MILESTONE 9

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Competition Strategy

- Spin upper X-Wing Engine to between 21 and 25 rad/s (~200 to 240 rpm)
- (As time allows) Raise light saber to 2x multiplier
- Time Allocation
  - *Autonomous (30 sec):* Position robot at bottom of ramp or elevator
  - 30 sec: Drive robot to top floor
  - 30 sec: Spin X-Wing Engine
  - 30 sec: Raise light saber
- Control
  - ***PS2 Controller*** *with Programmed Arduino*
- Total Predicted Points: ***220 to 312.5 (plus multiplier)***

Design Requirements

- X-Wing Engine
  - *Overcome ~0.12 Nm of frictional torque on engine*
  - *Final rotational speed: 200 to 240 rpm*
  - *Time to steady state speed: ~20 seconds*

- Locomotion Requirements
  - *Activate elevator (center located ~9 in. from platform)*

- Light Saber (as time allows)
  - *Overcome torque due to weight of light saber (~ 9 Nm)*
  - *Lift light saber base to height of 4.5 inches (45° angle from vertical)*

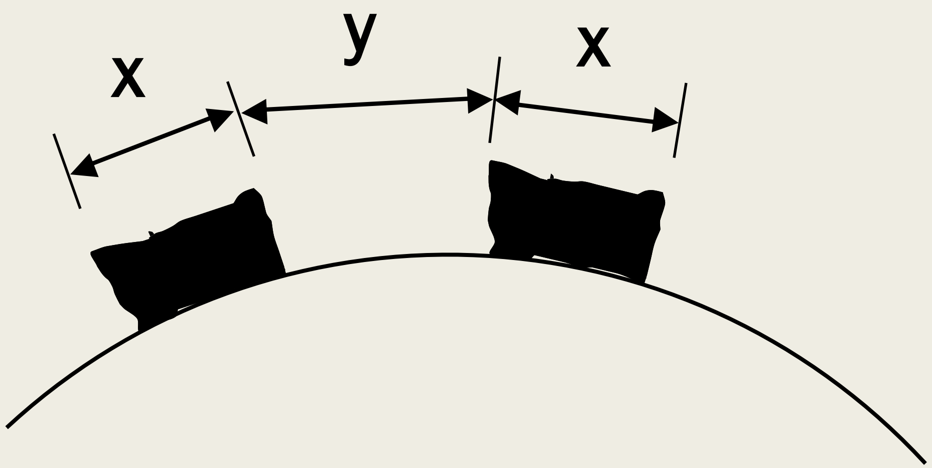
X-Wing Module: Custom Gear Design

$$r = \frac{x + y}{2\pi} m$$

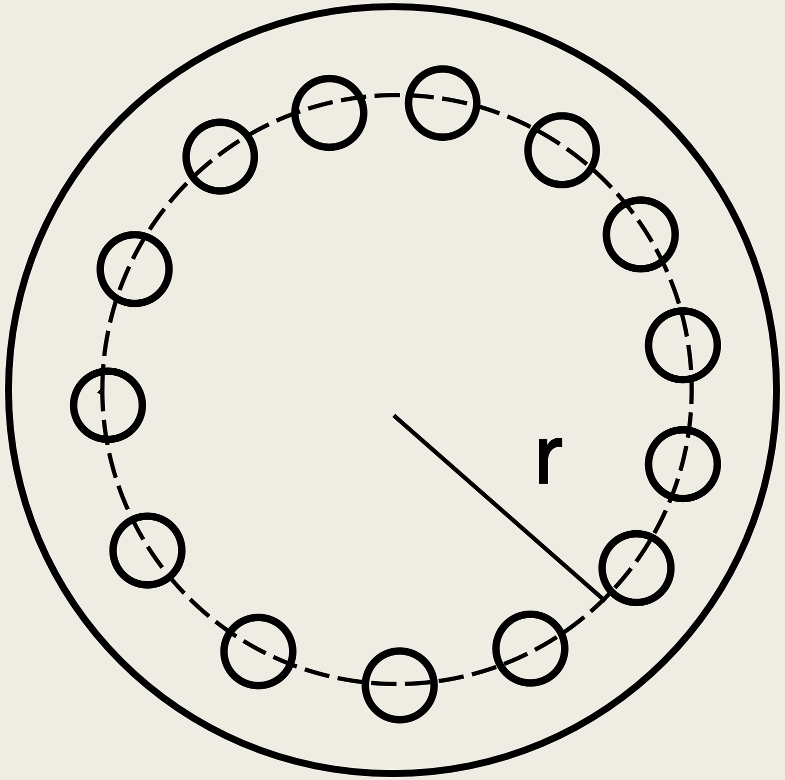
y = 0.25 in.

