

***FIRST* Robotics Drive Systems**

Simbotics – October 16th, 2010



Two Wheels
Four Wheels
Six Wheels
Omnidirectional

Simplicity
Durability
Weight Distribution
Miscellaneous

Guidelines
Motor Curves
Gearing
Power Transmission
Traction
CAD
Testing/Practicing

Ian Mackenzie

- ▶ Involved in the FIRST Robotics competition since 1998
- ▶ Student (188, Woburn Robotics), mentor (1114, Simbotics), referee (Waterloo, Toronto, Championship), event organizer (Waterloo)
- ▶ Designed HexaDrive in 2002 (one of the earliest six-motor drivetrains) and SimSwerve in 2004 (omnidirectional swerve drive system with individually raised and lowered wheels)
- ▶ Currently a Ph.D. student in mechanical engineering at McMaster University
- ▶ ian.e.mackenzie@gmail.com



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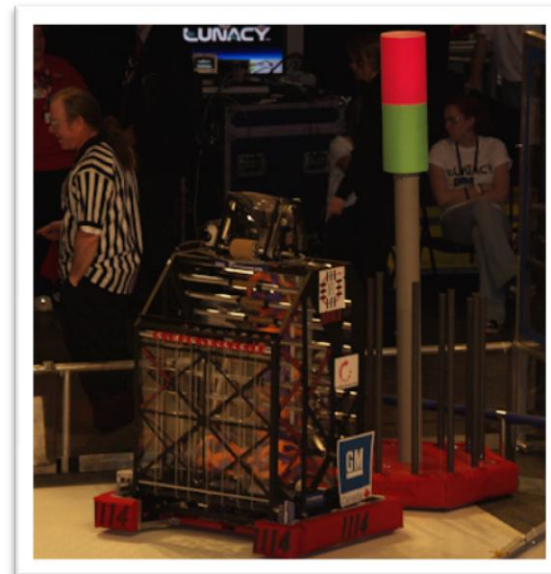
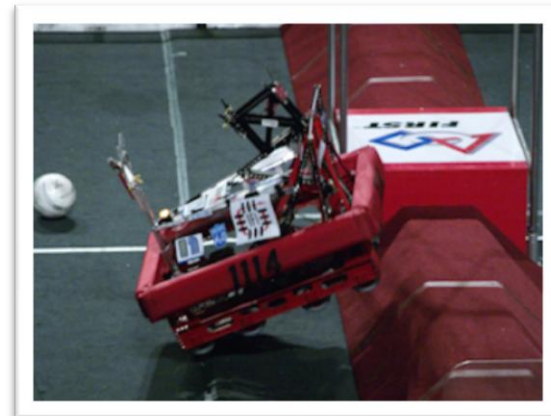
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Overview

- ▶ Move around field
 - ▶ 27' × 54', usually carpet
- ▶ Push/pull objects and robots
- ▶ Climb up ramps or over obstructions
- ▶ Speed and pushing force both important
 - ▶ In 2010, durability and power to get over the bump



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Types

- ▶ Two wheels
- ▶ Four wheels
- ▶ Six wheels
- ▶ Omnidirectional



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Two Wheels

- ▶ Easy turning, fast
- ▶ Susceptible to spin-outs at high speed
- ▶ Lose traction (weight on non-powered wheels)
- ▶ Caster wheels very annoying to drive





Four Wheels

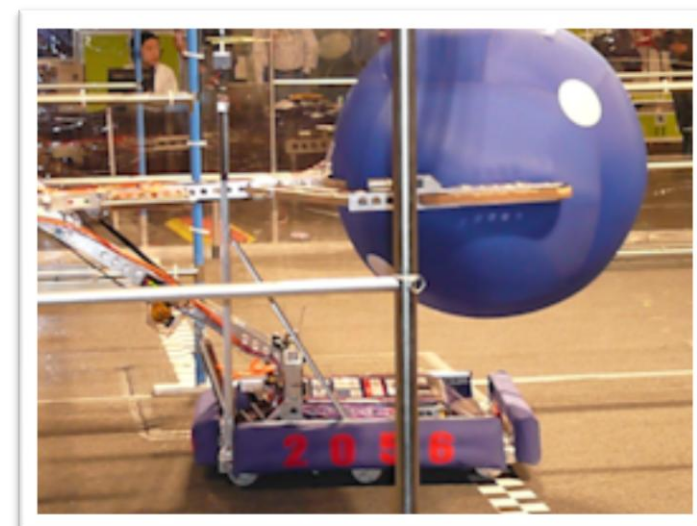
- ▶ Slightly less manoeuvrable, slightly slower
- ▶ More traction, more controllable
- ▶ Probably the most common configuration
 - ▶ Gearbox in middle, chains to each wheel
- ▶ Put along longer dimension to go straighter, along shorter dimension to turn more easily





