

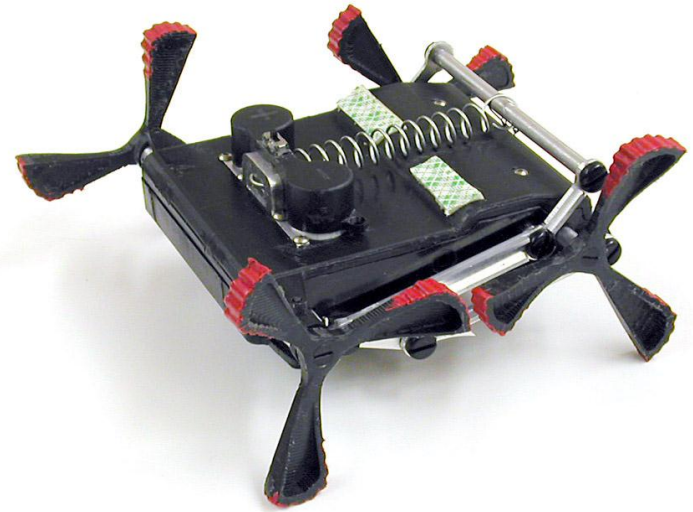


CASE

CASE WESTERN RESERVE UNIVERSITY



CENTER FOR
BIOLOGICALLY INSPIRED
ROBOTICS RESEARCH



A Small, Insect Inspired Robot that Runs and Jumps

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Thesis Adviser: Dr. Roger D. Quinn

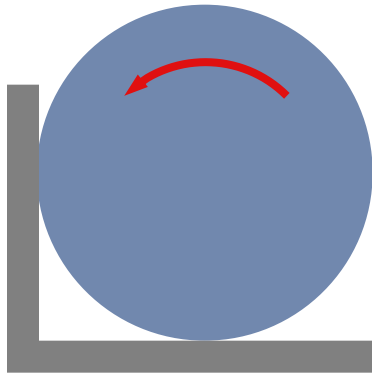
Master's Thesis Presentation
August 6, 2004



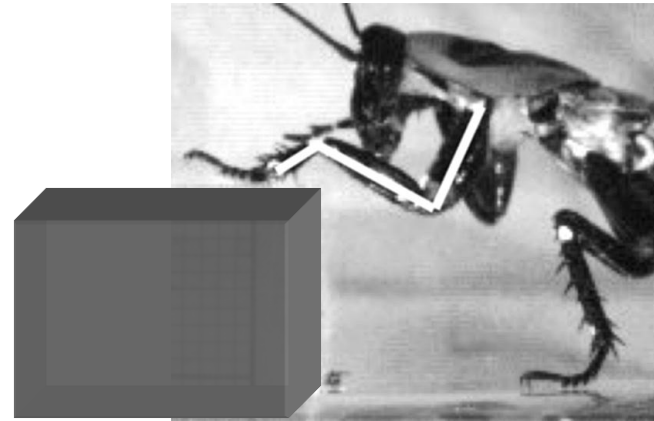
- Platform for autonomous or intelligent control research
- Distributed robotics
- Search and rescue
- Exploration
- Surveillance
- Insect inspired research



Wheels + Legs = Whegs



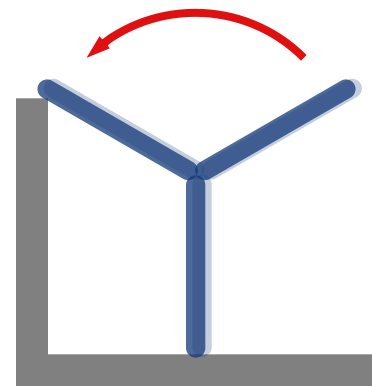
Wheels: smooth, firm terrain,
continuous ground contact

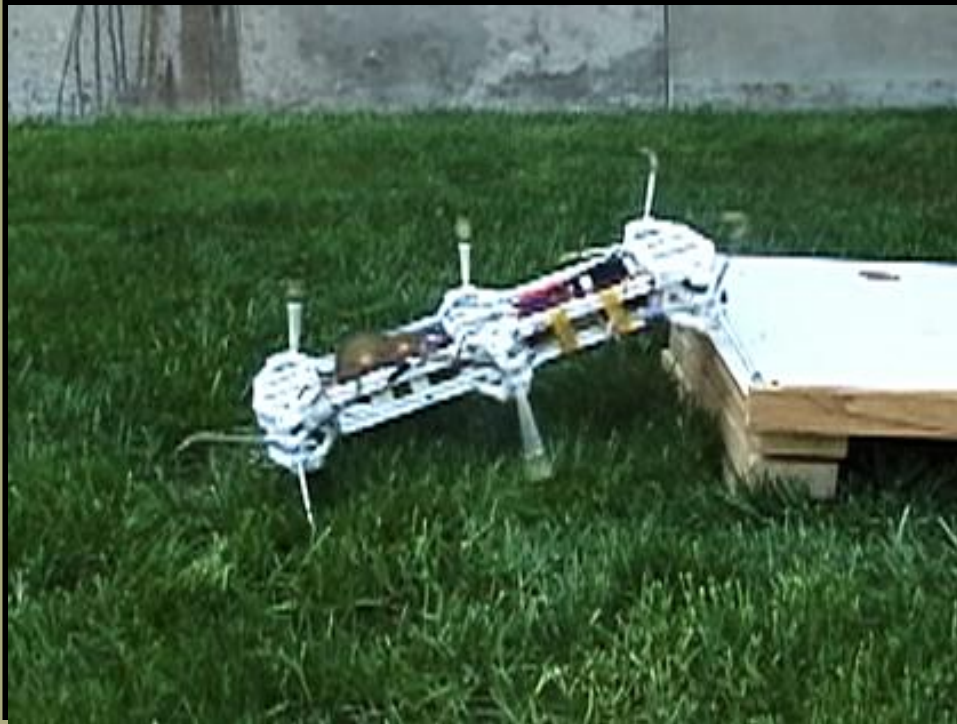


Legs: broken, uneven terrain,
discontinuous contact, climbing

Whegs:

- multiple spokes
- climbs like leg
- rolls like wheel
- constant motor speed



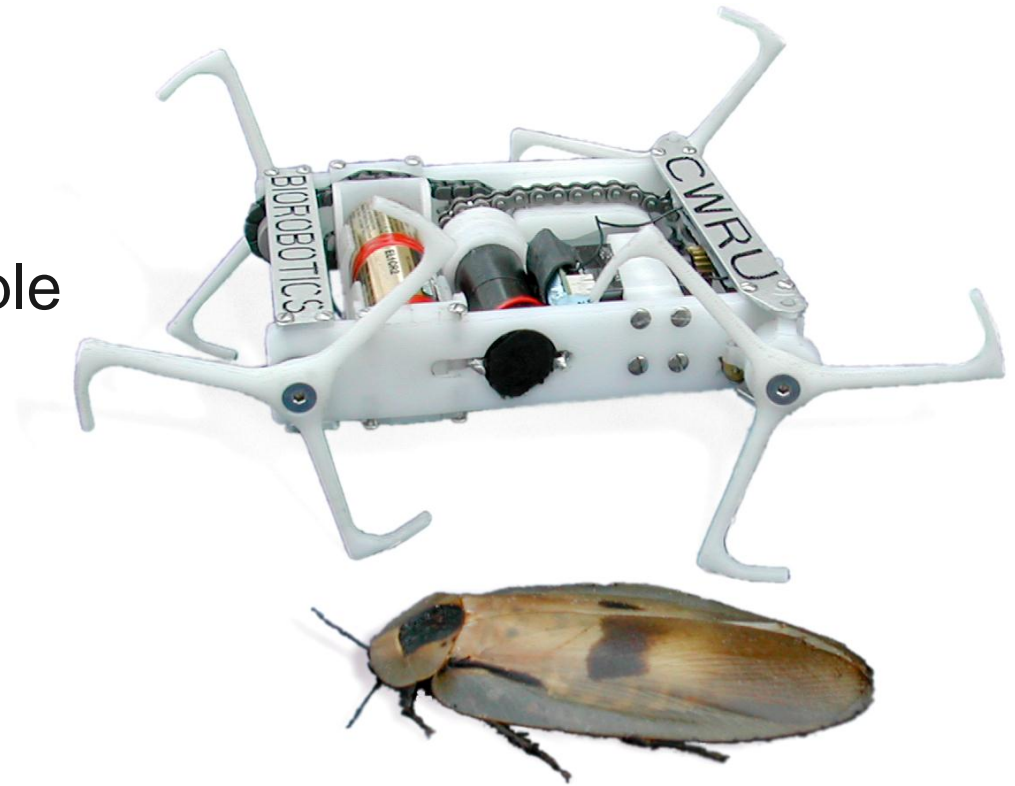


- Runs at 3 body lengths per second
- Climbs obstacles >1.5 leg length

Quinn et al., (2001), CLAWAR



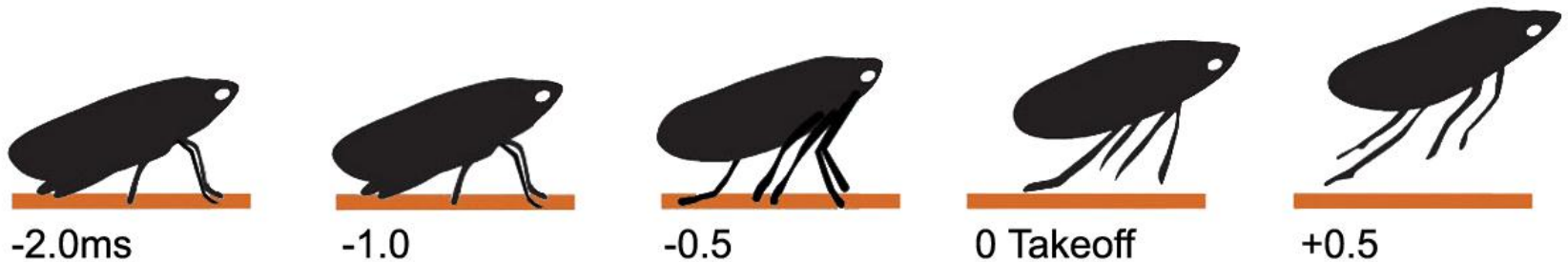
- Small
- Mechanically simple
- Fast
- Less expensive
- Scalable
- Large payloads



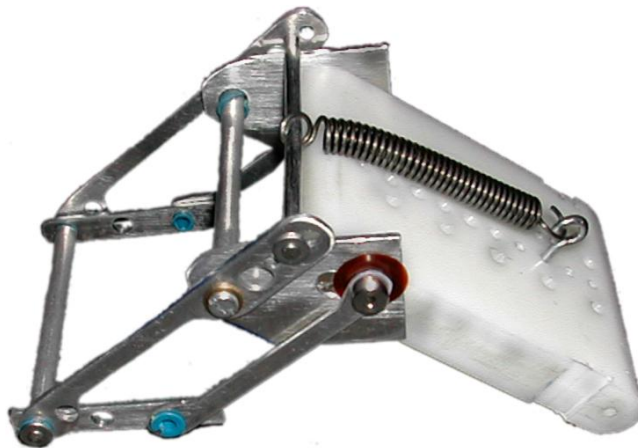
Mini-Whegs 5 with
Blaberus giganteus



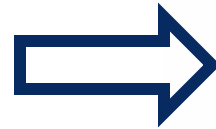
Composite of video frames showing Mini-Whegs 5 traversing two 3.5×9 cm boards while running at 3 body lengths per second



