Final Design

Team # 17

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Project Sponsor:

CISCOR
CENTER FOR INTELLIGENT SYSTEMS, CONTROL, AND ROBOTICS

Project Advisors:
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Introduction

Problem Statement

The current generation of assistive walking devices is limited in their traversable terrain and functionality.

- Indoor operation only
- Only perform basic functions
- Scooters / electric wheelchairs unnecessary or expensive

Proposed Solution

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

- Further empower the disabled and elderly community
- Offer wide-range of assistive functions
- Maintain ease of use and intuitiveness integral to current generation walkers

Specifications

Frame

- Resemble current generation walker in aesthetics and standards
- 1 inch diameter aluminum piping
- Supports up to 300 pounds
- Adjustable heights between 32 and 39 inches
- Adjustable handle width between 11 and 24 inches

Propulsion

- Minimum 11 inch diameter wheels or tracks
    - Travel over all indoor surfaces, grass, gravel, sand…
    - Travel up or down slopes up to 10 °
- Move transversely 45° from the center axis
- Maximum operating speed of 5 mph

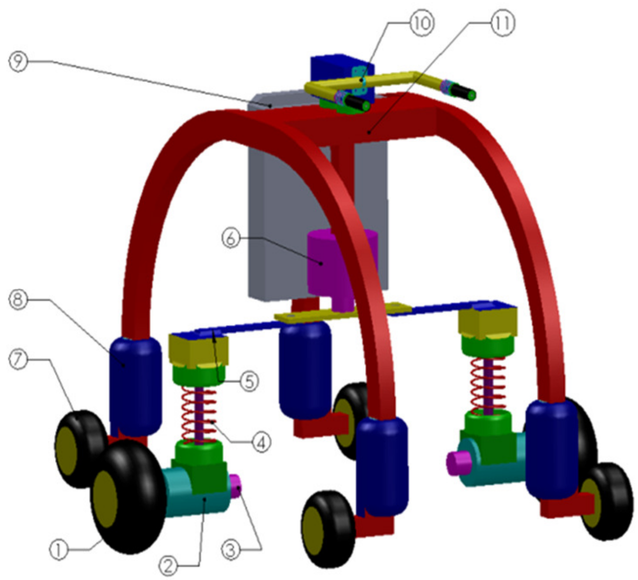
Control & Function

- Intuitive user input
    - Force-based drive control
- Fall Prevention
- Sit-Down/Stand-Up Assistance
- Object Detection/Avoidance
- Localization & Navigation

Criteria

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

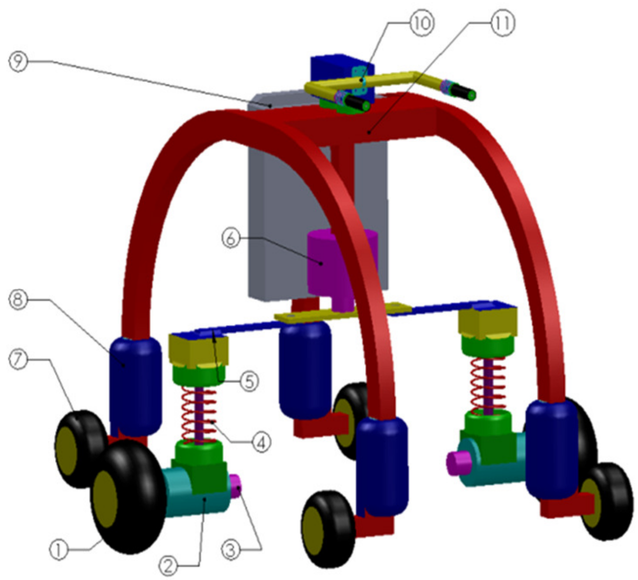
Concepts



Concept 1:

1. **6 wheels**
   a) **2 driving, 4 passive**
   b) **Air-filled**
   c) **30cm driving**
2. **3 motors**
   a) **2 driving, 1 steering**
   b) **Semi-omni-directional**
3. **Passive suspension**
4. **Force-plate driven**
5. **Passive dimension adjustment**
6. **Small payload capacity**
7. **Fall detection/Stand-up Assistance**
8. **Object avoidance**

Concepts



Concept 1:

Versatility – 3

Robustness – 4

User-friendliness – 3

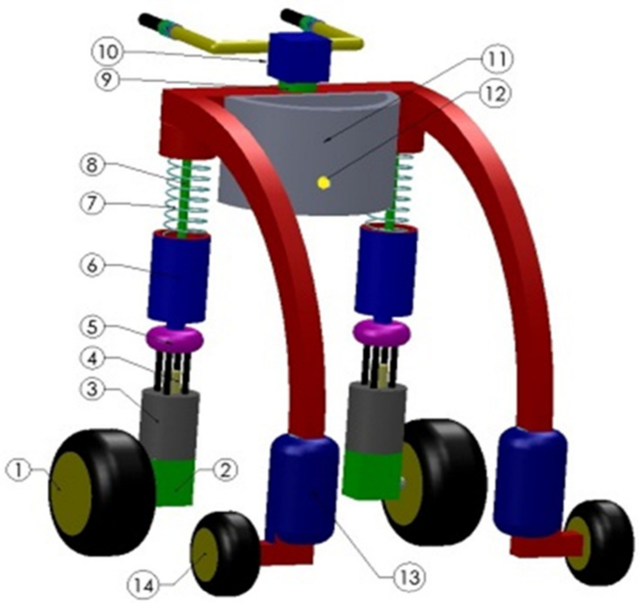
Cost – 2

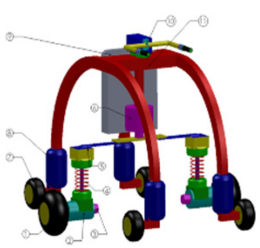
Indoor Operation – 3

Outdoor Operation – 4

Weight – 2

Concepts

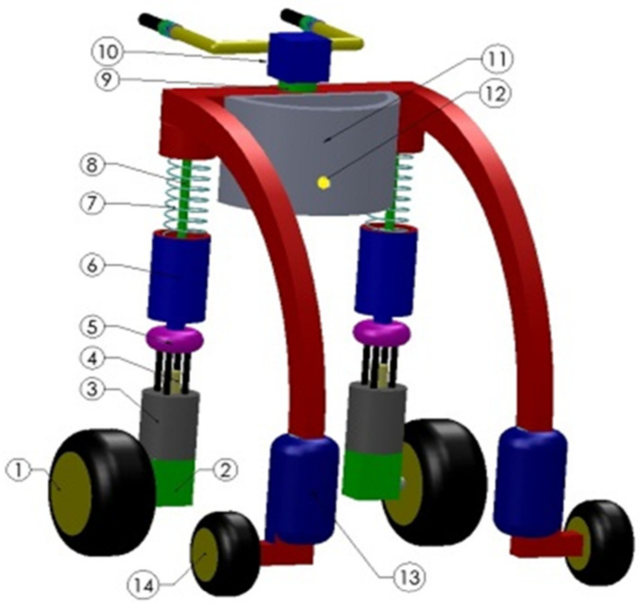


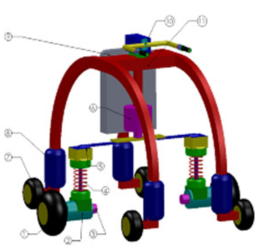


Concept 2:

1. **4 wheels**
   a) **2 driving, 2 passive**
   b) **Honeycomb**
   c) **30cm driving**
2. **4 motors**
   a) **2 driving, 2 steering**
   b) **Omni-directional**
3. **Passive suspension**
4. **Spring-based driven**
5. **Passive dimension adjustment**
6. **Small payload capacity**
7. **Fall detection/Stand-up Assistance**
8. **Object avoidance**

