

Halo

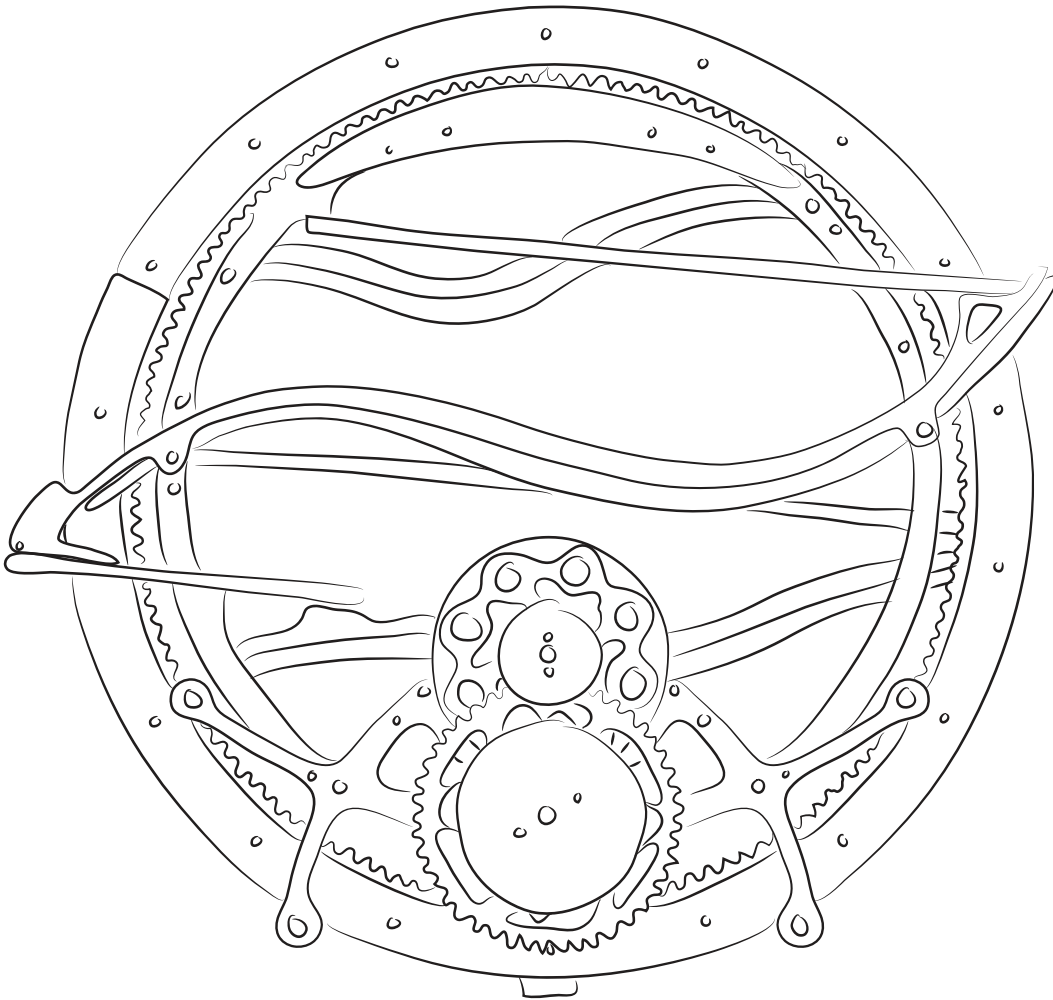
a mechanical marble machine

sample

Important information:

McMaster Carr, a supplier whose part numbers are referenced throughout this document, can only ship within the United States. Builders outside of the U.S. must find an alternate supplier for the required hardware.

Hardware part numbers and availability are subject to change.
Verify that all hardware or equivalents are obtainable prior to purchasing these plans.



design by Derek Hugger

The Basics

Contents

These plans include all the information required to build Halo. They provide an outline of the build process, tips for an accurate and successful build, lists of required tools and off-the-shelf components, a complete parts list, full scale patterns for all plywood parts, and step-by-step assembly instructions.

Before Building

Read and understand all instructions before building. Failure to do so will lead to increased frustration levels, lengthened build times, wasted material, and other vexing occurrences.

Build Process

Always wear eye protection and any other necessary personal protective gear. Read, understand, and abide by all manufacturer instructions and warnings for all tools used.

1. Use a light duty/general purpose spray adhesive to temporarily bond the patterns to plywood. Apply the adhesive evenly and sparingly.
2. Drill the holes first, and then cut out the parts. Hole alignment between parts is critical to proper function, so care must be taken to drill the holes accurately. Take time to cut out the parts accurately. An accurately cut part will require less sanding and less modification later.
3. Remove the patterns from the cut plywood parts, and then sand the parts to remove rough edges and any residual adhesive.
4. Following the assembly instructions, build all subassemblies and then the Top Level Assembly. While assembling, cut and tap all aluminum tubes and brass tubes as required. See Plywood Thickness Compensation in Tips + Tactics.
5. If desired, disassemble Halo to finish its components. Note that stain and other finish options can affect the thickness of parts and may also affect friction levels between moving parts.

Notes

When printing the patterns, always print at 100% scale. Do not use the “scale to fit page” option.

Halo contains many moving wood parts as well as wood parts that stack onto one another. As such, using a quality, flat Baltic birch plywood is very important. Cheaper, lower quality plywood, such as types often found at home improvement stores like Home Depot, can be warped and knotted.

Changing humidity levels can cause wood parts to swell and move. Some binding or changes in performance may occur with changes in humidity. As humidity levels return to normal, so too should the system’s performance.

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Tools

Power Tools

General

Drivers

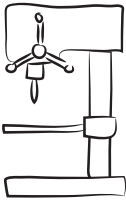
Required



bandsaw



scroll saw



drill press



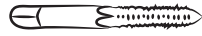
belt/disc sander



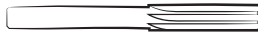
brad point drill index
1/16" to 1/2"
in 1/64" increments



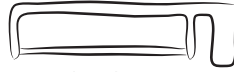
drill bits #29, 3/32", 3/16", 7/32", 1/4"



tap 8-32



reamers
0.0650", 0.2530"



hacksaw



clamps



calipers



precision files



phillips #1



hex 5/64"

Supplies



sandpaper

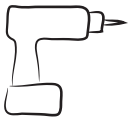


spray adhesive

Recommended
(but not required)



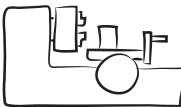
mini chop saw



drill



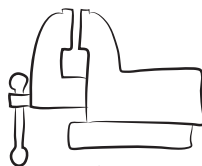
rotary tool



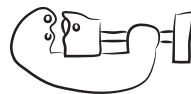
metal lathe



cnc router*



vice



tube cutter



automatic center punch

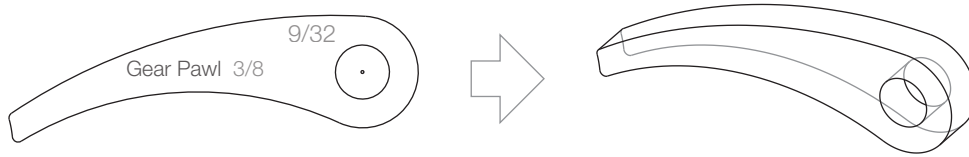
* A CNC router is an optional replacement for the bandsaw and scroll saw for cutting the plywood parts.

Tips + Tactics

Pattern Syntax

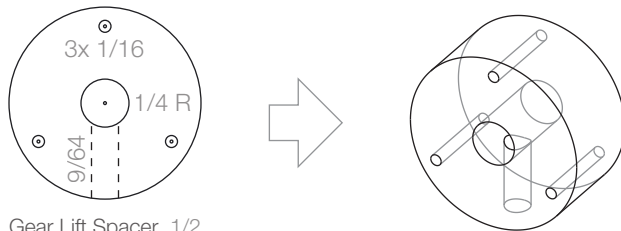
- Patterns are labeled with a part name followed by a thickness dimension.

Example: Gear Pawl is cut from 3/8" plywood. It also has a hole to be drilled thru with a 9/32" bit.



- Straight dashed lines indicate a hole drilled from the side, centered on the thickness of the part (unless otherwise noted).
- An "R" after a hole dimension means "ream". The hole should be drilled to the specified dimension, and then reamed slightly larger. For required reamer sizes, see the Tools page.

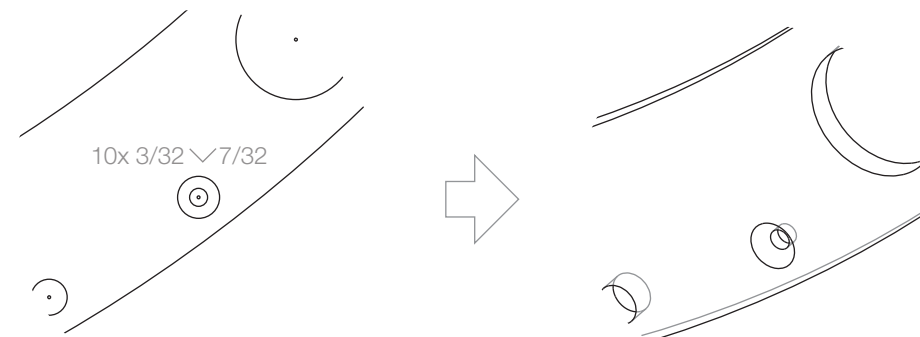
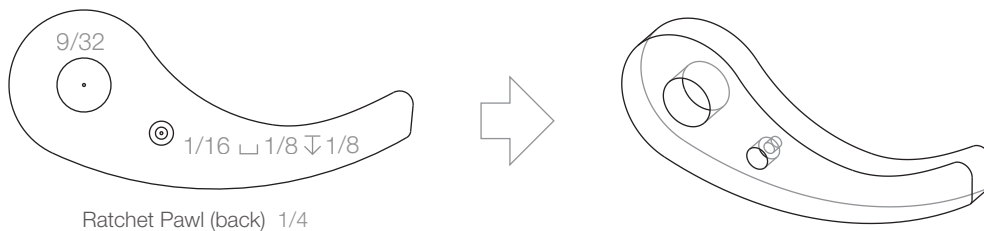
Example: Gear Lift Spacer has a 9/64" hole drilled from the side. It also has three 1/16" thru holes and a 1/4" thru hole that is then reamed to 0.253".



