Build Team Workshop

Building Tips & Tricks:
Design process & Pros and Cons of Mechanisms

A Little About Me

Mechanical Engineering,
Biomedical Specialty

Vehicle Safety, Automated (“Driverless") Cars

- Founding mentor (2017)
- Three kids in FTC
- Winners of the Inspire, Connect, Think, & Motivate Awards
- Winning Alliance (Novi)

- Mentor
- Former World Champions
- Impact, sustainability, & many more awards

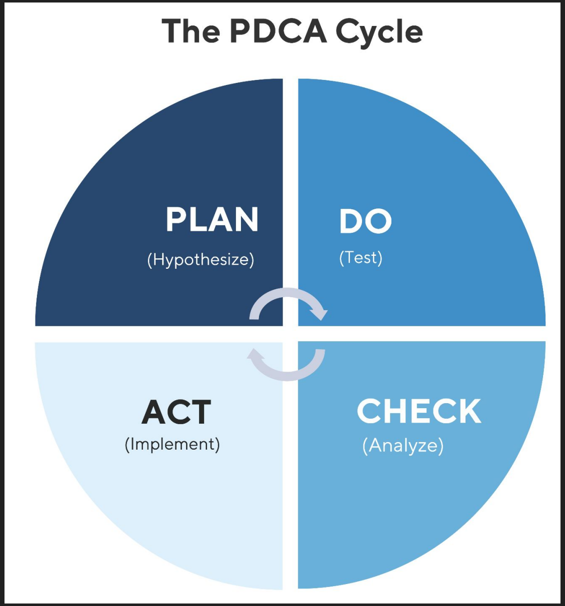
Overview

We'll review the following:

- Design Steps
- Core Concepts: Force, torque, work, and power
- Mechanisms: Types, Merits & Demerits

Design Process

1. Determine Game Strategy for Auto and Tele-op periods
2. Brainstorm Robot Concepts
3. Take a Break
4. Prototype and testing phase
5. Design Freeze
6. Build the robot for competition
7. Test final Robot
8. Compete
9. Evaluate and improve the robot

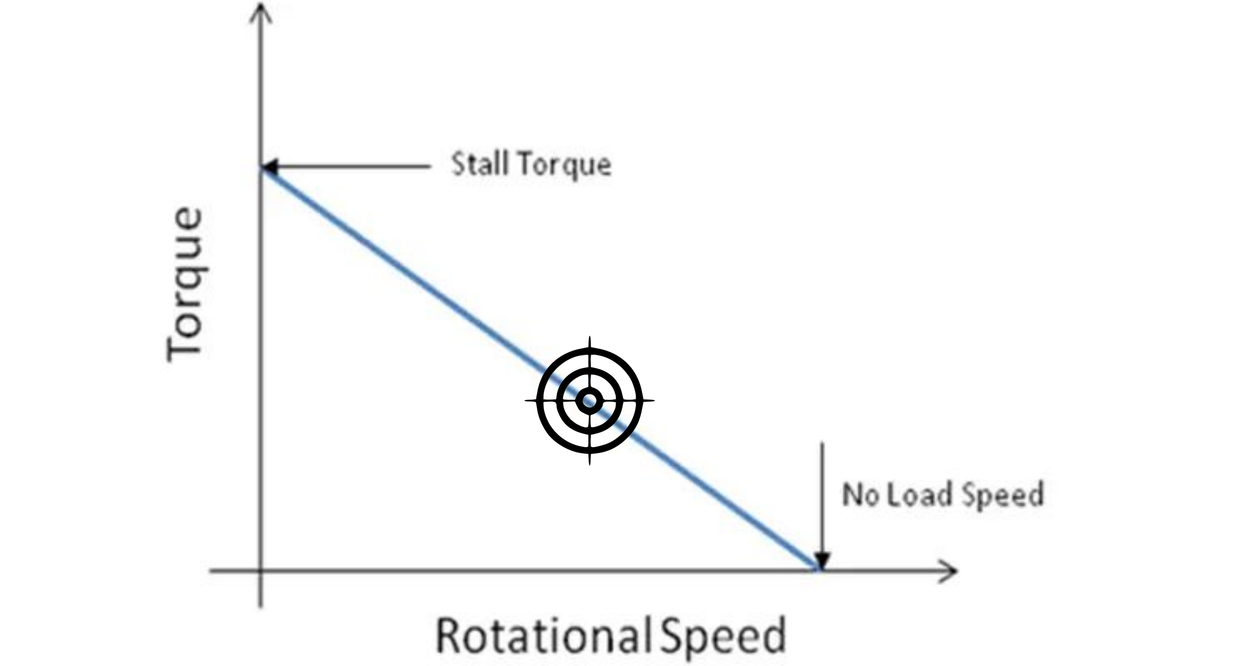


Why are we learning about force, torque, work & power?

