
This month, instead of the usual product we receive for tweaking, we were given the Vex Robotics Design System — a robotics kit. We can't very well tweak a box of parts, so this time we will take you through the entire process of designing, building, and competing with this kit. A competition? That is what makes this an epic. In keeping with the epic tradition of such masters as Homer and Chaucer, we will begin each section with a few lines of heroic couplets.

## The Vex Robotics Design System

***Now we embark on a didactic quest where this design system will be put to the test.***

The Vex Robotics Design System is the Carnegie-Mellon University designed robotics kit that will serve as the successor to the Robovation Kit as an introduction to robotics for FIRST Robotics Teams. The Vex kit is also available commercially through RadioShack.

The Vex Robotics Design System seeks to enter the arena of robotics education already dominated by such offerings as the LEGO Mindstorms Robotics Invention system and the outgoing Robovation Kit. Despite this stiff competition, the Vex kit certainly has many sterling qualities that will allow it to work with and not necessarily against other robotics education systems.

The Vex Robotics Design System Kit.

For example, a cursory glance through this new kit reveals it to be quite a complex and comprehensive package. Despite its initial look of complexity, the Vex kit comes with a 246 page manual written in an accessible way that breaks down even the most difficult concepts into easy to read language and helpful illustrations.

The manual is also divided into different "tracks." The All Users Track is a quick intro for everyone to the Vex kit. The Beginner Track is for those without much experience in robotics. The Beginner Track includes a walk-through of basic concepts and step-by-step instructions for building a simple robot. The Experienced Track is for veteran robot builders (like members of FIRST teams) that details some challenges designed to flex the intellectual muscles of all daring enough to try them.

Now, having the manual state that the Vex kit is an effective tool for all levels of robot builders and having that translate into practice are two different things, but the Vex system makes good on this claim. With all of the sensors and logical systems of the Vex kit, the learning curve certainly is steeper than that of LEGO Mindstorms, but that eventually translates to a greater opportunity for expansion and exploration.

The best way to discover the pros and cons of a new item is to work with it. The Vex manual gives instructions on how to build a simple robot for testing called the Squarebot. Building the Squarebot was an excellent way to explore the kit while testing firsthand the clarity of the instructions. The manual may seem a little unwieldy at 246 pages, but once acquainted with it, the manual is fairly easy to navigate. Its clear instructions and effective communication of concepts that form the foundation of robotics should make any user confident that they do, in fact, have what it takes to build a robot.

The 500 parts that come in the kit are all of the highest quality, and the starter kit comes with enough parts to build effective designs for a variety of challenges. A six channel radio is also included, which should bring a big sigh of relief from FIRST teams that won't need to drop another couple hundred bucks for their own (the Robovation Kit came with no radio).

The manual also details the contents of various accessory kits, and the vast number of additional parts is a testament to the potential to expand upon the Vex Robotics Design System. Ease of construction is paramount for an educational kit, and the Vex system is refreshingly easy to use.

The small set of tools that comes in the kit is perfect for structural work, and the socketed electronics makes wiring a breeze. With options for bumper sensors and limit switches, the Vex kit can be made autonomous and it even allows complete user control through the radio and partial or complete autonomy.

Also, one of the best parts of the Vex system is that it pays particular attention to the interactions between the different subsystems that compose the robot (structure, power, logic, etc.). This feature sets the Vex system apart from other robotics kits, and it very closely approximates the experience of building "real" robots (like FIRST robots).

## The Science Olympiad Competition

***We shall test the Vex robot in competition where our efforts will hopefully come to fruition.***

In a fortuitous turn of events, we received the Vex kit in the interim period between the Science Olympiad Inland Empire Regional and the Science Olympiad State event. Science Olympiad is a high school science competition with events ranging from robotics to ornithology. Events involve either taking a written test or competing with a contraption built by the students.

The robotics event — Robot Ramble — is actually what drew us into the competition, and now we've been involved for four years. Chaparral High School's scrappy team took third place in the regional, securing a spot at the state level competition. The Vex kit appeared as an ideal medium to use for the Robot Ramble event, and the competition provided a unique opportunity to detail the entire process of design, construction, and competition.