- Two concentric circles indicate a hole with a counterbore (□) or a countersink (∇).
- When a part name is followed by "(back)", that means the part pattern is shown from the back side.

Example 1: Ratchet Pawl has a 1/16" hole drill thru, with a 1/8" counterbore drilled 1/8" deep. It also has a 9/32" thru hole. This part is shown from the back side. Additionally, in the specific case of the Ratchet Pawls, each Ratchet Pawl must also be sanded thin. See the note above the Ratchet Pawls on their pattern page.

Example 2: Lift Ring Rear C (in the partial view shown below) has a 3/32" hole drilled thru, with a 7/32" diameter countersink. Note: Countersinks can be drilled with a standard drill bit; the angle of the countersink is not critical. The goal of the countersinks is to allow the heads of the fasteners that are inserted into them to sit slightly subflush with the wood.



Tips + Tactics

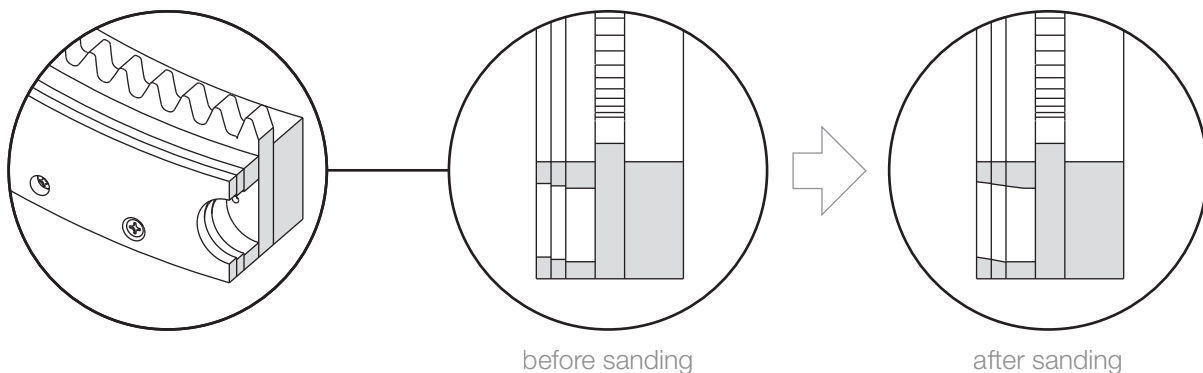
Plywood Thickness Compensation

The exact thickness of plywood is typically thinner than the plywood's specification. For example, 1/4" plywood may actually measure 0.23" thick. Because of this, it may be necessary to adjust the lengths of many of Halo's metal components. To save time and reduce the reworking of metal parts, cut the metal parts after cutting and measuring the thickness of their mating wood parts.

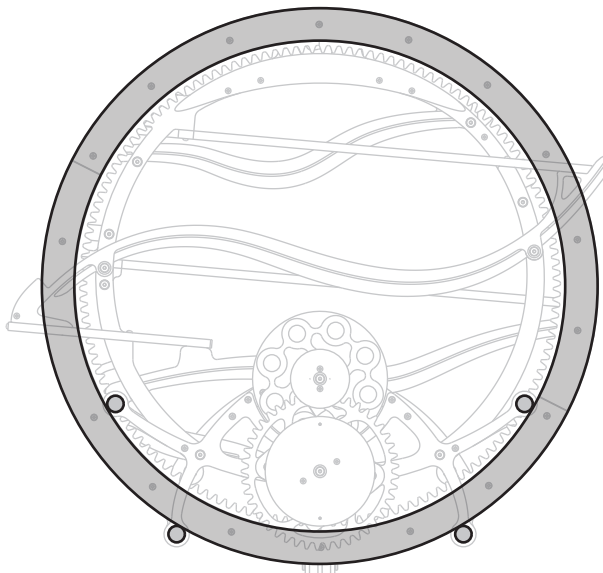
Lift Ring Asm

Halo's Lift Ring Asm uses stacked layers of wood with holes in slightly different locations to create stepped ramps that allow the marbles to enter or exit the Lift Ring. At the bottom of Halo, these ramps formed by the 5/8" holes allow the marbles to roll into the Lift Ring. As the Lift Ring rotates, carrying the marbles up to the top of the tracks, the holes (and the ramps formed by them) rotate as well. So, at the top of Halo, the ramps allow the marbles to exit. The alignment distance between the 5/8" holes only differs by about 0.020" between wood layers, so again, care must be taken to cut these holes accurately. If the 5/8" hole locations are too far off, the marbles may not enter or exit the Lift Ring, resulting in no marbles rolling down the tracks, even if the Lift Ring is rotating.

Once the Lift Ring is assembled, tested, and working, the edges of 5/8" holes may be sanded down slightly, to help the marbles enter and exit more smoothly.



In addition, the Lift Ring Asm rides on 8 flanged bearings, so not only must the holes that align/connect these parts be cut as accurately as possible, but the outer and inner diameters of each Lift Ring component must be cut accurately as well. If the diameters of these components are not cut accurately, the Lift Ring may bind on the bearings and not move at all. The Lift Ring must spin on flanged bearings with minimal resistance in order for Halo to function correctly.



Tips + Tactics

Tapping

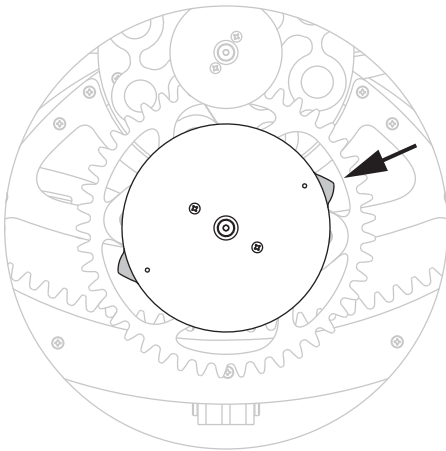
Halo's aluminum tubes must be tapped for an 8-32 thread, with a minimum thread depth of 1/2". Expand the 0.12" inner diameter holes with a #29 drill bit before tapping the threads. When tapping the metal tubes, use plenty of lubricant. Never force the tap; if it feels like it's going to break, it probably will. For every 1/2 to 3/4 turn the tap advances into the metal tube, back it out about 1/4 turn. Repeat this process until the tube is threaded to the desired depth - advance a bit, then back out a bit, advance a bit, then back out a bit.

Eddy Currents - a general FYI

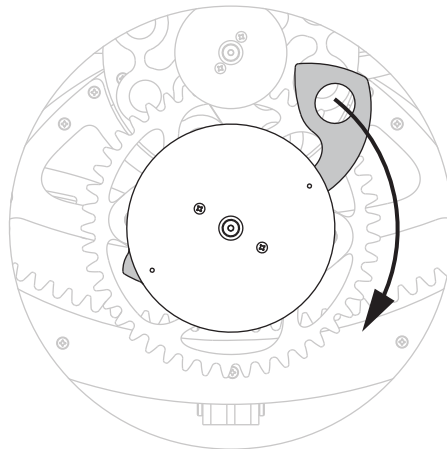
Eddy currents are loops of electrical current induced into conductive materials when the magnetic field around those conductive materials change. In the case of Halo, these currents are created when the 8 large magnets in the Limiter Magnet Array spin in close proximity to the aluminum Limiter Plate. The induced currents generate their own magnetic fields which oppose the magnetic fields of the magnets moving through them. This means that mechanisms acts as a silent, contactless brake. The faster the magnets move, the more they want to slow down. This mechanism allows Halo's Lift Ring to move at a slow, near-constant speed as the spring unwinds.

General Operation

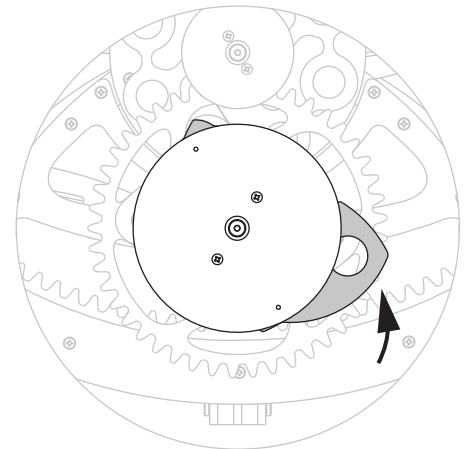
Prior to winding, always ensure Halo is mounted securely to the wall and that none of the three mounting points have lifted away from their respective screws. To wind Halo:



1. Press either of the two Winder buttons to extend a Winder.



2. Spin the Winder clockwise for a few revolutions. **Do not overwind** - stop before seeing the "stop" mark (see Subassembly Step 10).