X = 0.14 in.

m = # of holes in gear



X-Wing Engine Timing Belt



X-Wing Module: Custom Gear Design

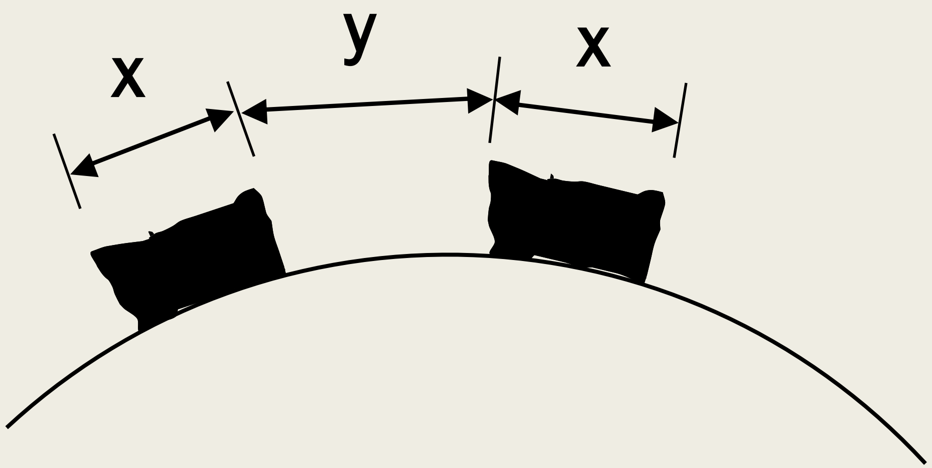
y = 0.25 in.

X = 0.14 in.

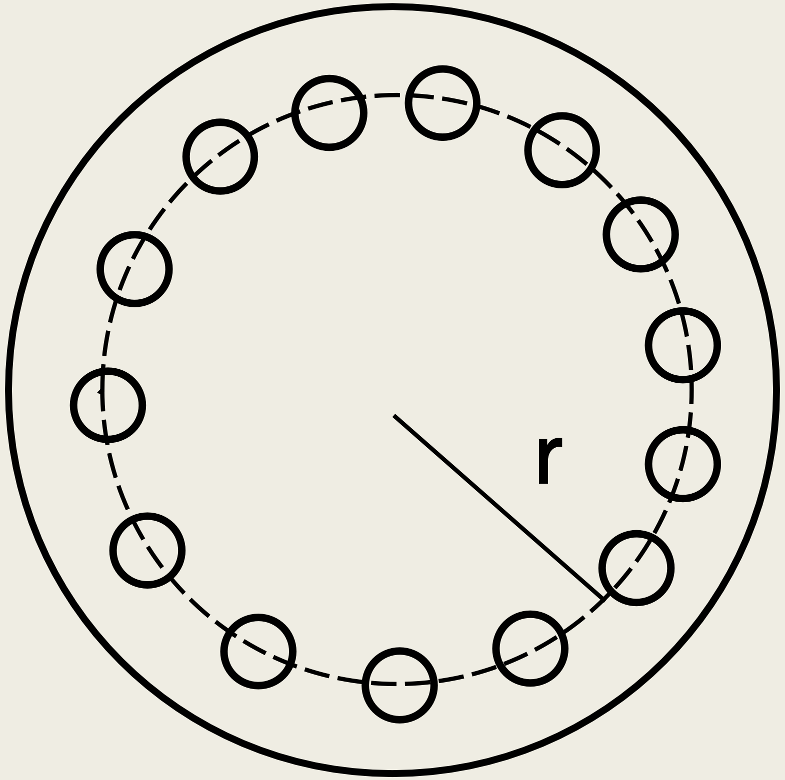
m = # of holes in gear

m = 14

r = 0.8244 in.



