FIRST Robotics Drive Systems

Simbotics – October 16th, 2010

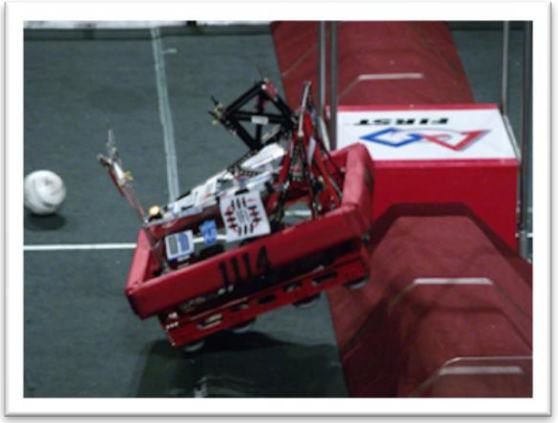
Ian Mackenzie

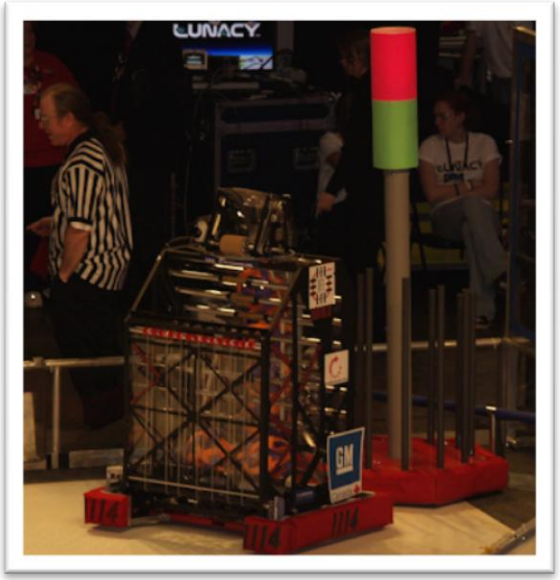
- Involved in the FIRST Robotics competition since 1998
- Student (188, Woburn Robotics), mentor (1114, Simbotics), referee (Waterloo, Toronto, Championship), event organizer (Waterloo)
- Designed HexaDrive in 2002 (one of the earliest six-motor drivetrains) and SimSwerve in 2004 (omnidirectional swerve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

