Manipulators Design in *FIRST* Robotics

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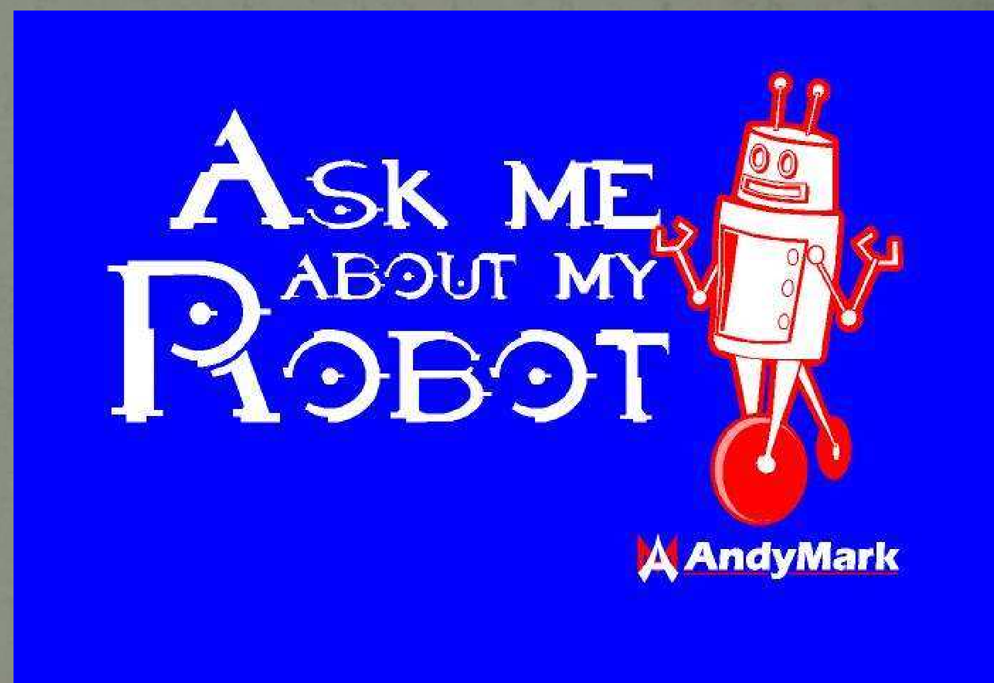
2003 Championship Woodie Flowers Award

Types of Manipulators

- Articulating Arms
- Telescoping Lifts
- Grippers
- Latches
- Turrets
- Ball Handling Systems
- Shooters
- Winches



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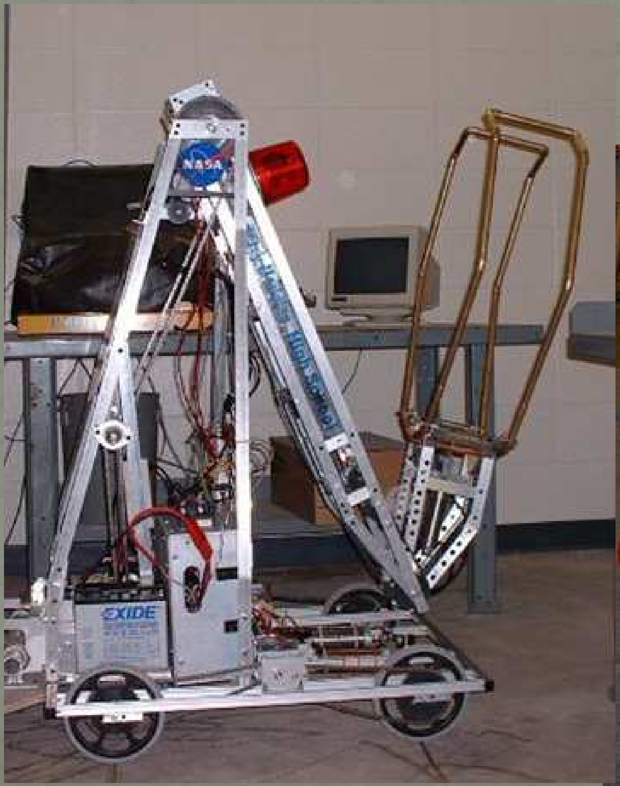
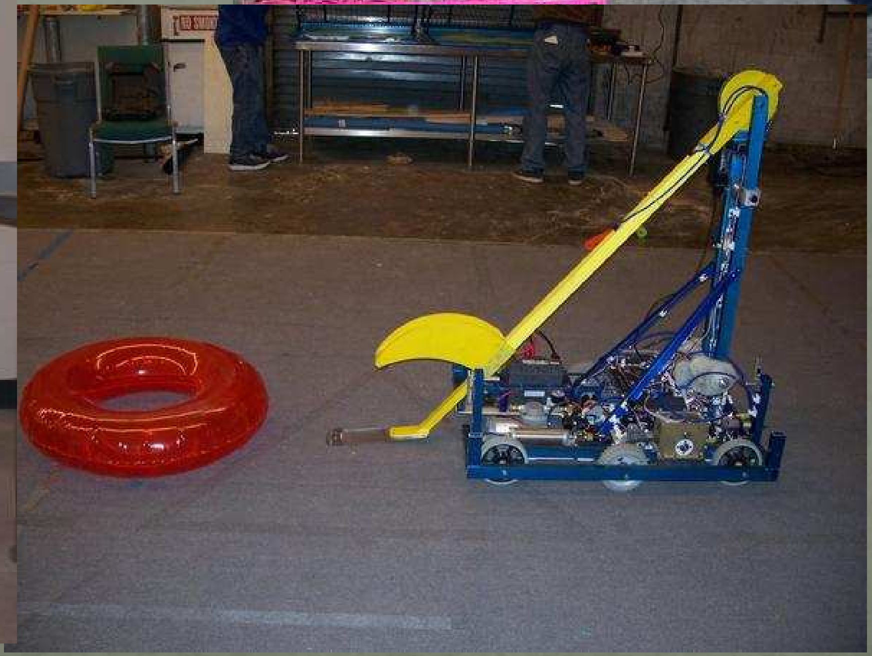
Articulating Arms