Goal: We want to be fast AND we want to be strong enough to perform the task

Why are we learning about force, torque, work & power?

Torque and speed are generally inversely proportional



Core Concepts

- Spe

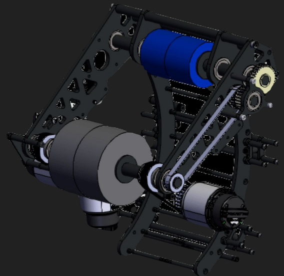
Core Concepts

- **Speed is distance traveled over time. What is the formula & units?**

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}} \rightarrow \frac{\text{miles}}{\text{hour}} \rightarrow \frac{\text{centimeters}}{\text{second}}$$

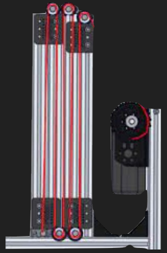
Core Concepts

- **Rotational speed is rotations over a period of time.**
- **What are the units for rotational speed?**



$$\textbf{Rotational Speed} = \frac{\text{Rotations}}{\text{Time}} \rightarrow \frac{\text{Revolutions}}{\text{Minute}} \rightarrow \text{RPM}$$

- **How to convert RPM to linear speed the elevator will travel up in cm/s?**



Circumference = C = 2*Pi*radius (cm)

$$\textbf{Elevator Speed Up (cm/s)} = \frac{\cancel{\text{Rev}}}{\cancel{\text{Min}}} \times \frac{\text{C (cm)}}{\cancel{\text{Rev}}} \times \frac{\cancel{\text{Min}}}{\text{60 (s)}}$$

Core Concepts

- **Torque is.the force to twist or turn something**

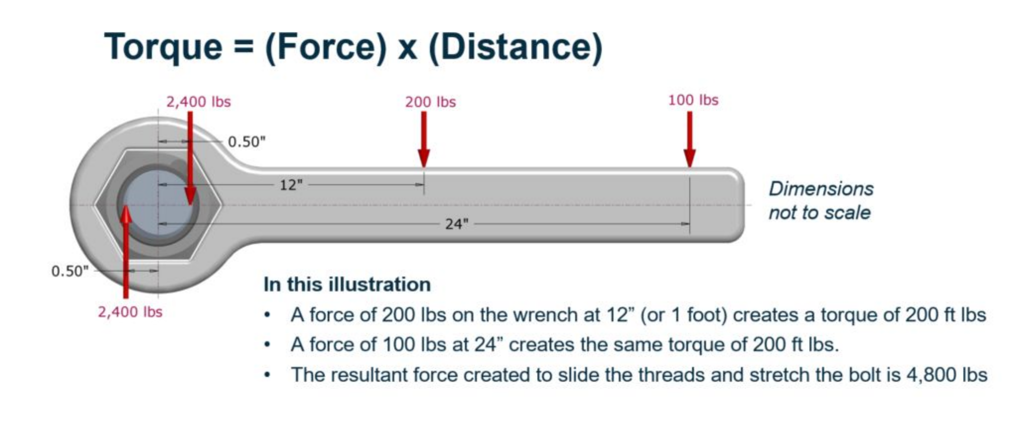
Which wrench would you choose that requires the least amount of force from you?