- Specialized rear legs
 - Not used during walking
 - Ridge on femur locks onto coxal protrusion
- Jumping
 - Muscle contracts slowly with legs locked in position
 - Femur and coxa disengage
 - Insect leaps over 100 body lengths high



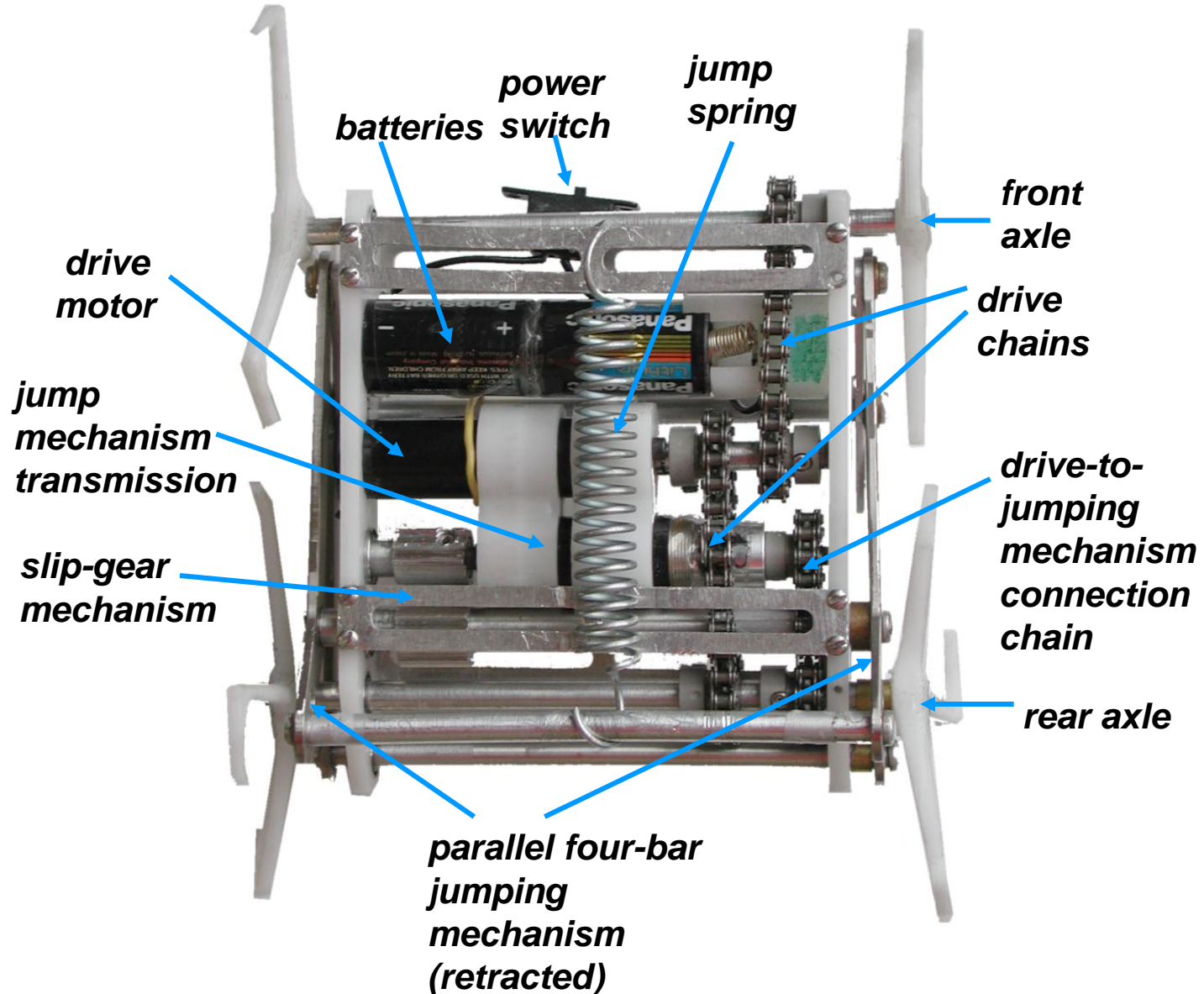
Four-bar jumping
mechanism concept



Mini-Whegs 4J
Proof-of-concept

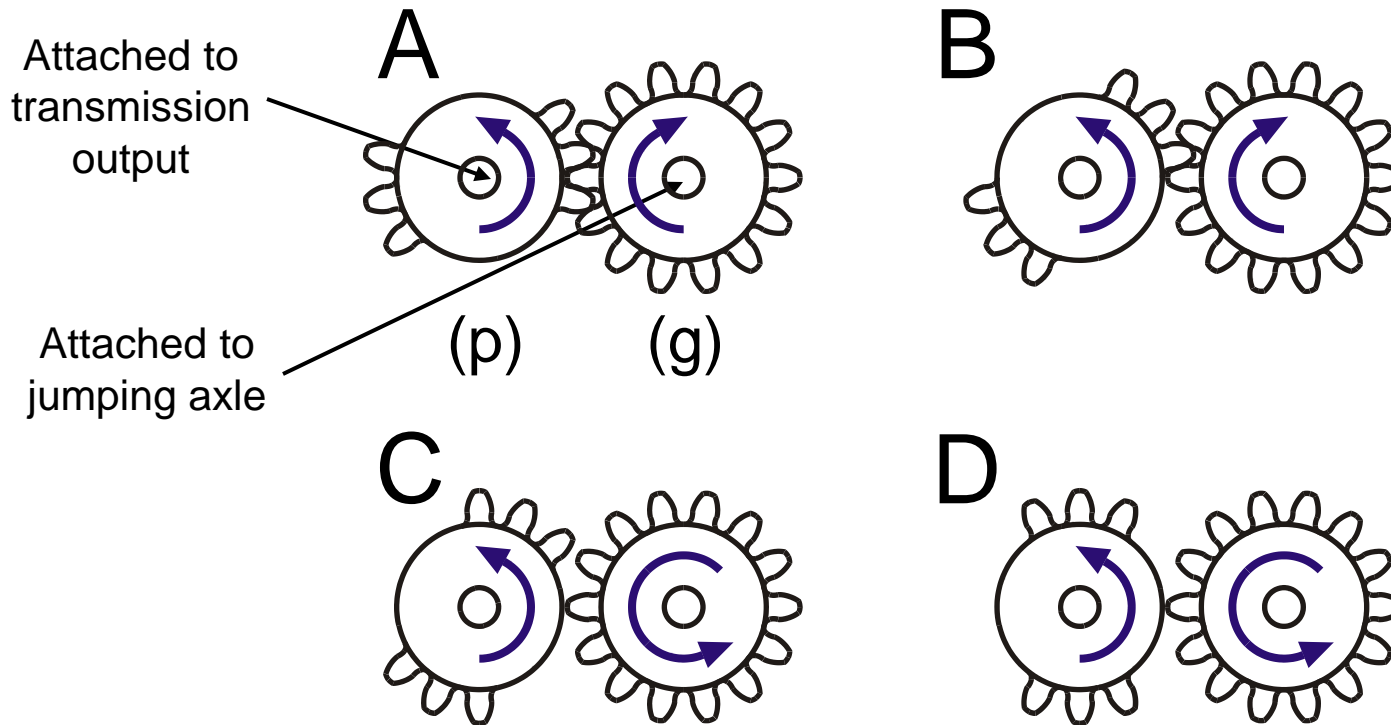


Mini-Whegs 4J Layout

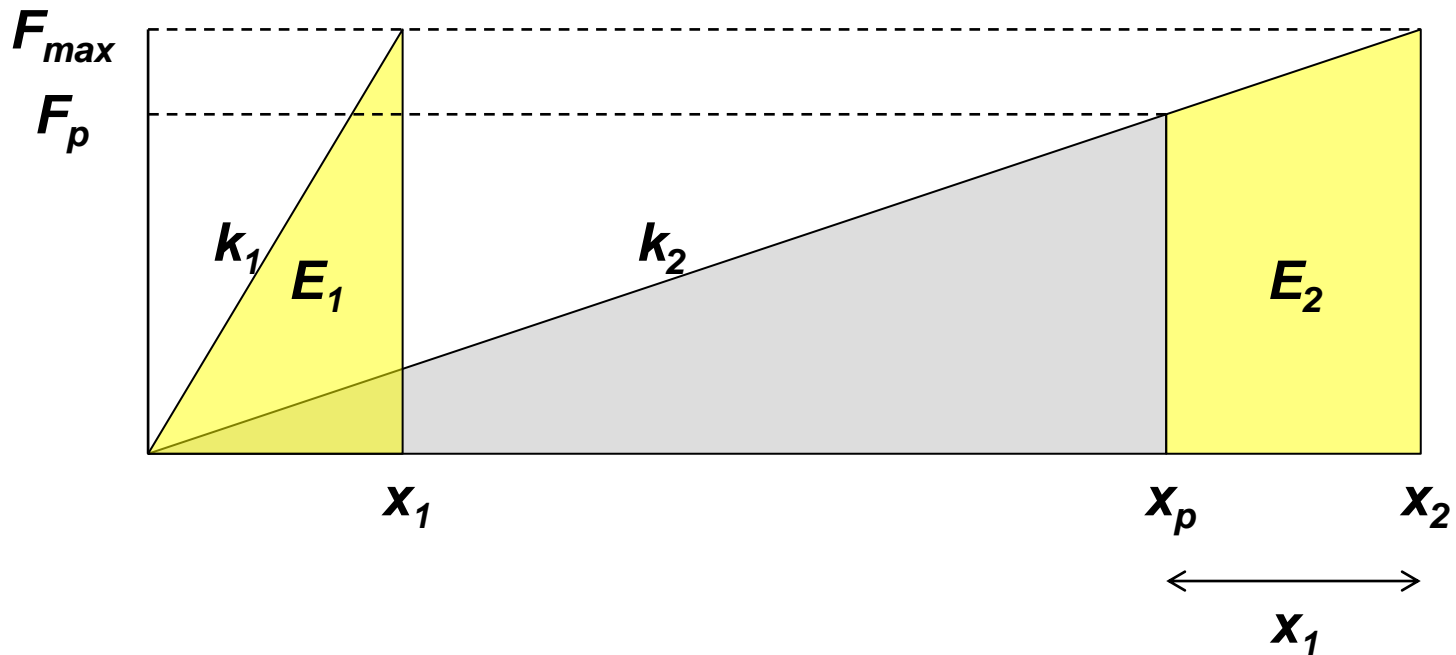




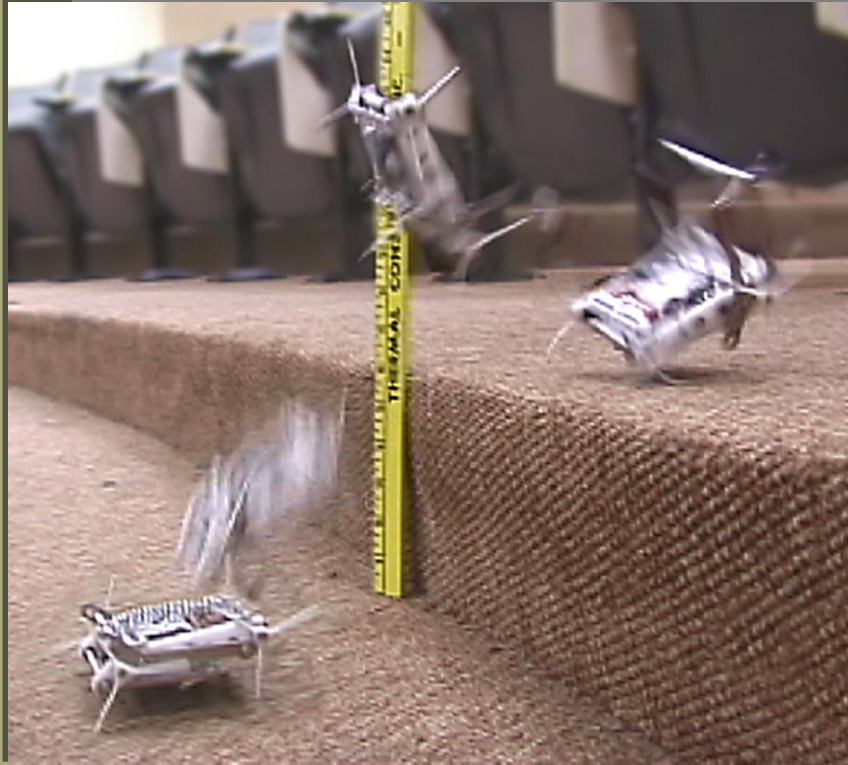
Slip-Gear Jumping Activation



A-B: Slip-gear pinion retracts jumping mechanism
