Computer Controlled Aiming and Tagging System

Fall Final Presentation

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Project Overview

- Background and Problem Statement
- Concepts
- Motors
- Controller & Components
- Power systems
- Firing system

Background

- Real time analysis to test the ability and accuracy of C-CATS program
- Old Way:
  - Run dynamic cable testing with cameras and data sensors
  - Hours of post processing to evaluate data
  - Must start all over if the data is bad

Problem Statement

- Solution:
  - System with ability to see the accuracy immediately
  - Real time mark on target to collect data
  - Immediate feedback for good run/bad run
- Project Goal:
  - Tagging system that can be statically tested for accuracy, repeatability, fire latency and safety

High Level Specifications

Specification	Value
Budget	$2000
Maximum Range	25 m
Azimuth Range	360 deg
Elevation Range	90 deg
Angular Velocity	≥ 360 deg/s
Resolution	≤ 1 deg/s
Maximum Weight	50 lb.
Power Source	Honda EU1000i Generator
Motors	Servos
Tagging System	Paintballs

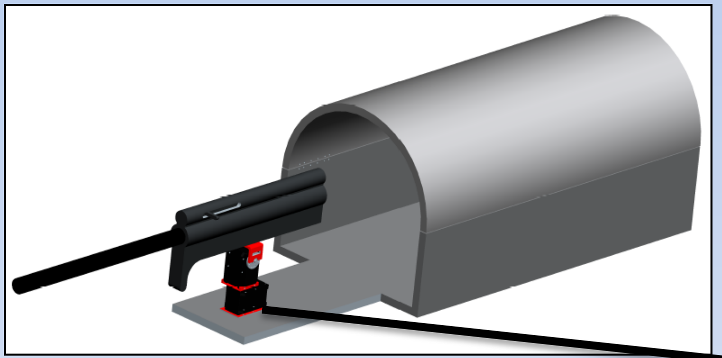
Mechanism

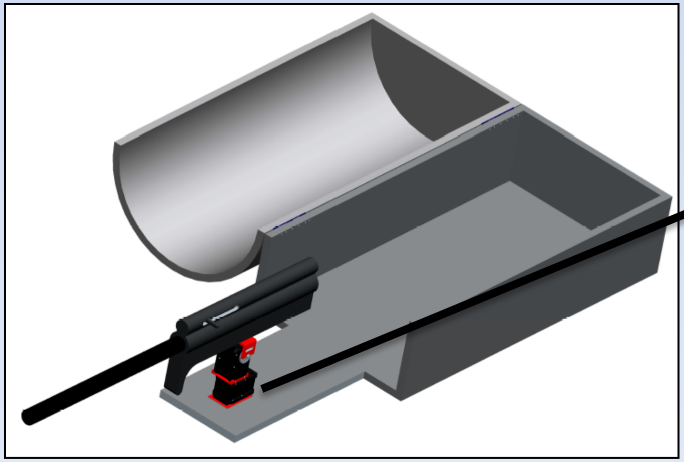
- Will incorporate a Double Gimbal assembly
- A gimbal is a pivoted support that allows the rotation of an object about a single axis.
- Double-Gimbal assembly will provide the mechanism with two degrees of freedom
  - Requires two motors

The Phalanx close in weapon system (CIWS)
http://www.armybase.us/2009/05/raytheon-us-navy/

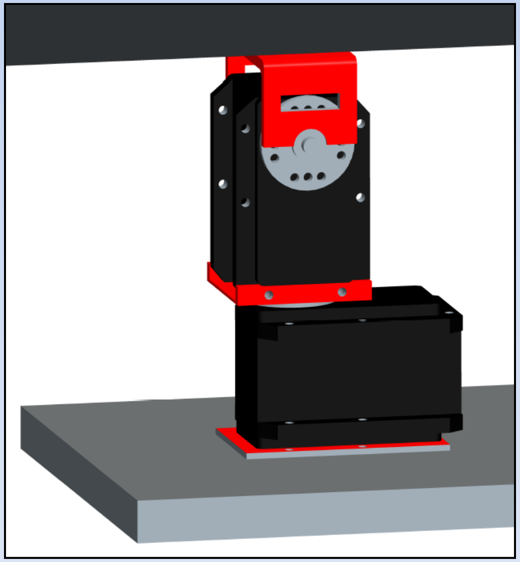
Concepts

Concept 1





Zoom of Motor Configuration



Concept 1 Data

$$I_x = 101.80 \frac{lb}{in^2} \qquad I_y = 90.23 \frac{lb}{in^2}$$

$$\tau_x = I_x \alpha_{\max} \qquad \tau_y = I_y \alpha_{\max}$$

Concept 1 Properties:	
Housing	Aluminum 6061
Elevation Torque Needed	4.95 N*m
Azimuth Torque Needed	5.59 N*m
System Weight	49 lbs.