Core Concepts

- **Torque is the force to twist or turn something**

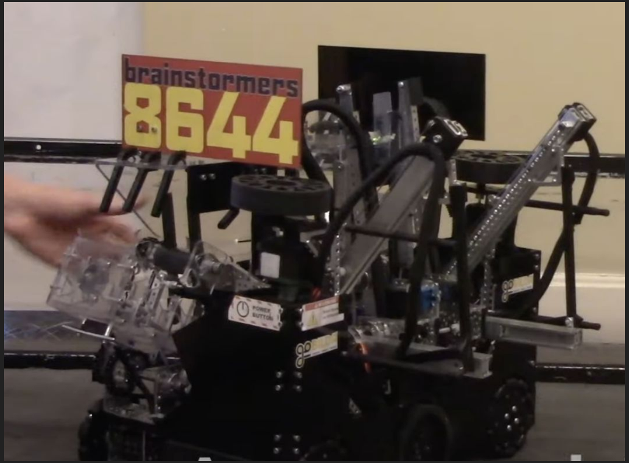
Torque = Force x Distance

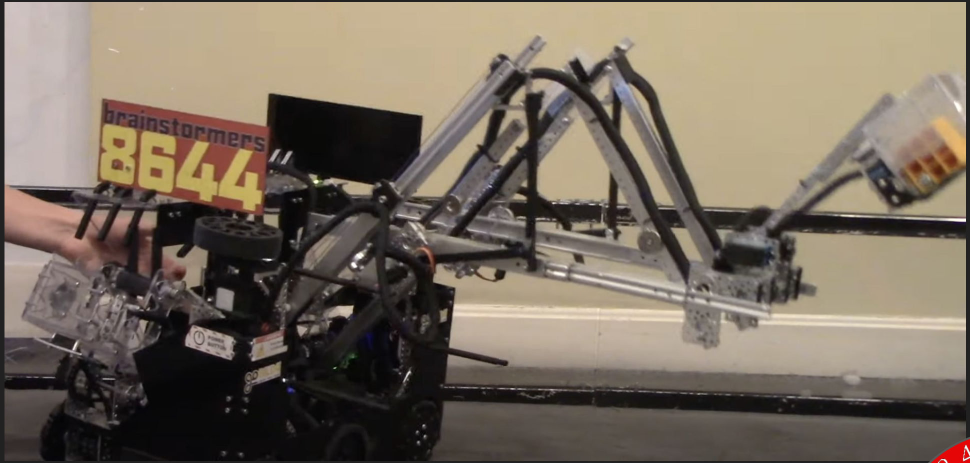
T = Fd (Nm)



Core Concepts

- **Work is a change in energy.**
  - **For FTC, this means moving something from one place to another**





Work = **Force x distance** = **Fd (Joules)**

Core Concepts

- **Power is.the rate of change in energy.**

more time => less power

less time => more power

Power = Work / Time (Watts)

Mechanisms

Types, Merits & Demerits

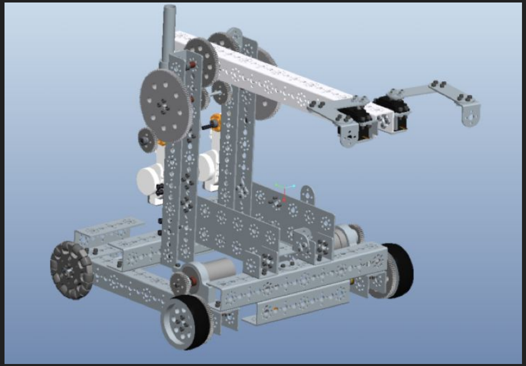
We Stand on the Shoulders of Giants

Thank you Team Rush Robotics 27 for the following tips!!!!

Design Tips

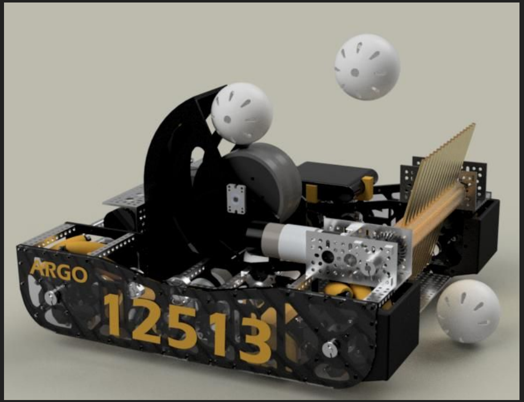
- Focus on doing a few objectives well…you can always add something later ;-)
- The lighter, the better
- Less is more
- Understand your team's abilities
- Establish milestones

