

LEGO Mindstorms NXT

The Mayan Adventure



James Floyd Kelly

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LEGO Mindstorms NXT: The Mayan Adventure

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CHAPTER 1



Tomb, Trap, and Trigger

Location: Southwest Guatemala

85 miles SW of Guatemala City

Coordinates: 14° 02' N / 90° 42' W

Weather Conditions: 94 degrees Fahrenheit, Humidity 40%

Day 2: King Ixtua Tomb Excavation, 4:42 PM

Evan leaned against a large stone at the base of the pyramid and sprayed more insect repellent on his left arm. The smell was horrible, but unlike the sunscreen, at least it worked. Evan wasn't sure which was more burned, his nose or his ears. He couldn't wait to get inside the pyramid and the shade it offered. The pyramid and the base camp were completely covered by the jungle and not visible from above, but the sunlight still managed to find its way through the leaves and branches and heat the air.

"A slight problem here," said Uncle Phillip as he walked away from the large stone entry door to the Mayan tomb. He continued walking across the camp, with his two assistants, Max and Grace, running to keep up.

Evan turned and ran to catch up with his uncle. "What's wrong?" he asked, almost running into two Guatemalan guides carrying a box of excavation equipment.

"Follow me, Evan, and I'll show you," Uncle Phillip replied as they continued walking towards the communications tent.

Dr. Phillip Hicks was the lead excavator for a newly discovered Mayan tomb, deep in the Guatemalan jungle. Evan's uncle was a professor of archaeology and taught at Florida State University, but he jumped at any chance he could find to leave the classroom and do some hands-on research. Two weeks ago Evan's parents had received a call from Uncle Phillip, asking if Evan would like to tag along; his parents had agreed to let him travel with his uncle for a few weeks to finish off his summer vacation. It would also be a nice break from Evan's younger twin brothers, Les and Wes.

As they entered the communications tent, Uncle Phillip threw his FSU cap on a nearby chair. Sitting next to the chair was a large opened chest with numerous books and strange equipment. Uncle Phillip was an expert in Mayan history, and earlier in the day he had shown Evan a picture of a Mayan glyph from one of the books. Uncle Phillip told Evan that the strangely drawn symbol represented King Ixtua. That same symbol was carved in stone above the tomb's entry door, confirming that the Mayan pyramid was the tomb of the ancient Mayan king.

Uncle Phillip began flipping maps on a large table, looking for something. “Where’s the enlargement of the Tupaxu manuscript? That drawing makes sense now,” he said.

One of the assistants, Max, was looking on a small side table. Evan stood quietly, not wanting to interfere. The other assistant, Grace, began to dig through the chest of books.

“Have you ever heard the story of King Ixtua, Evan?” asked Uncle Phillip. He continued to shuffle maps and papers on the table.

Evan shook his head. “No, sir. My history grades aren’t so hot. Sorry.”

“That’s okay,” replied Uncle Phillip. “I didn’t really become interested in history until college. But I think you’ll like this story.”

Evan’s last history grade had not been impressive; science and math were more to his liking. But when his uncle had told him that this pyramid was unopened and had been hidden for more than 700 years, Evan couldn’t resist. He had packed his clothes, MP3 player, laptop, and the new robotics kit his parents had given him for his birthday last month, and met his uncle at the airport. If the pyramid turned out to be one big boring rock, he’d have his music and could at least spend some time designing some robots to show his friends when he got home.

“This King Ixtua liked monkeys, you see,” said Uncle Phillip as he continued to search through a smaller pile of maps and papers. “He had numerous spider monkeys that he trained to do tricks. The story tells us that King Ixtua had a pyramid built as his final resting place. To keep out tomb robbers and other unwelcome guests, he had the builders design the pyramid so only someone friendly to his monkeys could gain access to the tomb. A nice legend, huh?”

“Weird,” Evan said, and then laughed. His uncle smiled at him and laughed, too.

“Here it is!” yelled Max, as he pulled a large sheet off the small table and walked over to Uncle Phillip. Evan watched as his uncle carefully placed the sheet in front of his team.