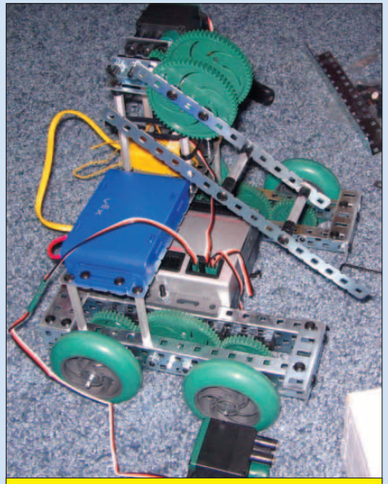
## The Robot Ramble Event

***Manipulating objects is the goal of this event — either succeed with an effective arm or leave in lament.***

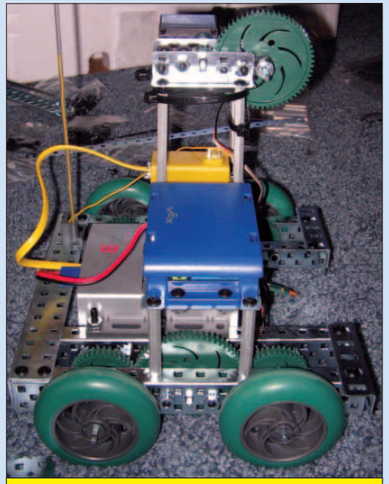
For the past fours years, the Robot Ramble event has involved putting small objects into a 30 x 30 x 30 centimeter box that the robot itself must also be able to fit into. This year, the scoreable items are four Ping-Pong balls, six laboratory cork stoppers, a film canister, and a golf ball. Bonus points are also awarded for deflating a balloon inside of the box.

The object of the game is to score the most points possible within the two-minute time limit. Points are awarded for placing the scoreable items into the box, deflating the balloon, and for keeping the robot within the playing field. Restrictions on the construction of the robot are minimal. Any materials from wood to LEGOs to metal can be used, as long as the finished product can fit inside of the box and the power doesn't exceed 9.6 volts. With this less than draconian set of rules, there is plenty of room for imagination.



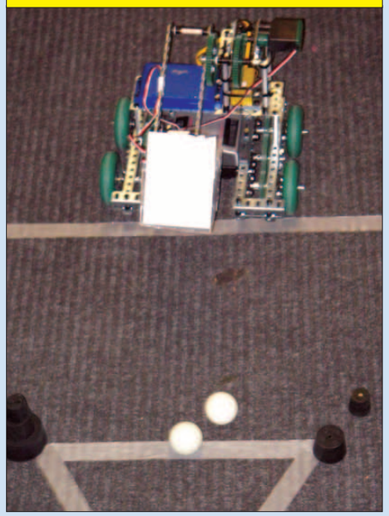


Pumping it up with a little armwork.



The Vex in progress ...

Time for a trial run.



PRACTICE MAKES PERFECT.

## Cast of Characters

***Now we will meet the major players and examine a comparison of many layers.***

As with any good epic, this is not a tale of a single character. As we said before, we had just competed in the Regional Science Olympiad. The robot we used in the regional was Gog VII, the latest award winning LEGO Mindstorms robot from the illustrious Gog lineage (a series of robots that we have built for a variety of competitions; five have won medals or trophies).

The Vex robot's impending confrontation with Gog VII (Gog wants to keep its place on the team) will not only provide an action-packed clash worthy of the history books, but it will also provide a backdrop for a meaningful comparison of LEGO Mindstorms and the Vex Robotics Design System — two contenders in the arena of robotics education.

## Thinking Inside of the Box

***We must conform to oppressive restrictions but we will triumph with our ingenuity and convictions.***

Certainly the most oppressive of the design considerations was the size restriction of having to fit within the 30 x 30 x 30 centimeter box. This does not leave much room for elegant arm mechanisms to lift the scoreable items, but designing an arm before the drive train is putting the carriage before the horse, so now would be a good time to discuss our chassis.

