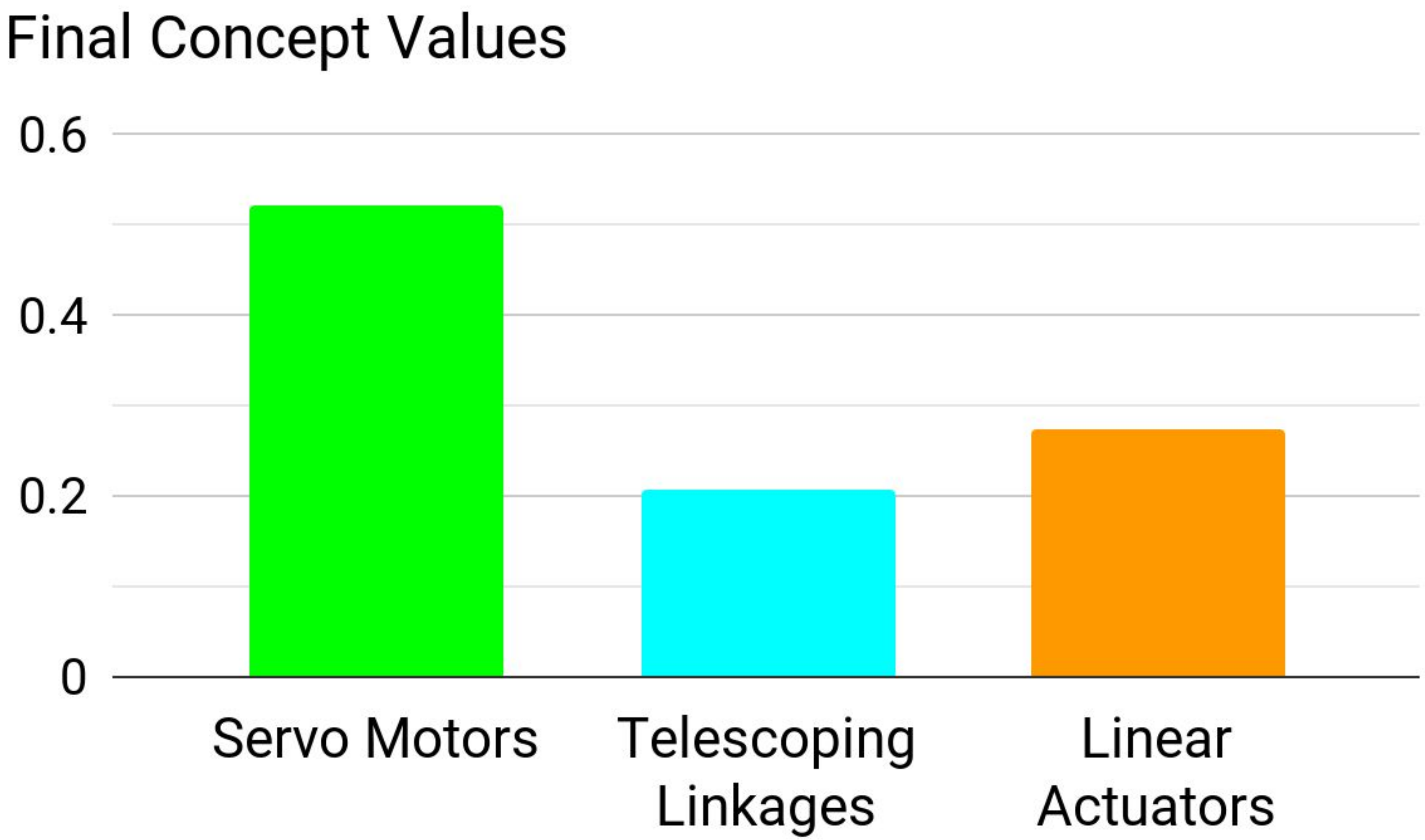
Concept Selection: Process

- House of Quality - compare customer requirements with engineering characteristics to find engineering characteristics with the highest weight

- Analytical Hierarchy Process - compare rating of each concept to each engineering characteristic to determine most effective concepts

Tristan Kirby

Concept Selection: Winner



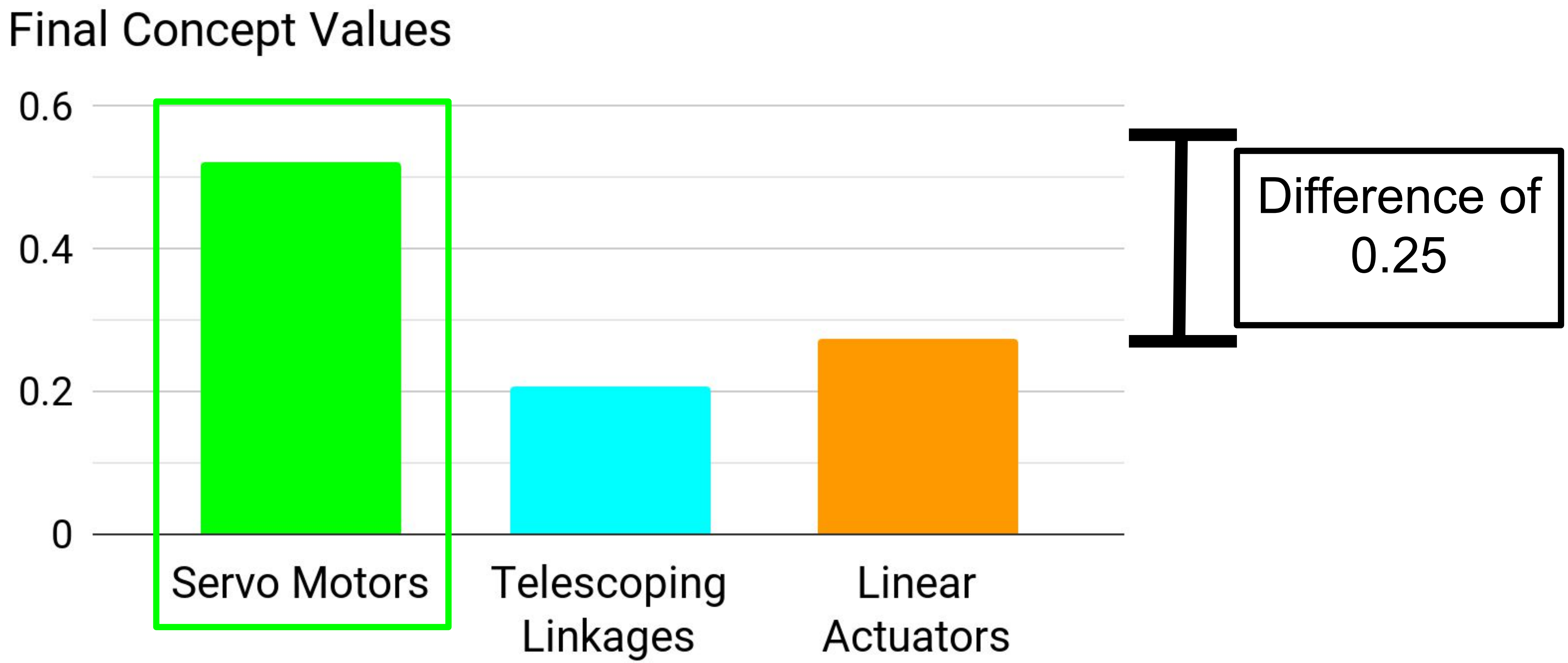
4 servo motors to correct x,y,z and angle

telescoping linkage to adjust y position

linear actuators for 2 degrees of correction

Tristan Kirby

Concept Selection: Winner



4 servo motors to correct x,y,z and angle

telescoping linkage to adjust y position

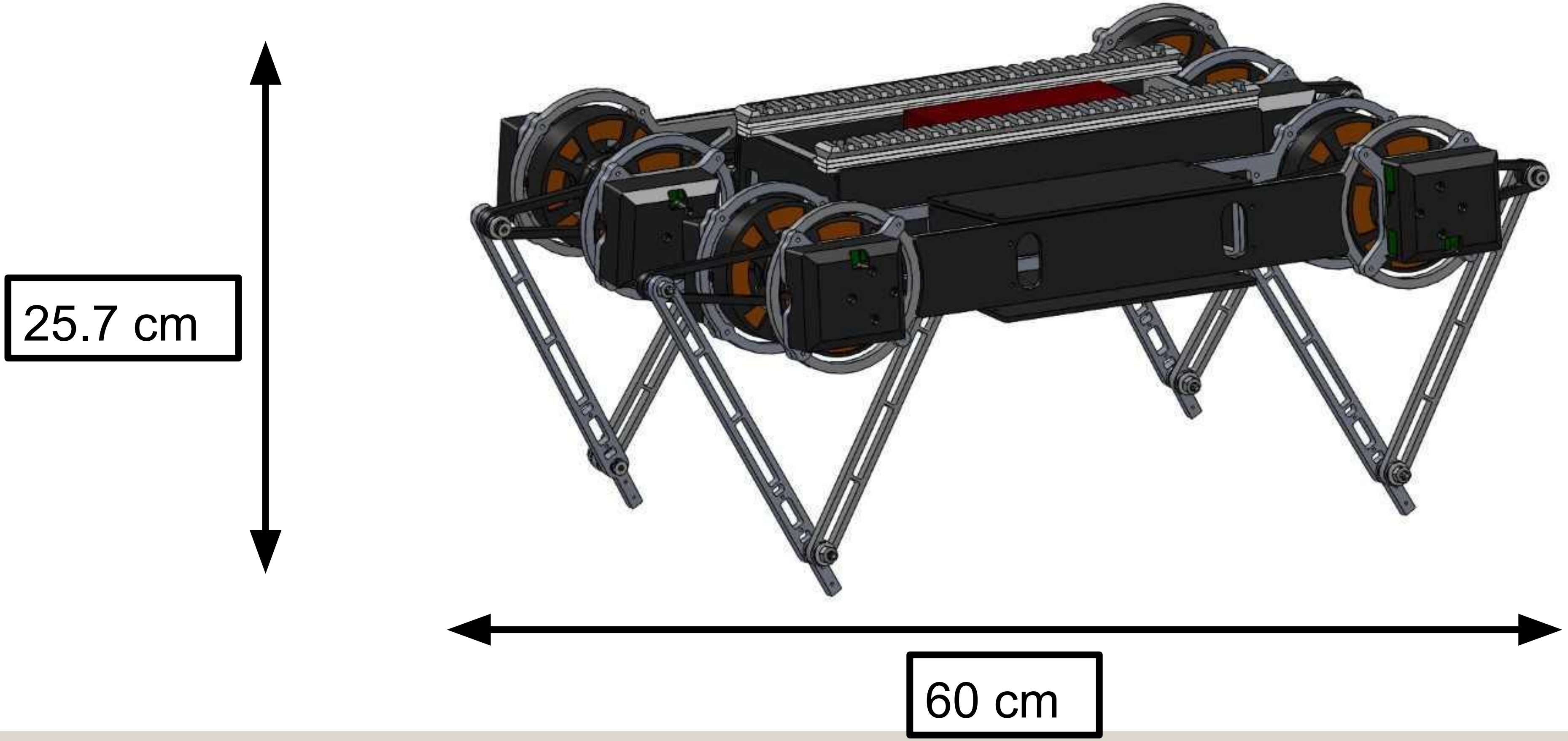
linear actuators for 2 degrees of correction