Six Wheels

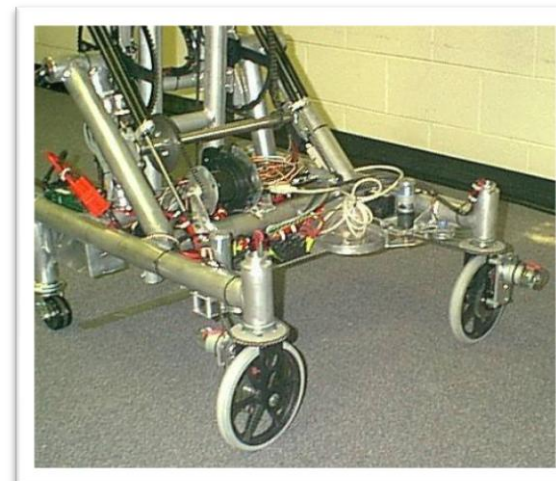
- ▶ High traction with better manoeuvrability
- ▶ Middle wheels usually lowered 1/8"-3/16" to help with turning
- ▶ Slightly trickier to deliver power to all wheels
 - ▶ Multiple chains or multiple gearboxes





Omnidirectional

- ▶ Various types of mobility systems with ability to move sideways
 - ▶ Swerve
 - ▶ Mecanum
 - ▶ Holonomic
- ▶ Very manoeuvrable, but...
 - ▶ Complex to build
 - ▶ Prone to failure
- ▶ Only use after careful strategic analysis!



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Design Principles

- ▶ Simplicity
- ▶ Durability
- ▶ Weight distribution
- ▶ Miscellaneous



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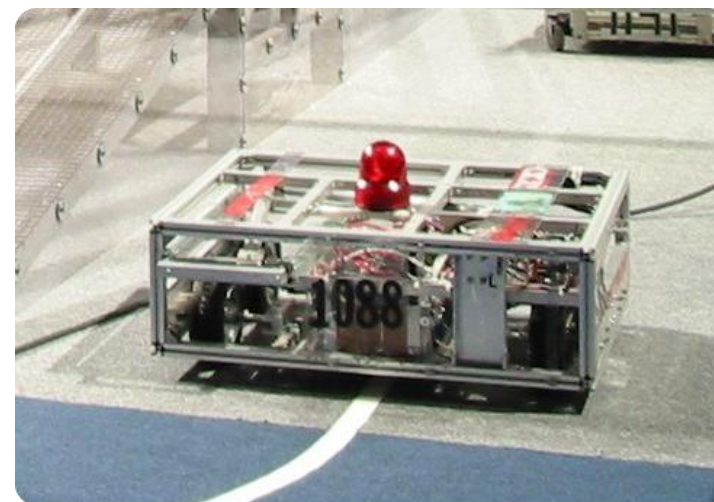
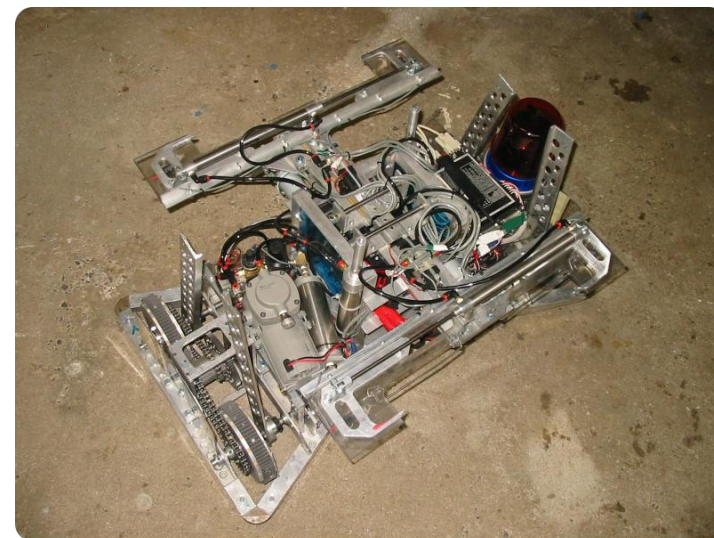
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Simplicity