C-D: Teeth disengage, and the jumping mechanism springs out



- A softer, preloaded spring stores more energy for the same displacement



Composite of video frames
showing Jumping Mini-Whegs
surmounting a 15 cm step

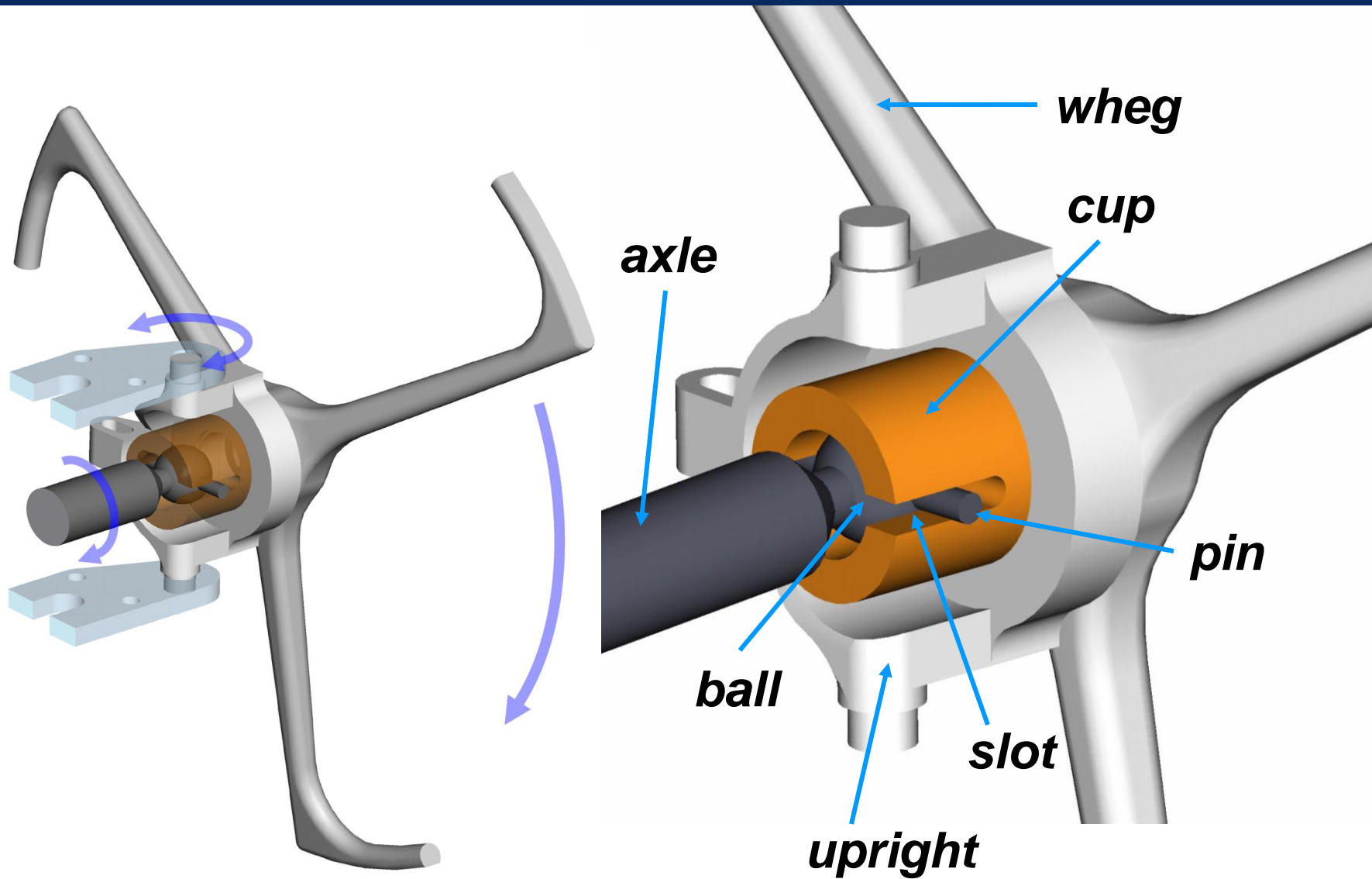


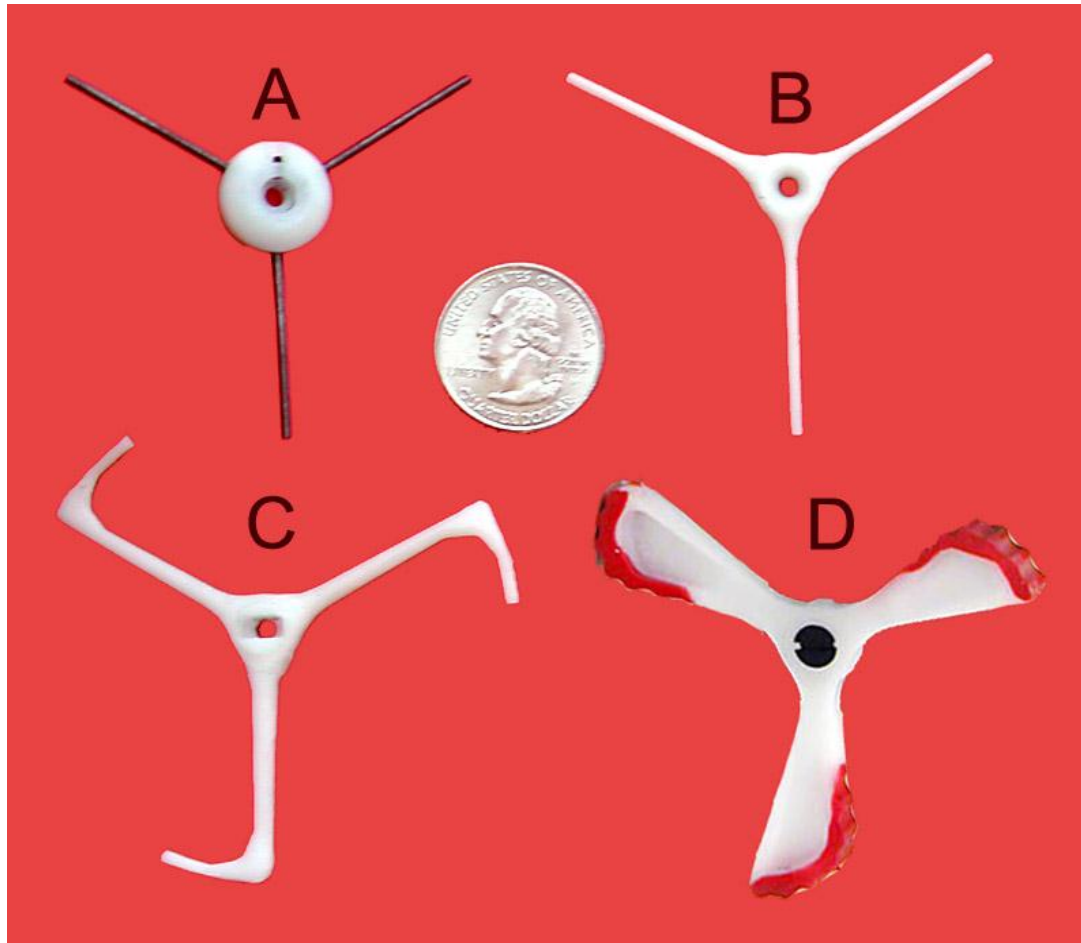


- Steering mechanisms
 - Mini-Whegs 1, 2, and 3 use various flexible couplings for transmitting torque to the whegs
 - Springs unwind or collapse
 - Delrin® fatigues and snaps
- Whég appendage design
 - Thin spokes provide little traction...or they get stuck and make the robot flip over.