Concepts

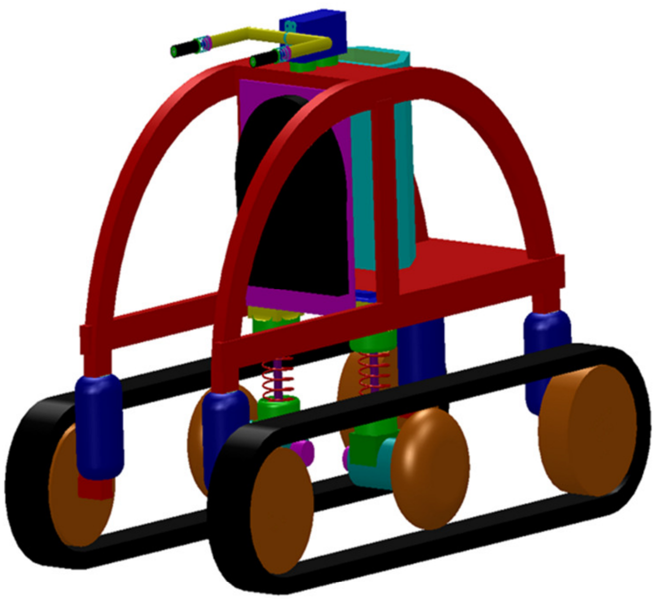


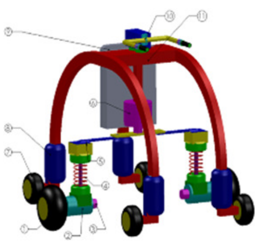


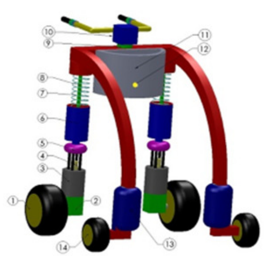
Concept 2:

- **Versatility – 5**
- **Robustness – 3**
- **User-friendliness – 4**
- **Cost – 2**
- **Indoor Operation – 3**
- **Outdoor Operation – 3**
- **Weight – 3**

Concepts



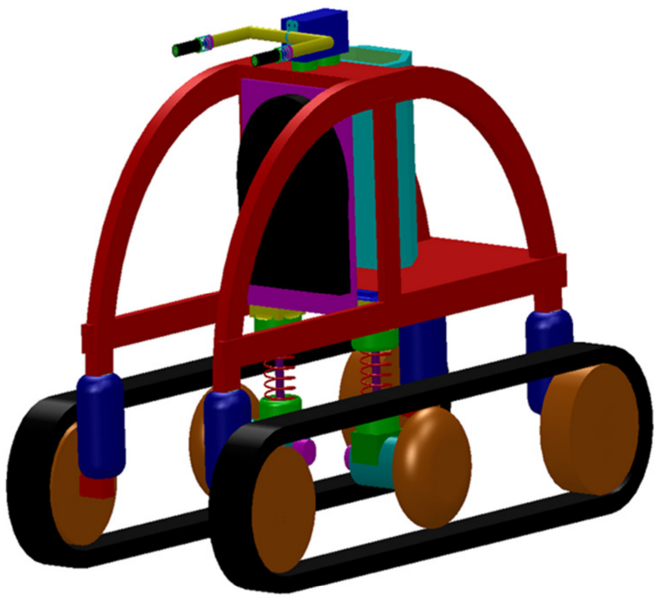


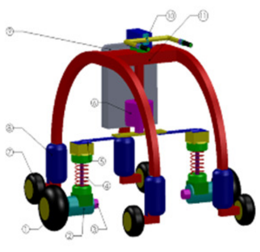


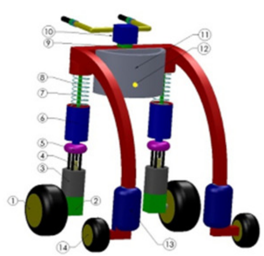
Concept 5:

1. Treads
2. 1 motor
    a) 1 driving, skid steering
    b) Semi-omni-directional
3. Active suspension
4. Spring driven
5. Passive dimension adjustment
6. Large payload capacity
7. Fall detection/Stand-up Assistance
8. Object avoidance
9. Riding Capability

Concepts





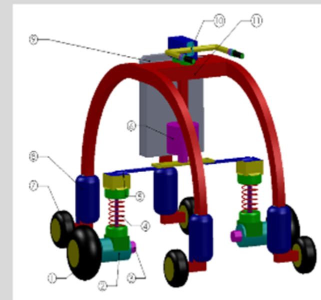


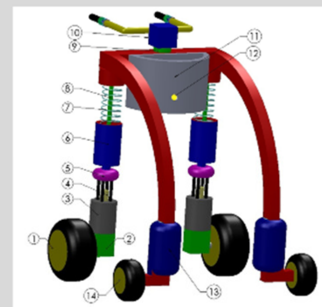
Concept 5:

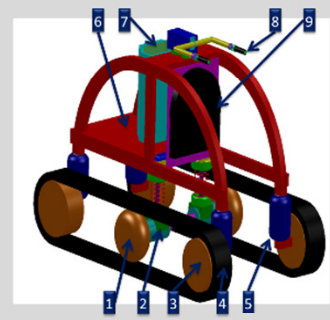
- **Versatility – 3**
- **Robustness – 4**
- **User-friendliness – 3**
- **Cost – 1**
- **Indoor Operation – 1**
- **Outdoor Operation – 5**
- **Weight – 1**

Interim Design Analysis

- Based on preliminary investigation, further detailed analysis was applied for:
  - -Concept 1
  - -Concept 2
  - -Concept 5
- Analyzed for:
  - -Locomotion
  - -Steering
  - -Controls







	Treads	Air Filled Tire	Honeycomb Tire
Average Life	75,000+ Miles	25,000+ Miles	25,000+ Miles
Traction	Very High	Average	Average
Outdoor Operation	High (Large footprint)	Average (High potential for slip, small footprint)	Average (High potential for slip, small footprint)
Indoor Operation	Low (Large footprint)	High (Small footprint)	High (Small Footprint)
Puncture Resistance	Highly Resistant	Mildly Resistant	Highly Resistant
Environment Conditions	All Conditions	Mud, Ice and Snow present potential issues	Mud, Ice and Snow present potential issues
Possible Failures	Cracked Tiles, chain or driving belt may come off	Exploding Tires (Over pressurized), tears or leaks that let out air	Chunks can be removed from tire
Possible Repairs	Replace Individual Tiles	Leak Stop, Foam Filling	Rubber like material to fill in gashes
Suspension Assistance	None	Average	High
Obstacle Traversibility	Very High	Low	Average
Overall Complexity	High	Low	Low

	Air Filled Tire	Honeycomb Tire	Treads
Average Life	25,000+ Miles	25,000+ Miles	75,000+ Miles
Traction	Average	Average	Very High
Outdoor Operation	Average (High potential for slip, small footprint)	Average (High potential for slip, small footprint)	High (Large footprint)
Indoor Operation	High (Small footprint)	High (Small Footprint)	Low (Large footprint)
Puncture Resistance	Mildly Resistant	Highly Resistant	Highly Resistant
Environment Conditions	Mud, Ice and Snow present potential issues	Mud, Ice and Snow present potential issues	All Conditions
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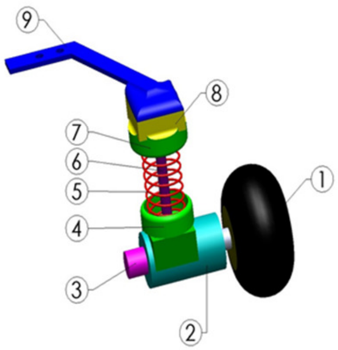
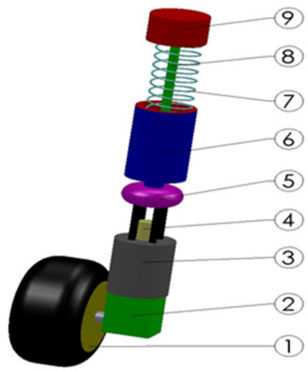
Possible Repairs	Leak Stop, Foam Filling	Rubber like material to fill in gashes	Replace Individual Tiles
Suspension Assistance	Average	High	None
Obstacle Traversibility	Low	Average	Very High
Overall Complexity	Low	Low	High