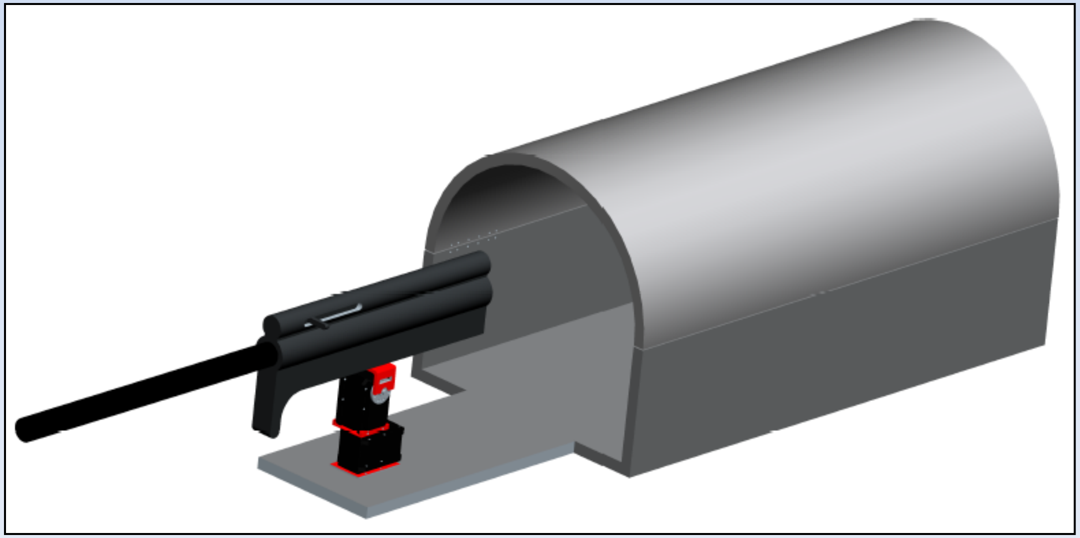
Concept 1

Pro

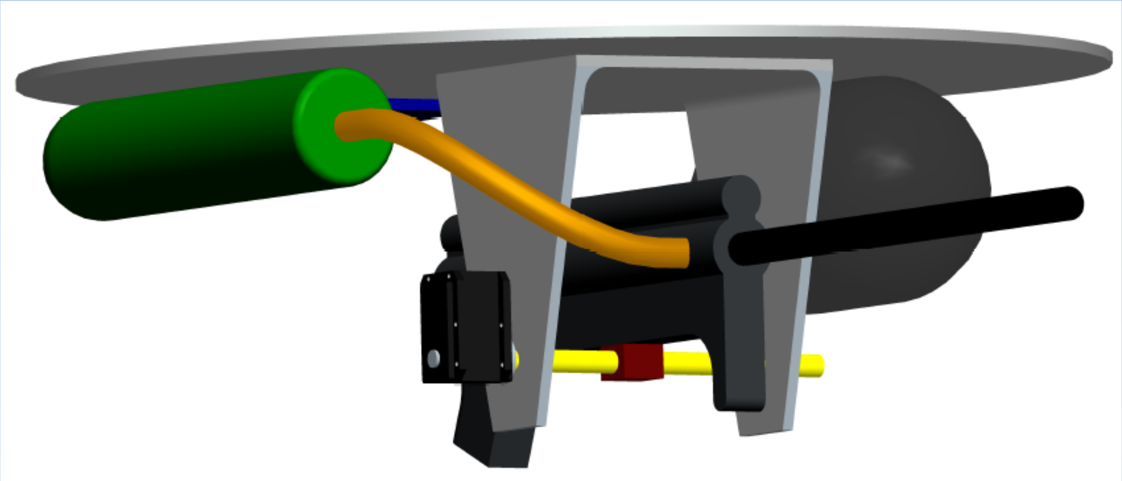
- **All components enclosed in box**
- **Motors move gun directly**

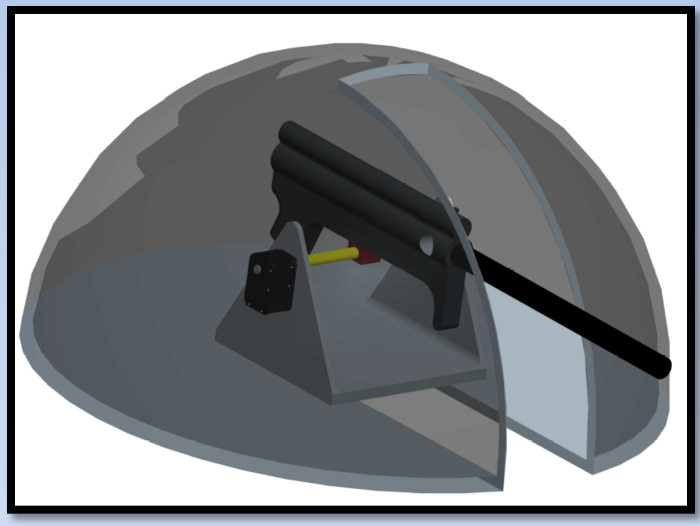
Con

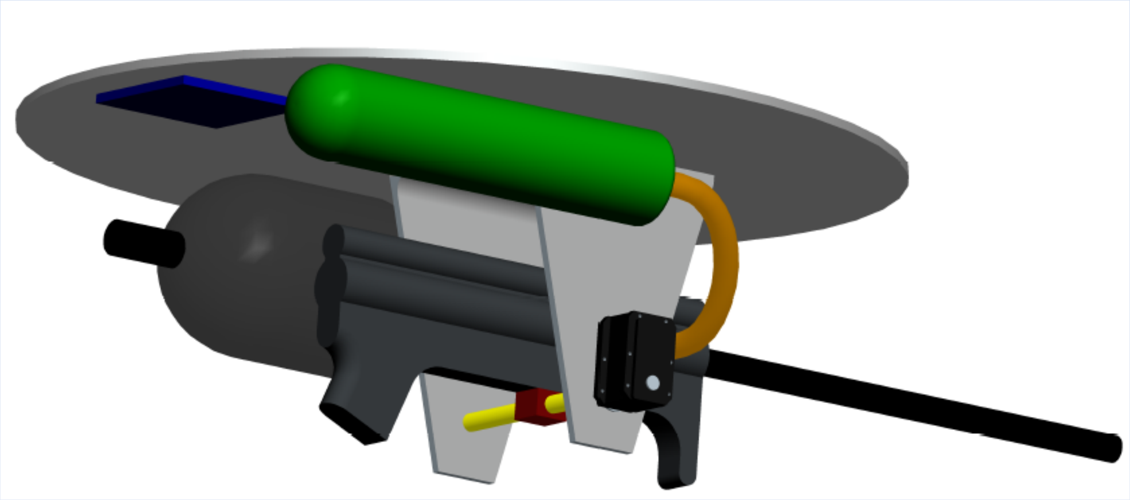
- **Wires and hoses can get tangled when operating and restrict movement**
- **System weight ~ 49 lbs**



Concept 2 Revised







Concept 2 Revised Data

$$I_x = 1255.23 \frac{lb}{in^2} \qquad I_y = 90.23 \frac{lb}{in^2}$$

$$\tau_x = I_x \alpha_{\max} \qquad \tau_y = I_y \alpha_{\max}$$

Concept 2 Properties:	
Baseplate	Aluminum 6061
Gun Bracket	Aluminum 6061
Elevation Torque	4.95 N*m
Azimuth Torque	77.8 N*m
System Weight	21 lbs.