“Two years ago, Evan, one of my old professors found a Mayan manuscript in a sealed jar on a dig and gave it to me. I translated the writing and found it was written by Tupaxu, the king’s pyramid builder. It gave a general description of the location of the pyramid, among other things,” said Uncle Phillip. “Look at this,” said Uncle Phillip, pointing his finger at a strange drawing on the sheet.

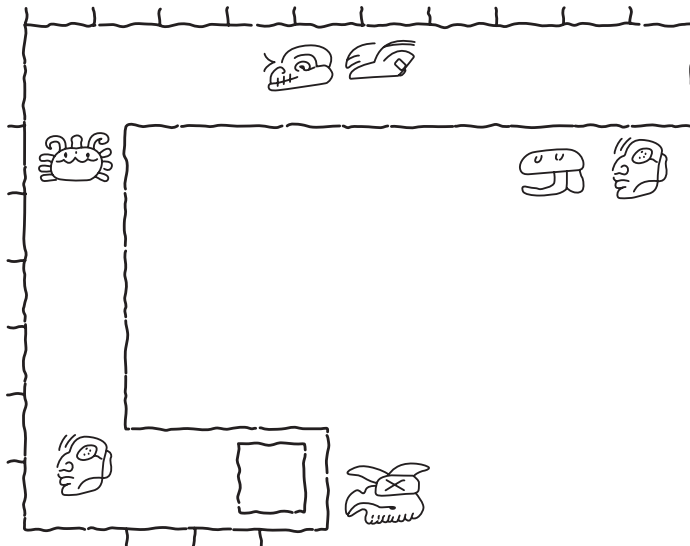


Figure 1-1. Tunnel drawing

Evan looked at the small drawing. It was surrounded by the strange Mayan writing he had seen on the various ruins in the camp.

Evan shook his head. “What is it?” he asked.

Grace pointed at the strange writing. “It’s a drawing of a small tunnel. Your uncle was right about the monkeys, it seems,” she said. “That drawing shows us how to unlock the stone entry doorway to the tomb.”

Evan still didn’t understand, and he frowned. “What are these symbols?” he asked, pointing at the small shapes.

“Measurements,” answered his uncle. “These measurements translate to a tunnel entrance roughly eighteen inches high by eighteen inches wide. Too small for a person, but just the right size for a small spider monkey.”

“But if you’ve found the door, why can’t you just drill through it or knock it down?” asked Evan.

Uncle Phillip shook his head. “First, we don’t destroy or damage any ruins. And second, the door has a trap that is disabled by a pressure switch. If the switch isn’t pressed, the trap, whatever it is, will go off if we open or tamper with the door. Tupaxu was a very smart designer.”

“So you just need to find this pressure switch and press it, right?” asked Evan.

“The first part is easy, Evan,” said Uncle Phillip. “We found the pressure switch, but it’s in a very bad location. Come on, I’ll show you.”

Tunnel Challenge

Evan pointed his flashlight down the tunnel. The bright beam ended about ten feet ahead where the tunnel turned to the left and continued.