Tristan Kirby

Embodiment

Tristan Kirby

CAD: Minitatur



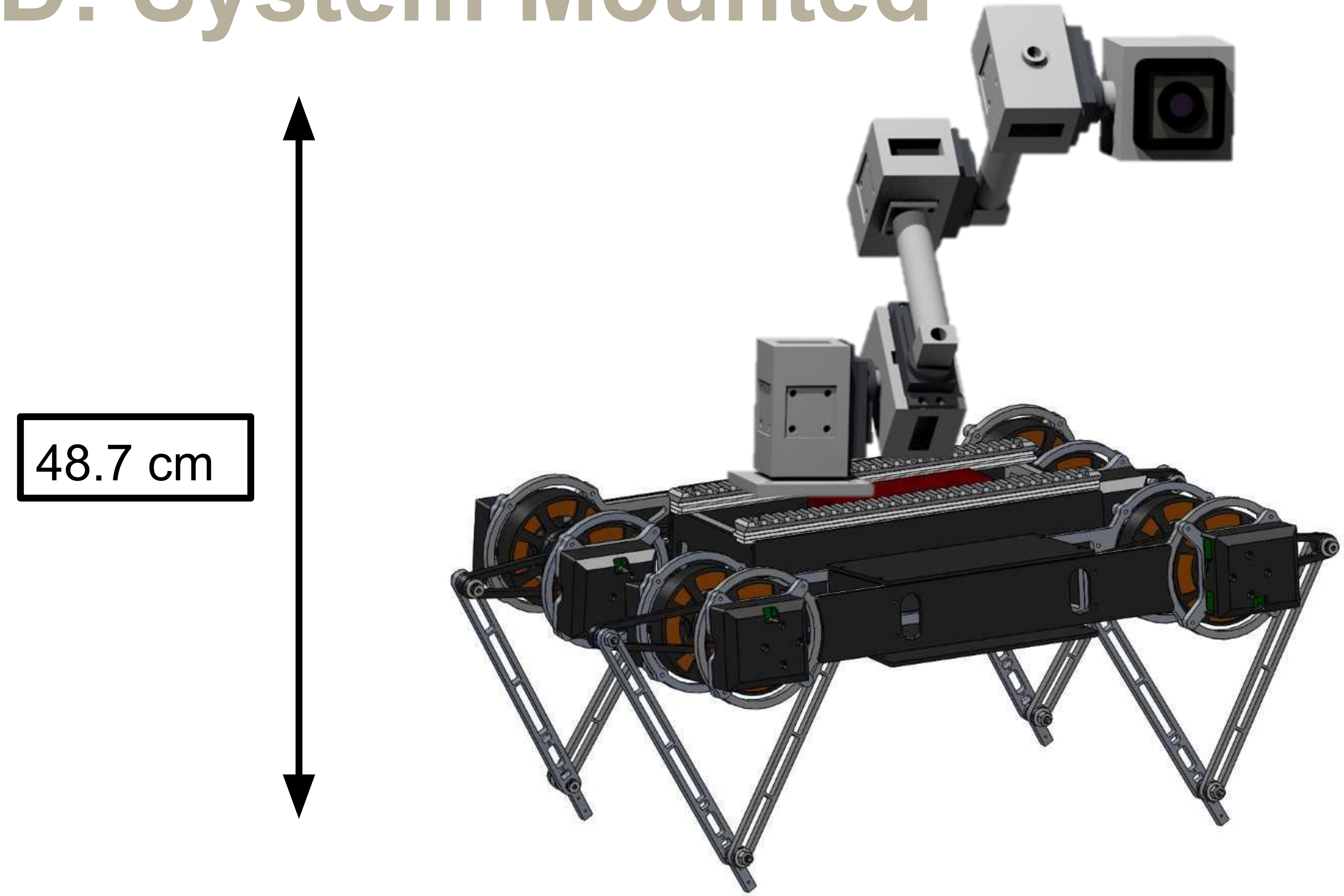
Tristan Kirby

CAD: Stabilization System

23 cm
Fully Extended

Tristan Kirby

CAD: System Mounted



Tristan Kirby

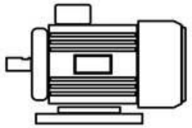
Design Analysis

- Weight of 1 motor : 55g

- Weight of camera : 73g

- Length of one Linkage: 10 cm
  - Weight is negligible

- Motor Stall Torque at 6V: 12kg x cm



Torque = 55g x 10cm + (73g +55g) x 20cm = 3.11kg x cm

<<12 kg x cm

Tristan Kirby

Manufacturing

Anthony Wyrick

Round 1

3D Print

Figure 1. 3D printed linkages.

Figure 2. Servo motor in motor in 3D printed motor mount.

Anthony Wyrick

Round 1

3D Print

Figure 1. 3D printed linkages.

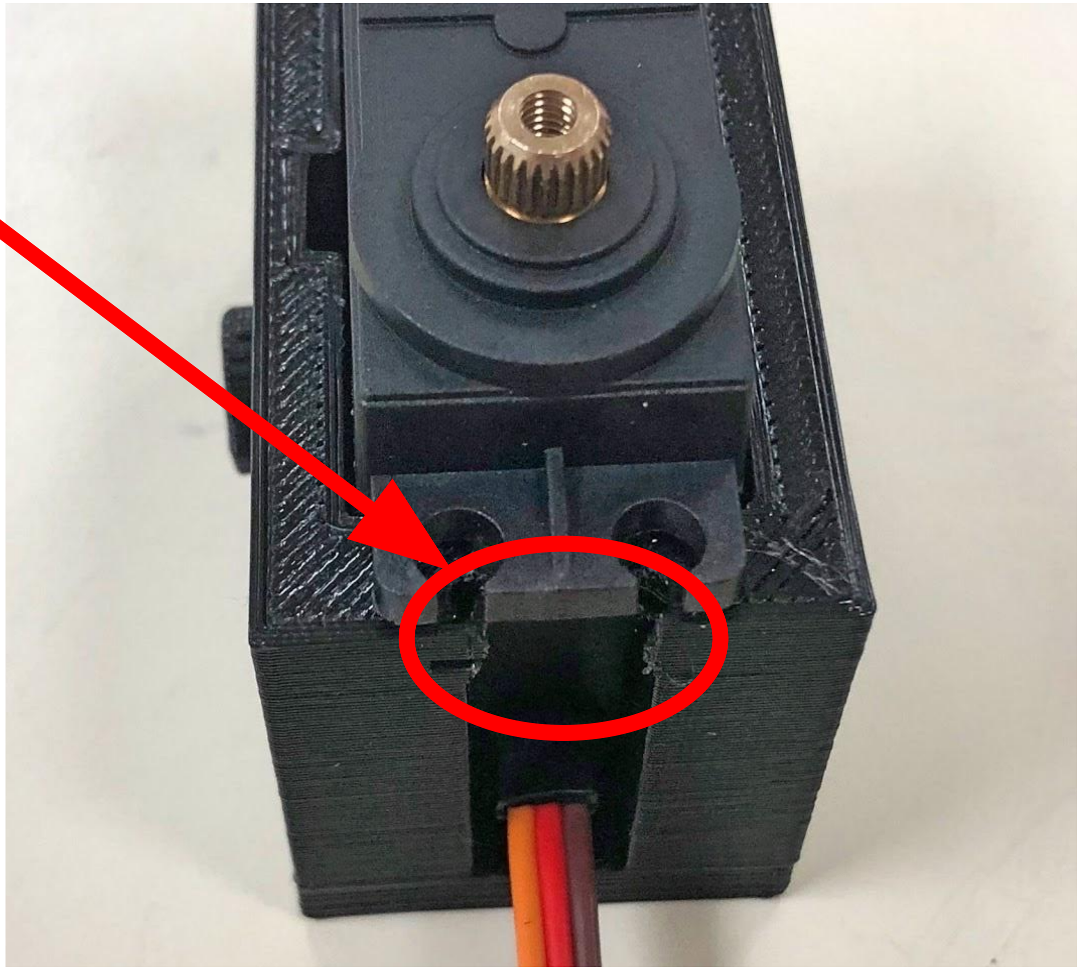
Figure 2. Servo motor in motor in
3D printed motor mount.

Anthony Wyrick

Round 1

3D Print

Space for wires cut with knife



Anthony Wyrick

Round 1

3D Print: Failures

- Tolerances too tight
- Servo motors can’t slide into housing because of wiring
- Motor housing walls too thick
- Round tops of linkages difficult to fit into motor mounts

Anthony Wyrick

Round 2

3D Print

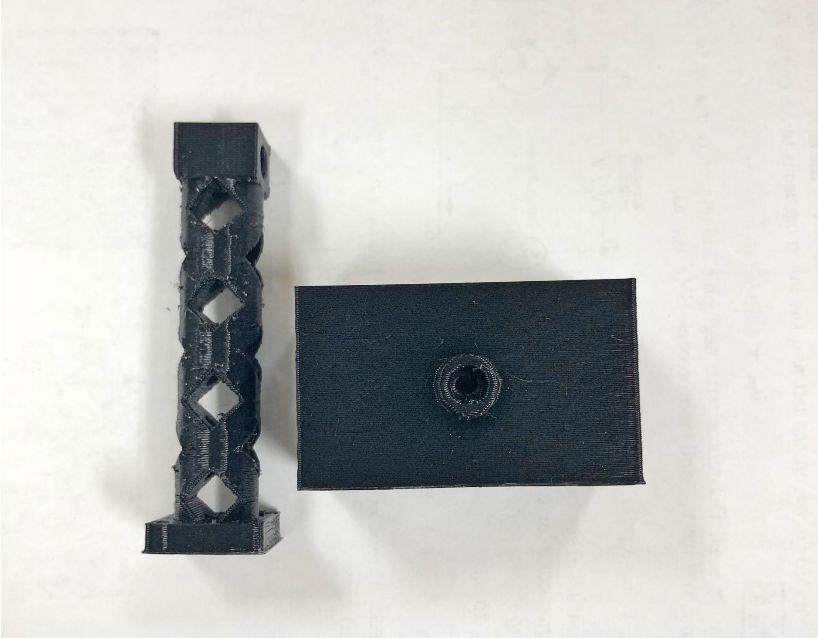


Figure 1. 3D printed linkage and motor mount, round 2.