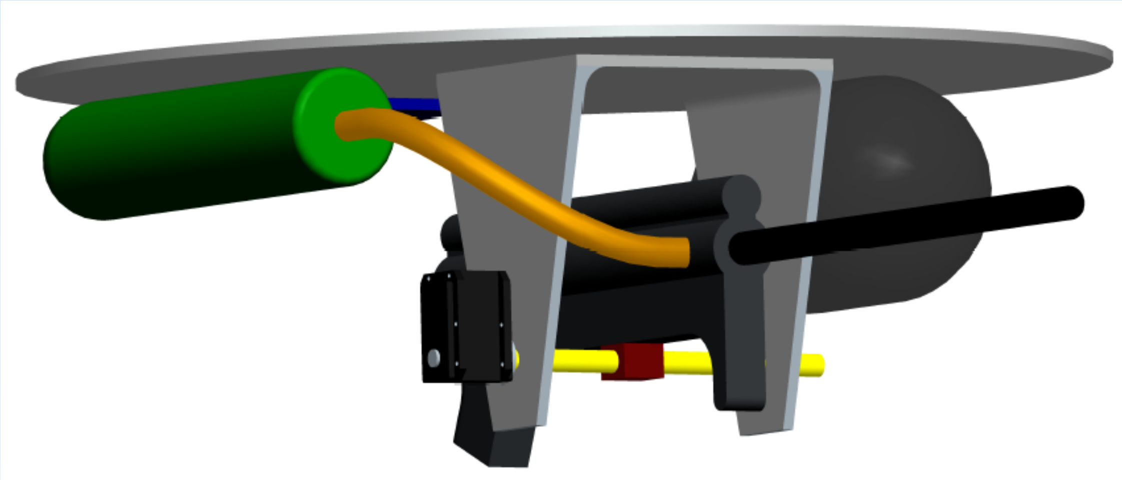
Concept 2 Revised

Pro

- All components rotate with gun
- Can mount brackets for future dynamic testing

Con

- Azimuth torque is extremely high ~ 77.8 Nm



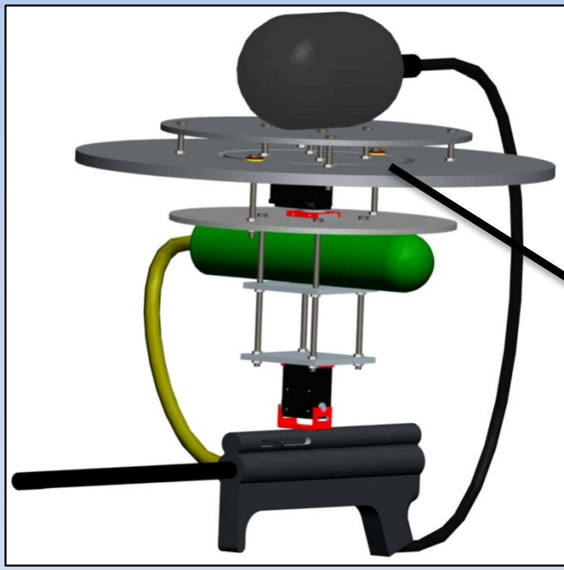
Concept Decision Matrix

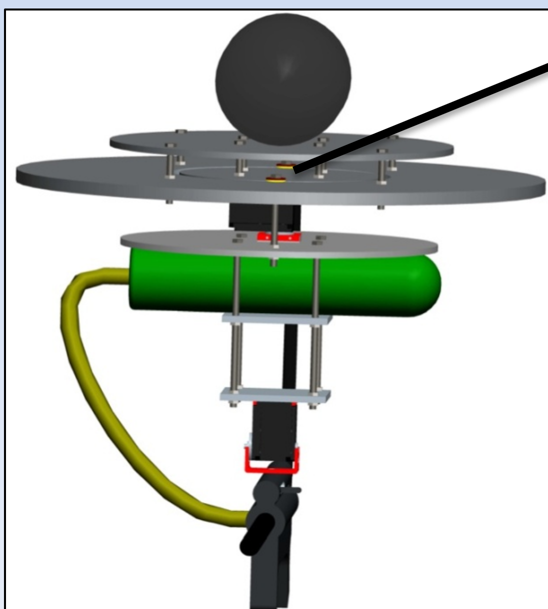
		Concepts			
		Concept 1		Concept 2	
Specifications	**Weight**	Rating	Score	Rating	Score
System Weight	30.0%	2	0.60	4	1.20
Elevation Torque	25.0%	4	1.00	4	1.00
Azimuth Torque	25.0%	4	1.00	1	0.25
Area for Components	20.0%	2	0.40	3	0.60
Total	100.0%		3.00		3.05

Optimization

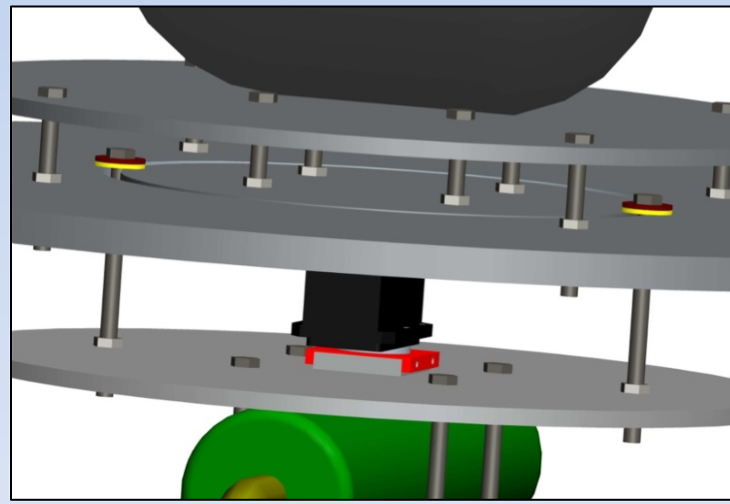
- Both scored very close in decision matrix
- Both exhibit significant cons
- Best from concept 1:
  - Best setup for motor torque values
- Best from concept 2:
  - Most maneuverability
  - Maximum space for component mounts