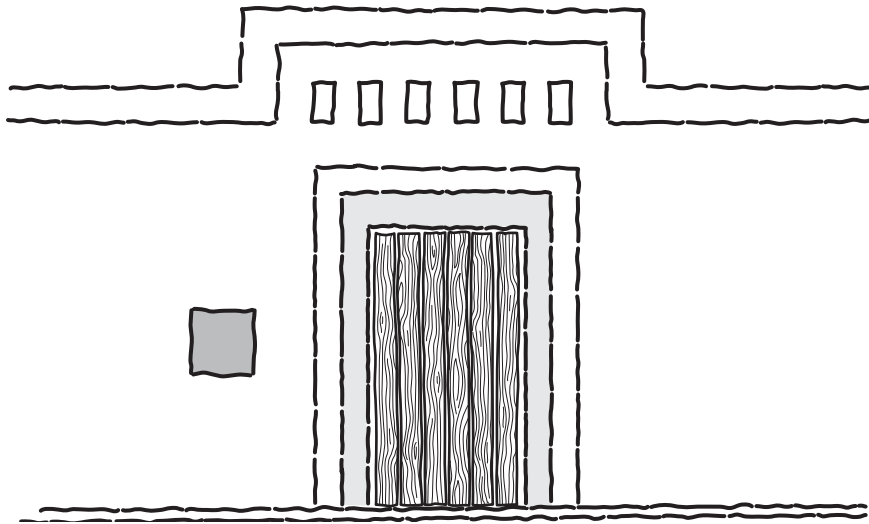


Figure 1-2. Tunnel at tomb entry

“According to the manuscript, the tunnel is about ten feet deep. It then goes left about six feet and then turns left again for another three feet. At the end of the tunnel is a small pressure plate,” said Uncle Phillip. “If the pressure plate isn’t triggered, we can’t get in.”

Grace was busy taking measurements of the tunnel with a tape measure. She nodded and wrote in her notebook. “It definitely matches the dimensions of the drawing. It looks like you were right; a trained monkey would follow the path and step onto the pressure plate, triggering the release for the doorway,” she said. “The legend of King Ixtua is true.”

Uncle Phillip shook his head. “Unfortunately, the story of the monkeys is also true. I don’t think we have any trained monkeys in our tents. And Evan may be too big to send down the tunnel,” he replied.

“What!” yelled Evan. “Are you serious?”

Uncle Phillip laughed. “Just kidding, Evan,” he said. “We’ll find another way.”

Evan watched his uncle scratch his head and turn to walk back to camp. It appeared that the exploration of the tomb was at a standstill. Evan felt sorry for his uncle and the assistants, knowing they had spent so much time planning this expedition. It was hard to believe the solution to the problem was something as simple as a small monkey stepping on a pressure plate.

Uncle Phillip, Grace, and Max talked quietly as they walked back to camp. Evan looked down the small tunnel and shook his head. *If only we had a small trained monkey*, he thought. And then the idea came to him.

“Wait!” Evan yelled and then spun to face the others. “I’ve got it!”

Evan’s Solution

Back in the communications tent, Evan set a small, plastic yellow toolbox on the table. Next to it was his dad’s old laptop that was currently booting up. Evan opened the toolbox and reached in, pulling out a small rectangular object.

“This is the Mindstorms NXT Intelligent Brick,” he said. “This is the brains of any robot I build with this kit.” Evan handed it to his uncle and continued pulling out various objects. He watched as his uncle turned the Brick over in his hands and examined it closely.

“And these are sensors and other parts that are used to build a robot.” He set a few of the objects on the table in front of the team and then logged into the computer.



Figure 1-3. Mindstorms NXT Intelligent Brick and other components

Max and Grace each picked up some of the components and examined them, and Uncle Phillip handed the Brick back to Evan. Evan set the Brick on the table and pointed at the computer screen.

“This software allows me to program the robot to do various tasks. I can tweak the software until I get the robot to do exactly what I want it to do. Pretty cool, isn’t it?” he asked.

Uncle Phillip smiled and nodded. “Are you telling me that you can build a small robot with this stuff that can go down that tunnel and trigger the pressure plate?”

Evan smiled. “Yep. And I don’t think it will take me that long, either,” he replied. He pulled out a small brown notebook from the laptop case and opened it up. He had been playing with the Mindstorms NXT kit for about a month and had plenty of notes and comments written in it.

Max handed his component to Evan and pointed at it. “What does that do?” he asked.

“That’s a servo motor. It does a lot of different things, but I use it mainly to give a robot wheels to move. Grace is holding the sound sensor,” Evan said, pointing at a small block that Grace was examining.

Uncle Phillip pulled a chair over to the table and sat down with Evan. He looked over all the parts Evan was placing on the table and nodded.

“This might work,” Uncle Phillip said. “How much time do you think you’ll need?”

“Well, I’ll need to do some planning first, mainly to figure out the best parts to use. The actual building and programming will take some time, too. I’m guessing three or four hours,” Evan replied.

Max and Grace looked at Professor Hicks, waiting for his decision.

Evan’s uncle looked at his watch. “It’s almost dinner time, and the sun will be down in a few hours. There’s really no point in trying to open the tomb tonight. If you can get the robot working, we’ll let you send it down the tunnel tomorrow,” he said. “Is there anything else you need, Evan?”