- ▶ Fewer things to fail
- ▶ Easier and faster to build and repair
- ▶ Lighter
- ▶ More durable
- ▶ More elegant



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Durability

- ▶ Simplest mechanisms often the most durable
- ▶ Robot will likely go through much more stress than you expect
- ▶ Support shafts on both sides
- ▶ Use large sprockets to reduce load on chain
 - ▶ #25 (1/4" pitch) chain usually quite adequate



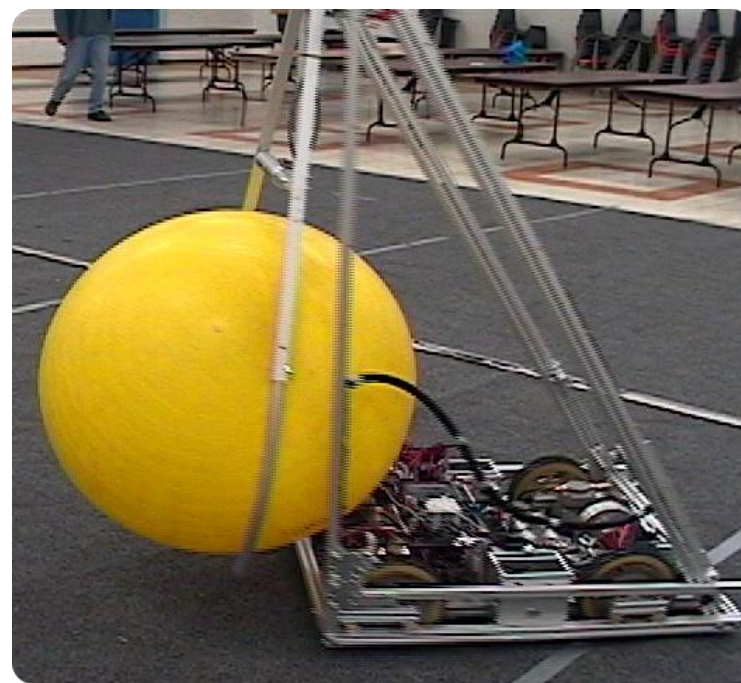
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Weight Distribution

- ▶ Keep as much weight as low as possible
- ▶ Put weight over the drive wheels
- ▶ Battery is a large component of the total weight (14 lbs) and can move center of gravity
- ▶ 2010: just because the bumpers have to be up high doesn't mean the main frame does!



Miscellaneous

▶ Vibration

- ▶ Robots go through a lot of vibration, especially at competitions
- ▶ Bumpy wheels increase vibration
- ▶ Use Loctite or nylon lock nuts to avoid nuts falling off
- ▶ Check bolted connections and shaft collars frequently

▶ Design for assembly and disassembly

- ▶ Fast work necessary at the competition!
- ▶ Leave nuts and bolts accessible



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Design Process

- ▶ Guidelines
- ▶ Motor curves
- ▶ Gearing
- ▶ Power transmission
- ▶ Traction
- ▶ Computer Aided Design
- ▶ Testing and practicing



Guidelines

- ▶ 3 ft/s: Very slow, very good pushing force
- ▶ 4-7 ft/s: Slow
- ▶ 8-12 ft/s: Medium, medium pushing force
- ▶ 13+ ft/s: Hard to control, little pushing force
 - ▶ Teams have done it successfully, but it may require some fancy programming



