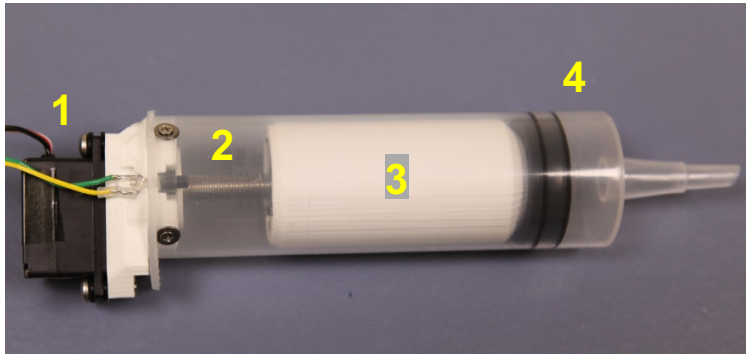


2. Buoyancy Engine

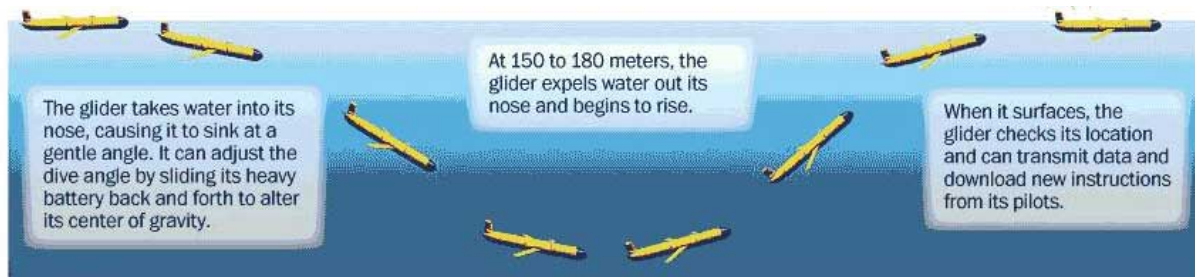


The buoyancy engine is a major component inside the glider. It changes buoyancy and pitch. As the buoyancy engine's large syringe takes in water, the glider becomes heavier and sinks. When it expels water, the glider becomes lighter and rises.

Pitch changes when the weight-filled plunger moves backwards and forwards. This tilts the angle of the glider either downward or upward.

The change in both buoyancy and pitch enable the wings on the glider to generate lift and thus forward motion as the glider dives or rises in water. (See illustration below for a typical dive cycle of a commercial underwater glider.)

Diving and resurfacing
intervals are set remotely and can be adjusted on the fly. A typical cycle takes 40 minutes from the start of a dive to the start of the next dive.



SOURCE: Rutgers University Coastal Ocean Observation Laboratory | Bonnie Berkowitz, Patterson Clark and Laris Karklis/The Washington Post - December 15, 2009

The main components of the buoyancy engine are:

1. SERVO MOTOR – Drives the lead screw backwards and forwards.
2. LEAD SCREW – Provides mechanical advantage to push and pull the plunger.
3. CYLINDER PLUNGER – Contains ballast for pitch control.
4. 100ml SYRINGE – Provides the casing for the buoyancy engine.

To assemble the buoyancy engine follow the build instructions below.

Build an Underwater Glider

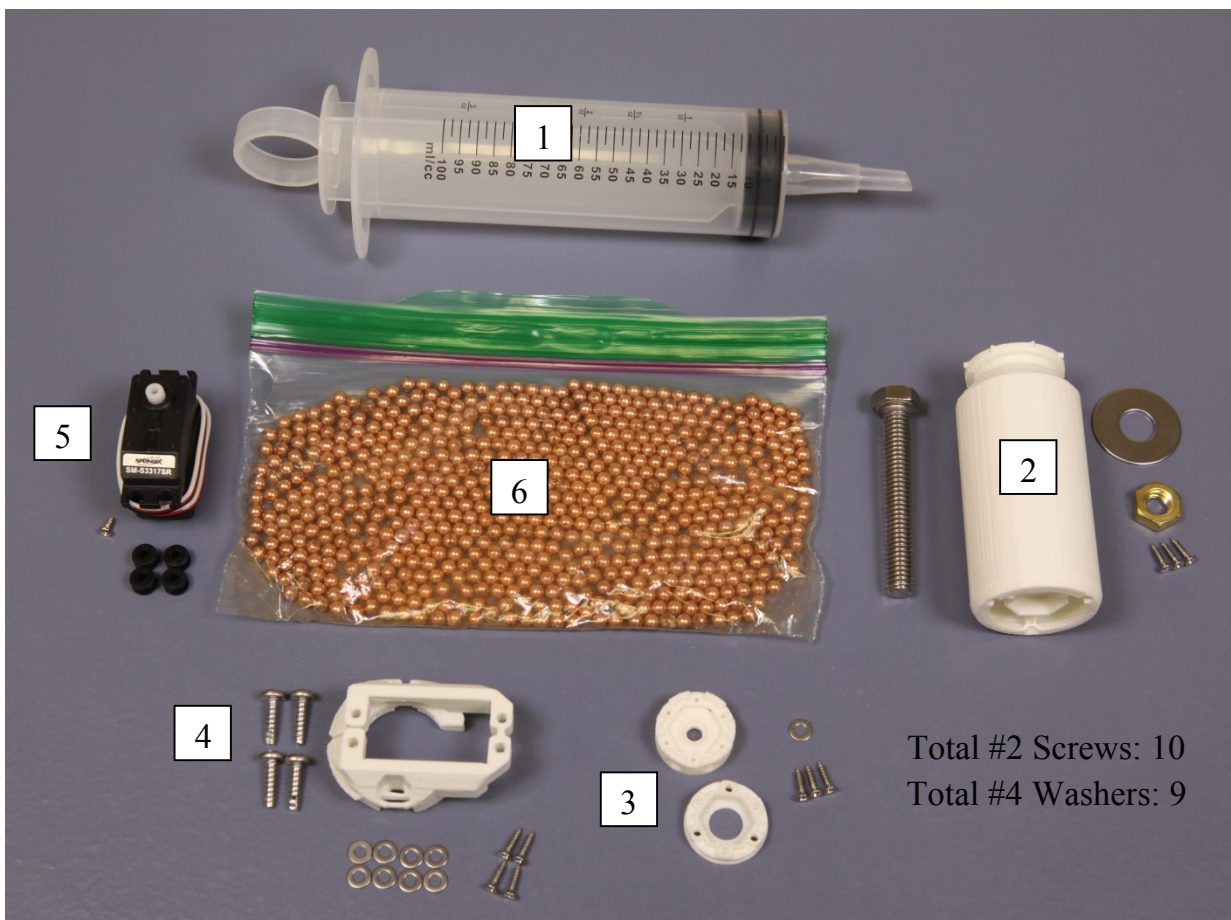
BUOYANCY ENGINE KIT

Assembly instructions for the **100ml Buoyancy Engine** follow:

KIT PARTS:

1. **100 ml/cc Syringe** with original plunger.
2. 3D printed **Plunger Cylinder** with hex-head bolt, fender washer (3/8"ID 1"OD), brass nut, and three small screws (#2x3/8").
3. **Two-Piece Shaft Coupling** with three small screws (#2x3/8") and small washer (#4).
4. **Servo Mount** with four thread-cutting screws (#6x1/2"), eight small washers (#4), and four small screws (#2x3/8").
5. **Continuous Rotation Servo** with a tiny servo screw and four rubber grommets.
6. **BBs** for ballast.