FIRST

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





FIRST

Types

- Two wheels
- Four wheels
- Six wheels
- Omnidirectional

FIRST

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

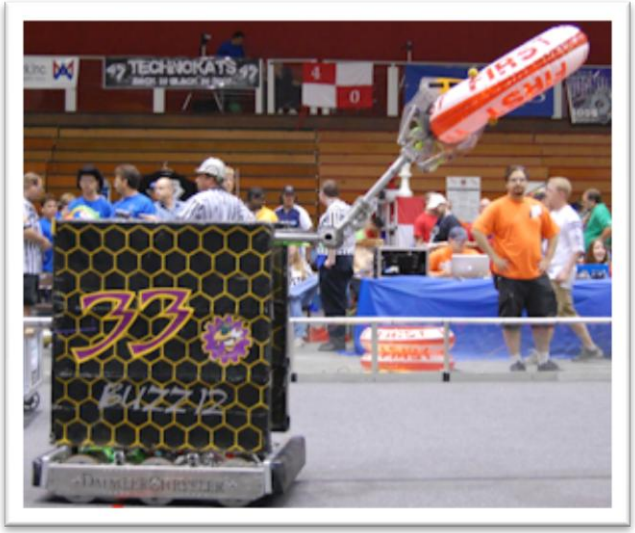
Four Wheels

- 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

FIRST

Six Wheels

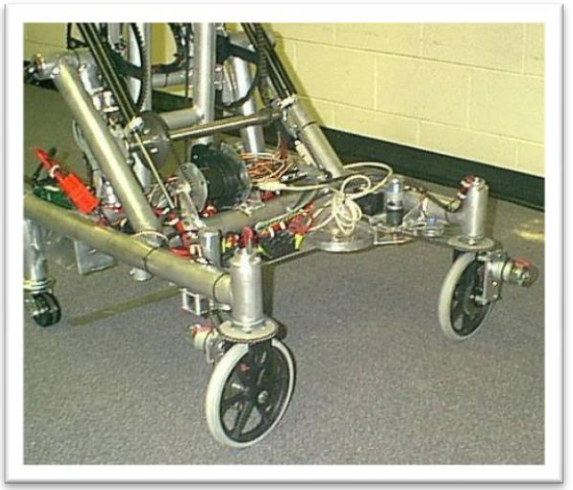
- High traction with better manoeuvrability
- Middle wheels usually lowered 1/8”-3/16” to help with turning
- Slightly trickier to deliver power to all wheels
  - Multiple chains or multiple gearboxes



FIRST

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!



FIRST

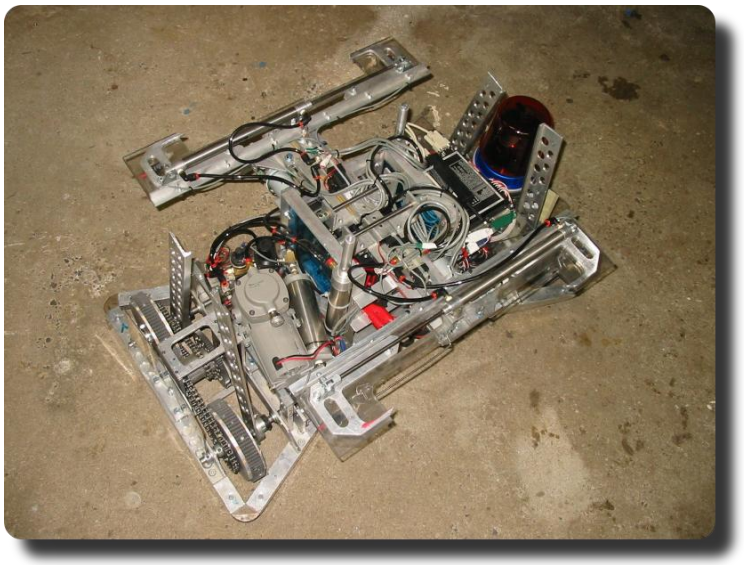
Design Principles

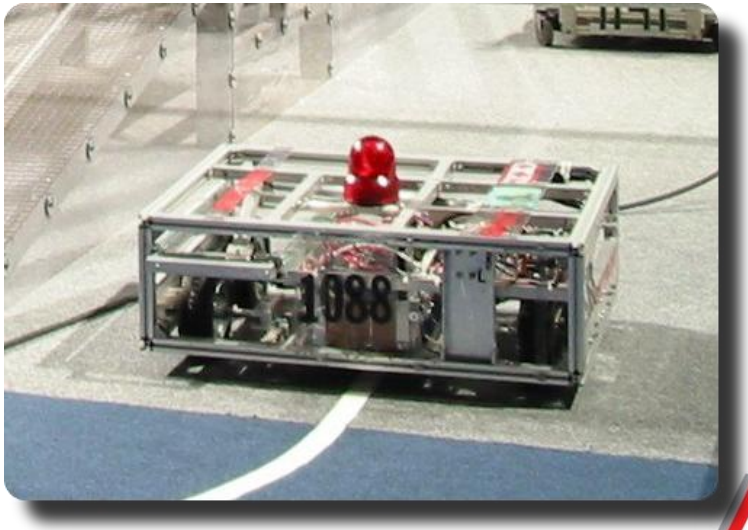
- Simplicity
- Durability
- Weight distribution
- Miscellaneous