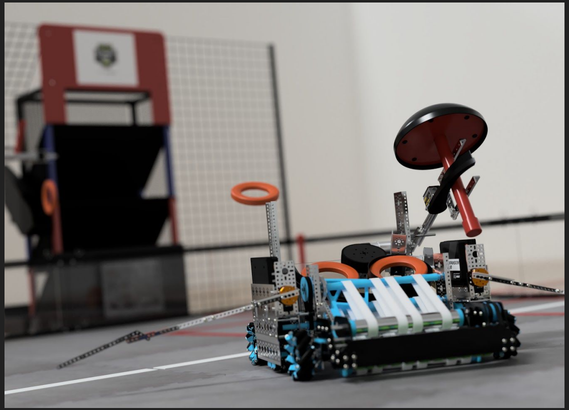
Arms with Grippers



Merits	Demerits
Efficient use of material	Unstable extended while moving
Good reach	Fragile
Limited number of motors	Can only move light loads
Easy to build	High CG

Shooters

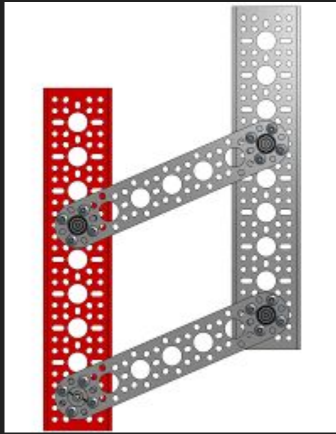




Merits	Demerits
Fun	Inaccuracy
Can move fast	Temperamental when moving
Limited number of motors	Could be driver-dependant

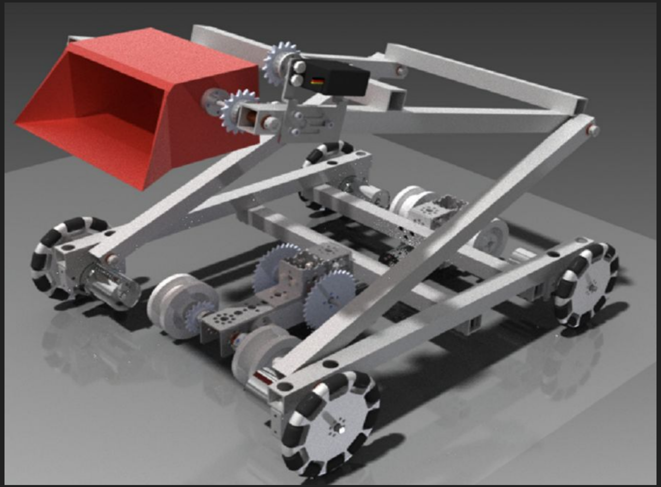
Team 13684 Infinity Tech

Four-bar Linkage



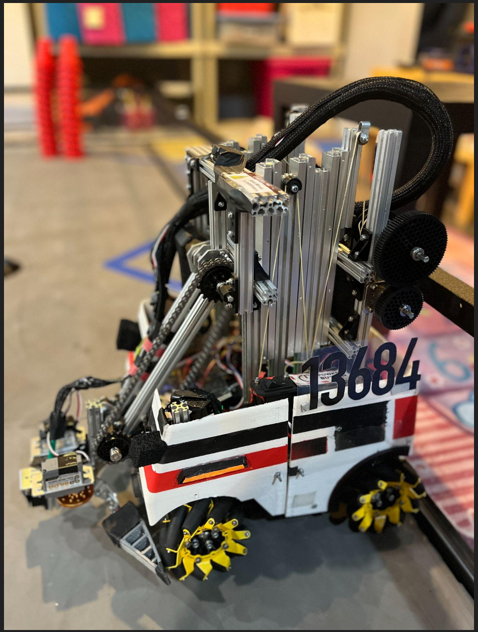
Merits	Demerits
Robust and durable	Can be complex
Moves fast	Sway at extension
Robotics’ Top Gun	Not much adjustment

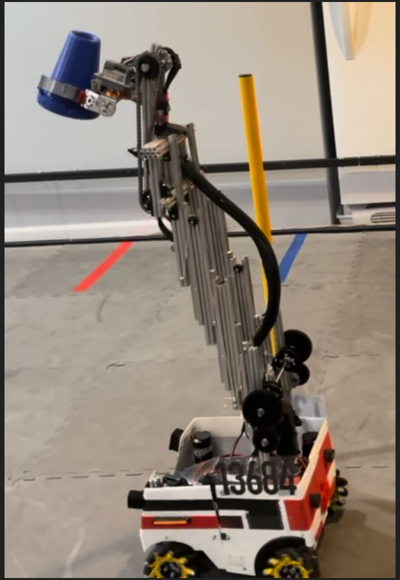
Scoop Arms



Merits	Demerits
Simple	Hard to accurately dump
Moves fast	May collect too many parts
Collects many pieces at once	Not much adjustment