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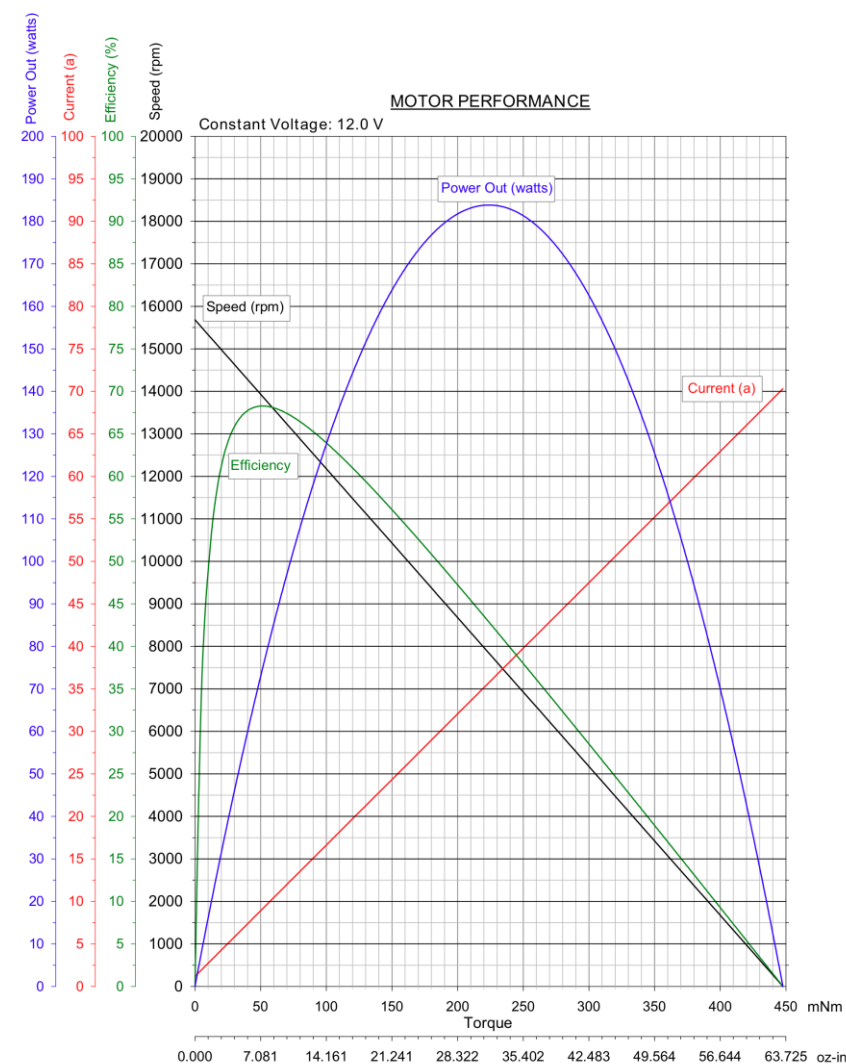
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Motor Curves

- ▶ Very valuable source for designing mobility systems
- ▶ Usually torque on x-axis, all other variables on y-axis



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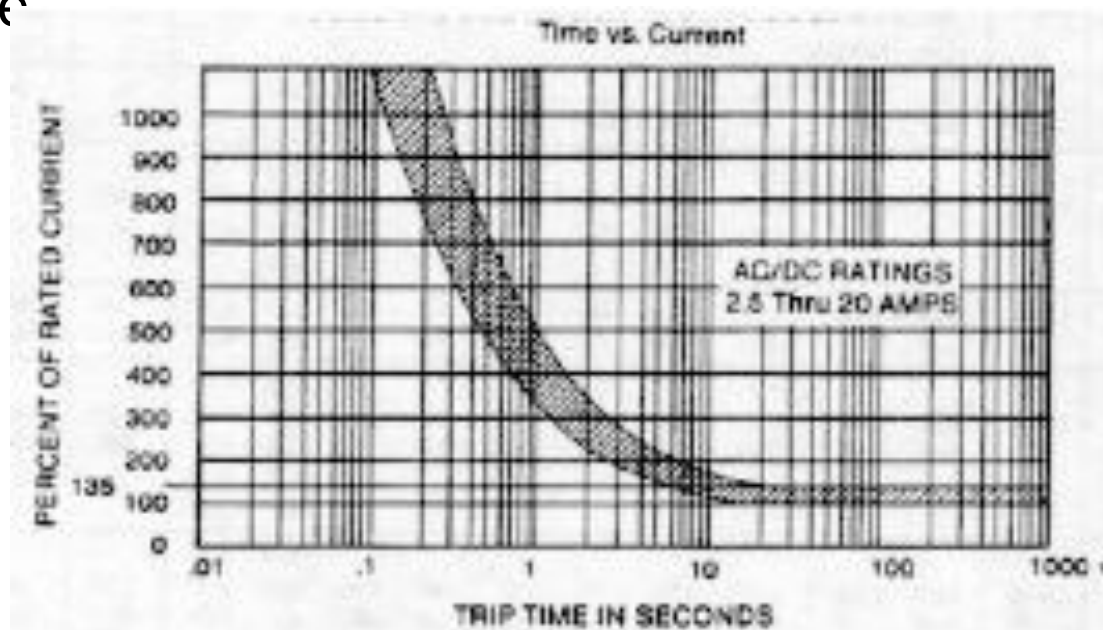
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Motor Curves

