BUILD REPORT: Building a Better Beatle Beater Bar!

Part 1 – The Beater

● by Pete Smith

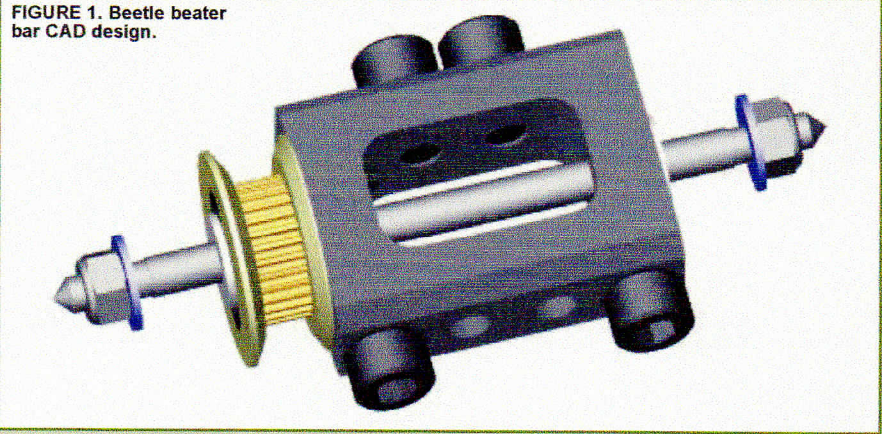

FIGURE 1. Beetle beater bar CAD design.

Beaters are a popular adaptation of the conventional drumbot design. The circular drum is replaced with a thresher or beater bar. My beetleweight drumbot Weta, God of Ugly Things, was originally fitted with a 6061 aluminum drum that had M8 socket head screws as teeth. This worked well enough, but the soft 6061 (it was cheap and easy to machine) was not up to the task of retaining the teeth and by the end of the event, it was definitely worse for the wear. The event also showed I needed a bigger hit and a better bite.

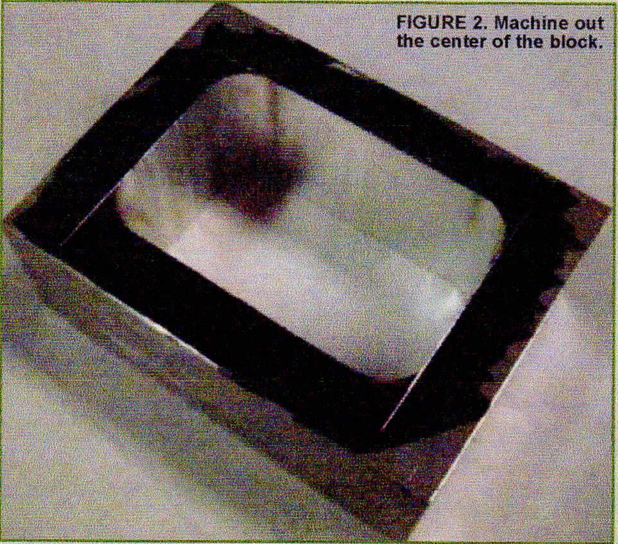

FIGURE 2. Machine out the center of the block.

A higher rotational speed gives a bigger hit but it also reduces the bite. One way around this is to use a beater bar design. This article will show you how a simple beater bar can be created.

First thing is to design the bar assembly and calculate its weight. It's too easy to design an effective weapon and then find out it's too heavy to be used on your bot!

Personally, I design using SolidWorks, and it includes a weight calculator. Other CAD tools can be used, or even pencil, paper, and a little math will get you very close to the finished weight.

The chosen design can be seen in **Figure 1**. An aluminum block uses needle roller bearings to revolve on a 5/16" diameter ground titanium shaft. The teeth are M10 socket head screws. A 30 tooth 3 mm HTD pulley with UHMW flanges (down from 40 tooth in the original to increase RPM by 33%) is mounted on one end. It is designed to work in a bot with the axle centerline 1.5" off the ground.

All drawings are available as a download from *SERVO* through the article link or through **www.kitbots.com** under the 3 lb beetle kit section.

The block is cut from a 2" x 1" bar of 7075 aluminum. This conveniently gives two of the three required outside dimensions without further machining. The block was cut roughly to length using an abrasive cut-off saw, and the ends were machined square and to length in my mill.