3. Fold the Winder back into the Drum, and watch Halo work.

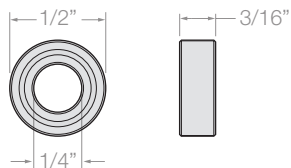
Parts + Assemblies List

Type	Description	Qty	Type	Description	Qty	Type	Description	Qty
Aluminum Tube	ATube 0.610"	4	Aluminum 1/4"	Limitter Plate	1	Subassembly	Drum Large A Asm	1
Aluminum Tube	ATube 0.625"	4				Subassembly	Drum Large Asm	1
Aluminum Tube	ATube 0.680"	2	Plywood 1/8"	Drum Large Cover	1	Subassembly	Drum Small Asm	1
Aluminum Tube	ATube 0.700"	2	Plywood 1/8"	Drum Large D	1	Subassembly	Frame Front Asm	1
Aluminum Tube	ATube 0.740"	4	Plywood 1/8"	Drum Small A	2	Subassembly	Frame Rear Asm	1
Aluminum Tube	ATube 0.875"	6	Plywood 1/8"	Frame Cover	1	Subassembly	Front Asm	1
Aluminum Tube	ATube 1.000"	6	Plywood 1/8"	Lift Ring Rear B	2	Subassembly	Gear Asm	1
Aluminum Tube	ATube 1.375"	1	Plywood 1/8"	Lift Ring Rear C	2	Subassembly	Gear Limiter Large Asm	1
Aluminum Tube	ATube 1.430"	2	Plywood 1/8"	Limitter Spacer Small	1	Subassembly	Gear Pawl Asm	1
Aluminum Tube	ATube 3.613"	1	Plywood 1/8"	Return Track Left	1	Subassembly	Lift Ring Asm	1
Aluminum Tube	ATube 4.867"	1	Plywood 1/8"	Return Track Lower	1	Subassembly	Limitter Magnet Array Asm	1
			Plywood 1/8"	Return Track Right	1	Subassembly	Ratchet Pawl Asm	2
Brass Tube	BTube 0.200"	2	Plywood 1/8"	Return Track Upper	1	Subassembly	Rear Asm	1
Brass Tube	BTube 0.250"	2	Plywood 1/8"	Track Front A	2	Subassembly	Return Track Asm	1
Brass Tube	BTube 0.375"	1	Plywood 1/8"	Track Front B	1	Subassembly	Track Front Asm	1
Brass Tube	BTube 0.500"	1	Plywood 1/8"	Track Front Stop Thin	1	Subassembly	Track Top Asm	1
Brass Tube	BTube 0.680"	2	Plywood 1/8"	Track Rear Bottom	1	Subassembly	Winder Asm	2
Brass Tube	BTube 0.750"	1	Plywood 1/8"	Track Rear Lower A	1			
Brass Tube	BTube 1.125"	1	Plywood 1/8"	Track Rear Lower B	1	Top Level Assembly	Halo	1
Brass Tube	BTube 1.750"	1	Plywood 1/8"	Track Rear Lower C	1			
			Plywood 1/8"	Track Rear Upper A	1			
Stainless Steel	Rod 7/8"	2	Plywood 1/8"	Track Rear Upper B	1			
Stainless Steel	Rod 1-1/4"	1	Plywood 1/8"	Track Spacer Large Thin	2			
			Plywood 1/8"	Track Switch Spacer	2			
Hardware	Bearing	2	Plywood 1/8"	Track Top Wall	1			
Hardware	Bearing Flanged	8						
Hardware	LSHCS 8-32 x 1/4"	27	Plywood 1/4"	Drum Large Spacer	1			
Hardware	LSHCS 8-32 x 3/8"	8	Plywood 1/4"	Frame Front Spacer	1			
Hardware	LSHCS 8-32 x 1/2"	7	Plywood 1/4"	Gear Lift	1			
Hardware	LSHCS 8-32 x 5/8"	5	Plywood 1/4"	Lift Ring Gear	2			
Hardware	LSHCS 8-32 x 3/4"	15	Plywood 1/4"	Lift Ring Rear A	2			
Hardware	Magnet 1/8"	6	Plywood 1/4"	Limitter Spacer Large	1			
Hardware	Magnet 1/4"	2	Plywood 1/4"	Ratchet Pawl	2			
Hardware	Magnet 1/2"	8	Plywood 1/4"	Ratchet Wheel	1			
Hardware	Marble	15	Plywood 1/4"	Return Track Spacer Large	2			
Hardware	Screw #2 x 3/8"	9	Plywood 1/4"	Return Track Spacer Small	4			
Hardware	Screw #2 x 1/2"	18	Plywood 1/4"	Track Horizontal A	1			
Hardware	Screw #2 x 1/2" Flat	20	Plywood 1/4"	Track Horizontal B	1			
Hardware	Screw #2 x 5/8"	42	Plywood 1/4"	Track Horizontal C	1			
Hardware	Screw #2 x 3/4"	24	Plywood 1/4"	Track Spacer Large Medium	10			
Hardware	Set Screw 8-32 x 1/4"	2	Plywood 1/4"	Track Spacer Small	6			
Hardware	Shim	10	Plywood 1/4"	Winder	2			
Hardware	Spring	1						
Hardware	Washer	30	Plywood 3/8"	Frame Front	1			
			Plywood 3/8"	Frame Front Support Left	1			
			Plywood 3/8"	Frame Front Support Right	1			
			Plywood 3/8"	Frame Rear Support Left	1			
			Plywood 3/8"	Frame Rear Support Right	1			
			Plywood 3/8"	Gear Pawl	1			
			Plywood 3/8"	Limitter Plate Mount	1			
			Plywood 3/8"	Track Top A	1			
			Plywood 3/8"	Track Top B	1			
			Plywood 3/8"	Wall Mount	1			
			Plywood 1/2"	Drum Large A	1			
			Plywood 1/2"	Drum Large B	1			
			Plywood 1/2"	Drum Small B	1			
			Plywood 1/2"	Frame Rear Lower	1			
			Plywood 1/2"	Frame Rear Upper	1			
			Plywood 1/2"	Gear Lift Spacer	1			
			Plywood 1/2"	Gear Limiter Large	1			
			Plywood 1/2"	Gear Limiter Small	1			
			Plywood 1/2"	Lift Ring Front	2			
			Plywood 1/2"	Limitter Magnet Array	1			
			Plywood 1/2"	Track Front Stop Thick	1			
			Plywood 1/2"	Track Spacer Large Thick	1			
			Plywood 1/2"	Track Switch	1			

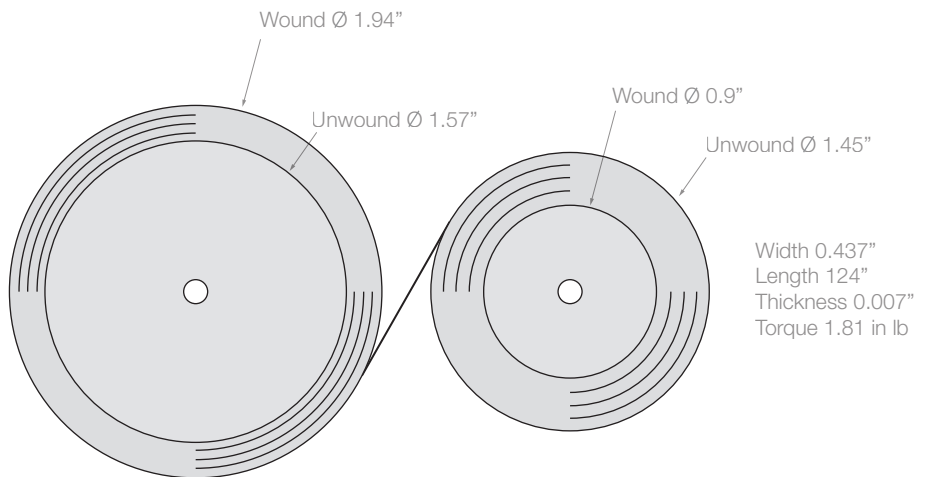
Hardware

Description	Qty	McMaster P/N *	K&J P/N**	SDP P/N***
Bearing (see image below)	2	57155K376	-	-
Bearing Flanged (see image below)	8	57155K323	-	-
LSHCS 8-32 x 1/4" Low Socket Head Cap Screw	27	93615A317	-	-
LSHCS 8-32 x 3/8" Low Socket Head Cap Screw	8	93615A315	-	-
LSHCS 8-32 x 1/2" Low Socket Head Cap Screw	7	93615A320	-	-
LSHCS 8-32 x 5/8" Low Socket Head Cap Screw	5	93615A321	-	-
LSHCS 8-32 x 3/4" Low Socket Head Cap Screw	15	93615A323	-	-
Magnet 1/8" Neodymium, Grade N52, Ø1/8" x 1/8"	6	5862K101	or D22-N52	-
Magnet 1/4" Neodymium, Grade N52, Ø1/4" x 1/4"	2	5862K116	or D44-N52	-
Magnet 1/2" Neodymium, Grade N52, Ø1/4" x 1/4"	8	5862K129	or D88-N52	-
Marble Steel Ball, Ø1/2"	15	1995T15	-	-
Screw #2 x 3/8" Pan Head Self Tapping Screw	9	92470A097	-	-
Screw #2 x 1/2" Pan Head Self Tapping Screw	18	92470A098	-	-
Screw #2 x 1/2" Flat Flat Head Self Tapping Screw	20	90065A082	-	-
Screw #2 x 5/8" Pan Head Self Tapping Screw	42	92470A101	-	-
Screw #2 x 3/4" Pan Head Self Tapping Screw	24	92470A103	-	-
Set Screw 8-32 x 1/4"	2	92311A190	-	-
Shim 3/8" OD, 1/4" ID, 0.045" thick	10	97022A212	-	-
Spring (see image below)	1	-	-	A 3X51-20007
Washer 3/8" OD, 0.174" ID, ~0.30" thick	30	90107A010	-	-

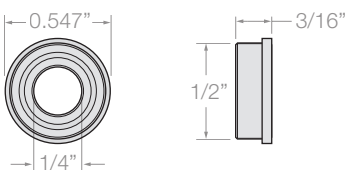
Bearing Shielded, ABEC-5



Spring NEG'ATOR Spring Motor (aka Constant Torque Spring)



Bearing Flanged Shielded, ABEC-5



* Part numbers referenced are from www.mcmaster.com.
 ** Part numbers referenced are from kjmagnetics.com.
 *** Part numbers referenced are from sdp-si.com.

Metal

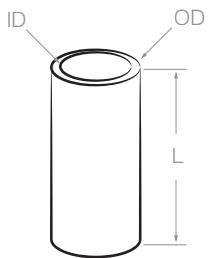
Description	OD x L *	ID	Qty	McMaster Carr P/N **
Brass Tubes:				
BTube 0.200"	9/32" x 0.200"	0.253"	2	8859K25
BTube 0.250"	9/32" x 0.250"	0.253"	2	
BTube 0.375"	9/32" x 0.375"	0.253"	1	
BTube 0.500"	9/32" x 0.500"	0.253"	1	
BTube 0.680"	9/32" x 0.680"	0.253"	2	
BTube 0.750"	9/32" x 0.750"	0.253"	1	
BTube 1.125"	9/32" x 1.125"	0.253"	1	
BTube 1.750"	9/32" x 1.750"	0.253"	1	
Stainless Steel Rods:				
Rod 7/8"	1/16" x 7/8"	-	2	8936K35
Rod 1-1/4"	1/16" x 1-1/4"	-	1	
Aluminum Plate:				
Limiter Plate	4" x 1/4"	0.252"	1	9246K423

See Limiter Plate pattern for additional details.

Aluminum Tubes:

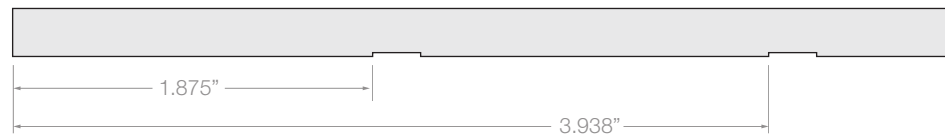
ATube 0.610"	1/4" x 0.610"	0.120"	4	89965K23
ATube 0.625"	1/4" x 0.625"	0.120"	4	
ATube 0.680"	1/4" x 0.680"	0.120"	2	
ATube 0.700"	1/4" x 0.700"	0.120"	2	
ATube 0.740"	1/4" x 0.740"	0.120"	4	
ATube 0.875"	1/4" x 0.875"	0.120"	6	
ATube 1.000"	1/4" x 1.000"	0.120"	6	
ATube 1.375"	1/4" x 1.375"	0.120"	1	
ATube 1.430"	1/4" x 1.430"	0.120"	2	
ATube 3.613"	1/4" x 3.613"	0.120"	1	
ATube 4.867"	1/4" x 4.867"	0.120"	1	

Tap both sides of all aluminum tubes. Shorter tubes may be tapped thru. Minimum thread depth 1/2".



