Design & Control of an Outdoor Robotic Walker
Final Presentation – 4/12/2012

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Project Sponsor:

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Overview

1) Project Introduction
2) Design Specifications
3) Concept Generation
4) Interim Designs
5) Final Design
6) Manufacturing & Assembly
7) Testing & Results
8) Discussion & Conclusions

Problem Statement

The current generation of mobility assistive devices limits the user in freedom of motion and provides little additional assistance to the user beyond simple stabilization.

http://www.hizook.com/blog/2009/08/10/robotic-walkers-assist-elderly

Current Generation Limitations:

- **Traversable terrain**
  - **Indoor operation only**
- **Functionality**
  - **Only perform basic functions**
- **Expensive or unnecessary**
  - **Scooters / electric wheelchairs**

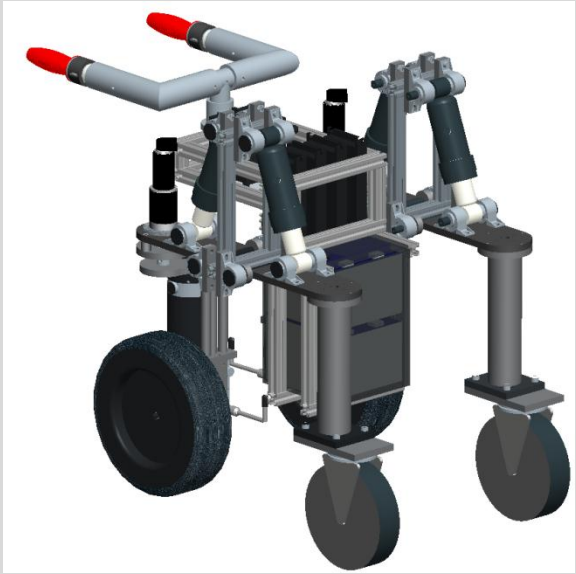
http://www.4-medical-supplies.com/electric-power-wheelchairs

Proposed Solution

Develop an assistive walking device designed to actively assist the user in both indoor and outdoor maneuverability.

Objectives:

- **Further empower disabled & elderly**
- **Offer wide-range of assistive functions**
- **Maintain ease of use & intuitiveness**



Proposed solution

Project Scope

Design and construct the initial research platform for a user-controlled outdoor robotic walker.

Final assembly

Project Constraints:

- **Traverse varied terrain surfaces**
  - **Indoor: Tile, Carpet**
  - **Outdoor: Concrete, Grass, Gravel, Dirt**
- **Operate within the Americans with Disabilities Act (ADA) standards**
- **Utilize force-based user controls**
- **Cost less than $5000**
- **Allow for design evolution of future platforms in years to come**

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Specifications

Frame:

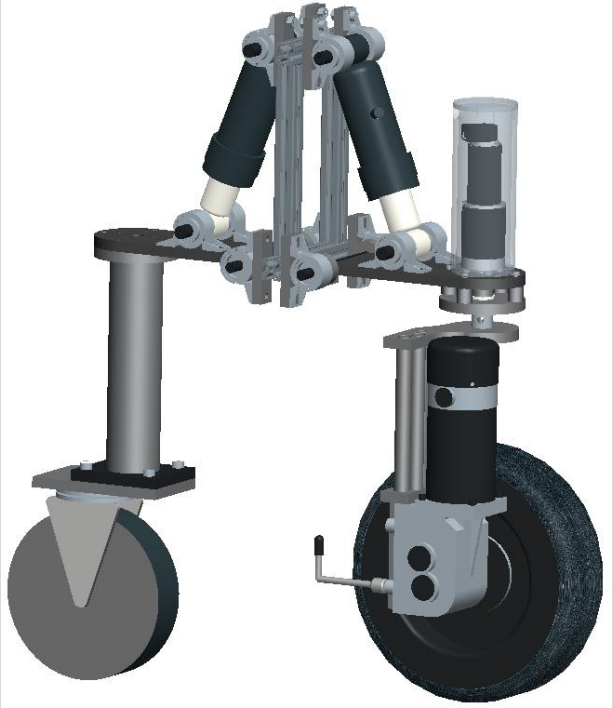
- Aesthetics
  - Resemble current generation of walkers
- Dimensions
  - Handle height – 32 to 39 inches
  - Handle width – 14 to 23 inches
- Safety Standards
  - Support up to 300 pounds
- Light weight
  - Less than 200 pounds
  - Aluminum framing

CAD of core frame

Specifications

Propulsion:

- Minimum 11 inch diameter wheels or tracks
- Travel up / down slopes up to 10°
- Semi-omni-directional movement
  - Move transversely 45° from the center axis
- Maximum operating speed of at least 5 mph

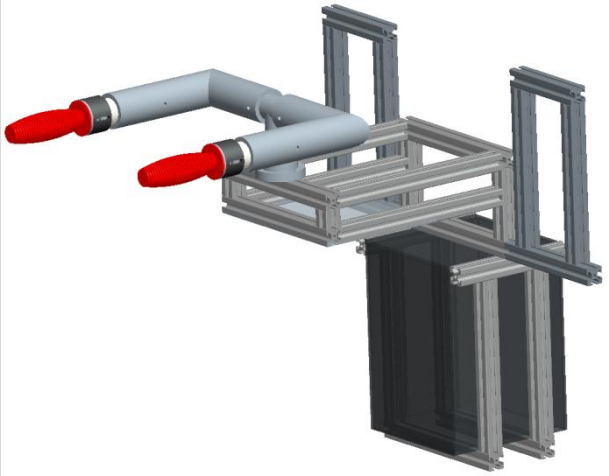


CAD of propulsion system used in finalized design

Specifications

Control & Function:

- Intuitive user input
  - Force-based drive control
- Proposed control algorithms
  - Fall prevention
  - Sit-down / stand-up assistance
  - Object detection / avoidance
  - Localization & navigation

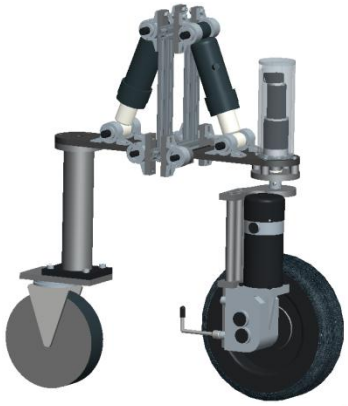


CAD of control systems used in finalized design

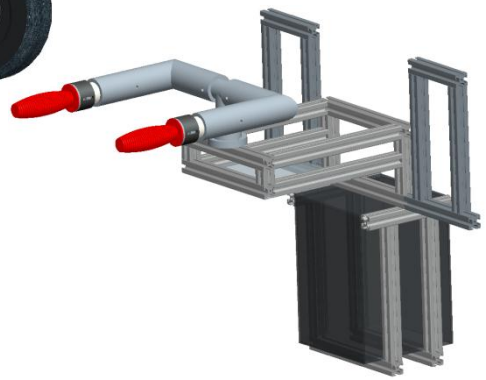
Design Criteria

Frame

Propulsion



Control & Function



Maximize:

- Versatility
- Robustness
- User-friendliness
- Indoor operation
- Outdoor operation

Minimize:

- Cost
- Weight

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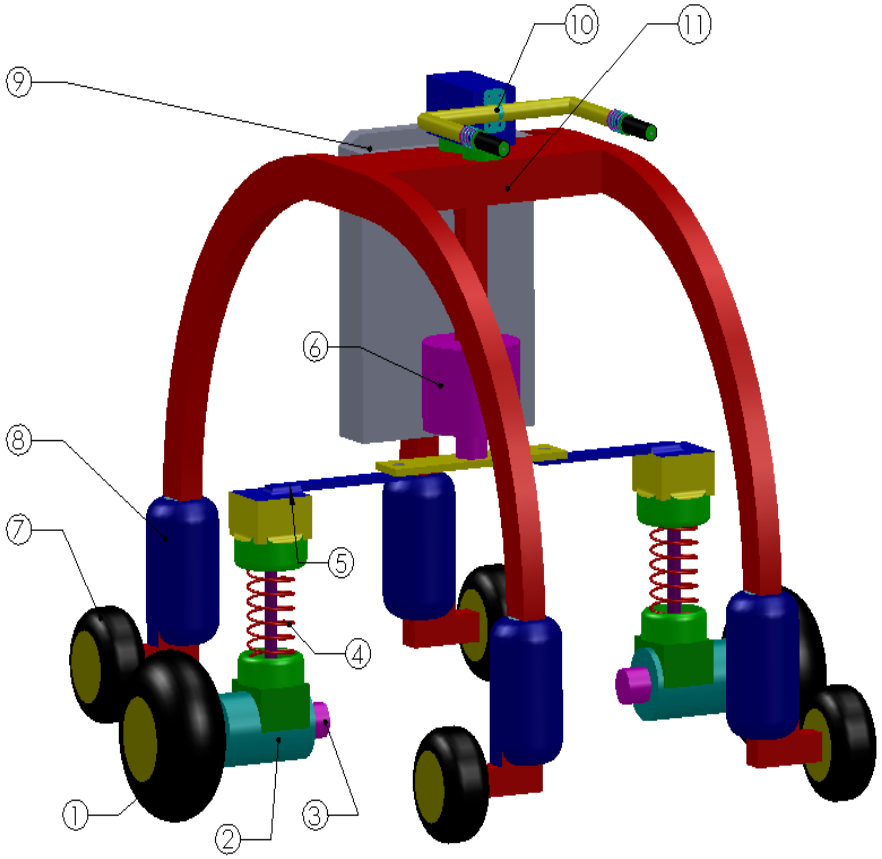
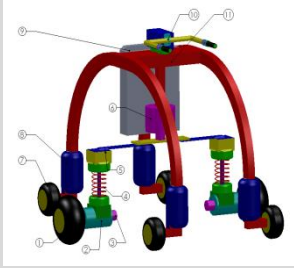
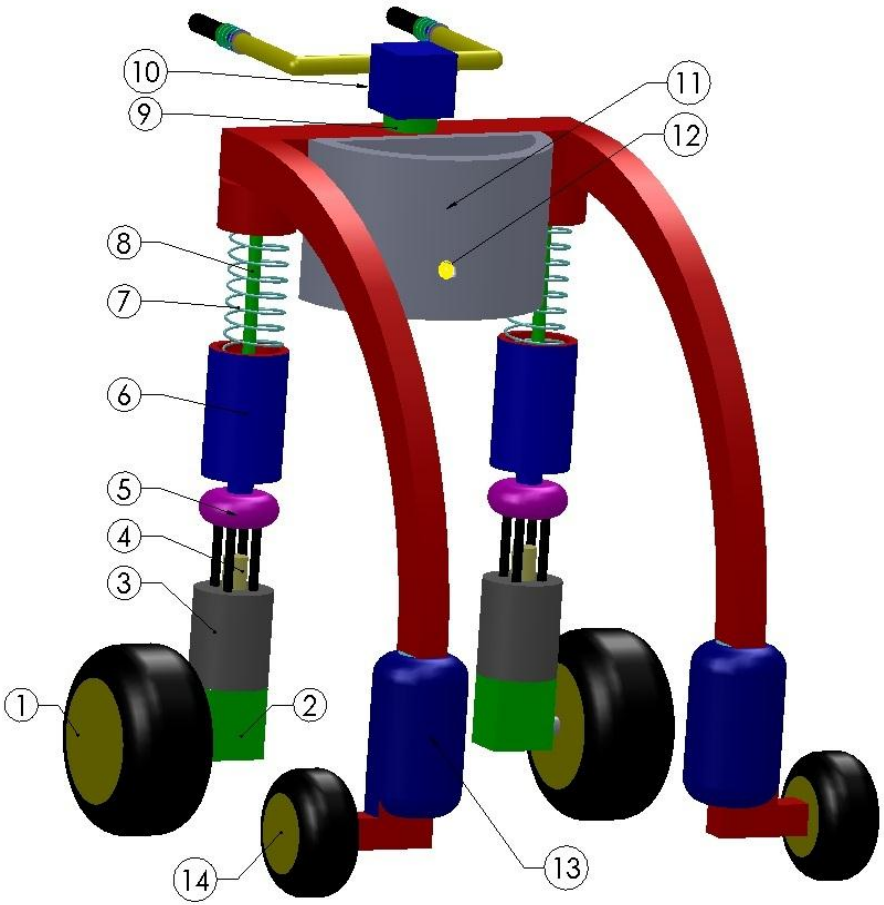
Initial Designs