X-Wing Engine Timing Belt



Choosing Motor and Gear Reduction: X-Wing Module

n = number of motors
N = gear ratio between motor(s) and custom gear
T_m = torque outputted by one motor
ω_m = speed of motor
T_G = torque outputted by custom gear
ω_G = speed of custom gear
T_f = frictional torque on engine
R_E = radius of X-Wing engine
R_G = radius of custom gear
T_{stall} = stall torque of motor
ω_{nl} = no-load speed of motor
$N_G \equiv R_G / R_E$

Motor Dynamics

$$T_m = T_{stall}\left(1 - \frac{\omega_m}{\omega_{nl}}\right)$$

X-Wing Module: Choosing Motor and Gear Reduction

n = number of motors
N = gear ratio from motor(s) to custom gear
T_m = torque output of one motor
ω_m = speed of motor
T_G = torque output from custom gear
ω_G = speed of custom gear
T_f = frictional torque on engine
R_E = radius of X-Wing engine
R_G = radius of custom gear
T_{stall} = stall torque of motor
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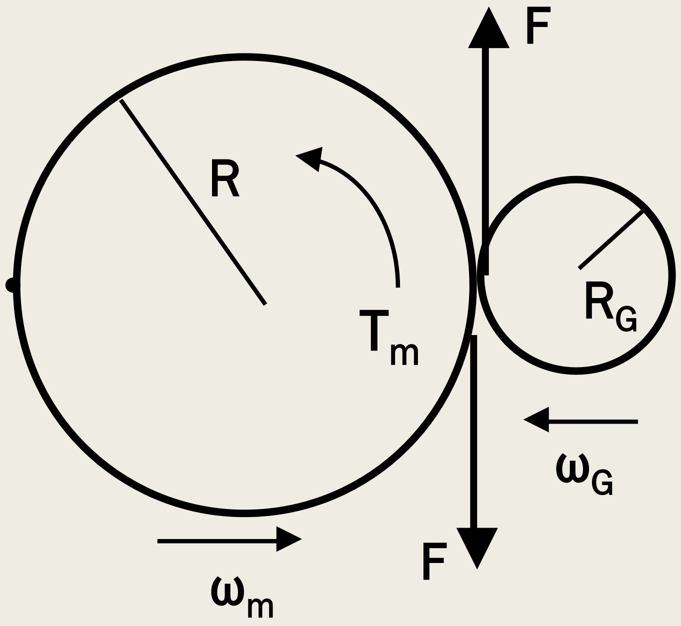
$N_G \equiv R_G / R_E$

Motor to Custom Gear



$$F = \frac{nT_m}{R}$$

$$\Longrightarrow \boxed{T_G = R_G F = nT_m N}$$

(*where* $N \equiv R_G / R$)

$$\omega_m R = \omega_G R_G$$

$$\Longrightarrow \boxed{\omega_G = \frac{1}{N}\omega_m}$$

Choosing Motor and Gear Reduction: X-Wing Module

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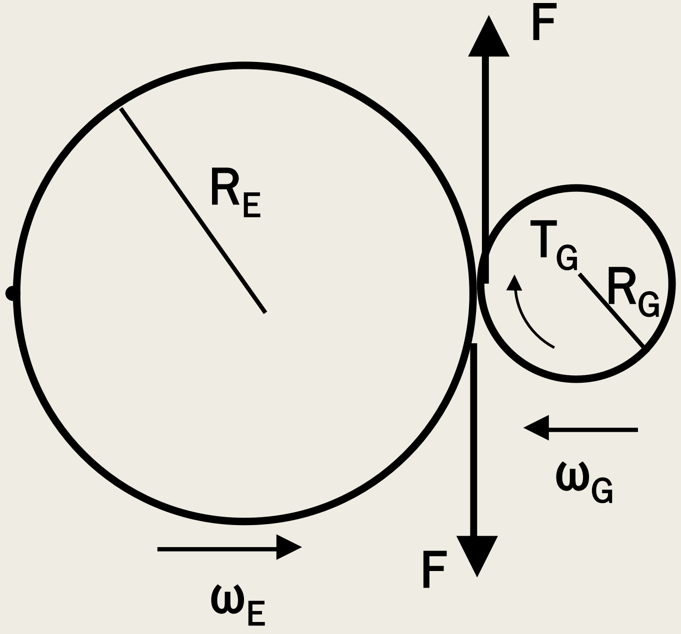
Custom Gear to Engine



$$F = \frac{T_G}{R_G}$$

$$\Longrightarrow \boxed{T_E = R_E F = T_G N_G}$$

(*where* $N_G \equiv R_G / R_E$)