- Shoulder
- Elbow
- Wrist

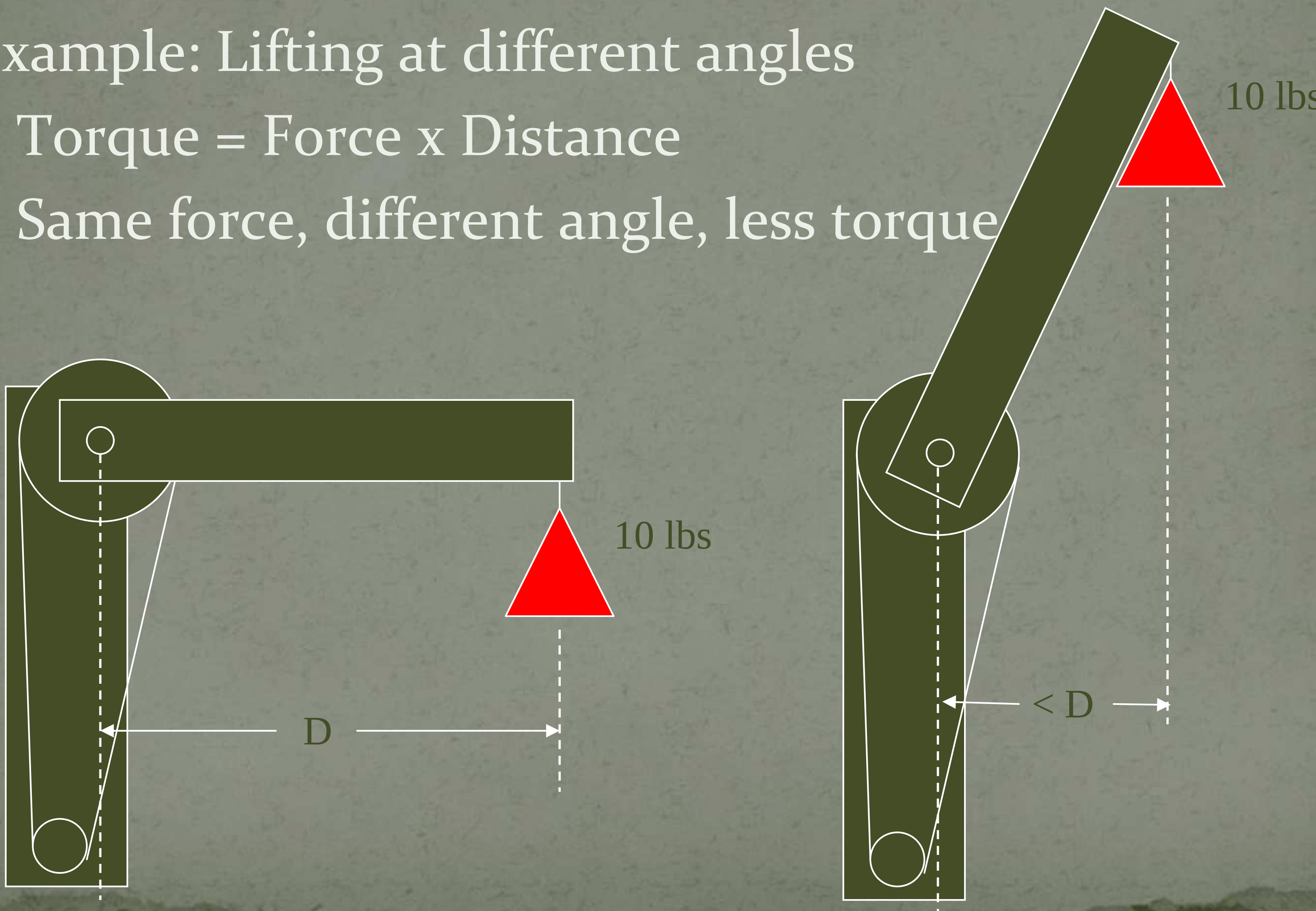




Arm: Forces, Angles & Torque

Example: Lifting at different angles

- Torque = Force x Distance
- Same force, different angle, less torque

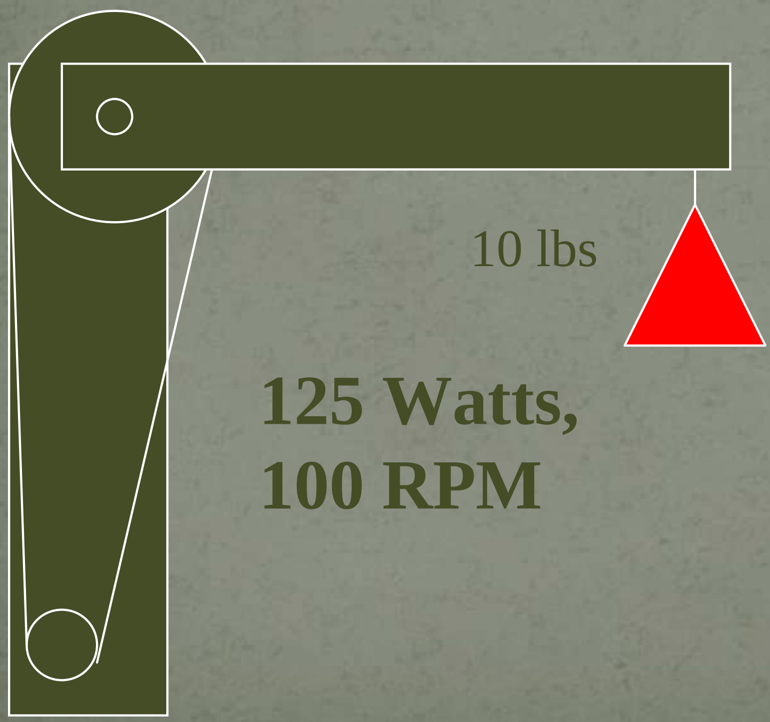


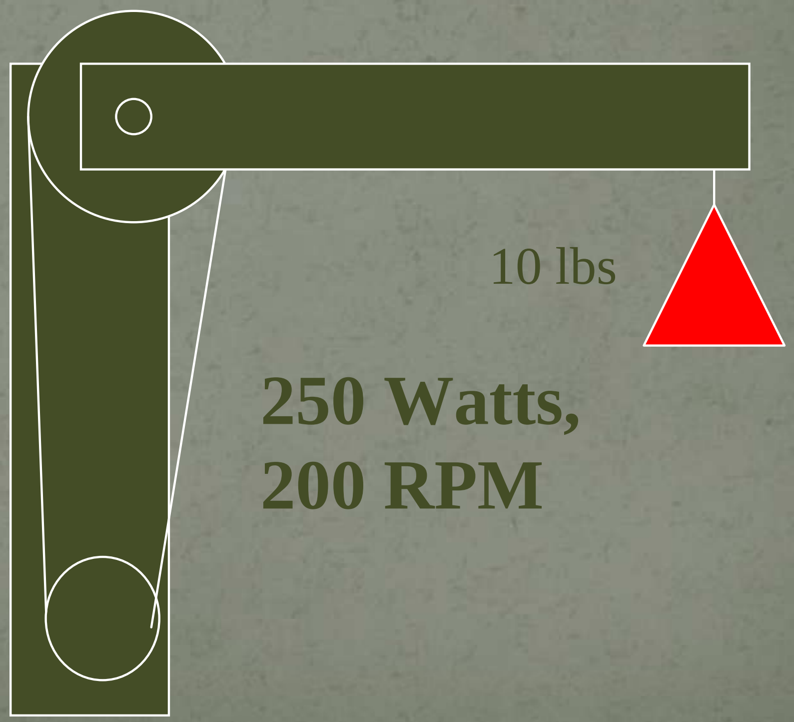
Power

- Power = Torque/ Time
  OR
- Power = Torque x Rotational Velocity
- Power (FIRST definition) – how fast you can move something

Arm: Power Example

- Same torque w/ Twice the Power results in Twice the Speed
- Power = Torque/ Time



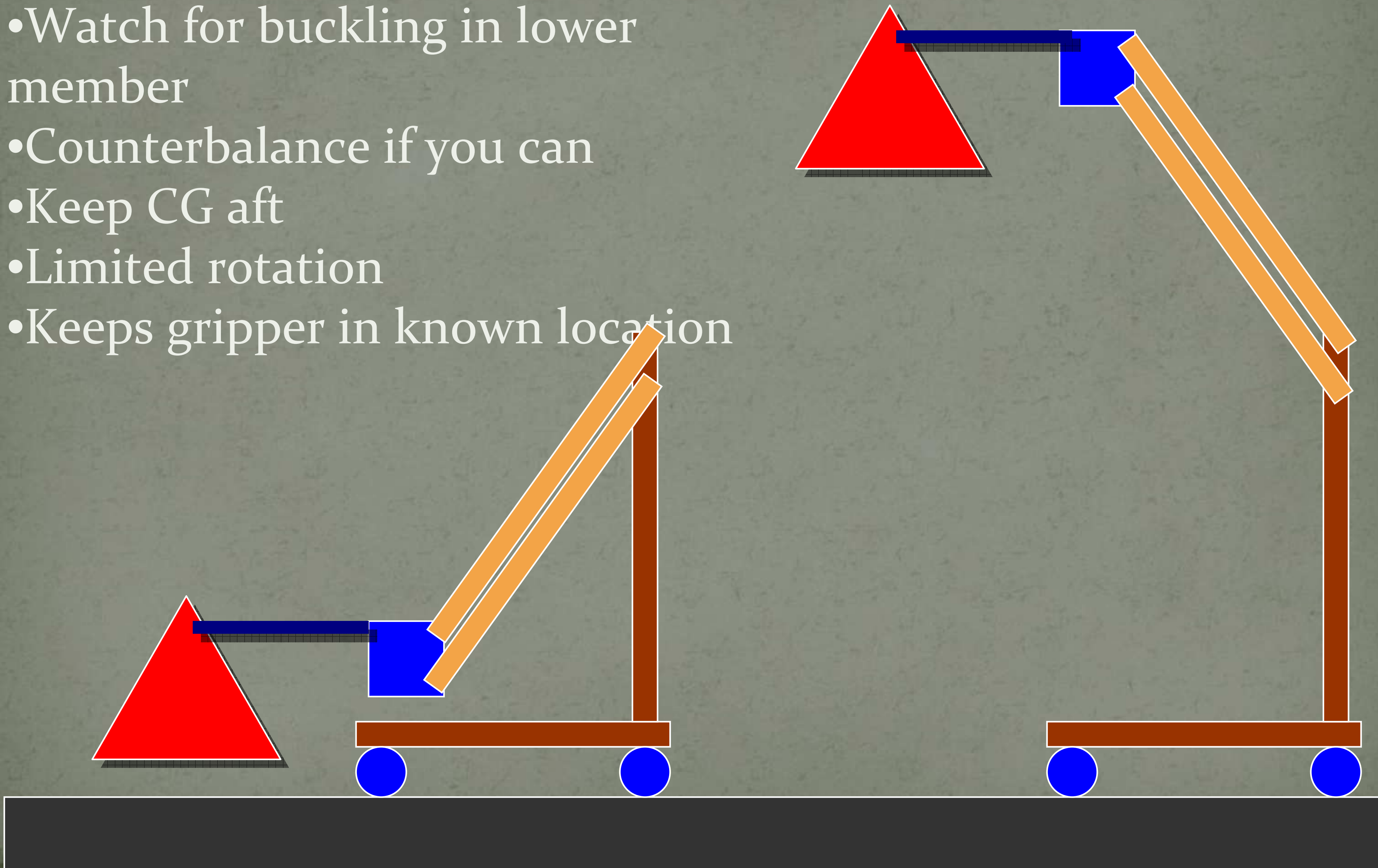


Arm: Design Tips

- Lightweight Materials: tubes, thin wall sheet
- Design-in sensors for feedback & control
  - limit switches and potentiometers
- Linkages help control long arms
- KISS
  - Less parts… to build or break
  - Easier to operate
  - More robust
- Use off-the-shelf items
- Counterbalance
  - Spring, weight, pneumatic, etc.

