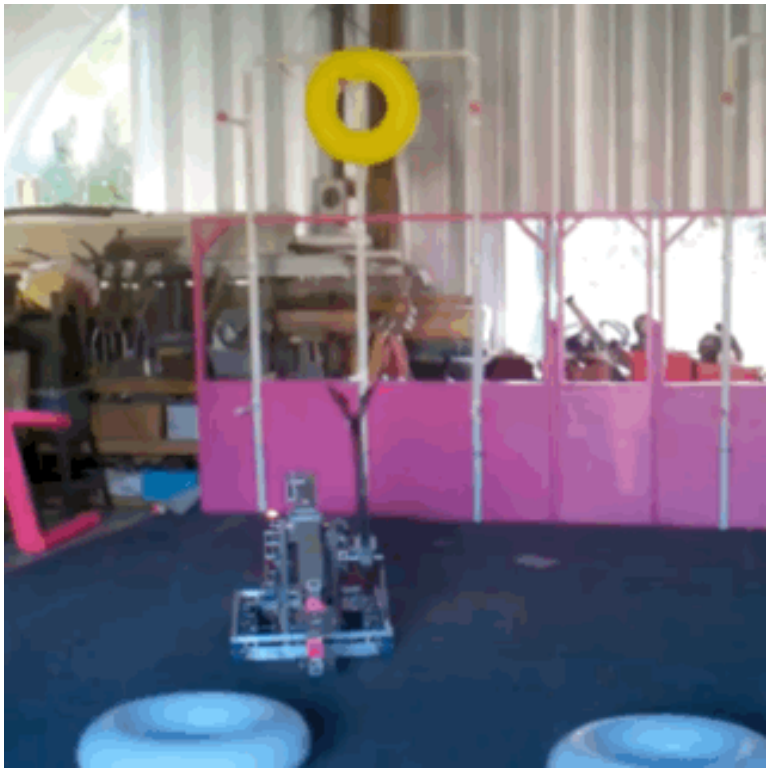
Module 2: How Do *FIRST*® Robotics Competition Robots Work?

EXTENDERS: LIFT, REACH, AND CLIMB

Extenders are robot mechanisms that allow a robot to **lift** up, **reach** out, and **climb**. When deciding which type of mechanism to use, ask:

- How high will the robot need to **lift** a game piece in order to score it?
- How far will the robot need to **reach** outside of its frame perimeter?
- Are there height or **extension limit rules** in the season's game manual?
- If the task is to **climb**, how will the robot's center of mass impact how it hangs when it is off the ground?



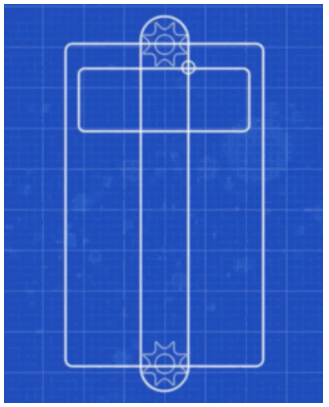
FRC 233 Pink Arm

A **single-stage elevator** is a common mechanism that provides up and down linear motion.

Single-Stage Elevator Mechanics

- **Carriage** – What moves up and down along the uprights. The front of the carriage is typically attached to the game piece manipulator mechanism (such as a claw), while the back side is attached to a pulley system.
- **Uprights** – Often made of box tubing, the uprights are the bars on either side that support the carriage. Uprights often need a diagonal support that connects to the frame.
- **Linear Slides** or **Bearings** – Allows the carriage to ride smoothly up and down the uprights.
- **Pulley System** – Chain, belt, string, or rope can be used to rig the elevator, allowing the carriage to move.

Single Stage Elevator


How Do I Use Elevators in *FIRST*?

Intake Arm Tips and Tricks

- **Sensors** are important to allow the robot to track the position of the elevator. More information on sensors is covered later in this lesson.
- **Wire chain** helps with wire management so that the wires can move with the elevator in a safe and reliable manner.
- **Roller claws** are often added to elevators to allow robots to possess a game piece on the ground and lift it to score.

Elevator Materials and Resources

- **Linear Slides and Bearings** examples include:
  - Local hardware stores and vendors
  - REV Robotics
  - AndyMark
- **Wire Chain** examples include:
  - AndyMark
- **Elevator Resources** examples include:
  - How Do I Use Elevators in *FIRST*?
  - Elevator Overview | Ri3D Redux 2023

Multi-stage elevators extend far but take up less space when they're not extended. The way each "stage" is lifted depends on the rigging.

