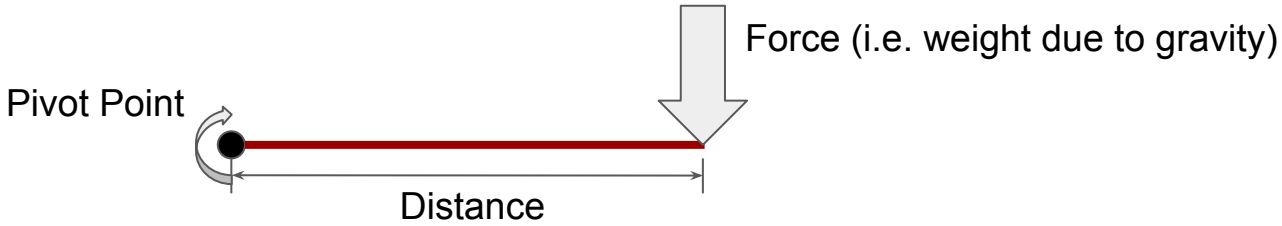
Terms

- **Stall Torque:** Amount of torque that a motor will output at its absolute maximum. At this level of torque, the motor will not spin, but can hold its position
- **Free Speed/No-Load Speed:** the fastest speed the motor will ever spin. At this speed, the motor cannot output any torque
- **Design Torque:** the torque that your system needs to hold its position (i.e. holding the arm out at 90°)
- **Power:** how much work the motor can do divided by time
    - Higher power = faster + more torque
- **Gear Ratio:** reduction ratio. In most scenarios, this will refer to how much the **Torque** is increased and the **Speed** is decreased

Torque Review

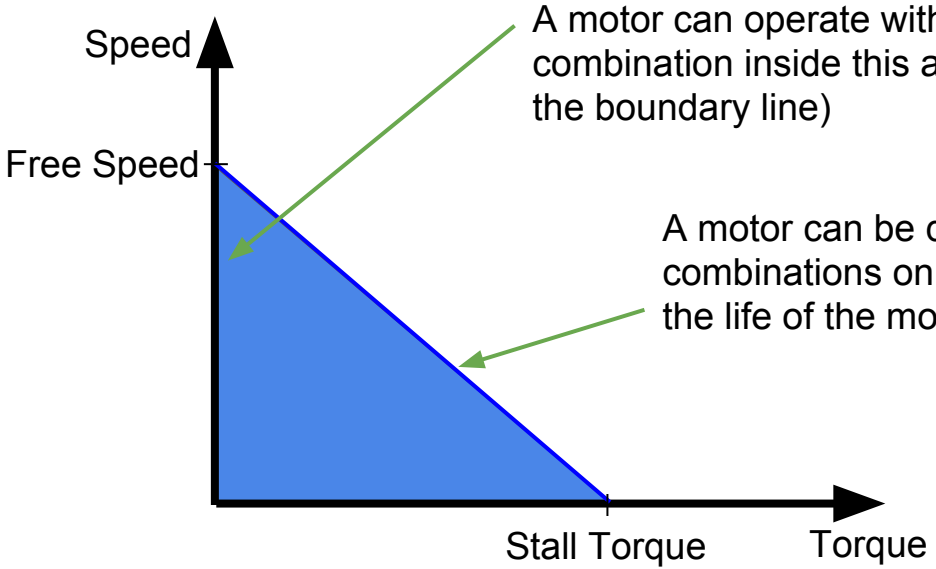
Torque = Force x Distance



Motor Specifications

- Motors online will be defined by 3 main specifications
  - Stall Torque
  - Free Speed/No-Load Speed
  - Power
- The two main parameters we care about are Stall Torque and Free Speed (for now)
- DC motors (what we use in FRC) generally have very low torque, but very high speed

Motor Specification Visualization



A motor can operate with any torque/speed combination inside this area (including along the boundary line)