Safety Note: Milling machines are dangerous if not used correctly. Remove jewelry and any loose items of clothing, and ALWAYS wear safety glasses.

The center cut-out was marked carefully and then machined out using a 1/2" diameter center cutting end mill. I rough-machined to within 1/16" of the finished sized and then carefully did a finish cut to the scribed lines (**Figure 2**).

The next job is to drill, then ream the axle bearing mounting holes. In an attempt to keep the two holes as accurate and as in line as possible, I machined both in a single operation.

First, I carefully positioned the mill head over the scribed center point, then milled a 3/8" hole through both. I followed this with a 15/32 drill, then finished with a 1/2" reamer (**Figure 3**). If you mess up (as I have on occasion) and end up with the holes a little off-center, don't panic as you can further machine the block so the holes are on-center. What you need to remember is the block is no longer 1" thick or 2" wide, and compensate appropriately. Do not be tempted to think the off-center position won't matter. It will make balancing the bar much harder if you do not deal with it now.

There are only two teeth on either side of the beater. Staggering them (as shown in the **photo**) gives a potential bigger bite as the bar can turn almost a full revolution before a tooth first hits the target. However, we still need to have four holes in each side since the outer holes are blind and will require deeper holes to allow them to be easily tapped.

If I did not drill the same holes to the same depths on both sides, it would make balancing the bar much harder. The four holes were carefully scribed, center-punched, and then given a start with a smaller sized drill bit. I find this helps reduce the bigger finish size drill bit from wandering (**Figure 4**). It's also important to control the depth of the outer holes to prevent going too far and possibly affecting the axle holes or the screws that will be used to mount the pulley.

The holes were given a little chamfer with a countersink bit and then were tapped M10 using a

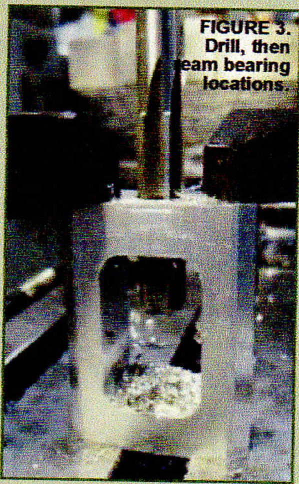

FIGURE 3. Drill, then ream bearing locations.

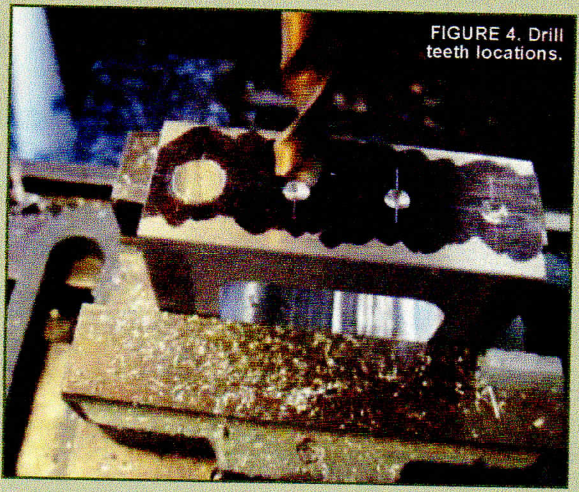

FIGURE 4. Drill teeth locations.

regular, and then plug or bottoming tap to get the thread complete almost to the bottom of the blind holes (**Figure 5**). I only tapped two holes on either side, but in hindsight it would have been better to tap all four as this would make it easier to swap teeth around if the beater gets damaged in a fight. One could also put a button head screw in the empty holes — if weight allows — increasing the mass of the beater.

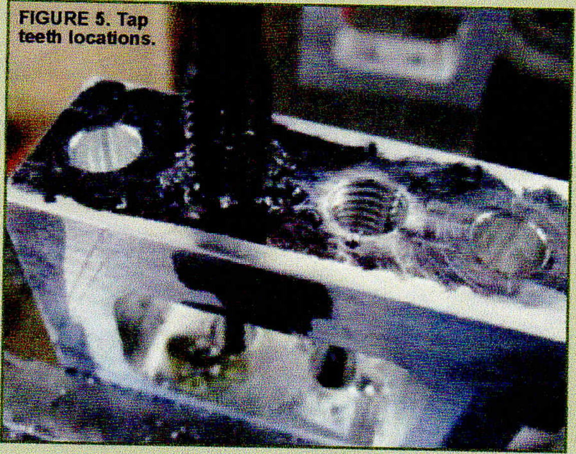

FIGURE 5. Tap teeth locations.