	Ackerman Steering	Individual Steering Motors	Skid Steer
Necessity for additional support electronics	Low	High	Low
Size of Additional Motor Necessary	Large (Must steer both wheels)	Small (Load is split amongst motors)	None (Driving motors steer)
Capability for Use Unpowered/Broken	High	High	Very Low
Turning Radius	~5 ft min	0	0
Holographic Movement	No	Yes	No
"Module" Compatibility	No	Yes	Yes
Possible Failures	Joints or joining bar may deform or break	Rotary Connection may fail	Chain or driving belt may come off
Overall Complexity	Average	High	Low





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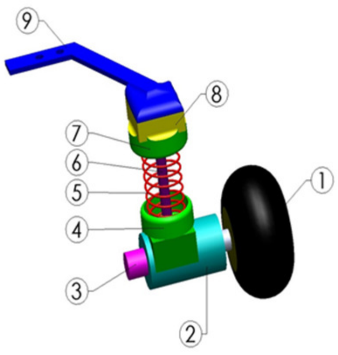
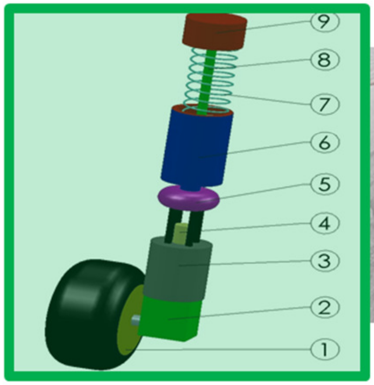
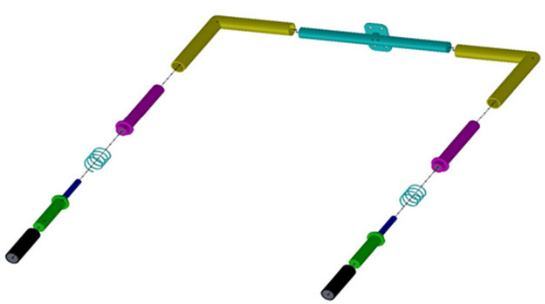




	Spring Driven Controls	Force Plate
Max Input Force	~500 Pounds	~5 Pounds
Part Replacement/Repair	Cost Effective and Easy	Expensive and Difficult
Moving Parts	Yes	No
Possible Failures	Potentiometers may break, springs may deform	Solid State electronics may be damaged
Environment Conditions	All Weather	Water must be kept away from force plate
Number of Input Axes	2	6
Overall Complexity	Low	High
Cost	Low (~$100)	High (~$5,000)



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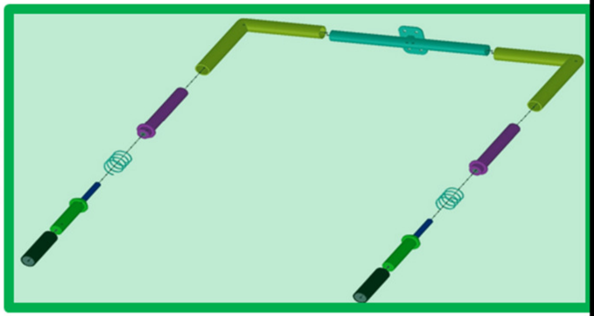
Max Input Force	~5 Pounds	~500 Pounds
Part Replacement/Repair	Expensive and Difficult	Cost Effective and Easy
Moving Parts	No	Yes
Possible Failures	Solid State electronics may be damaged	Potentiometers may break, springs may deform
Environment Conditions	Water must be kept away from force plate	All Weather
Number of Input Axes	6	2
Overall Complexity	High	Low
Cost	High (~$5,000)	Low (~$100)



Design Synthesis

Based on our further investigation, aspects of each of the designs were combined to form a Final Design Concept:

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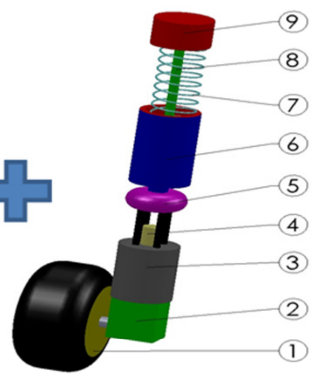

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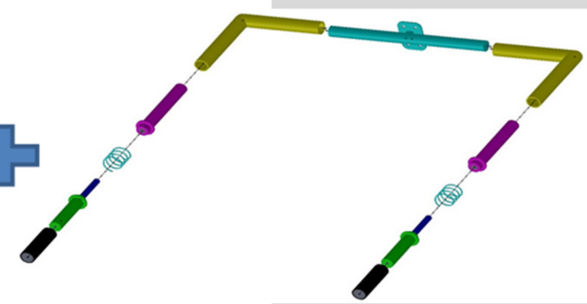

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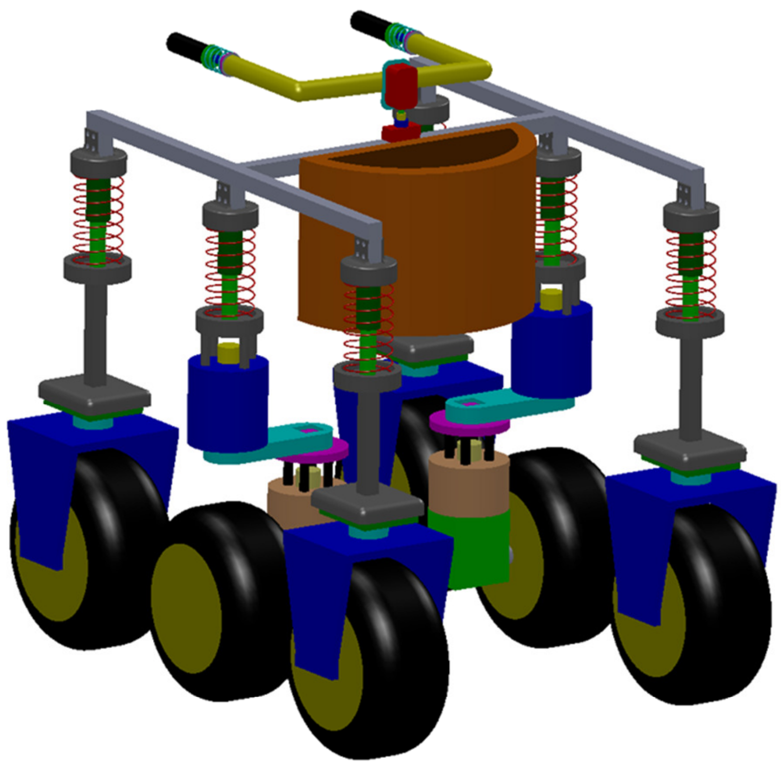
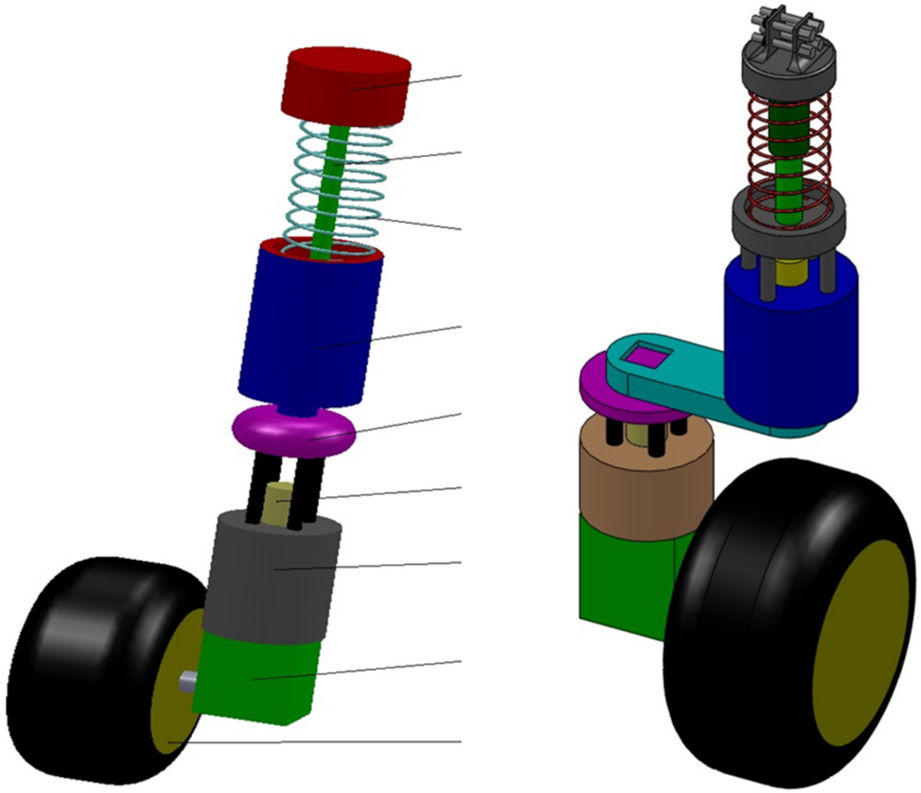
Final Product Design 1.0