Buoyancy Engine Kit

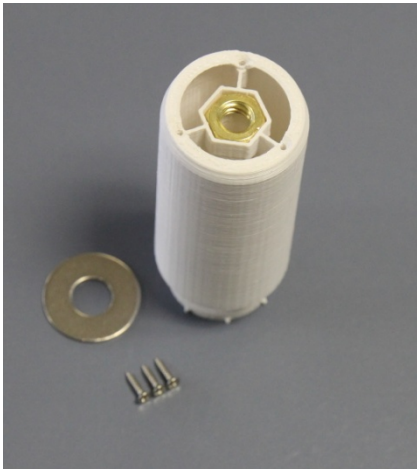


ASSEMBLY:

Just follow the photos. (You know you aren't going to read these instructions anyway.)*

1. Grab that white cylinder thing and drop the brass nut in the slot provided.
2. Throw the fatty washer on top and place three #2 screws in the pilot holes.
3. Tighten those suckers down! But not too tight!

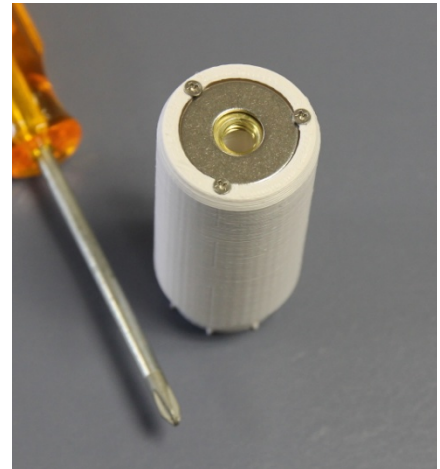
Brass Nut in Slot



Fatty Washer on Top
Start three Screws



Tighten those Suckers
Down until Flush



Okay, nice job. Now...

1. Flip the white cylinder thing over. (Oh yeah, your cylinder thing could be printed in a different **color** plastic other than white – you figure it out.)
2. Grab the stuff in the photo below. That long bag is the thing the syringe came in. You saved it, right?

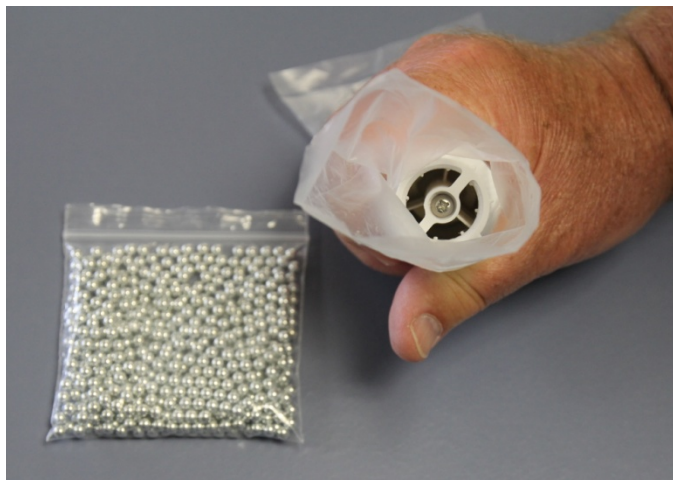
Cylinder Thing (Cylinder Plunger), BBs and Syringe Bag



*My colleagues tell me that I should encourage reading. Okay, so read the instructions... I'll keep 'em short.

3. Squeeze the syringe bag snugly around the cylinder and fill it with BBs. **Follow the Photo Instructions:**

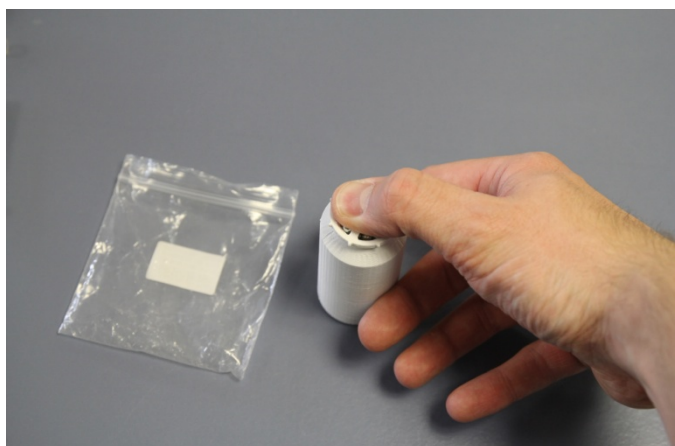
Squeeze Syringe Bag around Cylinder



Fill the Cylinder with BBs



Compress the BBs in Cylinder



Cylinder with BBs should weigh 220-232g



Yes, BBs can also be Copper Colored



A Box Top helps to corral BBs



Get those BBs covered up or they'll be all over the floor! Here's how:

You'll need the Syringe



Remove the Plunger



Hey! Don't touch that black rubber tip on the plunger. It has **One-of-a-Kind Oil** on it!