OD outer diameter
ID inner diameter
L length

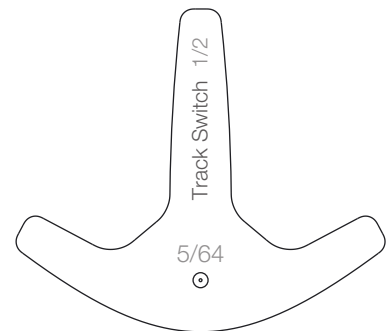
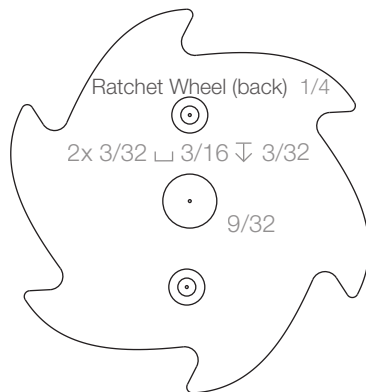
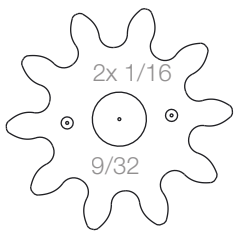
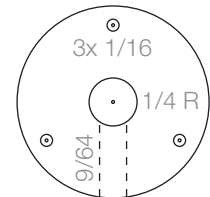
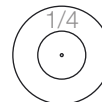
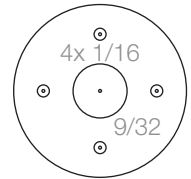
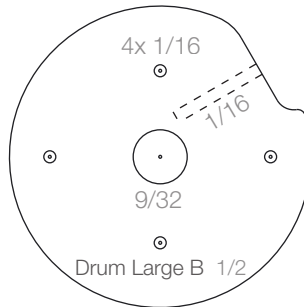
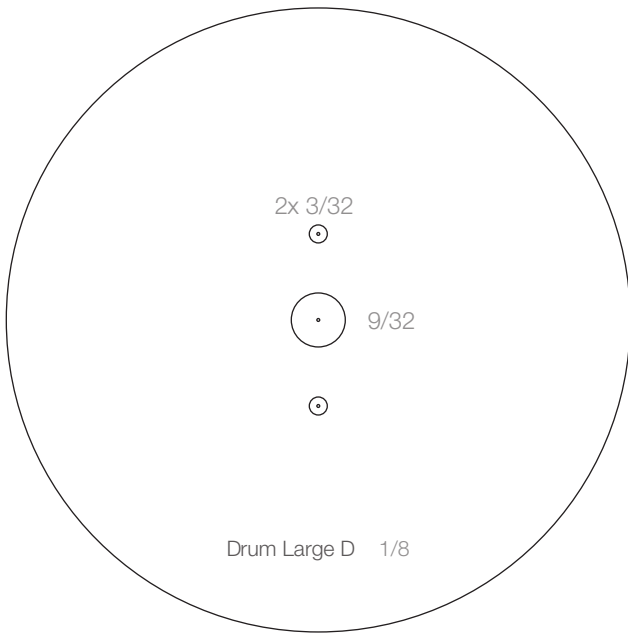
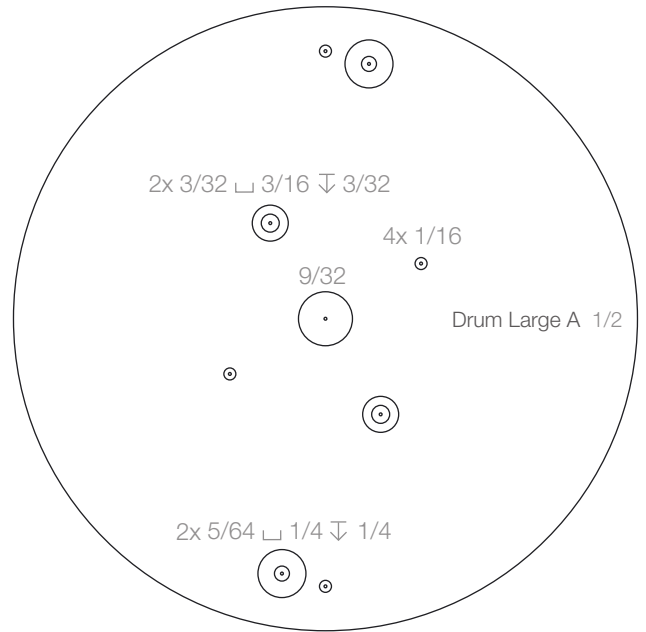
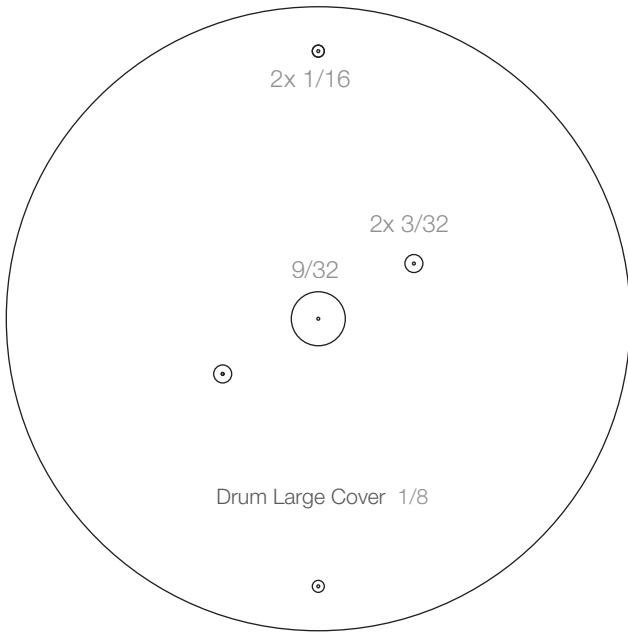
Cut, grind, or file the flats into ATube 4.867".
Flats Width: 0.25"
Flats Depth: 0.02"
Cut flats when assembling parts; dimensions may vary.



* Due to variations in plywood thicknesses, required tube lengths may vary.
See Plywood Thickness Compensation in Tips + Tactics.

** Part numbers referenced are from www.mcmaster.com.

Scale reference. To measure exactly six inches when printed.

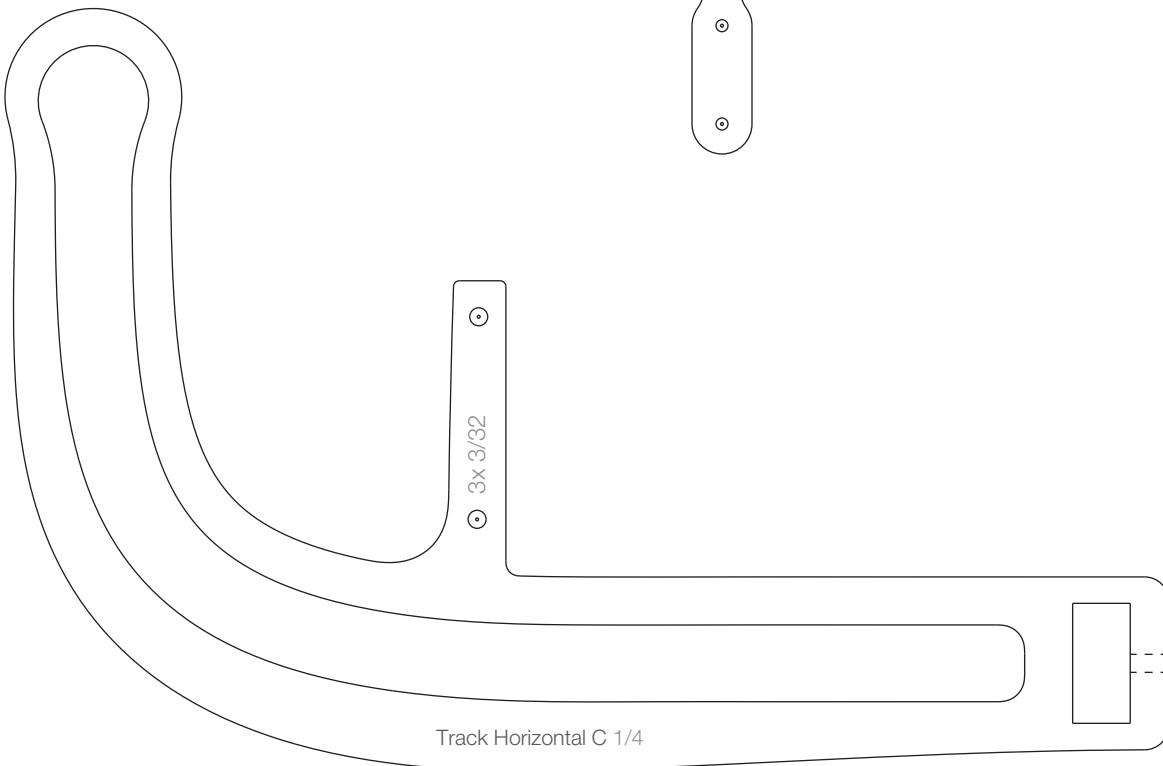
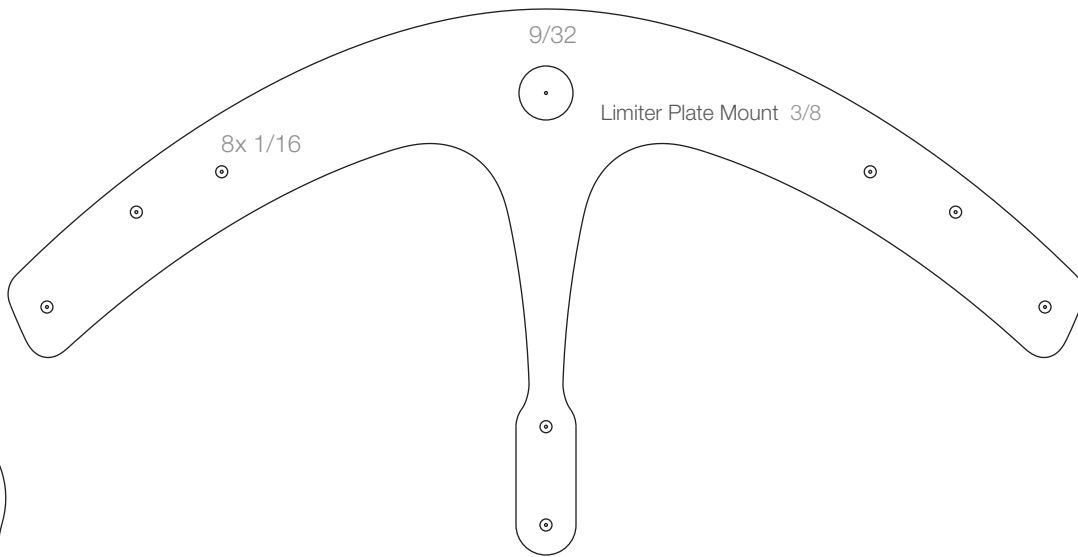
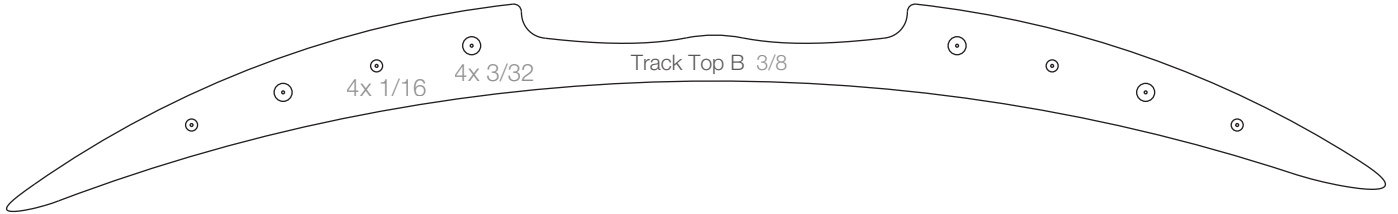
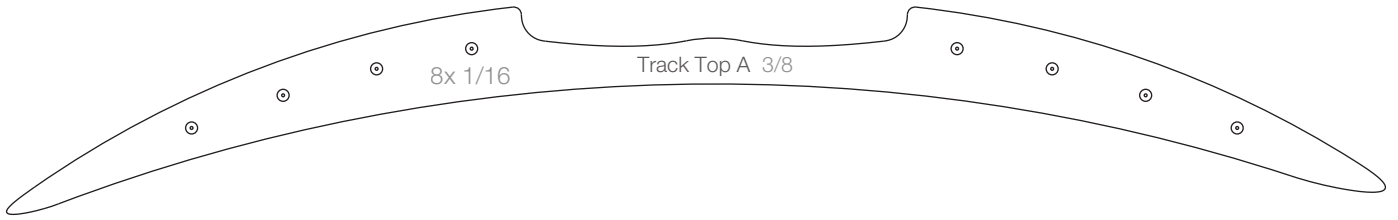