Concept 3

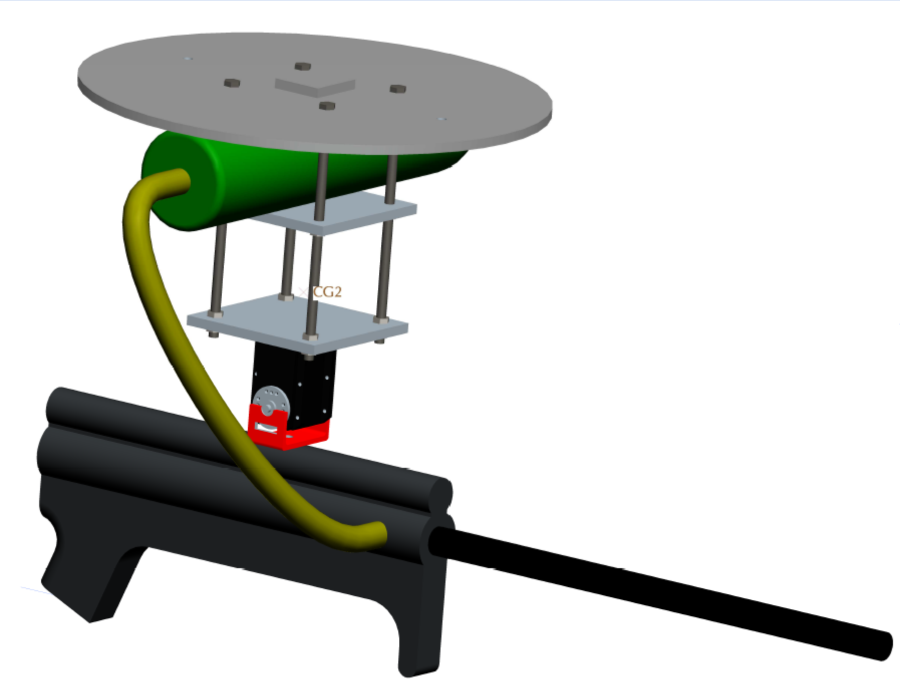


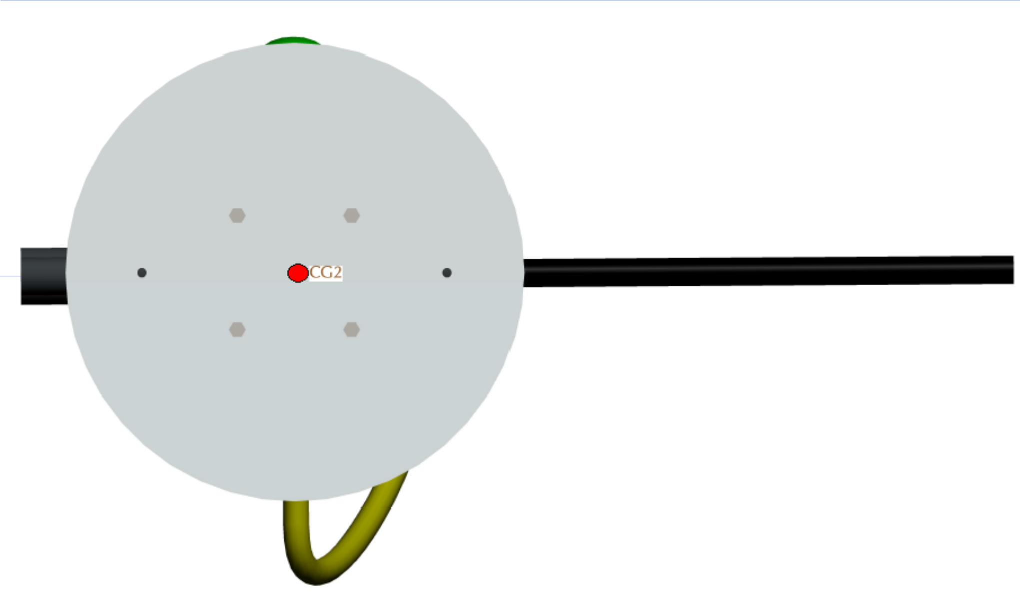


Zoom of Thrust Bearings



Concept 3 Bottom Section





Concept 3 Data

$$I_x = 189.11 \frac{lb}{in^2}$$

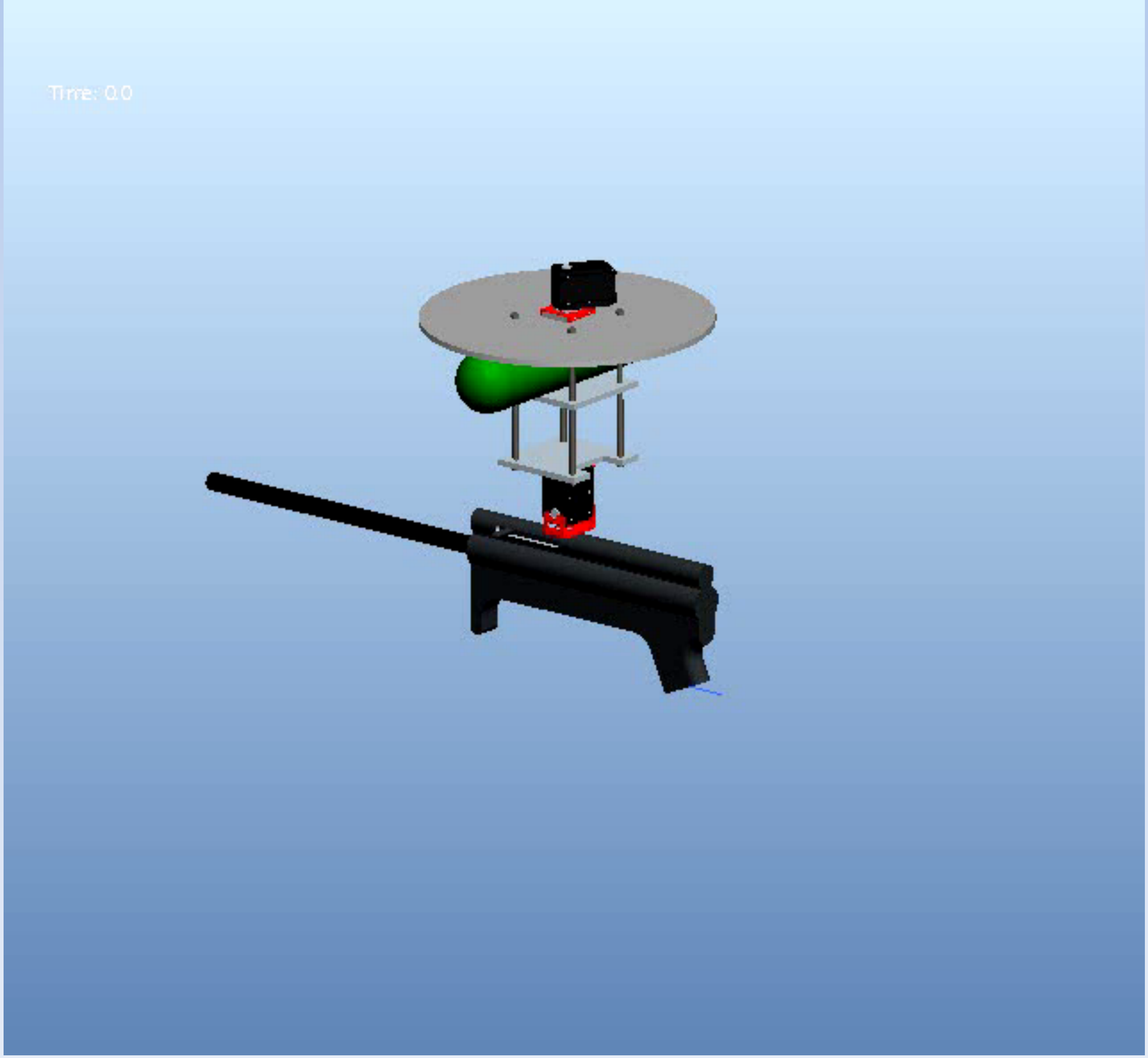
$$I_y = 90.23 \frac{lb}{in^2}$$

$$\tau_x = I_x \alpha_{\max}$$

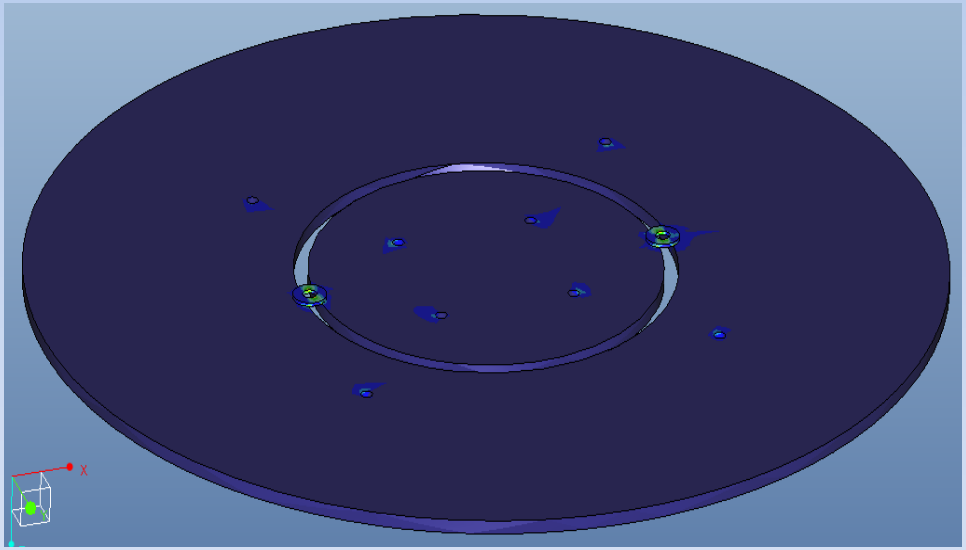
$$\tau_y = I_y \alpha_{\max}$$

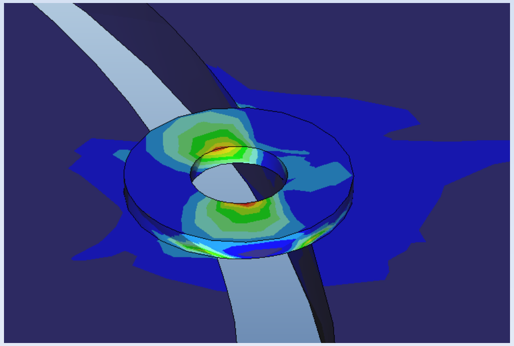
Concept 3 Properties:	
Discs	Aluminum 6061
Elevation Torque	4.95 N*m
Azimuth Torque	10.21 N*m
System Weight	30 lbs.

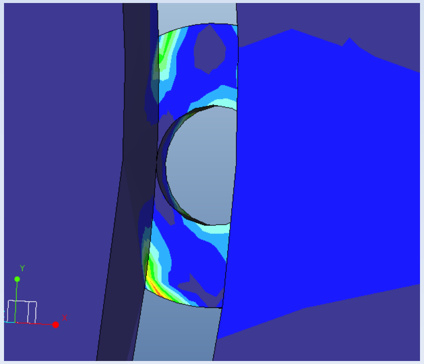
Concept 3



Finite Element Analysis







- Pro/E Mechanica
- Max stresses at thrust bearings
- Max stress only about 9,000 psi
- Factor of safety of 4.4

Motors

Motors

- Two different Dynamixel servo motors will be integrated into our system.
  - RX-64
    - Responsible for elevation position.
  - EX-106+
    - Responsible for azimuth position.
- Both will be linked in series by a daisy chain bridge from the Arbotix controller to power and control.