Evan thought for a moment, looking at the robotics kit in front of him and all the components.

“I just need some time to work through my design notebook. I’ll start building and programming after dinner,” he said. “This’ll be fun.”

Uncle Phillip smiled at Evan. “All right, this sounds like a good plan,” he said, and stood up. “Dinner is in 40 minutes.”

Evan watched as Uncle Phillip, Grace, and Max left the tent, and then he took a deep breath. “Time to get started,” he said.

Story continues in Chapter 5 . . .

CHAPTER 2



ExploroBot—Planning and Design

In this chapter you're going to learn (drum-roll, please—cue the announcer) . . .
A PLANNING AND DESIGN PROCESS!

Please don't let the words scare you. Yes, "planning and design process" sounds boring, but I promise that you'll have fun with this chapter. I know you're ready to start putting pieces together to build a bot, but if you take some time and go through these P&D chapters, you'll be building and programming your own robots in less time, with fewer mistakes.

So, let's get started. That tomb door is still locked, and you're going to need the ExploroBot to open it.

The ExploroBot

Do you have a picture of the ExploroBot in your mind already? If so, I'll bet that it doesn't look exactly like the one pictured here (see Figure 2-1). (If it does, you are an amazing mind reader. Call me—we can make a fortune on the stock market.)

Note There are five blank design journal pages in the back of this book that you can cut out. You're going to use them to design the robots in this book *and* robots of your own. If you need more pages, you can find a file titled `DesignJournal.pdf` in the Source Code/Download area of the Apress Web site (<http://www.apress.com>) that you can use to print more pages.

At the top of the design journal page you'll see the words `Robot Name`. Go ahead and write **ExploroBot** in the box, and pat yourself on the back. The PLANNING AND DESIGN PROCESS has begun. (You could write something else, such as **RobotThatOpensTombDoors**, but you might run out of space.)

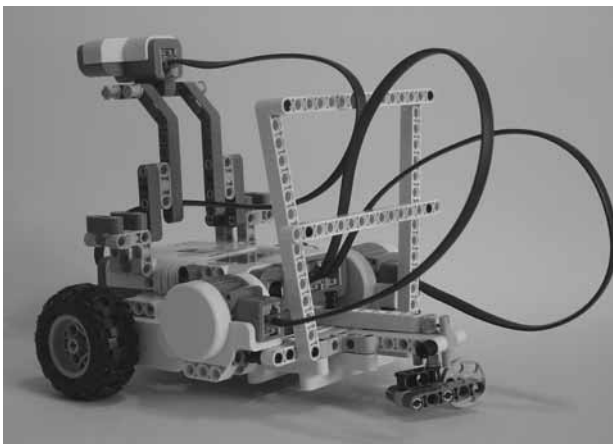
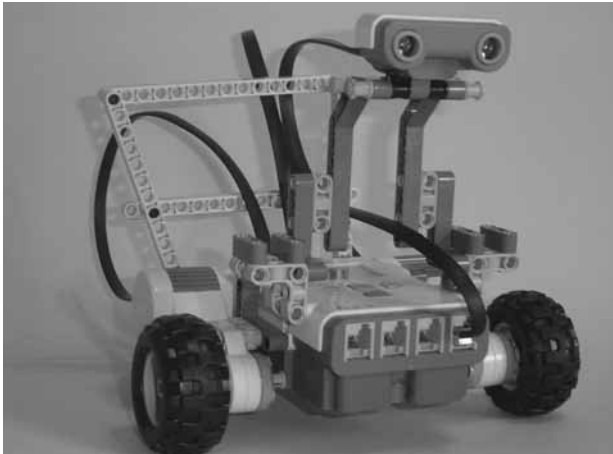
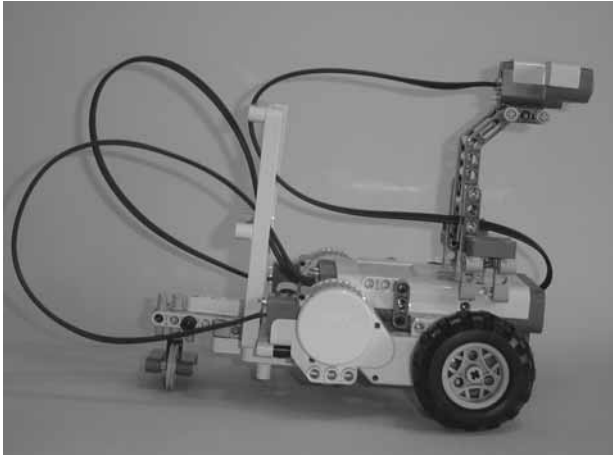


