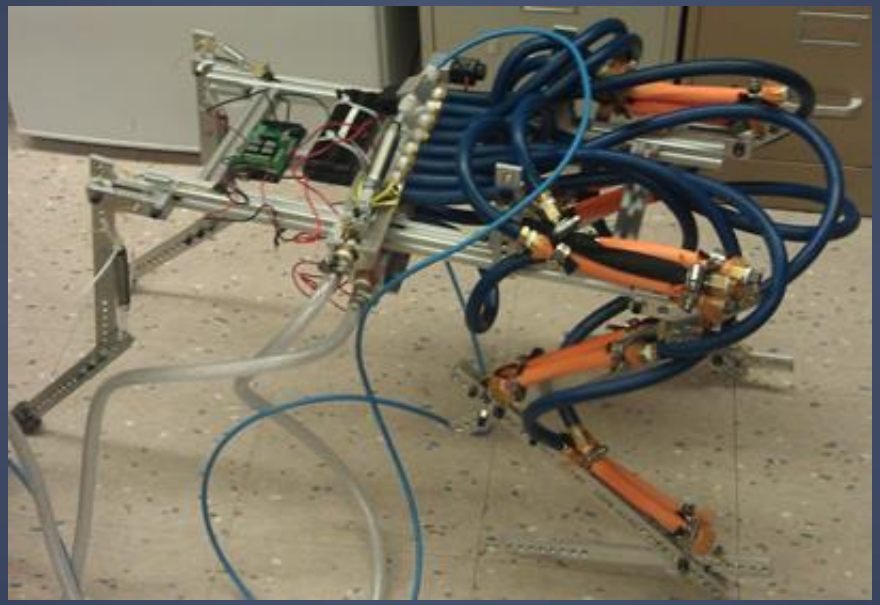
Air Muscle Robotic Tiger



P13029

Presentation Agenda

- Specs and Customer Needs
- Concept Summary
- Design Summary
- System Testing Results
- Successes and Failures
- Future Work Suggestions

Project Description

- Goal of project was to create a robot using McKibben Air Muscles to mimic the jumping motion of a tiger
- The project builds upon past research and MSD projects on air muscles
- First RIT air muscle project requiring large muscle forces and quick fill times

Customer Needs

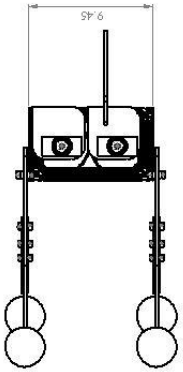
Customer Need	Importance (1 = high)	Description
CN1	1	Can jump forward a distance equal to at least the length of its body (only 1 jump required per tank fill)
CN2	1	Use air muscles to provide jumping force
CN3	1	Lands safely without damage
CN4	2	Is ready to jump again after landing, without user adjustment of robot body or legs
CN5	2	Self-contained (on board power sources)
CN6	2	Portable (small enough for one person to carry)
CN7	2	Reasonable battery life; battery charging takes hours
CN8	3	Resemble a tiger
CN9	3	Controls do not yield a noticeable delay