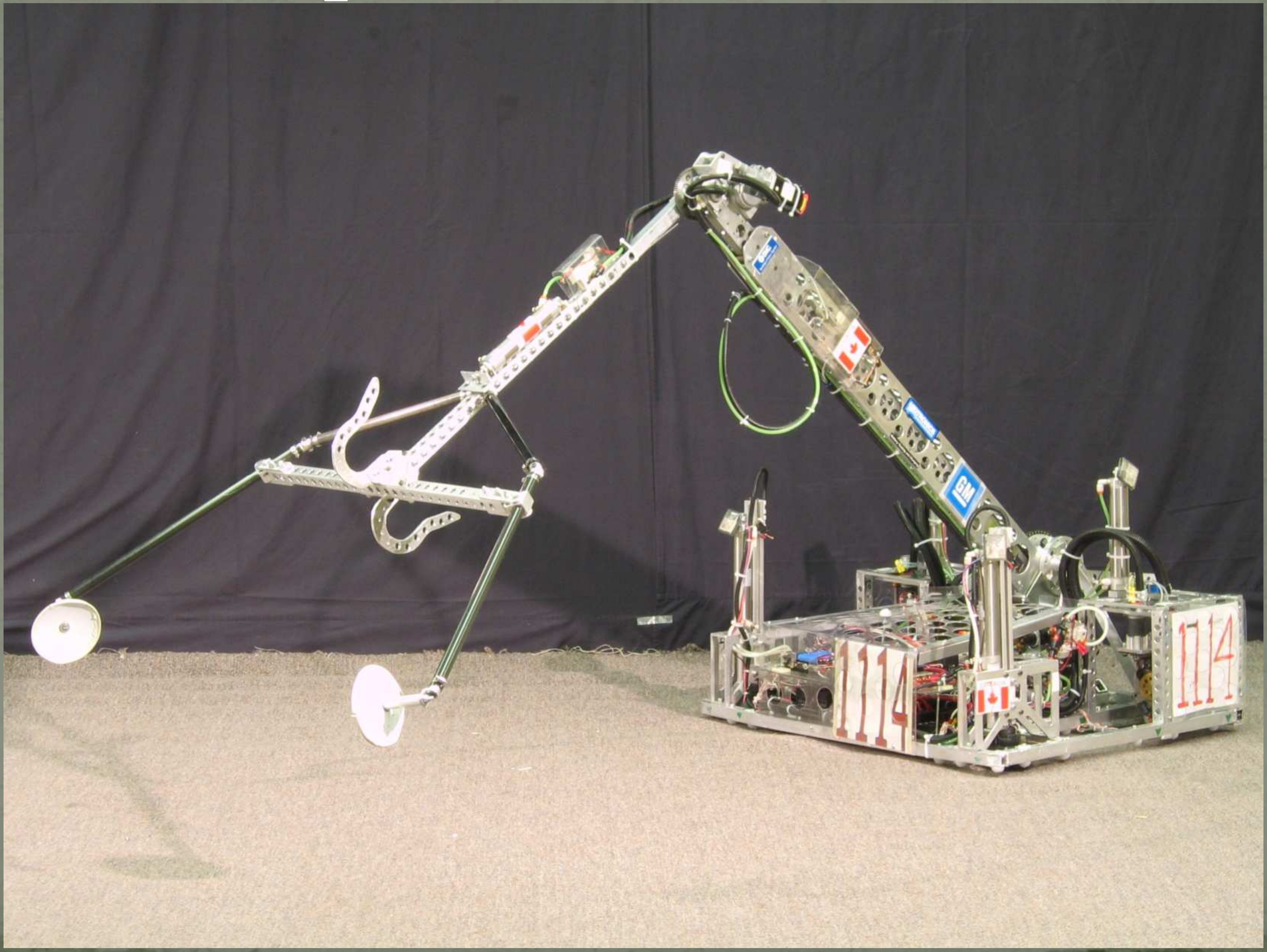
Four Bar Linkage

- Pin loadings can be very high
- Watch for buckling in lower member
- Counterbalance if you can
- Keep CG aft
- Limited rotation
- Keeps gripper in known location



4 bar linkage example: 340 & 217 in 2007

Arm Example: 1114 in 2004



Telescoping Lifts

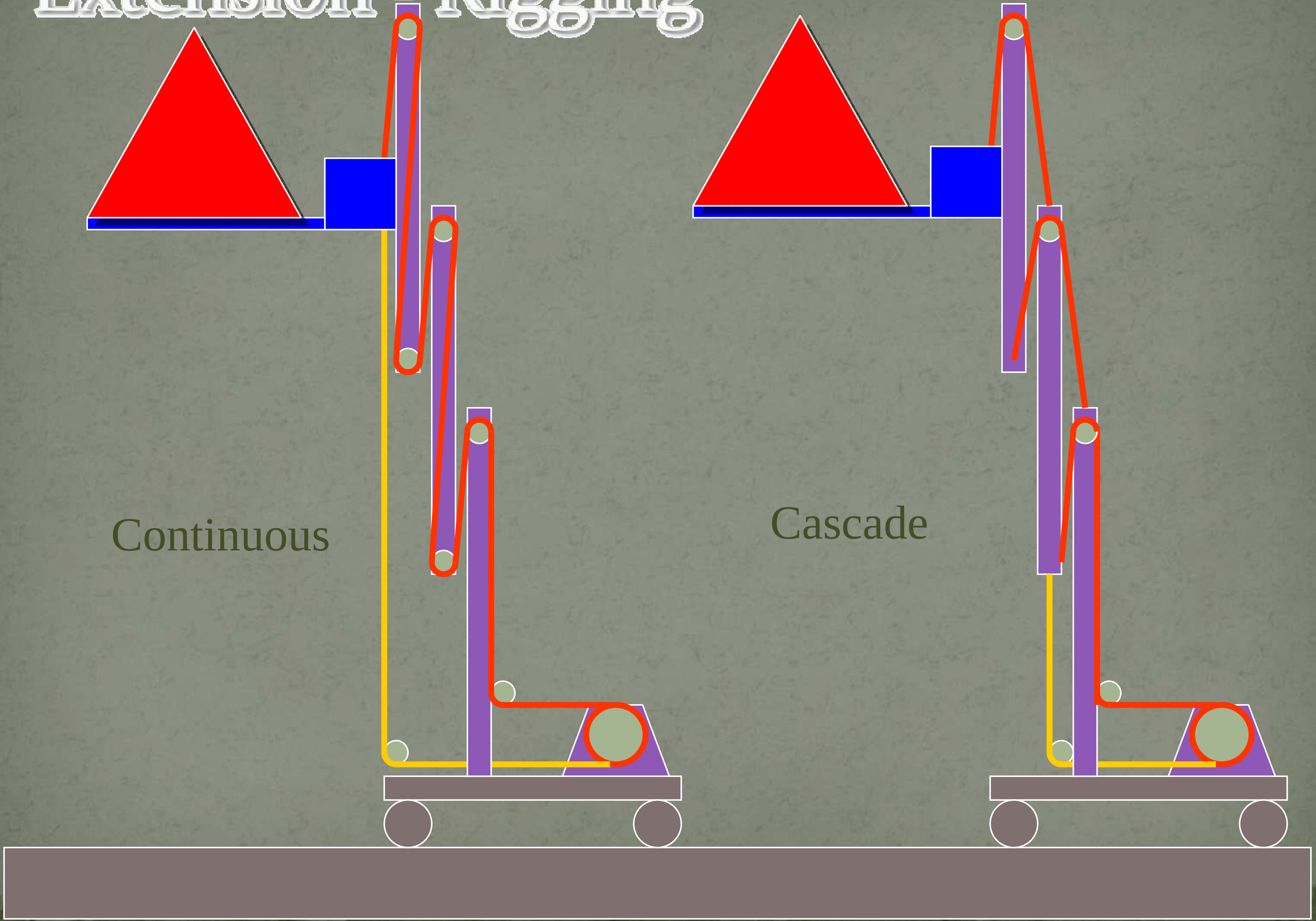
- Extension Lift
  - Motion achieved by stacked members sliding on each other
- Scissor Lift
  - Motion achieved by “unfolding” crossed members

Extension Lift Considerations

- Drive cables up AND down, or add a cable recoil device
- Segments must move freely
- Cable lengths must be adjustable
- Minimize slop and free-play
- Maximize segment overlap
  - 20% minimum
  - more for bottom, less for top
- Stiffness and strength are needed
- Heavy system, overlapping parts
- Minimize weight,
  especially at the top