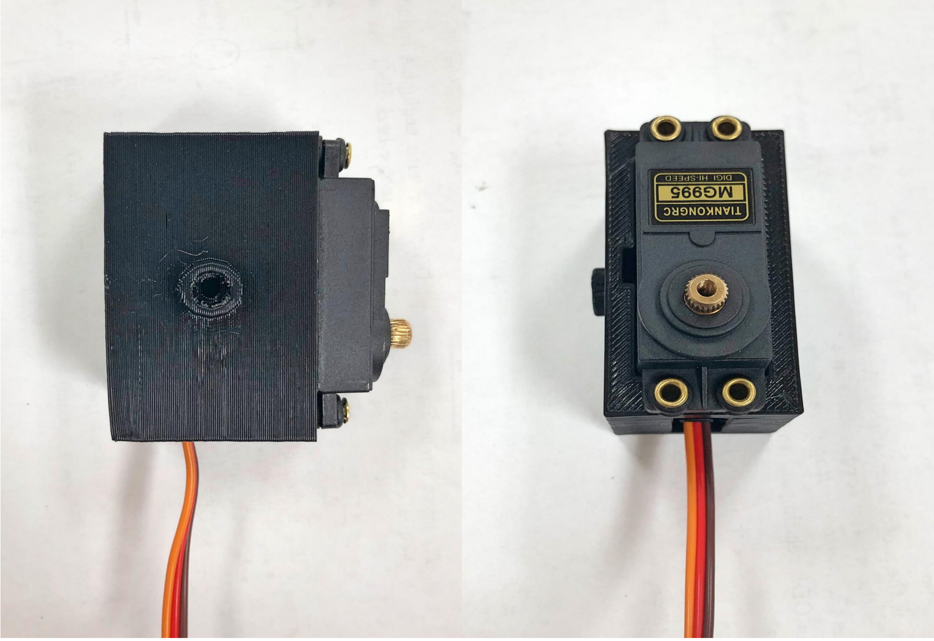


Figure 2. 3D printed motor mount with servo motor, round 2.

Anthony Wyrick

Round 2

3D Print

- Motor mounts fit
- One of the linkages snapped early in assembly
- The other snapped shortly during attachment
  - Redesign and reprint

Figure 1. Broken linkage next to non-broken linkage.

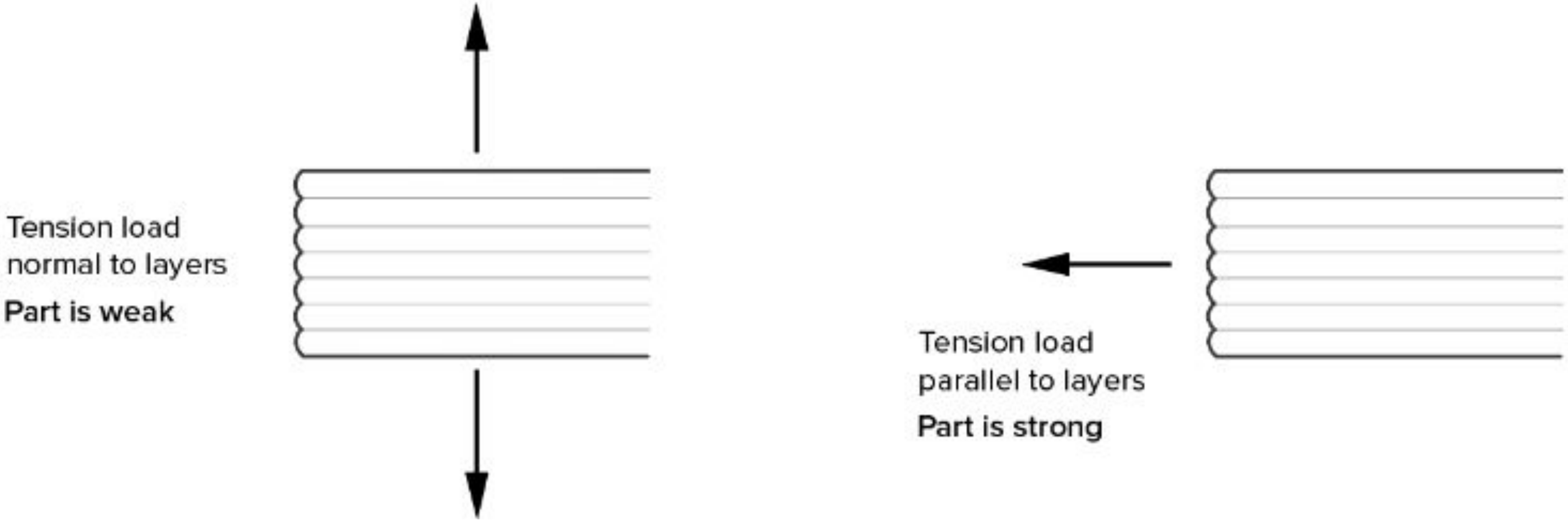
Figure 2. Second broken linkage attached to motor mount.

Anthony Wyrick

Round 3

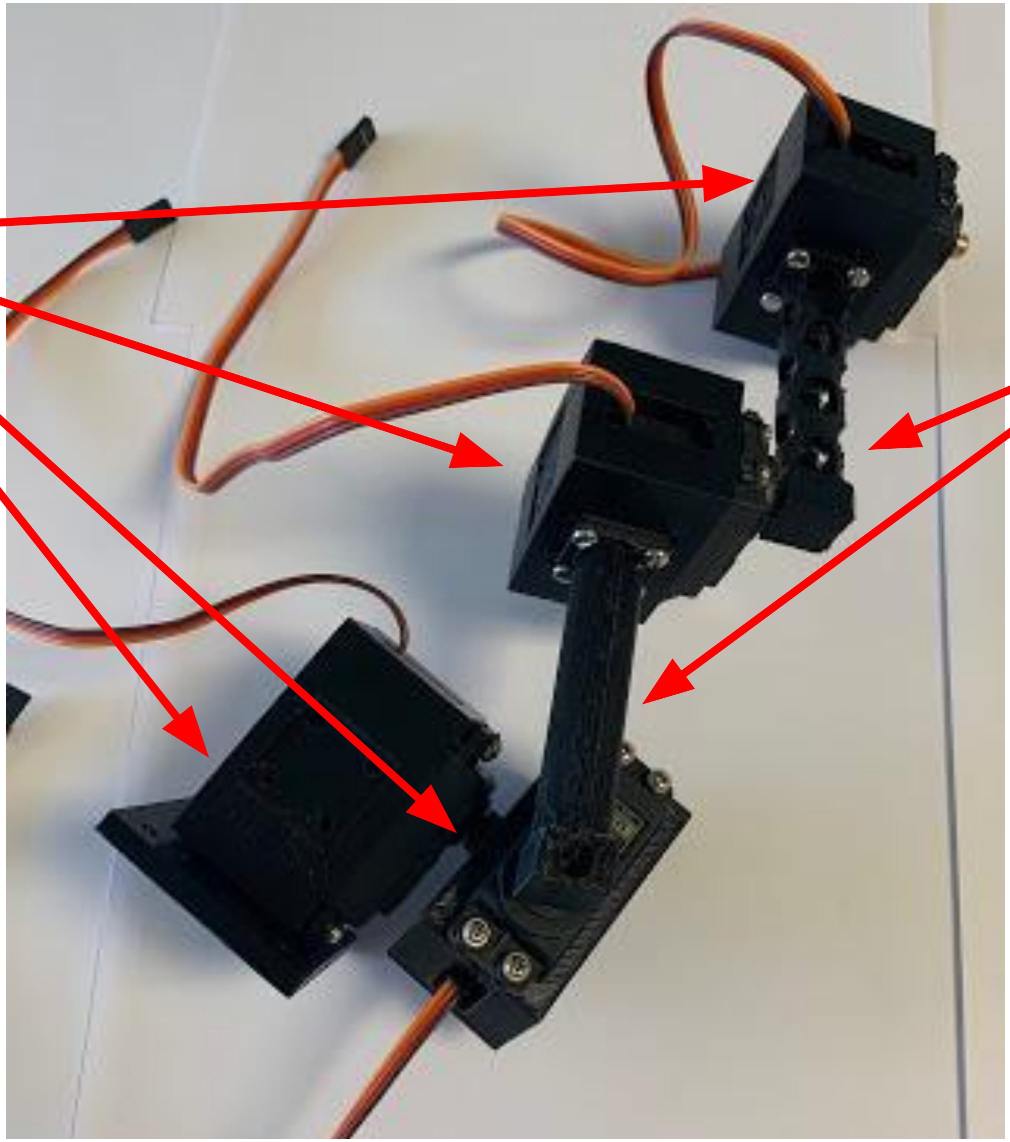
3D Print

- Used the same motor mounts from round 2
- Linkages printed as solid parts
    - Also printed in a different orientation



Anthony Wyrick

Assembly



Servo Motors

Linkages

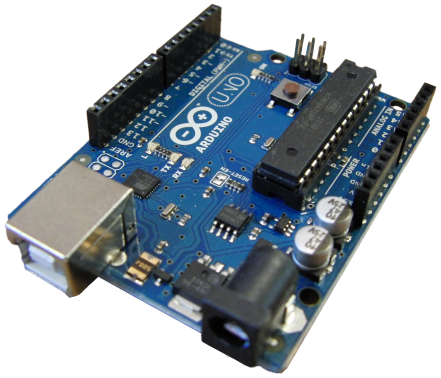
Anthony Wyrick

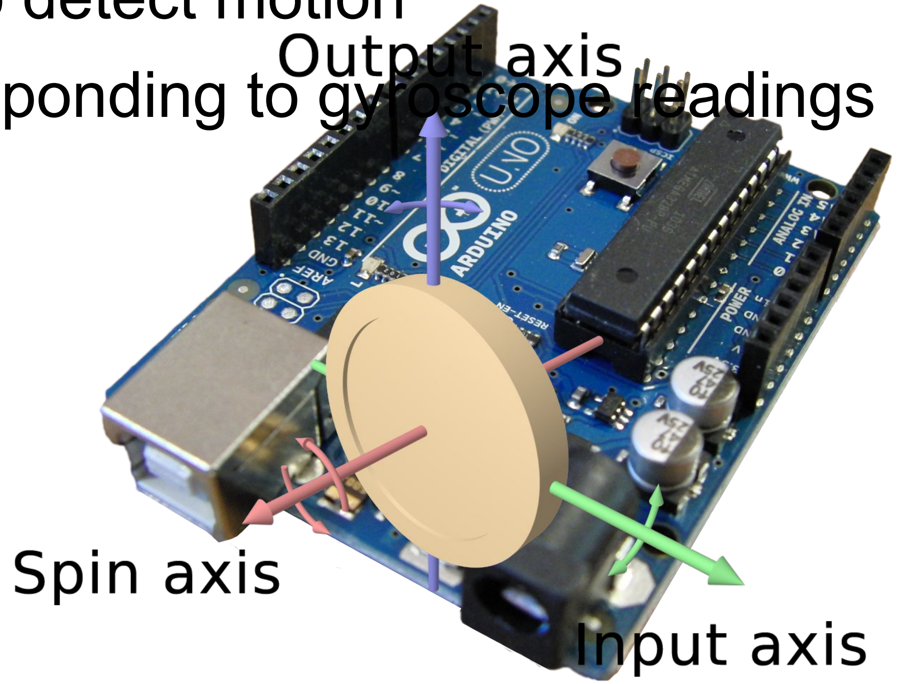
Coding

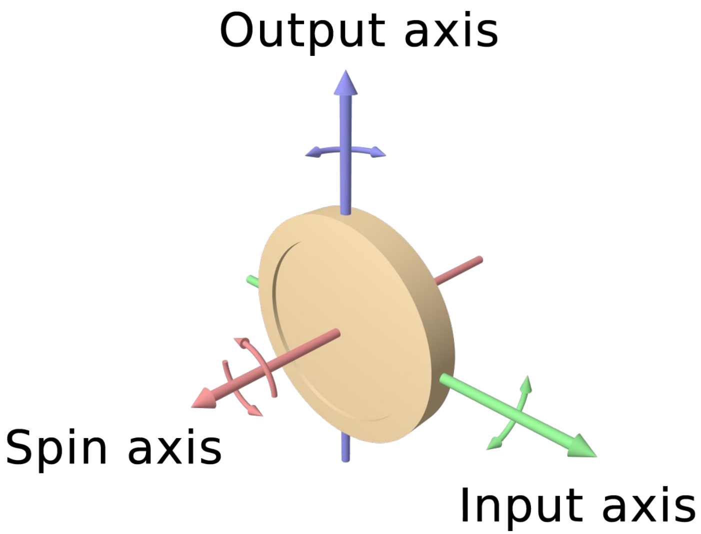
John Bryant

Coding

- Using an Arduino as the microcontroller
- Using gyroscopes to detect motion
- Have the motors responding to gyroscope readings