Pry up the Rubber Tip with a Screwdriver



Cover your Hand with a Bag and Remove Tip



Seal the open end of the Cylinder with the Rubber Tip

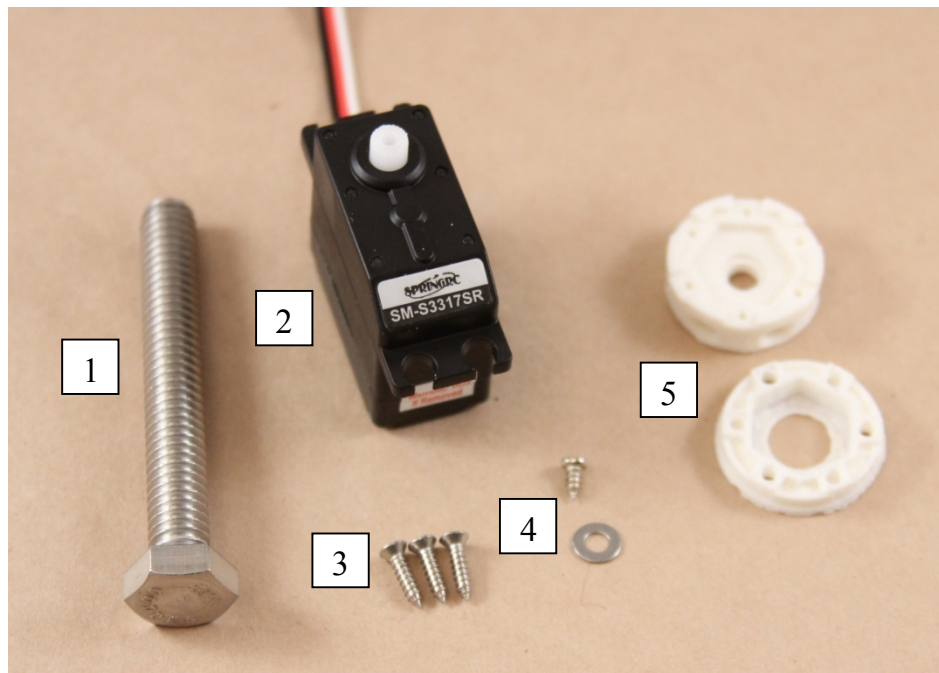


Push the BB filled Cylinder Plunger into Syringe until it is past the Opening



Congratulations! Take a break! You earned it!

Now... from your set of parts find all the items in the photo below:

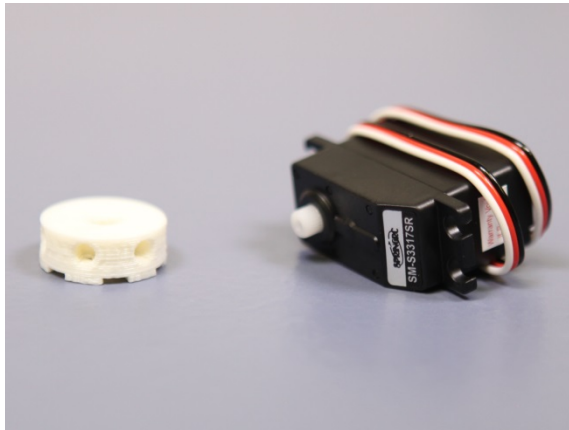


Large Bolt (1), Servo (2), Three #2 Screws (3), small Servo Horn Screw* with #4 Washer (4), and Two-Piece Shaft Coupling (5)

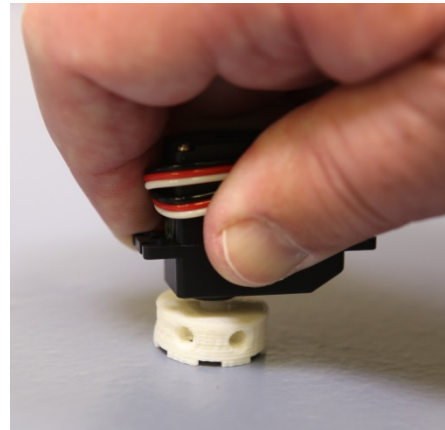
*If this screw is lost, it may be replaced by a #2 screw using TWO washers.

Press servo output gear into small center hole in coupling. **Follow the Photo Instructions:**

Small-Hole-Coupling with smooth Side up



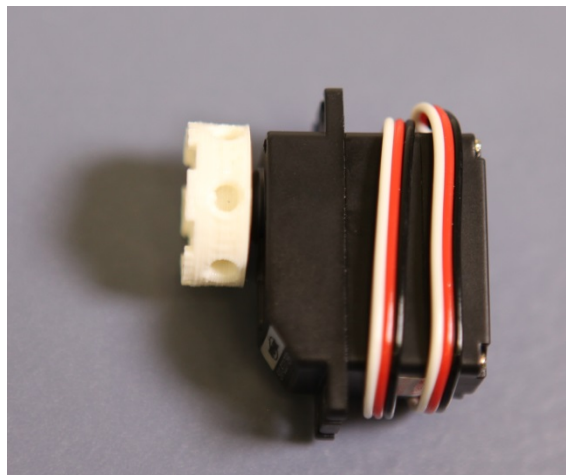
Position servo Output Gear over Hole



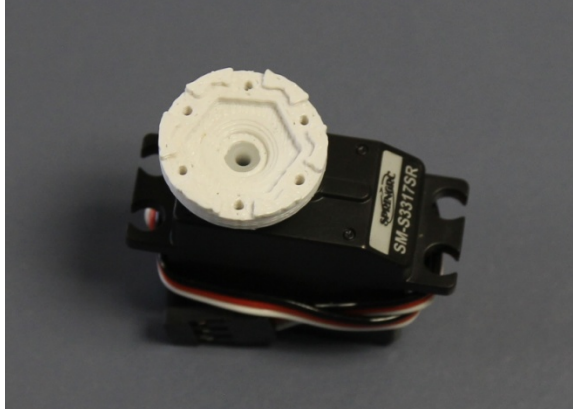
Press down with heel of Hand until Output Gear slides into Coupling



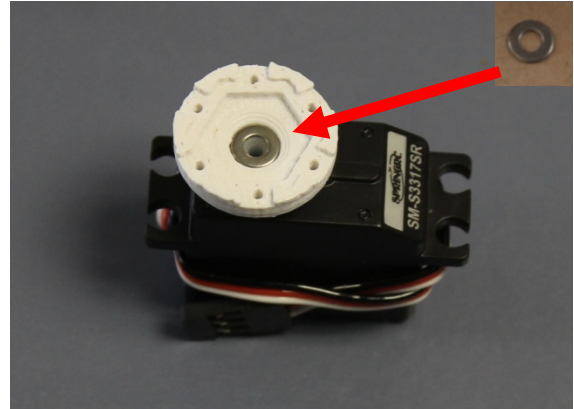
Servo with attached Coupling



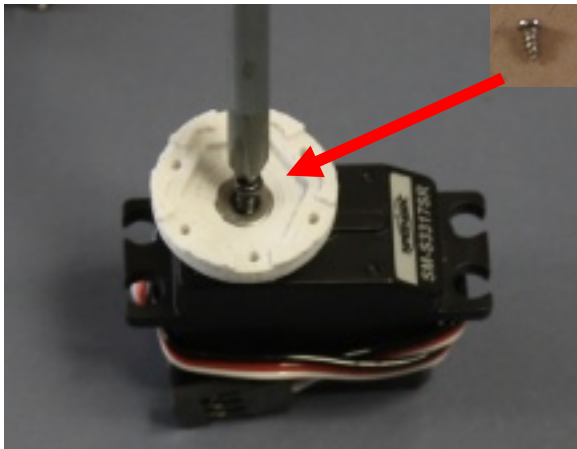
Coupling fitted over Servo Output Gear



Place a **SMALL WASHER** into the center recess



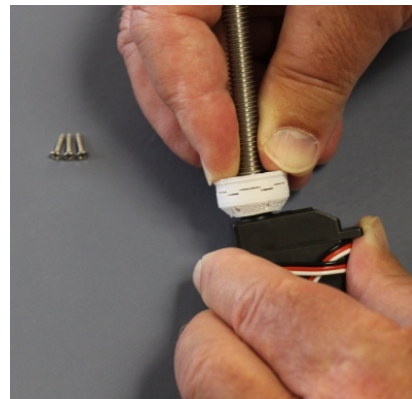
Screw the small **Servo Horn Screw** (black or silver) into the Servo Output Gear



Push the Bolt through the indented Side of the Large-Hole-Coupling



Matchup the Indentations on the Couplings and Push them Together



They fit like Puzzle Pieces

Place the three Small #2 Screws in the open Holes and Tighten



Tighten until screw heads are **FLAT** and **SMOOTH** with the top of the shaft coupling.