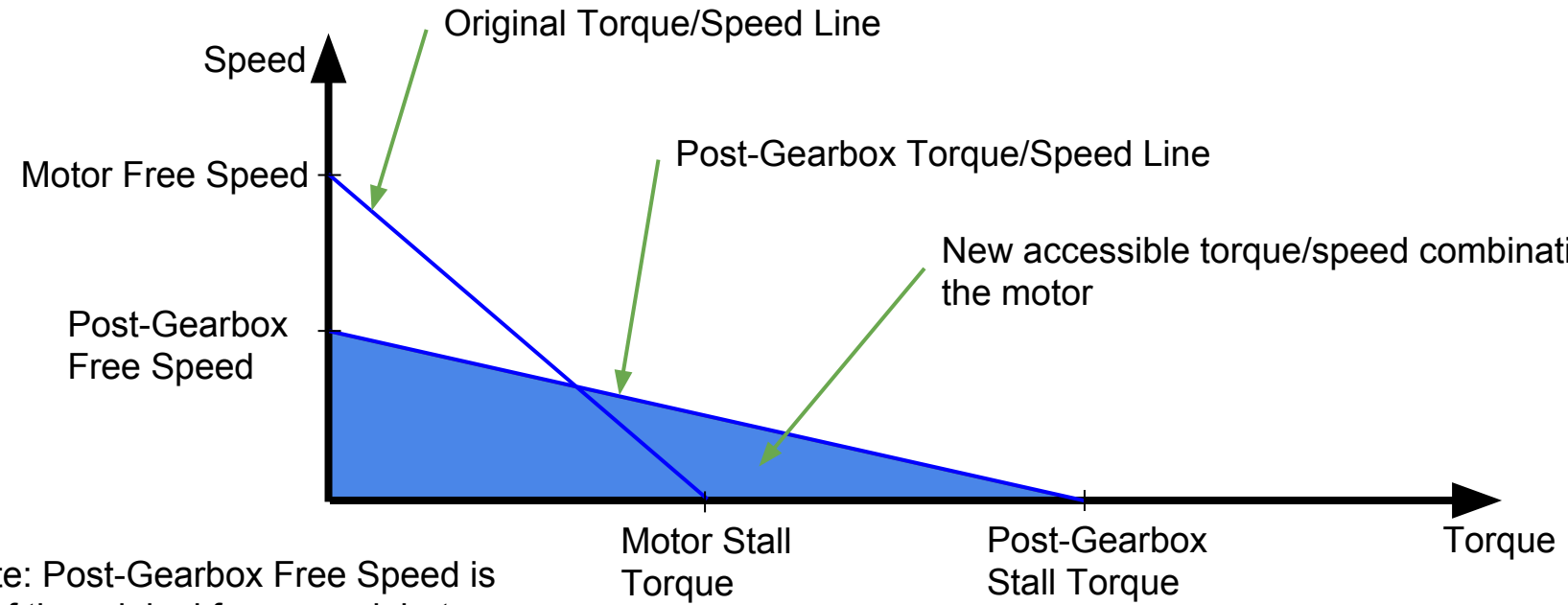
A motor can be driven at the maximum rating (at torque/speed combinations on the boundary line), but it will severely reduce the life of the motor if driven for too long at this point

This is generally called a “torque-speed curve.” Some manufacturers will give you real data for the torque/speed relationship of their motors. For DC motors, it is safe to assume that the graph is linear, as shown here

Gear Ratios

- Gear ratios change the relationship of torque and speed for a motor
- There is no such thing as a free lunch
  - If you gain torque, you lose speed
  - If you gain speed, you lose torque
- For almost every application in FRC, you will want to **reduce** the speed and **increase** the torque

Gear Ratio Effect on Torque/Speed Curve



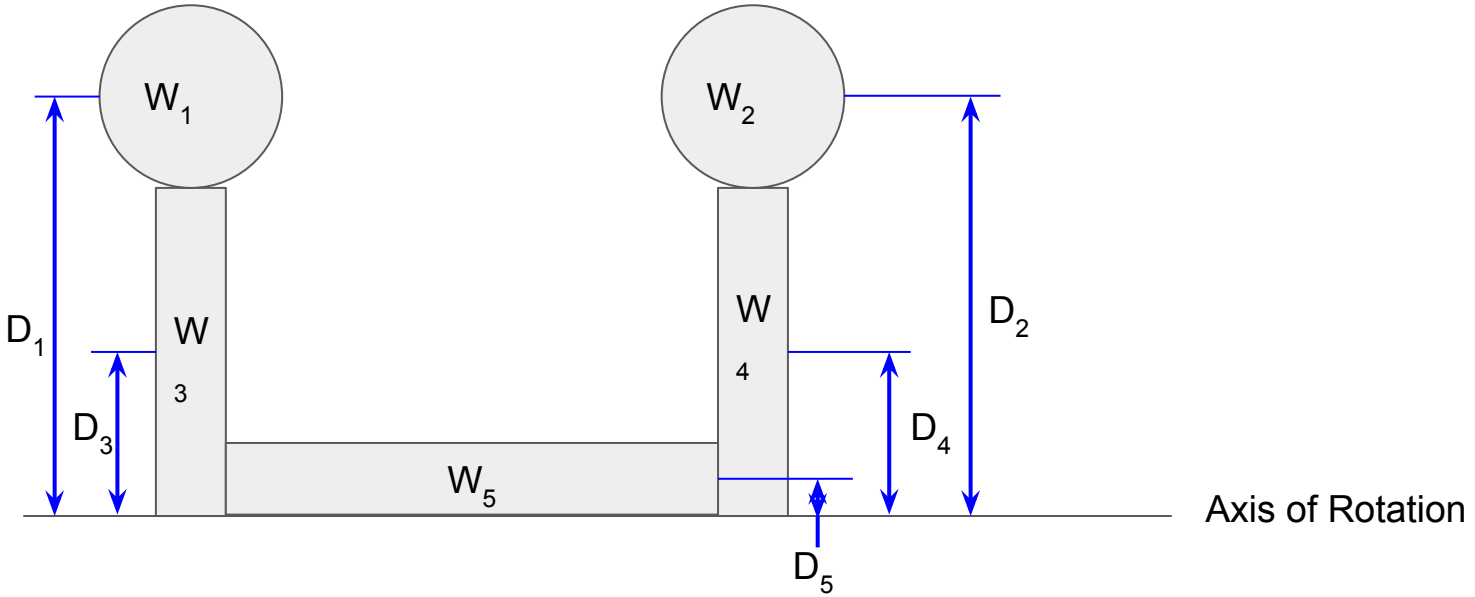
Note: Post-Gearbox Free Speed is ½ of the original free speed, but Post-Gearbox Stall Torque is 2x as large