Initial Design 1

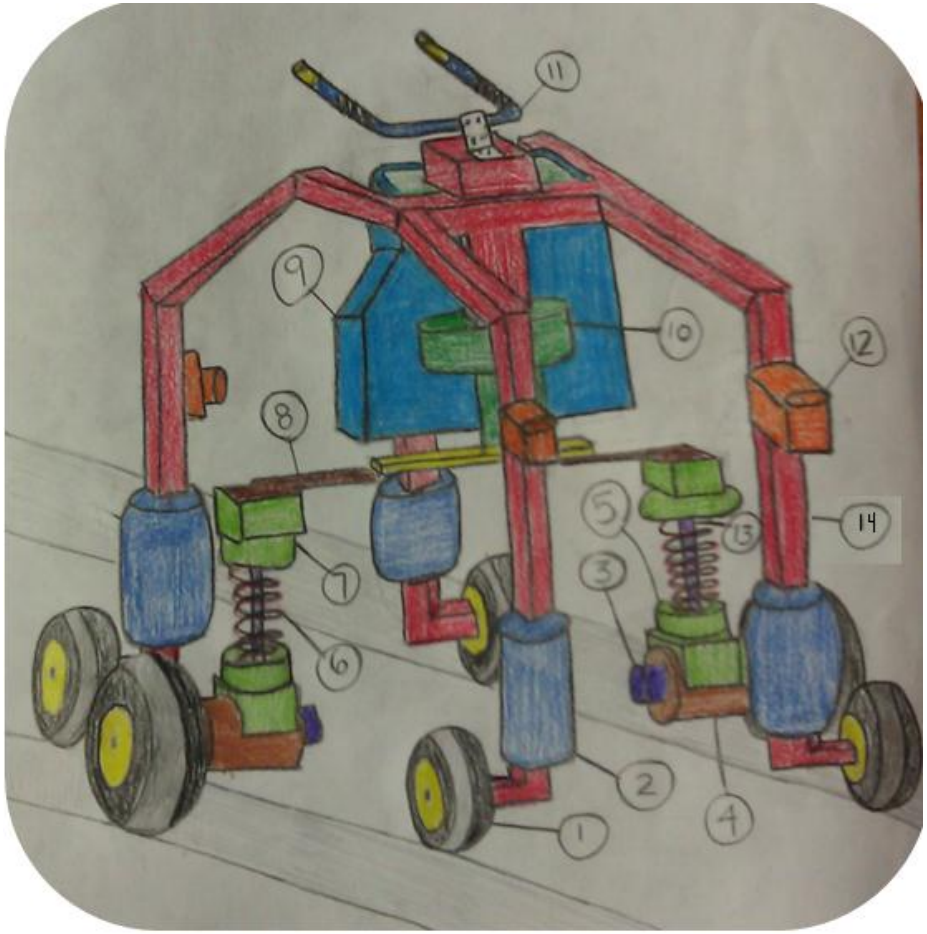
Initial Designs



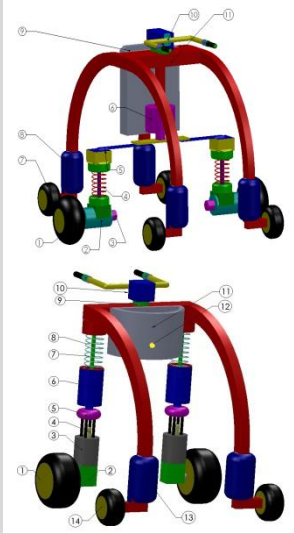


Initial Design 2

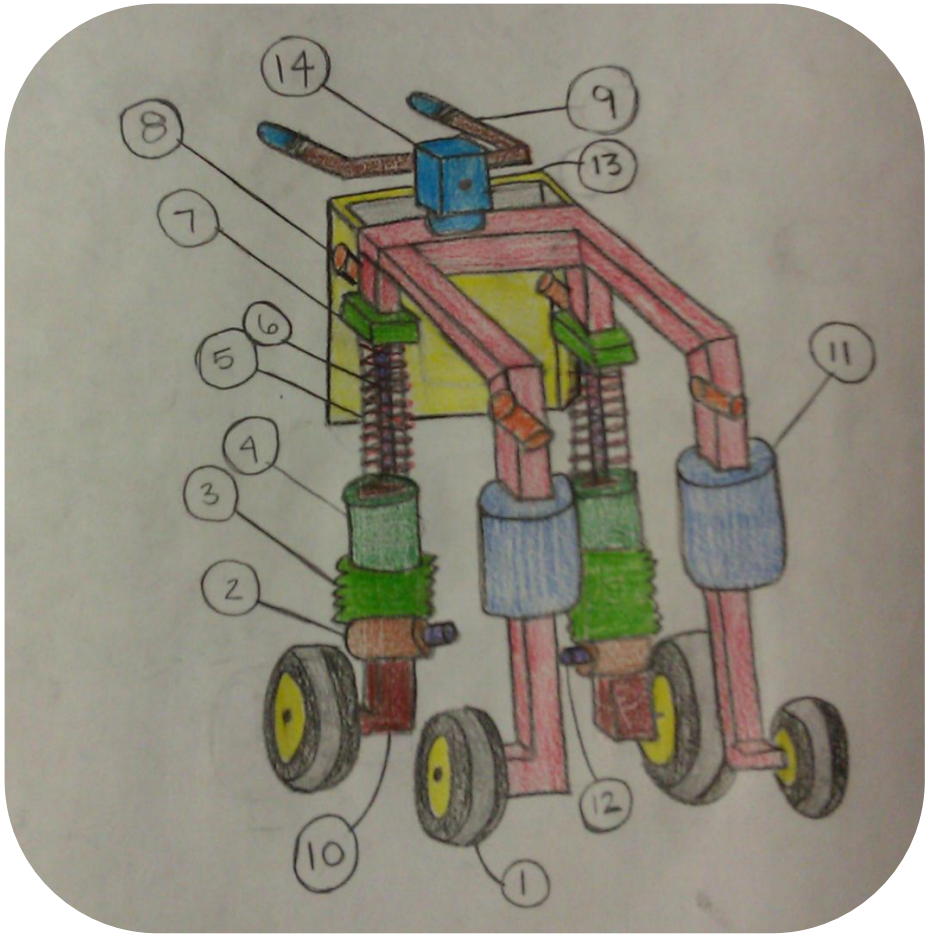
Initial Designs



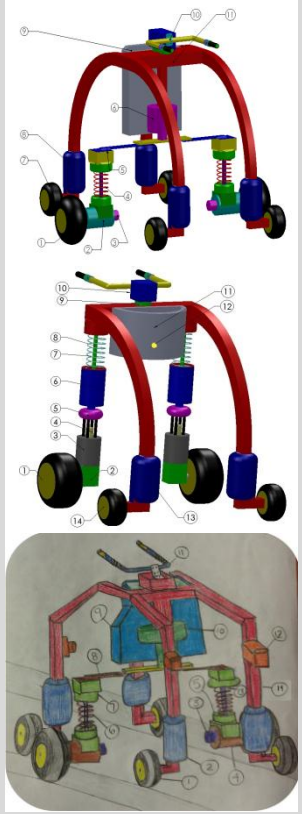
Initial Design 3



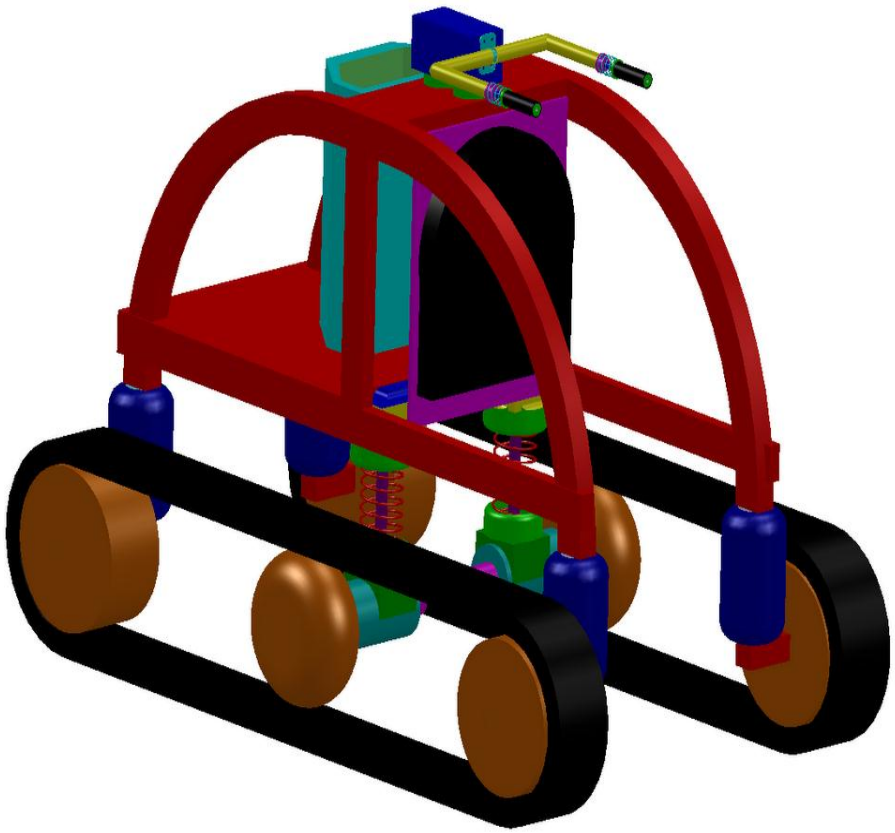
Initial Designs



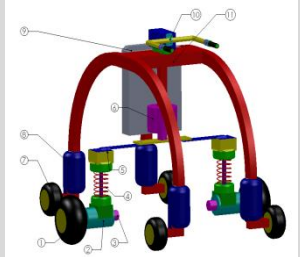
Initial Design 4

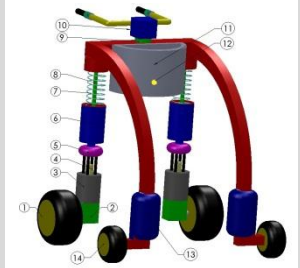


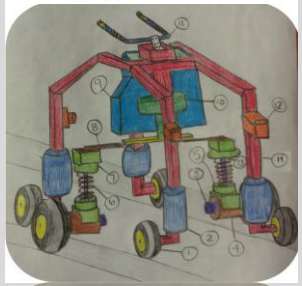
Initial Designs

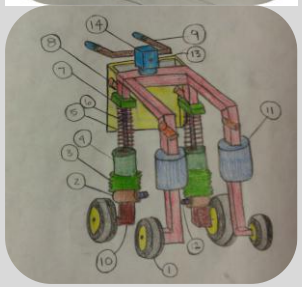


Initial Design 5



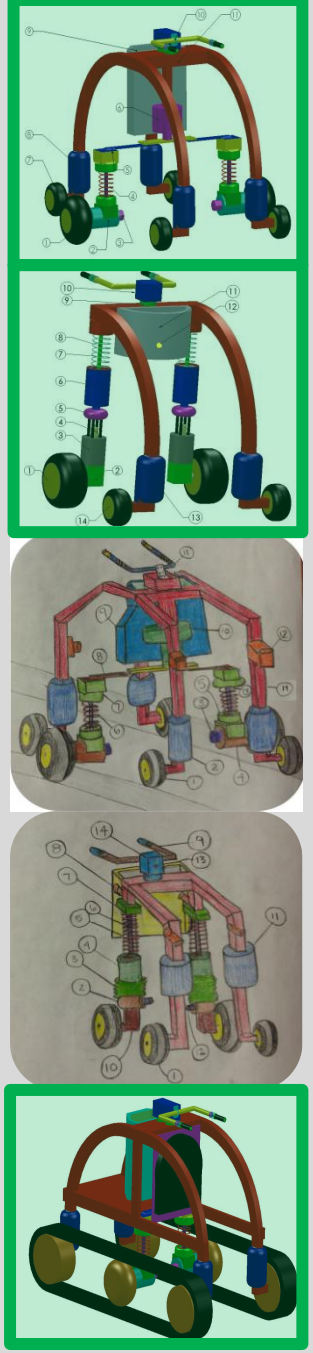






Decision Matrix

		Initial 1		Initial 2		Initial 3		Initial 4		Initial 5	
	Weight	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Versatility	0.15	3	0.454	5	0.757	3	0.454	3	0.454	3	0.454
Robustness	0.17	4	0.699	3	0.524	5	0.874	3	0.524	4	0.699
User-friendliness	0.22	3	0.670	4	0.894	2	0.447	5	1.117	3	0.670
Cost	0.04	2	0.086	2	0.086	1	0.043	1	0.043	1	0.043
Indoor	0.14	3	0.429	3	0.429	2	0.286	3	0.429	1	0.143
Outdoor	0.23	4	0.926	3	0.695	3	0.695	2	0.463	5	1.158
Weight	0.03	2	0.066	3	0.099	1	0.033	4	0.132	1	0.033
		Sum	3.331		3.483		2.832		3.163		3.200



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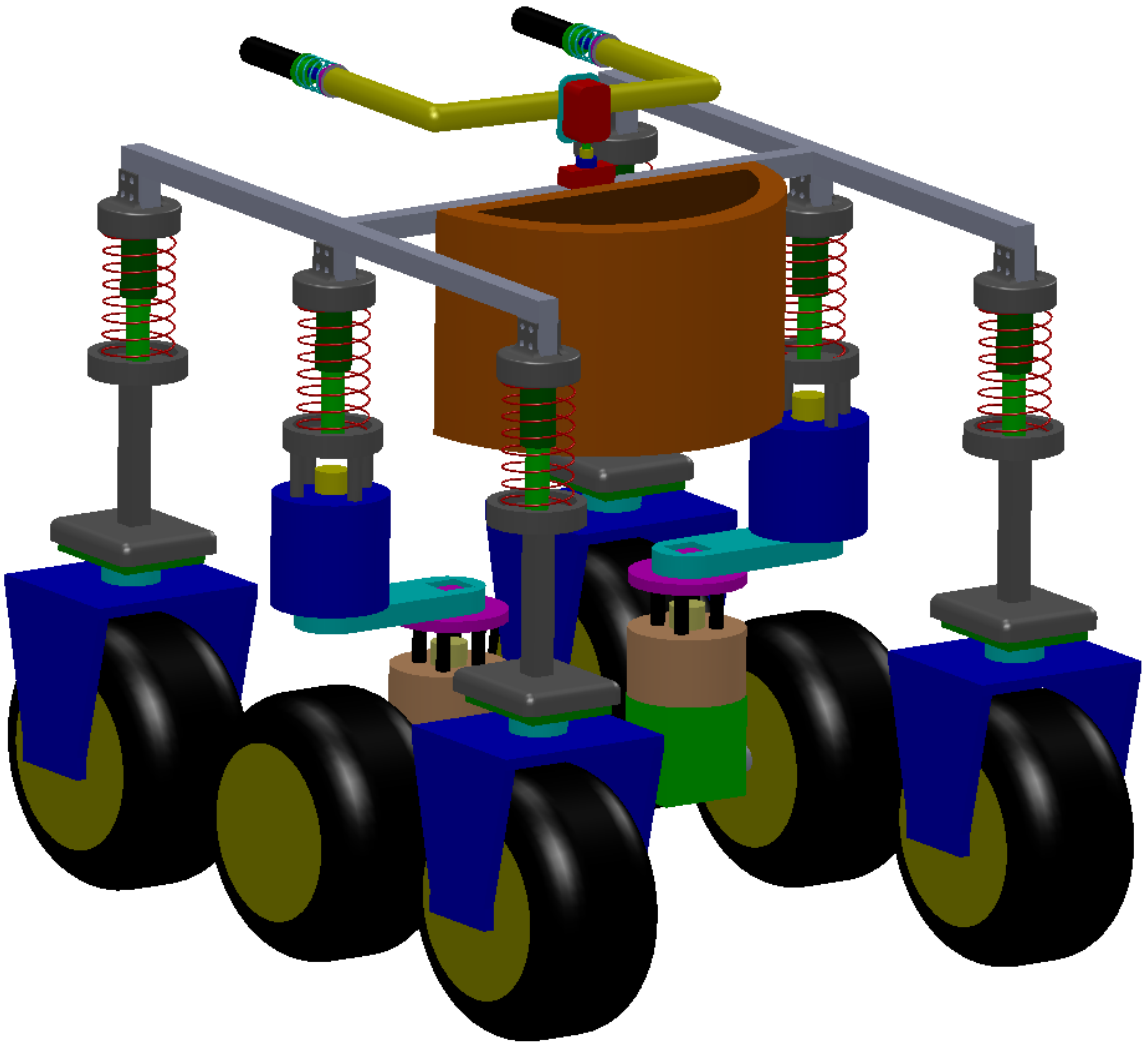
Interim Designs

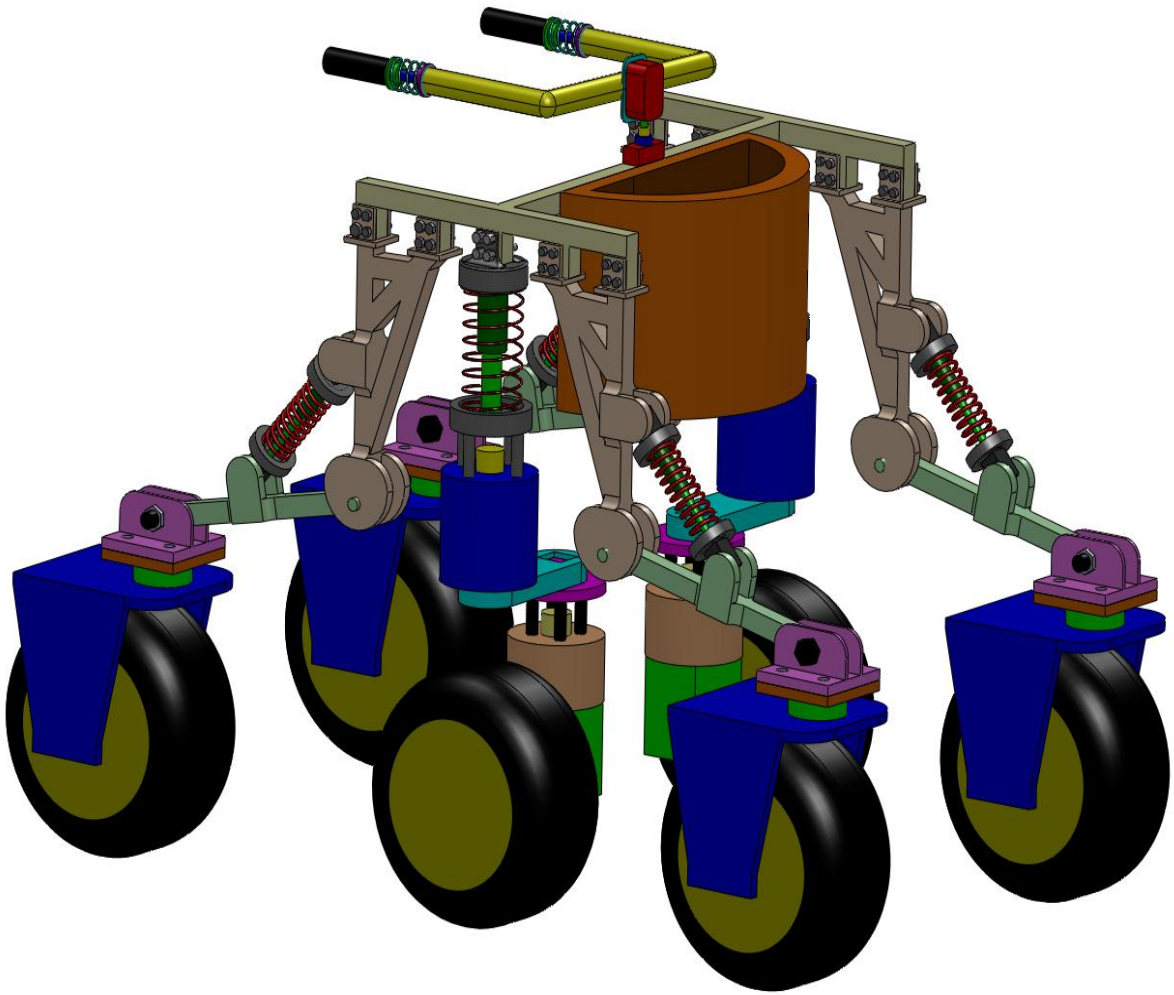


Interim Design 1

Problems:

1. Zero offset passive casters
2. No horizontal shock absorption
3. Too constricting to user

Interim Designs

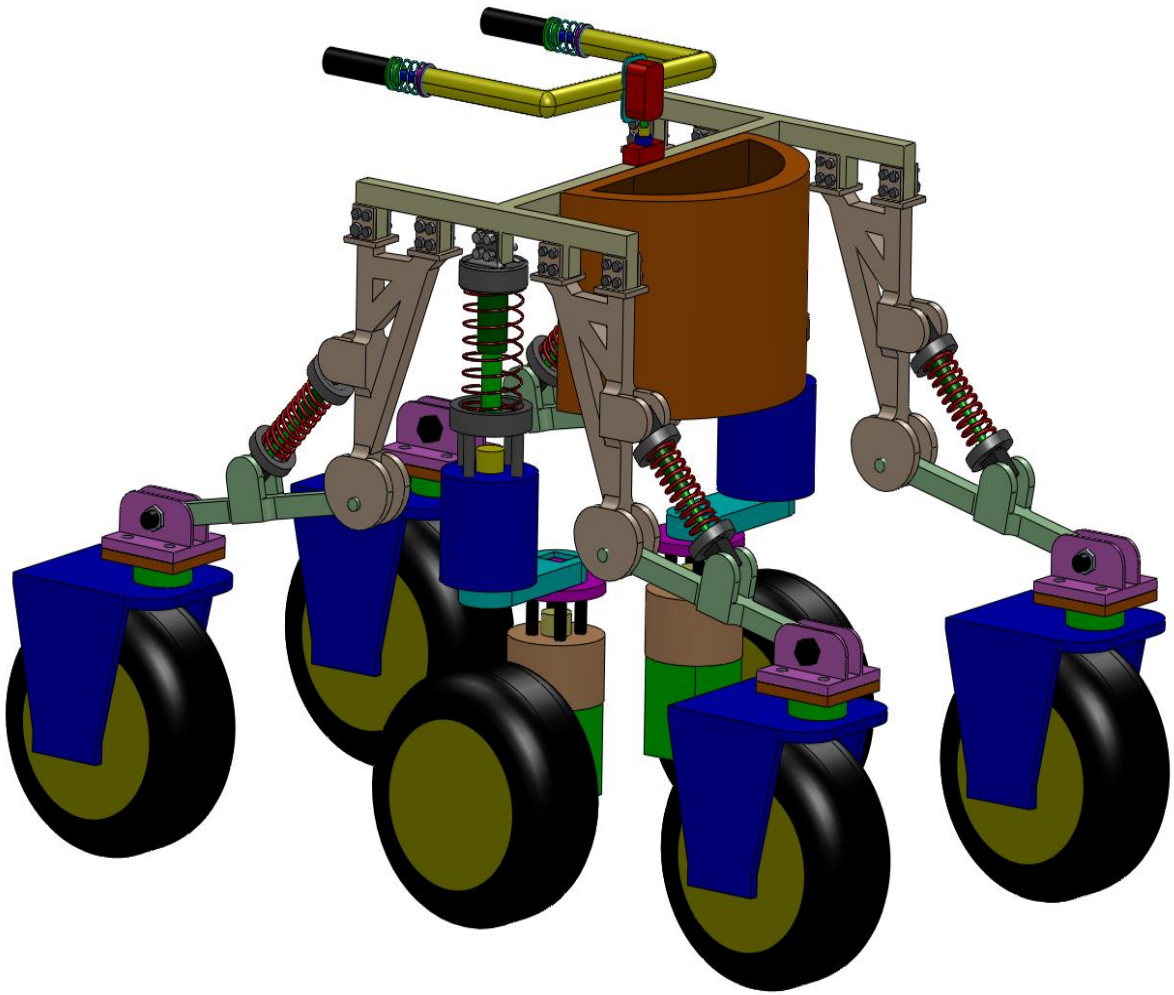


Interim Design 2

Fixes:

1. Swivel offset casters
2. Angled caster suspension
3. Smaller user restriction

Interim Designs

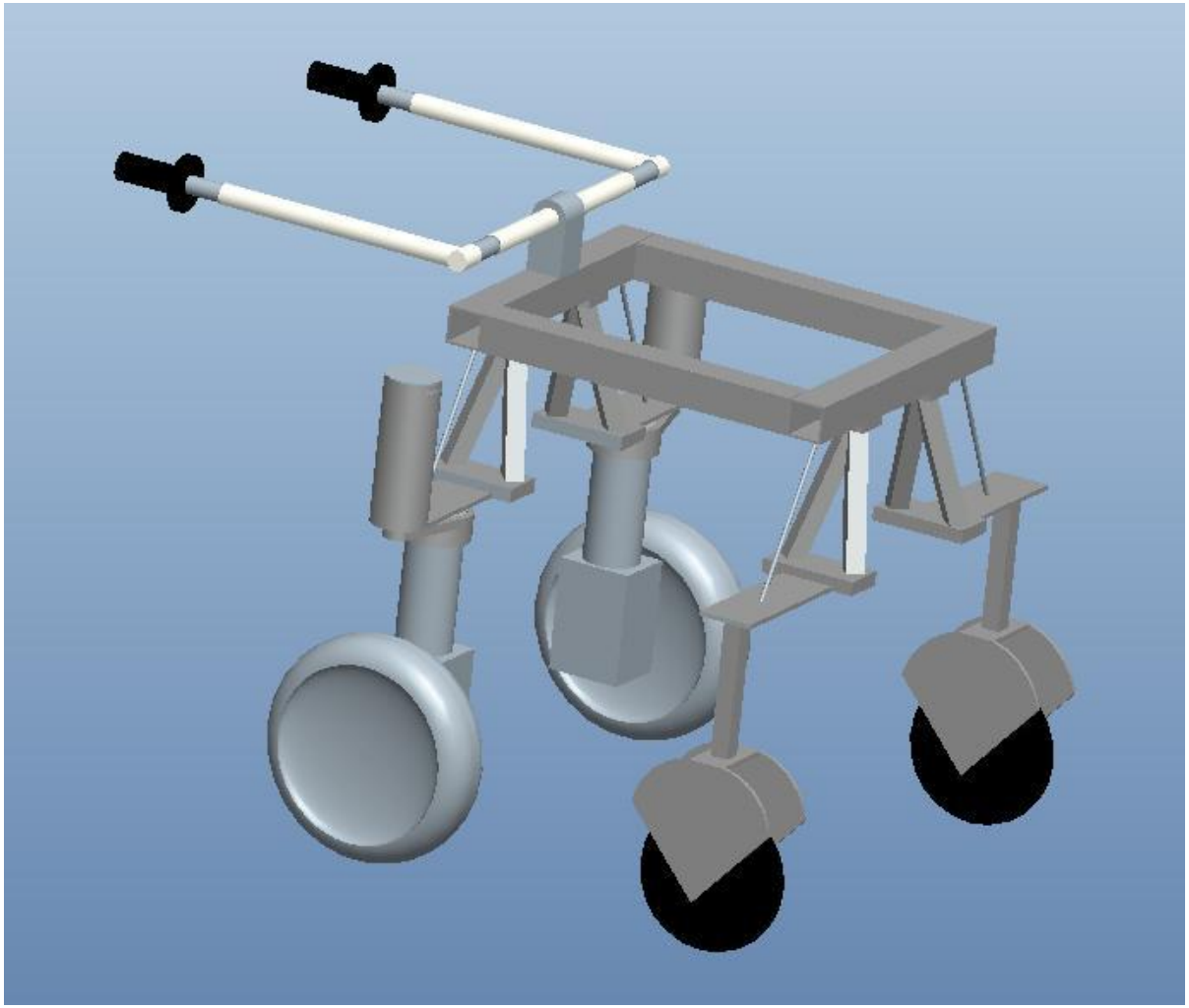


Interim Design 2

Problems:

1. No horizontal support for driving wheels
2. Low maneuverability
3. No room to house power and control systems

Interim Designs

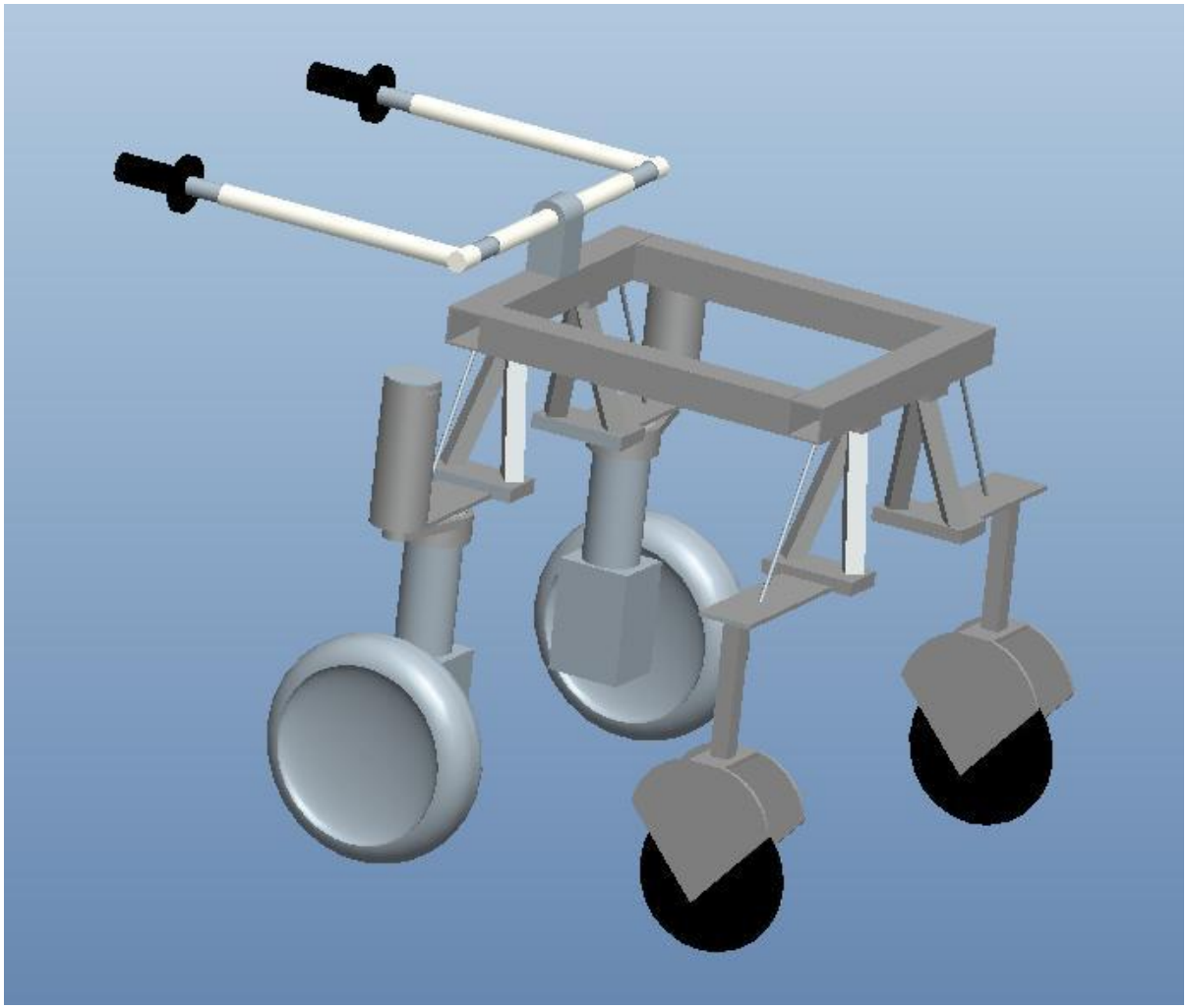


Interim Design 3

Fixes:

1. Angled suspension for all wheels
2. Four wheel design
3. Larger frame area to house electrical components

Interim Designs



Interim Design 3

Problems:

1. 90° offset of suspension
2. Poor / unavailable material choices
3. Flimsy handles

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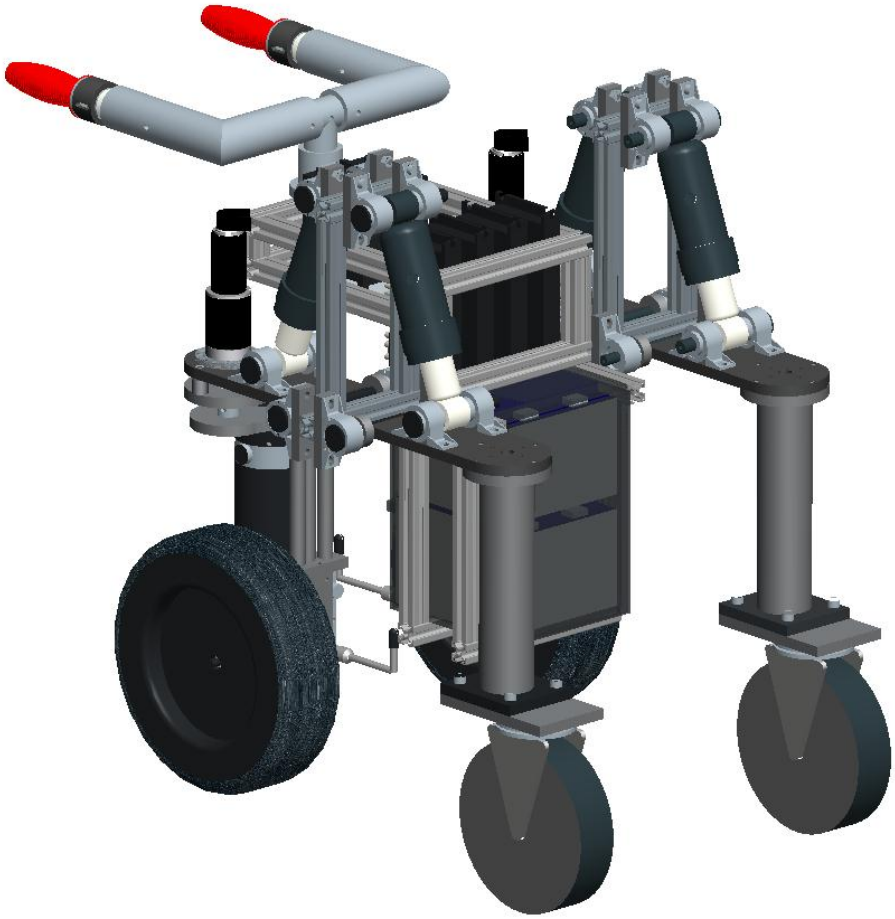
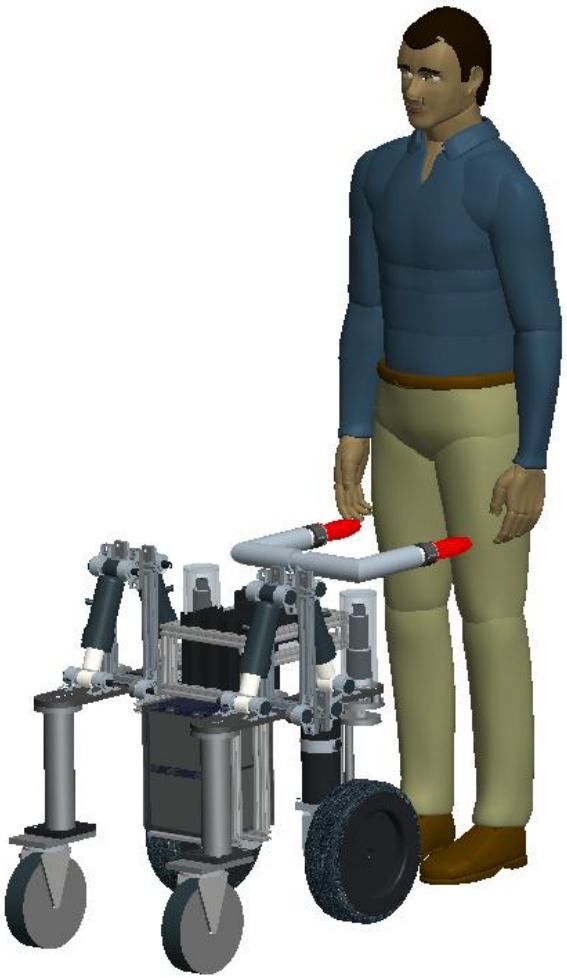
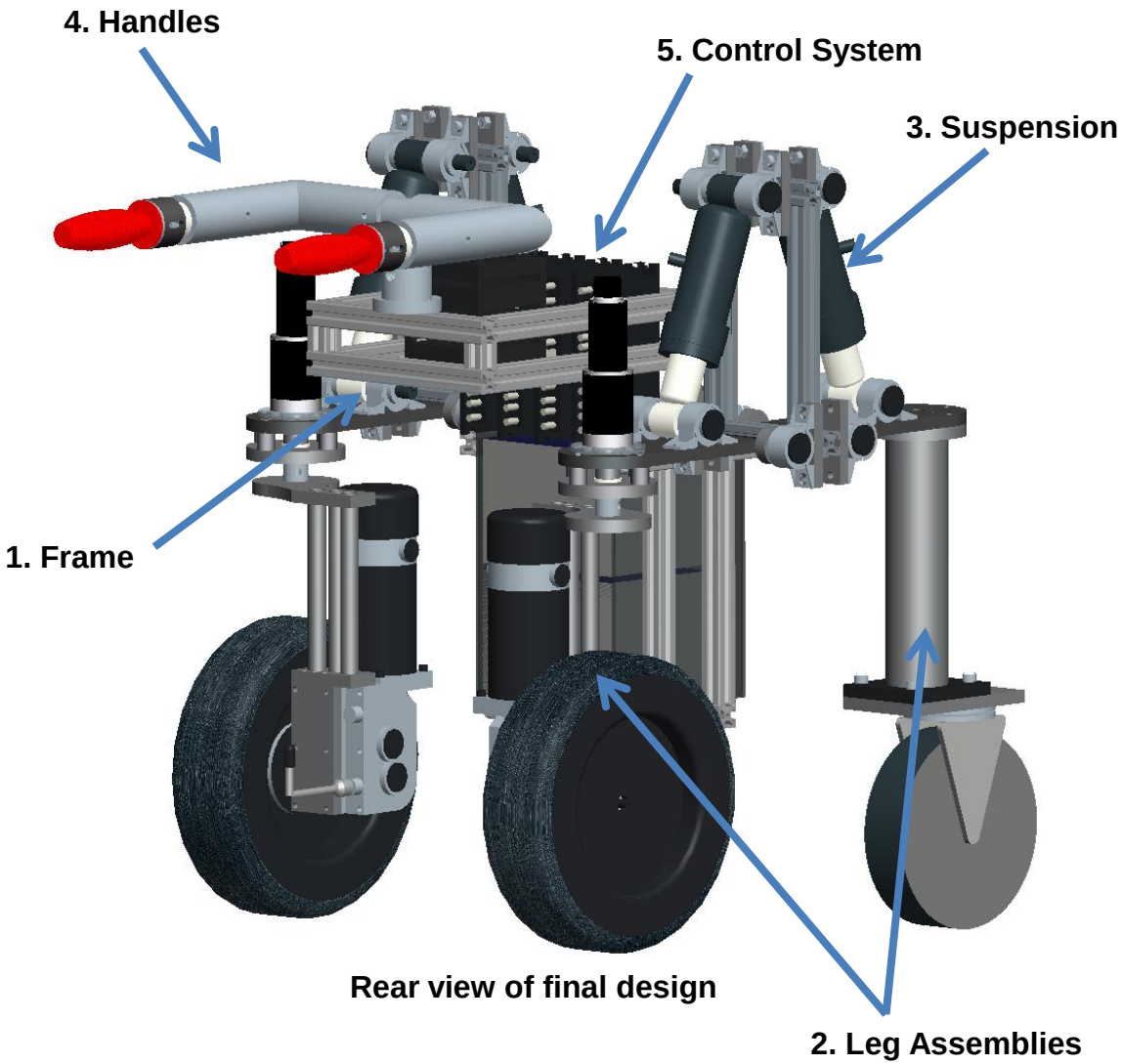
Final Design





Final Design

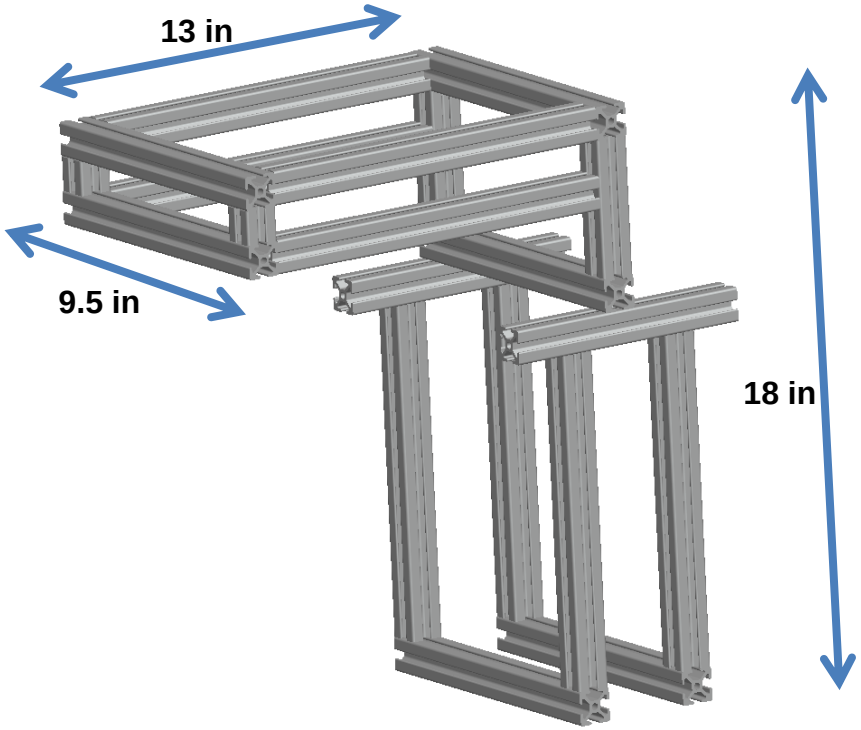


Rear view of final design

Major Components:

1. Frame
2. Leg Assemblies
3. Suspension
4. Handles
5. Control System

Frame

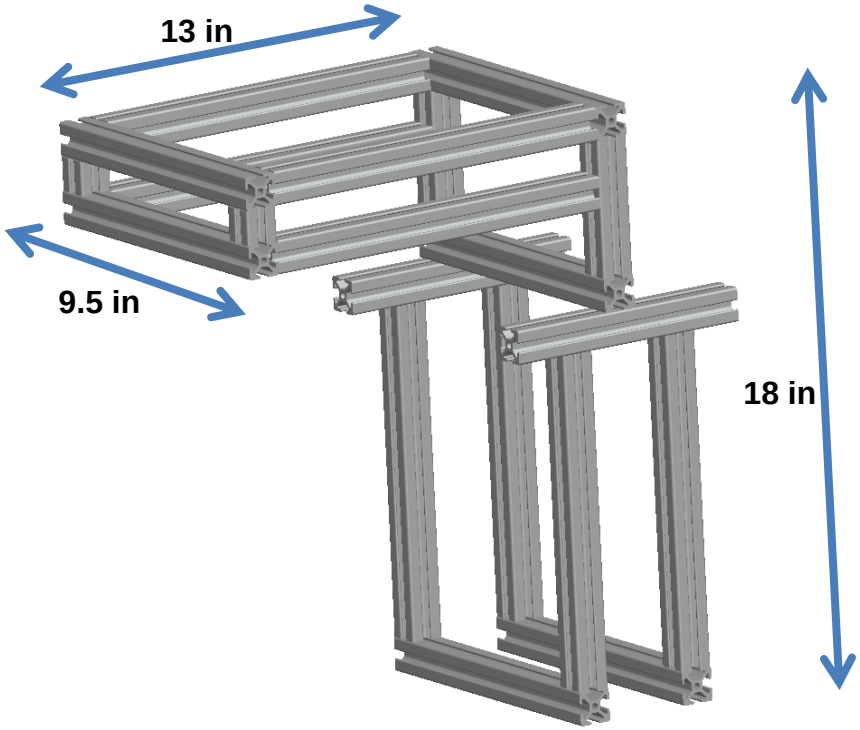


Basic frame structure

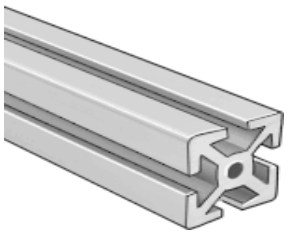
Dimensions:

- **Width: 9.5 in**
- **Length: 13 in**
- **Height: 18 in**

Frame



Basic frame structure



1x1 inch t-slotted 80/20

http://www.mcmaster.com/#catalog/118/1922/=gx58qp

Primary attachment pieces

http://www.mcmaster.com/#catalog/118/1924/=gx5d84

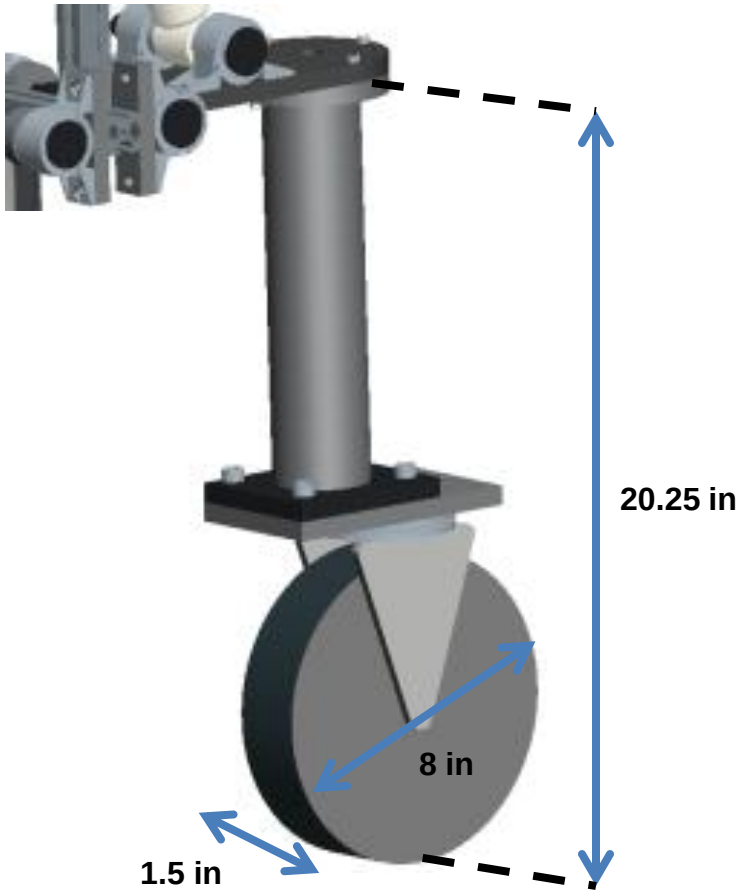
Dimensions:

- Width: 9.5 in
- Length: 13 in
- Height: 18 in

Features:

- 1x1 inch t-slotted aluminum 80/20
- Variable mounting locations
- Design evolution

Leg Assemblies



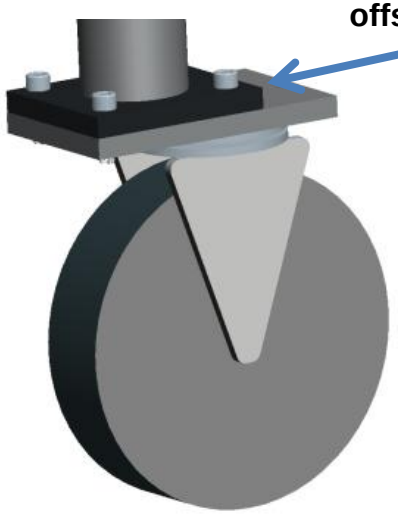
Final caster wheel design

Caster Wheels

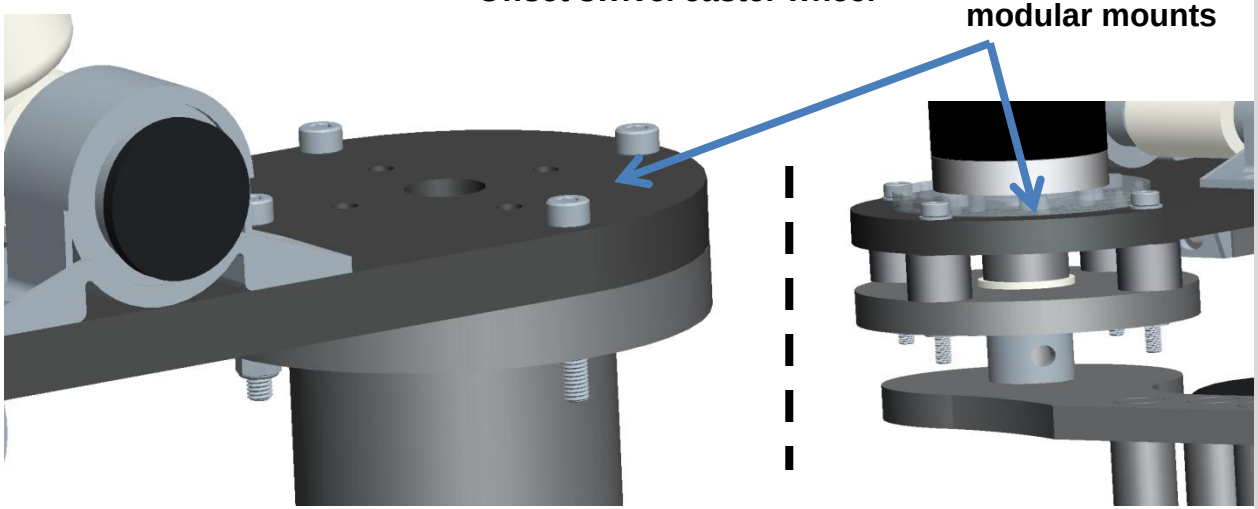
Dimensions:

- Diameter: 8 in
- Width: 1.5 in
- Height: 20.25 in

Leg Assemblies



Offset swivel caster wheel



(Caster) Modular mounting plates (Driving)

Caster Wheels

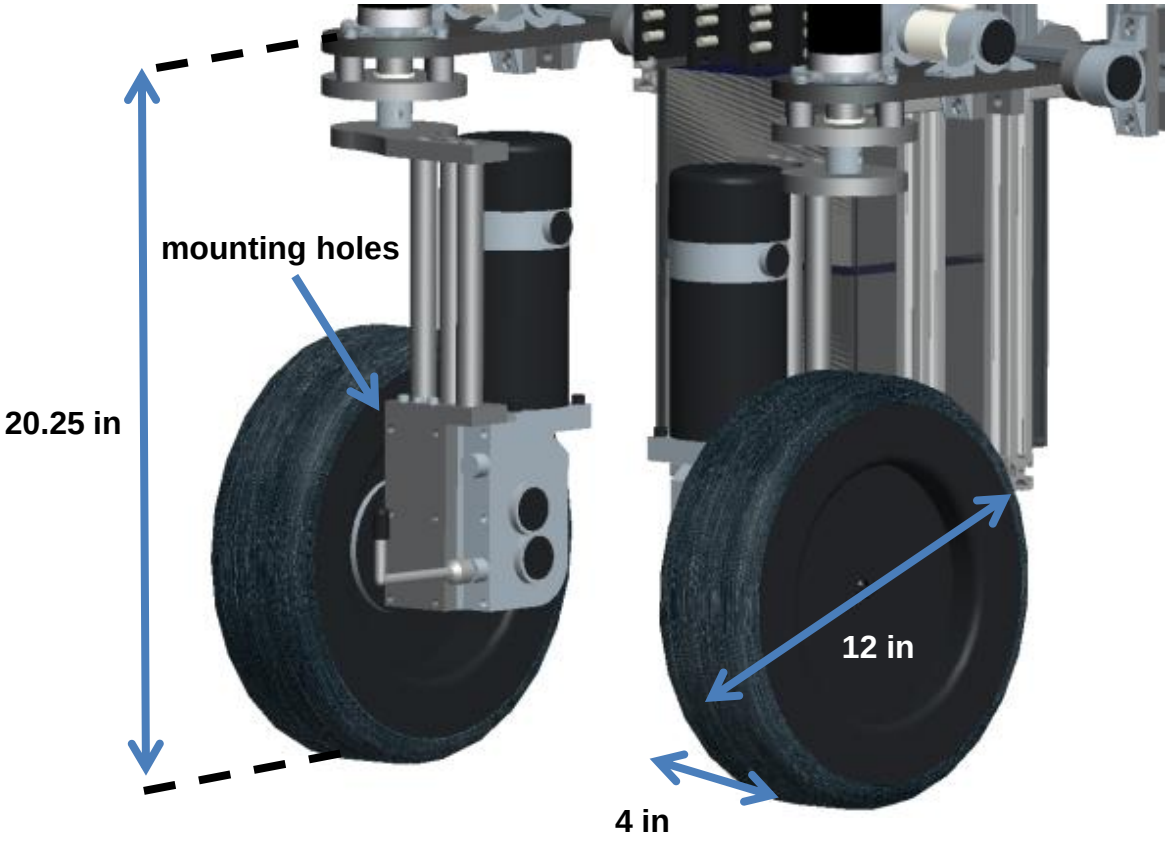
Dimensions:

- Diameter: 8 in
- Width: 1.5 in
- Height: 20.25 in

Features:

- Solid rubber
- Offset swivel
- Modular mounting plate

Leg Assemblies



Final driving wheel design

Driving Wheels

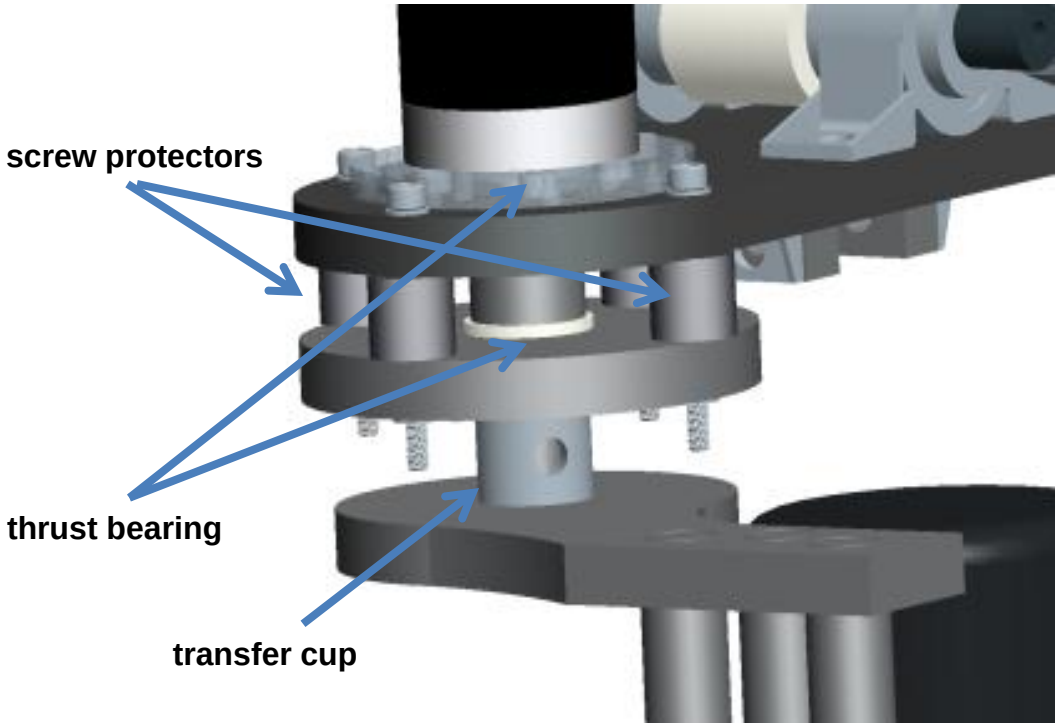
Dimensions:

- Diameter: 12 in
- Width: 4 in
- Height: 20.25 in

Features:

- Air filled / Metal rimmed
- Preexisting mounting holes

Leg Assemblies



Driving Wheels

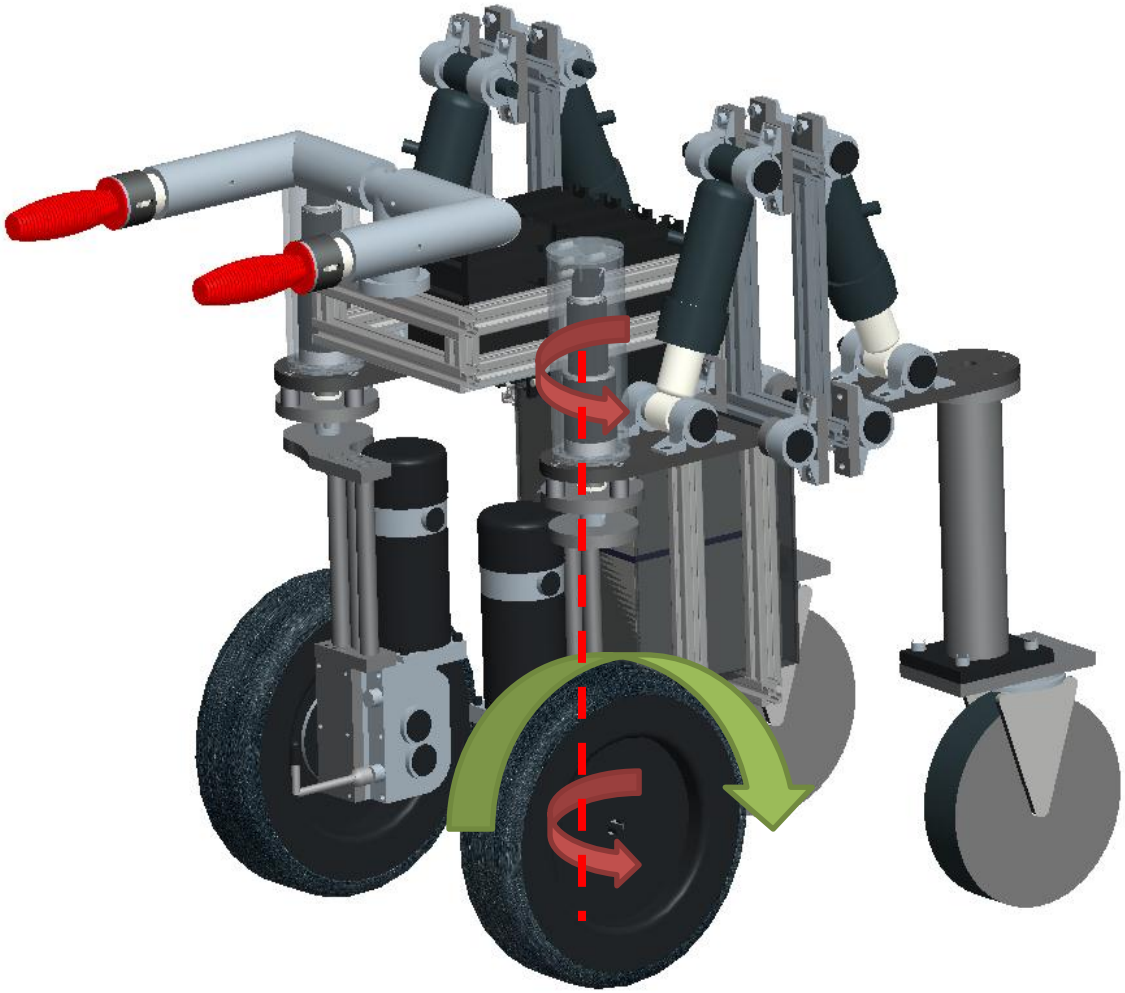
Dimensions:

- Diameter: 12 in
- Width: 4 in
- Height: 20.25 in

Features:

- Air filled / Metal rimmed
- Preexisting mounting holes
- Transfer cup
- Screw protectors
- Thrust bearings

Leg Assemblies



Motor spin diagram

Driving Wheels

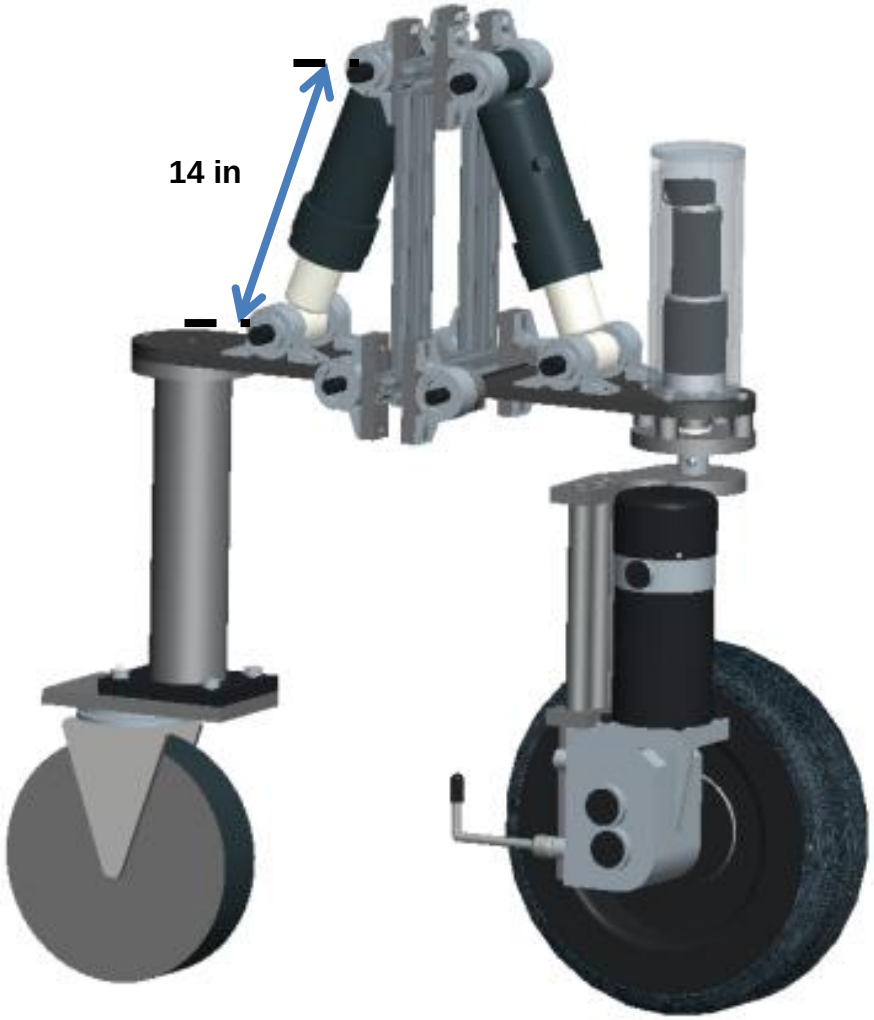
Dimensions:

- Diameter: 12 in
- Width: 4 in
- Height: 20.25 in

Features:

- Air filled / Metal rimmed
- Preexisting mounting holes
- Transfer cup
- Screw protectors
- Thrust bearings

Suspension

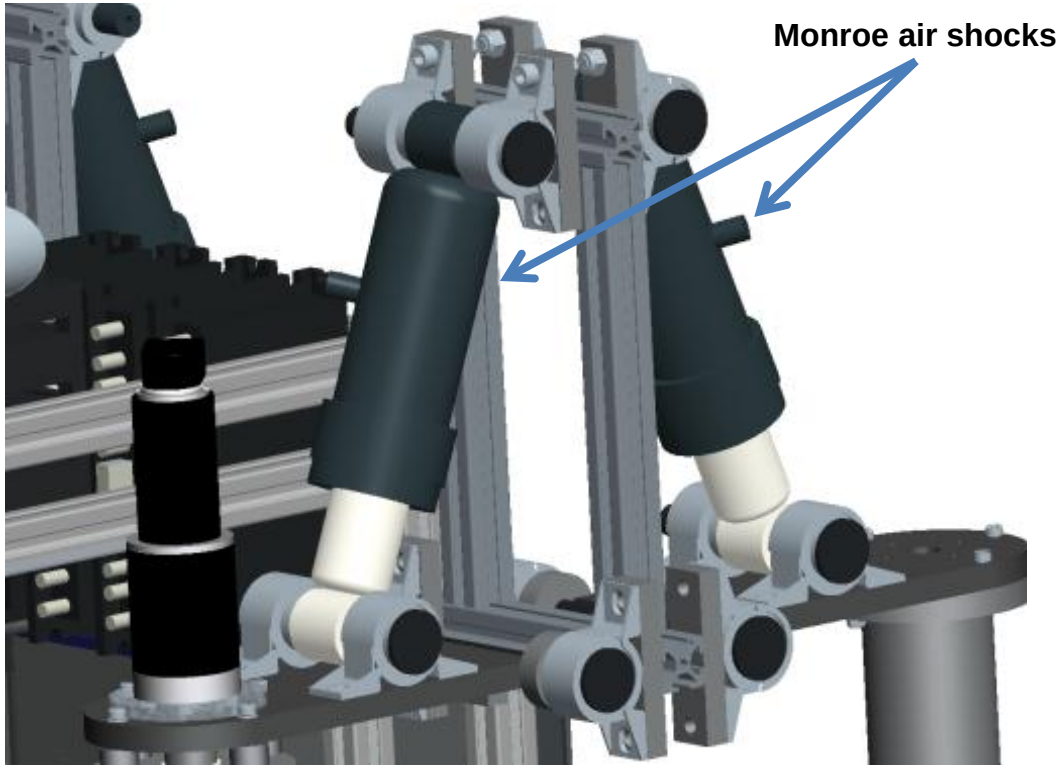


Final suspension design

Dimensions:

- Natural: 14 in
- Compressed: 9.375 in

Suspension



Suspension mount

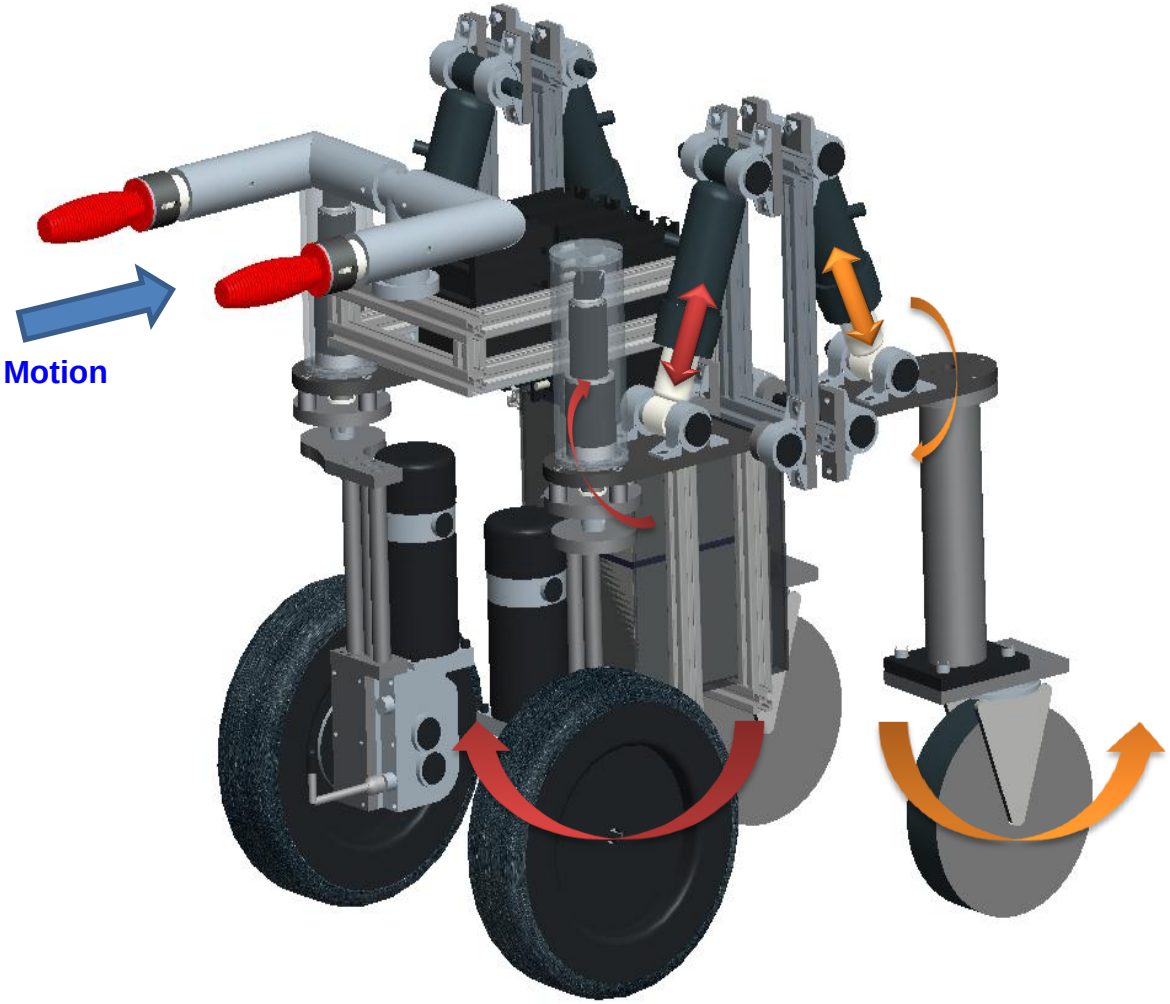
Dimensions:

- Natural: 14 in
- Compressed: 9.375 in

Features:

- Monroe Max-Air adjustable air shocks
- Same for all wheels
  - Modular

Suspension



Suspension movement diagram

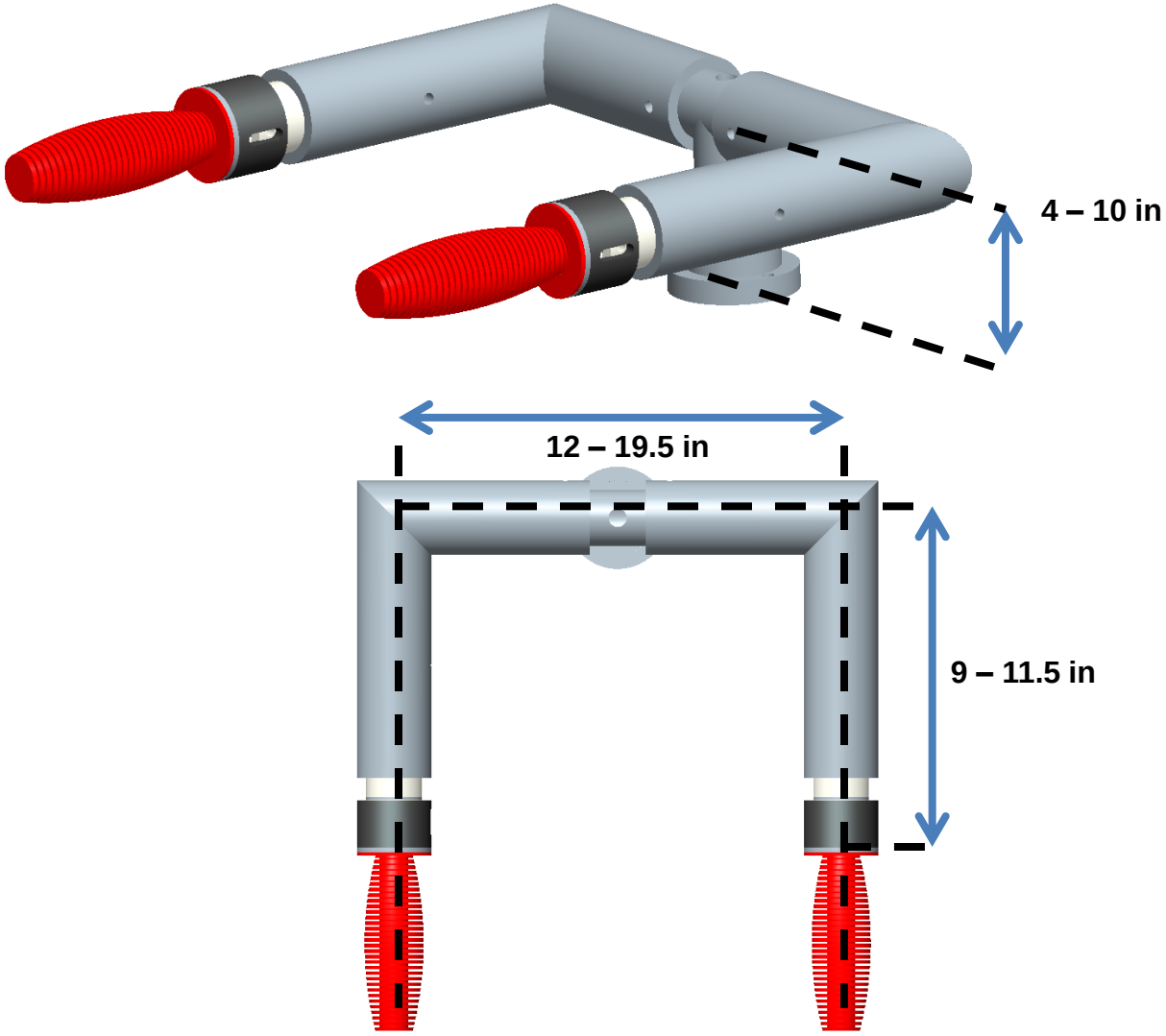
Dimensions:

- Natural: 14 in
- Compressed: 9.375 in

Features:

- Monroe Max-Air adjustable air shocks
- Same for all wheels
  - Modular
- In-line with direction of travel

Handles

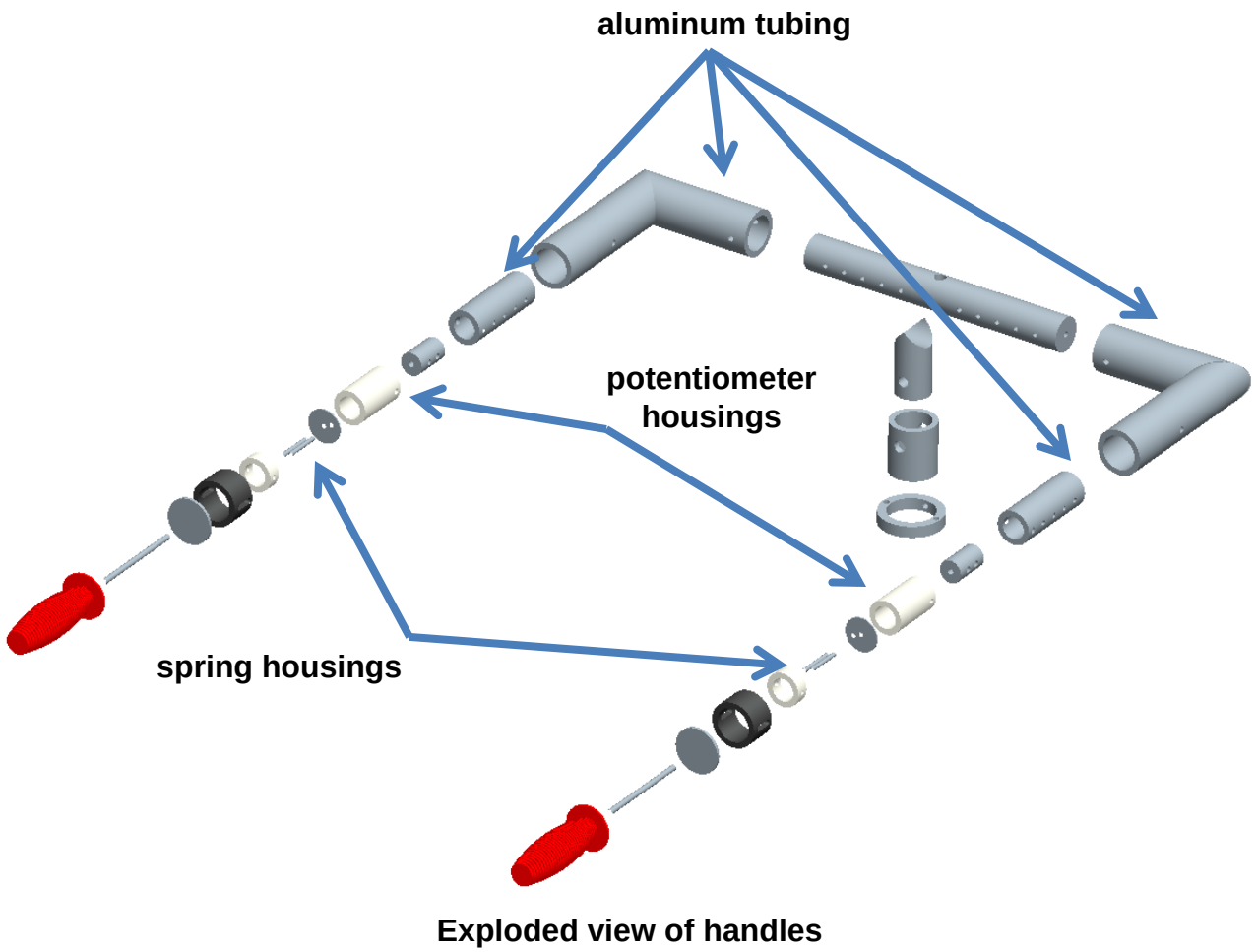


Final handle design

Dimensions:

- Width: 12 – 19.5 in
- Depth: 9 – 11.5 in
- Height: 4 – 10 in

Handles



Exploded view of handles

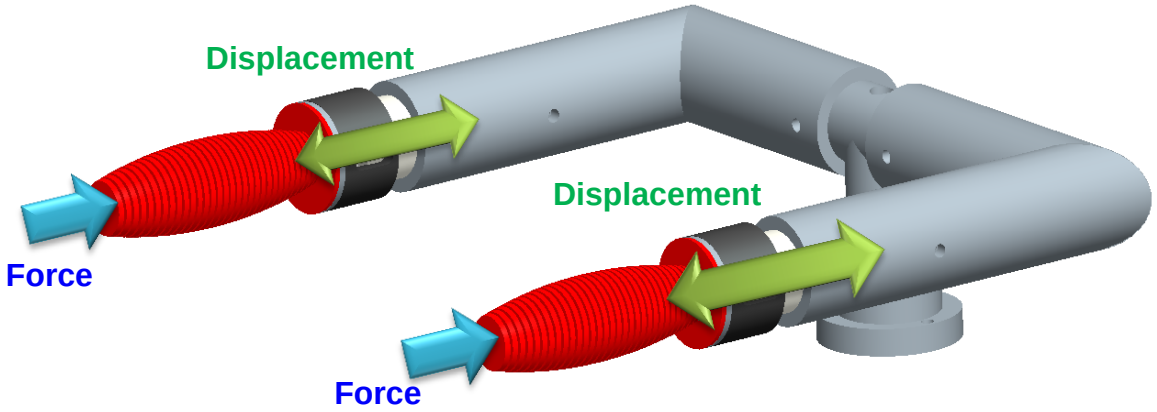
Dimensions:

- Width: 12 – 19.5 in
- Depth: 9 – 11.5 in
- Height: 4 – 10 in

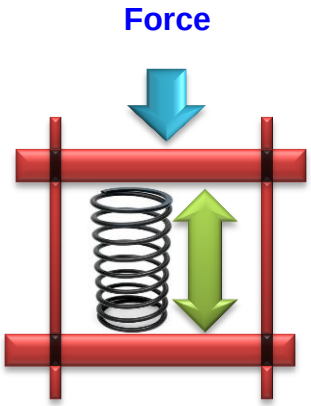
Features:

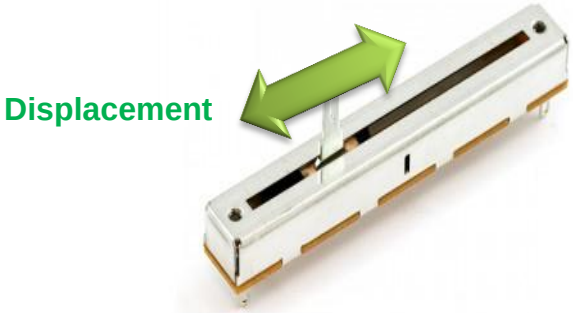
- Concentric aluminum tubing
- Linear potentiometers
- Interchangeable spring housing