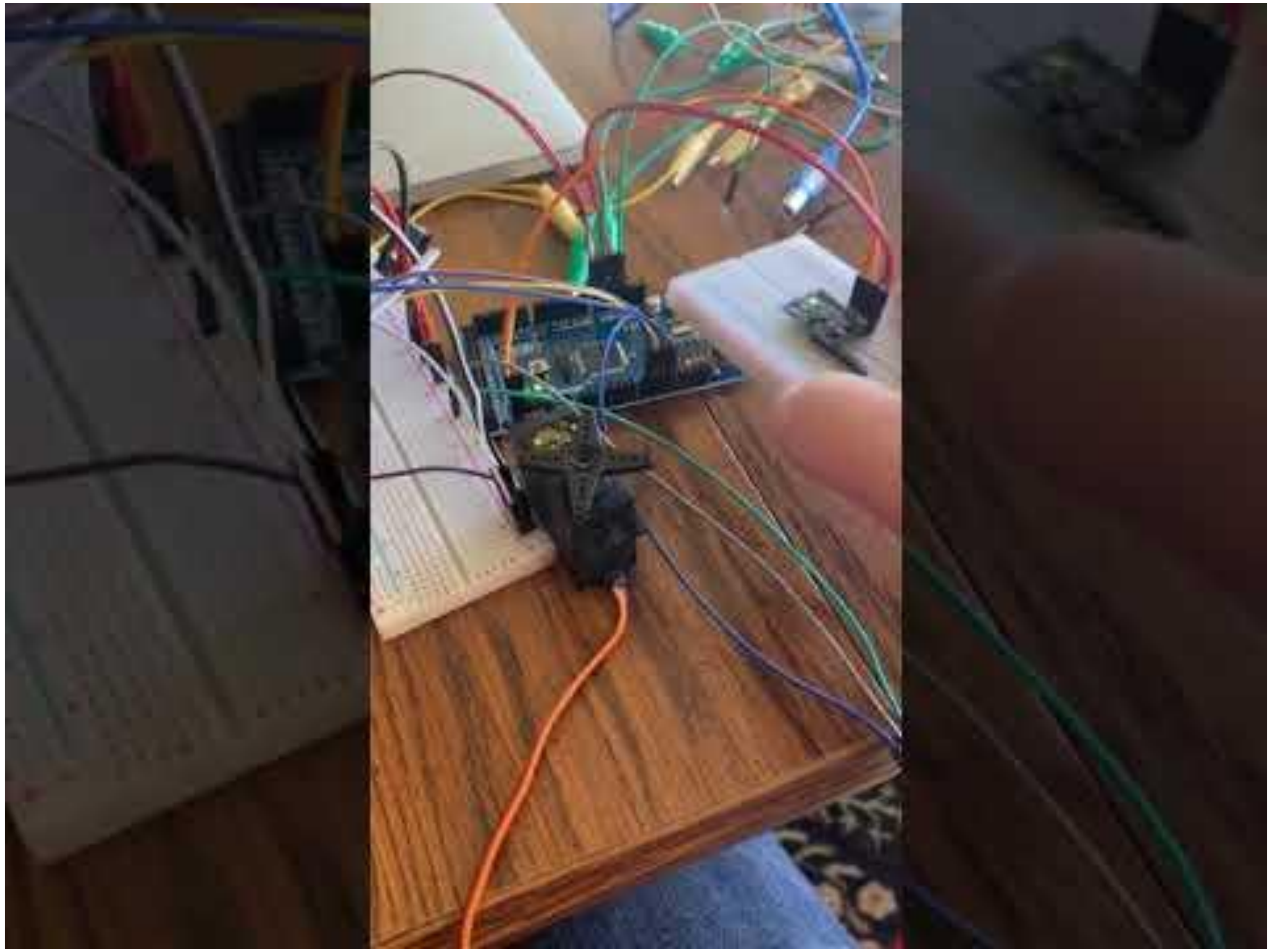






John Bryant

Code in Action



John Bryant

Testing

John Bryant

Testing Method

- Create a cam system that simulates robot motion
- Mount a laser to measure the position change without stabilization system
- Mount the stabilization system with a laser and measure the position change
- Compare data with and without stabilization system

John Bryant

Future Work

Junyi Wang

Future Work: Timeline

February

- 3D Print Parts
- Build Prototype
- Begin Testing

March

- Finish Testing
- Redesign, Rebuild, Retest

April

- Finalize Project
- Documentation

April 18

- Engineering Design Day

Junyi Wang

Future work summary

1. Goals are to improve stability while keeping weight down.
2. The background of the project has been completed and a design selected.
3. Building of the project is complete. Coding and testing is in progress.
4. Future work includes retesting and documentation.
5. Engineering design day is on April 18th.

Junyi Wang

Lessons Learned

- Nothing 3D printed ever prints correct the first time
- Square shapes are better for 3D printing than round ones
- Consider wiring in the hardware design