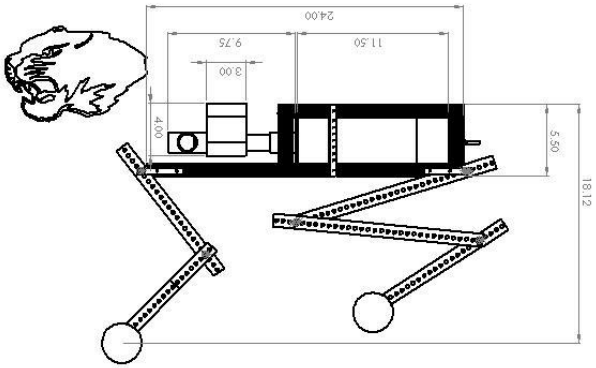
Engineering Specs

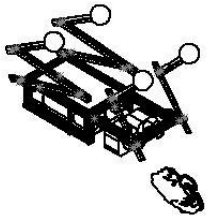
Spec	Source	Metric	Unit of Measure	Marginal Value	Ideal Value	Preferred Direction
S1	CN1	Horizontal Jump Distance	Feet	1*body length	1.5*body length	Up
S2	CN1,2	Uses Air Muscles	Binary		Yes	
S3	CN3	Sliding Distance After Landing	Inches	3	2	Down
S4	CN4,5	Self-Contained	Binary		Yes	
S5	CN3,6	Overall Weight	Lbs	50	25	Down
S6	CN3,5,6	Overall Length	Feet	4	2	Down
S7	CN3,5,6	Overall Height	Feet	2	1	Down
S8	CN3,5,6	Overall Width	Feet	1		Down
S9	CN8	Resemble a Tiger	Percent	80	100	Up
S10	CN2	Regulated Air Pressure	psi	<60		Down
S12	CN9	Total Response Time to Jump Command	s	0.3	0.15	Down
S13	CN2,9	Solenoid Response Time	ms	50	25	Down
S14	CN2,9	Muscle Fill Time	s	0.1	0.75	Down
S15	CN2,7	Battery Life	# of Jumps	50	100	Up
S16	CN2,8	Four Actuated Legs	Binary		Yes	
S17	CN4,5	Tank can be removed in 5 min, without tools	Binary		Yes	
S18	CN1,2,3,4	Allowable error in leg measurement/adjustment	Degrees	3	1	Down

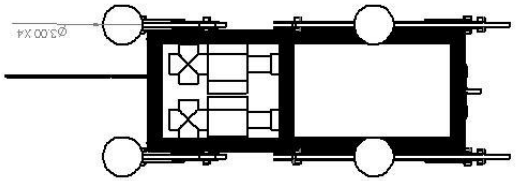
(green ideal, yellow marginal, red out of desired range, blue no longer applicable)