FIRST

Simplicity

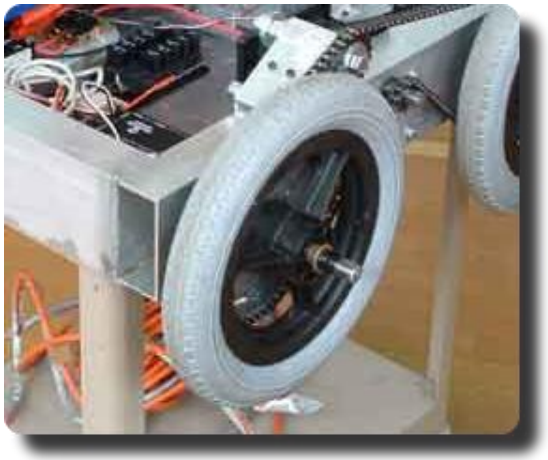
- Fewer things to fail
- Easier and faster to build and repair
- Lighter
- More durable
- More elegant

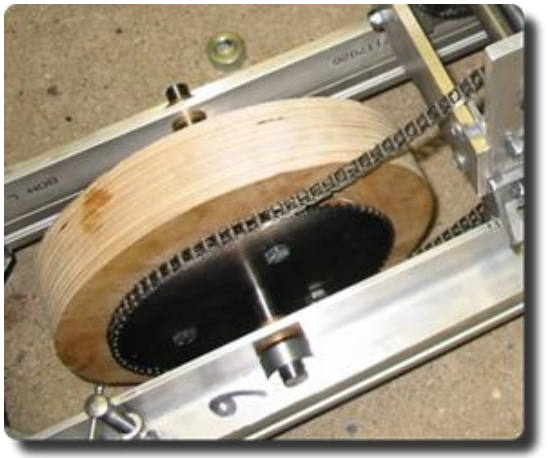




Durability

- 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

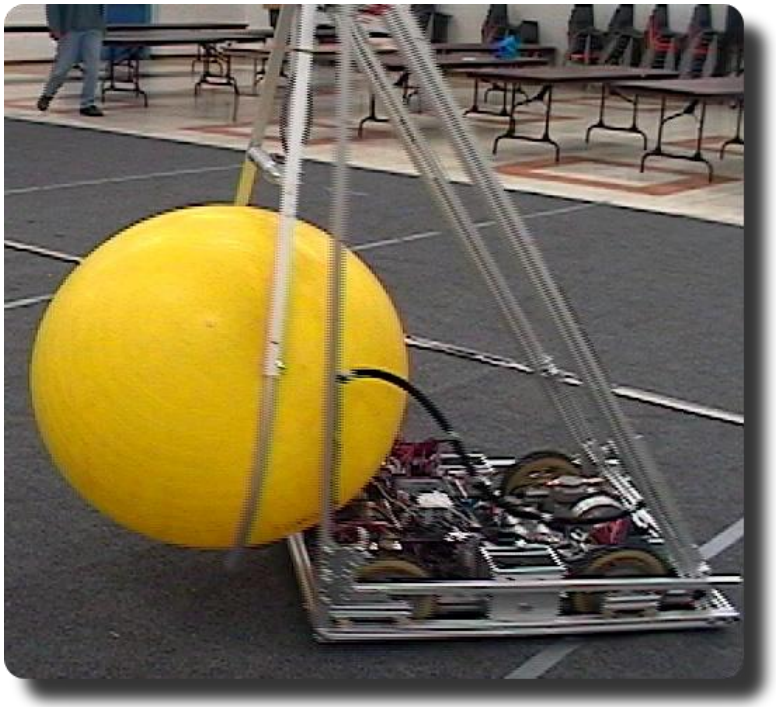




FIRST

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!