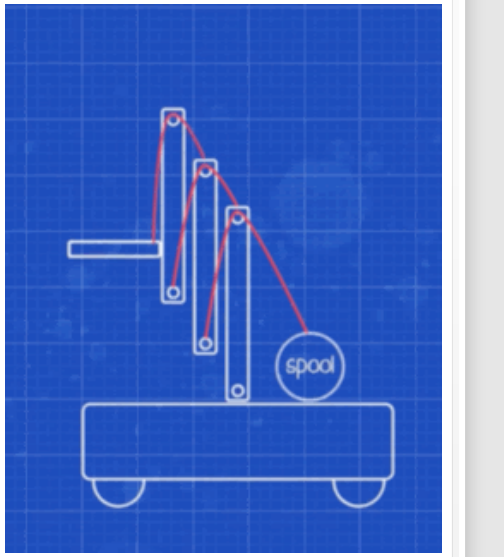
Continuous Elevators

- One stage moves at a time. The carriage moves to the top of the first stage, then the second stage rises up, and so on.
- A motor pulls on a single rope, belt, or chain used for the rigging.
- Has less tension but is more likely to jam.
- Make sure to keep the rigging away from anything on the robot that is sharp, which might cut or damage the rigging over time.

Cascading Elevators

- Each stage moves the same amount simultaneously.
- Each stage has its own rope, belt, or chain used for the rigging, which makes it less likely to jam, but tension forces are higher.
- Note that because more mass is moving at once, the center of gravity changes more rapidly as the elevator goes up, which can make a robot more tippy.

Continuous Elevator AndyMark



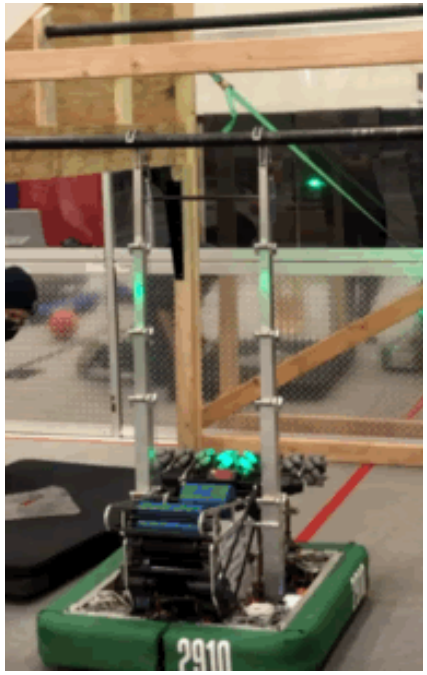
Cascading Elevator AndyMark

Multi-Stage Elevator Examples and Resources

- How Do I Use Elevators in *FIRST*?
- AndyMark SDS Elevator Kit
- WestCoast Products Cascading Elevator Kits
- FRCdesign.org Continuous Elevators
- FRCdesign.org Cascading Elevators
- Linear Mechanism Calculator

Telescoping arms are frequently used to climb when a robot needs to reach a bar, chain, or other field element and lift itself off the ground. Arms can also be used to reach a game piece and lift it.

4-Stage, 3-Stage, 2-Stage and 1-Stage Arms



FRC 2910, 2022 Climber Testing

Telescoping Arm Mechanics

- **Telescoping arms** involve stages, like elevators except that the stages nest inside one another, like a telescope, which allows for a compact design.
- An **active-extension arm** extends like a cascading elevator, with a motor pulling a rope, chain, or belt.
- A **passive-extension arm** uses constant force springs to extend the arm.

Telescoping Arm Tips and Tricks

- Mechanisms or hooks at the end of an arm should be made as durable and lightweight as possible.
- Space is tight inside a telescoping arm. Make sure to leave enough clearance for moving parts

Telescoping Arm Examples and Resources

- **Telescoping Arm Kit** examples include:
  - WestCoast Products GreyT Telescope
  - ThriftyBot Telescoping Tube Kit
  - AndyMark Climber in a Box

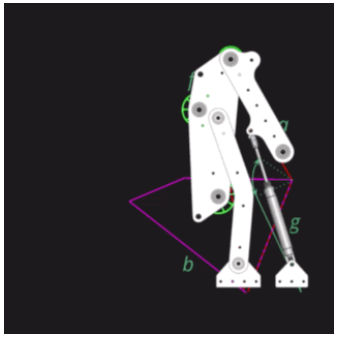
Linkages are made up of bars that are connected at rotating joints. Varying the length of the bars and position of the joints creates a wide variety of motions that are excellent for intakes that reach out or up.