• Daisy chain link

http://www.trossenrobotics.com/images/productdownloads/EX106%28English%29.pdf

Motors

- Dynamixel Rx-64
- Torque: 64 kg-cm (6.276Nm)
- Speed: 0.157sec/60º
  (382 º/s)
- 18 V
- Resolution 0.29 deg
- 300 deg operating angle

http://www.trossenrobotics.com/dynamixel-rx-64-robot-actuator.aspx

Motors

- Dynamixel EX-106+
- Torque: 106 kg-cm (10.395Nm)
- Speed: 0.143sec/60º (420 º/s)
- 18 V
- Resolution 0.06 deg
- 251 deg operating angle

http://www.trossenrobotics.com/dynamixel-ex-106-robot-actuator.aspx

Controller & Components

Controller

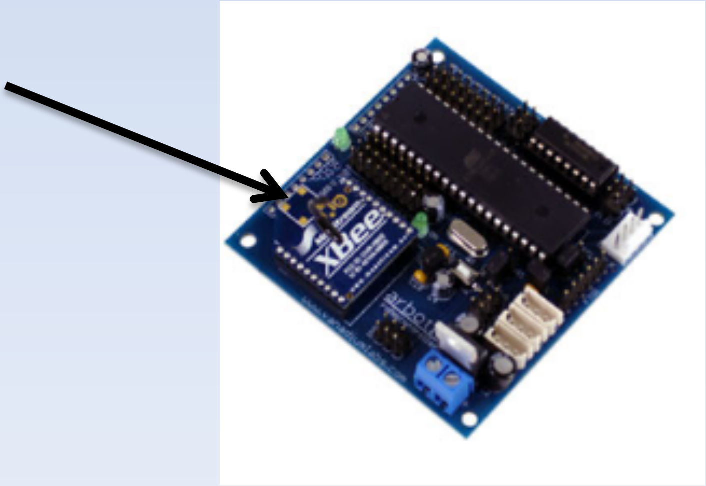
http://www.trossenrobotics.com/p/arbotix-robot-controller.aspx

- ArbotiX RoboController
  - ATMEGA644p microcontroller.
  - 16 MHz clock speed for accuracy.
  - 2 serial ports, 1 dedicated to Bioloid servo controller,

    the other to the XBEE wireless radio.
  - BioloidController library (open source) available for use with the Arduino IDE for Dynamixel servo motors.