Gear Limiter Small 1/2

Ratchet Wheel (back) 1/4

Track Switch 1/2

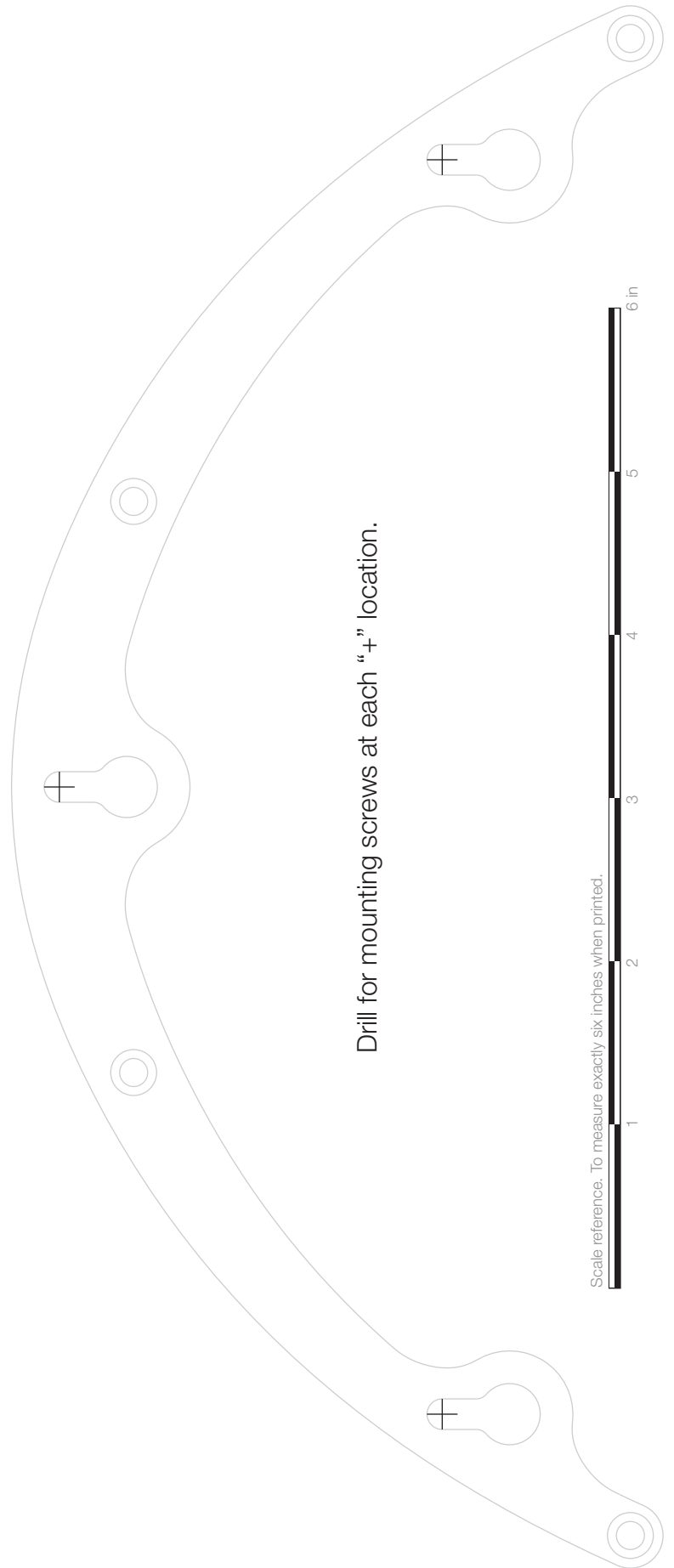
Scale reference. To measure exactly six inches when printed.



Wall Mount Template

Level this line.

Halo's center.



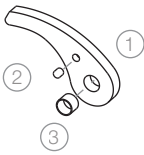
Drill for mounting screws at each "+" location.

Scale reference. To measure exactly six inches when printed.



Subassemblies

Steps 1, 2, 3, 4, 5



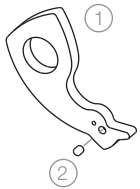
Ratchet Pawl Asm (2x)

1	Ratchet Pawl	1x
2	Magnet 1/8"	1x
3	BTube 0.200"	1x



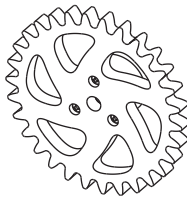
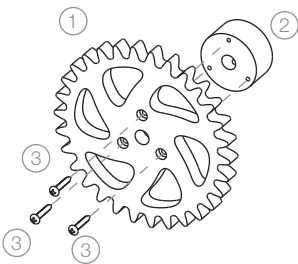
Gear Pawl Asm

1	Gear Pawl	1x
2	BTube 0.250"	1x



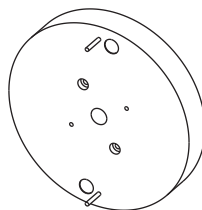
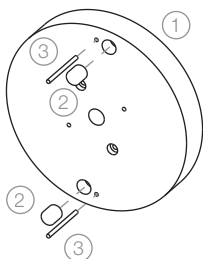
Winder Asm (2x)