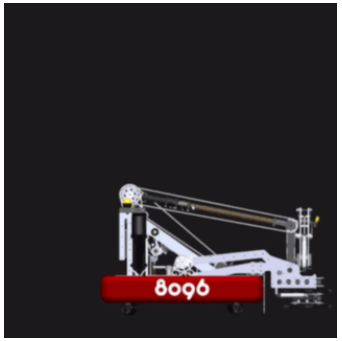
Common Types of Linkages

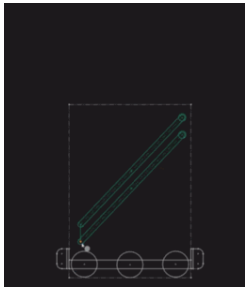
- **Parallel Four-Bar Linkage** – Allows a mechanism to maintain its orientation while moving up and down.
- **Non-Parallel Four-Bar Linkage** – Commonly used on intake arms, its motion allows it to extend outside and retract into the frame perimeter.
- **Scissor Lift** – Uses a series of cross-connected bars.
  - Pros: Compact form factor with significant reach.
  - Cons: Not great at lifting a heavy amount of weight.
- **"Virtual" Four-Bar Linkage** – Uses chain and a robust sprocket to create the motion of a four-bar linkage.

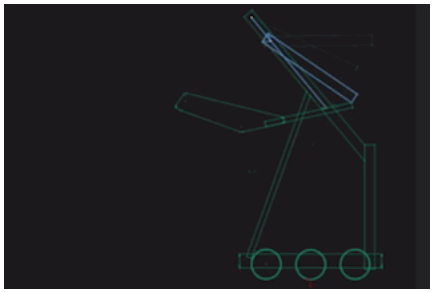
Linkage Mechanics

- **Intake arms** with linkages typically have a linkage on each side, connected by cross bars.
- **Rotating joints** are one of the most important features of a linkage. Bearings and shafts are commonly used.
- **Pneumatic pistons** are sometimes used as one of the "bars" to power the mechanism.
- The 2023 Everybot designed by Team 118 Robonauts used a Non-Parallel Four-Bar linkage as an effective arm design.









Linkages Examples and Resources

- Intake and Arm Linkage Design
- 2023 Everybot Build Manual
- Thangs Mechanisms

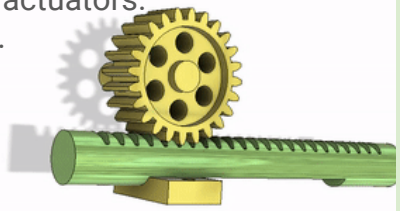
There are a wide variety of **mechanisms** that allow a robot to lift, reach, and climb. While there are common additional mechanisms, there have also been many creative engineering solutions!

Climbing Mechanisms

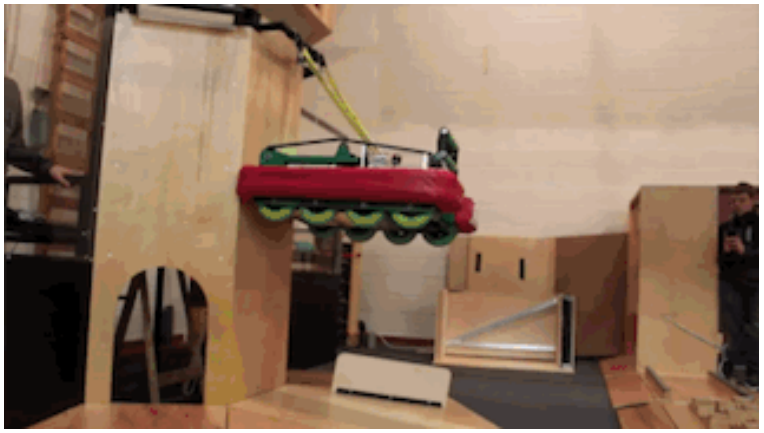
- A **winch** winds a rope, belt, strap, or other material around a drum. If the rope latches onto a field element via hook or another method, the robot lifts up as the rope coils around the drum.
- To reach the field element, the rope material must be stiff enough to extend on its own or be deployed by a mechanism such as an elevator.

Other Extending Mechanisms

- **Lead Screws** – Provide linear motion that extends outward with less back driving. Used in some linear actuators.
- **Linear Sliders** – Provide linear motion.
- **Rack and Pinion Gears** – Extend quickly and are easy to control but tend to be heavy.



Rack and Pinion Gear



Team Titanium 1986 Premier Reveal 2016

Additional Examples and Resources

- **COTS Examples**:
  - REV Robotics Linear Actuator
  - REV Robotics Linear Motion Kit
  - AndyMark Climber in a Box Winch Kits
  - AndyMark Linear Slide
- **Explore Mechanisms**:
  - Project Bucephalus: The Unofficial FRC Mechanism Encyclopedia
  - Spectrum 3847
  - FRCDesign.org