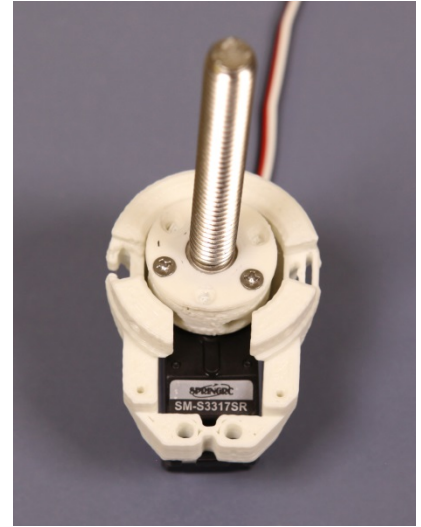
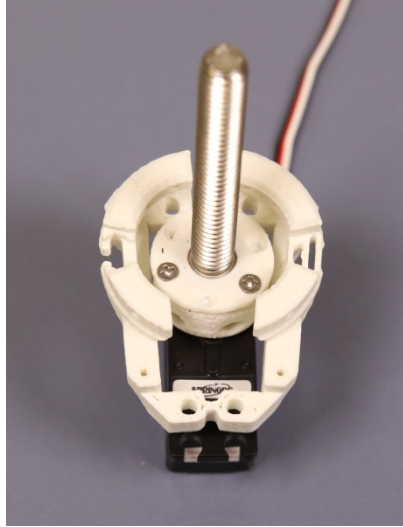
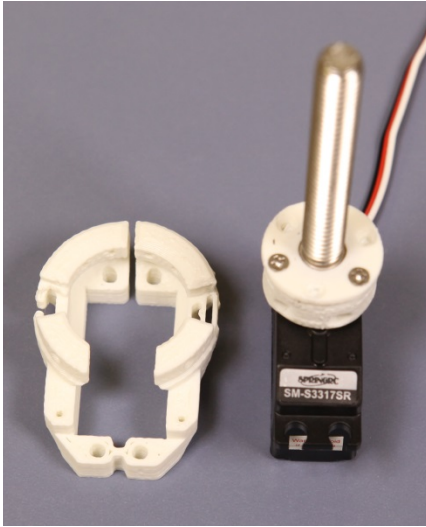
Wonderful!

Next, we'll expand the servo assembly to include the servo mount. Here's what you need:

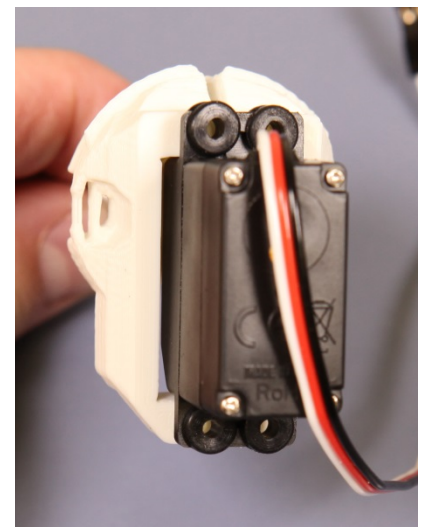
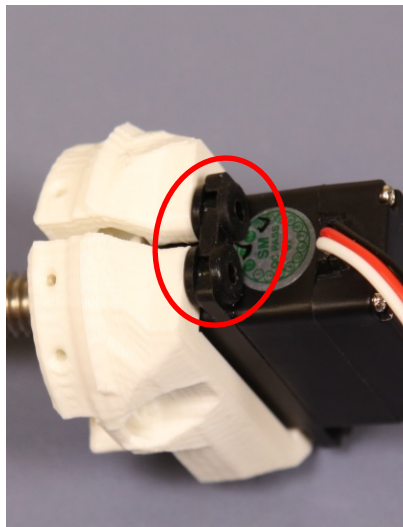
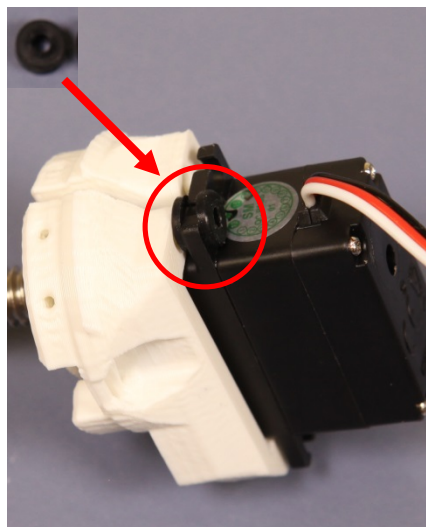


Four # 6 Thread-Cutting Screws, Four Rubber Grommets (from servo hardware bag), Servo Mount and the Servo Assembly

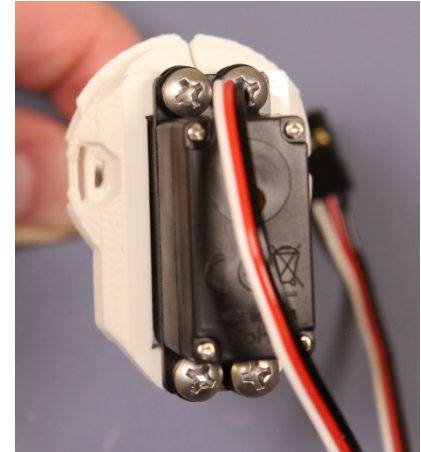
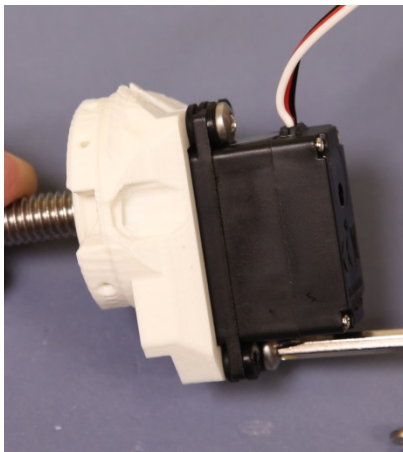
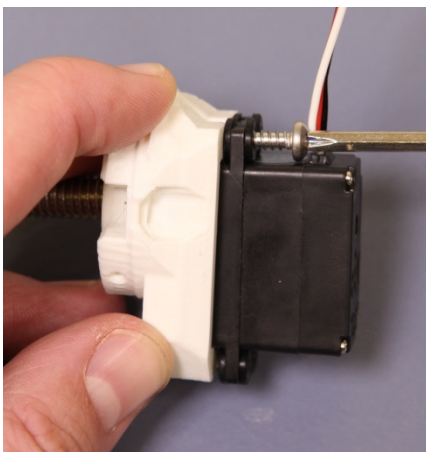
Fit Servo Mount over the Servo Assembly as shown