1	Winder	1x
2	Magnet 1/8"	1x



Gear Asm

1	Gear Lift	1x
2	Gear Lift Spacer	1x
3	Screw #2 x 1/2"	3x



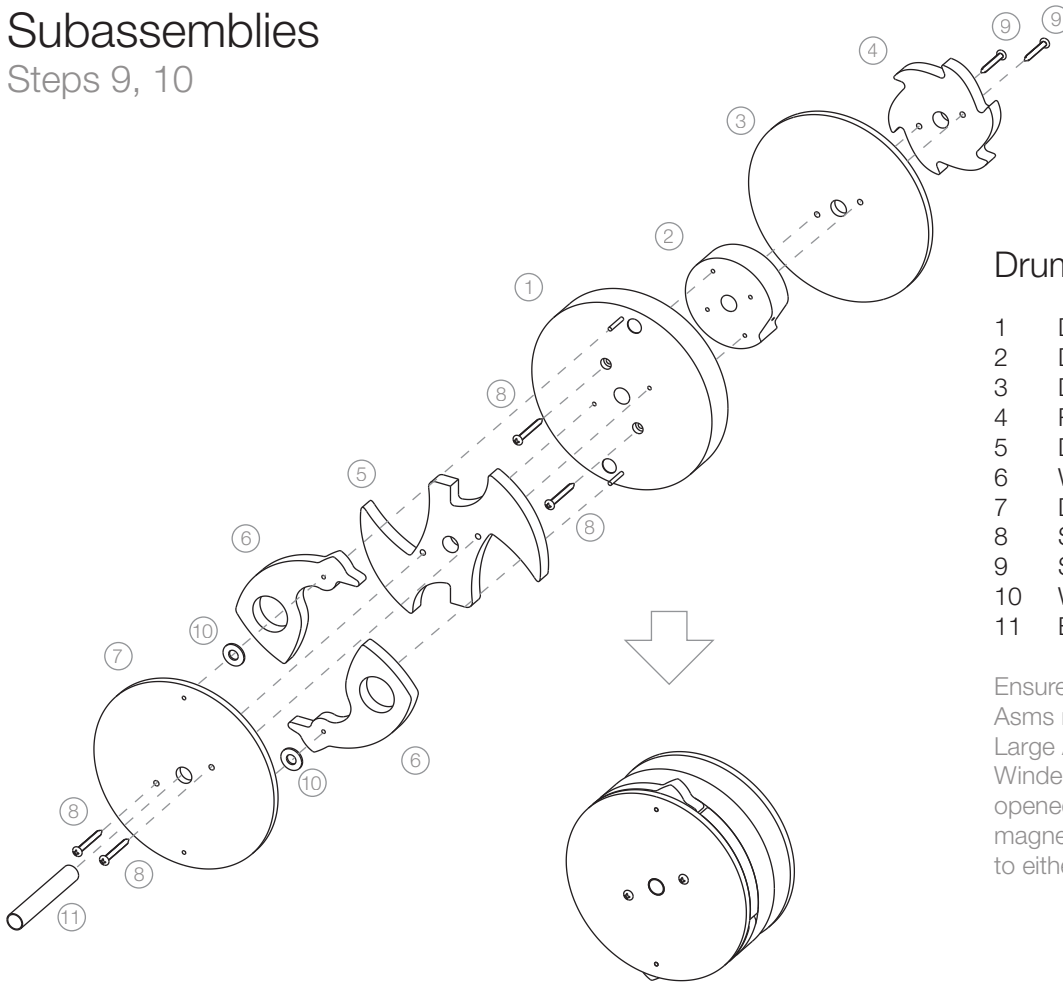
Drum Large A Asm

1	Drum Large A	1x
2	Magnet 1/4"	2x
3	Rod 1/16" x 7/8"	2x

Install Magnets such that they repel the magnets in the Winder Asms, when the 1/8" and 1/4" magnets on each respective assembly face each other.

Subassemblies

Steps 9, 10



Drum Large Asm

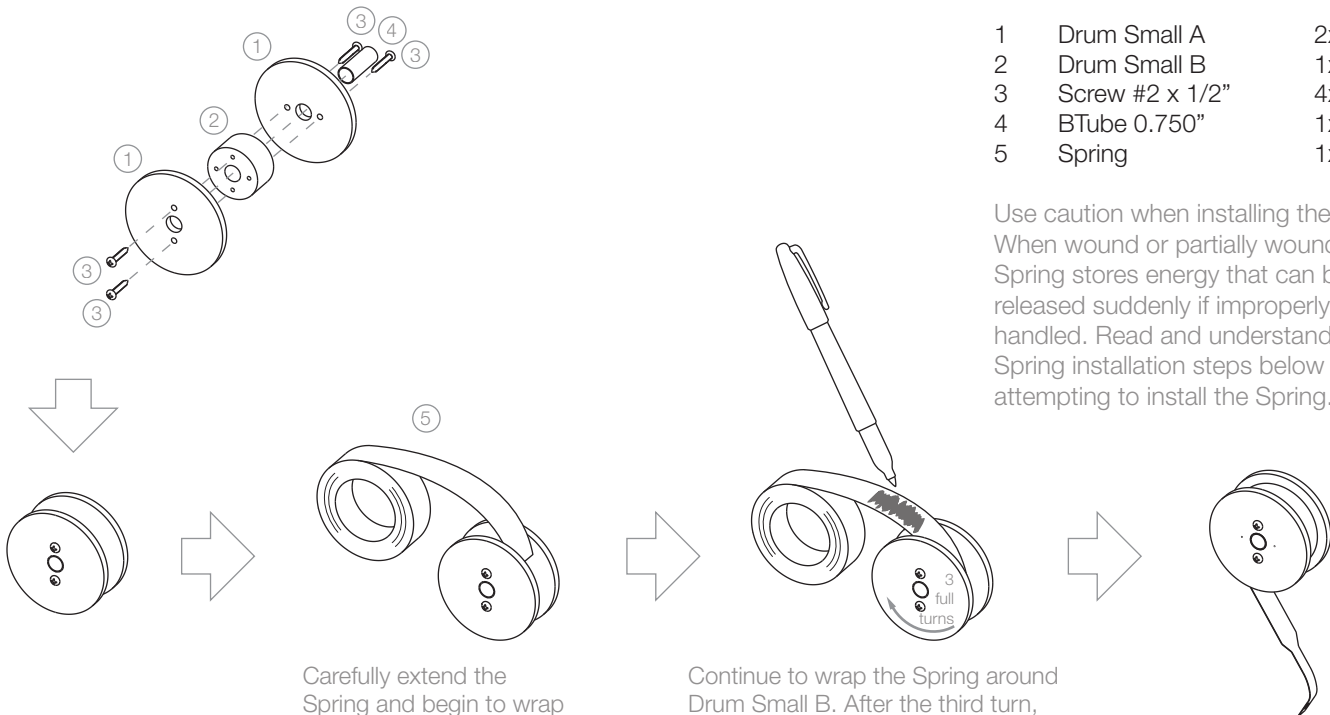
1	Drum Large A Asm	1x
2	Drum Large B	1x
3	Drum Large D	1x
4	Ratchet Wheel	1x
5	Drum Large Spacer	1x
6	Winder Asm	2x
7	Drum Large Cover	1x
8	Screw #2 x 3/4"	4x
9	Screw #2 x 5/8"	2x
10	Washer	2x
11	BTube 1.750"	1x

Ensure the magnets in the Winder Asms repel the magnets in the Drum Large A Asm. When assembled, each Winder should move easily between its opened and closed position. The magnets will help to snap each Winder to either position.

Drum Small Asm

1	Drum Small A	2x
2	Drum Small B	1x
3	Screw #2 x 1/2"	4x
4	BTube 0.750"	1x
5	Spring	1x

Use caution when installing the Spring. When wound or partially wound, the Spring stores energy that can be released suddenly if improperly handled. Read and understand the Spring installation steps below before attempting to install the Spring.



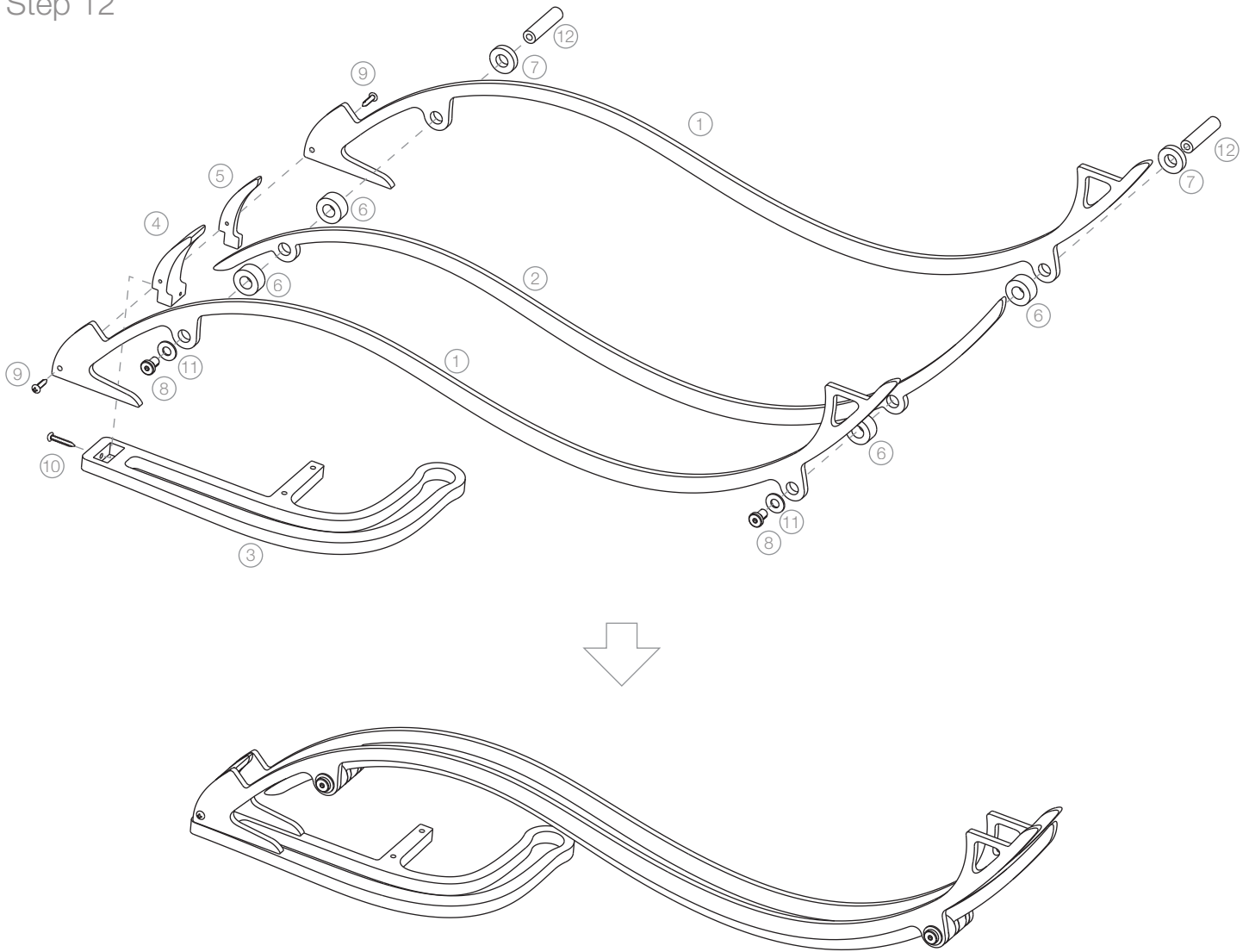
Carefully extend the Spring and begin to wrap it around Drum Small B as shown.

Continue to wrap the Spring around Drum Small B. After the third turn, mark the Spring with a permanent marker. This mark indicates "stop." It will be used as a visual reference to know when to stop winding Halo.

Wrap the rest of the spring.