Concept Summary



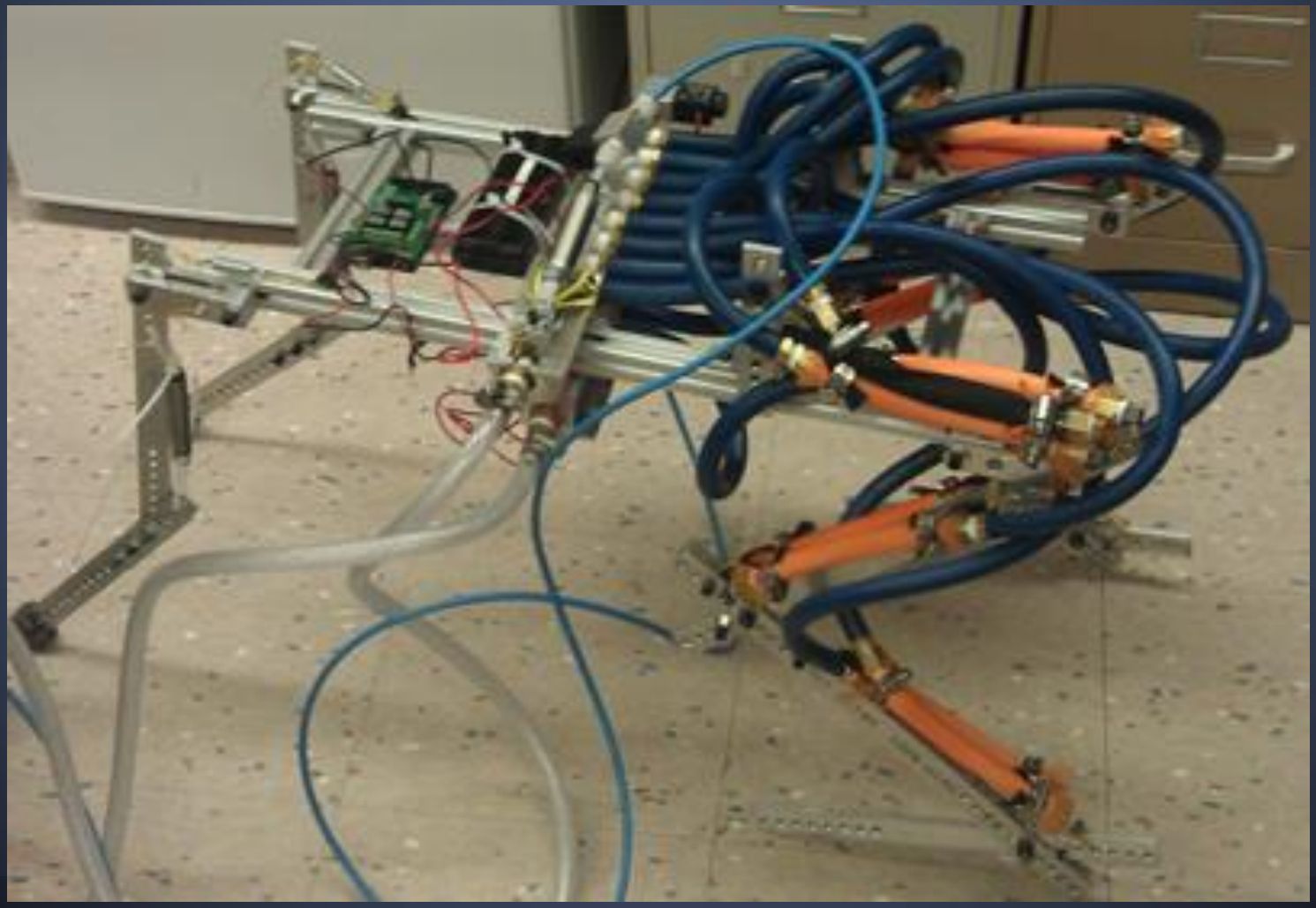






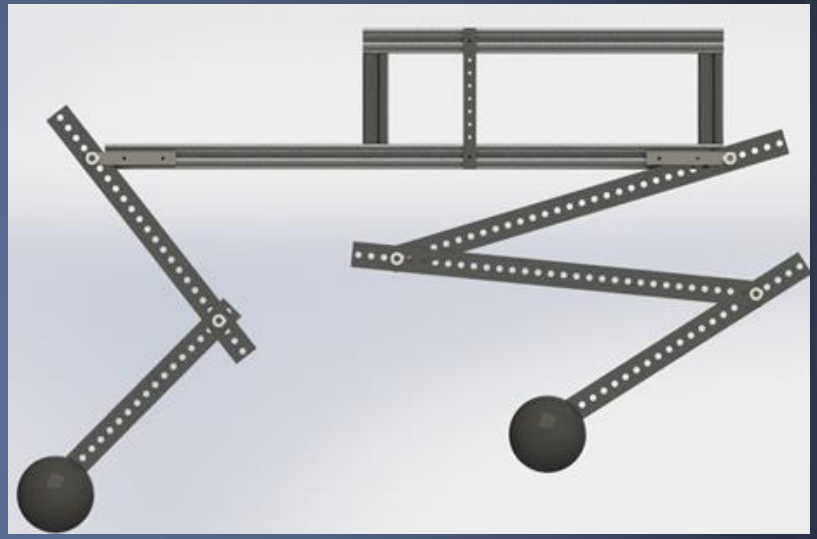
Concept Summary

Final Design



Final Design: Mechanics

- 80/20 frame
  - Allowed for adjustment of anchor points
  - Easy assembly
- Leg design
  - Adjustable anchor points, hard stops, and pivot points
  - Easy to manufacture
  - Lightweight
- Springs
  - Dampening springs



Final Design: Mechanics

- Lower friction
  - Nylon washers added to reduce joint friction
  - Stainless steel dowel pins
- Front legs
  - Fixed leg positions to help stabilize landing
  - Keep body upright while jumping and landing
- Feet
  - Reduce damage to floor/leg and add friction
- Ramp
  - Adjustable
  - Assists takeoff during jump

Final Design: Air Supply

- 10 gallon, 200 psi tethered air tanks
  - Reduce weight
  - Minimal pressure drop
- Manifold
  - Distributes air to upper and lower muscle groups
- Flexible tubing (blue)
  - Unrestricted motion
  - High pressure

Final Design: Controls

- Arduino controls muscle firing order
  - Used Labview during testing
- Pneumatic actuator on main muscle valve
  - Fast air release into the muscles
- Solenoids
  - Exhaust to allow leg return after jump
- 24V Battery
  - Powers solenoids, relay board, arduino

Final Design: Muscles

- 3/8" brass fittings
- 3/4" to 1-3/4" mesh range
- 3/8" ID 1/8" THK Very soft silicone rubber tubing

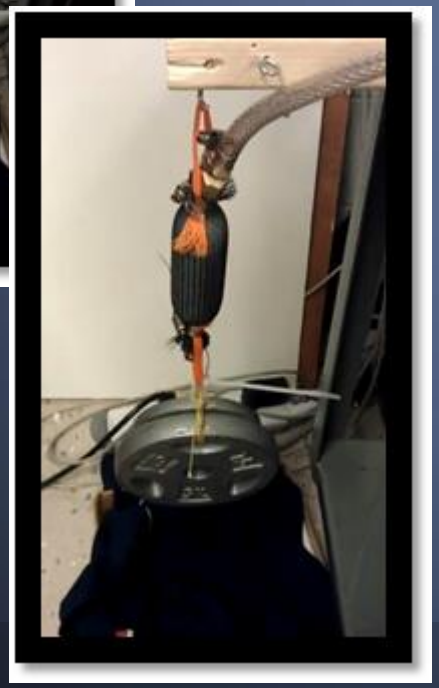
Deviations From Concept

- No onboard tank
  - Became tethered
  - Top rack removed
- Ramp added for legs to push against
- More Muscles added
  - From 1 per leg to 2-3 per leg
- Muscle group delay timing
  - 100ms delay between upper and lower muscles
- Manifold/actuator
  - Ball valve instead of sprinkler