The chamfers on the edges beside the teeth are added last using a chamfer bit in the mill. These reduce the chance of the soft aluminum hitting the target rather than the hard steel of the teeth.

The teeth are then screwed in (I use McMaster part 91290A510) and the needle roller bearings (I use part# BA-57Z from **www.bearingsdirect.com**) are pressed in using a bench vise (protect the bearing by padding the vise jaws or use a set of soft jaws) so that they are flush with the face of the beater.

The beater can now be balanced by running a section of the titanium rod that will be used as the axle (McMaster part 89055K341) and spinning the beater while holding the rod horizontal (similar to how it will spin in the finished bot). If the beater always stops or returns to the same position, it means that the side at the bottom is slightly too heavy.

This can be remedied by removing a little metal from that side of the bar. The bearings are remarkably friction free and even a very small difference will be obvious. Don't remove too much metal at one time, and always protect the bearings from metal filings, etc., by taping over them with painter's blue masking tape. Repeat this process until the beater no longer stops spinning in the same place. It is now balanced and will run much smoother in the finished bot. This helps the bot drive since the wheels are not bouncing around so much, and also reduces vibration damage to the other components.

In a future article, I will show how to create the axle, drive pulley, and flanges. SV

BUILD REPORT: Building a Better Beatle Beater Bar!

Part 2 – The Axle and the Pulley

● by Pete Smith

In Part 1, I showed how to machine a simple and cheap beater bar for a 3 lb Beetleweight combat robot. This month, I will show how to create the axle, drive pulley, and flanges.

The axle used in my Weta kits is a 5/16" ground titanium shaft. This is much lighter than a steel shaft, and has proved to be stiff and strong enough to survive many fights without failure. I buy the stock shafting from **www.mcmaster.com**; their part number is 89055K341. This provides a ground surface for the needle roller bearings to run on (most needle roller bearings — unlike ball bearings — run directly on the shaft surface) and is reasonably cheap for the small size required.

The first version of Weta used shaft collars to retain the axle, but these proved to be very vulnerable in combat and nearly cost us a couple of fights when they failed to hold the axle in position. The solution was to thread the last 5/8" or so of both ends of the axle and use washers and locking nuts to keep everything solidly in place.

Safety Note: Lathes are dangerous if not used correctly. Remove jewelry, any loose items of clothing, and ALWAYS wear safety glasses.

I first cut the axle to length using a cut-off tool and then machined the external diameter down to the correct size for the external thread being used. I have a set of metric threading dies, so I chose the right size for an M8 thread.

Threading titanium is tough, so you may want to make the diameter a little undersized so that it's easy to thread. I've found that even a 50% thread height still works well. Machining a small piece of titanium is more difficult than it is for most materials. It's hard but springy, and will tend to simply bend away from the tool. It took a lot of passes to finally get it to the desired diameter over the length required (**Figure 1**).

I've found a good lead-in for the die helps, so I created a sharp point (**Figure 2**) on the end of the shaft to form one. It not only looks good, it also makes the bot less likely to stay balanced on its side in a fight. Repeat the above for the other end of the shaft.

The axle is then held vertically in a bench vise. I protected its ground surface with a thick layer of paper towels, but if possible get a set of soft jaws or similar as I have damaged shafts even with the paper.

A hardened steel die is used to create the external thread (**Figure 3**). Take your time and use plenty of lubricant, and you can form a nice thread (**Figure 4**).

A drive pulley is required to power the beater bar. I have found

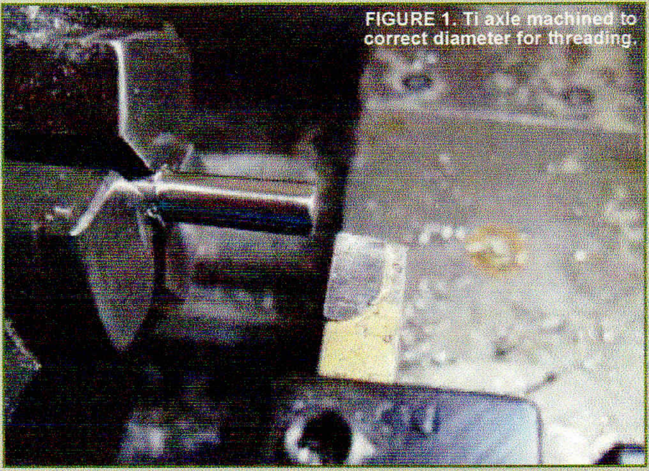

FIGURE 1. Ti axle machined to correct diameter for threading.