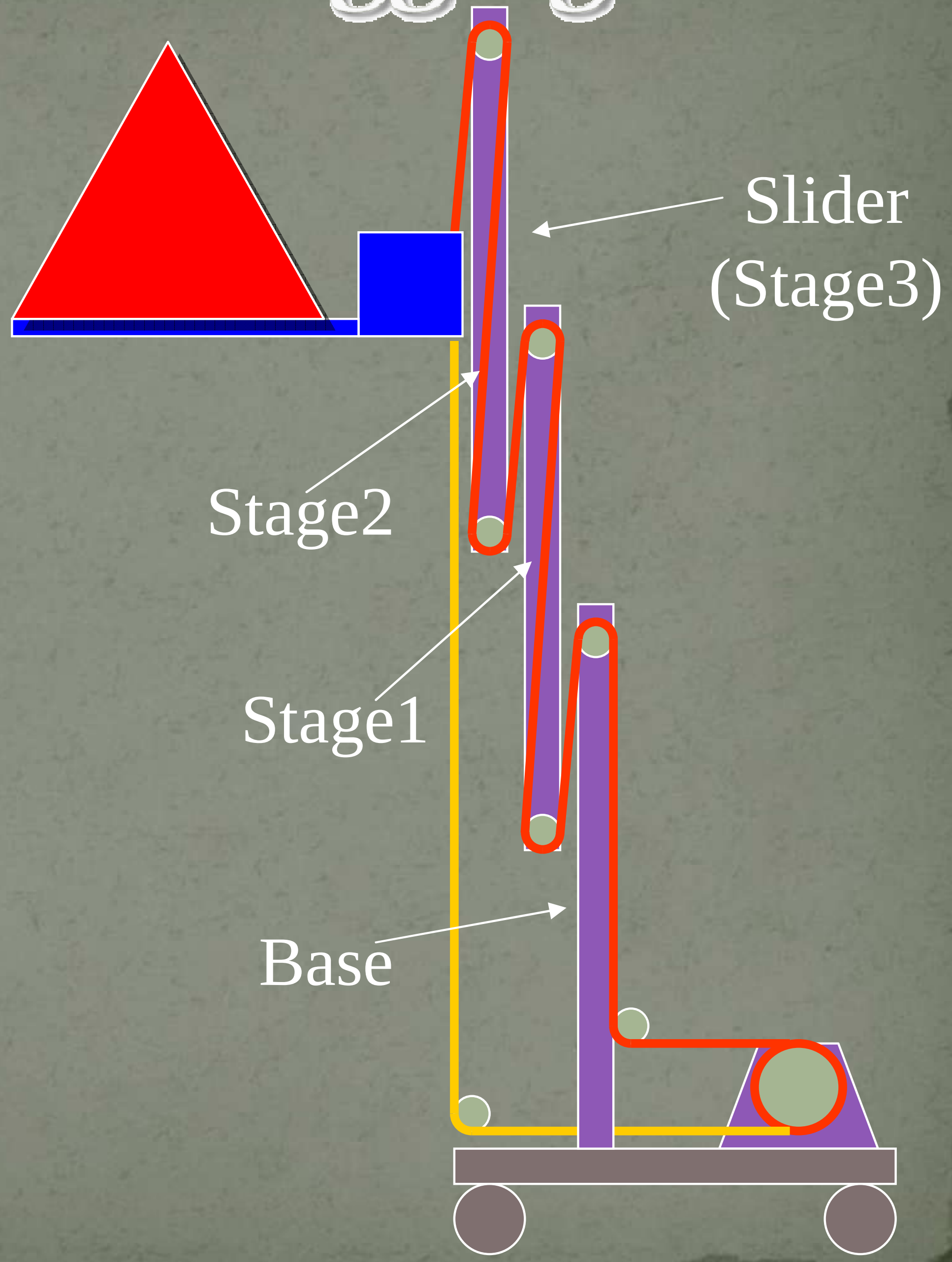
Pink Team 233 - 2008

Extension - Rigging



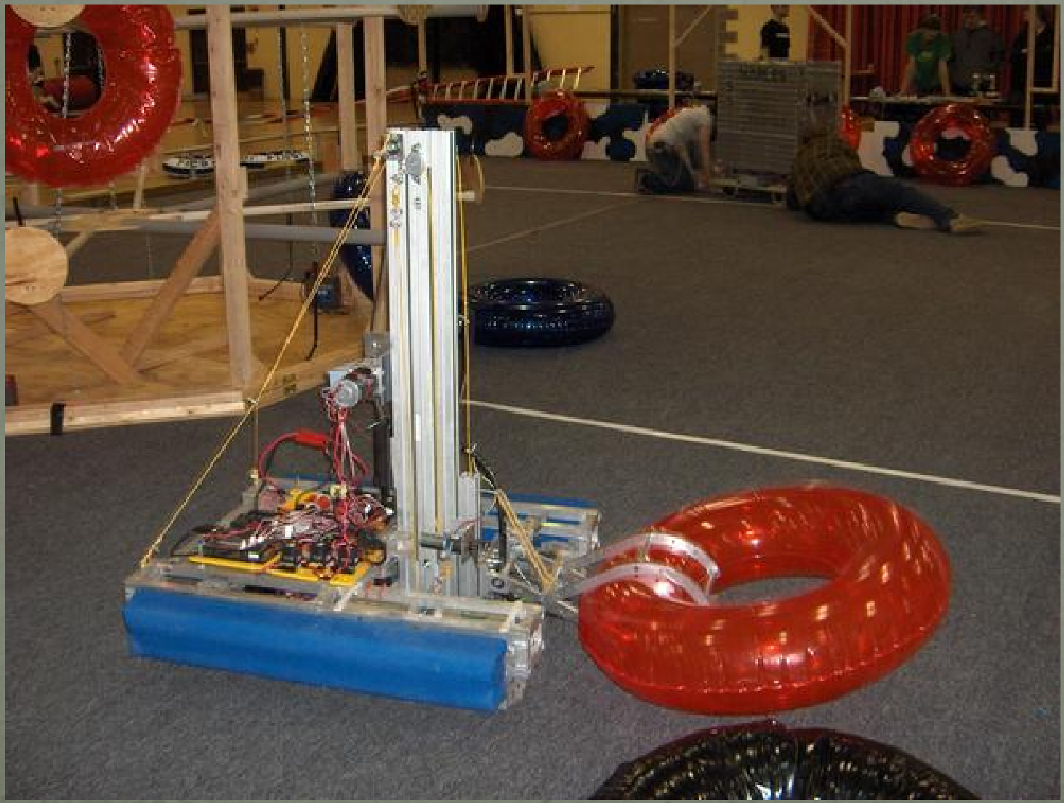
Extension: Continuous Rigging

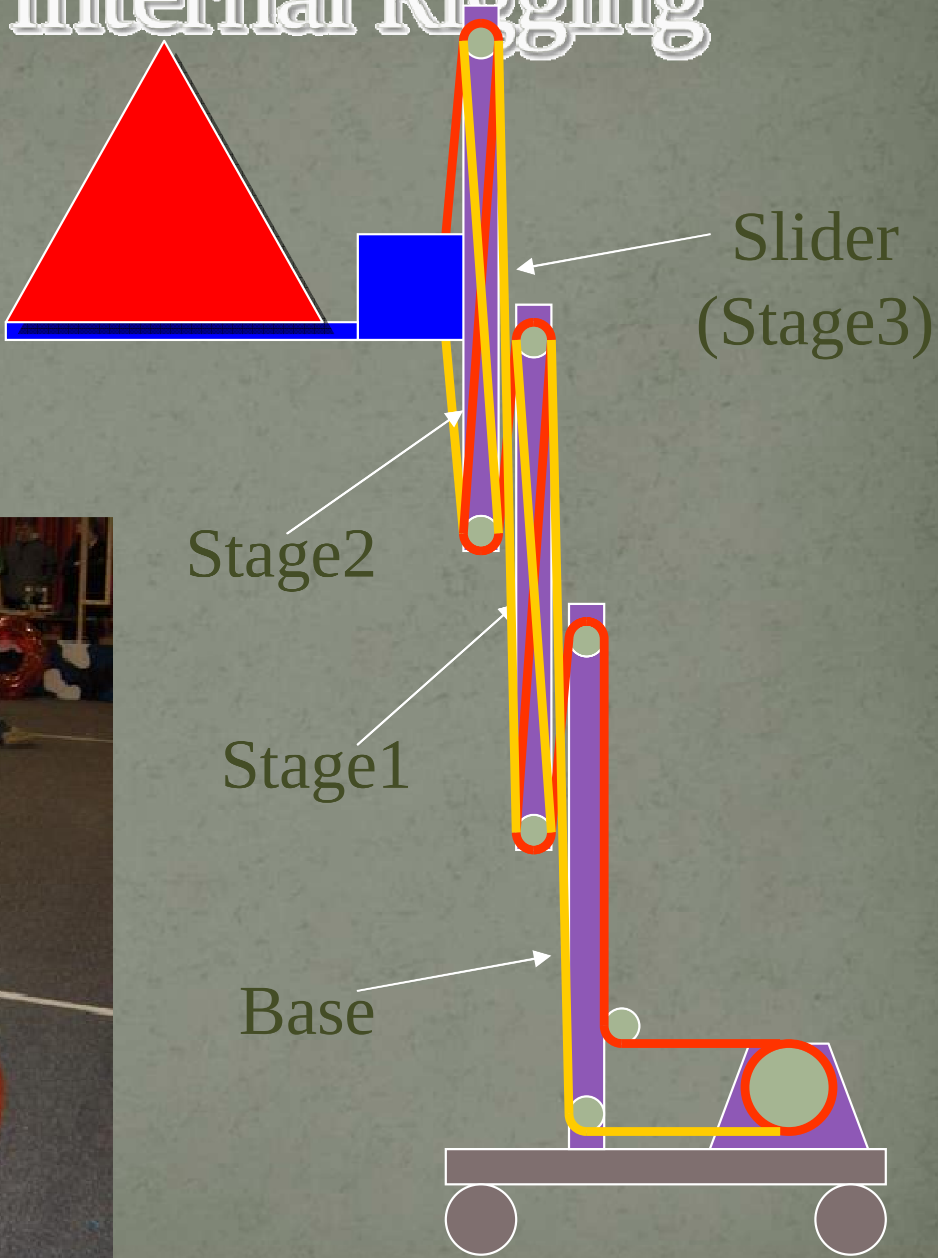
- Cable Goes Same Speed for Up and Down
- Intermediate Sections sometimes Jam
- Low Cable Tension
- More complex cable routing
- The final stage moves up first and down last