Subassemblies

Step 12



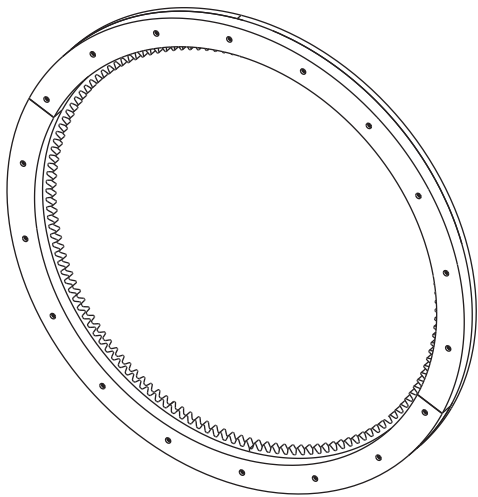
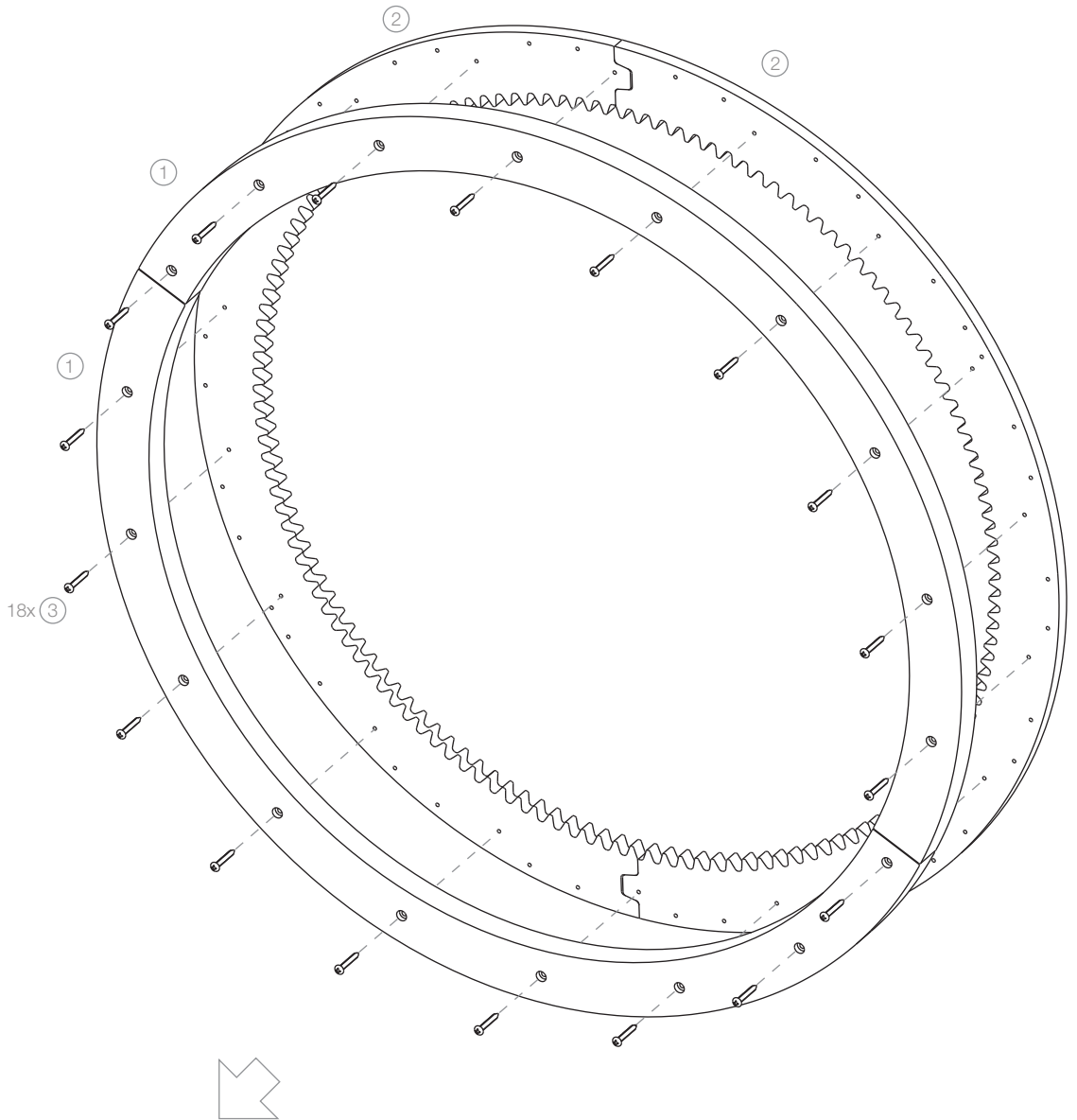
Track Front Asm

1	Track Front A	2x
2	Track Front B	1x
3	Track Horizontal C	1x
4	Track Front Stop Thick	1x
5	Track Front Stop Thin	1x
6	Track Spacer Large Medium	4x
7	Track Spacer Large Thin	2x
8	LSHCS 8-32 x 1/4"	2x
9	Screw #2 x 3/8"	2x
10	Screw #2 x 1/2"	1x
11	Washer	2x
12	ATube 1.000"	2x

Drill 1/16" side hole in Track Front Stop Thick after it is assembled and pressed into Track Horizontal C. Then, fasten with Screw #2 x 1/2".

Lift Ring Asm

Step 1

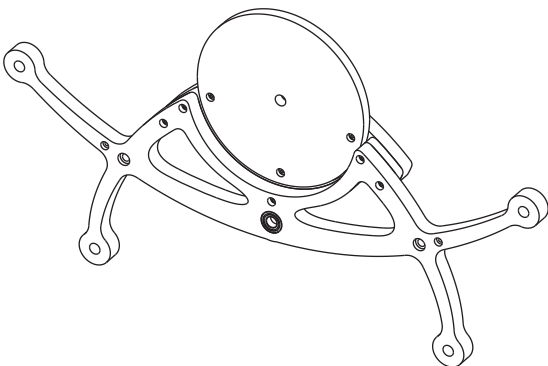
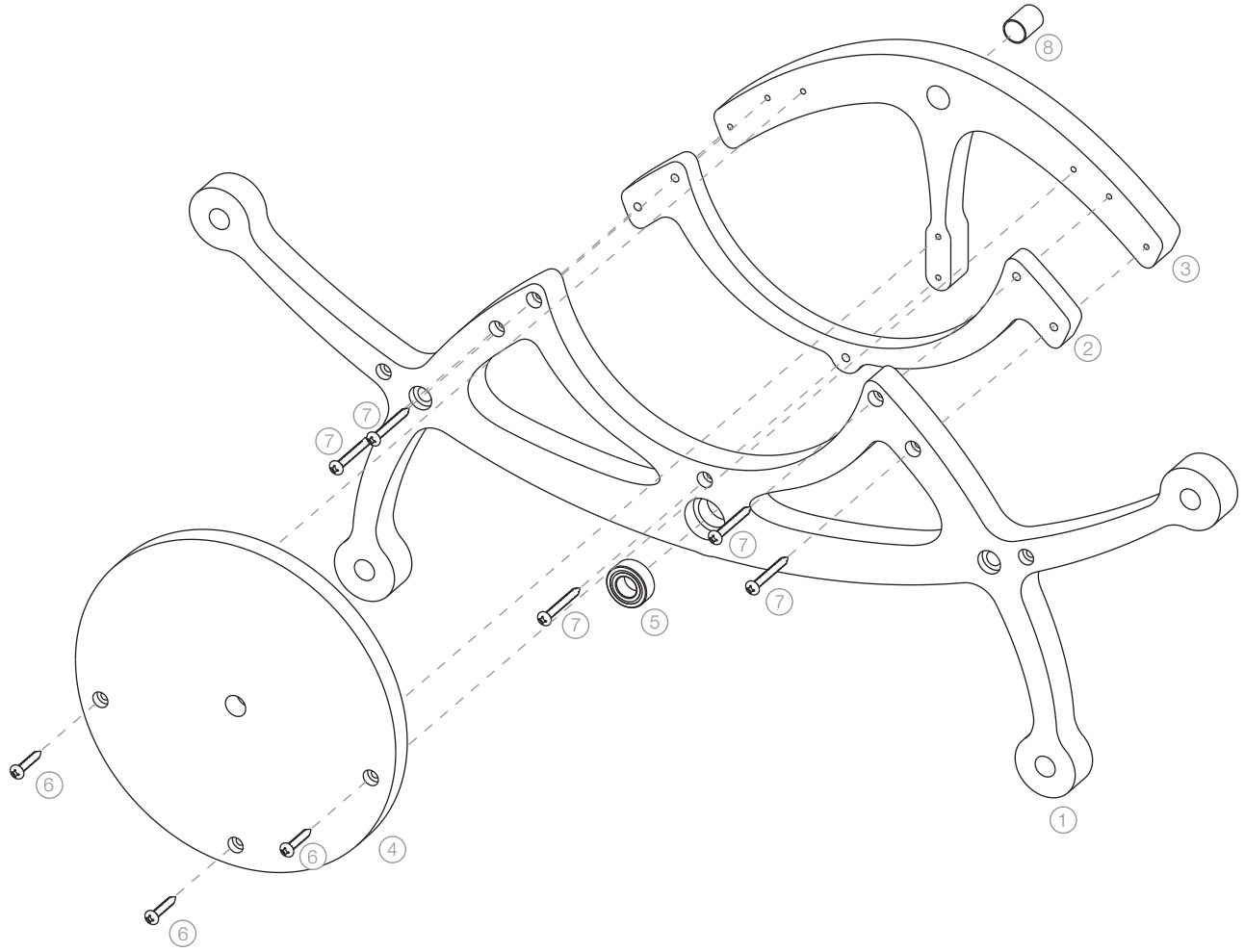


- | | | |
|---|-----------------|-----|
| 1 | Lift Ring Front | 2x |
| 2 | Lift Ring Gear | 2x |
| 3 | Screw #2 x 5/8" | 18x |

Alignment of parts is important; pay close attention to hole alignment.