Components:

1) **6 Wheels -2 Driving, 4 Passive Casters**
2) **All Individual Steering**
3) **New Wheel Design**
4) **Modular Wheel Attachment**

Final Product Design 1.0



(old) (new)

Components:

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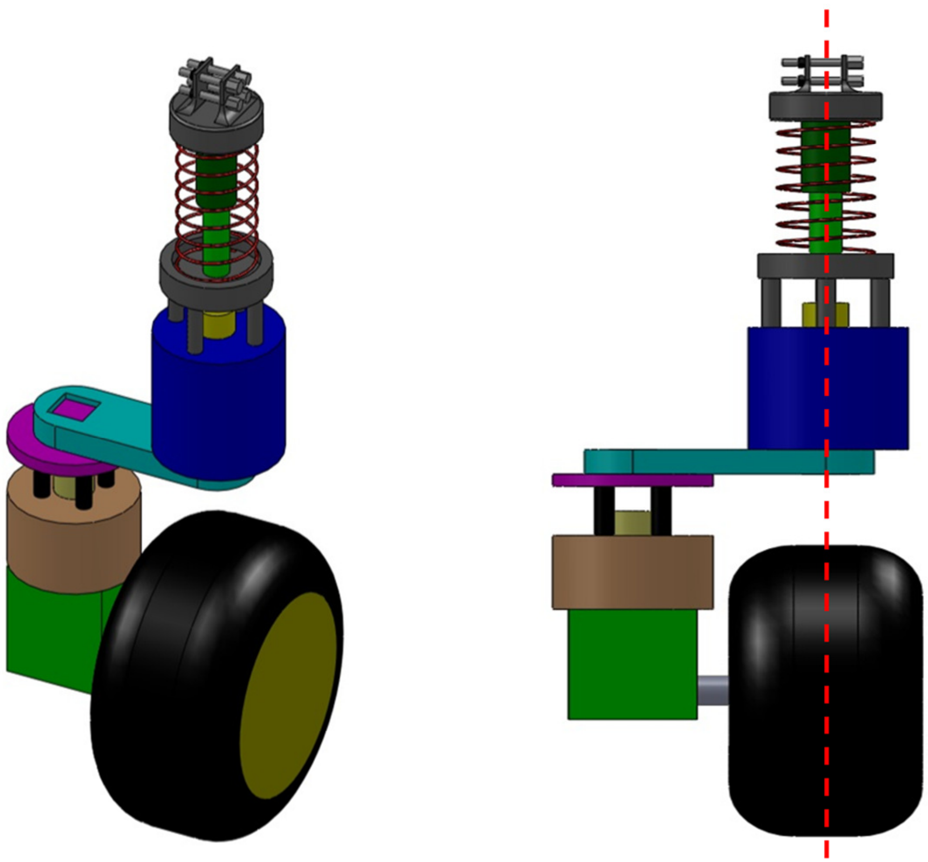

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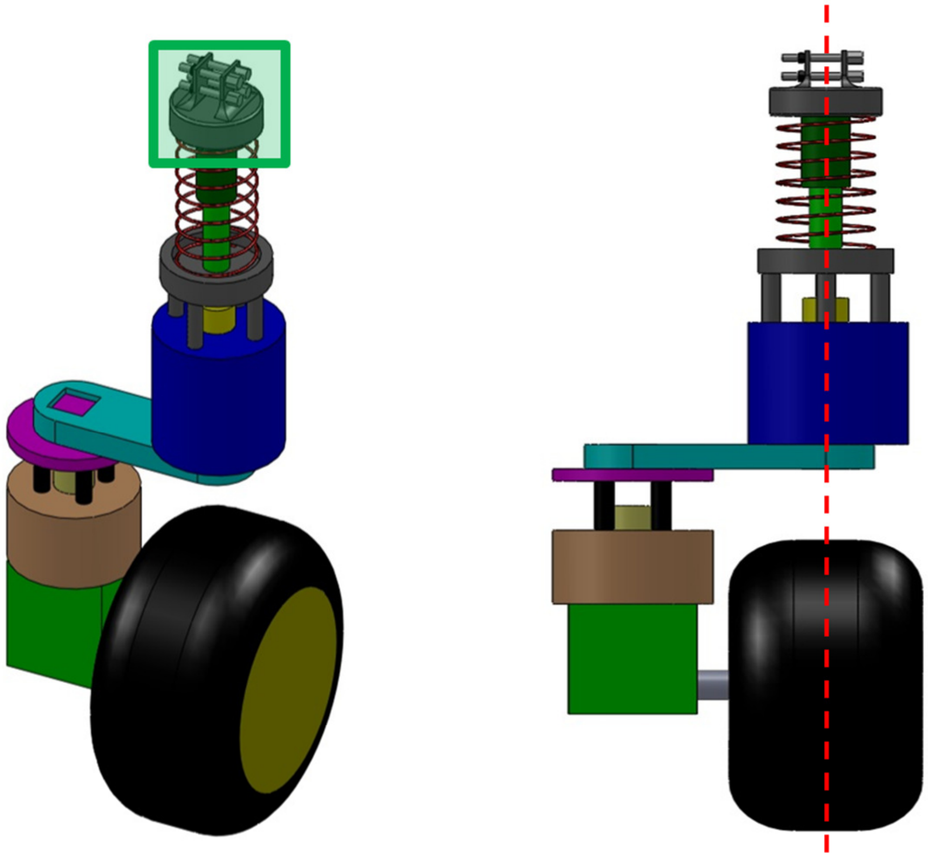

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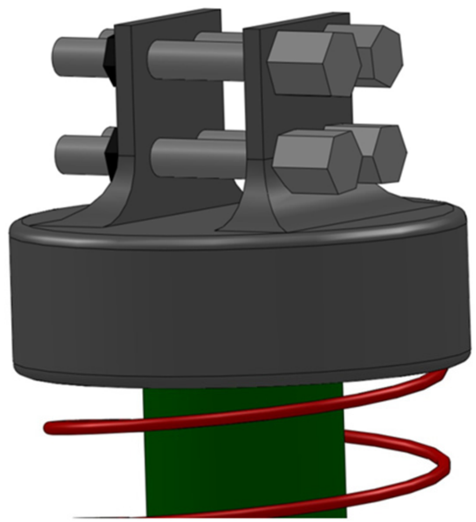