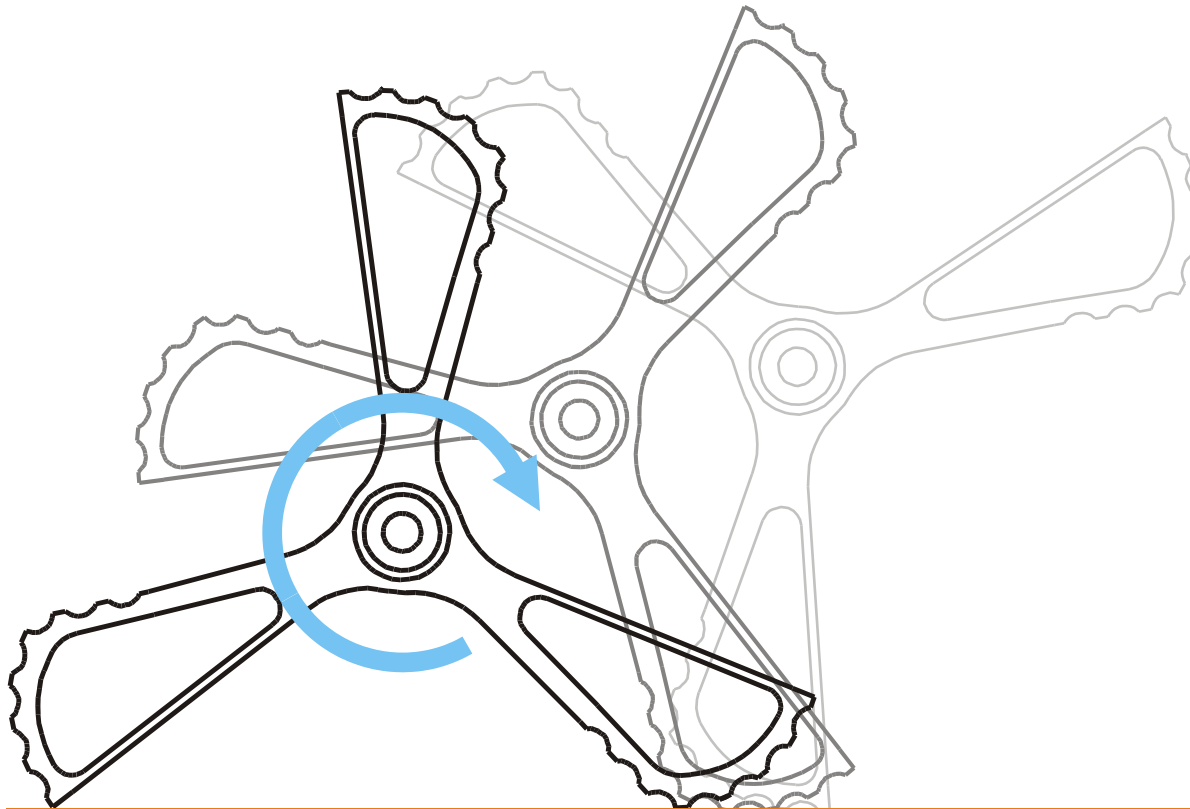
Ball and Cup Universal Joint



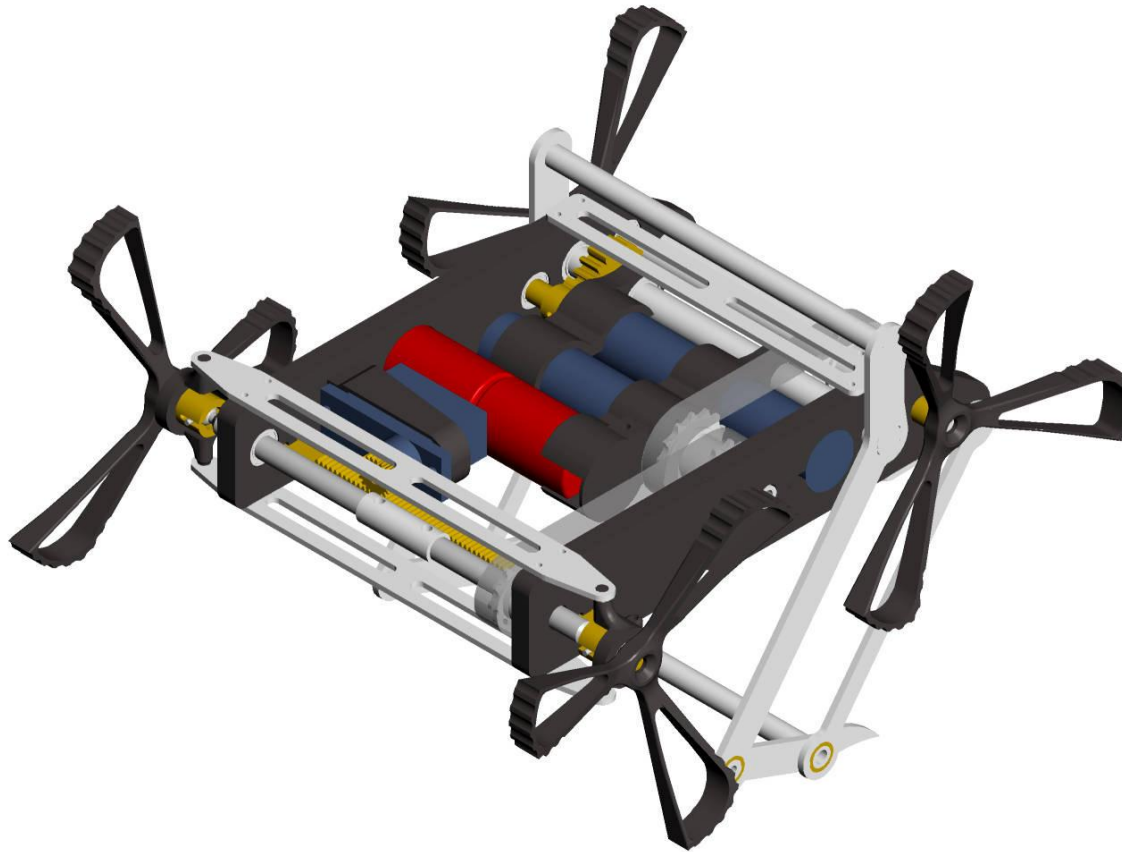


- A: Mini-Whegs 1
- B: Mini-Whegs 2,3
- C: Mini-Whegs 5
- D: Mini-Whegs 7

Short feet improve traction and smooth walking



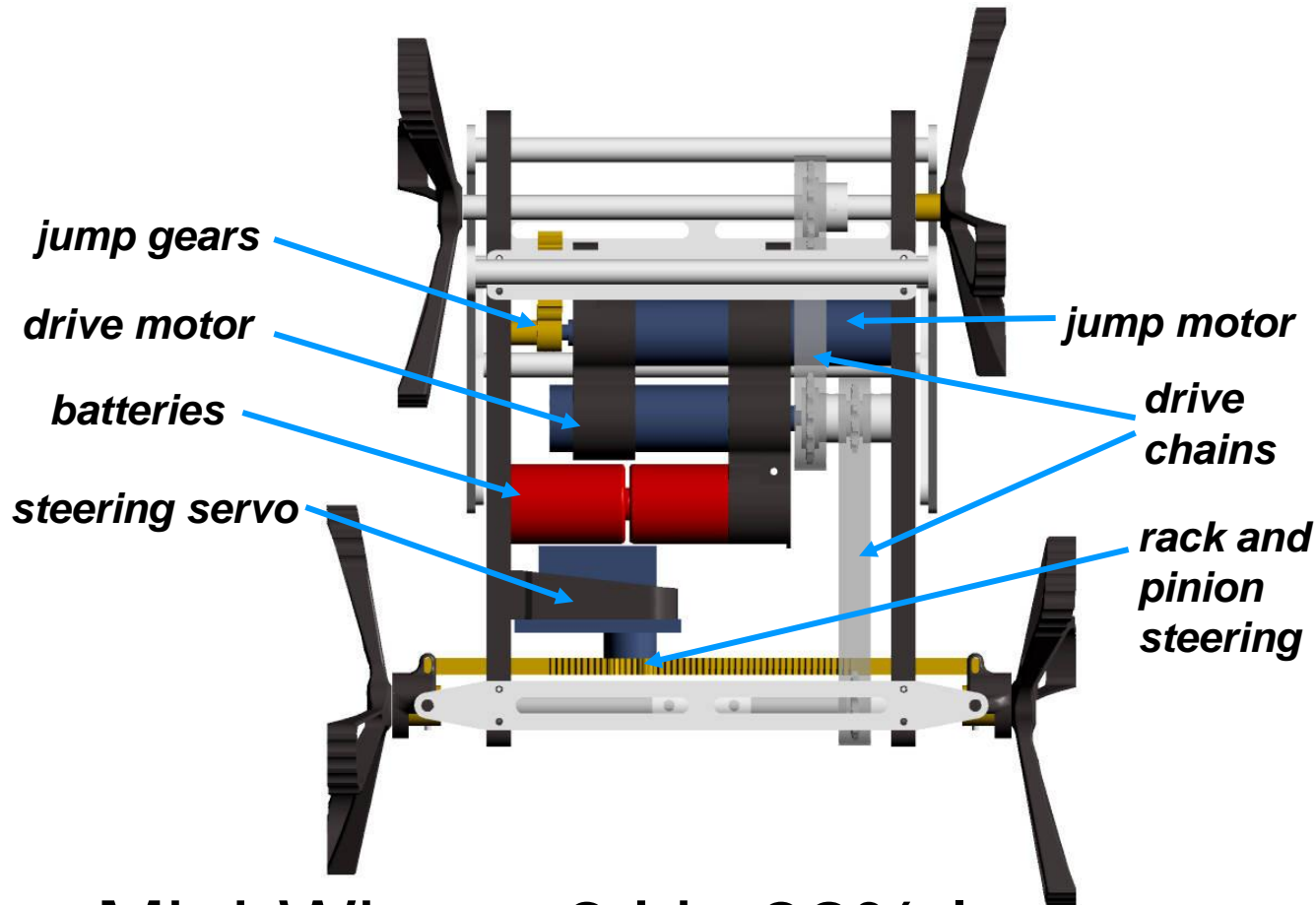
- Rounded heel smoothes transition between steps
- Scalable design works for other size Whegs robots



- Mini-Whegs 6J combines features of Mini-Whegs 4J and Mini-Whegs 5.