Figure 2-1. *The ExploroBot*

Are you wondering how that little robot is going to open the tomb door? Good question. And you're going to answer that question by following along using a page out of Evan's design journal.

The Robot Description

Okay, now that you've named your robot, it's time to describe it. No, I'm not talking about "Short, grey and white, with wheels." What I mean is, what is this robot supposed to do? At this point, I hope you've read Chapter 1. If not, I'll wait . . . Go back and read it. Okay, have you finished it? Good. Now, what is this robot supposed to do? Don't say it, write it.

Look on your design journal page, and you'll see Robot Description and a large blank box. Don't be shy here. This is where you're going to try your hardest to describe accurately what this robot will do for you. Look back to Figure 1-2 in Chapter 1 if you need a reminder about the path the robot needs to follow. Let me show you what I wrote down, and you can compare it to your description, okay? Here goes (see Figure 2-2).

DESIGN JOURNAL [] [] [] []

ROBOT NAME ExploroBot

ROBOT DESCRIPTION

The Mayan Explorobot must go down a small tunnel about 10 feet and stop before it hits the wall. It then has to turn left and go about 6 feet and stop before it hits another wall. It will make one final left turn and go about 3 feet and stop before hitting, yes, another wall. It needs to wait there about 30 seconds and then turn around to leave. It will go forward 3 feet, stop, and make a right turn. It should go forward about 6 feet, stop, and make another right turn. Finally, it will go about 10 feet so I can retrieve it from the tunnel.

Figure 2-2. Robot description

If your description isn't exactly like mine, that's okay. What *is* important is that you got the major points: Robot moves forward about ten feet, stops, turns. Robot moves six feet, stops, turns. And on and on. Trust me—without an accurate description of the robot, it will be more difficult to build (Chapter 3) and program (Chapter 4). Don't worry if your description missed something; you'll get better at this, I promise. You're going to have more opportunities to write robot descriptions later in the book. By the time you're finished, you'll be an expert.

So, what's next, you ask? Okay, I'll tell you—you're going to take the description you wrote and break it down into small, single-item tasks.

The Task List

On your design journal page, locate the Task List section. This section is where you're going to list each individual task that the robot must perform. The *good news* is that if you wrote down a detailed description (see the previous section), then this section is almost already done.

What do I mean by “individual task?” An individual task is something like “Walk forward five feet” or “Turn doorknob.” Something like “Press the button and turn the wheel” is not an individual task. Your goal is to list the actions your robot will perform, one at a time. Take a look at my task list (see Figure 2-3).

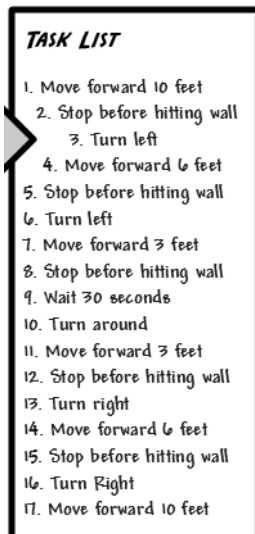


Figure 2-3. *The ExploroBot task list*

Compare your task list to mine. Were you able to break down the robot description into individual tasks? These individual tasks will help you in many ways, including assembling the correct form for your bot, picking the appropriate sensors to be used, and later when programming the bot.

I'll give you a small preview of how we'll use the task list later. Look at steps 2, 5, 8, 12, and 15—“Stop before hitting wall.” Are you already thinking about how to do this? You've got options, of course. There's the Touch sensor that can be programmed to stop the robot when it's triggered. And what about the Ultrasonic sensor? The sensor sends out a signal that's detected when it bounces back off an object in front of it, such as our wall. So you can see that this task list will help you to start thinking about the NXT components you'll use. For now, let's leave the Task List and move on to the next section of the Design Journal.