Junyi Wang

Team Introductions

Ariel Mathias
Team Lead &
Controls Engineer

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Mathematician

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Programmer

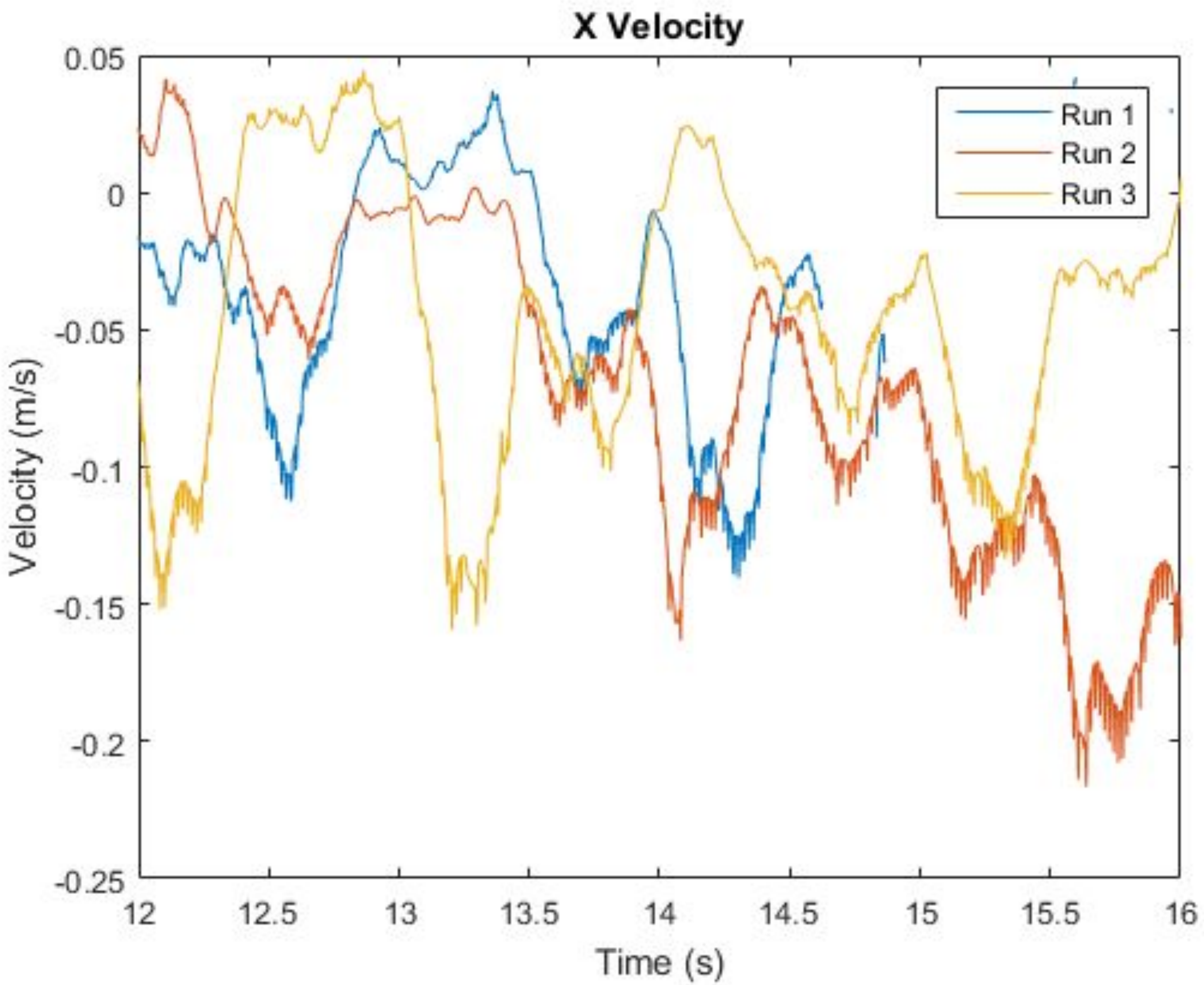
Tristan Kirby
CAD Engineer

Anthony Wyrick
Systems Engineer

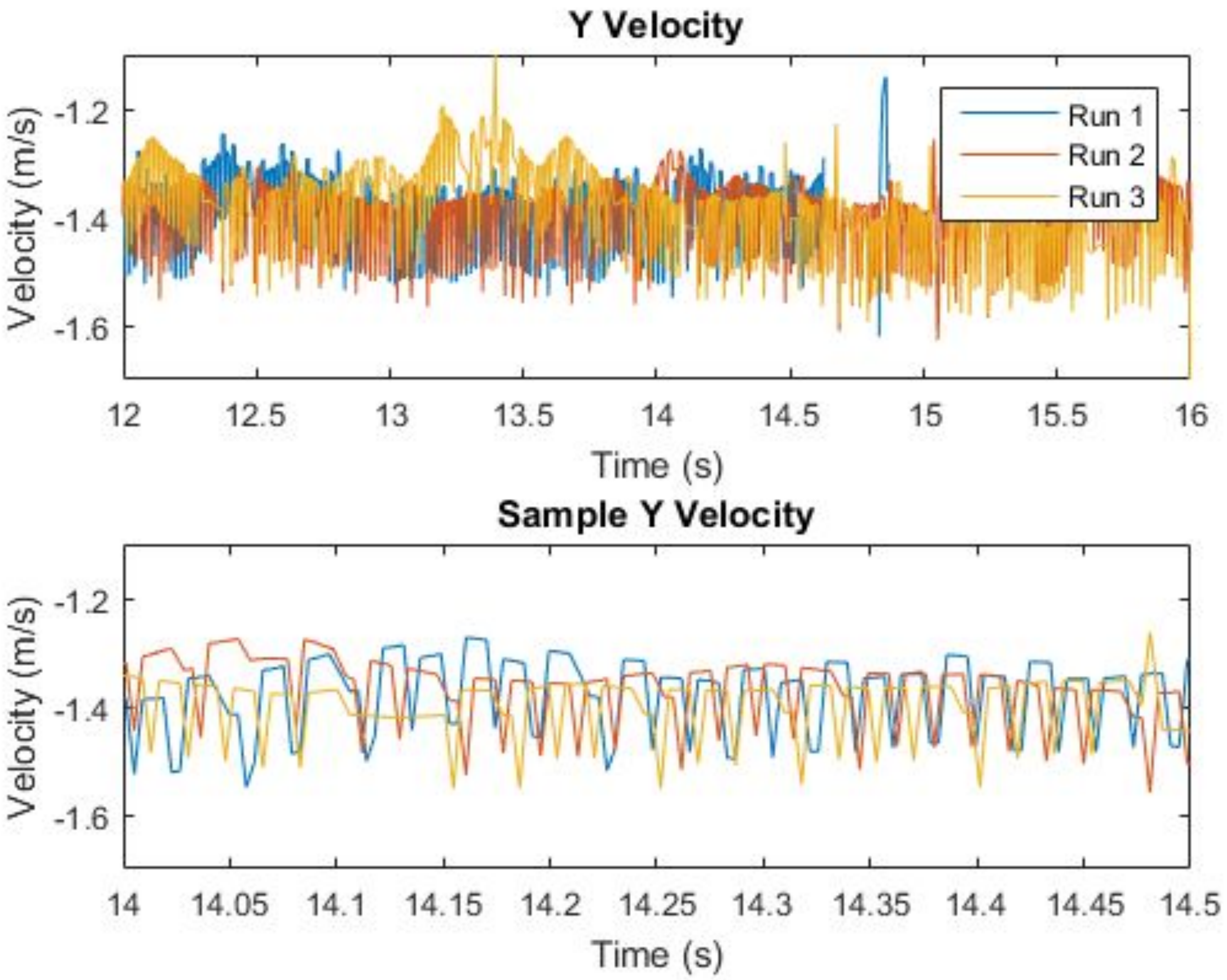
Questions?