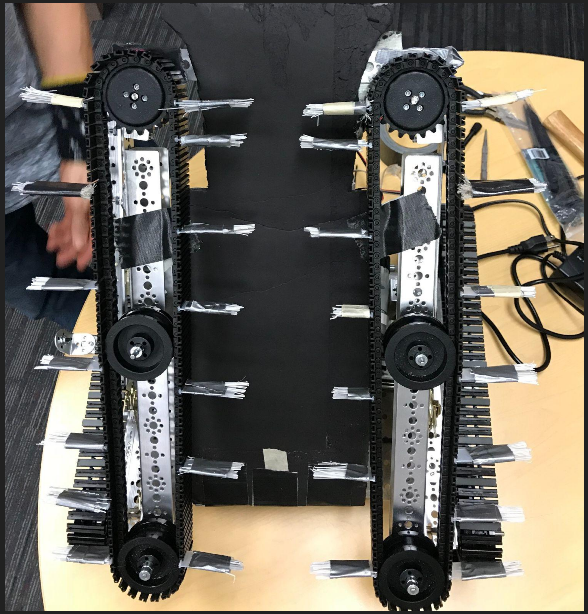
Sliders

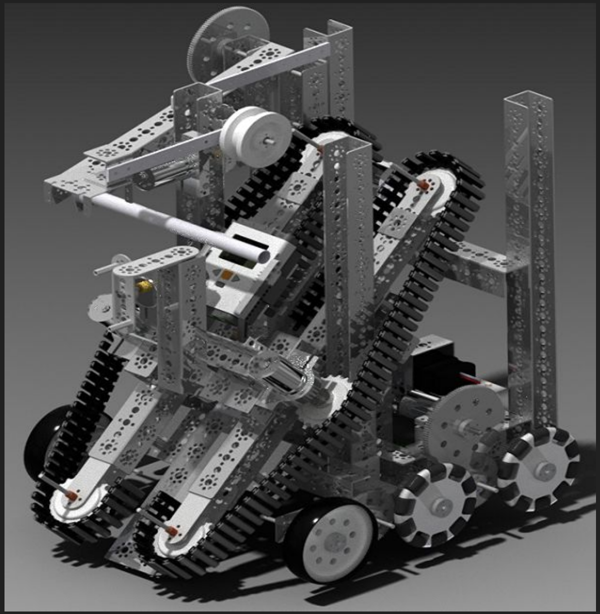




Merits	Demerits
Can be made with commercial, off the shelf parts	Keeping the string on can be tough; belts sacrifice room
Can reach high heights.	High CG when extended & moving. May tip & sway
Simple	Must drive up & down