Too Large, Too Heavy



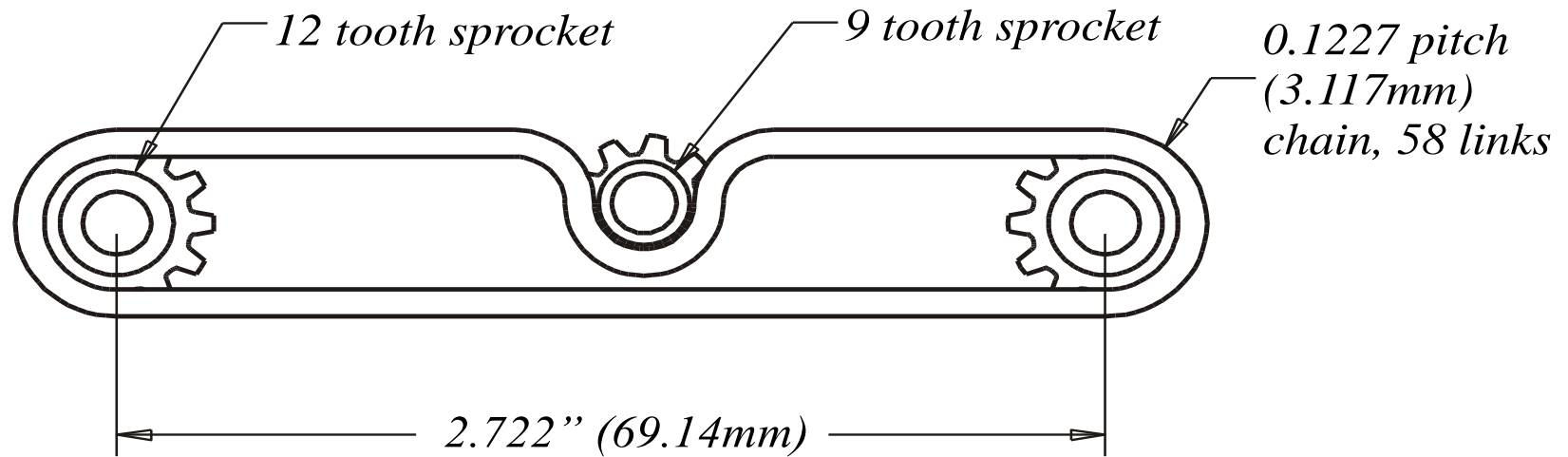
- Mini-Whegs 6J is 32% longer and 50% heavier than Mini-Whegs 4J



- **Lighter**
 - Less than 100 grams
- **Cheaper**
 - Half the cost of Mini-Whegs 5
- **Easier to Build**
 - More off-the-shelf components
 - Fewer fasteners



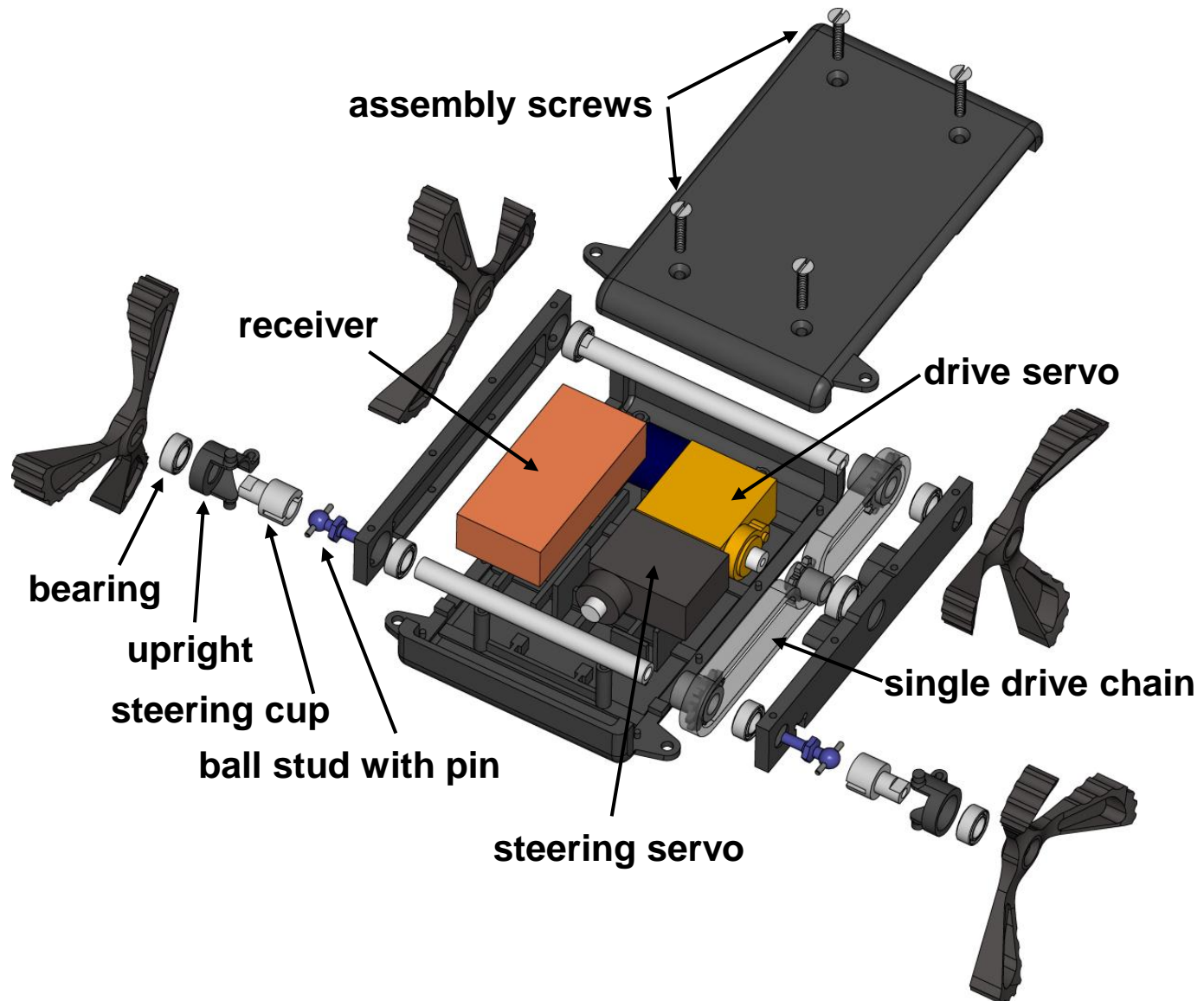
- Modified servo drive vs. Maxon Motor
- Hollow aluminum axles
- Plastic sprockets and gears
- Single plastic chain
- Nylon fasteners
- All Delrin® frame
- Single 6V 2CR-1/3N cell

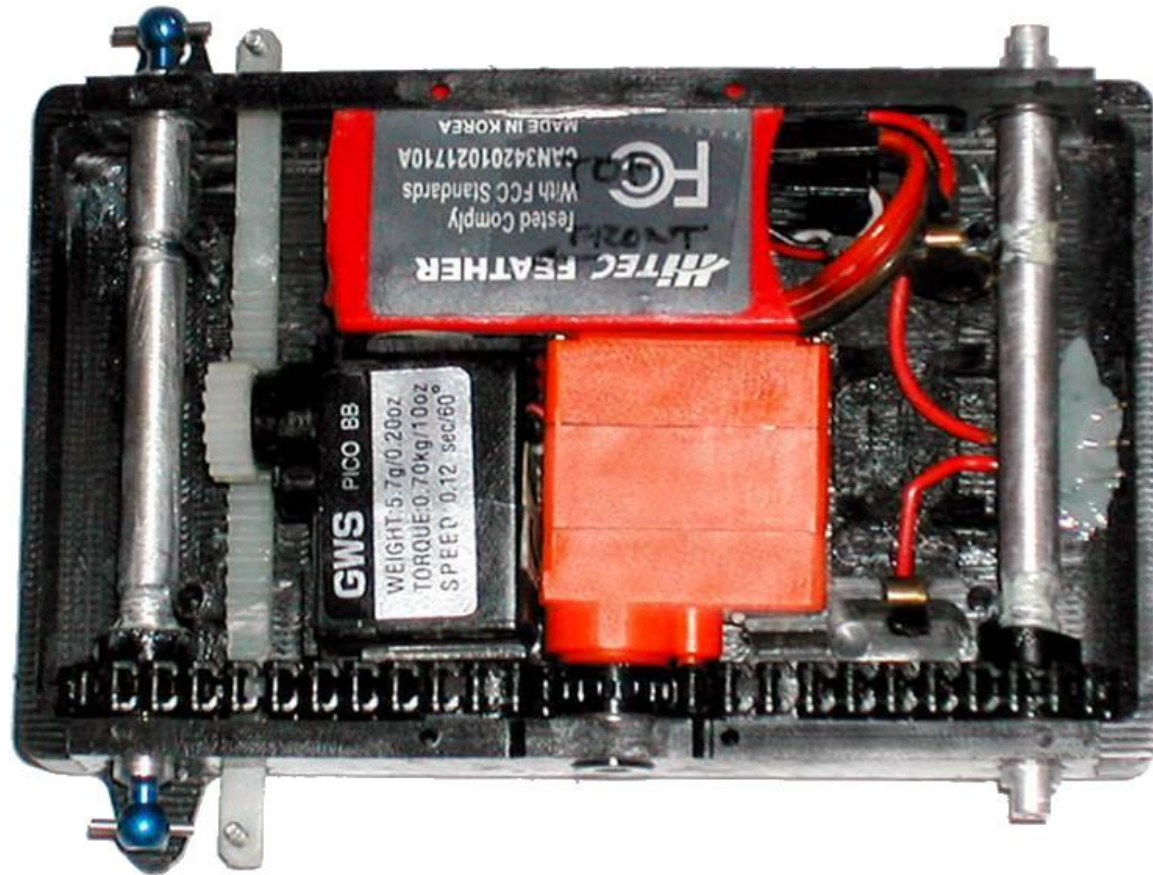


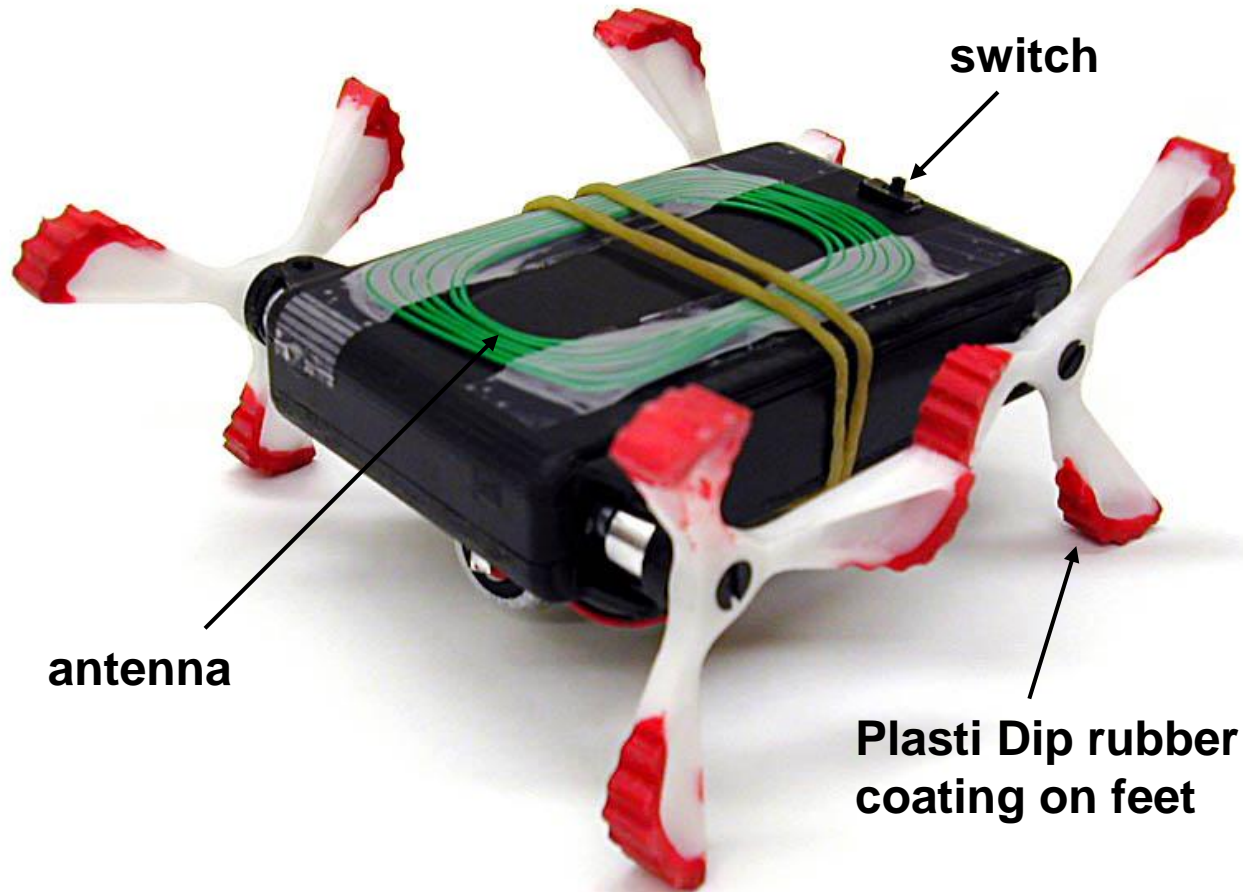
- A single, acetal plastic drive chain saves space and weight in Mini-Whegs 7