Control System



Force – displacement diagrams

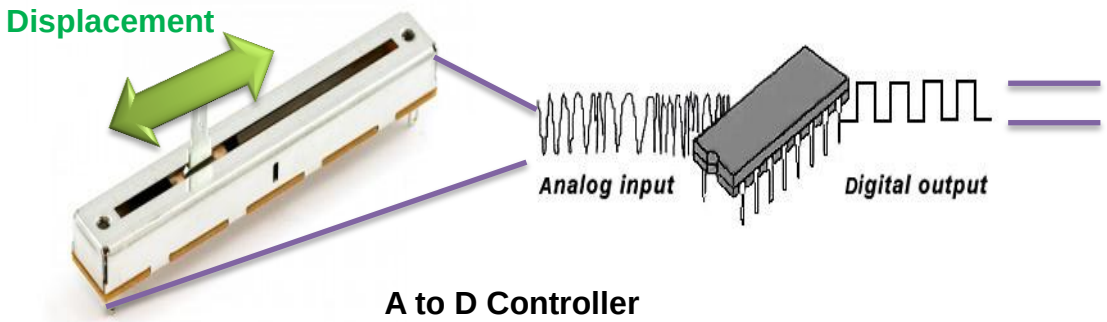




User Input

- 2 – exchangeable linear compression springs
- 2 – 10kΩ linear potentiometers

Control System



A to D Controller

Motor driver

http://www.a-m-c.com/images/productpics/120a10.jpg

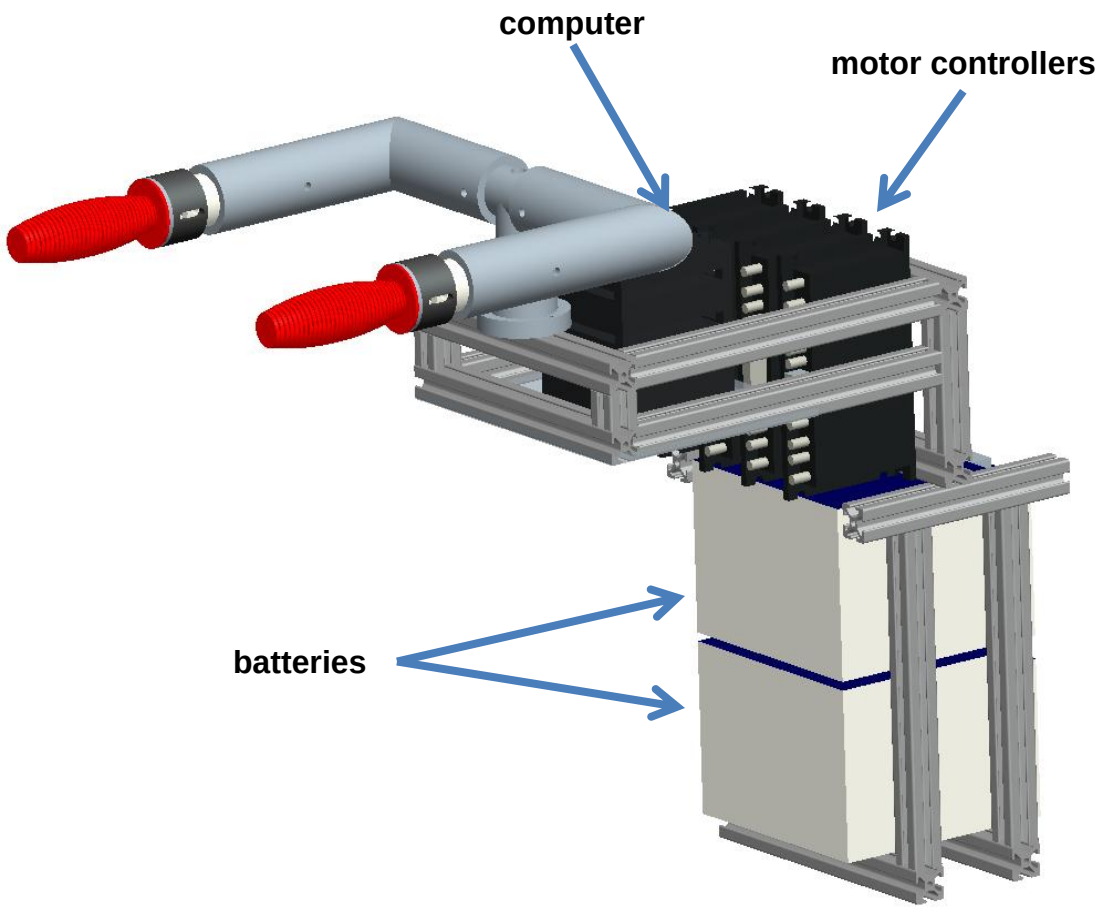
User Input

- 2 – exchangeable linear compression springs
- 2 – 10kΩ linear potentiometers

Control

- 1 – PC104 computer stack
- 4 – brushed motor drivers

Control System



Full control system and frame set-up

User Input

- 2 – exchangeable linear compression springs
- 2 – 10kΩ linear potentiometers

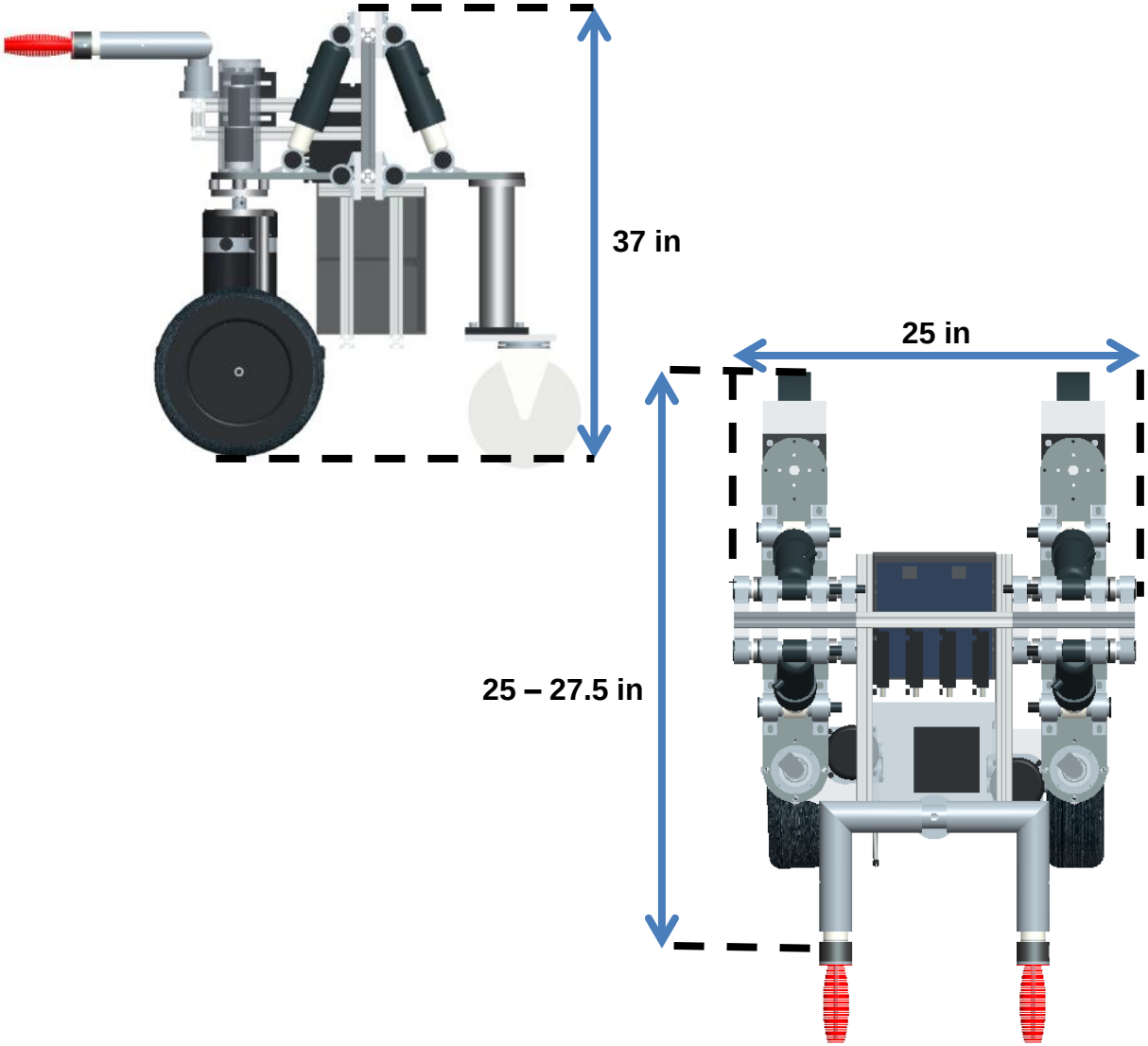
Control

- 1 – PC104 computer stack
- 4 – brushed motor drivers

Power

- 2 – 12V lead acid batteries

Final Design



Dimensions:

- Length: 25 – 27.5
- Width: 25 in
- Height: 37 in
- Weight: ~180 lbs

Decision Matrix Comparison

		Initial 1		Initial 2		Initial 3		Initial 4		Initial 5	
	Weight	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Versatility	0.15	3	0.454	5	0.757	3	0.454	3	0.454	3	0.454
Robustness	0.17	4	0.699	3	0.524	5	0.874	3	0.524	4	0.699
User-friendliness	0.22	3	0.670	4	0.894	2	0.447	5	1.117	3	0.670
Cost	0.04	2	0.086	2	0.086	1	0.043	1	0.043	1	0.043
Indoor	0.14	3	0.429	3	0.429	2	0.286	3	0.429	1	0.143
Outdoor	0.23	4	0.926	3	0.695	3	0.695	2	0.463	5	1.158
Weight	0.03	2	0.066	3	0.099	1	0.033	4	0.132	1	0.033
		Sum	3.331		3.483		2.832		3.163		3.200

		Interim 1		Interim 2		Interim 3		Final	
	Weight	Score	Weighted	Score	Weighted	Score	Weighted	Score	Weighted
Versatility	0.15	4	0.606	4	0.606	4	0.606	4	0.606
Robustness	0.17	3	0.524	3	0.524	2	0.350	3	0.524
User-friendliness	0.22	3	0.670	4	0.894	5	1.117	5	1.117
Cost	0.04	2	0.086	2	0.086	4	0.171	3	0.128
Indoor	0.14	2	0.286	2	0.286	5	0.715	5	0.715
Outdoor	0.23	5	1.158	5	1.158	3	0.695	4	0.926
Weight	0.03	2	0.066	2	0.066	3	0.099	2	0.066
			3.396		3.619		3.752		4.083

1) Project Introduction

2) Design Specifications

3) Concept Generation

4) Interim Designs

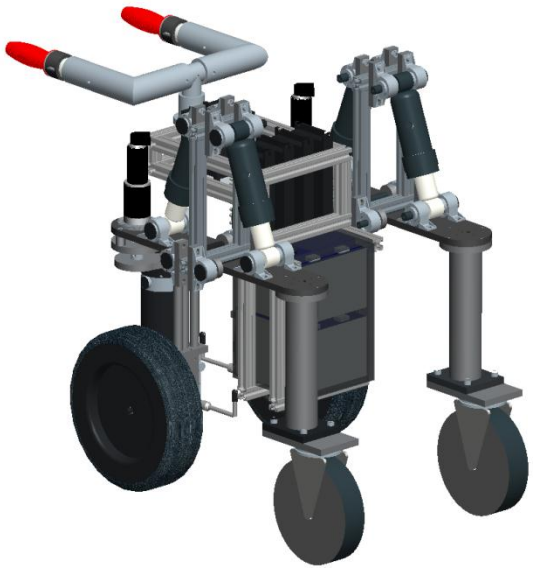
5) Final Design

6) Manufacturing & Assembly

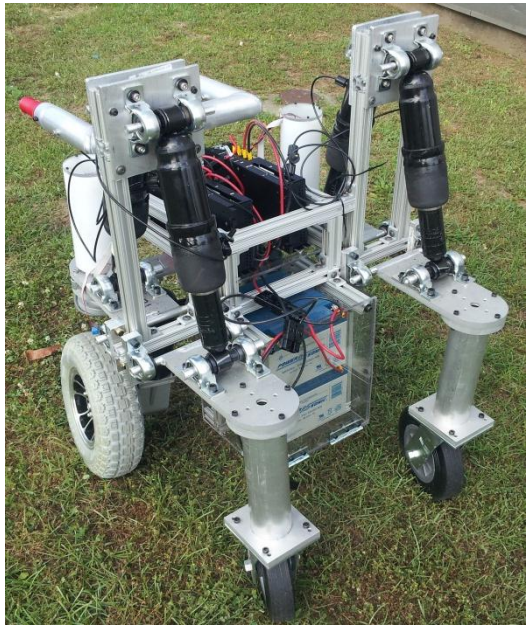
7) Testing & Results

8) Discussion & Conclusions

Manufacturing & Assembly



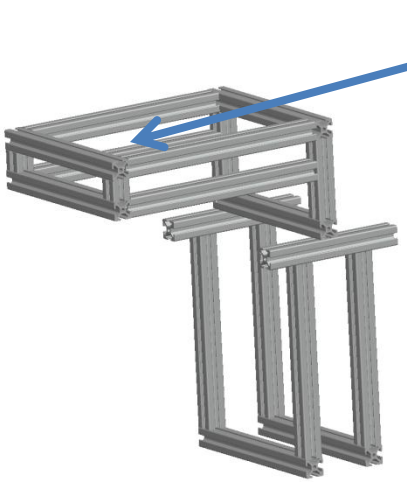
CAD of final design

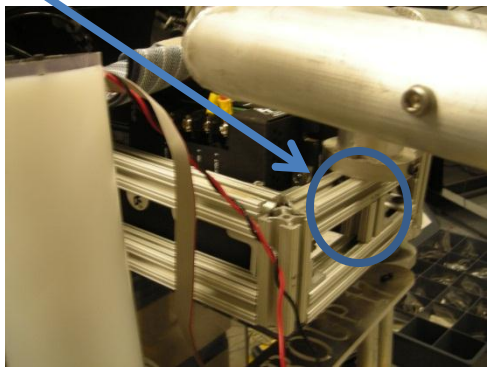


Final assembly

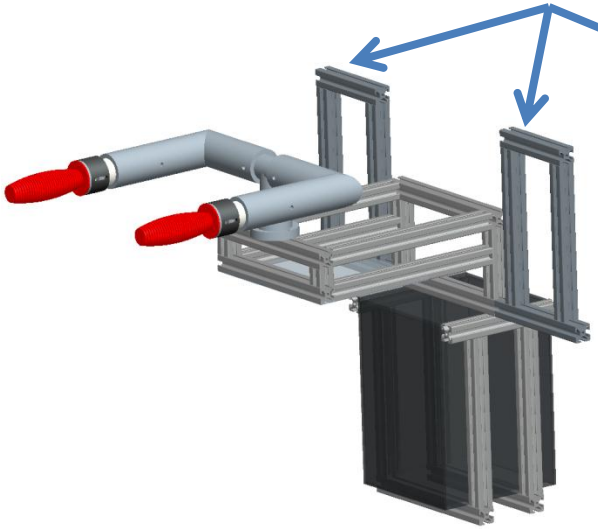
1. Frame
2. Suspension
3. Leg assemblies
4. Motor mounts
5. Handles

Manufacturing & Assembly

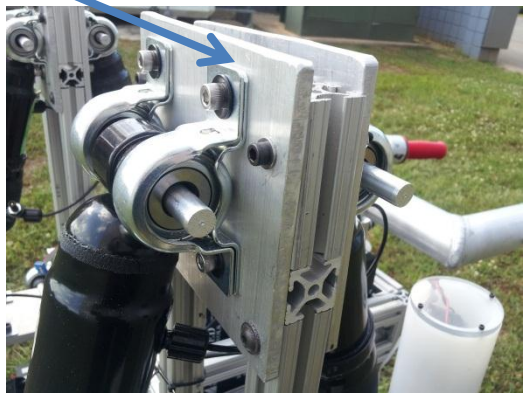




Close up of handle frame



CAD of final frame design



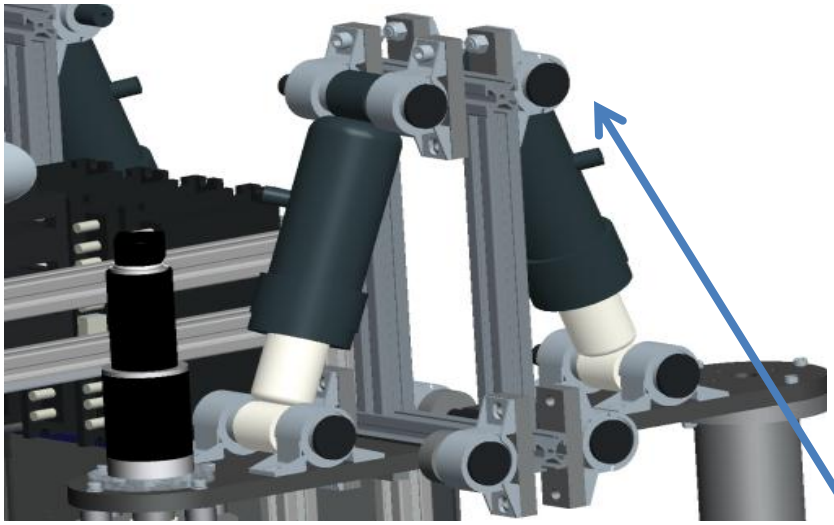
Close up of suspension mount

1. Frame

Modifications:

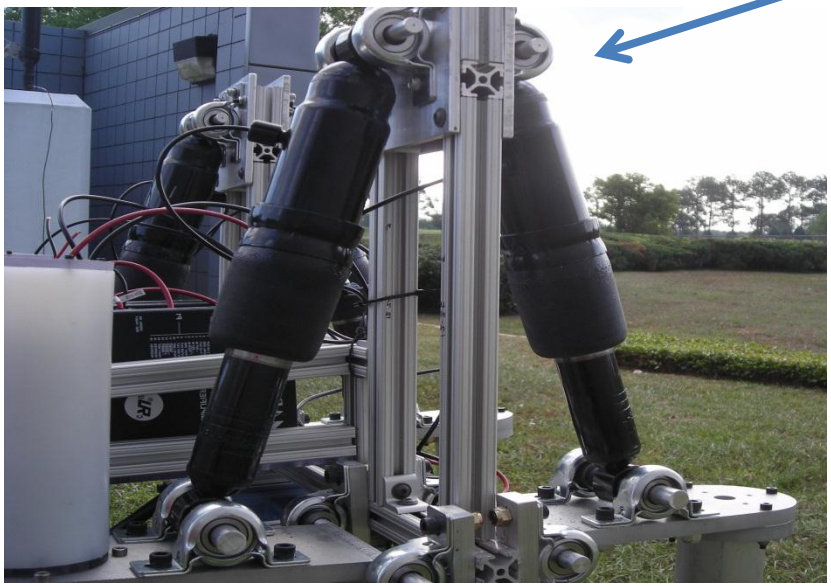
- Additional supports to prevent bending moment
- Extended plates for suspension mounting

Manufacturing & Assembly



CAD of final suspension design

higher mount



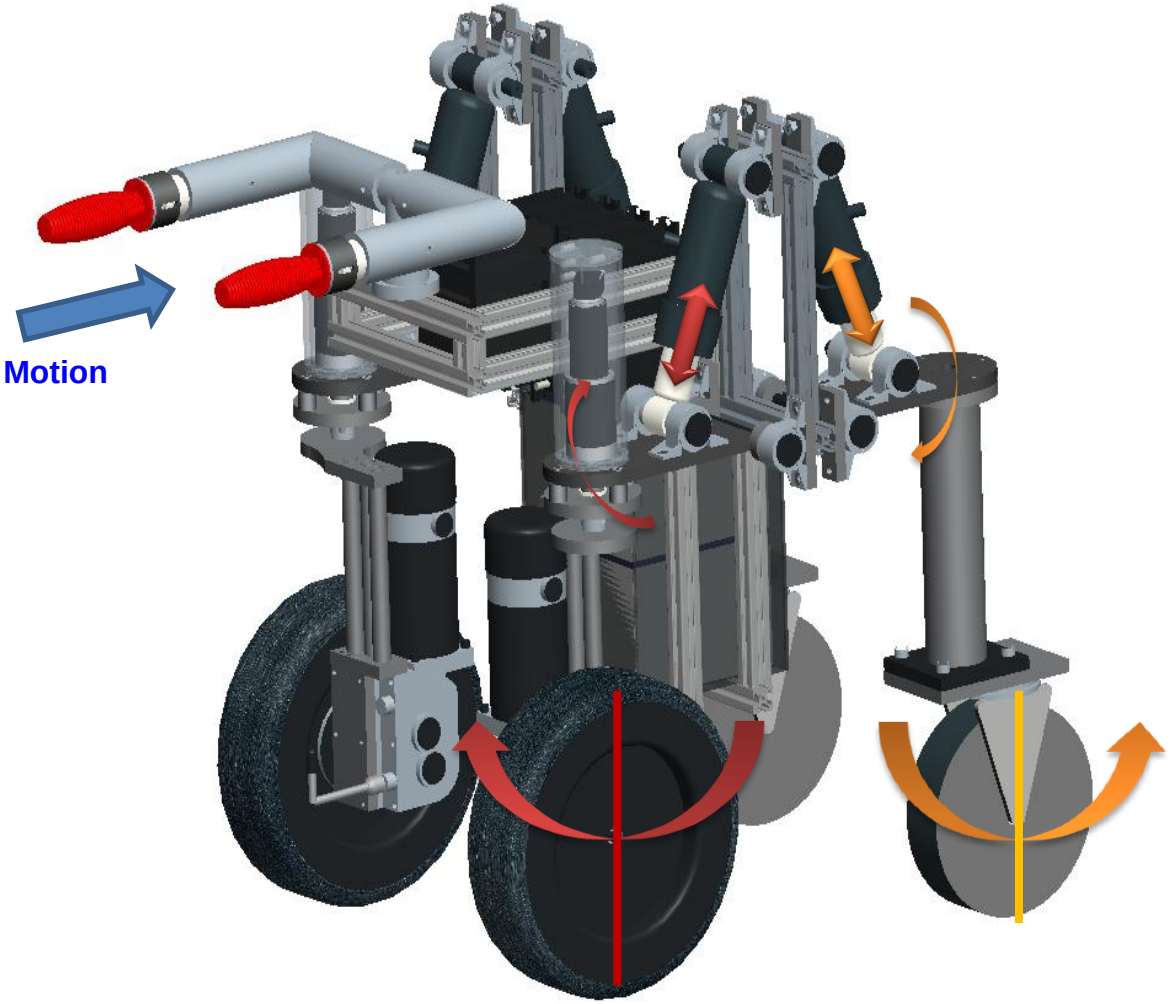
Suspension assembly

2. Suspension

Modifications:

- **Higher mounting location**

Manufacturing & Assembly



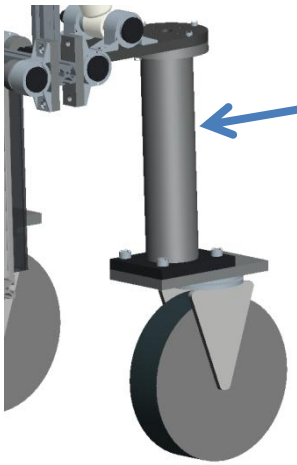
Suspension movement diagram

2. Suspension

Modifications:

- Higher mounting location

Manufacturing & Assembly



shorter tube

CAD of final caster wheel design

Caster wheel assembly

lock bar

CAD of final driving wheel design

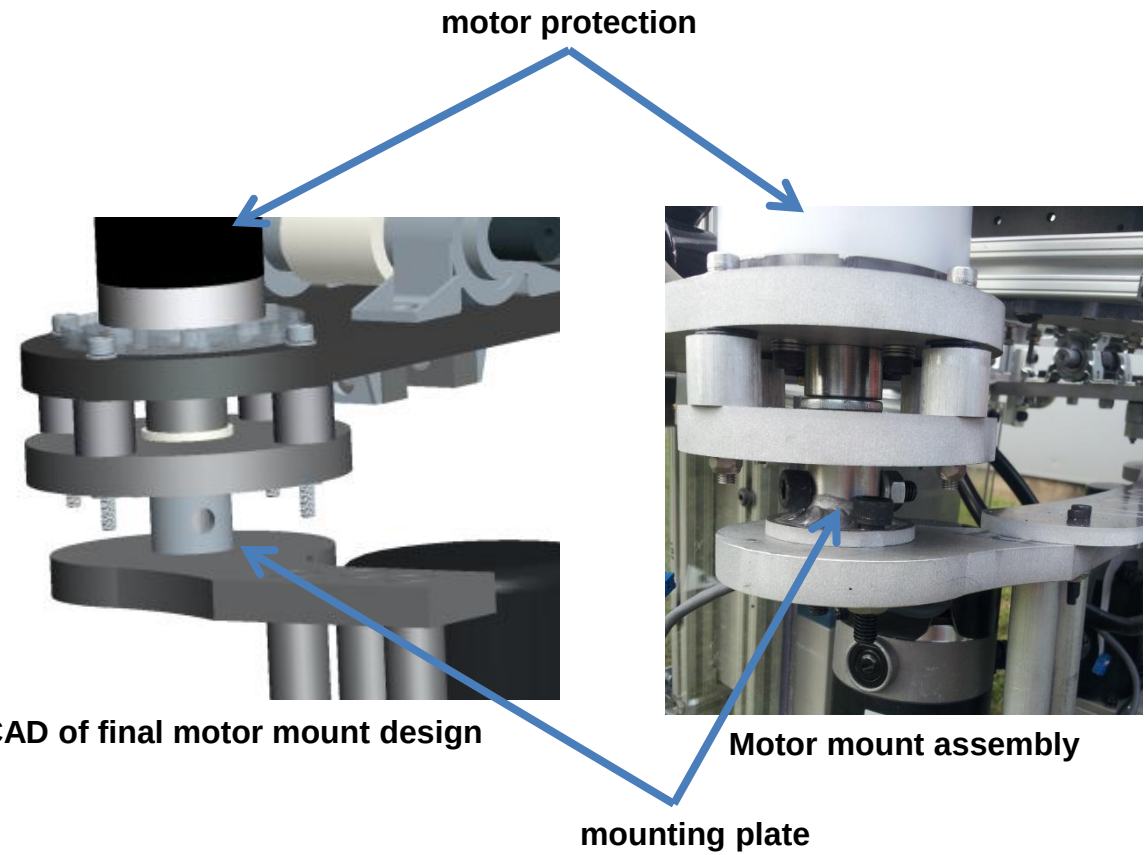
Driving wheel assembly

3. Leg assemblies

Modifications:

- Slightly shorter aluminum tubing
- Lock bar
  - Passive
  - Reduced complexity

Manufacturing & Assembly

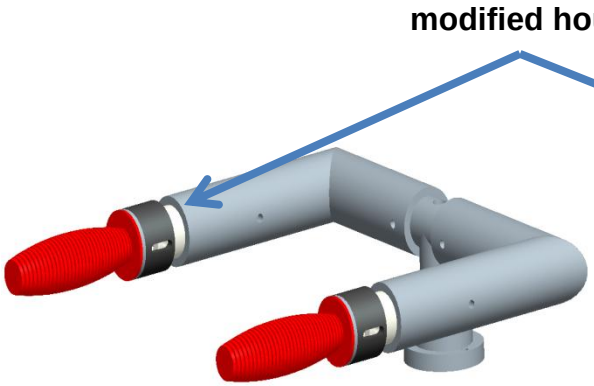


4. Motor mounts

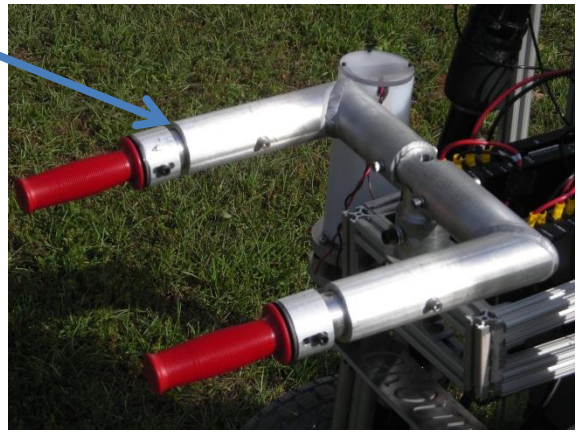
Modifications:

- Steering motor protective cover
- Bolted mounting plate

Manufacturing & Assembly



CAD of final handle design



Final handle assembly

5. Handles

Modifications:

- Modified potentiometer housing

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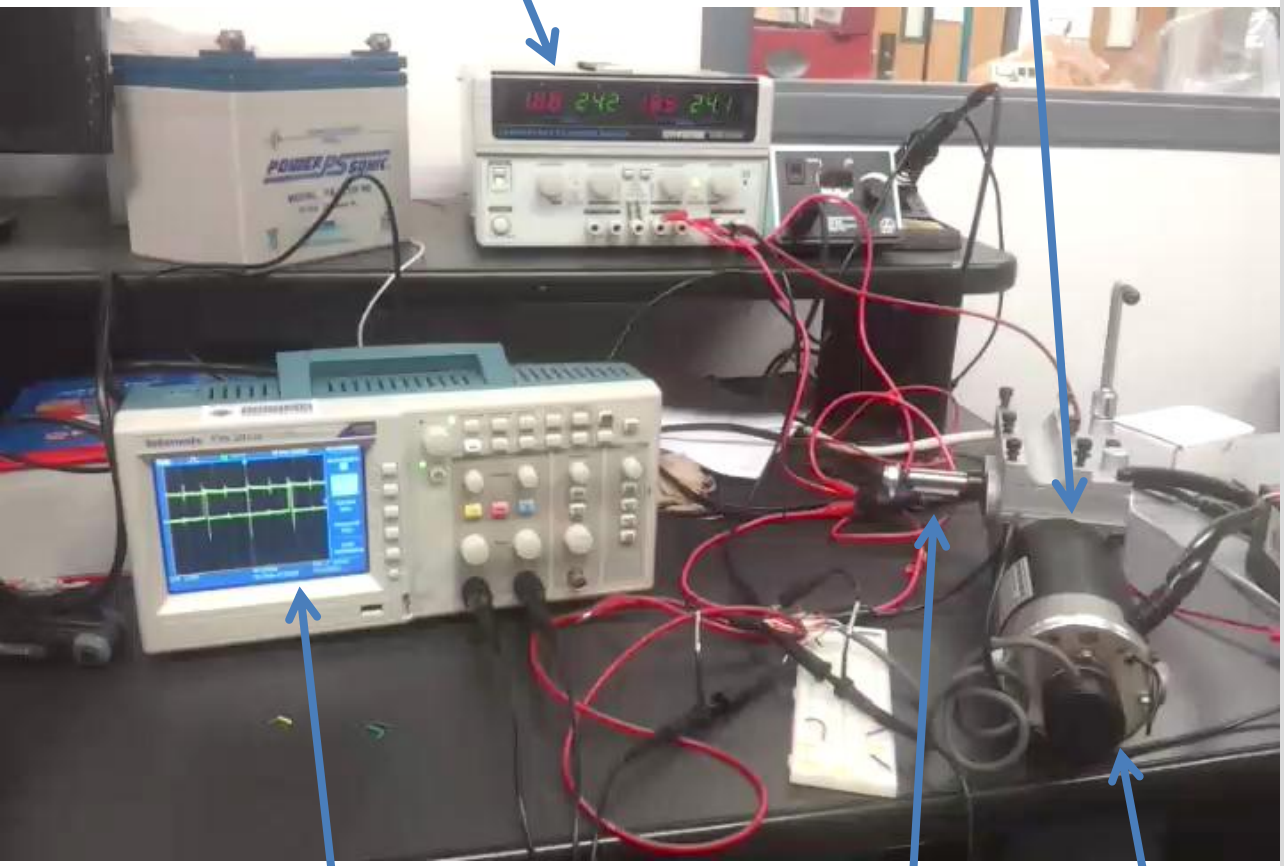
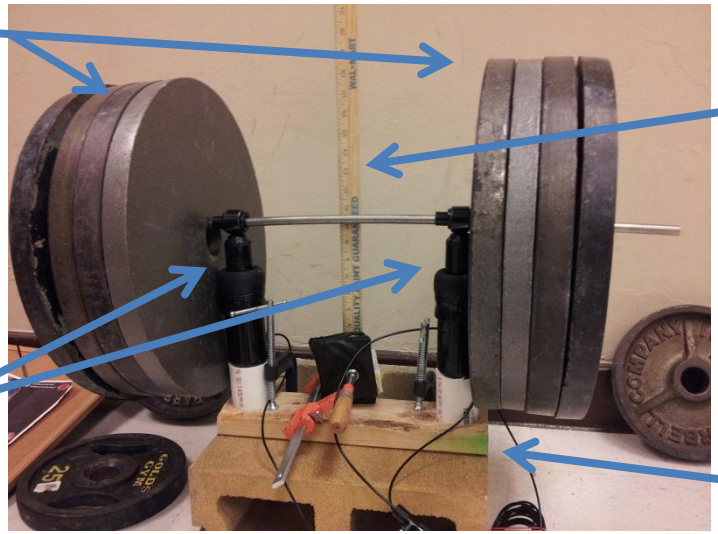
Initial Tests



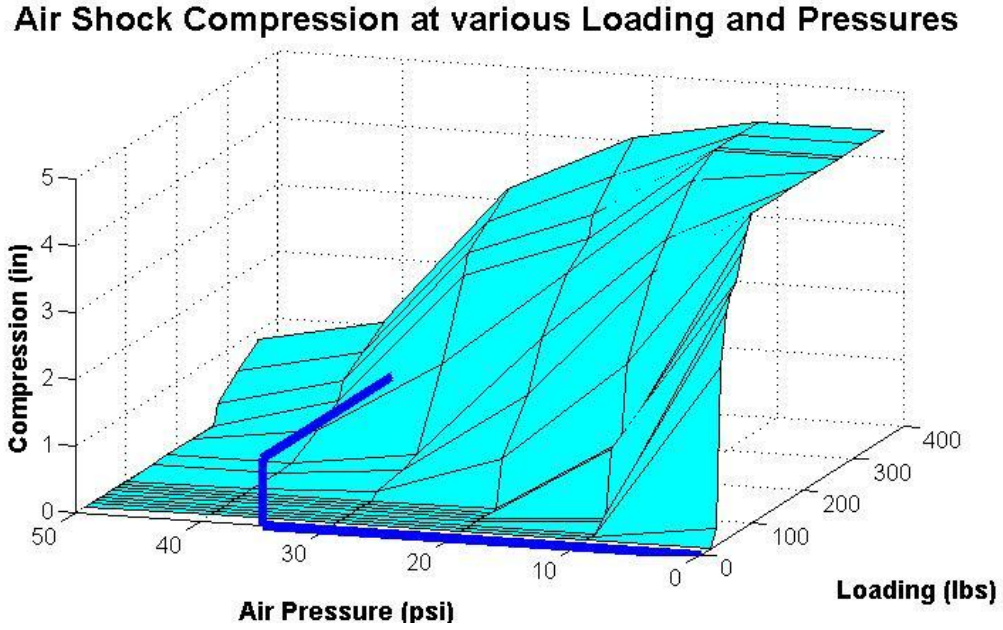
Testing driving motors (video)

1. Driving Motors

Initial Tests



Picture of testing setup



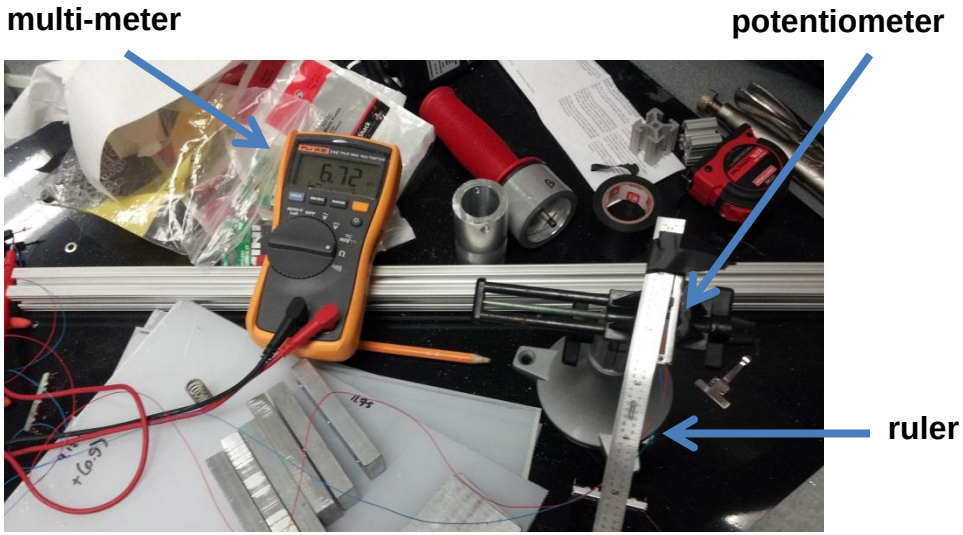
1. Driving Motors

2. Air shocks

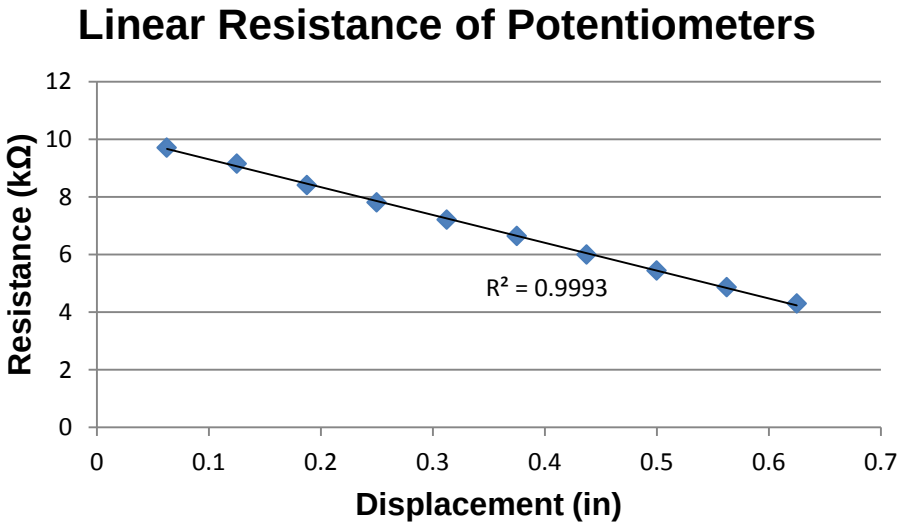
Example Specifications:

- **35 psi**
- **1.5 in compression**
- **150 lbs**

Initial Tests

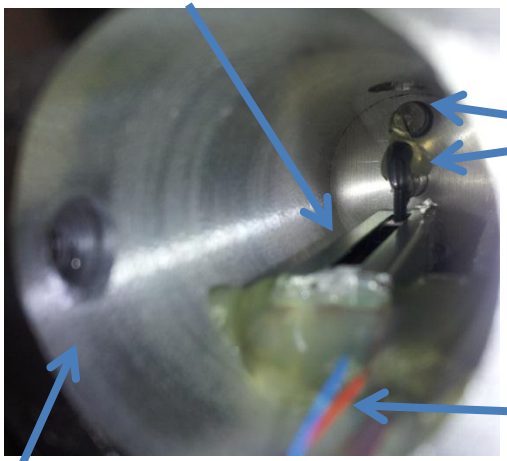


Picture of testing setup



1. Driving Motors
2. Air shocks
3. Linear potentiometers

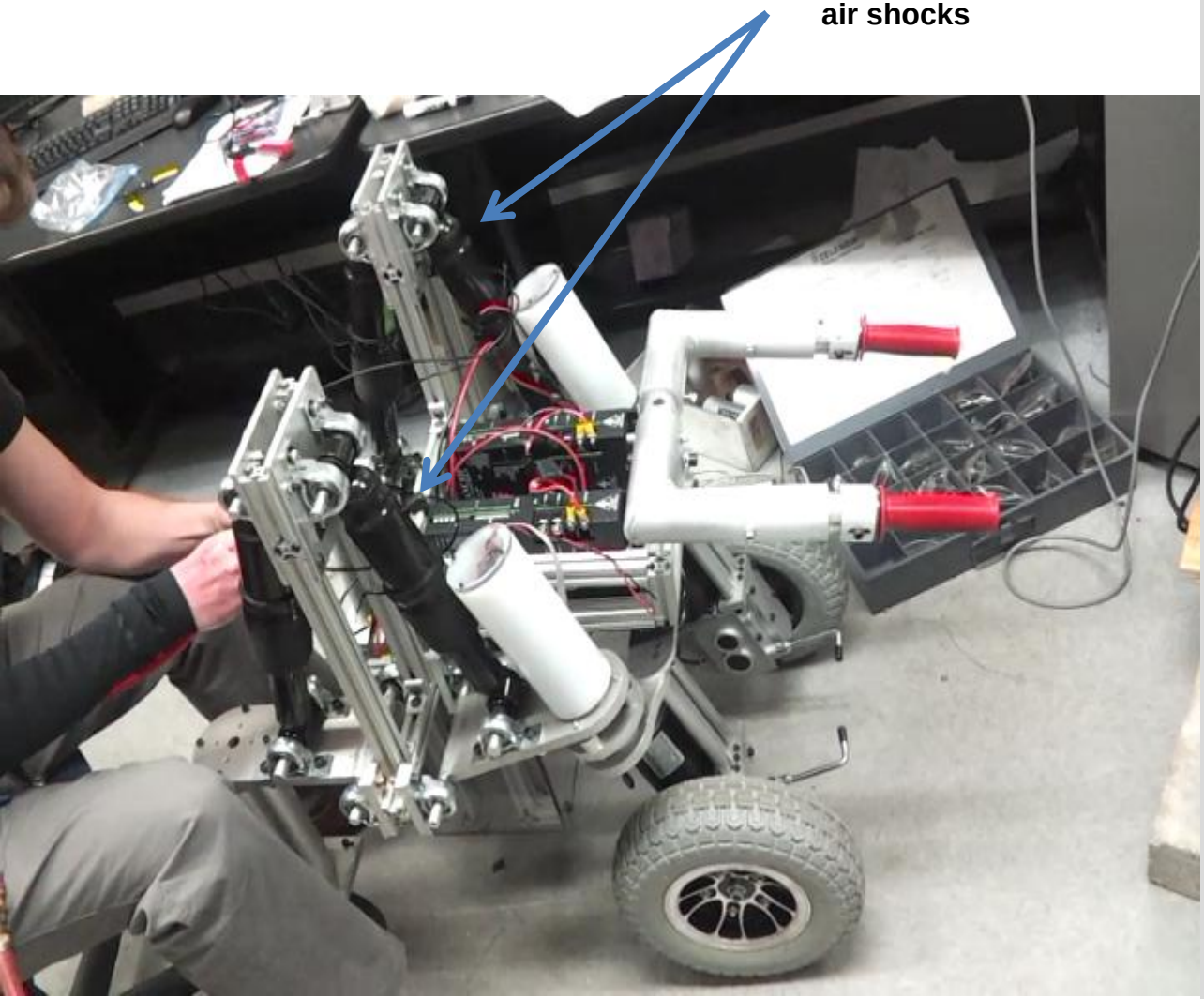
Initial Tests



Mounted potentiometer displacement response (video)