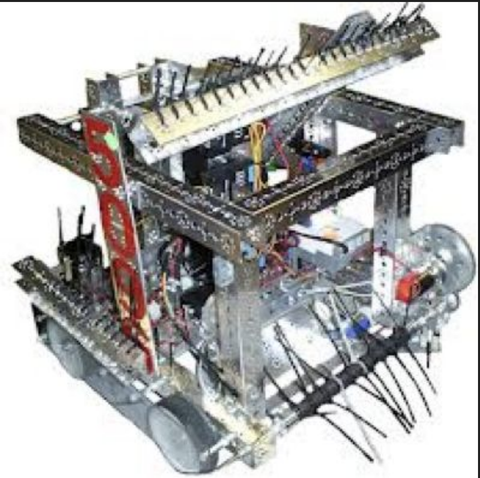
Belts

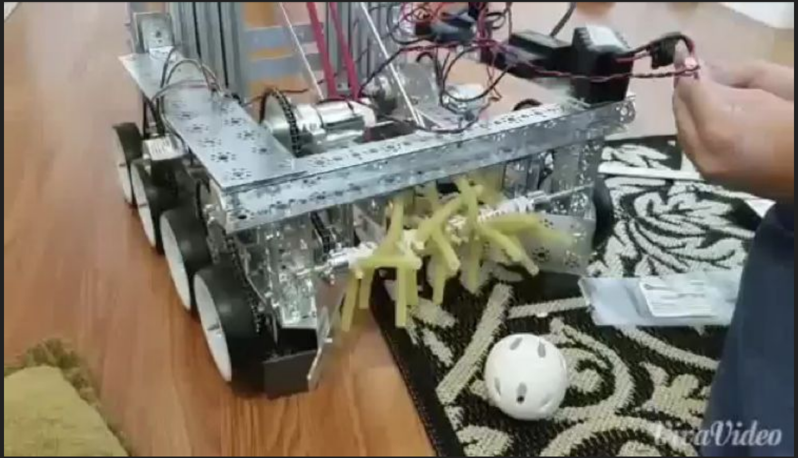




Merits	Demerits
Fast part loading	Treads tend to break or decouple
Can suck parts in from many directions	Belt tensioning can be a career

Sweeper





Merits	Demerits
Fast part loading	Can break when running into wall
Can suck parts in from many directions	Not great for outputting balls
Easy to build	Can be a tangle hazard

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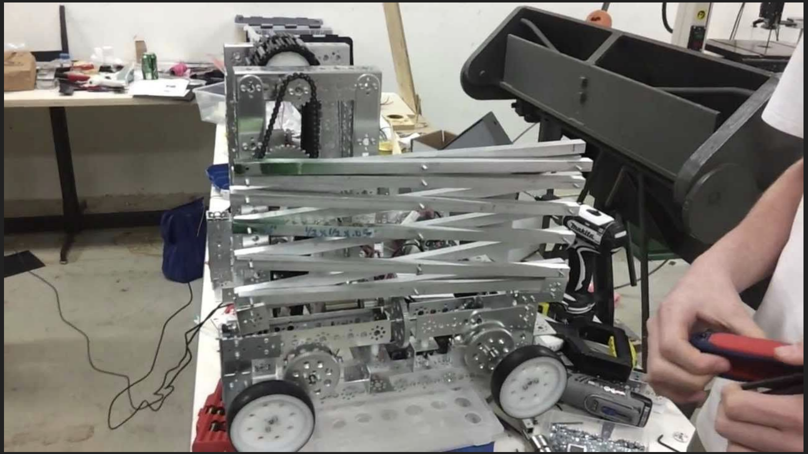
Scissor Lift



Merits	Demerits
Compact	Unstable at heights
High height	High CG may lead to tipping
Easy to build	Wobbles when moving

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Tape Measure

Merits	Demerits
Compact	Unstable at heights
High height	Susceptible to damage
Easy to build	Wobbles when moving

Recap

We reviewed the following:

- Design Process
  - Plan, Do, Check, Act
- Core Concepts: Force, torque, work, and power
  - Foundational equations to optimize both speed and strength
- Mechanisms: Types, Merits & Demerits
  - Learned the merits and demerits for various mechanisms
  - Blooket.com: Search for “Object collecting mechanisms” for a Blooket we made

Good luck this season!!!

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Infinity Tech Mentor

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How to choose an actuator

1. Calculate work (W = Fd = mad)
2. Calculate power (P = Work / time)
3. Compare power calculation result with maximum motor power output

Example Problem

- Assumptions
  - Instant acceleration
  - No friction
- Game piece weight: 0.5 kg
- Lifter weight: 1.5 kg
- Lifter maximum height: 1.5 meters
- Time to full extension: 5 seconds