Xbee Wireless Radio

- An Xbee 1 mW radio transmitter will be used to remotely communicate to our system.
- The user will be able to input commands from a distance of 100 meters.
- The XBee transmitter will be mounted on the USB module and connected to a laptop via USB cable and the receiver will be placed on the motor controller.



http://www.trossenrobotics.com/p/arbotix-robot-controller-starter-kit.aspx

http://www.trossenrobotics.com/p/arbotix-robot-controller-starter-kit.aspx

Power Systems

Power Supply

Power Generators

- Allows for testing to be done in an outside environment
- Customer prefers power generator
- Allow for multiple testing without any down time
- Uses existing inverter to allow for varying voltage output
- Operating time is 8+ hr

http://www.etpetersen.com/ope/honda.htm

Power Supply

- Standard wall plug
  - Powers board

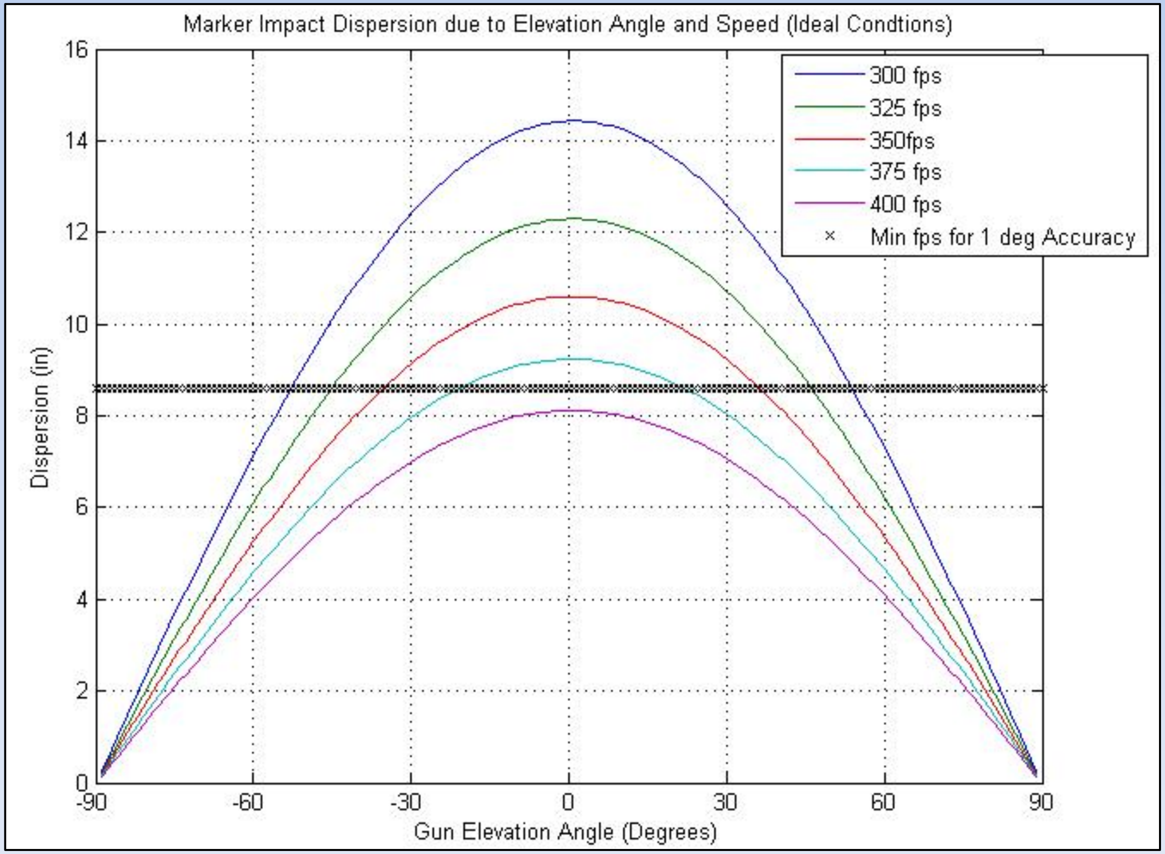
http://www.trossenrobotics.com/p/power-supply-12vdc-2a.aspx

- AC to DC Variable Power
  - Powers motors

http://www.trossenrobotics.com/p/power-supply-Variable-4-5amp.aspx

Firing Systems

Firing System Requirements



- Achieve dispersion of less than a degree
- Arc length radius calculated to be 8.59 in at 25 m range
- Muzzle velocity between 375 – 400 psi

Tagging System

- Tippmann A-5
  - Rugged
  - Relatively Light
    ~ 3.11 lb
  - "E" Trigger
  - Cost Effective

http://www.compulsivepaintball.com/mmCOMPULSIVEPAINTBALL/Images/Tippmann%20A5%20V2%20With%20Selector%20Switch.jpg

Model

Tagging System Components

Q loader Hooper

- Spring forces paintballs through feeding hose and into gun
- Hose can be adjusted to fit many design specifications
- The Q Loader can feed against gravity so it can be placed in a variety of positions

http://paintballking.wordpress.com/category/paintball-guns

Hammerhead Freedom Fighter Barrel

- Longer barrels for better accuracy and consistency
- Cost effective
- It is the barrel used in the modeled design

http://hammerheadpaintball.com

Tagging System Components Cont

Nitrogen Pressure System

- Maintains stable pressure at different ambient temperatures
- Customer provides Nitrogen at testing facility

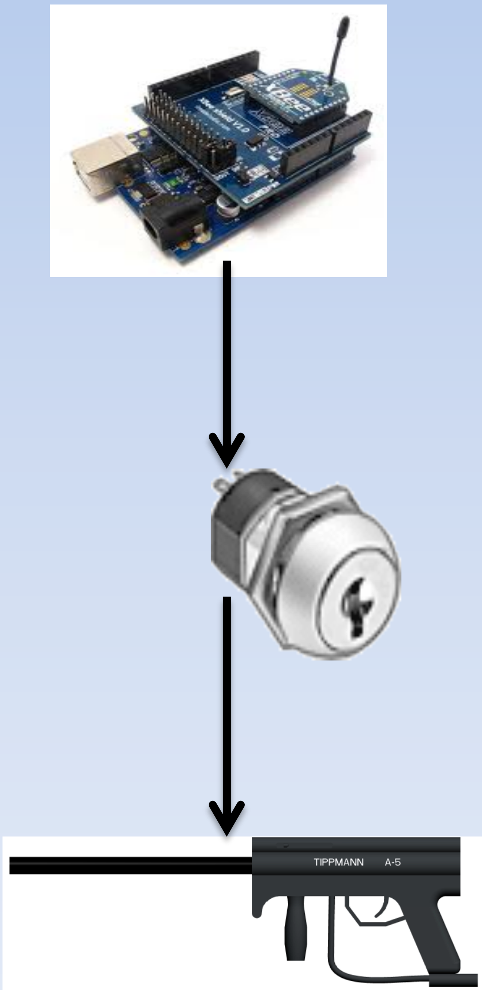
http://marketpaintball.info/4545-crossfire-high-pressure-tank-fs.html

Paintballs (Evil vs. Golf paintball)