To put ourselves in the mindset of the typical Vex user, we built the Squarebot — a driving platform detailed in the instruction manual. In addition to being a fun introduction to the refreshingly clear manual, the Squarebot turned out to be a perfect fit for the dimensions required in Robot Ramble. The squareness, however, did not leave much room for an end effector for the arm, so we cut some of the frame members with aviation shears, creating a niche where an end effector could be comfortably nestled. Its adaptable shape also made it an ideal base on which we could easily attach an arm.

The Robot Ramble event has been very similar in its different incarnations over the four years that we have participated, so by now we had a good handle on what the most effective design was. The winning strategy usually involved scooping up several, if not all, of the scoreable items at once, so a strong arm with a large gripper would be ideal.

Instead of a narrow claw like on Gog, we decided that a large box would be a more effective end effector for picking up several items at once. The new niche in the Squarebot's frame was the perfect size for a long, narrow box; definitely enough volume for a few Ping-Pong balls. Before making such a box, we needed a boom to mount it on, and a mechanism to drive the boom.

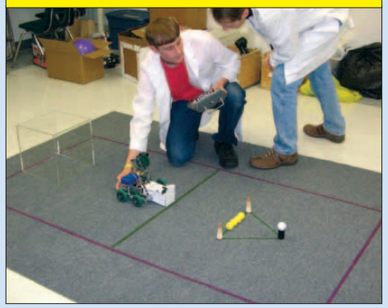
With two motors at work in the drive train, we only had one motor and one servo left with which to make our arm. The motor would be devoted to driving the boom since we needed rotation greater than what the servo could offer us. The servo did come in handy for a flap to close the box, which would ensure that no scoreable items would escape the box once gobbled up. This flap would require only the partial rotation of the servo to function effectively.

The limited number of parts forced us to devise a simple arm mechanism, but often the simplest designs are the most effective. We attached a small, 12 tooth gear to the motor to drive a large, 60 tooth gear. This was a combination of the smallest and largest gears in the kit, which would yield the greatest torque.

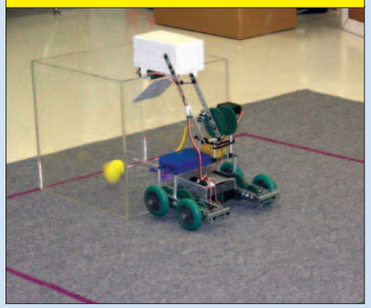
Sandwiching the gear train between two angle brackets raised up on stilts made for easy mounting. We had to mount the mechanism off-center on the raised electronics platform because of, well, the electronics.

TAKE YOUR PLACE AT THE STARTING LINE.

READY, SET, GO!



HE SHOOTS, AND HE SCORES!





This is not to say that the electronics are a burden. On the contrary, the Vex kit's inclusion of a separate battery pack, microcontroller, and receiver creates a more accurate representation than LEGO Mindstorms of what wiring a robot is really like.

With LEGO Mindstorms, all that has to be done is to run a wire between motors or sensors and the RCX brick. While this may be great for beginners that don't need confusing wiring when just trying to learn the mechanics, the Vex kit is better for those seeking to really understand what makes robots tick.

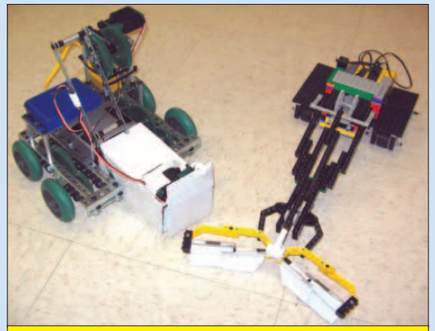
The manual does a laudable job of breaking down this potentially convoluted subject into easy-to-swallow portions while still focusing on how all of the subsystems interact to create the harmonious whole.

Back to the arm. Our off-center mechanism alone allowed us no room to attach our boom, but that's what long axles are for. With a long axle, we were able to attach another large gear outside of our mounting bracket, and this placed the boom significantly closer to the center. To figure out how to mount our boom to the end effector, though, we first needed our end effector.

The easiest thing to scoop a bunch of Ping-Pong balls into would be a box, so we proceeded to make a box for our end effector. With a ruler, some cardboard, and plenty of duct tape, we fashioned a box just under the dimensions of the niche in the frame. We determined the height of the box by figuring what dimension would make it fit over the lip of the goal box when the arm was lifted. The finished product was a long, narrow, thoroughly duct-taped end effector that could gobble up almost all of the scoreable items at once, if the Vex robot had the stomach for it.