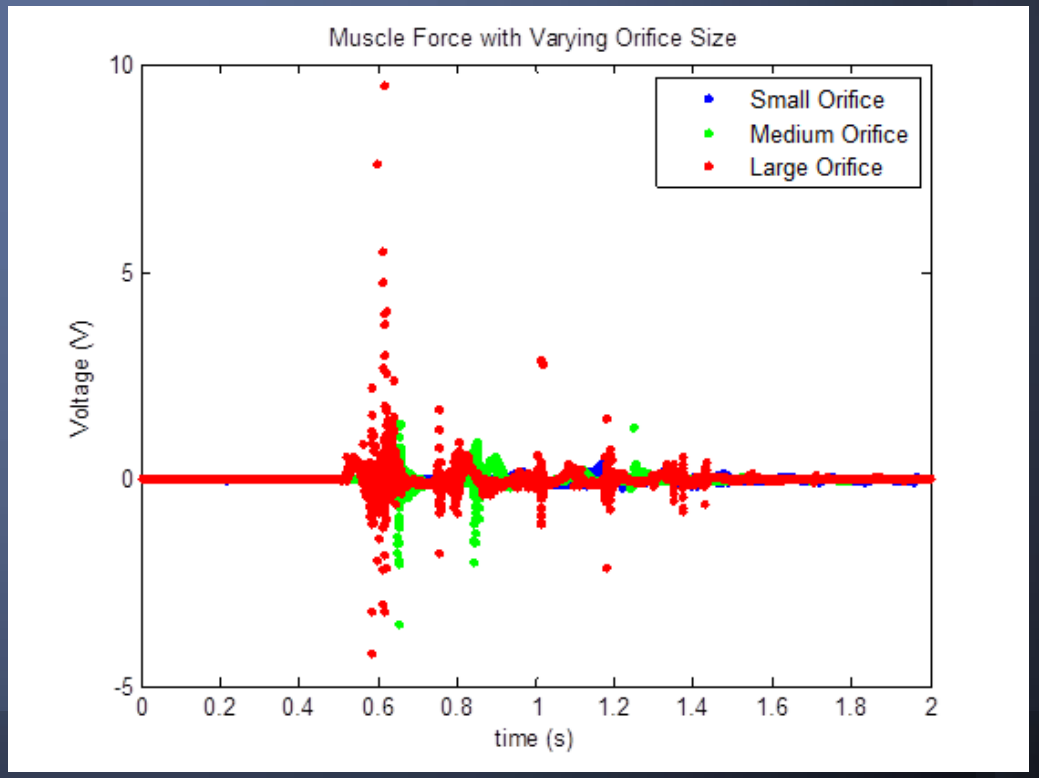
Test Plan

1. Muscle Testing/Development
    a. Vary tube thickness
    b. Vary orifice size
2. Theoretical Analysis
    a. Matlab simulation discontinued
        i. Time consuming/inaccurate
3. Prototype Build
    a. Machining of 80/20 frame, legs
4. Prototype Testing
    a. Tanks were too heavy, parts needed to be removed to achieve jump
5. Arduino Testing
    a. Arduino program used muscle timing delays found through labview testing