- ▶ Max power the most important single characteristic
 - ▶ Motor can always be geared to get correct speed/torque
- ▶ Check stall current; be careful if much higher than circuit breaker limit



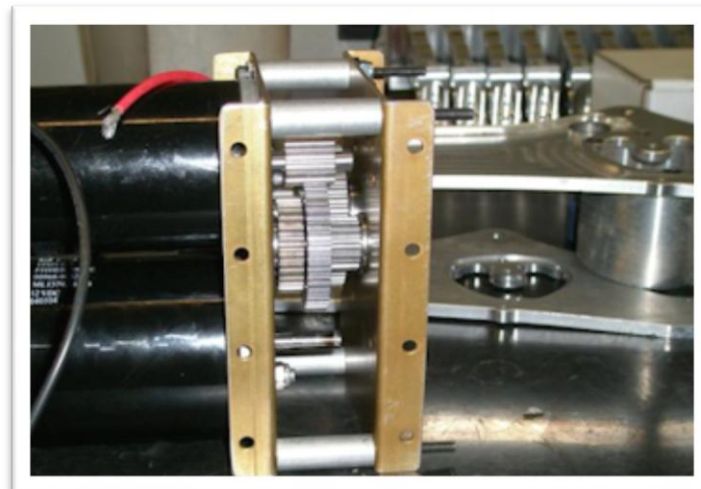
Gearing

- ▶ A simple pair of gearboxes will almost certainly be included in the kit
 - ▶ Very quick to build
 - ▶ May not be as powerful or flexible as other methods
- ▶ DeWalt drill gearboxes
 - ▶ “Nothing But Dewalts” white paper:
<http://www.chiefdelphi.com/media/papers/1592>



Gearing

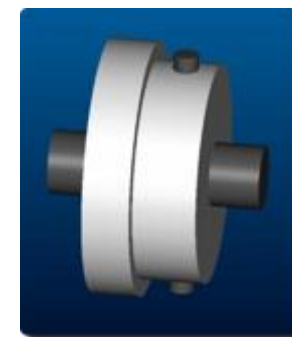
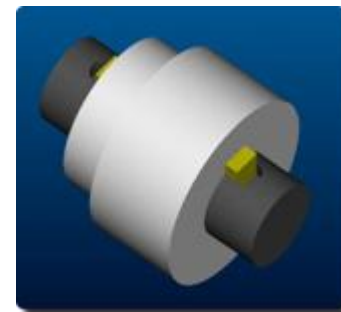
- ▶ AndyMark gearboxes
 - ▶ Designed and built by two extremely experienced FIRST veterans
 - ▶ Two-speed, shift on the fly gearboxes
 - ▶ Adapters available for a variety of motors
 - ▶ www.andymark.biz





Power Transmission

- ▶ Keyways
 - ▶ Strong, hard to machine
- ▶ Pins
 - ▶ Easy to machine, weak
- ▶ Set screws
 - ▶ Can come loose easily; Loctite if using
- ▶ Bolts
 - ▶ Very effective for large gears/sprockets, but annoying when connecting multiple things



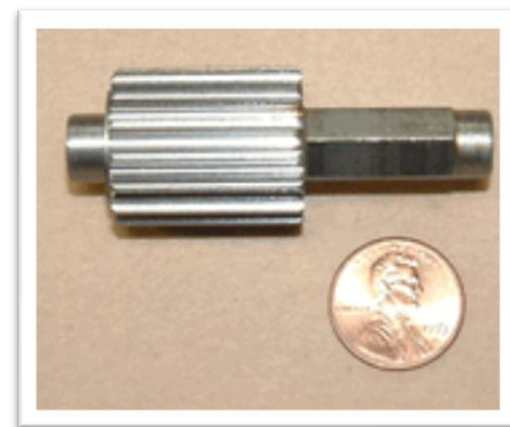
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Power Transmission

- ▶ Hex shafts
 - ▶ Very strong, easy to assemble
 - ▶ Gears, bearings available at www.andymark.biz
 - ▶ Need a hex broach if using other gears/hubs
 - ▶ Can turn down shaft end to fit in bearings