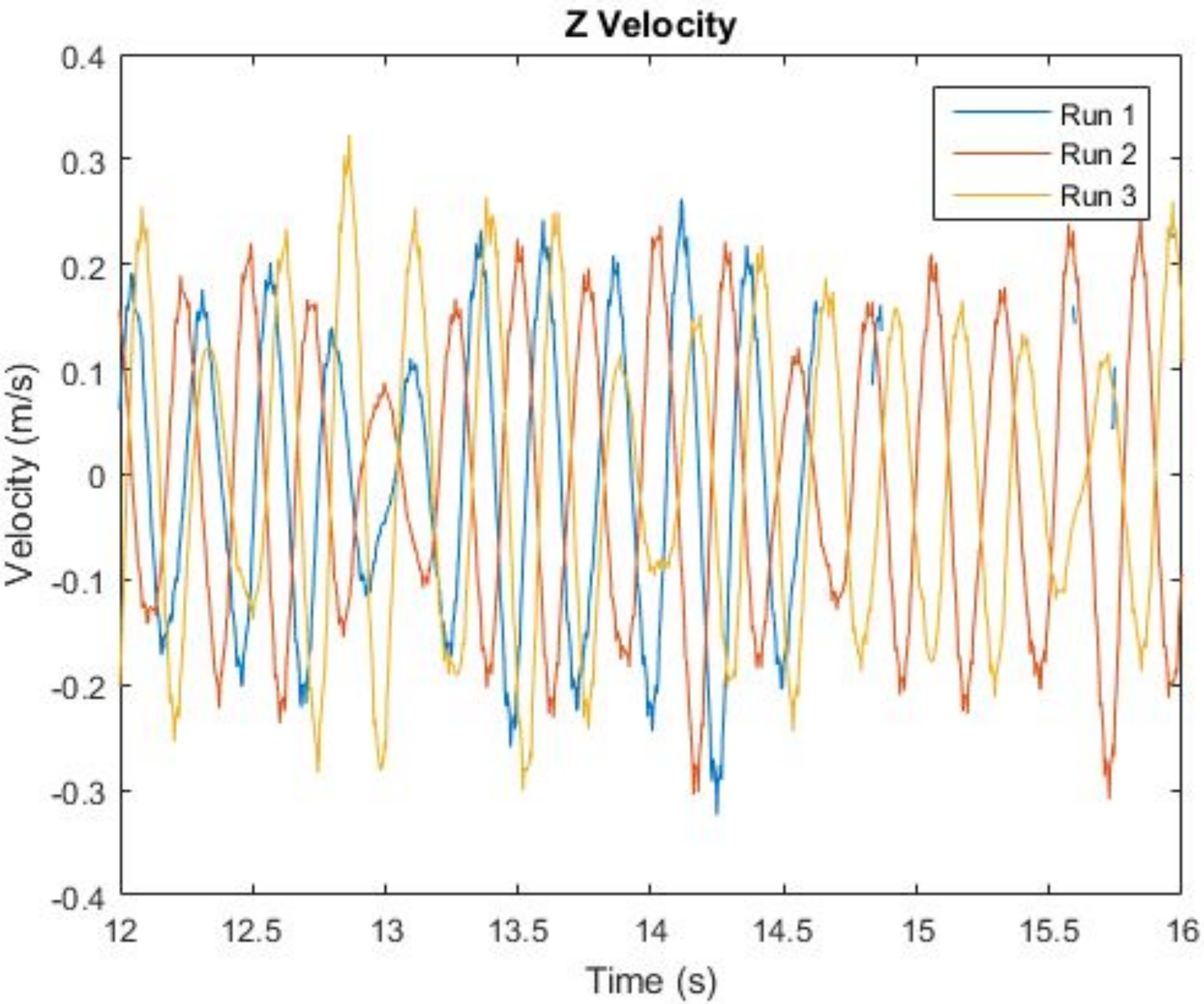
Backup Slides

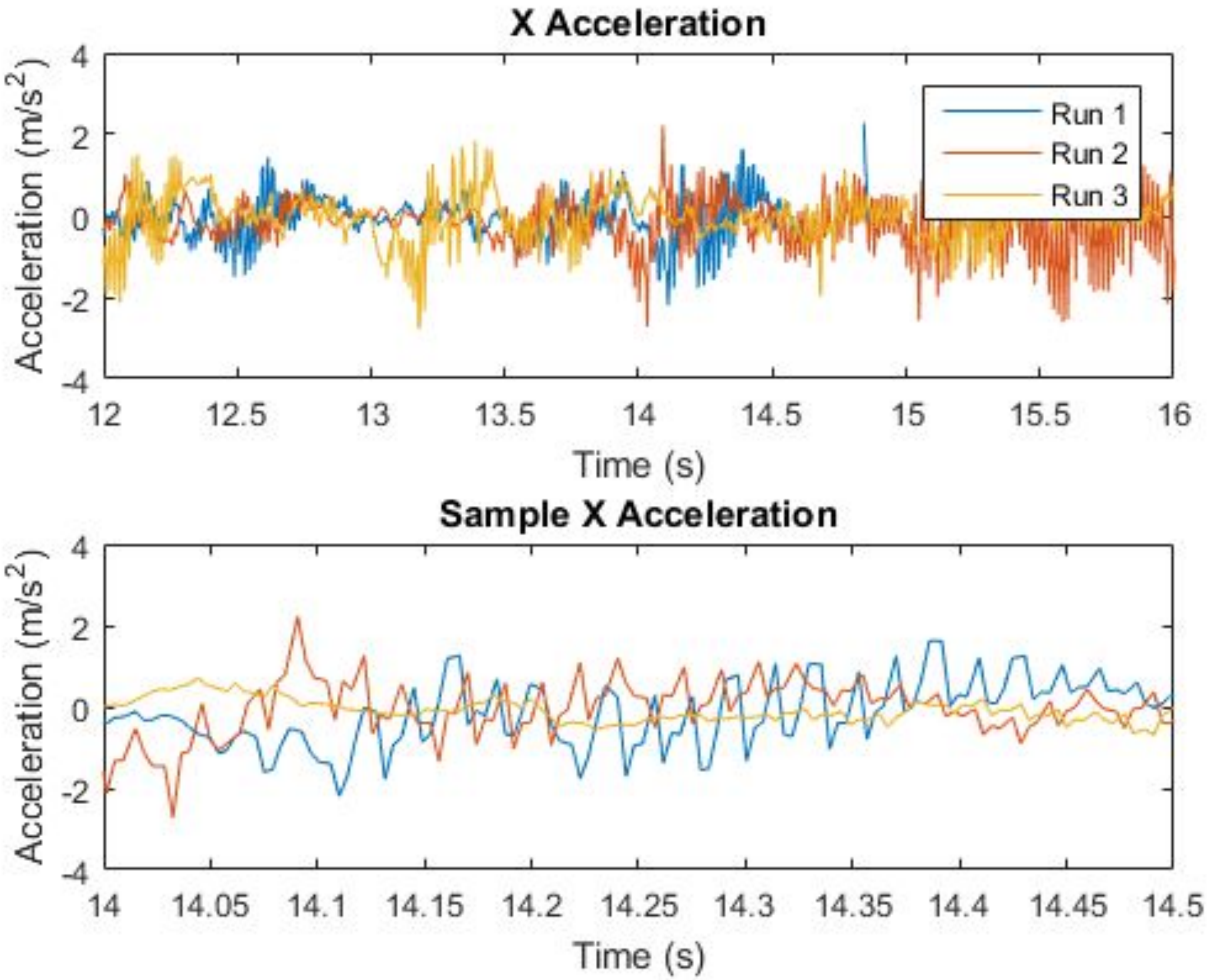
Minitaur Data Backup

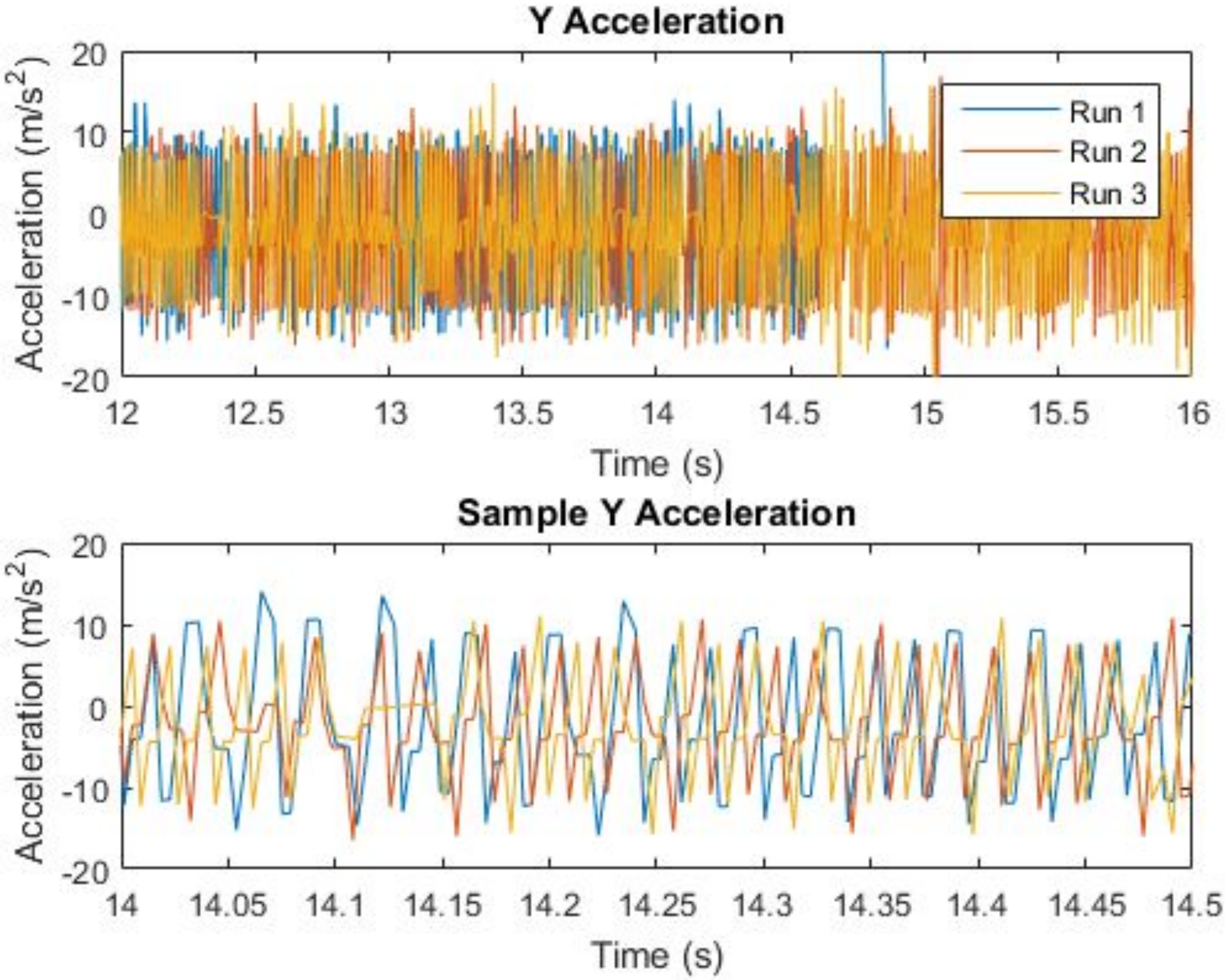


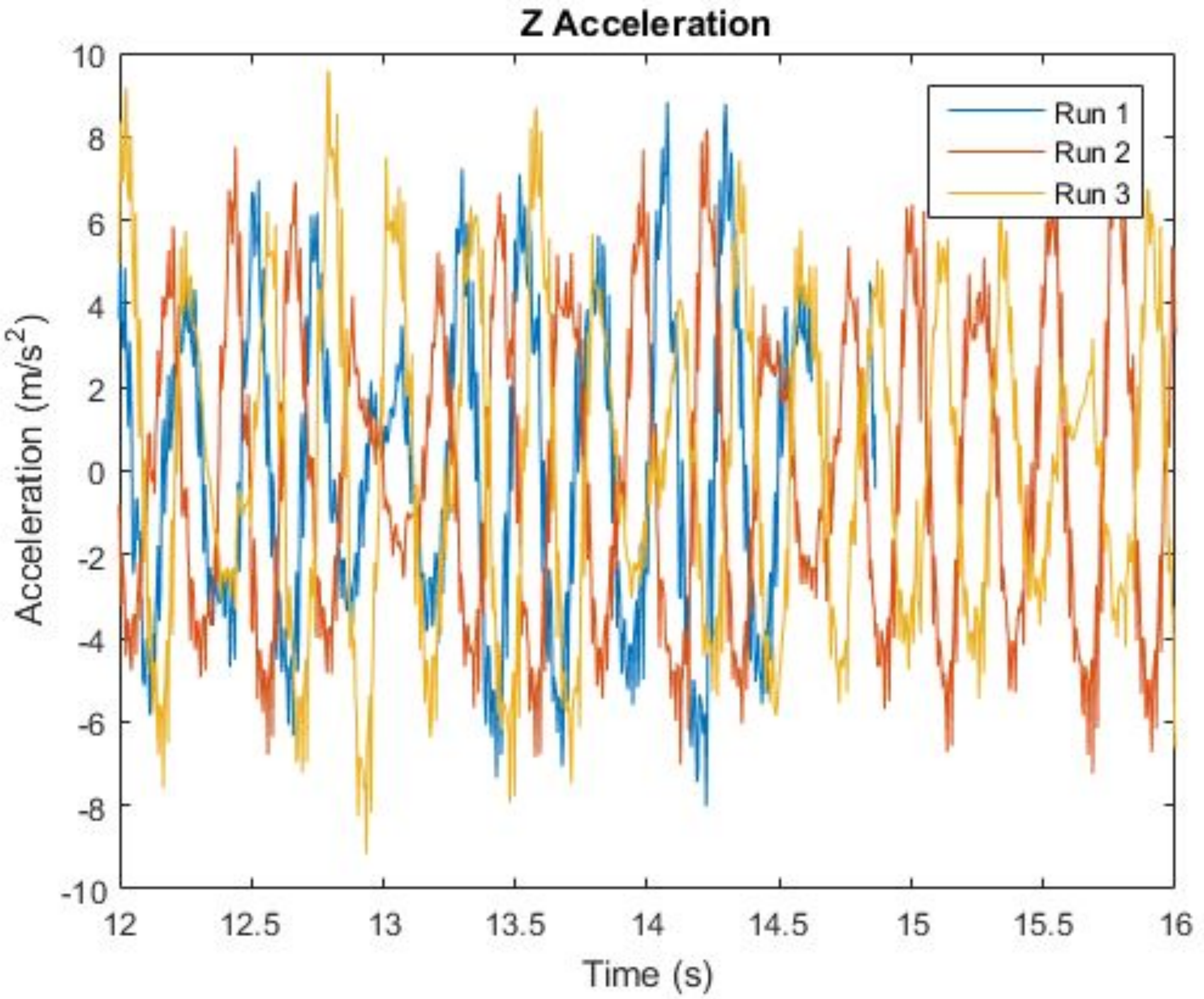
X Velocity
Run 1
Run 2
Run 3
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
Velocity (m/s)
12
12.5
13
13.5
14
14.5
15
15.5
16
Time (s)


Y Velocity
Velocity (m/s)
-1.2
-1.4
-1.6
12
12.5
13
13.5
14
14.5
15
15.5
16
Time (s)
Run 1
Run 2
Run 3
Sample Y Velocity
Velocity (m/s)
-1.2
-1.4
-1.6
14
14.05
14.1
14.15
14.2
14.25
14.3
14.35
14.4
14.45
14.5
Time (s)


Z Velocity
Run 1
Run 2
Run 3
Velocity (m/s)
Time (s)
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
12
12.5
13
13.5
14
14.5
15
15.5
16


X Acceleration
Acceleration (m/s²)
4
2
0
-2
-4
12
12.5
13
13.5
14
14.5
15
15.5
16
Time (s)
Run 1
Run 2
Run 3
Sample X Acceleration
Acceleration (m/s²)
4
2
0
-2
-4
14
14.05
14.1
14.15
14.2
14.25
14.3
14.35
14.4
14.45
14.5
Time (s)


Y Acceleration
Acceleration (m/s^2)
20
10
0
-10
-20
12
12.5
13
13.5
14
14.5
15
15.5
16
Time (s)
Run 1
Run 2
Run 3
Sample Y Acceleration
Acceleration (m/s^2)
20
10
0
-10
-20
14
14.05
14.1
14.15
14.2
14.25
14.3
14.35
14.4
14.45
14.5
Time (s)


Z Acceleration
Acceleration (m/s^2)
Time (s)
Run 1
Run 2
Run 3
10
8
6
4
2
0
-2
-4
-6
-8
-10
12
12.5
13
13.5
14
14.5
15
15.5
16

Project Background Backup

Active vs. Passive Stabilization

- Active
  - actuators, gyroscopes, and sensors are often involved
  - microcontroller directs singal
  - software involved
  - use of mechatronics to ensure recovery even when there is constant disruption
- Passive
  - needs no energy for stabilization or control power
  - use of a countermass and springs
  - simple but require that disruptions are absent long enough for a full recovery

Gyros and Logic Systems

- Gyros
  - Vibrating masses are set about a specific axis. When any change in angular motion occurs the mass has a tendency to resist the change, in accordance with Newton's laws. The Coriolis moments cause vibration in the plane normal to the original plane. Torque is applied to counteract the change in movement and a voltage proportional to this torque is given as the output.
- Logic
  - Take the readings from the gyroscopes, then output the necessary signal to correct any error in stabilization.