- Golf paintballs are more feasible since the mark can be measured easily
- Evil are more cost effective and are commonly used in standard paintball guns
- Testing is needed to conclude which paintball is more accurate

http://www.rap4.com/rap4-golf-paintball-training-projectiles-a-258.html

Safety



3 Ways:

1) Remove mechanical trigger
   - No accidental pull

2) Have separate channel for firing command
   - Does not allow for mixed signals when positioning the system

3) Simple on/off Switch
   - Wired between controller and trigger
   - No signal can be sent unless keyed switch is turned ‘on’

Budget

Paint:	
G.O.L.F Paintballs (500)	$24.95
EVIL Paintballs (2000)	$70.00
Gun & Upgrades:	
Tippmann A5 with E-Trigger	$368.45
Hammerhead Barrel	$59.00
Air Supply	$129.95
Coiled Air Hose	$30.00
Grip Rail	$20.00
Motors:	
Motors & Brackets Package	$651.40
Controller/Components:	
Controller & Bridge	$139.94
Wireless Receiver	$21.95
Wireless Remote	$24.95

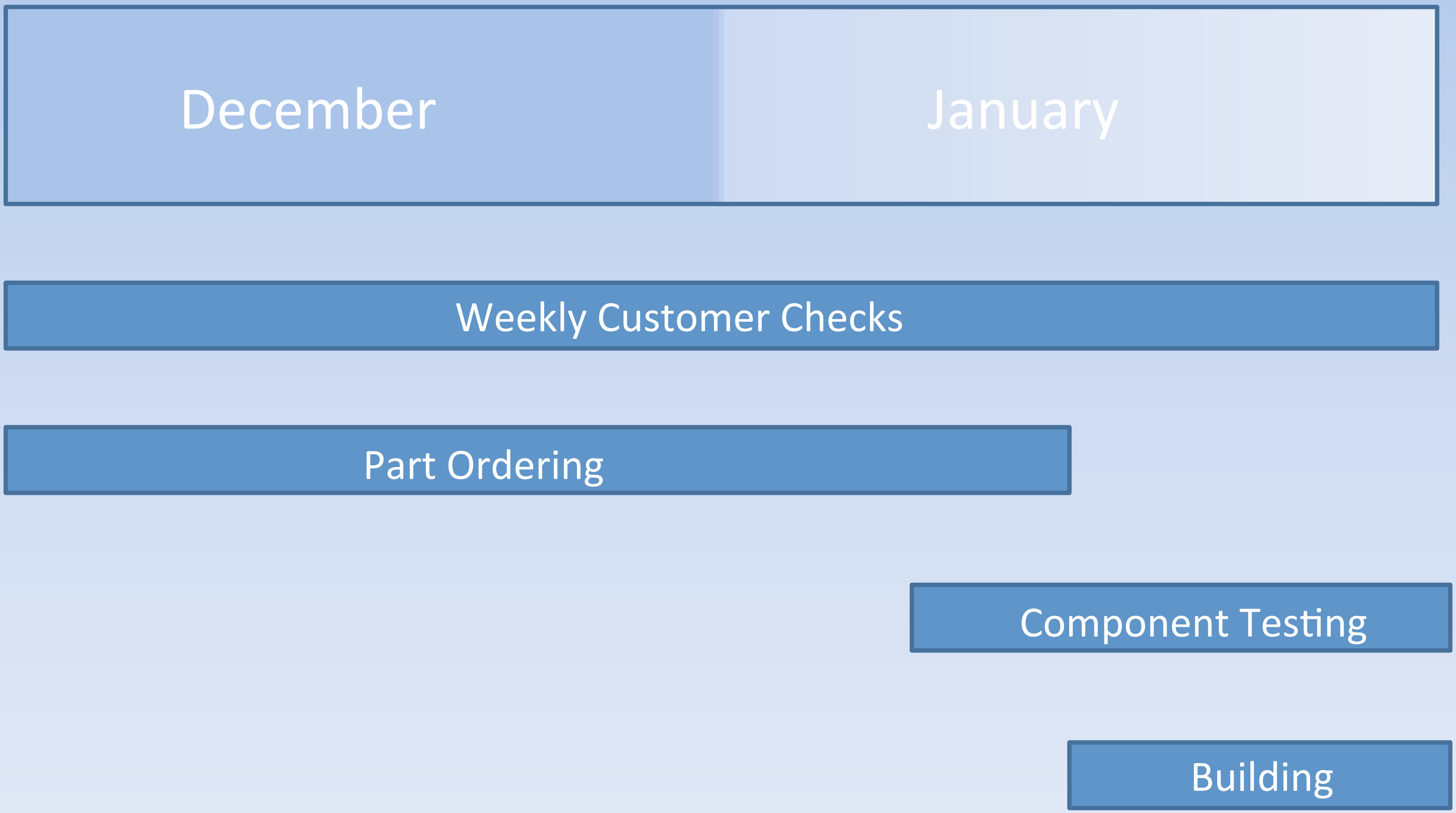
Left Over	$459.41
Assembly Materials	TBD
Extra Compnents	TBD

- *Motor value excluding sponsor provided higher torque motor

Ordering

- Orders completed:
  - Motors
  - Controller
  - Controller Bridge
  - Wireless connector
  - Paintball Gun
- Pending Orders:
  - Safety Mechanism
  - Air Supply
  - Paint
  - Materials

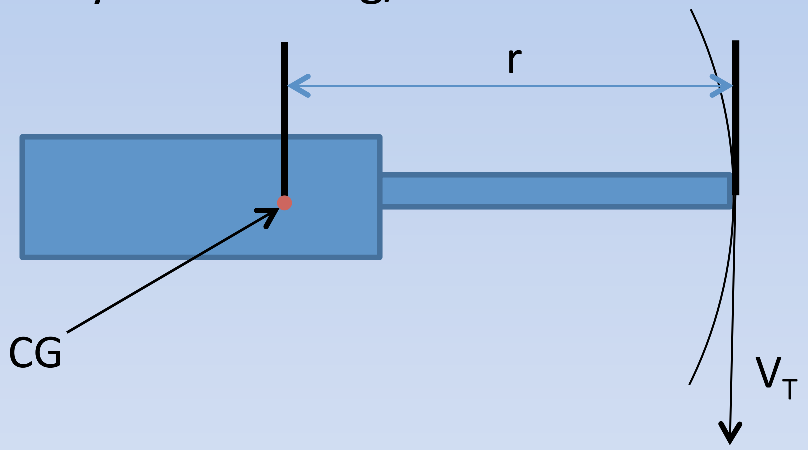
Timeline


December
January
Weekly Customer Checks
Part Ordering
Component Testing
Building

Questions ?