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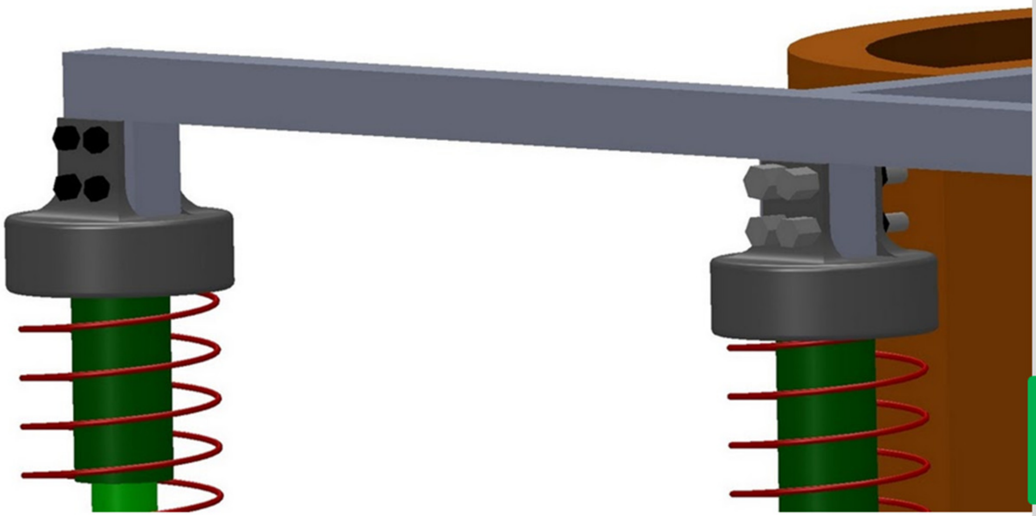

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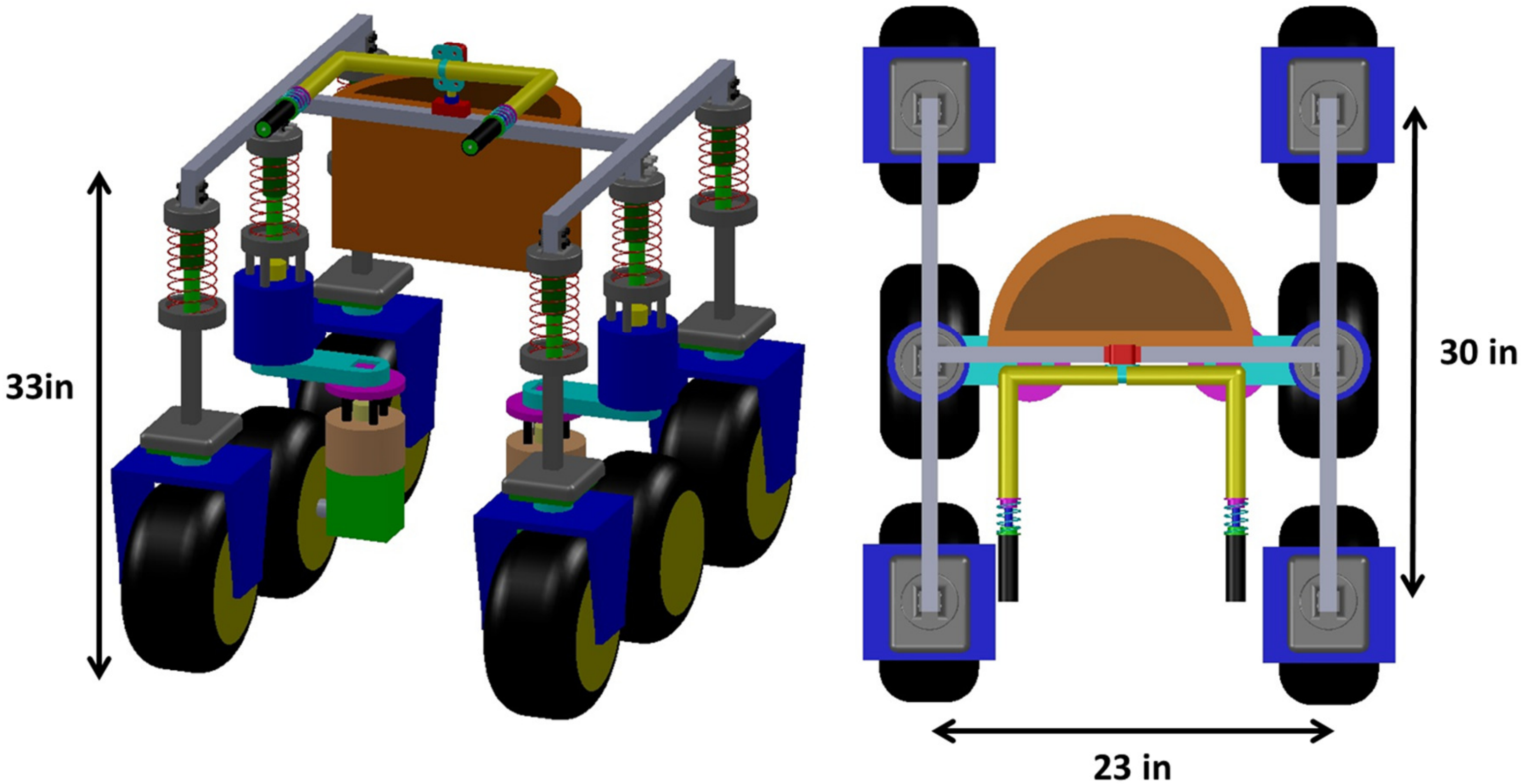
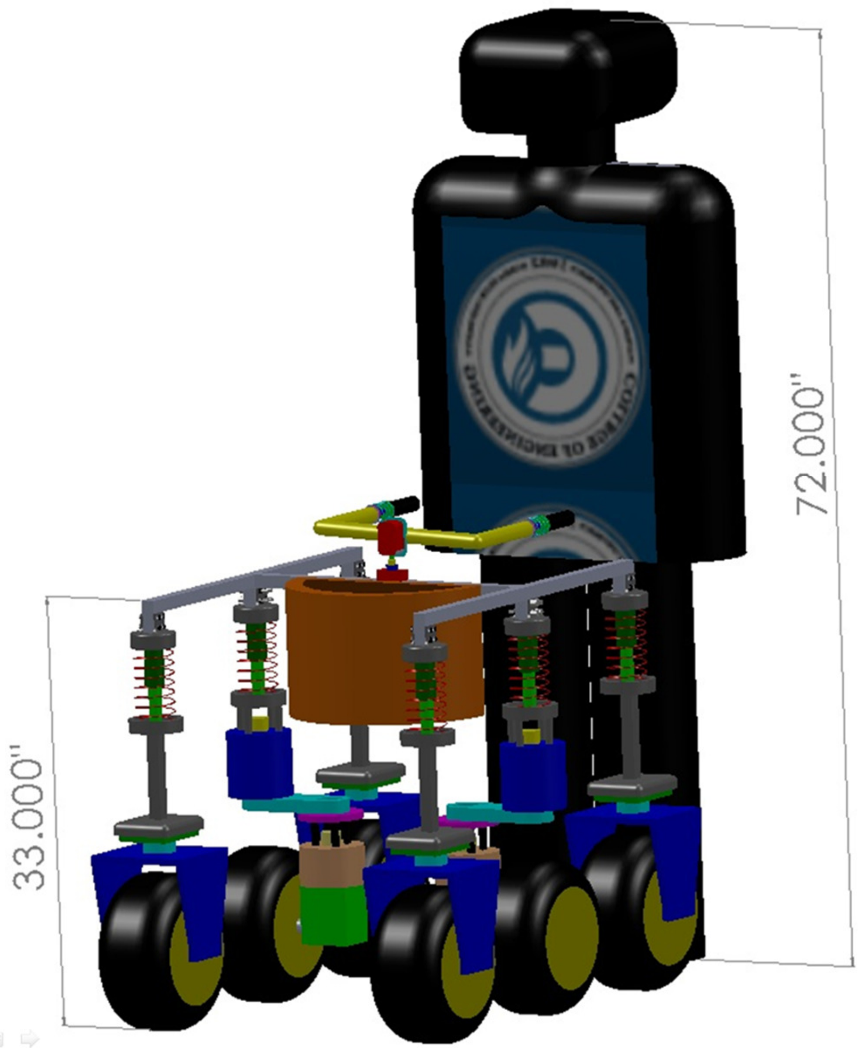