Frame Front Asm

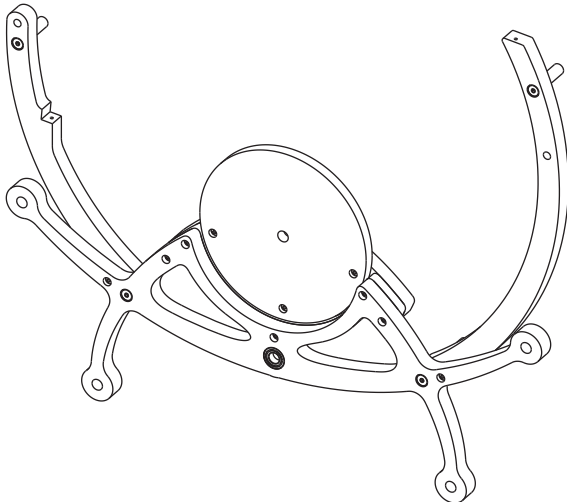
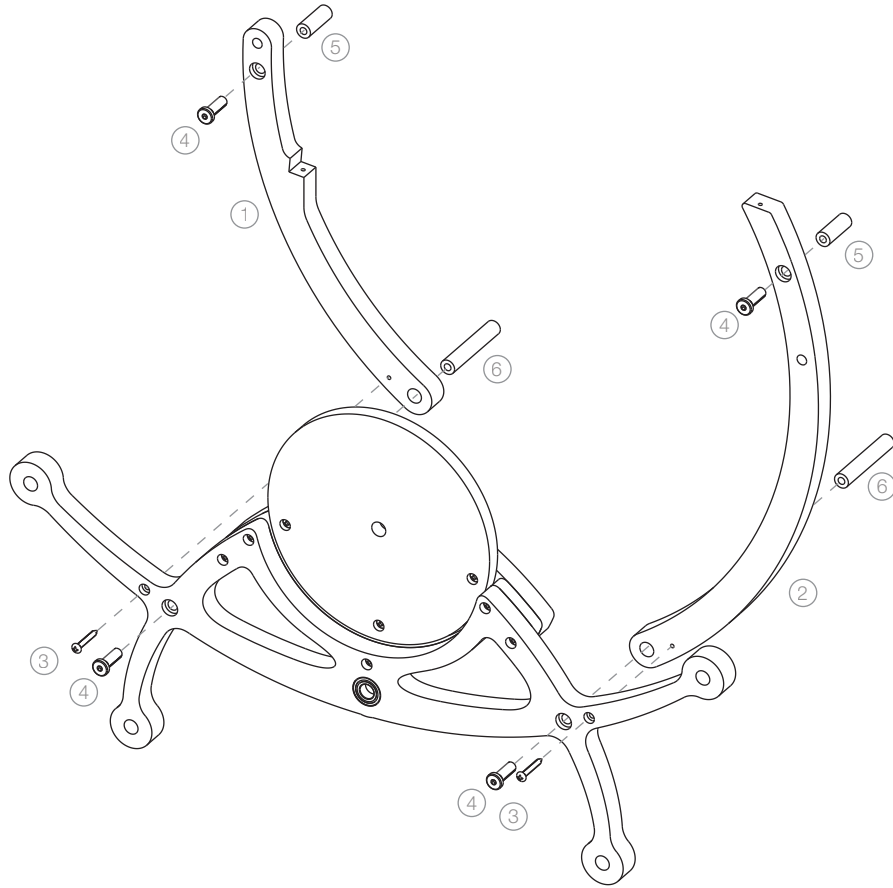
Step 1



1	Frame Front	1x
2	Frame Front Spacer	1x
3	Limiter Plate Mount	1x
4	Limiter Plate	1x
5	Bearing	1x
6	Screw #2 x 1/2"	3x
7	Screw #2 x 3/4"	5x
8	BTube 0.375"	1x

Frame Front Asm

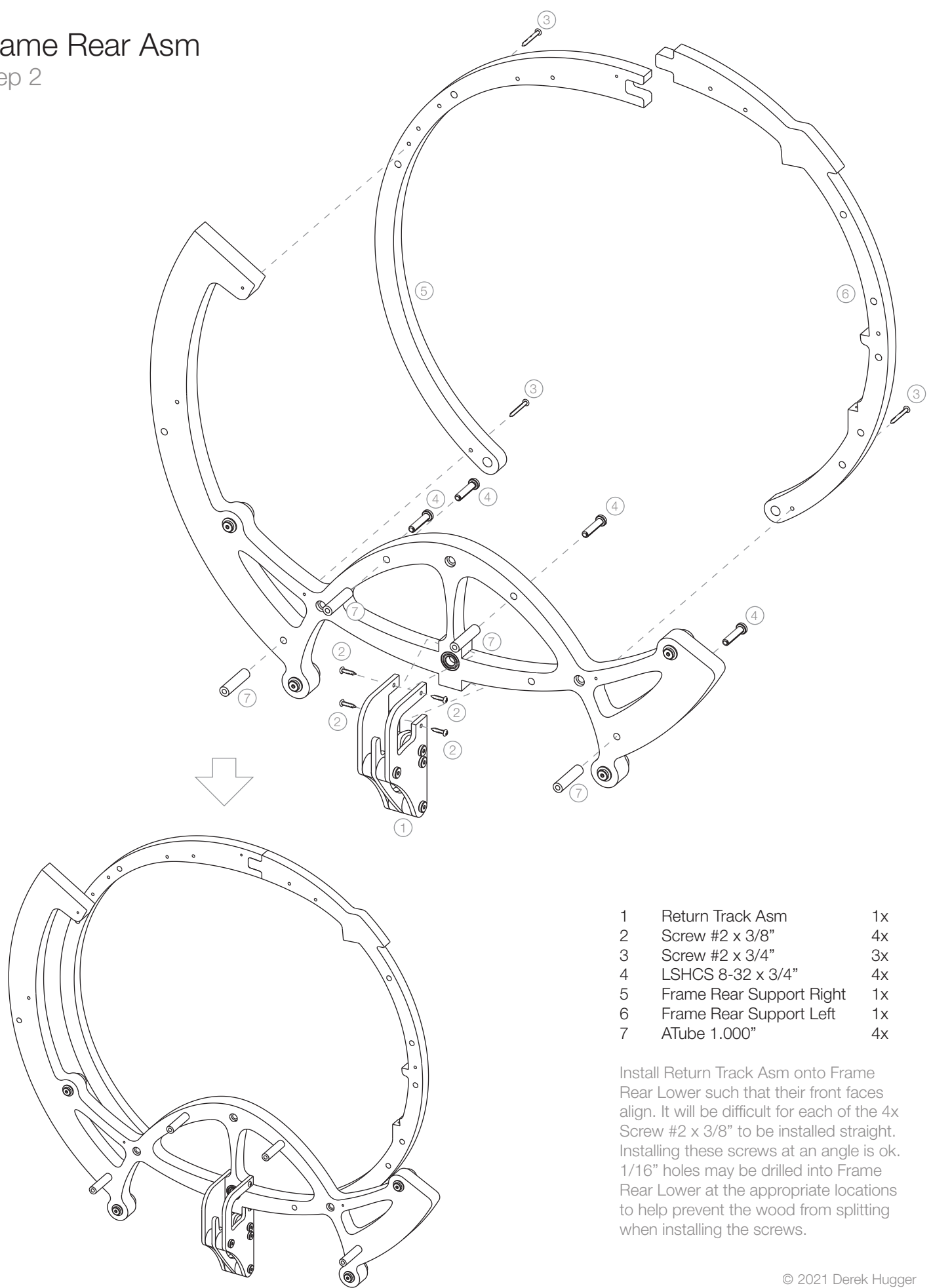
Step 2



1	Frame Front Support Left	1x
2	Frame Front Support Right	1x
3	Screw #2 x 5/8"	2x
4	LSHCS 8-32 x 1/2"	4x
5	ATube 0.680"	2x
6	ATube 1.430"	2x

Frame Rear Asm

Step 2

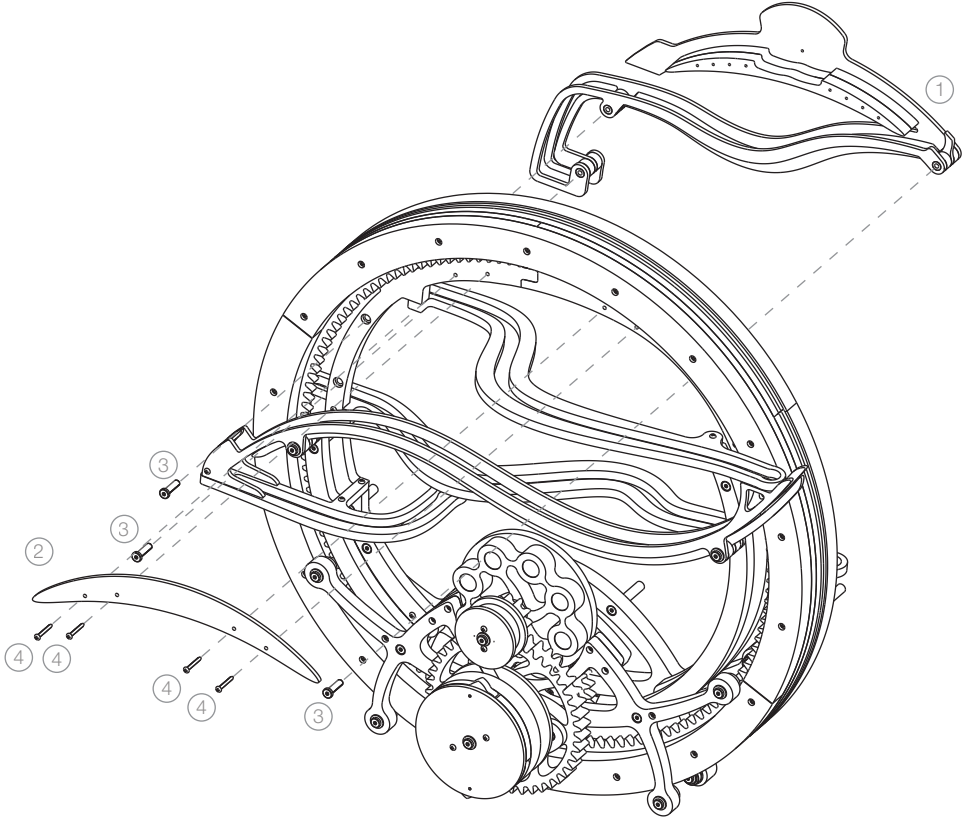


1	Return Track Asm	1x
2	Screw #2 x 3/8"	4x
3	Screw #2 x 3/4"	3x
4	LSHCS 8-32 x 3/4"	4x
5	Frame Rear Support Right	1x
6	Frame Rear Support Left	1x
7	ATube 1.000"	4x

Install Return Track Asm onto Frame Rear Lower such that their front faces align. It will be difficult for each of the 4x Screw #2 x 3/8" to be installed straight. Installing these screws at an angle is ok. 1/16" holes may be drilled into Frame Rear Lower at the appropriate locations to help prevent the wood from splitting when installing the screws.

Top Level Assembly

Step 2



- | | | |
|---|------------------|----|
| 1 | Track Top Asm | 1x |
| 2 | Frame Cover | 1x |
| 3 | LSHCS 8-32 x5/8" | 3x |
| 4 | Screw #2 x 3/4" | 4x |