Extension: Continuous Internal Rigging

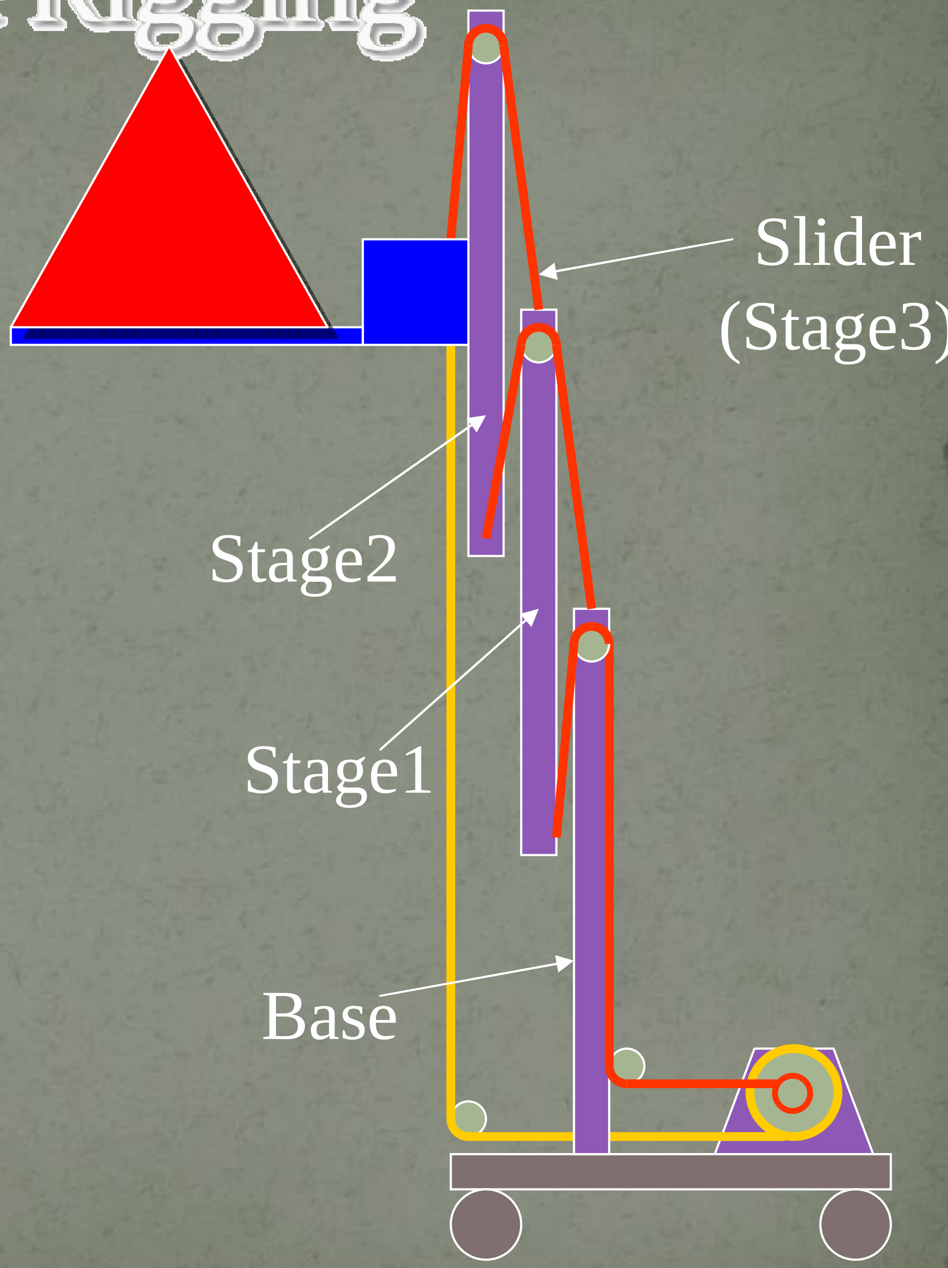
- Even More complex cable routing
- Cleaner and protected cables





Extension: Cascade Rigging

- Up-going and Down-going Cables Have Different Speeds
- Different Cable Speeds Can be Handled with Different Drum Diameters or Multiple Pulleys
- Intermediate Sections Don't Jam
- Much More Tension on the lower stage cables
  - Needs lower gearing to deal with higher forces



Scissor Lifts

- Advantages
  - Minimum retracted height - can go under field barriers
- Disadvantages
  - Tends to be heavy to be stable enough
  - Doesn't deal well with side loads
  - Must be built very precisely
  - Stability decreases as height increases
  - Loads very high to raise at beginning of travel

- **I recommend you stay away from this!**

Arm vs. Lift

Feature	Arm	Lift
Reach over object	Yes	No
Fall over, get up	Yes, if strong enough	No
Go under barriers	Yes, fold down	Maybe, limits lift height
Center of gravity (Cg)	Not centralized	Centralized mass
Small space operation	No, needs swing room	Yes
How high?	More articulations, more height (difficult)	More lift sections, more height (easier)
Complexity	Moderate	High
Powerful lift	Moderate	High
Combination	Insert 1-stage lift at bottom of arm	←

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Braking: Prevent Back-driving

- Ratchet Device - completely lock in one direction in discrete increments - such as used in many winches
- Clutch Bearing - completely lock in one direction
- Brake pads - simple device that squeezes on a rotating device to stop motion - can lock in both directions
  - Disc brakes - like those on your car
  - Gear brakes - applied to lowest torque gear in gearbox
- Dynamic Breaking in electrical components let go when power is lost
- Any gearbox that cannot be back-driven alone is probably very inefficient

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Power

- Summary
  - All motors can lift the same amount (assuming 100% power transfer efficiencies) - they just do it at different rates
- No power transfer mechanisms are 100% efficient
  - Inefficiencies (friction losses, binding, etc.)
  - Design in a Safety Factor (2x, 4x)

Grippers

Gripper (FIRST definition):