Fit Grommets into four screw-hole Slots in Servo

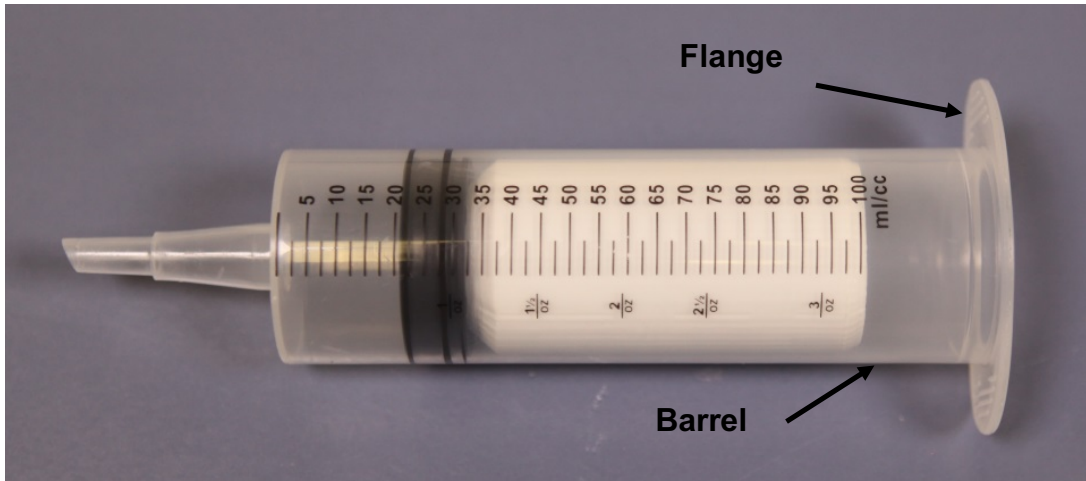


Use four #6 thread-cutting Screws to secure the Servo to the Servo Mount



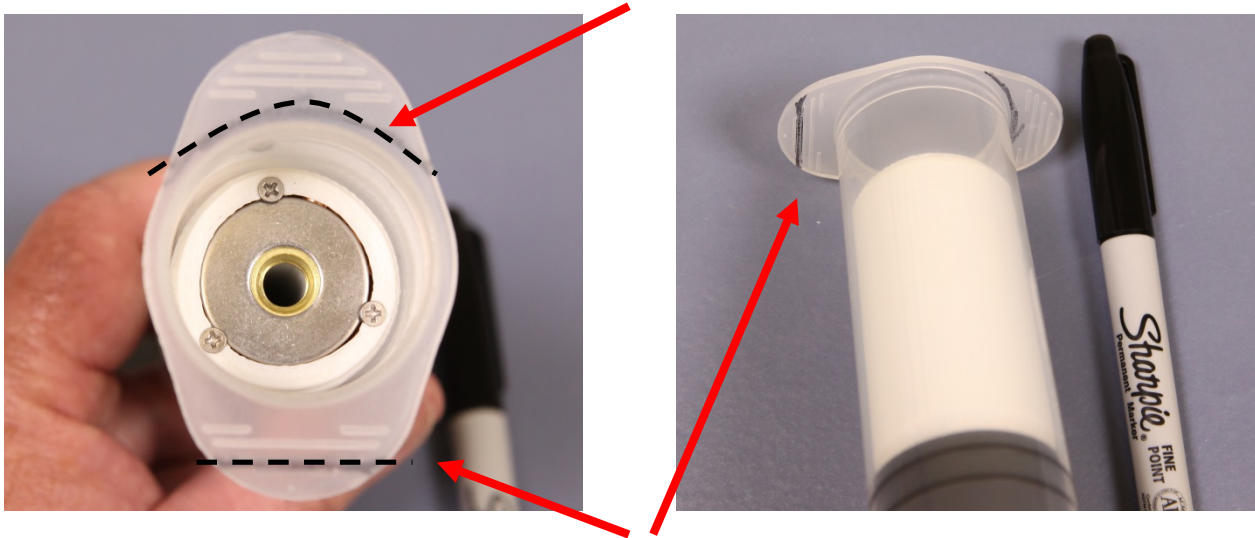
That was Fun! (Set the servo assembly aside for now.)

Okay, now... you trim the flange around the syringe so that it will smoothly fit into the glider bottle. You need:



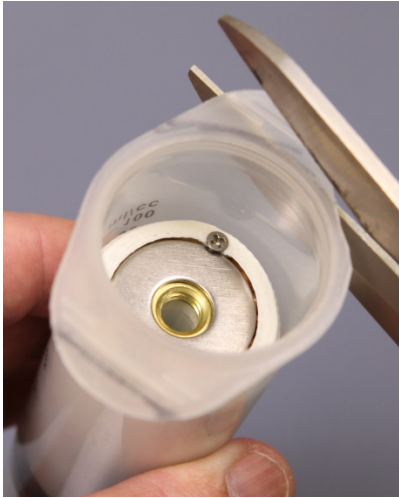
The Syringe Assembly, heavy duty Scissors, and a Marker

Mark one side of the flange with a curved line $1/16^{\text{th}}$ inch from the syringe barrel.

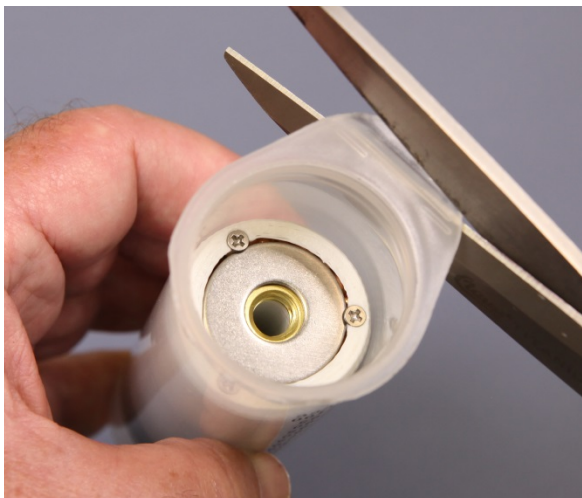


Mark the other side with a straight line following the second ridge from the outside.