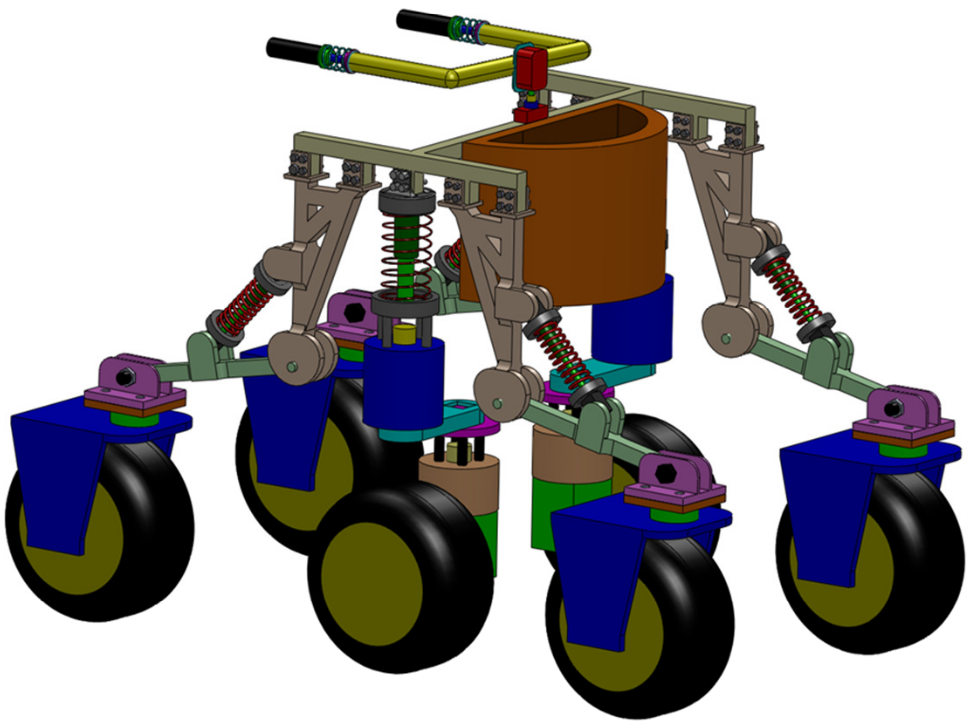
Final Product Design 1.0



Problems:

1) **"In Line" Passive Casters**
2) **No horizontal shock absorption**
3) **Too constricting to user**

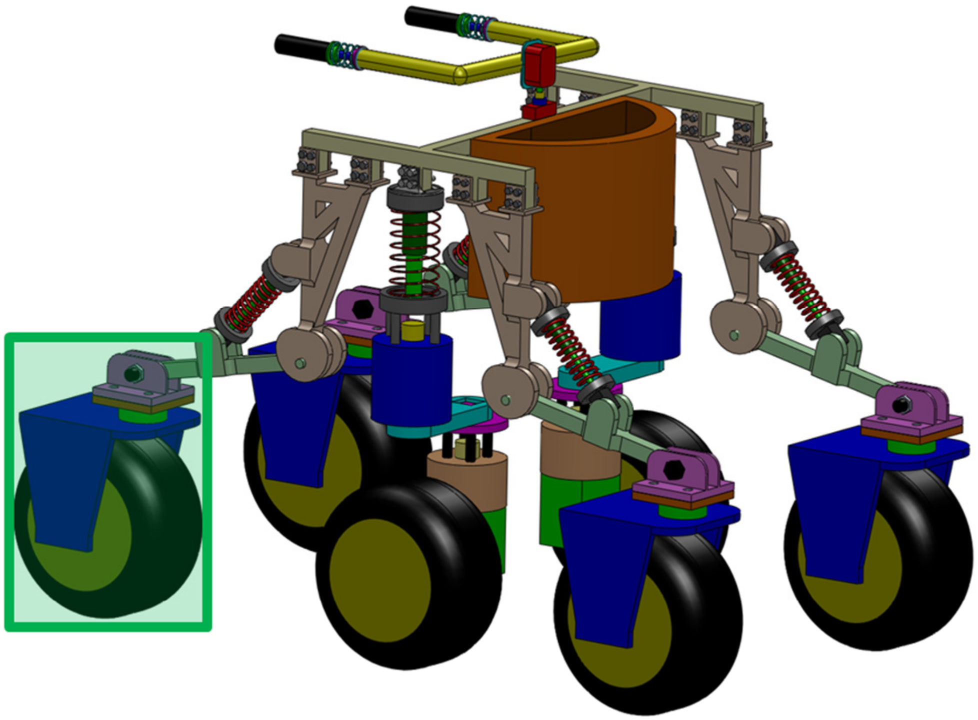
Final Product Design 2.0



Fixes:

1) **Swivel Casters**
2) **Angled Caster Mechanisms**
3) **Smaller User Restriction**

Final Product Design 2.0



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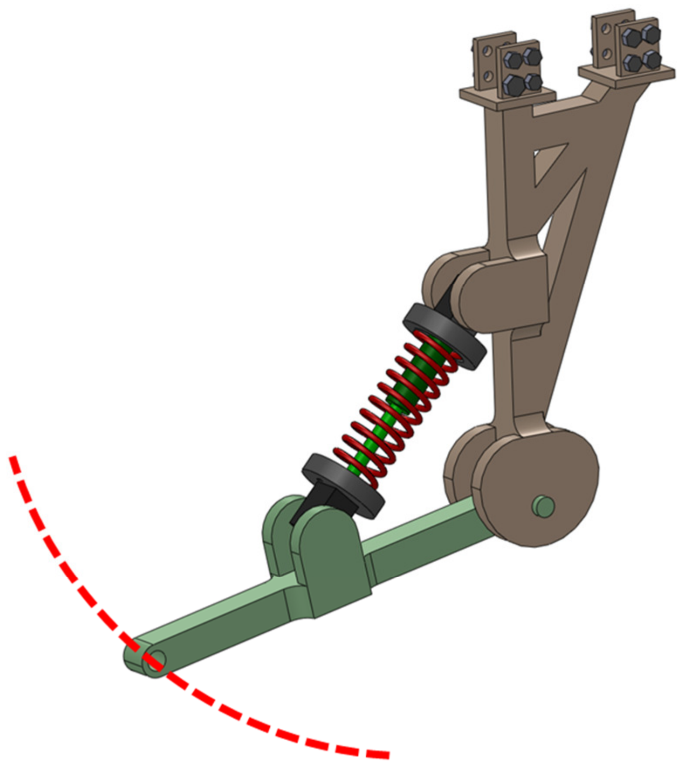