FIRST

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

FIRST

Design Process

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

FIRST

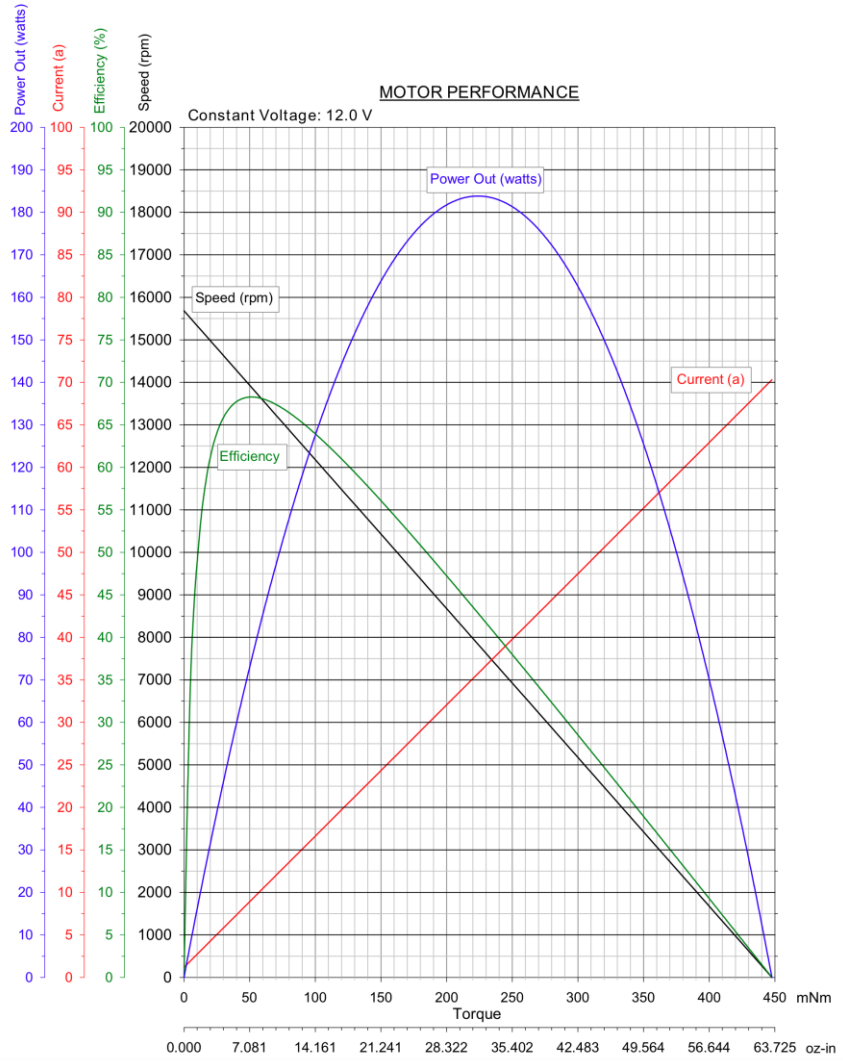
Guidelines

- 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

FIRST

Motor Curves

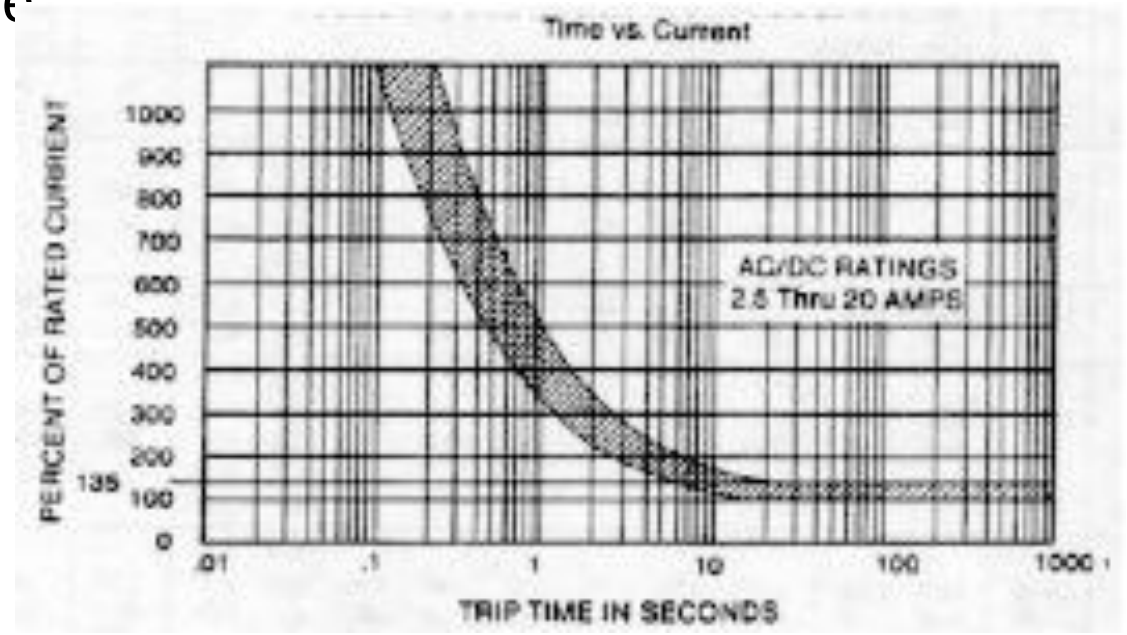
- Very valuable source for designing mobility systems
- Usually torque on x-axis, all other variables on y-axis



FIRST

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