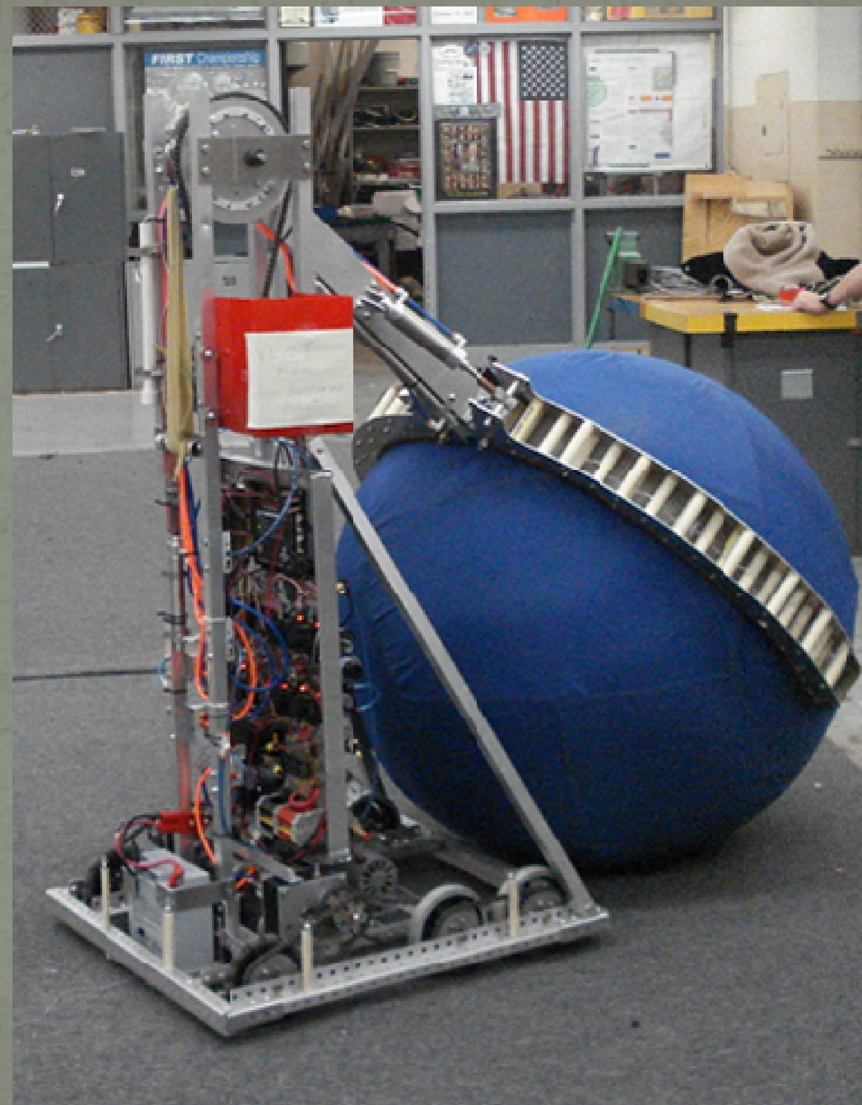
- Device that grabs a game object

- How to grip
- How to hang on
- Speed
- Control

254 in 2008

How to grip

- Pneumatic linkage grip
  - 1 axis
  - 2 axis
- Motorized grip
- Roller grip
- Hoop grip
- Pneumatic grip



768 in 2008

Pneumatic linear grip

- Pneumatic Cylinder extends & retracts linkage to open and close gripper
- Easy to manufacture
- Easy to control
- Quick grab
- Limited grip force
- Requires pneumatic system

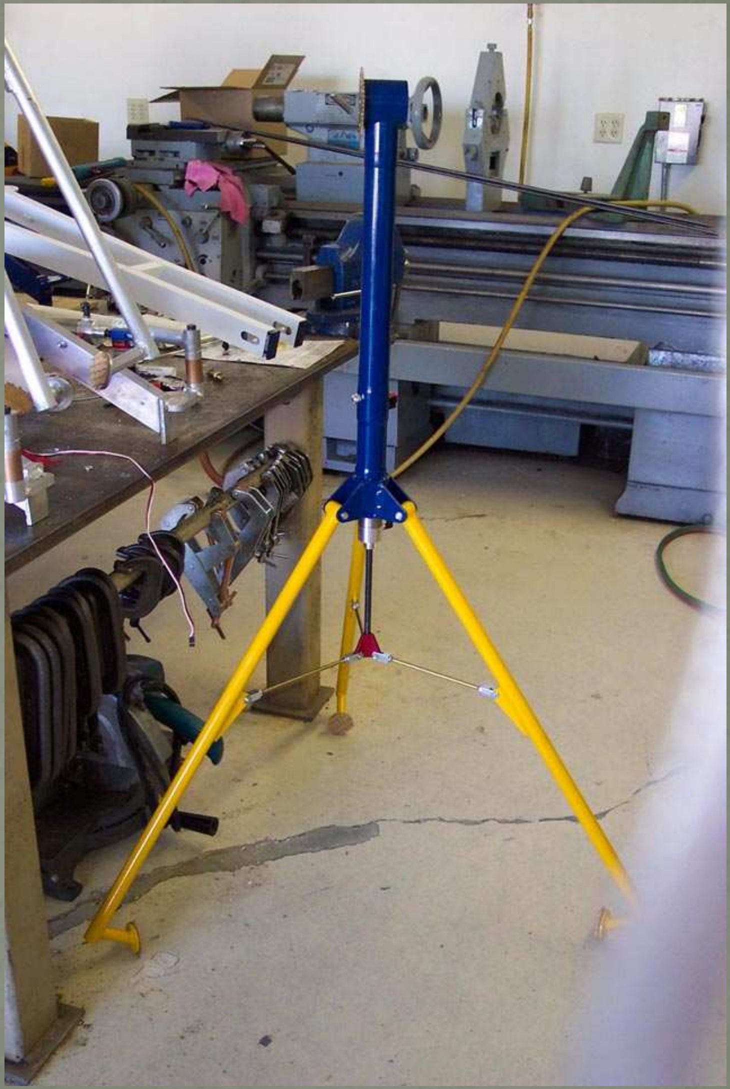
Recommended

968 in 2004

Pneumatic linear grip

- Pneumatic Cylinder, pulling 3 fingers for a 2-axis grip

Recommended



60 in 2004

Motorized Linear Grip

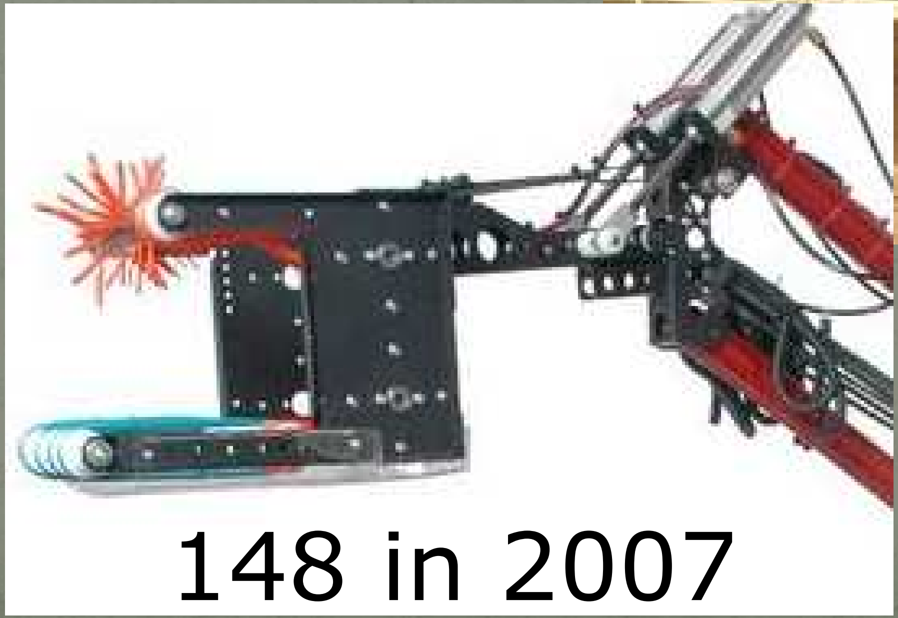
- Slow
- More complex (gearing)
- Heavier
- Tunable force
- No pneumatics