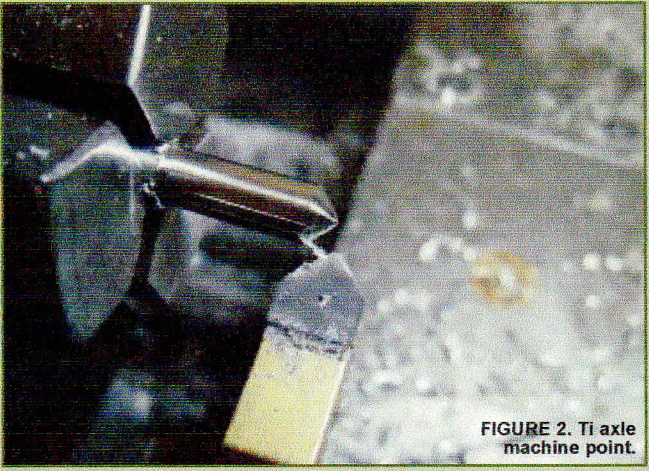

FIGURE 2. Ti axle machine point.

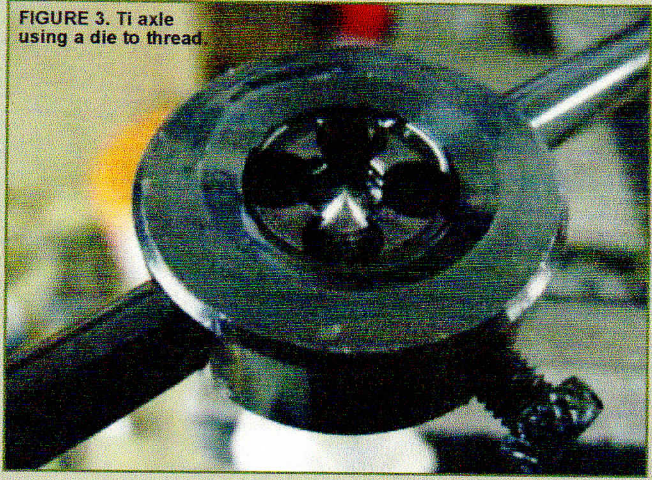
FIGURE 3. Ti axle using a die to thread.

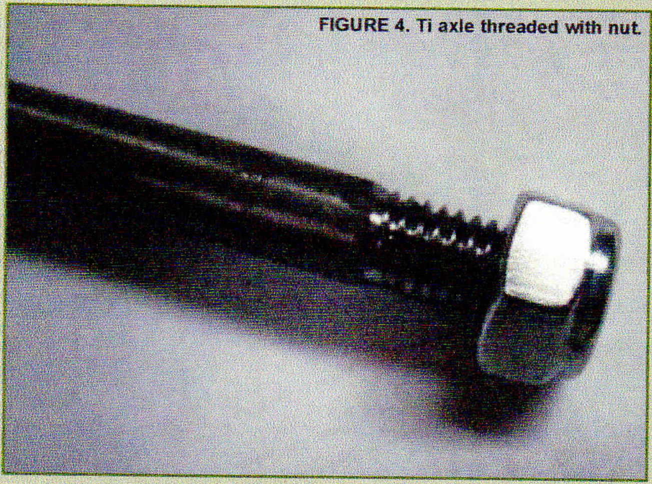
FIGURE 4. Ti axle threaded with nut.