$$\omega_E R_E = \omega_G R_G$$

$$\Longrightarrow \boxed{\omega_m = \frac{N}{N_G}\omega_E}$$

Choosing Motor and Gear Reduction: X-Wing Module

n = number of motors
N = gear ratio between motor(s) and custom gear
T_m = torque outputted by one motor
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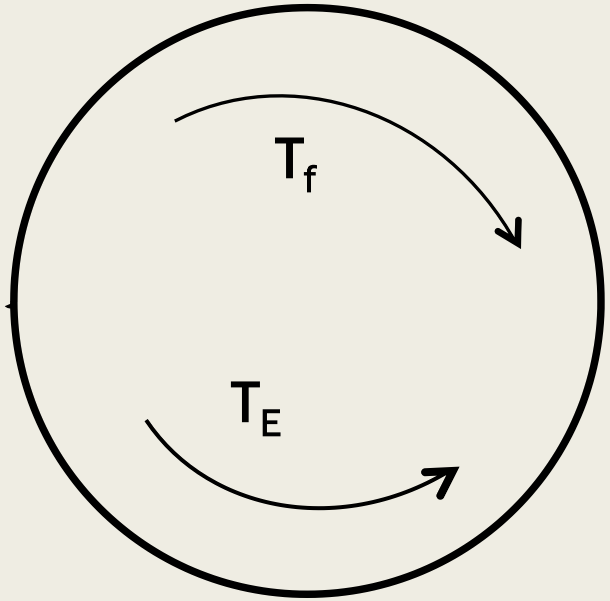
Engine Dynamics



$$\Sigma M = T_E - T_f = 0$$

$$\Longrightarrow \boxed{T_m = \frac{T_f}{n}\left(\frac{N_G}{N}\right)}$$

Choosing Motor and Gear Reduction: X-Wing Module

Combining all four analyses…

n = number of motors
N = gear ratio between motor(s) and custom gear
T_m = torque outputted by one motor
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T_f = frictional torque on engine
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T_{stall} = stall torque of motor
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$N_G \equiv R_G / R_E$

$$\boldsymbol{\omega_{nl}\left(\frac{N_G}{N}\right)\left[1-\frac{T_f}{T_{stall}}\left(\frac{N_G}{nN}\right)\right] > \omega_E}$$

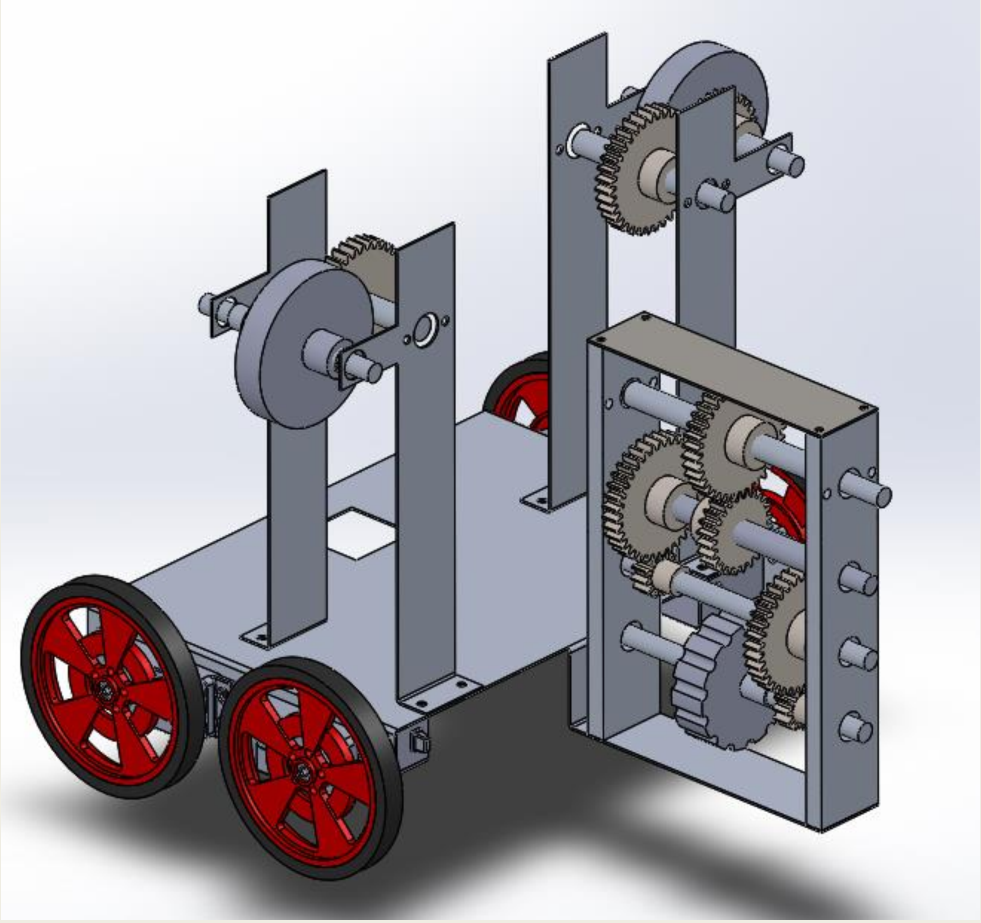
$$\boldsymbol{T_{stall} > \left(\frac{1}{n}\right)\left(\frac{N_G}{N}\right)T_{f,s}}$$