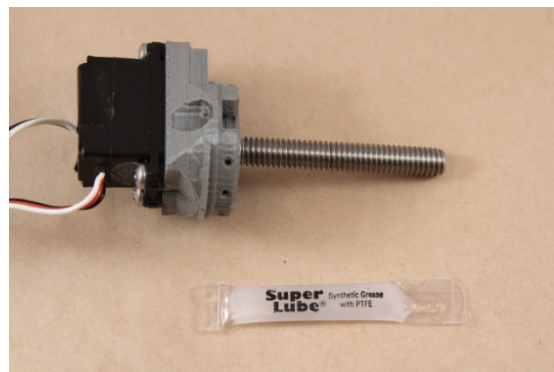
Trim both Marked Sides of the Syringe Flange.



Use Short Snips to Avoid Cracking the Plastic



Lubricate the bolt. You will need:

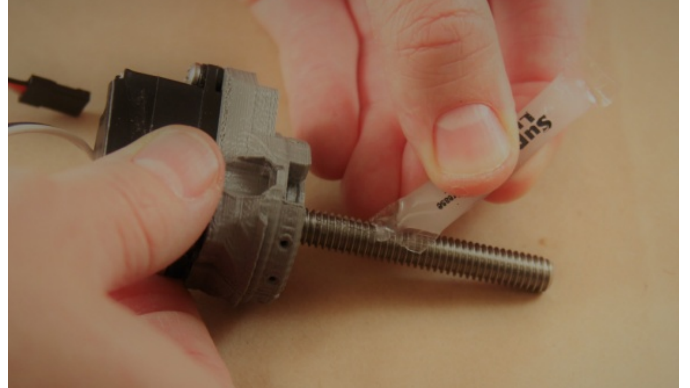


The Servo Assembly and Synthetic Grease found in the Kit bag of tools.

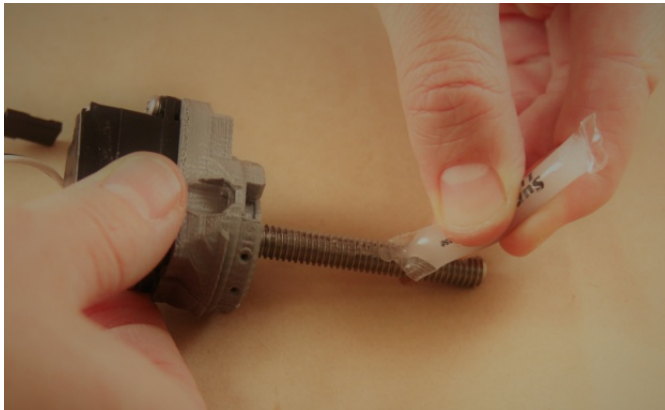
Tear open Packet



Apply Grease to Bolt



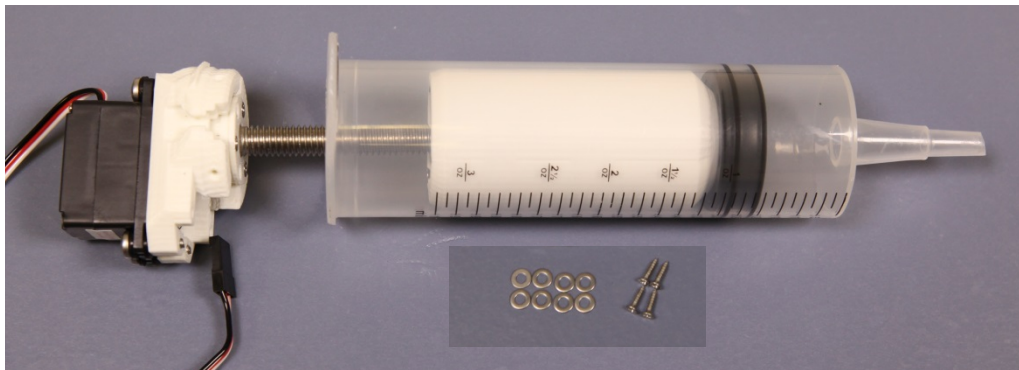
Apply to the Total Length of the Bolt



Seal Grease with Tape for Later Use



Put It All Together! You will need:

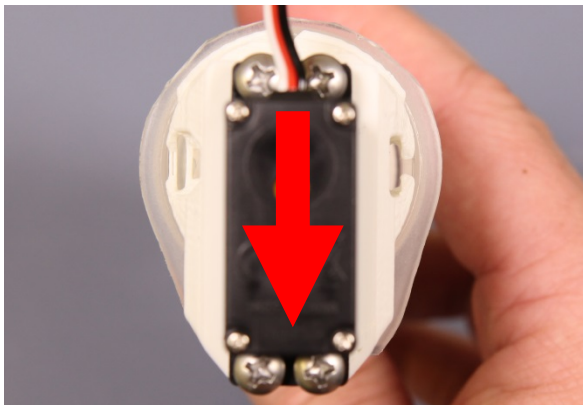


Servo Assembly, Syringe Assembly, 8 small #4 Washers and 4 small #2 Screws

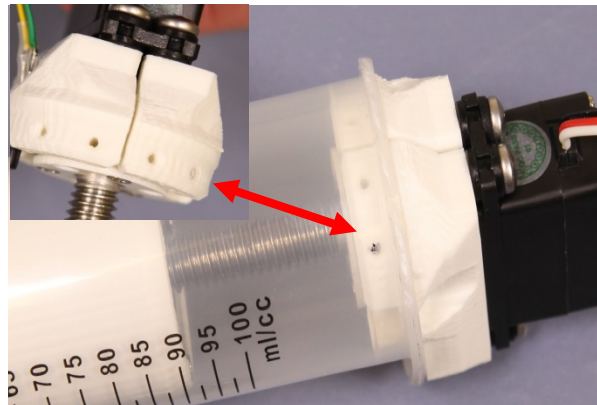
Screw the Servo Assembly into Plunger Cylinder until it reaches Syringe Flange



Align elongated end of Servo with extended end of the Syringe Flange

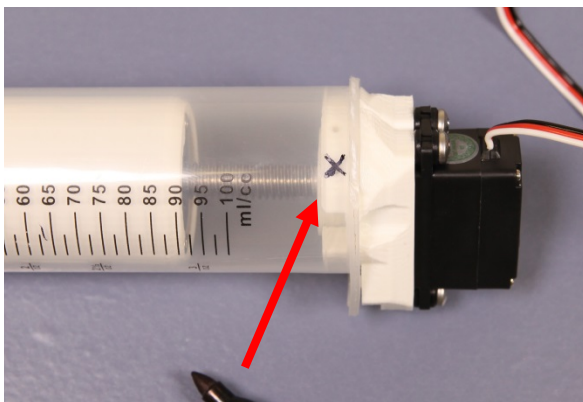


Mark the Position of this Hole on the Outside of the Syringe Barrel*



*This is the non-elongated side of the syringe flange. There is a set of four holes on this side of the servo mount. **Only the two holes on either end of this set will be used.**