Exploded View of Mini-Whegs 7

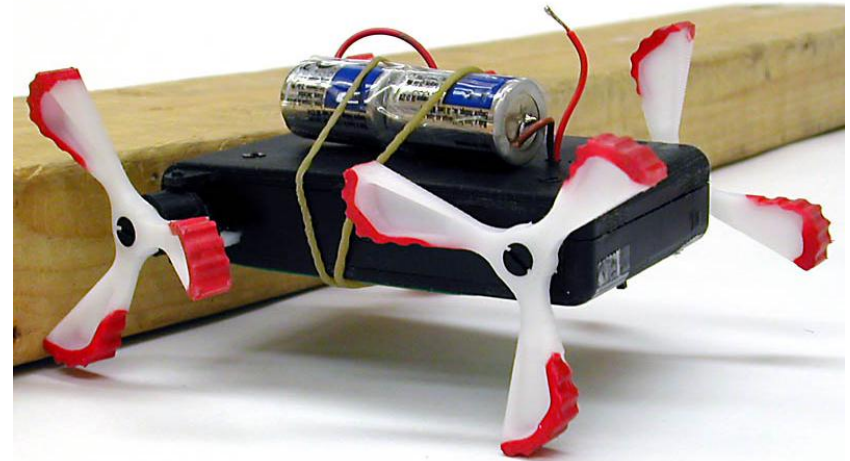


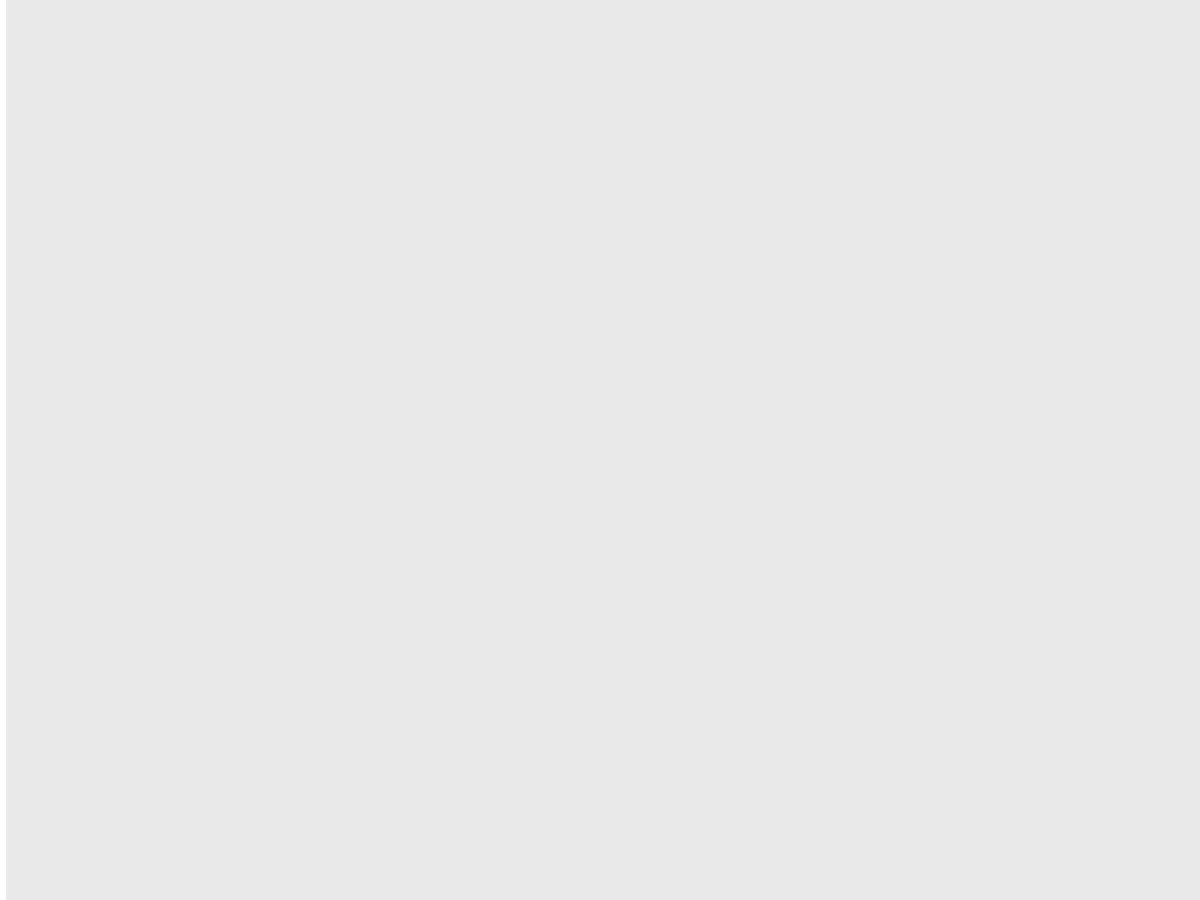


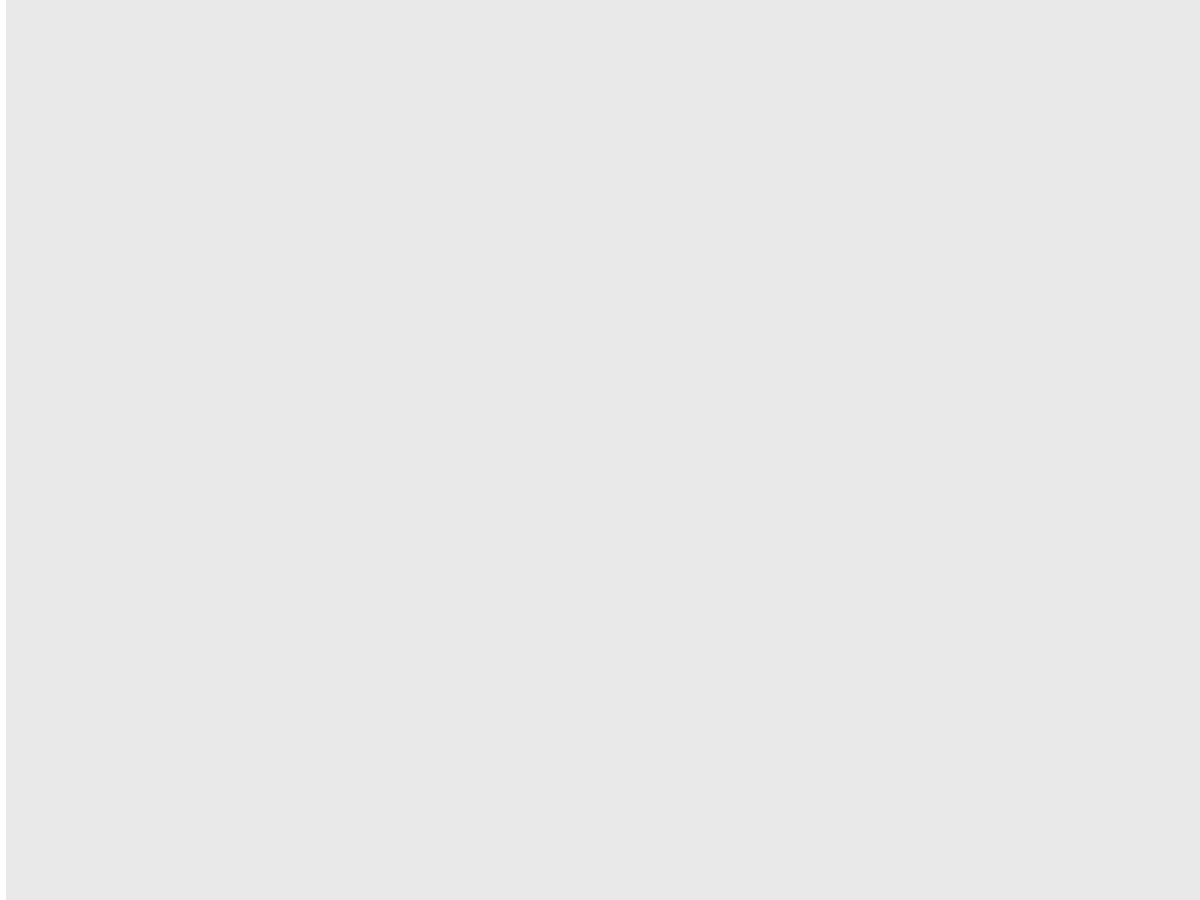




- Small: 6 x 9 cm
- Light: < 90 grams
- Cheap: < \$180
- Mobile
 - Single 6V 2CR-1/3N cell
 - 2.7 body lengths per second
 - Pair of 3V CR2 cells in series (adds ~18 grams)
 - 3.8 body lengths per second
 - Obstacles > 1.25 leg length
 - Incline up to 25 degrees







Mini-Whegs 8: Enclosed Batteries



- ABS body shell is lighter than Delrin®
- Same weight as Mini-Whegs 7 despite slightly larger size
- Easily carries a 50-100g payload

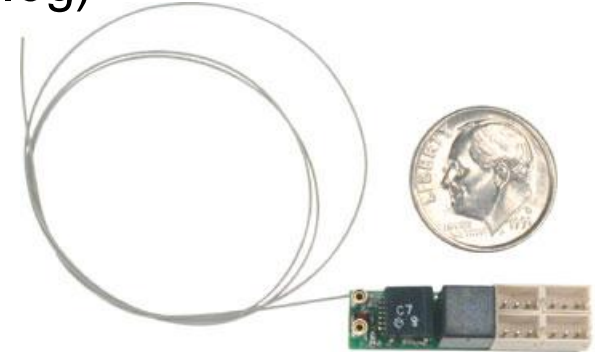


- Lightweight
 - Maintain weight reduction techniques of Mini-Whegs 7
 - Reduce weight in jumping mechanism components
 - Target weight < 200g
- Small
 - Pack components closely
 - Single drive chain



steering servo (4.4g)

speed controller (2.0g)