Limitations and Constraints

You're going to encounter one obstacle quickly when you begin to design your robots using the Lego Mindstorms NXT kit. What is it? It's the number of parts in your kit.

It would be nice if you had access to an unlimited number of sensors, motors, connectors, beams, and other components. But for this book, and the robot designs included in it, I'm not making any assumptions about your collection of parts except that you have the Lego Mindstorms NXT kit or the Lego Mindstorms Education NXT version of the kit.

When you begin to design your robots, you need to be aware of limitations (or constraints) such as this one. Limitations and/or constraints can come from many different places. Besides the number of parts in your robotics kit, you need to keep in mind things such as the following:

- Robot size and weight (tall, short, heavy, light, wide, thin, square, circular)
- Weather and lighting conditions (outdoors, indoors, artificial light, no light)
- Floor or surface conditions (soft, hard, wet, slippery, and so on)
- Movement requirements (up, down, left, right, forward, backward, diagonal)

There may be some constraints that you won't encounter until you begin building and testing your robots. Don't worry if this happens. Your main goal at this point should be to write down any limitations that come immediately to mind. Just look back at your `Robot Description` and `Task List` and the environment or objects where the robot will interact. Do any constraints come to mind? Write them down on your `Design Journal` page in the `Limitations/Constraints` area.

Take a look at Figure 2-4. I've written down a few sentences that describe what I think are some major constraints for the ExploroBot. Remember, there may be other constraints that won't show up until we begin testing our design. The important part is to try and identify any obvious constraints before you begin to design and build your bot.

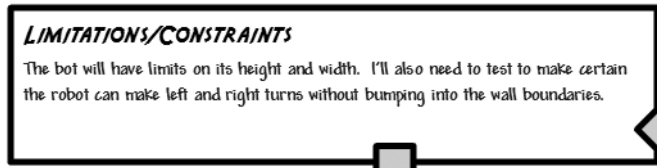


Figure 2-4. *The ExploroBot has a few constraints to consider.*

The constraints for the ExploroBot aren't too difficult to work around. Let's take a look at the challenge and see how these constraints will affect the robot design.

First, the robot will enter a tunnel that has a fixed height and width. So the robot you build cannot be too wide or too tall or it simply won't fit into the tunnel. We know the measurement of the tunnel is 18 inches tall and 18 inches wide. We'll keep that in mind when we begin to design.

The second constraint is a little trickier. Take a look at Figure 2-5. This is an overhead view of the tunnel and its dimensions. Pay attention to the two corners where the robot will turn.