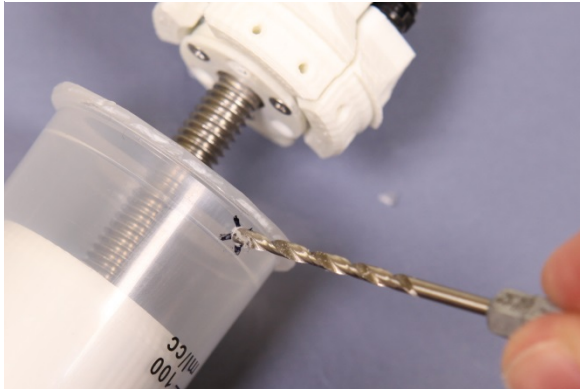
Position for Anchor Screw



Make Pilot Hole with Push-Pin



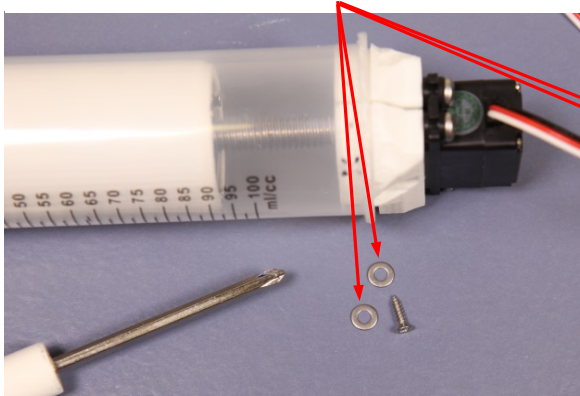
Hand drill Hole Larger with 3/32 Bit



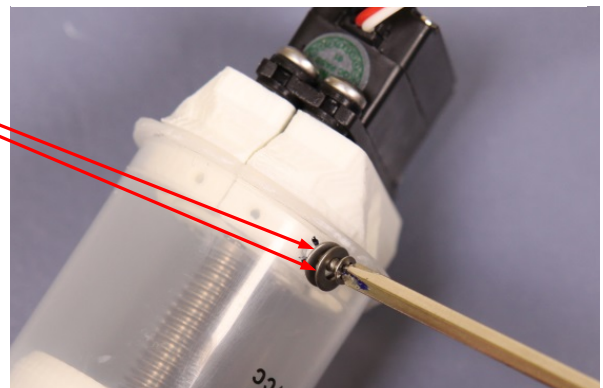
Remove excess Plastic



Use **TWO WASHERS** and a Screw



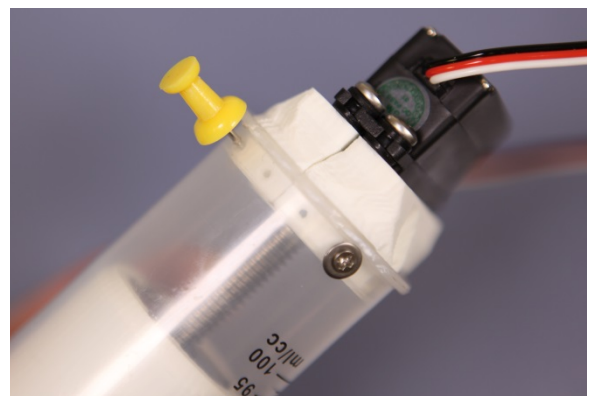
Secure Servo Assembly in Place



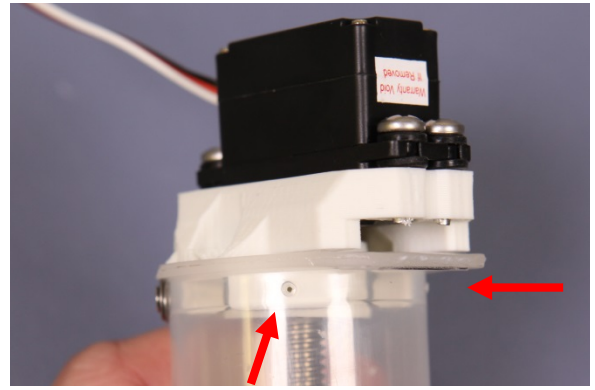
Avoid over Tightening



Make a Pilot Hole with Push-Pin on
other end of the four-hole Set



Make two Pilot Holes under the elongated End of the Syringe Flange

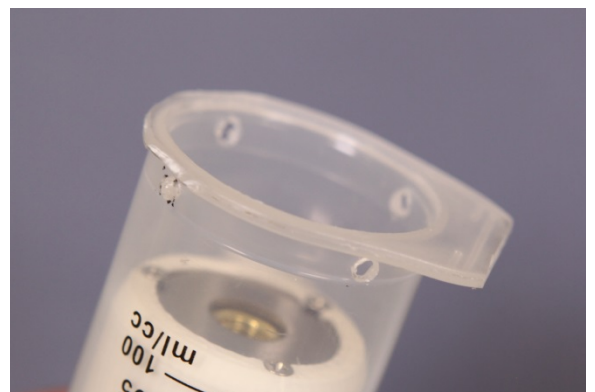


Remove the servo assembly and hand drill the pilot holes with a 3/32 drill bit. There should be a total of four holes spaced around the barrel of the syringe as pictured below.

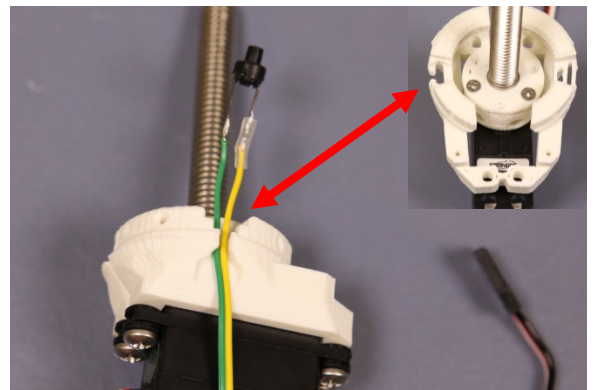
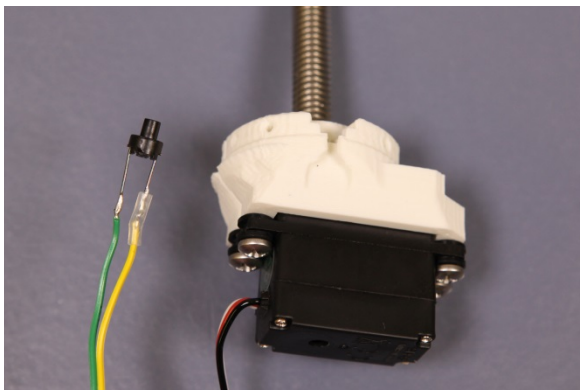
Enlarge Pilot Holes