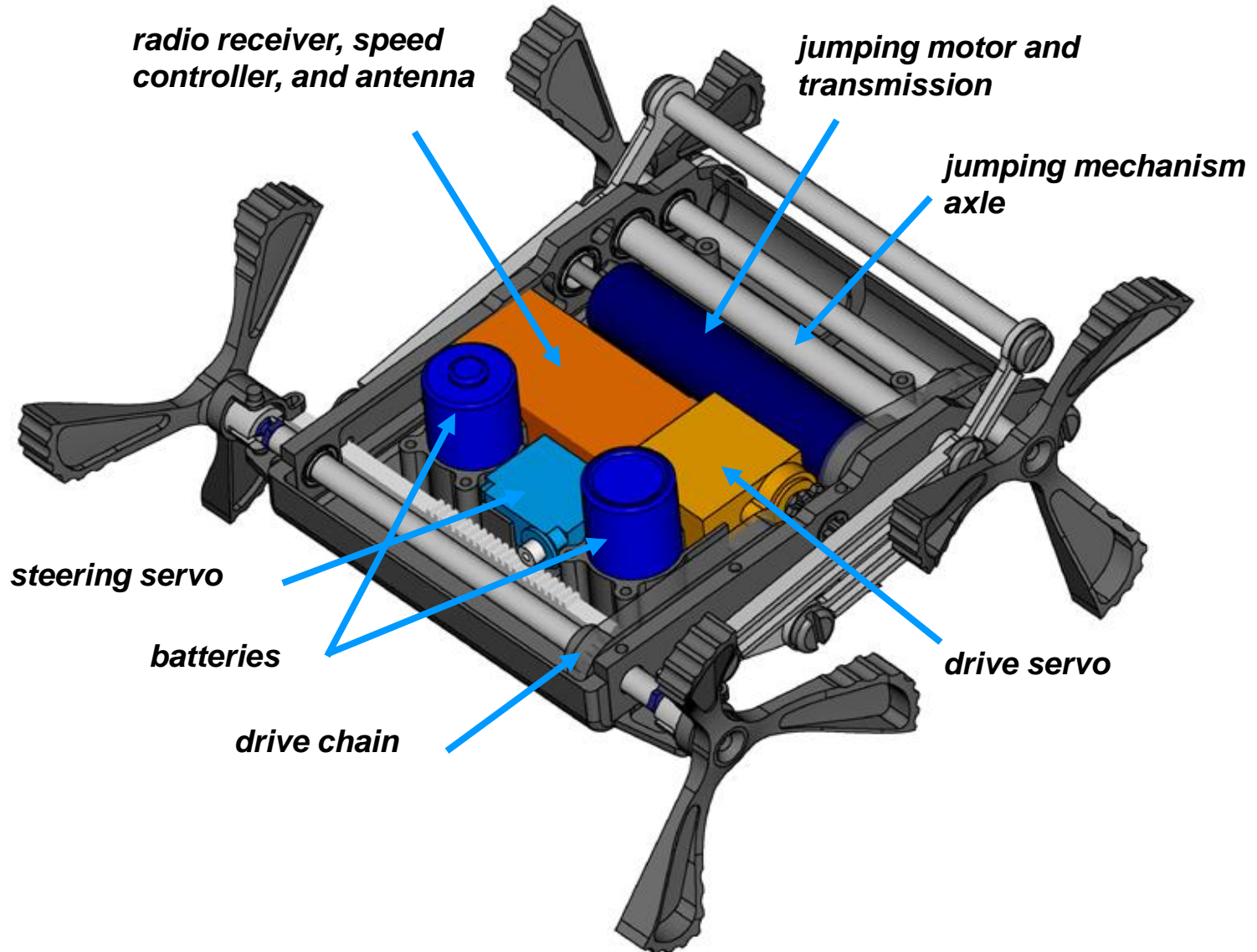


radio receiver (3.5g)

- Same sprockets, drive servo, and materials as Mini-Whegs 8
- Smaller steering servo, receiver, and speed controller by Cirrus
- Maxon jumping motor from Mini-Whegs 6J

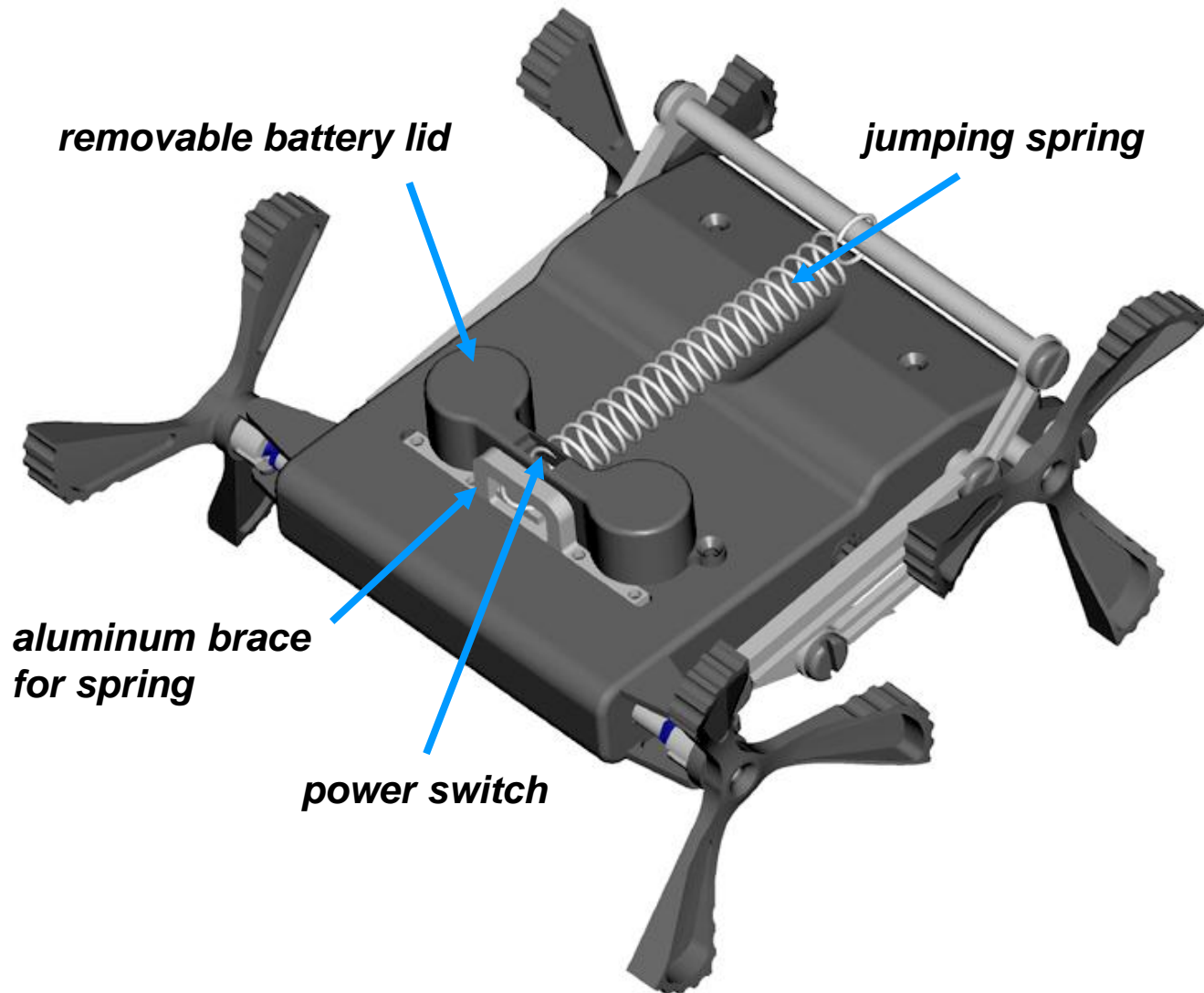


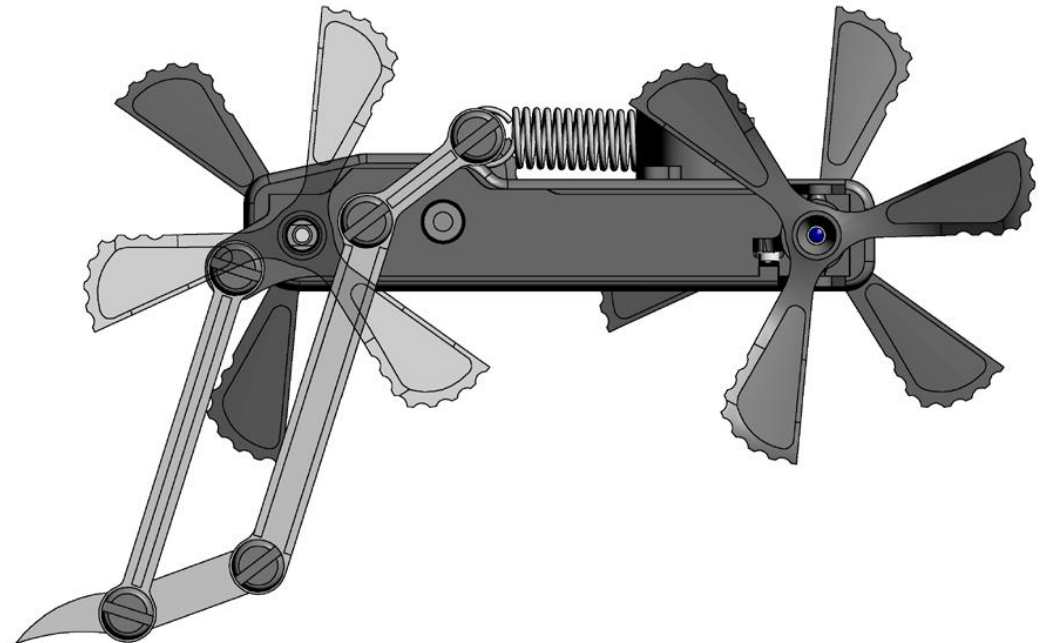
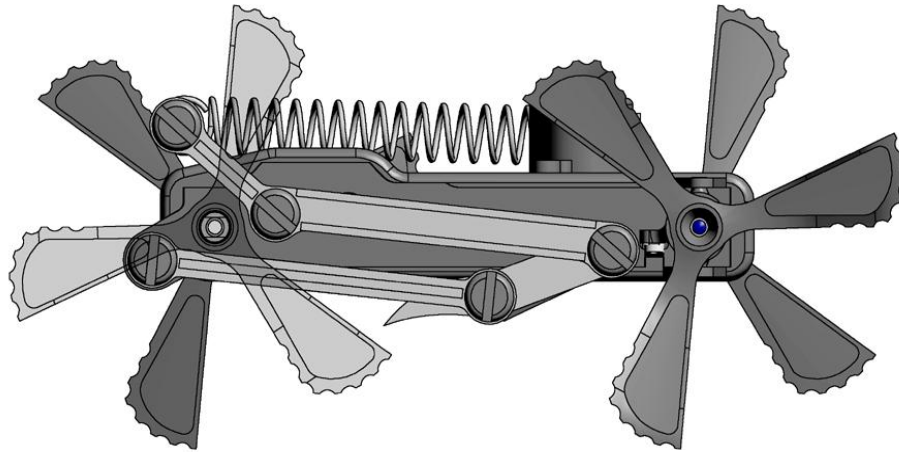
Layout of Mini-Whegs 9J