1. Driving Motors
2. Air shocks
3. Linear potentiometers

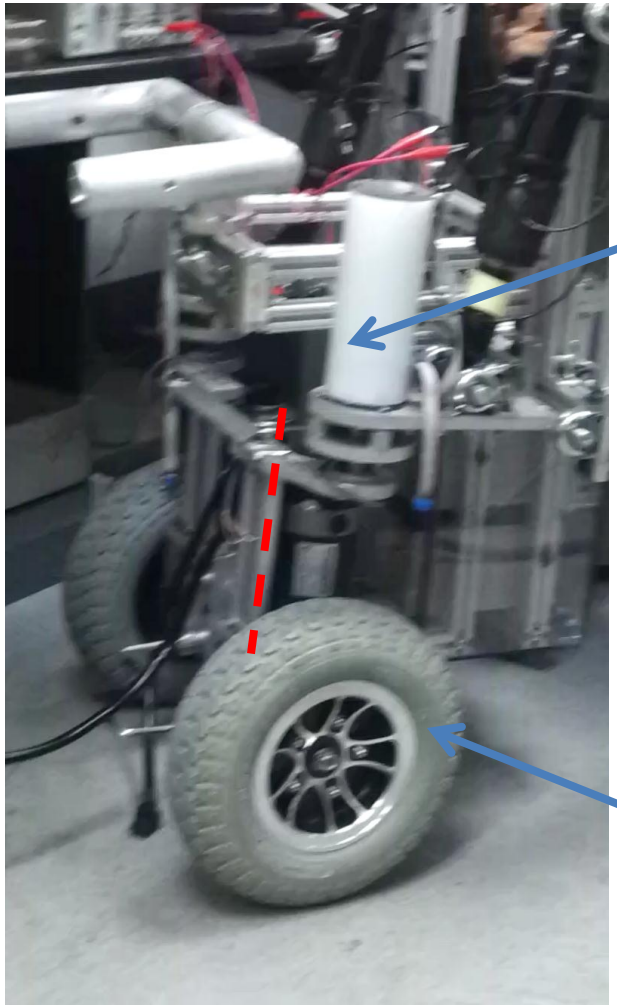
Design Tests



Testing air shocks (video)

1. Air Shocks

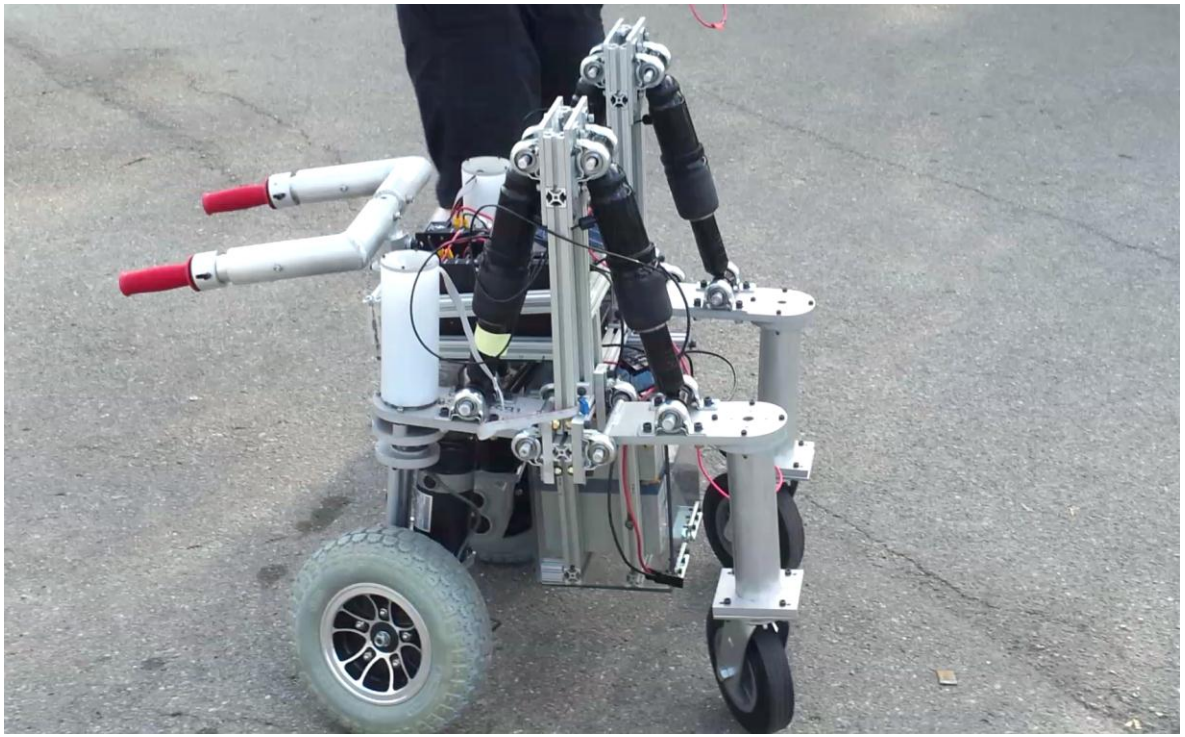
Design Tests



Testing steering motors (video)

1. Air Shocks
2. Steering Motors

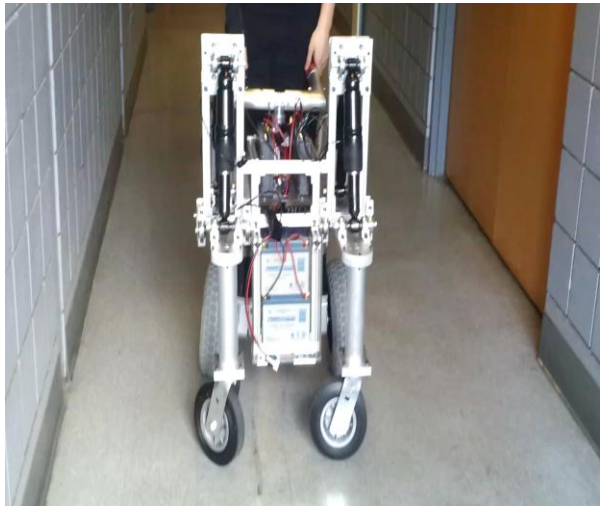
Design Tests



Testing driving motors (video)

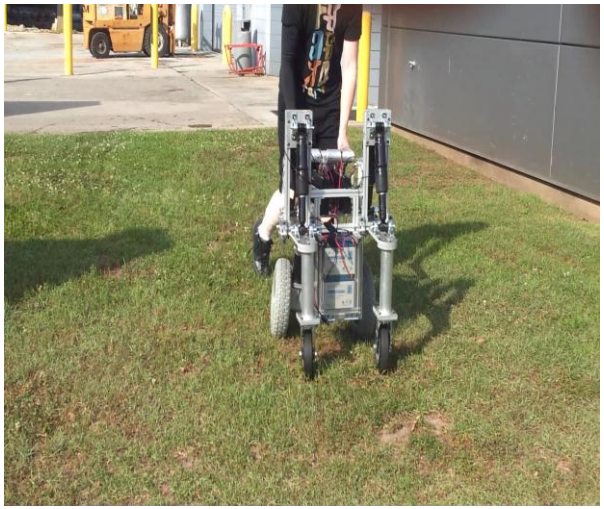
1. Air Shocks
2. Steering Motors
3. Driving Motors

Design Tests



Tile, carpet, cement, grass (video)

Gravel (video)

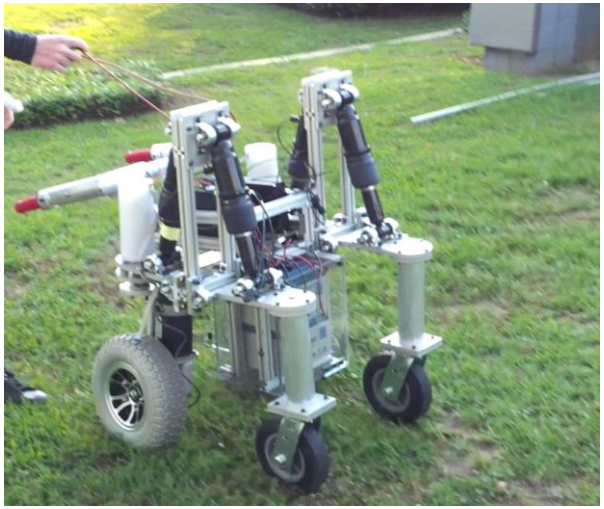


Large obstacles (video)

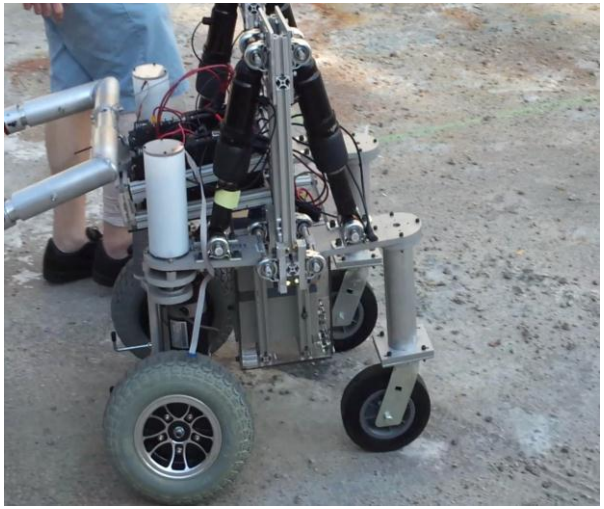
Ramps (video)

1. Air Shocks
2. Steering Motors
3. Driving Motors
4. Various Surfaces
   - Pushing

Design Tests



Grass, cement (video)



Gravel (video)

Tile (video)

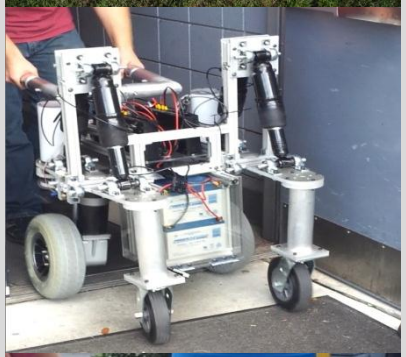
Slopes (video)

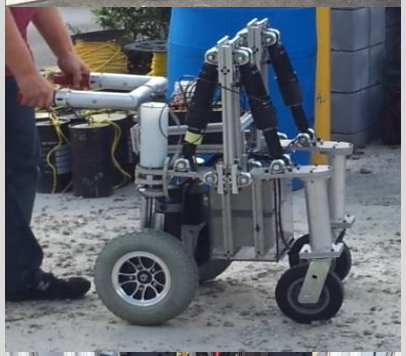
1. Air Shocks
2. Steering Motors
3. Driving Motors
4. Various Surfaces
   - Pushing
   - Driving

Results Summary

Completed Objectives:

- Construct stable walker
  - Passive / Active
- Operate within ADA standard environments
  - Width less than 32 inch
  - Weight less than 200 lbs
- Traverse varied terrain
  - Indoor: Tile, Carpet
  - Outdoor: Concrete, Grass, Gravel, Dirt, Slopes
- Incorporate operational power systems
  - Driving motors
  - Steering motors
  - Potentiometers

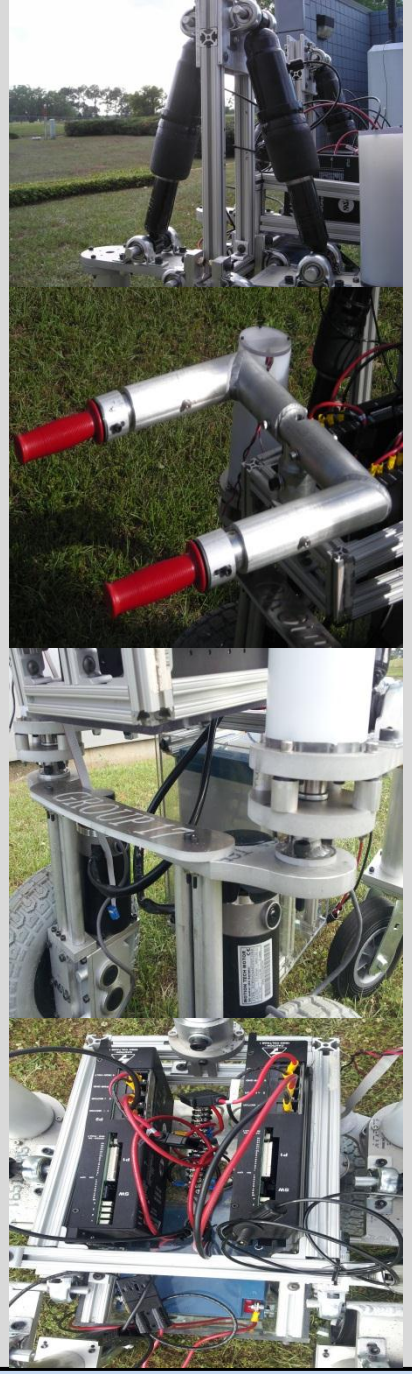




Results Summary

Remaining Tasks:

- Recalibrate shocks
  - Experimentally or empirically
- Stabilize / finalize handles
  - More mounting holes
  - Finish machining height inserts
- Reinforce structure
  - Connection braces
  - Locking washers to counteract vibrations
- Incorporate control system
  - Program microcontroller
  - Test / debug
- Continue testing
  - Obstacle traversing
  - Loading



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Project Budget

Budget Allowance	$5,000.00
Total Money Spent as of 4/12/2012	$4,513.35
Available funds as of 4/12/2012	$486.65

Expenditures:

- Motors: $1900
- Hardware: $1500
- Electronics: $800
- Miscellaneous: $300

Provided:

- Machine Shop: 75+ hrs
- Motor drivers: $2900
- Computer: $1000
- Encoders: $700
- Raw Material: $500
- Miscellaneous: $100

Economics

Potential Markets:

- Medical field
  - Hospitals
  - Rehabilitation Centers
- Direct to consumer
  - Elderly
  - Disabled

Estimated Costs:

• Motors:	$2000
• Controls:	$2000
• Hardware:	$1000
Total:	$5000

Standard power chair: $5000

http://www.case.edu/think/breakingnews/careproject.html

http://www.flickr.com/photos/chrisgold/6435078007/lightbox/

Health & Safety

Immediate Safety Concerns:

- Hardware
  - Sharp edges / corners
  - Heavy
- Electronics
  - High voltage
  - Exposed wires

Consumer Safety Concerns:

- Run-away hazard
  - Kill switch
- Shocking hazard
  - Not waterproof
- Falling hazard
  - Heavy

http://en.wikipedia.org/wiki/File:Caution_sign_used_on_roads_pn.svg

Summary

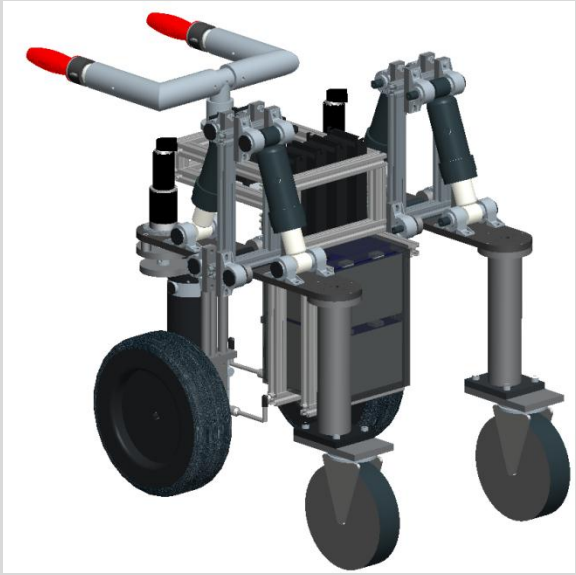
Problem:

- **Elderly & disabled utilizing current generation assistive devices are limited in their outdoor mobility**

Glasshouse Images ©

Solution:

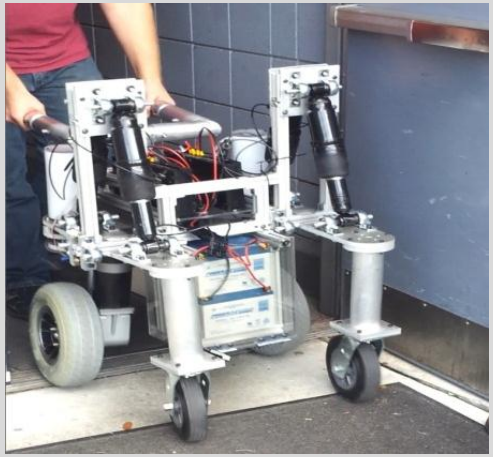
- **Develop robotic outdoor walker to improve mobility and quality of assistance provided**



Summary

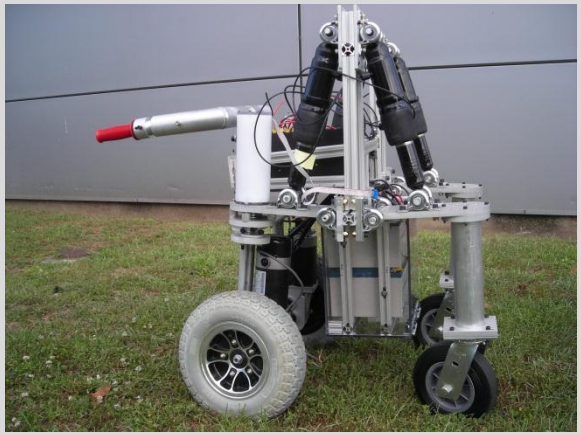
Objectives:

- Traverse varied terrain
- Scale 4 inch obstacles
- Operate within ADA standards
- Easily adaptable into future work



Results:

- Successful passive & non-controlled active prototype with appropriate dimensions
- Reinforcement to frame & slight modifications to suspension may improve performance
- Larger casters & more even weight distribution may improve obstacle scaling
- Further tests required on slopes & in loading



References

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http://www.nashuatelegraph.com/sportslocalsports/954816-222/art-demers-focusing-on-return-to-classroom.html#
http://thesnowangels.org/
//http://hic2011.edublogs.org/2011/10/20/green/
//http://topnews.net.nz/content/211444-7000-red-cross-volunteers-put-100-worth-free-labour-each
http://www.access-board.gov/adaag/html/
http://www.a-m-c.com/images/productpics/120a10.jpg
http://www.easycomforts.com/EasyComforts/subcategory.aspx?id=mobility%20and%20accessories&bid=EC_Flash2^Mobility%20and%20Accessories
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http://www.rimdoor.com/page.cfm?page=140
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http://en.wikipedia.org/wiki/File:Mass_spring_damper.png
http://www.superstock.com/resultsframe.asp

Questions?