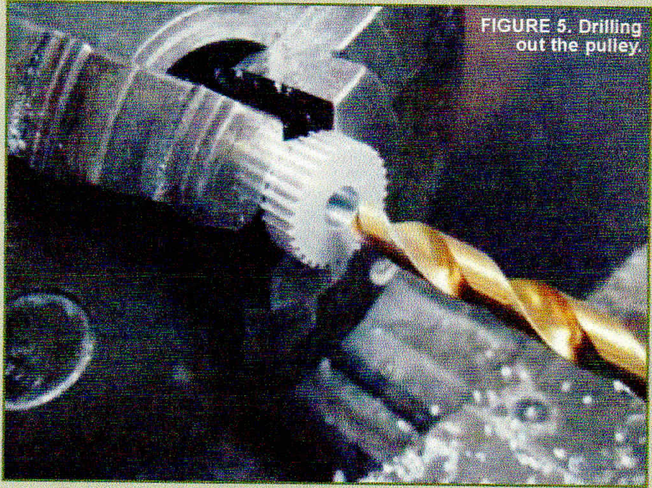
FIGURE 5. Drilling out the pulley.

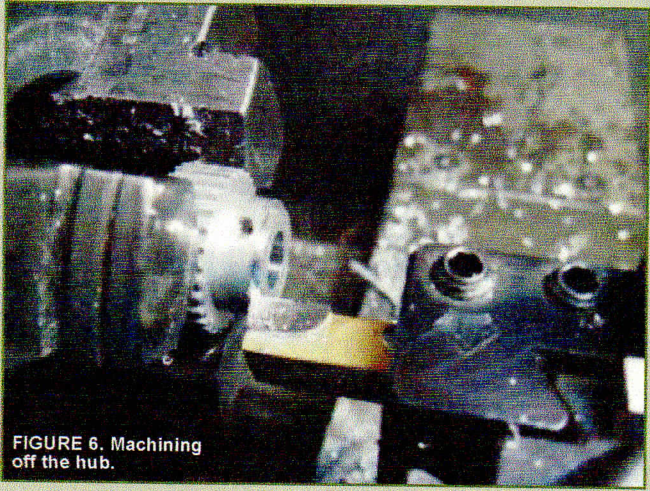
FIGURE 6. Machining off the hub.

that 3 mm pitch HTD x 6 mm wide belts work well in Beetle class bots. A good source for pulleys and belts is **www.sdp-si.com**. You can also get custom pulleys from **www.fingertechrobotics.com**.

On the original version of Weta, I used a 40 tooth pulley. I have since moved to the 30 tooth shown in the downloadable drawings from the article link.

You can buy pulleys with stock flanges, but they are not very deep, are made of soft aluminum, and are easily damaged. I wanted to have deep flanges that would not allow the belt to easily jump off the pulley and flanges that could take a light hit and keep functioning.

With this in mind, I designed two simple machined UHMW flanges that would be retained by the same screws that mount the pulley. It's also important that the attached pulley is on the same axis as the axle, but not actually touch it.

To ensure this, the assembly is


FIGURE 7. Pulley and flange on bearing.

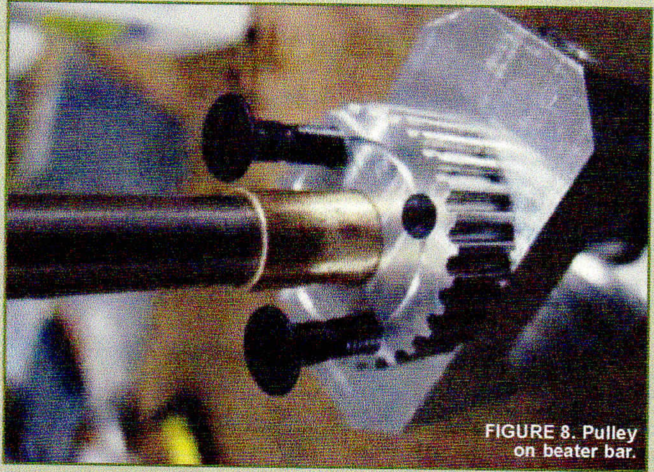
FIGURE 8. Pulley on beater bar.