49 in 2001

Roller Grip

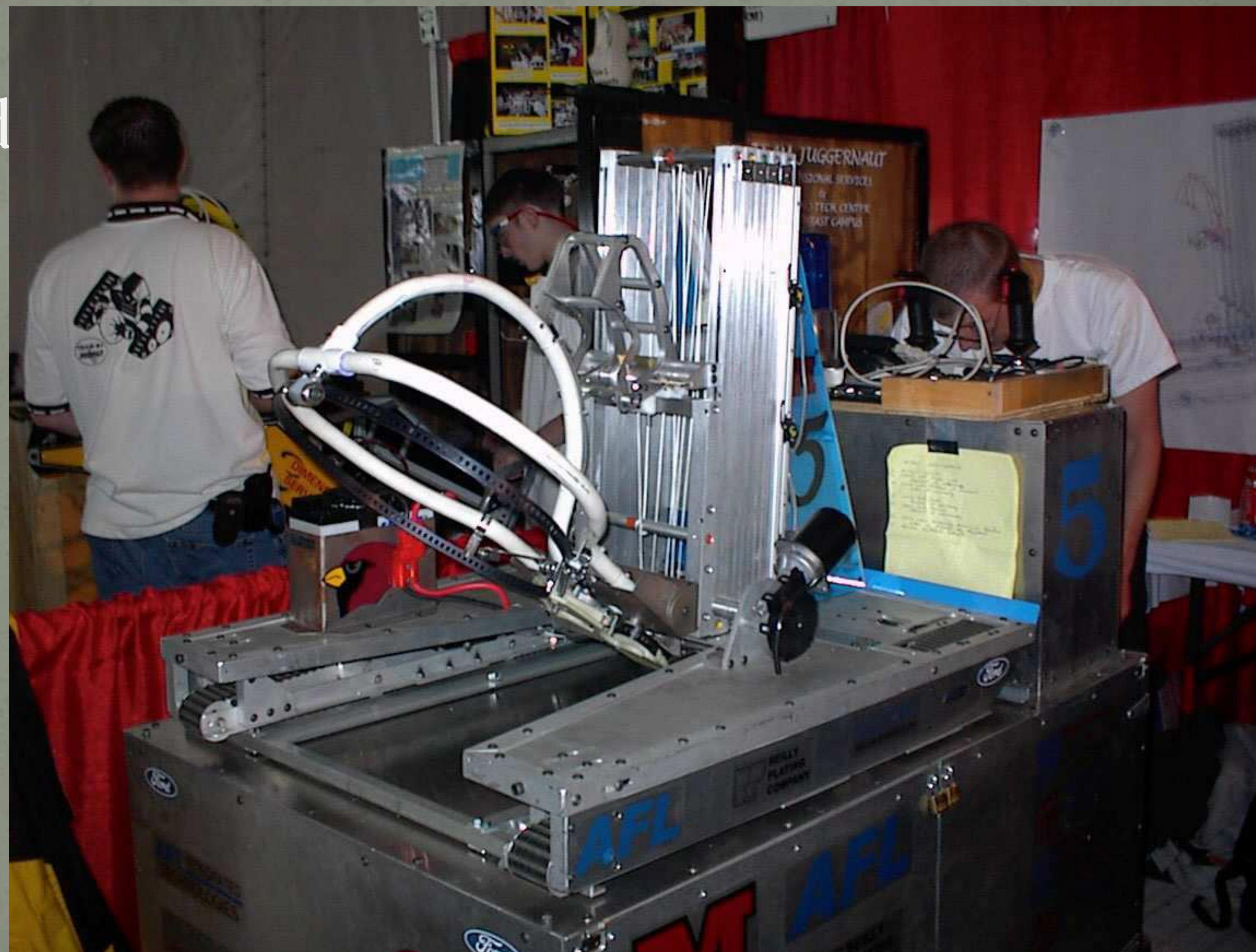
- Allows for misalignment when grabbing
- Won't let go
- Extends object as releasing
- Simple mechanism
- Have a "full in" sensor
- Slow

Recommended

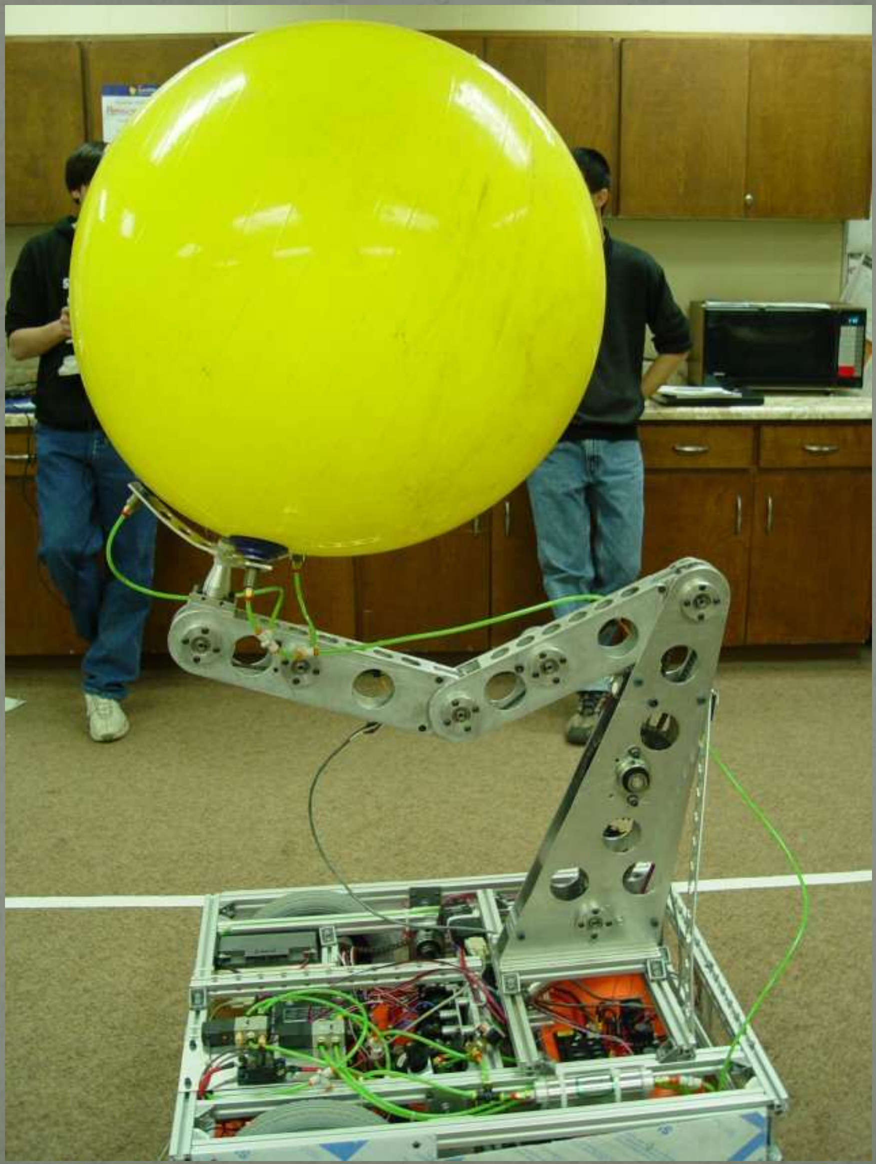


Hoop grip

- Slow
- Needs aligned
- Can’t hold on well



Pneumatic Grip



- Needs vacuum generator
- Uses various cups to grab
- Slow
- Not secure
- Not easy to control
- Simple
- Problematic

Not recommended

Hang on!

- High friction is needed
  - over 1.0 mu
  - Rubber, neoprene, silicone, sandpaper
  - … but don’t damage game object
- Force: Highest at grip point
  - Force = multiple x object weight (2-4x)
  - Use linkages and toggles for mechanical advantage
- Extra axis of grip = More control

Speed

- Quickness covers mistakes
  - Quick to grab
  - Drop & re-grab
- Fast
  - Pneumatic gripper
- Not fast
  - Roller, motor gripper, vacuum

Gripper Design Advice

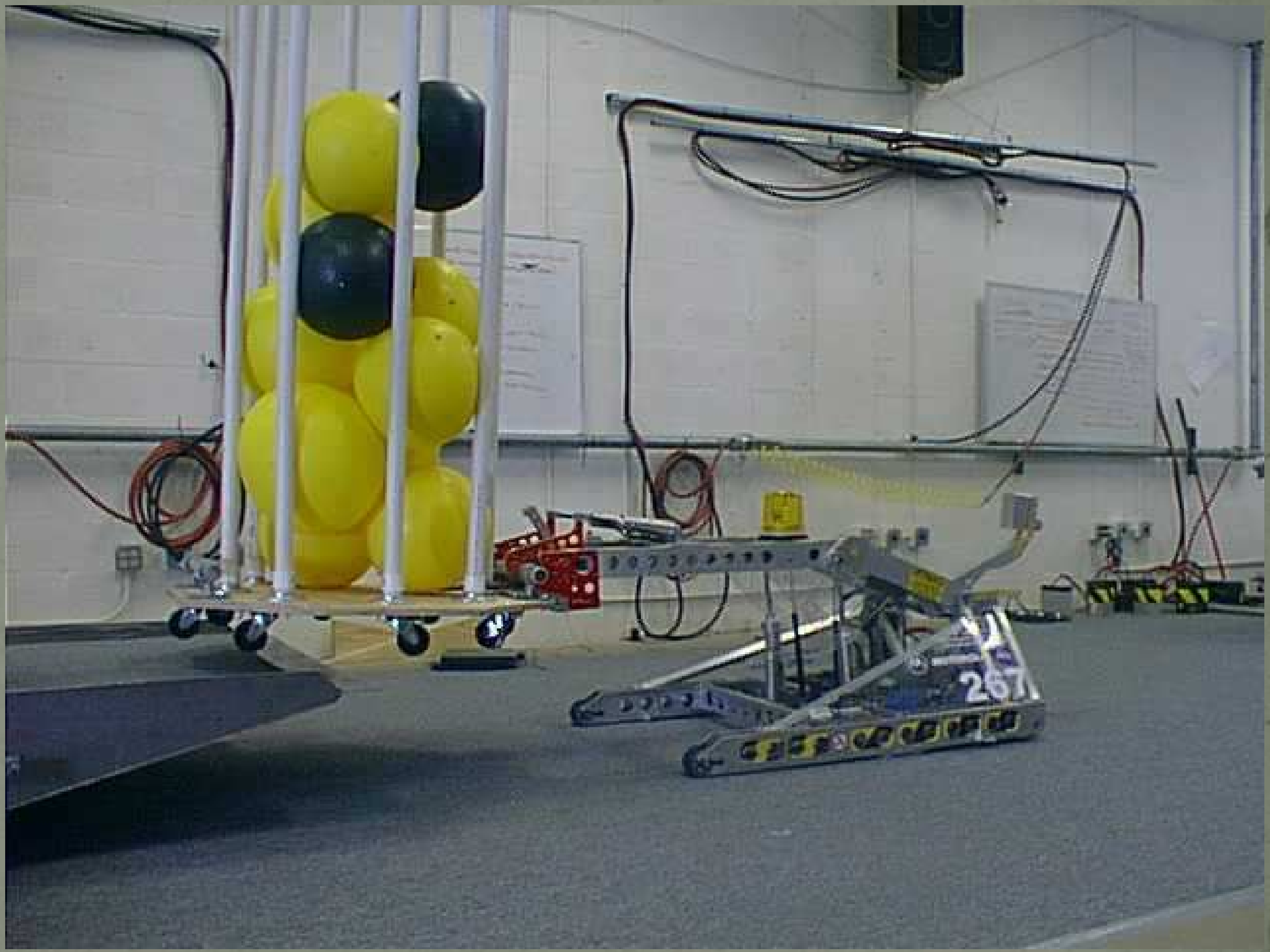
- Get object fast
- Hang on
- Let go quickly
- Make this easy to control
  - Limit switches
  - Auto-functions
  - Ease of operation