Bio-Inspired Robots

- Imitates biology and works on biological characteristics
- Can be used an environmental monitoring task
- Humanoid robots are being developed to make-up aspects of the labor force and solve social problems
- Integration of artificial intelligence
- Examples: Spot Mini, Atlas

References

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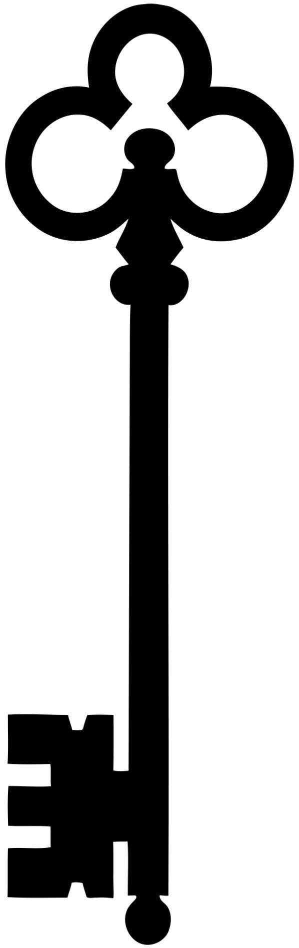
Project Scope Backup

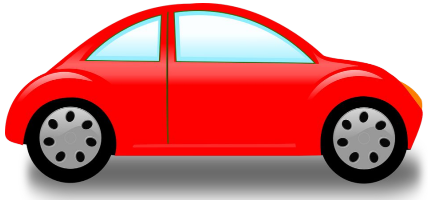
Key Goals

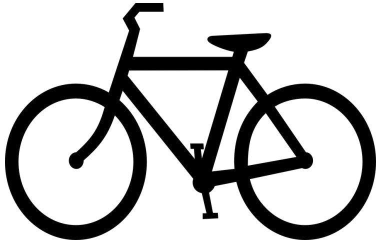


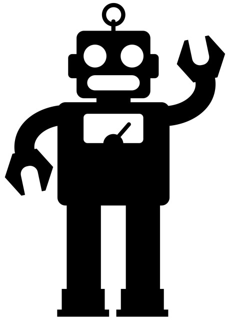
- Develop a damping system to counteract unwanted motion
- Utilize damping techniques to reduce vibration
- Effectively improve camera and sensor feedback data

Markets

- Bicycle camera footage
- Vehicle camera footage







- Data collection robots
- Law enforcement
  - Dash cams
- Military
  - Weapons
  - Drones

Assumptions

- Baseline is the Minitaur robot used in research at the Aero-propulsion, Mechatronics, and Energy center
- There will be weight restrictions on the load of the robot

Stakeholders

- ❑ Northrop Grumman
- ❑ Dr. Ordonez
  - ❑ Graduate research students
- ❑ FAMU-FSU College of Engineering
- ❑ Other research facilities
- ❑ Dr. McConomy

Targets Backup

Additional Targets

Target	Value
Minimum Correction Factor	50%
Minimum Motion Detection	1 g
Maximum System Payload Weight	150 grams
Motion Counteraction	5mm<x<150mm at at least 1g
Operating Temperature Range	60-80 degrees Celsius
Integrate with Larger System	3 runs of 10 feet on Minitaur

Target	Value
Stay on Minitaur	3 runs of 10 feet
Take Minitaur Impact without Damage	3 runs of 10 feet
Maximum Weight of System	1.5kg
Power Requirement	5V
System to Robot Movement	50% decrease
Correction Speed	0.25 seconds per 60 degrees

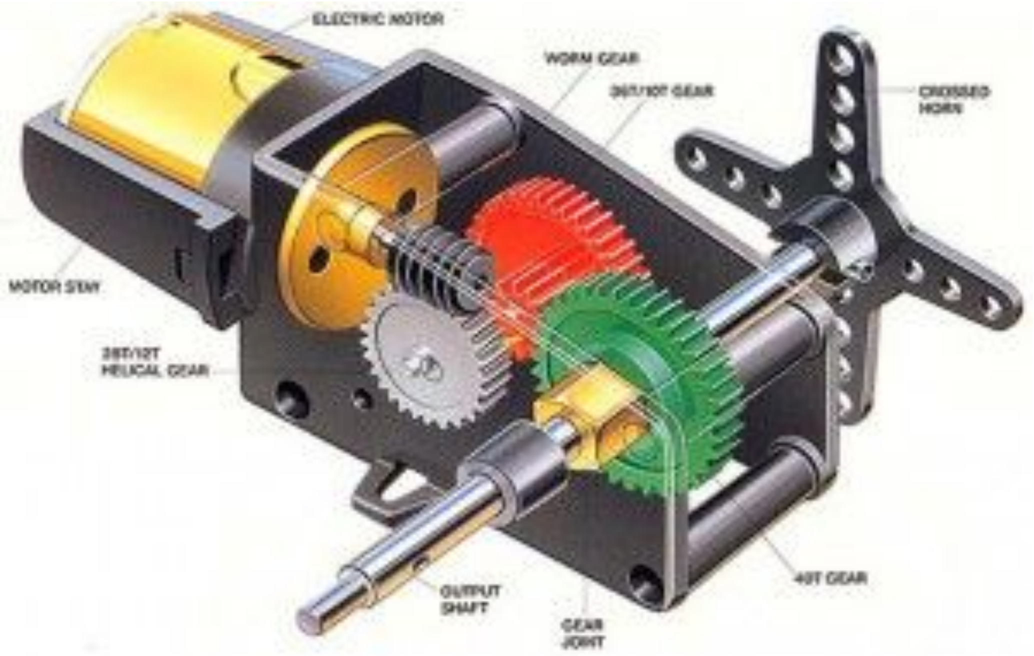
Concept Generation Backup

Concept 1

Four Servo Motors

- Connected by brackets and link arms to counteract motion on x, y, and z axis
- Three of the motors would focus solely on counteracting the movements in the specified axises
- Fourth motor controls the angle at which the payload deviates from the target

- Relatively heavy



Concept 2

A Telescoping Linkage

- Each end has a 3 degree of freedom joint
- Expand and contract vertically, removing the bounce of the robots walk
- This idea would be a more simple
- Less complexity also means less weight

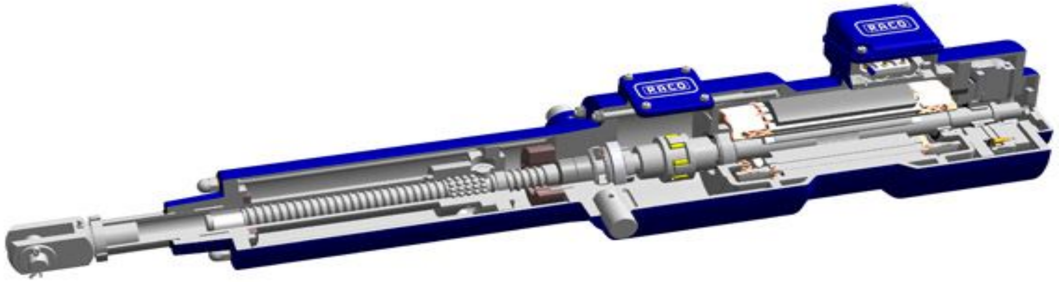
- More limited in its effectiveness

Concept 3

Two Linear Actuators

- One linear actuator corrects one degree of motion on a hinge
- The other corrects the other degree of motion on a hinge
- The entire system can have a flat platform about both hinges for the camera to be attached to
- Weight of this system could be optimized and kept relatively low

- Actuators reaction time would be too slow



Concept Selection Backup

House Of Quality
Engineering Characteristics

- Correction Factor
- Motion Detection
- System Payload Weight
- Motion Counteraction Range
- Operating Temperature Range
- Stay on Minitaur
- Larger System Integration
- Take Miniquat Impact
- System Weight
- Power Requirement
- Feedback Loop
- Correction Speed

House Of Quality
Customer Requirements

- Small
- Lightweight
- Improves Stabilization

- Simple
- Cost Effective
- Durable
- Operating Efficiency

Pairwise for Customer Needs

Customer Requirements	1	2	3	4	5	6	7	Total
1. Small	~	0	0	0	0	1	1	2
2. Lightweight	1	~	0	1	0	1	1	4
3. Improves Stabilization	1	1	~	1	1	1	1	6
4. Simple	1	0	0	~	0	1	0	3
5. Cost Effective	1	1	0	1	~	1	1	5
6. Durable	0	0	0	0	0	~	1	1
7. Operating Efficiency	0	0	0	1	0	0	~	1
Total	4	2	0	3	1	5	5	6

House of Quality

		Characteristics											
Units		%	meters/seconds(squared)	grams	mm	Celsius	runs x feet	runs x feet	runs x feet	kg	Volts	%	seconds/degrees
Requirements	Weight Factor	Correction Factor	Motion Detection	System Payload Weight	Motion Counteraction Range	Operating Temperature Range	Larger System Integration	Stay on Minitaur	Take Minitaur Impact	System Weight	Power Requirement	Feedback Loop	Correction Speed
1. Small	2	1		9	1		3	1		9	9		3
2. Lightweight	4			9			3	1	1	9	3		3
3. Improves Stabilization	6	9	9		3						3	3	3
4. Simple	3			3			1		1	3	3		1
5. Cost Effective	5	3	3	3	1	1			1	3	3		3
6. Durable	1			3		9		1	9	3	3		3
7. Operating Efficiency	1	1	1	3	3					1	9	1	3
Raw Score (560)		72	70	82	28	14	21	7	21	82	84	19	60
Relative Weight		0.129	0.125	0.146	0.05	0.025	0.038	0.013	0.038	0.146	0.15	0.034	0.107
Rank Order		4	5	2	7	11	8	12	8	2	1	10	6

AHP Critical Comparison Matrix

	Criteria Comparison Matrix				
Selection Criteria	Power Requirement	System Weight	System Payload Weight	Correction Factor	Sum
Power Requirement	1	0.143	0.333	0.111	1.587
System Weight	7	1	5	0.143	13.143
System Payload Weight	3	0.2	1	0.111	4.311
Correction Factor	9	7	9	1	26

AHP Pairwise Comparison Matrix

System Weight			
	Concept 1	Concept 2	Concept 3
Concept 1	1	1	3
Concept 2	1	1	3
Concept 3	0.33	0.33	1
Sum	2.33	2.33	7

Power Requirement			
	Concept 1	Concept 2	Concept 3
Concept 1	1	3	3
Concept 2	0.33	1	1
Concept 3	0.33	1	1
Sum	1.66	5	5

AHP Pairwise Comparison Matrix

Correction Factors			
	Concept 1	Concept 2	Concept 3
Concept 1	1	3	3
Concept 2	0.33	1	0.33
Concept 3	0.33	3	1
Sum	1.66	7	4.33

System Payload Weight			
	Concept 1	Concept 2	Concept 3
Concept 1	1	3	0.33
Concept 2	0.33	1	0.33
Concept 3	3	3	1
Sum	4.33	7	1.66

AHP Normalized Comparison Matrix

Power Requirement				
	Concept 1	Concept 2	Concept 3	Pi
Concept 1	0.6	0.6	0.6	0.6
Concept 2	0.2	0.2	0.2	0.2
Concept 3	0.2	0.2	0.2	0.2
Sum	1	1	1	