FIRST

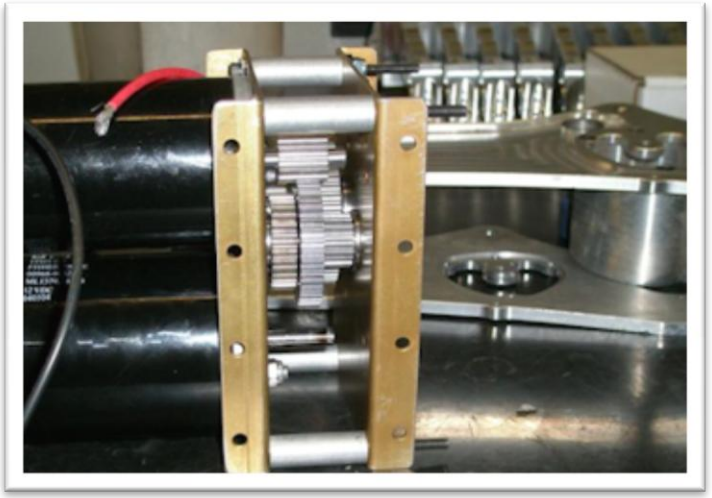
Gearing

- 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

FIRST

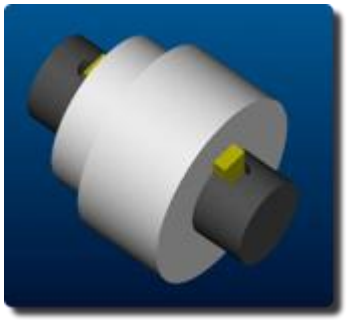
Gearing

- 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

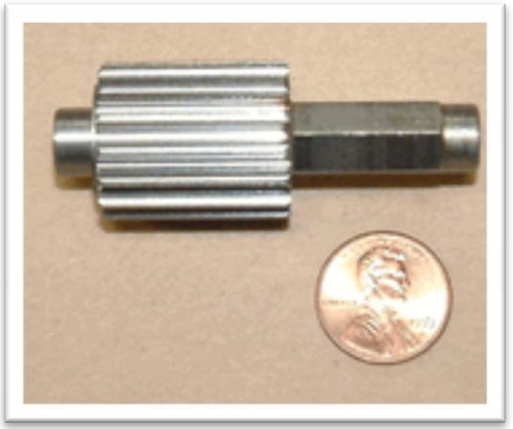
- Keyways
  - Strong, hard to machine
- Pins
  - Easy to machine, weak
- Set screws
  - Can come loose easily; Loctite if using
- Bolts
  - Very effective for large gears/sprockets, but annoying when connecting multiple things