It would be a little fiddly grafting the boom to the center of the box, so we attached a second length of metal to the arm that would fasten to the outside of the box's right face. A few screws through the cardboard made for a solid fusion of arm and end effector.

The final step in construction was to use the servo and one more scrap of cardboard to make a flap that would help scoop up scoreable items and keep them safely within the box until the time came to score. A scrap left over from the boom slid in nicely between the teeth of a small gear that attached to the servo, and a careful bend in the metal made it the perfect way to mount the flap. Liberal application of duct tape ensured the integrity of the joint, and, for all intents and purposes, the Vex robot was finished.



THE FACE-OFF.

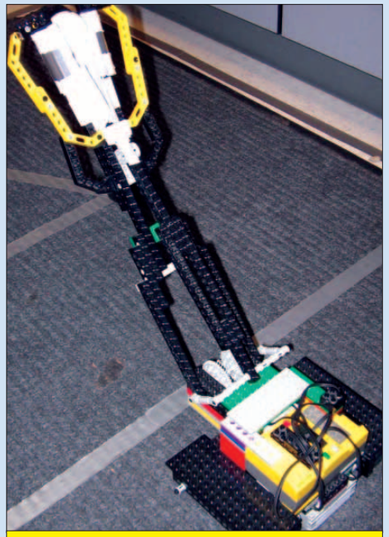
## Clash of the Titans

***Now Vex shall challenge the great Gog, its proud adversary, the loser will be banished to the dusty reliquary.***

With the Vex robot completed, Gog VII optimized, and only one more day until the Science Olympiad State Tournament, it was time to decide which robot would win the coveted spot on the Chaparral High School team. The Science Olympiad team had taken up residence in one of the science building pods, and we were able to secure a hallway between cabinets in which to set up a mock field.

The purpose of this face-off was twofold. First, it would allow us to determine which robot was more effective at playing the game, ensuring that we had the best chance of doing well at the state competition. More importantly, it was a practical juxtaposition of the Vex Robotics Design System and LEGO Mindstorms — two kits aimed at the noble goal of robotics education.

Gog VII was chomping at the bit to defend its honor, so our first trial was with the LEGO Mindstorms creation. Gog proved to be reliable albeit a little slow at scoring. Its claw was best for picking up single items and placing them in the box one at a time. While this was cutting it close with the strict two-minute time limit, once Gog had its claws on something it had a solid grip and was consistent in chalking up



Opponent, Gog, doing a trial run.

respectable scores.

The Vex robot was undaunted by its rival's confidence, and put in an impressive performance. The Vex robot was able to gobble up as many as four Ping-Pong balls in one go and dump them all back into the box. Its voracious style earned it the nickname of "Hungry Hungry Hippo." The stout motors also gave it mobility and speed superior to that of its LEGO adversary.

The Vex robot's advantages when compared to Gog VII can be boiled down to fundamental differences between the two robotics kits from whence the rivals came. The more effective end effector of the Hungry Hungry Hippo can be accredited to the more adaptable wiring of the Vex kit.

Gog's major limitation in this area was that the RCX brick only has three motor ports. Two are invariably dedicated to an effective drive train, so only one remains for the arm. A clever design was able to realize an arm that could open and close a claw and raise and lower the arm using only two motors on the same motor port, but that claw was really only suited to picking up singular items.

While many of the ports on the Vex microcontroller are reserved for interrupts, there were still four available for three motors and one servo, making an arm with two independent mechanisms possible. Differences in the controllers of both robots also contributed to the Vex robot's dominance.

The Vex kit comes with a high quality radio controller with six channels. The radio can even be programmed — the controls can be switched from tank mode (dual joystick) to arcade mode (single joystick). Arcade mode allowed the arm to be operated by the second joystick while creating a very manageable control scheme. An infrared remote for LEGO Mindstorms is only available in accessory kits, and is limited by line-of-sight and cumbersome buttons that make finessing the controls a tiresome necessity.