Latches

- Hooking and latching devices used to grab goals, bars, and other non-scoring objects
- Spring latches
- Hooks / spears
- Speed & Control

Latch example

- Pneumatic latch, solidly grabs pipe
- 2001 game
- No “smart mechanism”



Latch example: 469

- Spring-loaded latch
- Motorized release
- Smart Mechanism
- 2003

Latch Example: 118

- Spring-loaded latch
- Pneumatic release
- Smart mechanism
- 2002

Latching Advice

- Don't depend on operator to latch, use a smart mechanism
  - Spring loaded (preferred)
  - Sensor met and automatic command given
- Have a secure latch
- Use an operated mechanism to let go
- Be able to let go quickly
  - Pneumatic lever
  - Motorized winch, pulling a string

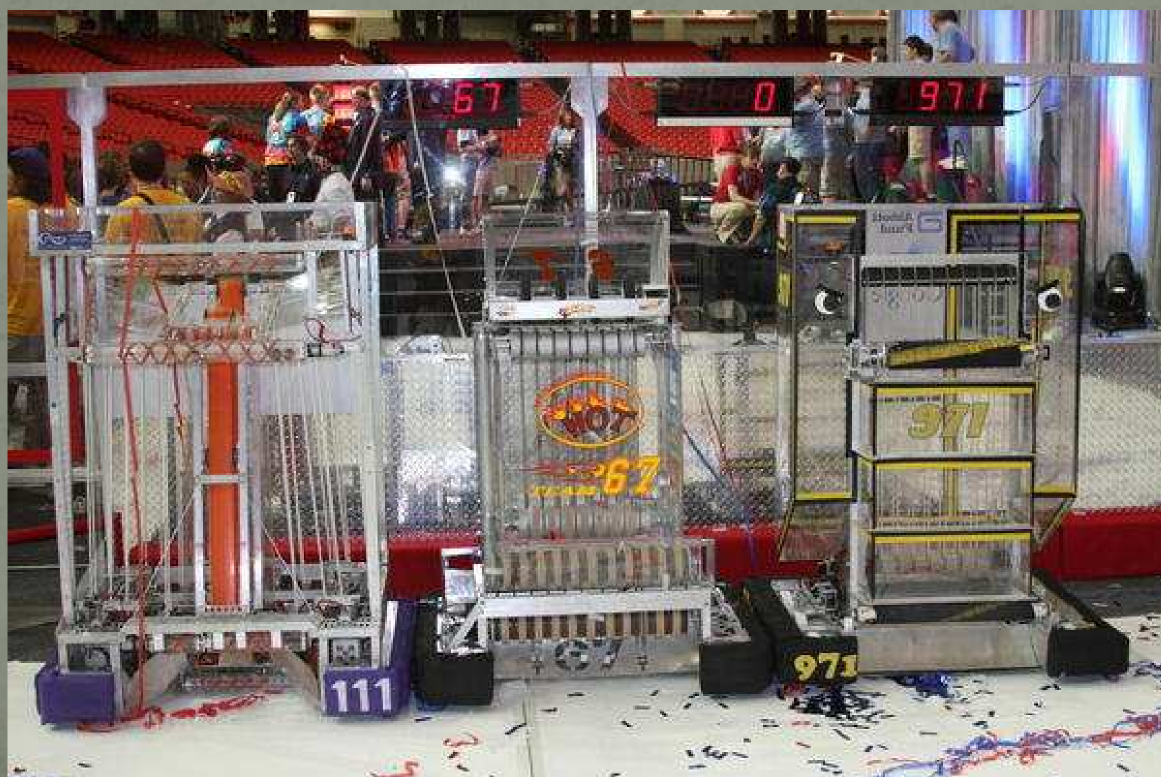
Turrets

- Tubular (recommended)
- Lazy Susan (not for high loads)
- Know when it is needed
    - 2004: One Goal = good
    - 2005: Nine Goals = not
- Bearing structure must be solid
- Rotation can be slow
- Design-in sensor feedback

Ball Systems

Accumulator: rotational device that collects objects

- Horizontal tubes: gathers balls from floor or platforms
- Vertical tubes: pushes balls between vertical goal pipes
- Wheels: best for big objects



Conveying & Gathering

- Conveyor - device for moving multiple objects, typically within your robot
- Continuous Belts
  - Best to use 2 running at same speed to avoid jamming
- Individual Rollers
  - Best for sticky balls that will usually jam on belts and each other

Conveyors

Why do balls jam on belts?

- Sticky and rub against each other as they try to rotate along the conveyor

Solution #1

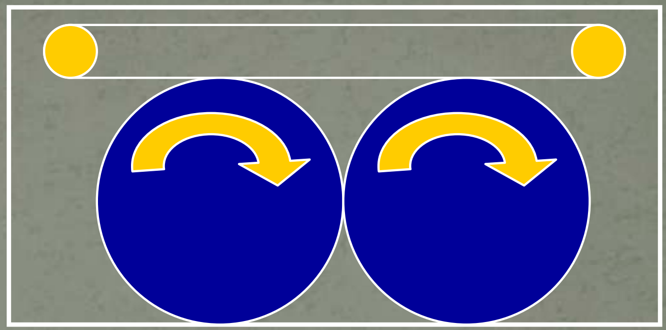
- Use individual rollers
- Adds weight and complexity

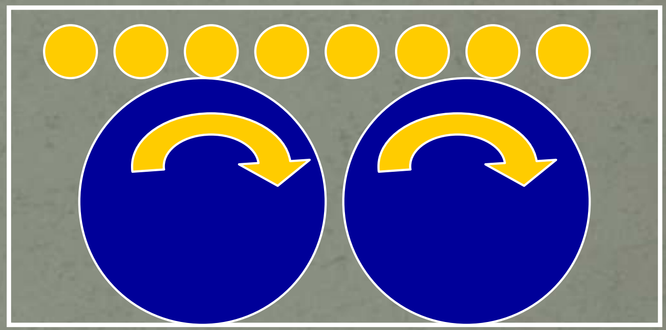
Solution #2

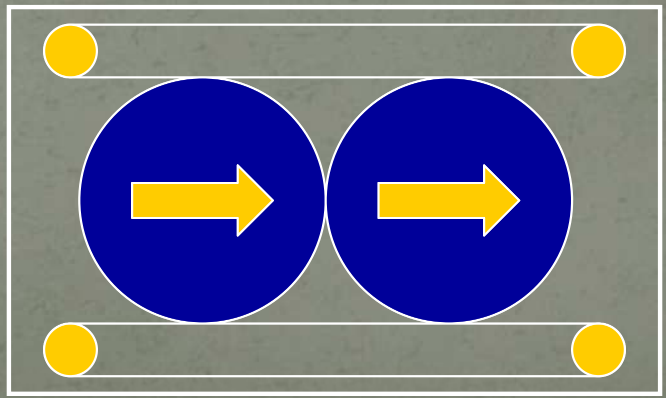
- Use pairs of belts
- Increases size and complexity

Solution #3

- Use a slippery material for the non-moving surface (Teflon sheet works great)







Ball System Tips

- More control is better
  - Avoid gravity feeds – these WILL jam
  - Try to reduce “random” movements
- Not all Balls are created equal
  - Balls tend to change shape
  - Building adaptive/ flexible systems
- Speed vs. Volume
  - Optimize for the game and strategy
  - The more capacity, the better