Appendix 1 Equations

- Minimum angular velocity ω = 360 deg/s

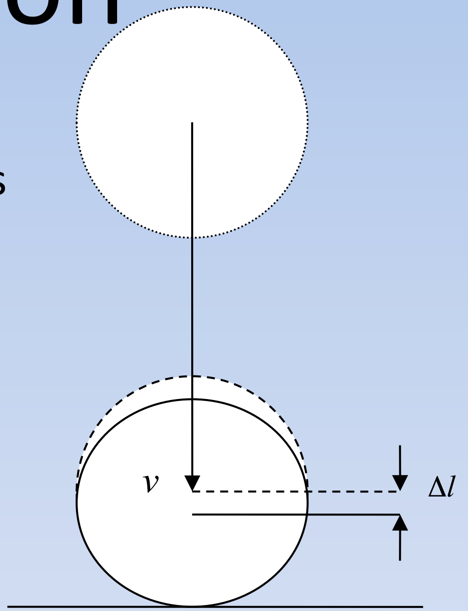


Tangential Velocity

$$V_{Tavg} = \omega r$$

Acceleration

- Maximum acceleration modeled as ball falling at tangential velocity with 2 inch travel of center mass



$$a_{T\max} = \frac{E_K}{m\Delta l} = \frac{\frac{1}{2}mv^2}{m\Delta l} = \frac{\frac{1}{2}v^2}{\Delta l}$$

Angular Acceleration

$$\alpha_{\max} = \frac{a_{T\max}}{r}$$

Required Torque

- Torque = Moment of Inertia * Angular Acceleration

$$\tau = I\alpha$$

- Moment of Inertia modeled in Pro/E.

- Max Required Torque:

$$\tau_{\max} = I\alpha_{\max}$$

Appendix 2

```
VOLUME =  6.4179570e+01  INCH^3
SURFACE AREA =  2.5125709e+02  INCH^2
DENSITY =  4.8500000e-02 POUND / INCH^3
MASS =  3.1127092e+00 POUND

CENTER OF GRAVITY with respect to _COMPLETE_MARKER coordinate frame:
X   Y   Z      1.9949758e-03 -1.0658488e+00  6.7722735e+00  INCH

INERTIA at CENTER OF GRAVITY with respect to _COMPLETE_MARKER coordinate frame:  (POUND * INCH^2)

INERTIA TENSOR:
Ixx Ixy Ixz  1.0180225e+02 -3.8512100e-03 -2.6614187e-02
Iyx Iyy Iyz -3.8512100e-03  9.0239872e+01 -9.0413392e+00
Izx Izy Izz -2.6614187e-02 -9.0413392e+00  1.2179945e+01
```

$\omega := 360\frac{deg}{s}$ $\quad r := 19in$ $\quad v := \omega \cdot r$ $\quad v = 3.032\frac{m}{s}$ $\quad l := 2in$ $\quad I_y := 90.27lb \cdot in^2$

$I_x := 101.82lb \cdot in^2$

$a_{Tmax} := \frac{0.5 \cdot v^2}{l}$ $\quad a_{Tmax} = 90.498\frac{m}{s^2}$

$\alpha_{max} := \frac{a_{Tmax}}{r}$ $\quad \alpha_{max} = 187.522 \cdot \frac{rad}{s^2}$

$\tau_y := I_y \cdot \alpha_{max}$ $\quad \boxed{\tau_y = 4.954 \cdot N \cdot m}$

$\tau_x := I_x \cdot \alpha_{max}$ $\quad \boxed{\tau_x = 5.588 \cdot N \cdot m}$

Appendix 3

```
VOLUME =   2.7981691e+02   INCH^3
SURFACE AREA =  1.7695312e+03   INCH^2
AVERAGE DENSITY =  7.6388289e-02 POUND / INCH^3
MASS =  2.1374735e+01 POUND

CENTER OF GRAVITY with respect to _ASSEMBLY2 coordinate frame:
X   Y   Z     1.2472702e+01  1.2085892e+01 -1.6546980e+00   INCH

INERTIA at CENTER OF GRAVITY with respect to _ASSEMBLY2 coordinate frame:  (POUND * INCH^2)

INERTIA TENSOR:
Ixx Ixy Ixz  6.8998472e+02 -2.8619231e+01  5.0353468e+01
Iyx Iyy Iyz -2.8619231e+01  7.6841504e+02  7.9118966e+00
Izx Izy Izz  5.0353468e+01  7.9118966e+00  1.2552376e+03
```

-

$\omega := 360\frac{deg}{s}$ $\quad r := 21.46in$ $\quad v := \omega \cdot r$ $\quad v = 3.425\frac{m}{s}$ $\quad l := 2in$ $\quad I_z := 1255.23lb \cdot in^2$

$$a_{Tmax} := \frac{0.5 \cdot v^2}{l} \qquad a_{Tmax} = 115.45\frac{m}{s^2}$$

$$\alpha_{max} := \frac{a_{Tmax}}{r} \qquad \alpha_{max} = 211.802 \cdot \frac{rad}{s^2}$$

$$\tau := I_z \cdot \alpha_{max} \qquad \boxed{\tau = 77.801 \cdot N \cdot m}$$

Appendix 4

```
VOLUME =  1.5772375e+02  INCH^3
SURFACE AREA =  7.0162309e+02  INCH^2
AVERAGE DENSITY =  6.2013963e-02 POUND / INCH^3
MASS =  9.7810748e+00 POUND

CENTER OF GRAVITY with respect to _ANIMATE coordinate frame:
X   Y   Z      6.8791061e-01  1.9365967e+00  5.0794214e+00  INCH

INERTIA at CENTER OF GRAVITY with respect to _ANIMATE coordinate frame:  (POUND * INCH^2)

INERTIA TENSOR:
Ixx Ixy Ixz  3.1662820e+02  4.6119390e+01  3.4980887e+00
Iyx Iyy Iyz  4.6119390e+01  3.6016569e+02 -1.0525470e+00
Izx Izy Izz  3.4980887e+00 -1.0525470e+00  1.8911818e+02
```

$\omega := 360\frac{deg}{s}$ $\quad r := 18.71in$ $\quad v := \omega \cdot r$ $\quad v = 2.986\frac{m}{s}$ $\quad l := 2in$ $\quad I_Z := 189.01lb \cdot in^2$

$$a_{Tmax} := \frac{0.5 \cdot v^2}{l} \qquad a_{Tmax} = 87.757\frac{m}{s^2}$$

$$\alpha_{max} := \frac{a_{Tmax}}{r} \qquad \alpha_{max} = 184.66 \cdot \frac{rad}{s^2}$$

$$\tau := I_Z \cdot \alpha_{max} \qquad \boxed{\tau = 10.214 \cdot N \cdot m}$$