As any economist would tell you, everything has an opportunity cost, and the Vex robot gains these advantages by sacrificing the simplicity that is an intrinsic quality of LEGO Mindstorms. This difference really distinguishes the individual stations that these two kits have in the theater of robotics education.

Gog scores!

LEGO Mindstorms is perfect for beginners. Lots of kids already play with LEGOs, and this system makes it only a short leap from building pirate ships to a serious and fun educational endeavor. Mindstorms is also adaptable enough to keep even the most experienced roboticists entertained.

The Vex Robotics Design System has a steeper learning curve, and even though it could act as someone's initial introduction to robotics, it seems to us like a perfect stepping stone from the natural simplicity of LEGOs to the inherent complexity of something like a FIRST robot.

The Vex System and LEGO Mindstorms don't necessarily need to exhibit the bitter rivalry of the Hungry Hungry Hippo and Gog VII. Rather, these two kits can work together to create a robotics curriculum that has the potential to take kids from building LEGO castles to mathematical conversations with scientists from NASA.

## The Calm Before

***Now for a few final changes to optimize the 'bot's mechanical ranges.***

The Vex robot was feeling invincible after it trounced Gog VII, but that is not to say that it couldn't stand a few last minute modifications. For example, the scoreable items often had the bad habit of sticking in the end effector when it came time to score.

To remedy this problem, we installed a Styrofoam ramp on the roof of the box that would create an inclined plane for the scoreable items to slide down when the arm was raised. We also installed some collars on the ends of the drive train axles to avoid the embarrassing gaff of having wheels fall off in public.

Our last modification was to punch a small tack through the flap on the box with the purpose of popping the balloon and snagging the 25 bonus points.

## The Abyss

***Will the Vex epic be cut short by a tragic denouement? All shall be revealed at the competition anon.***

In the traditional hero's journey, the abyss usually represents a climax — the point where the hero can finally start the trek back to the light. The Science Olympiad competition is by no means an abyss, but it will serve as a climactic proving ground for the Vex robot.

The competition was held on a Saturday at Long Beach City College in California. We were able to schedule our Robot Ramble time before we had to take our tests on glacial geology and remote sensing, which worked out nicely — we wanted to finish the event we had put the most effort into first. We had only a short time to quiz each other on glacial albedo before our appointed session, but we were ready to do our best. It was feeding time for the Hungry Hungry Hippo.

After some quick tests to see that everything was working properly, we were ready to go. Once the clock started, the first thing we did was gobble up some Ping-Pong balls. Once the Hungry Hungry Hippo had a mouthful, it headed back to the goal box. The arm was raised and POP! The balloon popped as the tack was brought down. The goal box now contained scraps of a purple balloon and several Ping-Pong balls.

The second course for the Hungry Hungry Hippo was comprised of two servings of laboratory corks, most of which made it into the goal box without incident. The Hippo would clean its teeth later; it was ready for dessert — a delicious film canister with a golf ball on top. Unfortunately, the Hippo was only able to grab the film canister — the golf ball was knocked off and rolled out of reach. When the time was called, the Hungry Hungry Hippo had all but the golf ball and a few corks in the box; definitely a respectable score.

Not medal worthy, however. At the awards ceremony, the Hippo's hopes for a medal were disappointed, but this in no way diminishes its accomplishments. There are other adventures to be had, like taking care of stray dogs at community swap meets. What we're trying to say is that even though the Vex robot wasn't recognized with a medal, we still most definitely recognize it as a triumph.

## Flourish. Exeunt.

***Finally, we realize the culmination of this educational peregrination.***

Even though the Vex robot didn't end up taking home a medal from the Science Olympiad State Competition, we can certainly count this competitive outing as a win. We think the motto of Team San Diego (an organization of San Diego, CA area FIRST Teams) is particularly appropriate for the occasion: No Victory Without Learning.

Even though we were already acquainted with the concepts that were presented in the Vex curriculum, the Vex system was an exciting platform for us to use. Exciting in the fact that it was an easy and effective platform for an introduction and continuation in robotics education, and also exciting for the tremendous potential it has through its use in the FIRST program.

We can say without a doubt that anyone who is fortunate enough to have the Vex Robotics Design System as their introduction to robotics will be victorious in any endeavors that they pursue. SV