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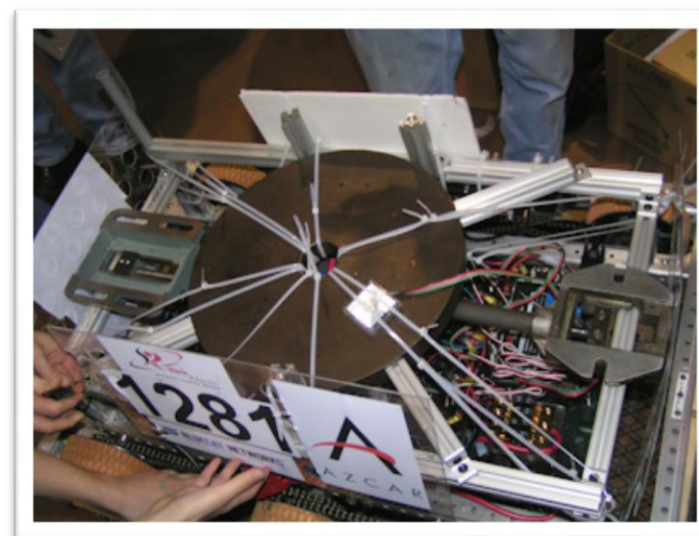
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Traction

- ▶ Often the most important factor in determining pushing force
- ▶ No metal or hard plastic cleats, etc. allowed
- ▶ Supplied wheelchair wheels have quite low traction



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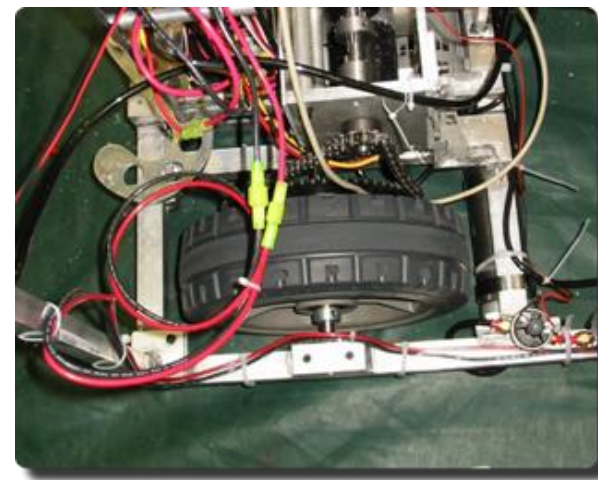
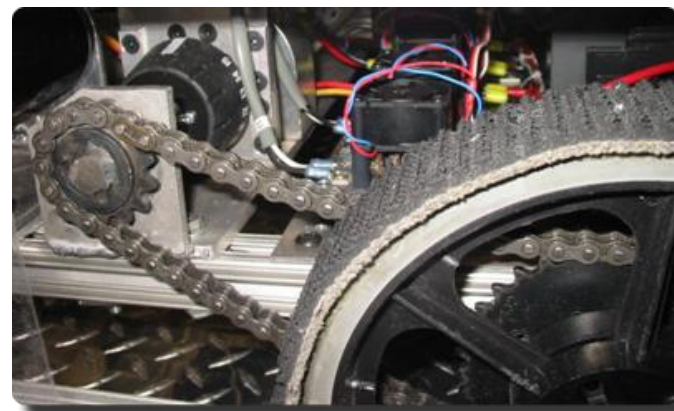
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Traction

- ▶ Rubber treads or conveyor belting attached to wheels
 - ▶ Innovation First supplies pre-made traction wheels
- ▶ Pneumatic wheels
 - ▶ Good for shock absorption
- ▶ Test on actual carpet!
 - ▶ Too much traction can make it too hard to turn