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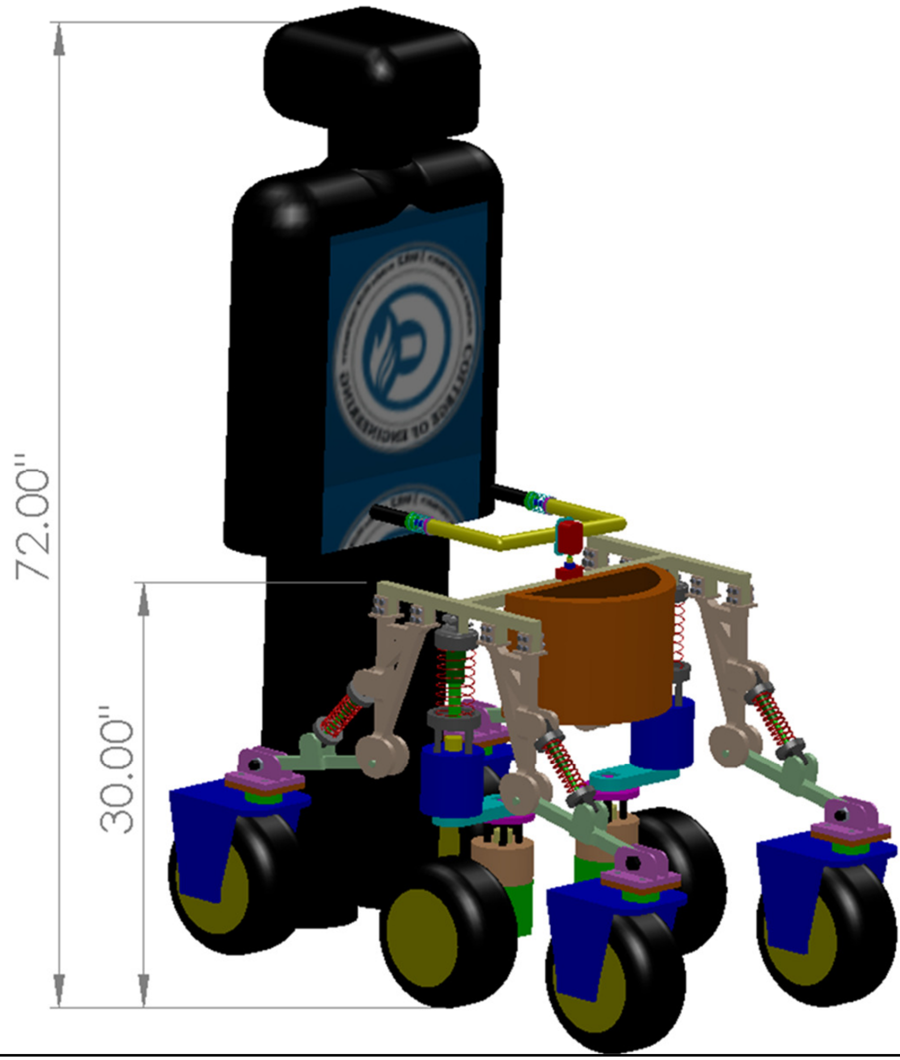

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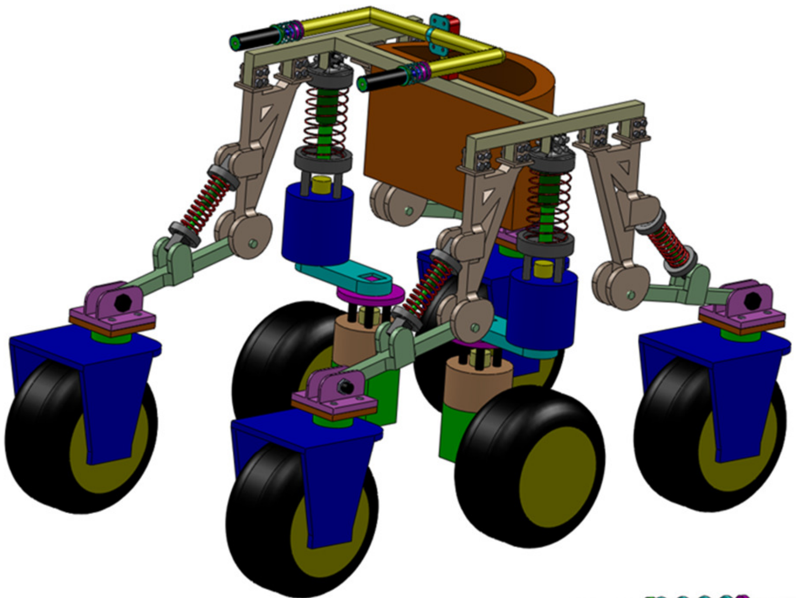
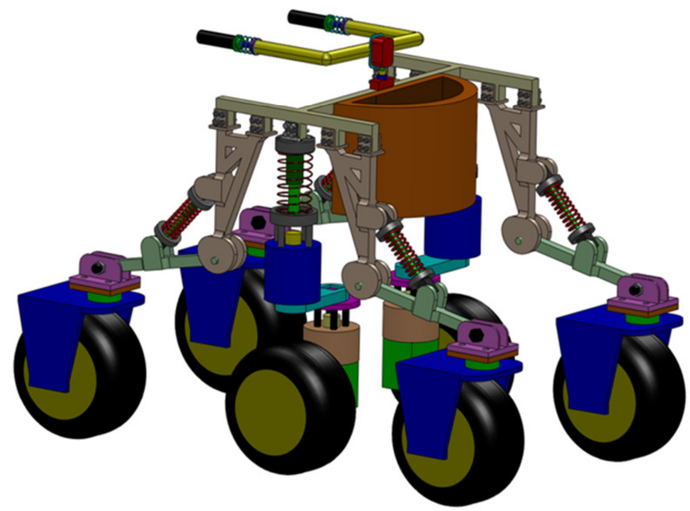
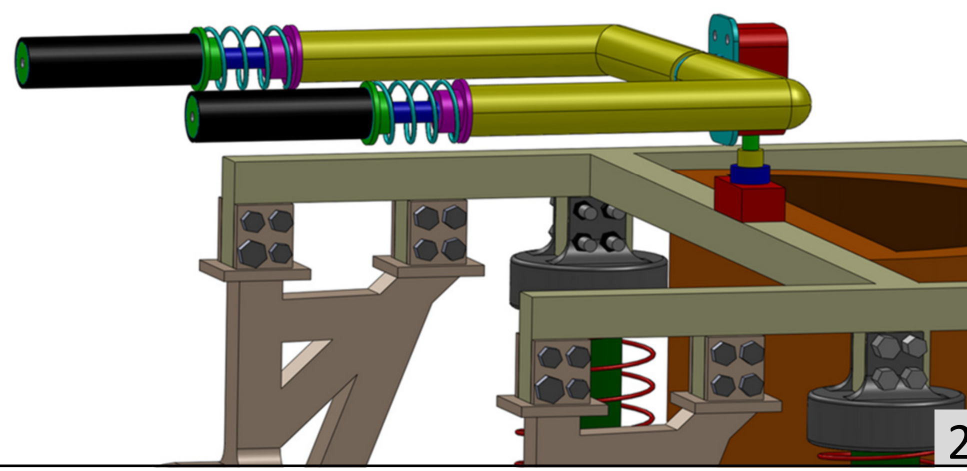






Spring Selection

At Equilibrium:

$$F = kx$$

$$k = \frac{mg}{x}$$

$$k_{handle} \approx 2000\ \frac{N}{m} \quad k_{outer} \approx 4000\ \frac{N}{m} \quad k_{inner} \approx 3000\ \frac{N}{m}$$

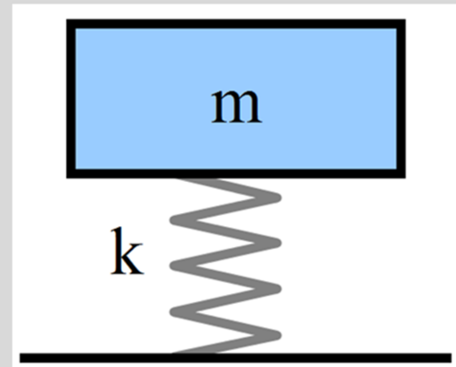
In Motion:

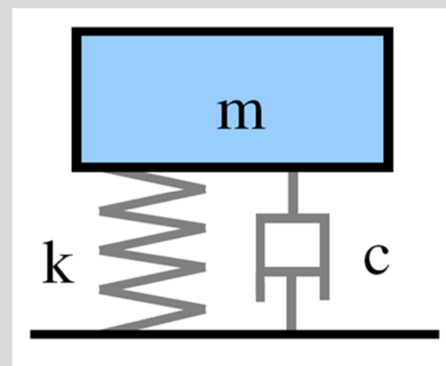
$$\frac{d^2y}{dt^2} + 2\zeta\omega_n\frac{dy}{dt} + \omega_n^{\ 2} = 0$$

$$t_{settling} = \frac{-\ln(settlingRatio)}{\zeta\omega_n}$$

$$c = \frac{-2m\ln(settlingRatio)}{t_{settling}}$$

$$c_{outer} \approx 200\ \frac{kg}{s} \qquad c_{inner} \approx 400\ \frac{kg}{s}$$