Remove Plastic Cuttings

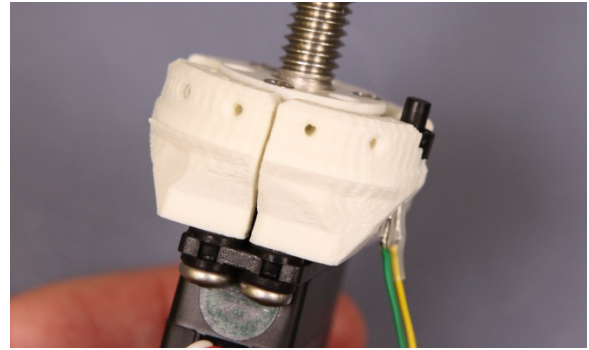
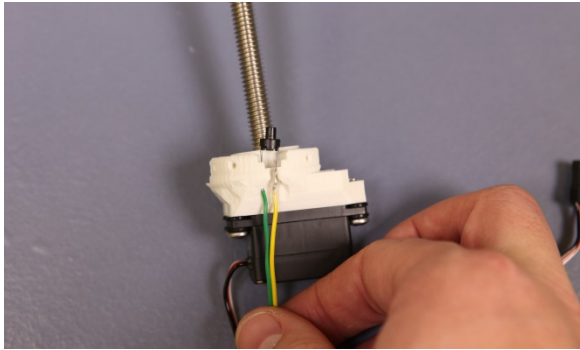


Attach Pushbutton Switch to the Servo Assembly



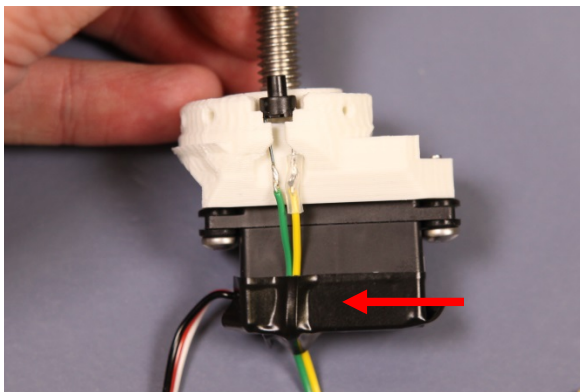
Slide the pushbutton switch with soldered wires into the open-slot on the side of the servo assembly as shown.

Pushbutton Switch should fit securely in Slot



The pushbutton should be perpendicular to the rim of the servo mount and extend beyond the shaft coupling as shown above right.

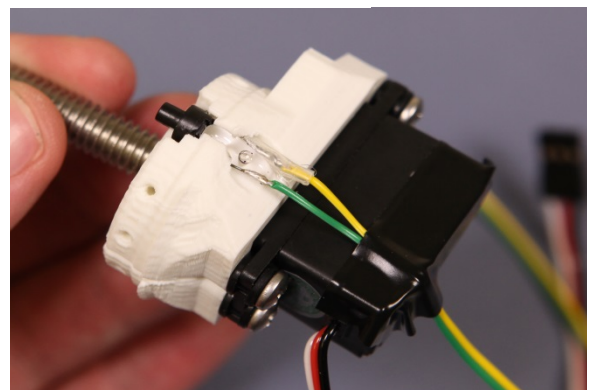
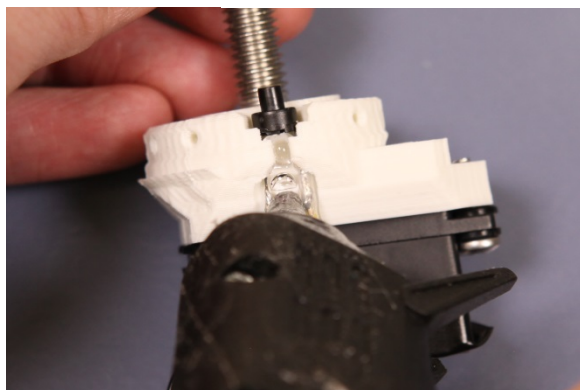
Tape Wires in Place



Hot Glue Switch in Place

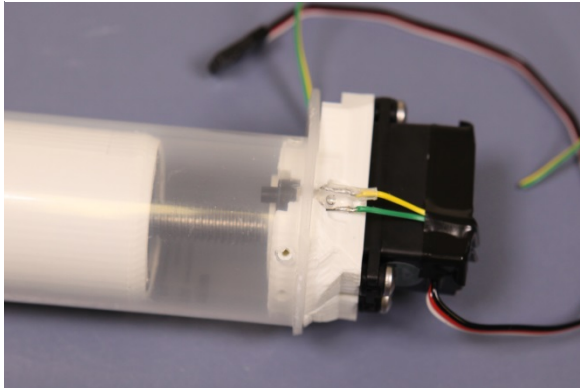


Ensure that Glue does not bulge out beyond the Circumference of the Servo Mount

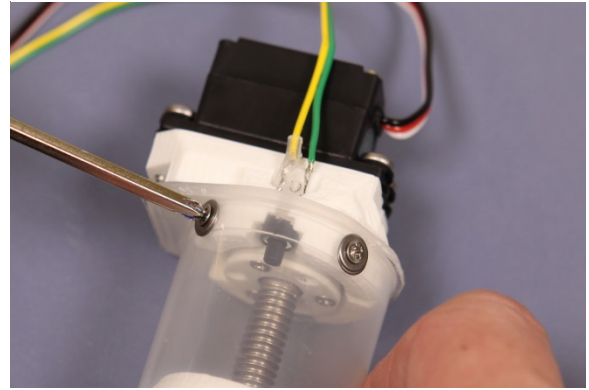


The servo assembly must smoothly fit back into the syringe. If there is excess glue, wait for it to cool and then cut it away with a sharp knife.

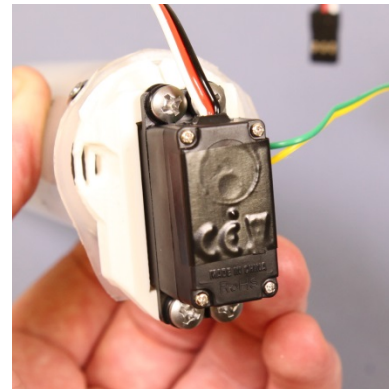
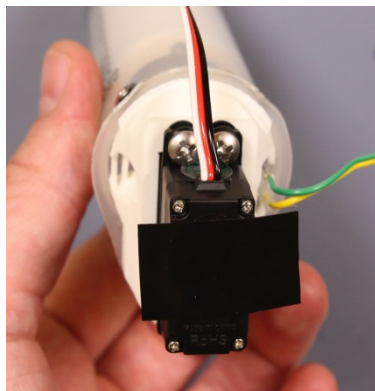
Fit Servo Assembly back into Syringe



Secure in place with Four Screws
each with Two Washers



Cover the Hole in the back of the Servo with Electrical Tape



This makes the servo more water resistant in case of leaks.

VOILÀ!

Completed Buoyancy Engine – Congratulations!