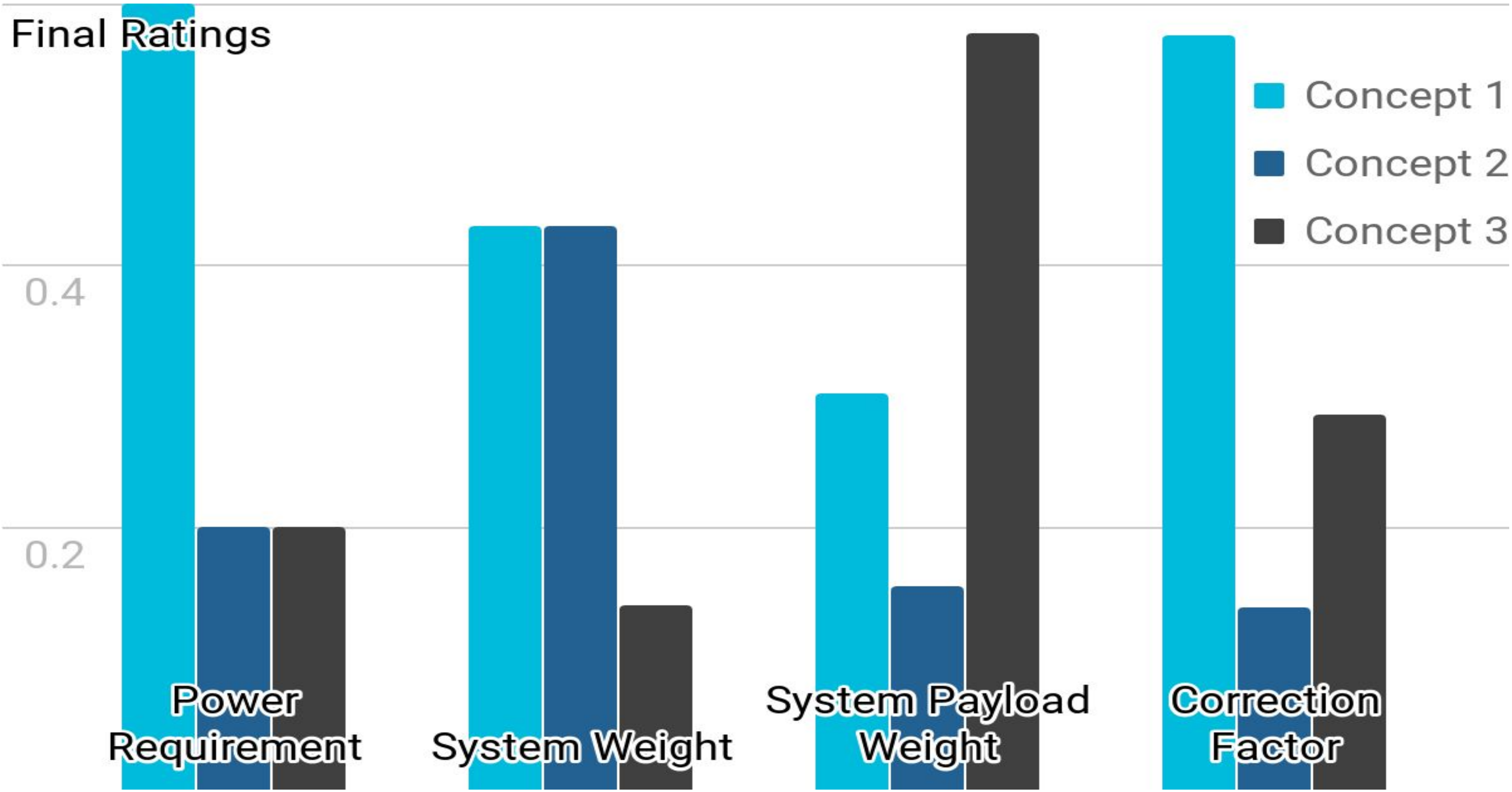
System Weight				
	Concept 1	Concept 2	Concept 3	Pi
Concept 1	0.43	0.43	0.43	0.43
Concept 2	0.43	0.43	0.43	0.43
Concept 3	0.14	0.14	0.14	0.14
Sum	1	1	1	

AHP Normalized Comparison Matrix

Correction Factor				
	Concept 1	Concept 2	Concept 3	Pi
Concept 1	0.602	0.429	0.693	0.575
Concept 2	0.199	0.143	0.076	0.139
Concept 3	0.199	0.429	0.231	0.286
Sum	1	1.001	1	

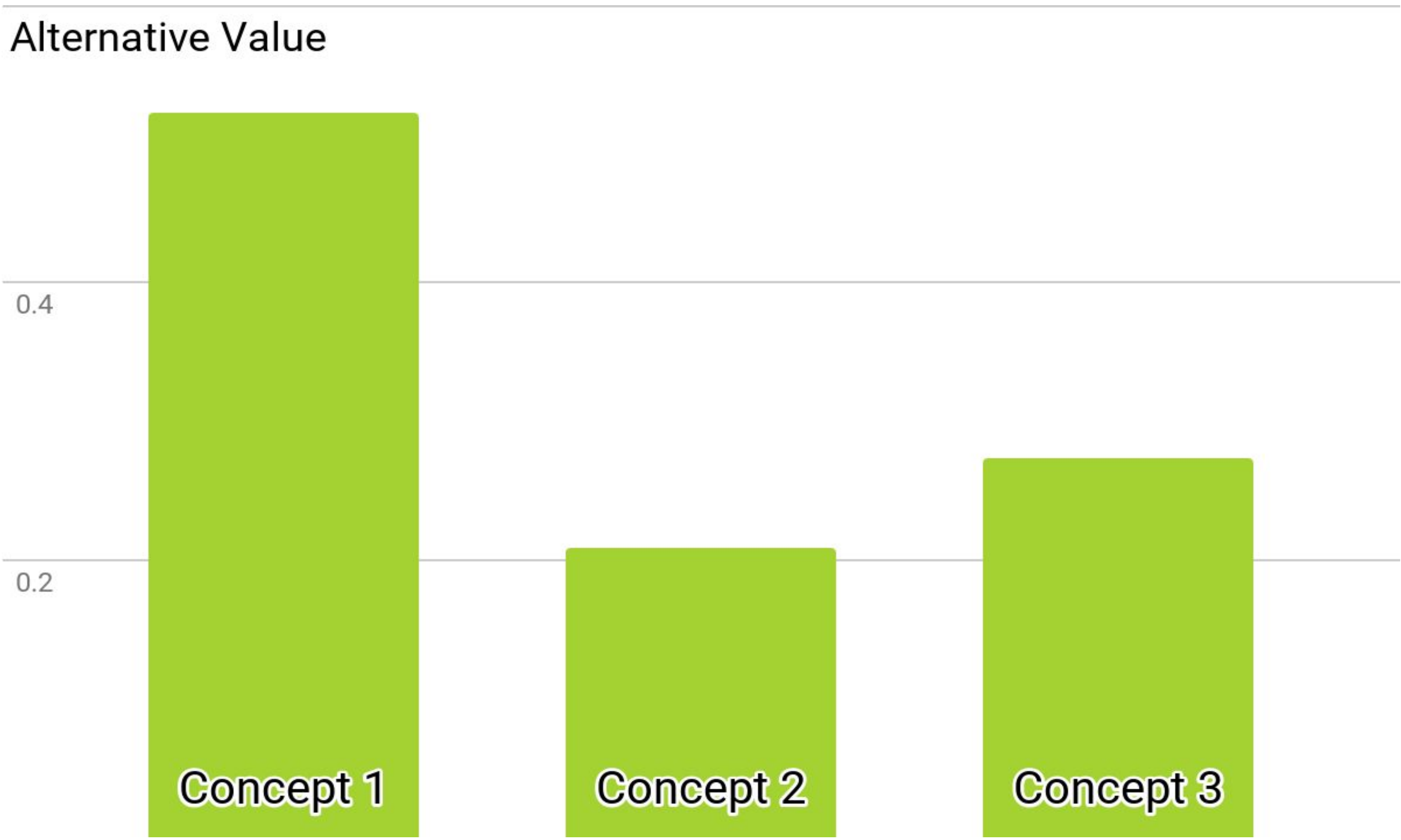
System Payload Weight				
	Concept 1	Concept 2	Concept 3	Pi
Concept 1	0.23	0.43	0.248	0.303
Concept 2	0.08	0.14	0.248	0.156
Concept 3	0.7	0.43	0.602	0.577
Sum	1.01	1	1.098	

AHP



Final Ratings
0.4
0.2
Concept 1
Concept 2
Concept 3
Power Requirement
System Weight
System Payload Weight
Correction Factor

AHP



Future Work Backup

Gantt Chart

Task Name	Start Date	End Date	Duration	Predecessors	% Complete	Status	Assigned To
Classes Begin	01/07/19	01/07/19	1d		0%	Not Started	
Detail Design (CAD)	01/07/19	01/11/19	5d		10%	In Progress	T Tristan
Design Review	01/14/19	01/15/19	2d	2	0%	Not Started	Team
Order Materials	01/16/19	01/16/19	1d	3	0%	Not Started	A Anthony
Parts Arrive	01/17/19	01/25/19	7d	4	0%	Not Started	A Anthony
3D Print Parts	01/29/19	01/30/19	2d	5FS +1d	0%	Not Started	Z John
Build Testing Rig	02/04/19	02/15/19	10d	6FS +2d	0%	Not Started	A Anthony
Build Stabilization System Prototype	02/04/19	02/15/19	10d	6FS +2d, 7FF	0%	Not Started	J Junyi
Testing	02/19/19	03/04/19	10d	7FS +1d, 8FS +1d	0%	Not Started	Team

Gantt Chart

Redesign	03/05/19	03/06/19	2d	9	0%	Not Started	Team
Rebuild	03/07/19	03/13/19	5d	10	0%	Not Started	Z John
Retest	03/14/19	03/15/19	2d	11	0%	Not Started	Team
Spring Break	03/18/19	03/22/19	5d	12	0%	Not Started	Team
Retest	03/25/19	03/29/19	5d	13	0%	Not Started	T Tristan
Project Finalization	04/01/19	04/09/19	7d	14	0%	Not Started	Team
Documentation	04/10/19	04/17/19	6d	15	0%	Not Started	A Ariel Mathi
Engineering Design Day	04/18/19	04/18/19	1d	16	0%	Not Started	Team
Finals	04/29/19	05/03/19	5d		0%	Not Started	Team
Graduation	05/04/19	05/04/19	1d		0%	Not Started	Team

Standard Shapes

Summary Box

Text box 1

Outlined Text Box

Approved Logos

FAMU-FSU
College of
Engineering

FAMU-FSU
Engineering

FAMU-FSU
Engineering

FAMU-FSU
College of Engineering

Color Palette

PANTONE® 2299 C 2299 C Color values: RGB 164 210 51 HEX/HTML #A4D233 CMYK 41 0 84 0	PANTONE® 1788 C 1788 C Color values: RGB 238 39 55 HEX/HTML #EE2737 CMYK 0 88 82 0	COE Dk Gray 75% Black Color values: RGB 64 64 64 HEX/HTML #404040 CYMK: 0 0 0 75
PANTONE® 2239 C 2239 C Color values: RGB 0 207 180 HEX/HTML #00CFB4 CMYK 59 0 39 0	PANTONE® 647 C 647 C Color values: RGB 35 97 146 HEX/HTML #236192 CMYK 96 54 5 27	COE Md Gray 50% Black Color values: RGB 128 128 128 HEX/HTML #808080 CYMK: 0 0 0 50
PANTONE® 2199 C 2199 C Color values: RGB 0 187 220 HEX/HTML #00BBDC CMYK 77 0 16 0	PANTONE® 7535 C 7535 C Color values: RGB 183 176 156 HEX/HTML #B7B09C CMYK 10 11 23 19	COE Lt Gray 25% Black Color values: RGB 191 191 191 HEX/HTML #bfbfbf CYMK: 0 0 0 25

APA Tables

Category 1	Category 2	Category 3	Category 4	Category 5
Item 1				
Item 2				
Item 3				
Item 4				

	Category 2			Category 3	
Category 1	subcategory 1	subcategory 2		subcategory 1	subcategory 2
Item 1					
Item 2					
Item 3					
Item 4					