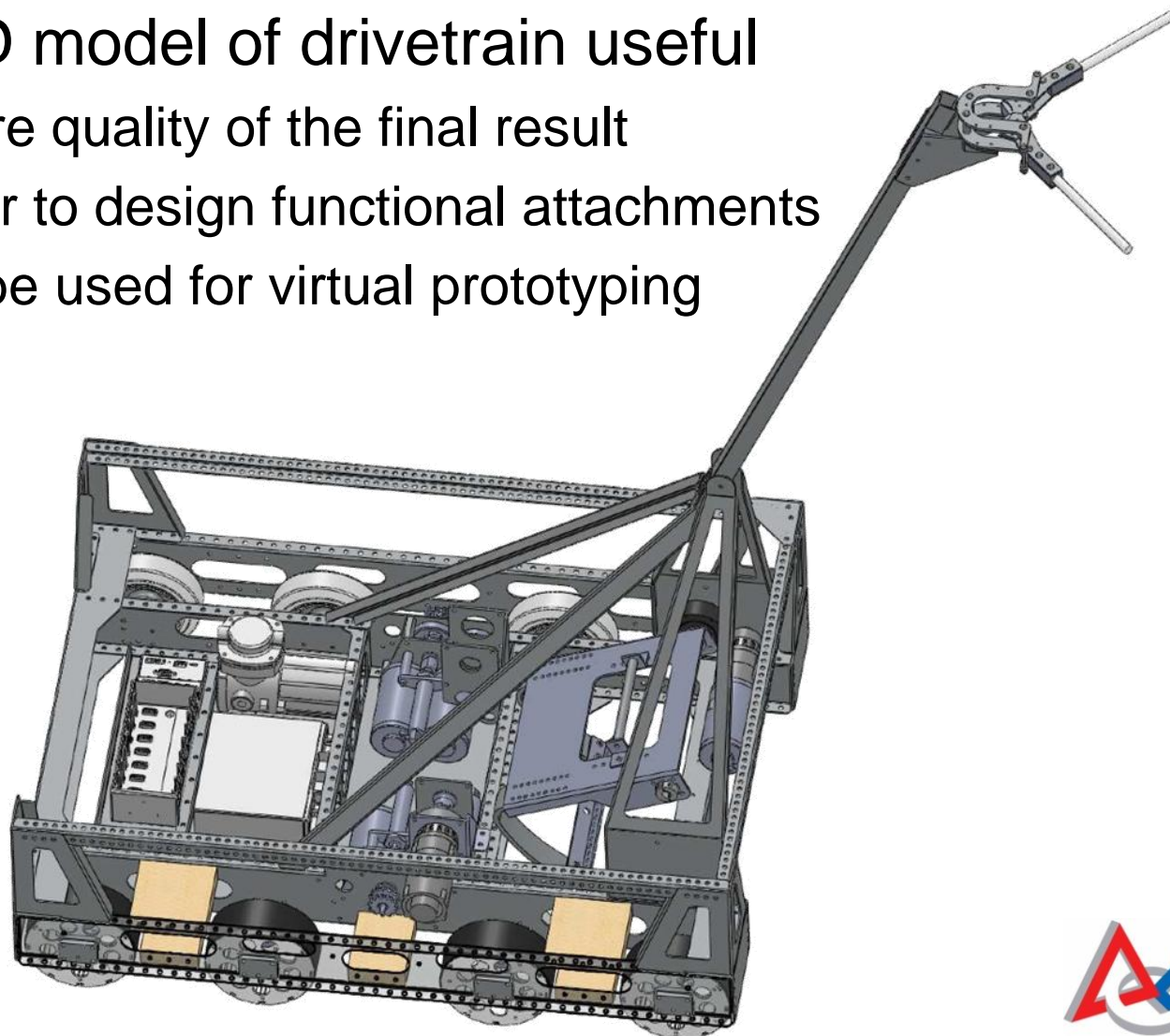
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Computer Aided Design

- ▶ Use sketching tools to design drivetrain layout
- ▶ 3D CAD model of drivetrain useful
 - ▶ Ensure quality of the final result
 - ▶ Easier to design functional attachments
 - ▶ Can be used for virtual prototyping



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Testing and Practicing

- ▶ Test beyond what the robot will likely experience
- ▶ Test many times in different circumstances
- ▶ Reinforce weak areas
- ▶ Tweak components
- ▶ Build spare parts for suspect components



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Resources

- ▶ www.chiefdelphi.com/forums/papers.php
 - ▶ White papers on many topics
- ▶ www.ChiefDelphi.com
 - ▶ Very active and helpful FIRST forums
- ▶ <http://www.vexrobotics.com/products/vexpro>
 - ▶ Traction wheels, Victor speed controllers, other useful components
- ▶ www.Andymark.biz
 - ▶ Gearboxes and other useful components
- ▶ www.Simbotics.org
 - ▶ This and other useful presentations