(assuming gear ratio of 2:1 for demonstration purposes)

Picking a Motor Step 1: Estimate System Design Torque

- Your system will most likely be made up of multiple components that you want to move as one single system
- The torque required to move this system (**Design Torque**) needs to be added up as a summation as the force caused by each individual piece
  - $DesignTorque = \sum_{i=1}^{n} Weight_i \times Distance_i$
  - For Calculation, assume that your system is in its highest-torque configuration (i.e. arm is extended horizontally from the fulcrum with gravity acting perpendicular to the arm)
  - Distance measurements should be taken from the (approximate) center-of-mass of the component
- BE CONSISTENT AND LABEL YOUR UNITS
  - Don’t use different units on different parts. Convert all units (weights/distances) to one standard system and make sure to label them clearly!

Picking a Motor Step 1: Estimate System Design Torque



$$DesignTorque = W_1 D_1 + W_2 D_2 + W_3 D_3 + W_4 D_4 + W_5 D_5$$

Top View: Gravity is oriented into the page

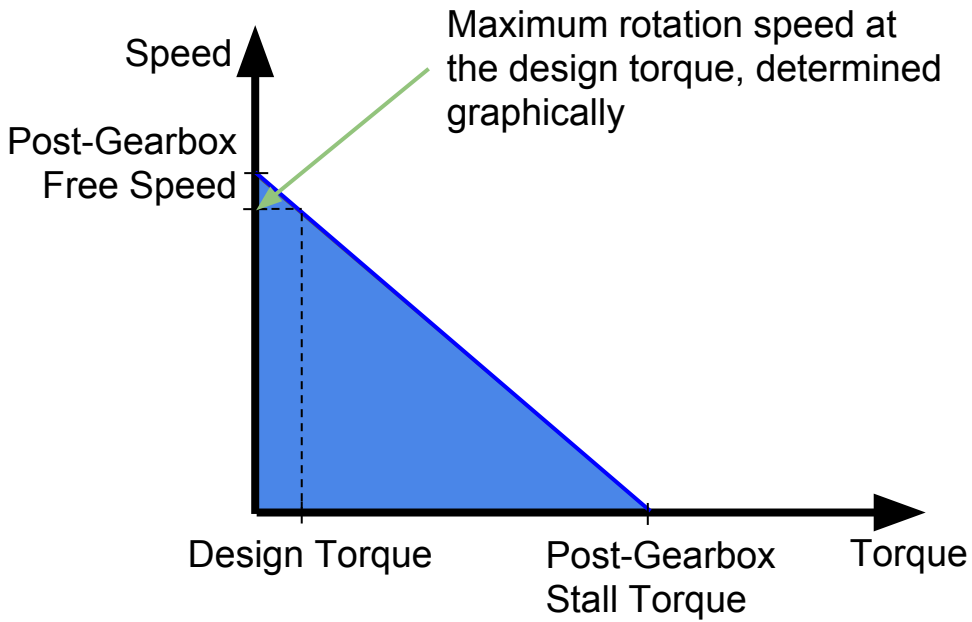
Picking a Motor Step 2: Motor Specifications

Ideally: **Design Torque** will be between 10% and 50% of the Post-Gearbox Stall Torque

If, for a given motor+gearbox combo, you find that the maximum rotation speed is too low, you will need a motor with higher power.

If the maximum rotation speed is too high, the speed can be lowered via software. This is the ideal situation, because running a motor slower than the maximum rotation speed will lead to a longer motor life

If the maximum rotation speed is way too high, select a motor with a lower power rating



Resources

DC Motors with integrated gearboxes:
http://www.andymark.com/Search-s/545.htm?Search=pg&Submit=

Customizable planetary gearboxes:
https://www.vexrobotics.com/versaplanetary.html