Motor Selection

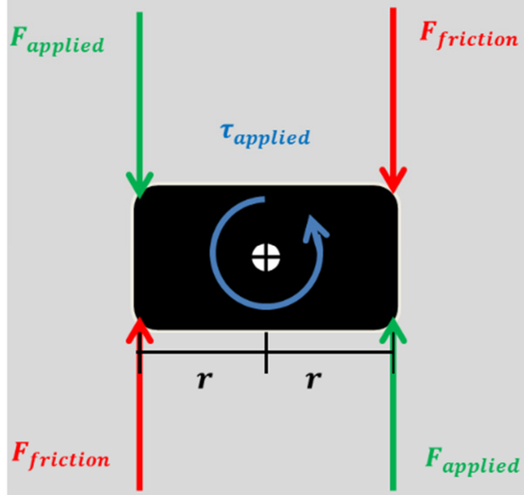
Steering Motor Torque:

$$\tau_{applied} = F_{applied} * r$$
$$F_{applied} \geq F_{friction} = \mu_{static} * mg$$
$$\tau_{applied} \geq \mu_{static} * mg * r$$

Driving Motor Torque:

$$\tau_{applied} = F_{applied} * r$$
$$F_{applied} \geq ma$$
$$\tau_{applied} \geq ma * r$$

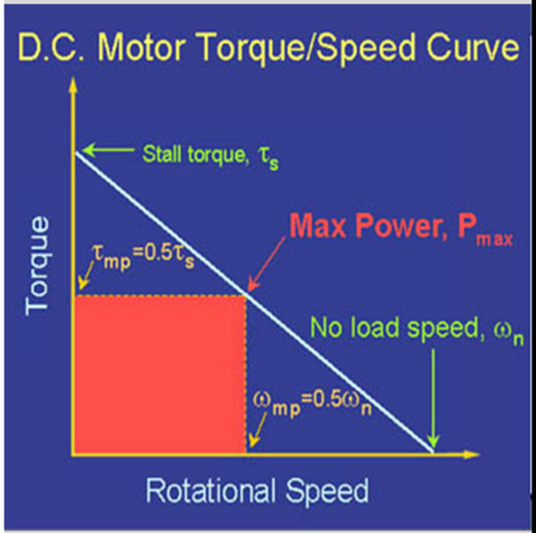
$$\tau_{steering} \approx 10\ Nm \qquad \tau_{driving} \approx 11.5\ Nm$$



Motor Selection

$$P_{motor}(\omega) = -(\frac{\tau_s}{\omega_n})\omega^2 + \tau_s\omega$$

$$P_{motor}(\tau) = -(\frac{\omega_n}{\tau_s})\tau^2 + \omega_n\tau$$



Health & Safety

- **Human Health & Safety:**
  - **-Stand-Up Assistance**
  - **-Fall Prevention**
  - **-Object Avoidance**
  - **-Control Calibration/Regulation**

- **Environmental Health & Safety:**
  - **-Electric Motors**
  - **-Permanent Basket**
  - **-Low Risk Materials**

Cost Estimation

Motors	Estimate	Quantity	Total
Driving	$100	2	$200
Steering	$500	2	$1,000
Wheels			
Driving	$50	2	$100
Caster	$40	4	$160
Stock Hardware	$300	1	$300
Electronics			
Computer	$0	Donated	$0
Power Supply	$0	Donated	$0
Battery	$50	2	$100
Encoders	$75	2	$150
		Overall:	$2,010

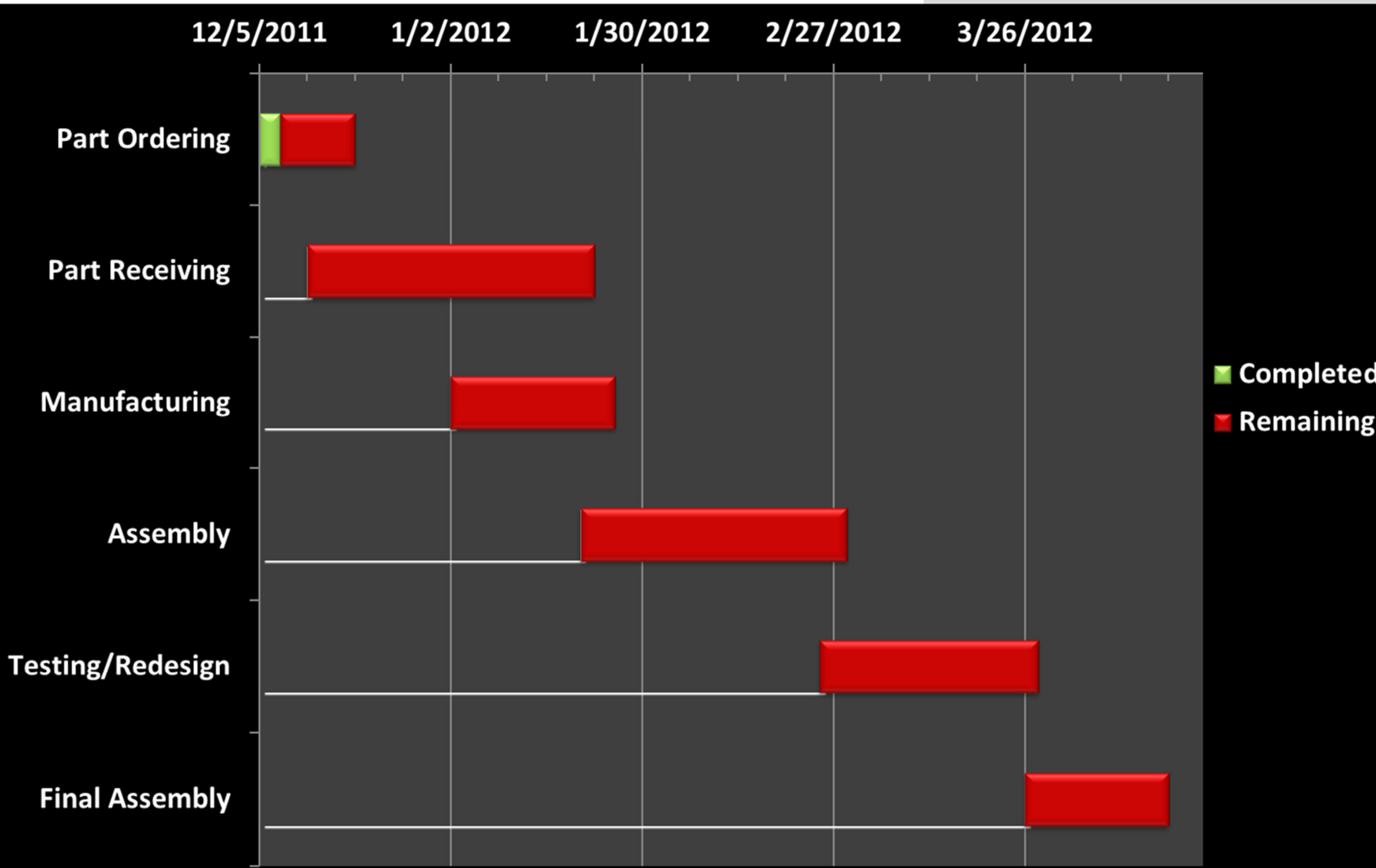
- Motors
- Wheels
- Stock Hardware
- Electronics
- Overall

Future Work

- Future work can be broken down into the following sections:
  - -Part Ordering
  - -Part Receiving
  - -Manufacturing
  - -Assembly
  - -Testing/Redesign
  - -Final Assembly

- Further Analysis will be conducted for:
  - -Center of Mass
  - -Payload Capacity
  - -Control Schemes

Timeline


12/5/2011
1/2/2012
1/30/2012
2/27/2012
3/26/2012
Part Ordering
Part Receiving
Manufacturing
Assembly
Testing/Redesign
Final Assembly
Completed
Remaining

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Questions?

Thank you

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