Work = (0.5 kg + 1.5 kg)(9.8 m/s^2)(1.5m) J

Power = 29.4J / 5s = 5.88 W

Power (w/ Safety Factor) = P*2 = 11.76 W

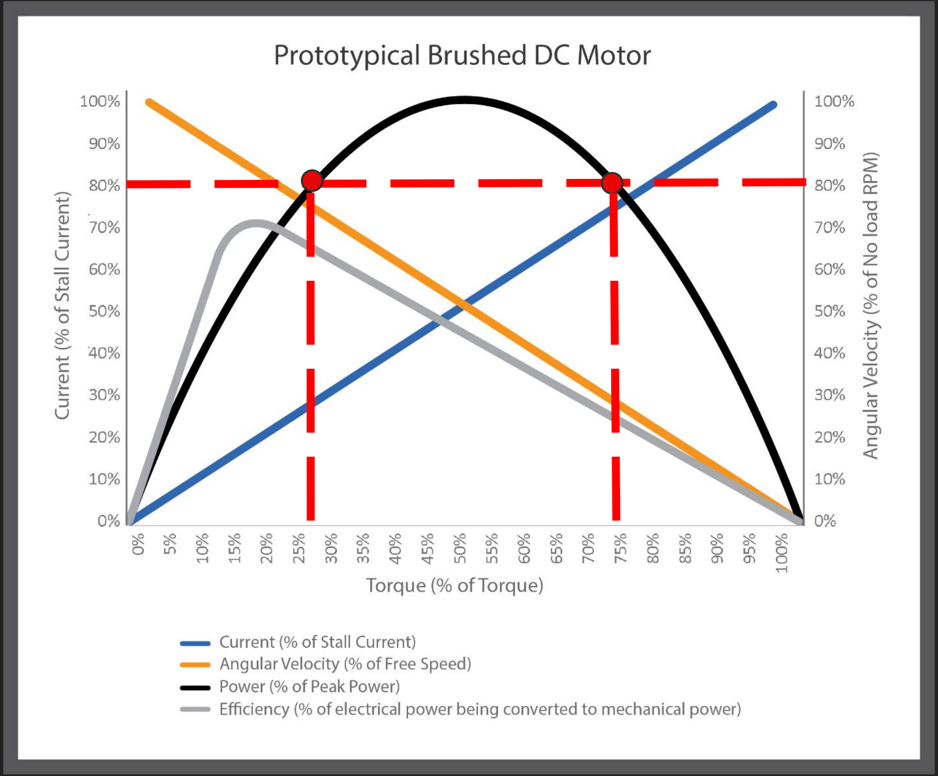
How to choose an actuator

Power (w/ Safety Factor) = P*2 = 11.76 W

	Stall Torque	Free Speed	Operating Voltage	Stall Current	Maximum Output Power
HD Hex, No Gearbox REV-41-1301	0.105 N·m 14.8 oz·in	628.3 rad/s 6000 RPM	12 V	8.5 Amps	15 Watts
HD Hex, 40:1 Spur REV-41-1301	4.2 N·m 594.7 oz·in	15.7 rad/s 150 RPM	12 V	8.5 Amps	15 Watts
HD Hex, 20:1 Spur REV-41-1301	2.1 N·m 297.4 oz·in	31.4 rad/s 300 RPM	12 V	8.5 Amps	15 Watts
HD Hex, 20:1 Planetary REV-41-1301	2.1 N·m 297.4 oz·in	31.4 rad/s 300 RPM	12 V	8.5 Amps	15 Watts
~~Core Hex, 72:1 REV-41-1300~~	~~3.2 N·m 453 oz·in~~	~~13 rad/s 125 RPM~~	~~12V~~	~~4.4 Amps~~	~~[illegible] Watts~~

How to choose an actuator

1. Use the power from our example and find on the y-axis (e.g 12 W/15 W = 80%)
2. Draw a horizontal line starting at the % of power
3. Draw two dots where the dotted line crosses the power curve
4. Where the vertical lines intersect the x-axis is the torque range of the motor
5. Tips:
    a. Prioritize maximizing power & efficiency
    b. Use the lower torque first; If it doesn't work out then can increase power



How to choose an actuator: REV Robotics Motor Example

- **Requirement:** Lift 10 lbs game piece w/ 2” diameter pulley
- **Stall torque =** 2.1 Nm x 27% = 0.567 Nm (~5 lbs. w/ 2 inch diameter pulley)

	Stall Torque	Free Speed	Operating Voltage	Stall Current	Maximum Output Power
~~HD Hex, No Gearbox REV-41-1301~~	~~0.105 N·m 14.8 oz·in~~	~~628.3 rad/s 6000 RPM~~	~~12 V~~	~~8.5 Amps~~	~~15 Watts~~
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~~Core Hex, 72:1 REV-41-1300~~	~~3.2 N·m 453 oz·in~~	~~13 rad/s 125 RPM~~	~~12V~~	~~4.4 Amps~~	~~9 Watts~~