FIRST

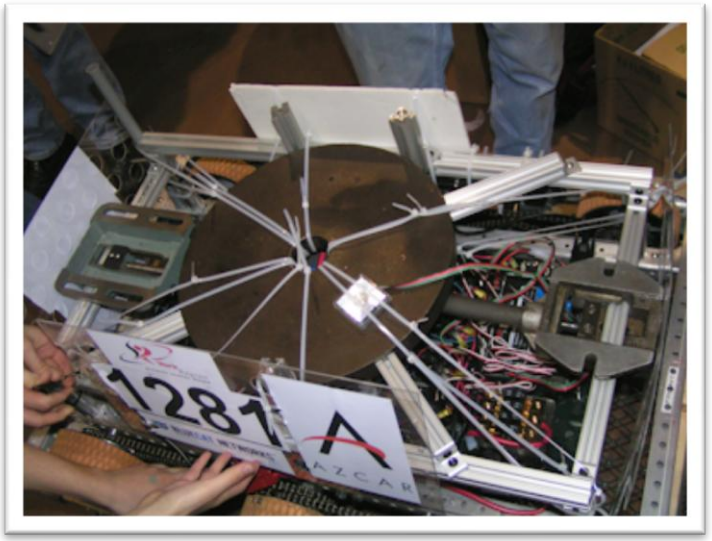
Power Transmission

- 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



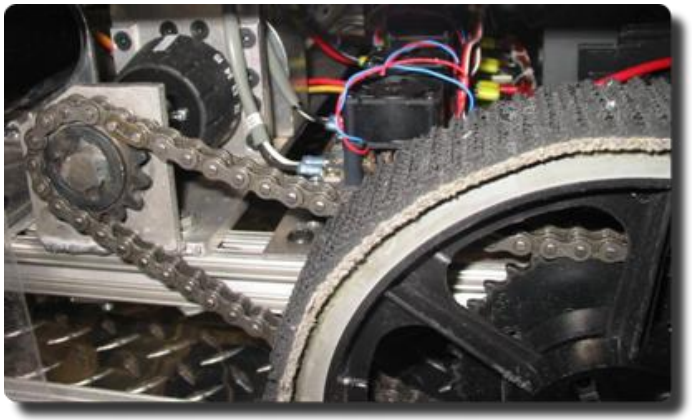
Traction

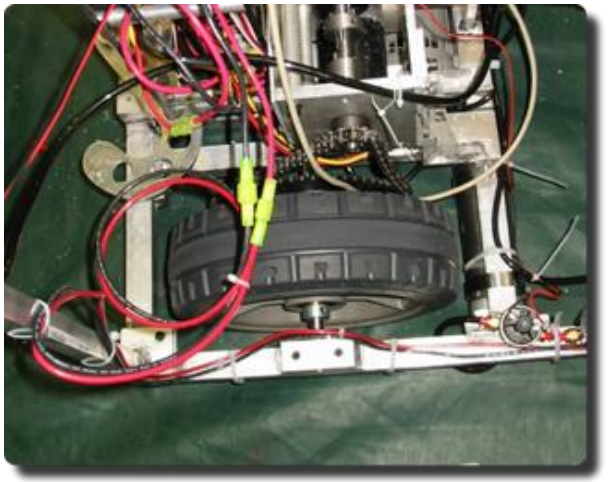
- Often the most important factor in determining pushing force
- No metal or hard plastic cleats, etc. allowed
- Supplied wheelchair wheels have quite low traction