Muscle Testing

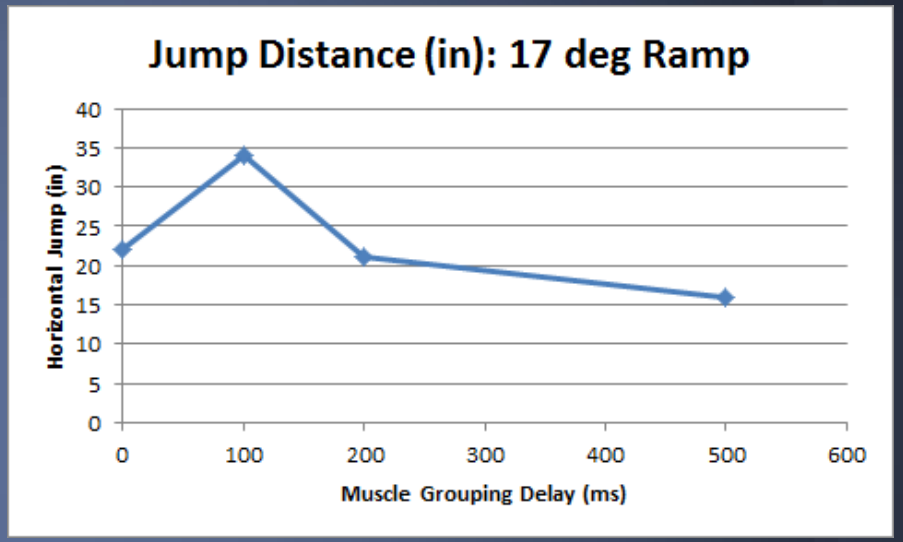


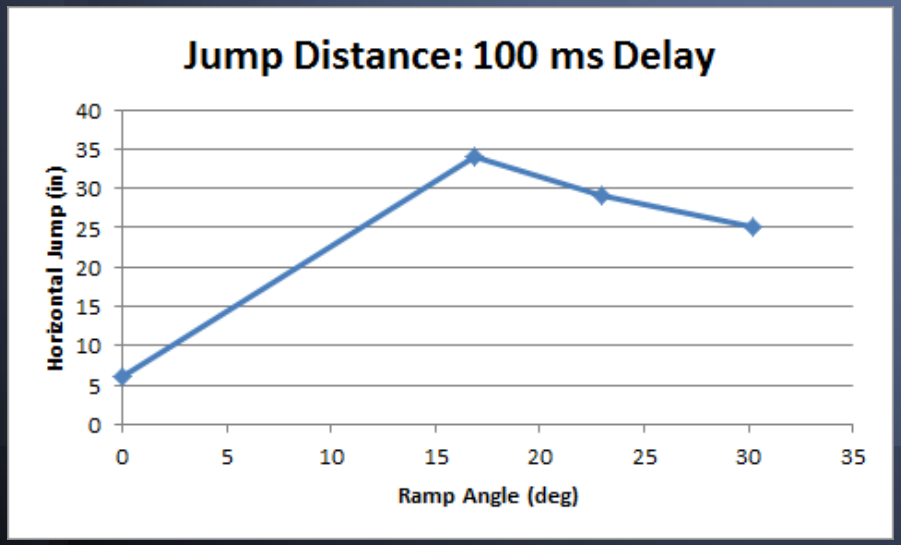
- Varied muscle orifice size and wall thickness
- Optimal: Largest orifice and medium wall thickness



Jump Testing

Varied ramp jump angle and muscle grouping delay





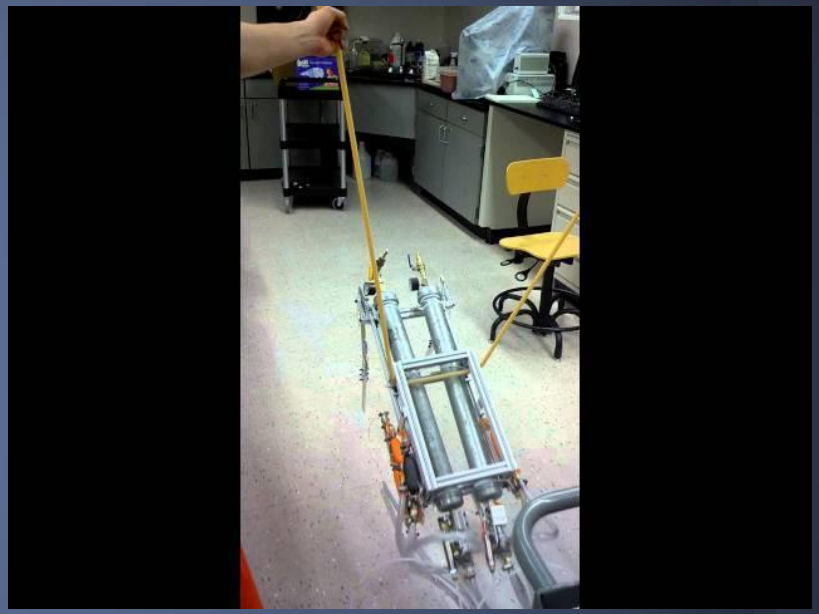
Largest jump:
100 ms at 17 deg

Successes

- Robot jumped farther than it's body length
- Repeatability was confirmed
- Arduino muscle delay and solenoids were fired as a standalone system
- Lands without damage

Failures

- Chassis too heavy
  - Tethered instead of onboard air supply
- Exhaust solenoid broke
  - Hind legs do not return
  - No spring return
- Inconsistent actuator return due to valve stick
- Mesh fatigue eventually causing failure



Too Heavy

Fatigue

Further Work

- Muscle exhaust and spring return
- Further weight reduction
  - Lighter frame, fittings, battery
- Untether
  - Lightweight tanks
- Elastic muscle connections
- Make robot resemble a tiger
- Remove need for ramp

Questions?