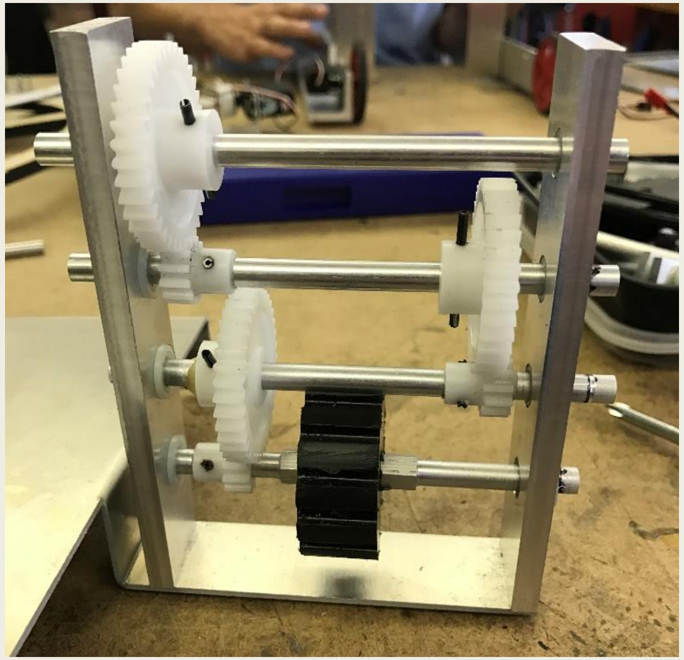
Choosing Motor and Gear Reduction: X-Wing Module

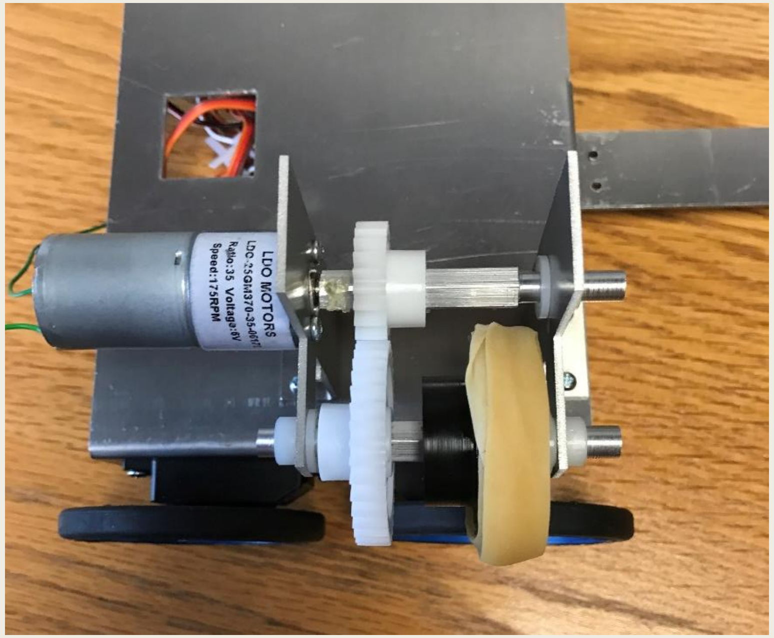
⟹ BO-P5 Running at 5V with 1 : 13.5 gear reduction yields theoretical engine speed of <u>*254 rpm*</u>

⟹ Minimum stall torque is achieved with S.F. of 2

Final Design







Moving Forward

- Required
  - *Finish assembling robot and test*
  - *Practice!*
- As time allows
  - *Program Arduino for autonomous period*
  - *Add simple device for light saber tilt*

Questions?

Presentation Appendix

Motor Operation: Torque vs. Speed Curve