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

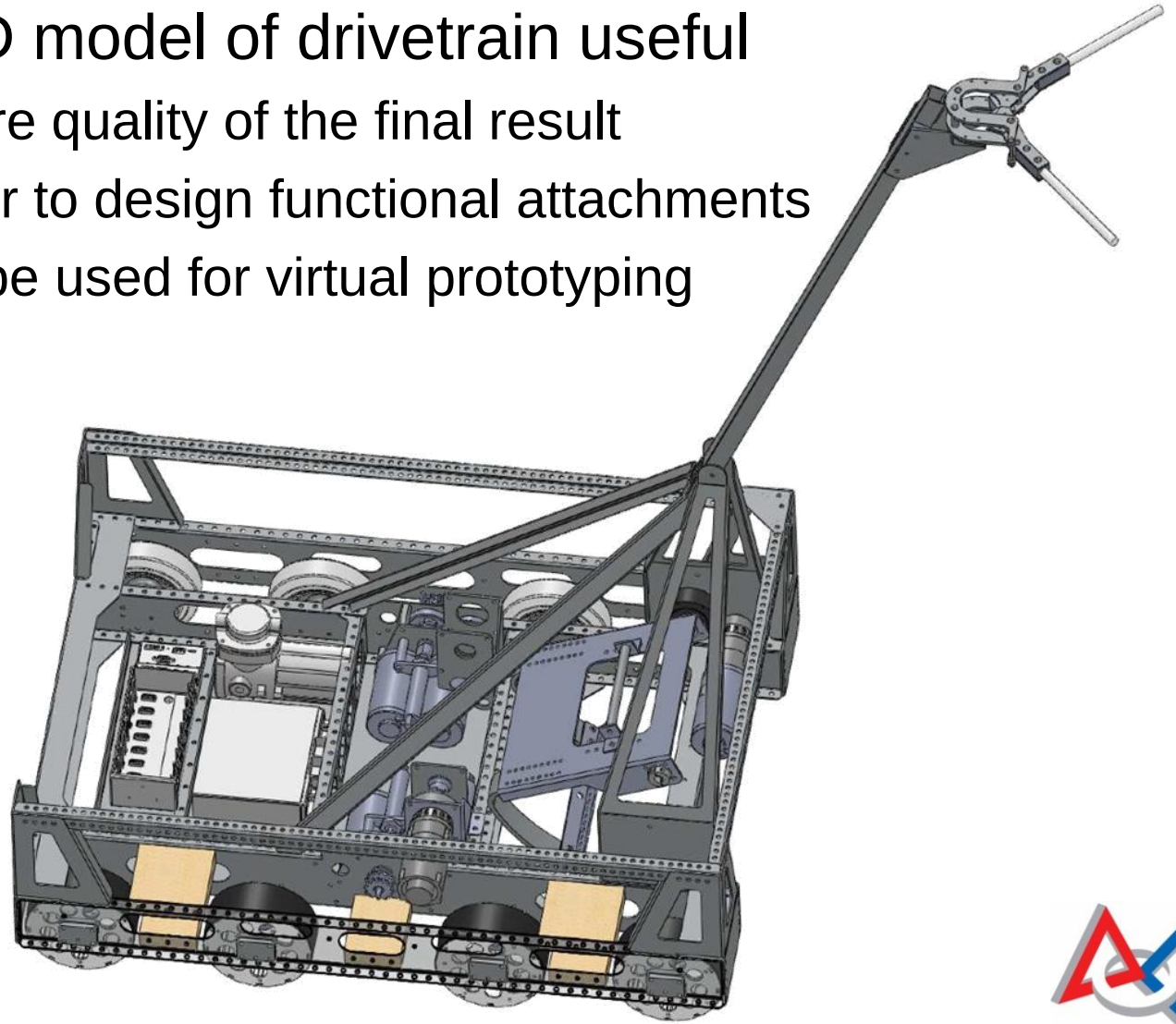




FIRST

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



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

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

FIRST