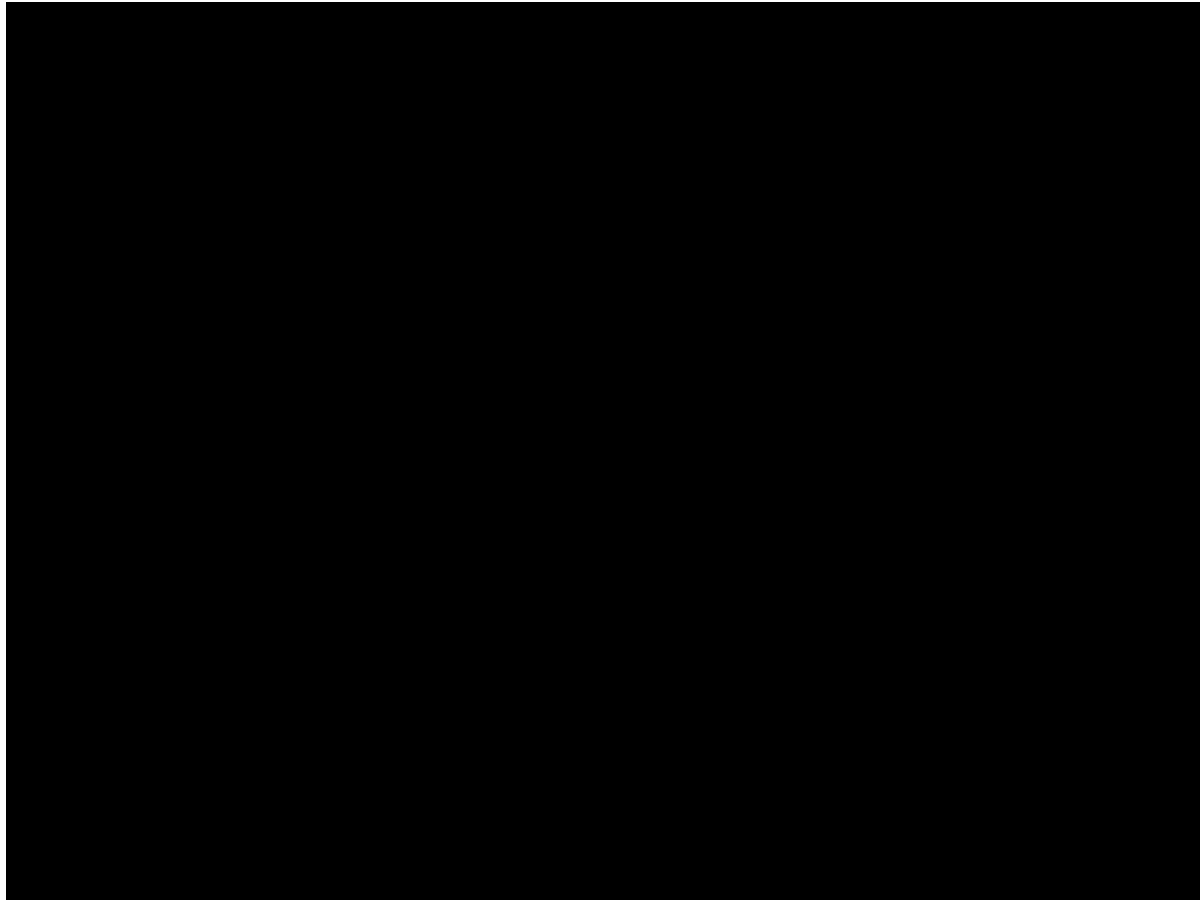




Assembled Mini-Whegs 9J

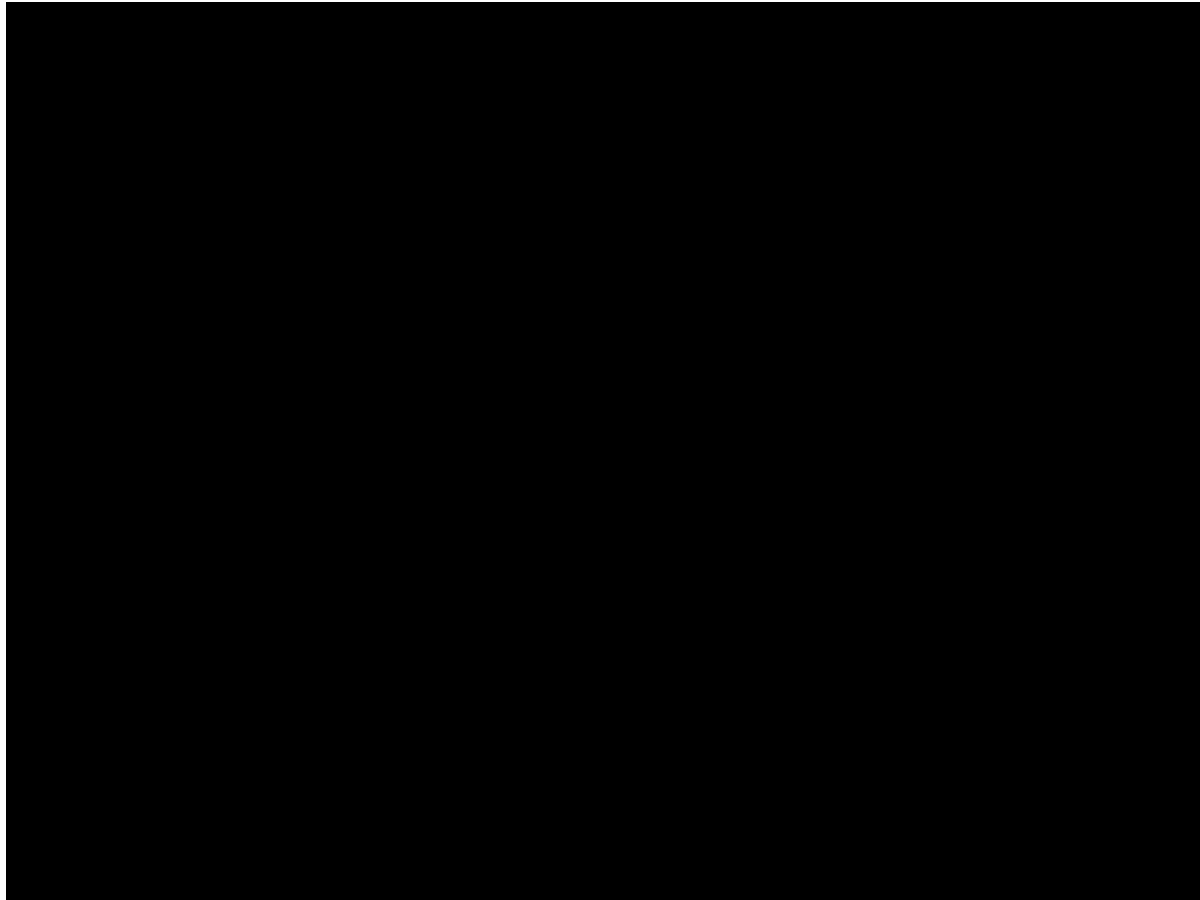


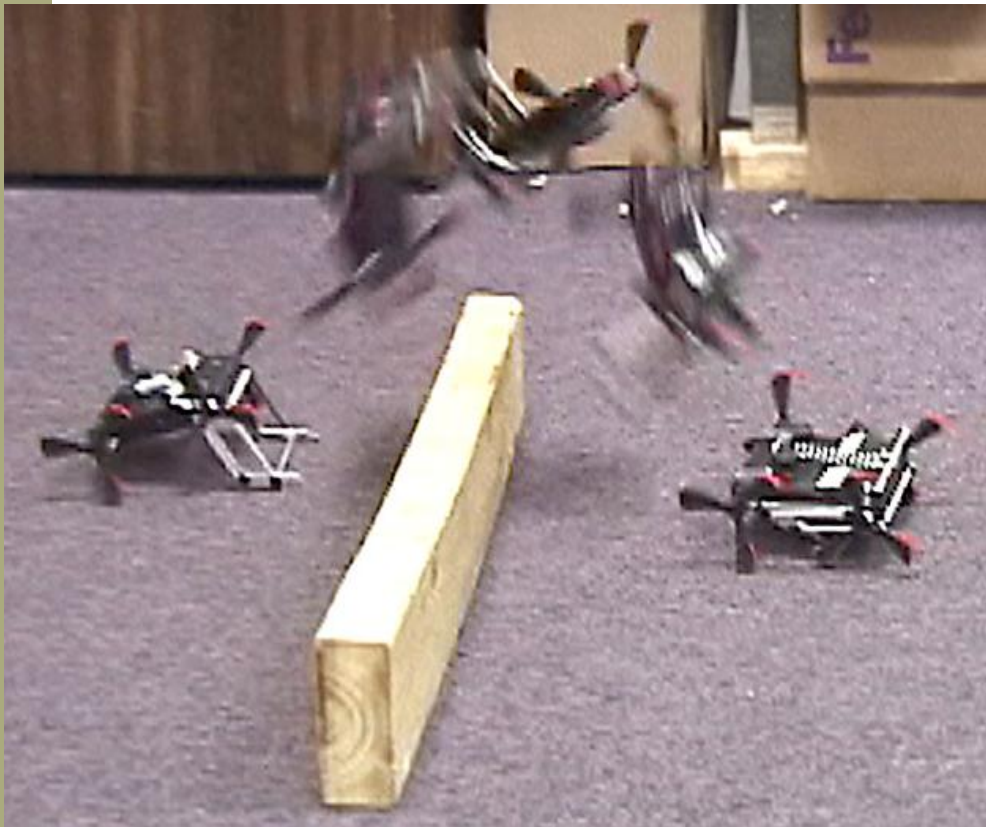






Jumping – Slow Motion





- Weight
 - 191g
- Walking speed
 - ~3 body len./second
- Jumping:
 - 15-18cm



- Alternative motors and transmissions
 - More force for higher jumps
 - Faster walking
- Torsion springs could fit entirely inside chassis
- FDM or injection molded chassis construction
- Improved control system for jumping
- Sensor integration

- Thanks to:
 - Roger Quinn, Malcolm Cooke, Vikas Prakash
 - Jeremy Morrey, Andrew Horchler, Bill Lewinger for previous work, ideas, and assistance
 - Christie for helping make parts this summer
 - Everyone else who has made my experience with the Biorobots lab fun and rewarding