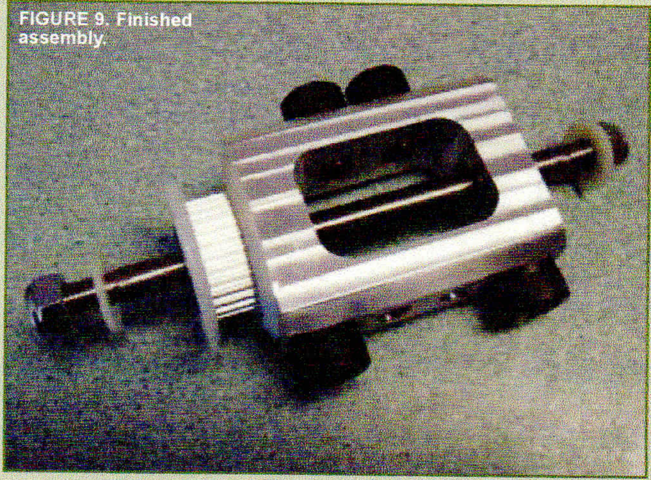

FIGURE 9. Finished assembly.

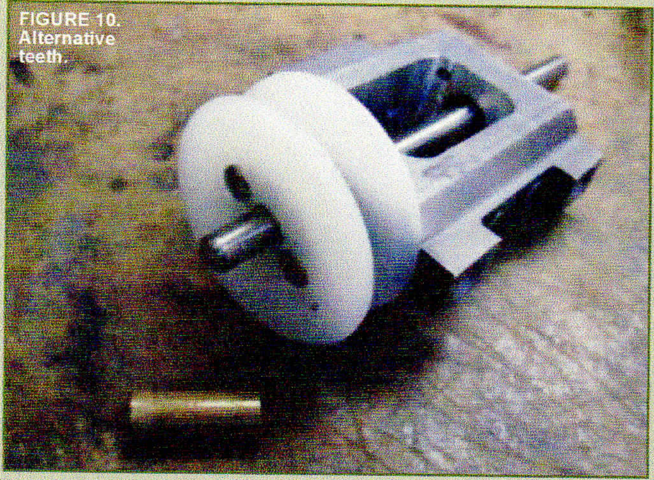

FIGURE 10. Alternative teeth.

built around a bronze sleeve bearing with a 5/16" diameter bore (to suit the axle) and a 3/8" outer diameter. I used McMaster part 6391K156.

The flangeless pulleys from SDP-SI usually come with a large hub and a steel setscrew. Remove the setscrew and then secure it in the lathe chuck by gripping the hub (**Figure 5**).

A 3/8" drill is used to drill out the bore of the pulley to match the bearing. The part can then be turned around and the hub removed (**Figure 6**).

Mark out and drill the two mounting holes. These don't have to be too precisely located since the bearing will control the position of the pulley relative to the beater bar.

The flanges are machined from 1.75" UHMW round bar; they have a 3/8 center bore and generous chamfers to help keep the belt on. The mounting holes in the flanges are added by mounting one of them at a time onto the bearing with the pulley and then marking the centers of the mounting holes using a transfer punch and the pulley as a guide (**Figure 7**).

Drill one hole at a time and use a 8-32 screw to align those holes while you use the transfer punch to mark the center of the second hole. Similarly you can use the axle, bearing, and the pulley to position the mounting holes in the beater bar (**Figure 8**).

Remember to position the mounting holes in the bar so that they avoid the holes drilled for the teeth, and protect the roller bearings (I use pieces of duct tape) from any metal swarf or other contamination when drilling and then tapping the holes.

Finally, attach the pulley and flanges to the beater bar using two 8-32 x 1.25" steel flat head screws (McMaster part 91253A201) with the sleeve bearing still in place.

Use a little loctite on the threads (be careful not to let any get in the roller bearings), and when the screws are both tight remove the sleeve bearing. If it's tight, use a pair of pliers.

Remember to also use loctite on the teeth threads as well to prevent them from working loose in testing or during a fight.

The finished assembly (**Figure 9**) weighs about 10 oz and is available already built on the Kitbots website (**www.kitbots.com**) as a stand-alone option for the 3 lb Crum Beetle Chassis kit.

The same basic design can be modified (if desired) to use separate hardened steel teeth (**Figure 10**), but this is a lot more work and expense.

The beater bar was first used in combat at Motorama 2010. SV

EVENTS

Upcoming Events for August – September 2011

The Homebrew Robotics Club will present their TABLEBot Phase II Challenge at Google (1400 Crittenden Lane) on August 31st. Phase III will be held on October 26th. Go to **www.hbrobotics.org** for more information.

House Of Robotic Destruction 2011 will be presented by the Ohio Robot Club at the Classic RC Raceways in Akron, OH on September 17th. Go to **www.ohiorobotclub.com** for more information. SV

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