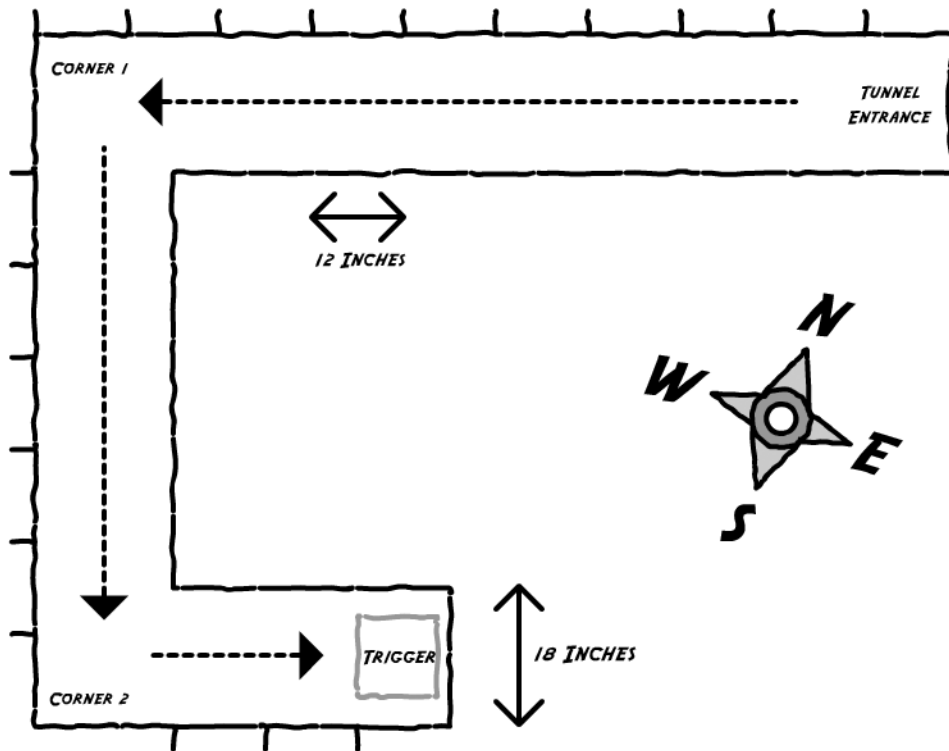


Figure 2-5. The ExploroBot has to turn a few corners to land on the trigger.

The robot must stop before it hits the wall at Corner 1. When it stops, it will turn left and proceed to Corner 2. When it's turning, we'll have to be careful to give the robot sufficient space to turn and not bump into the wall. There are numerous methods for building and programming a robot to make a right-angle turn, and I encourage you to experiment with other methods.

So, how will we do this right-angle (or 90 degree) turn and give the robot plenty of room to avoid bumping the walls? Glad you asked.

If you look at Figure 2-6, you'll notice I've zoomed in on the first corner and included some measurements, including the length and width of the ExploroBot. Ideally, we would like the robot to stop a certain distance from the wall and turn left, and the best place for the robot to stop would be directly in the middle of the corner. I don't want this to get too complicated, so just keep in mind that when the robot turns, it cannot be too close to the wall or, when it turns, it will bump the wall with its front right wheel. So be aware that during the building and programming of the ExploroBot, we'll be "tinkering" and "tweaking" to get the bot to perform well in a corner.

Note During the building and programming of the bot, you'll perform many tests. During this phase, you'll test many of the bot's functions—forward speed, stopping speed, detecting the wall, stopping at a proper distance, and more. I'll cover this in more detail in Chapter 3 and Chapter 4.

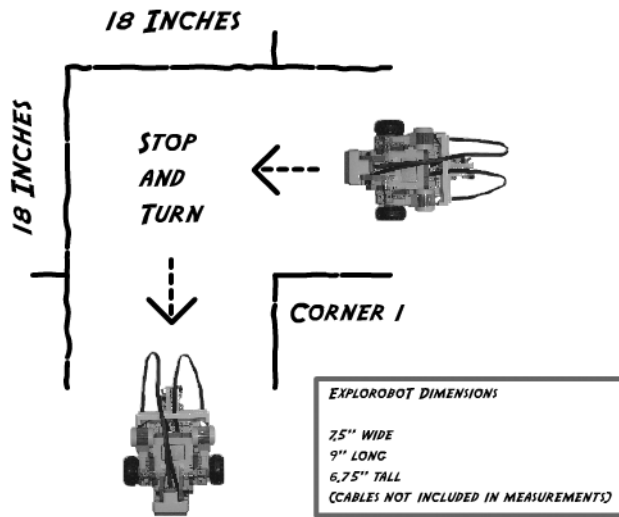


Figure 2-6. The ExploroBot should turn while centered in the corner.

The final constraint isn't so much a constraint as it is a condition that might affect the bot. The surface of the tunnel is stone. It's a flat rough surface, not made of sand. I'm including this constraint only to demonstrate that you must always be aware of the external conditions the robot will face. Because the surface is flat and rough, we should be able to use the large rubber wheels to move the robot, because they'll have a good grip on the surface of the tunnel. But this might not always be possible. A wet surface can sometimes cause plastic or thin wheels to simply spin without getting traction, keeping the robot from moving. And what if the robot doesn't have a surface to roll or walk across? I'll answer that question in Chapter 6.

Just try and always keep an open mind when thinking about the obstacles your robot will face. Examine the robot's environment, its tasks, and its overall goal as you start to brainstorm about how you'll solve the problem. And that's what you're going to do next. You're going to brainstorm about this bot's design, components, and overall appearance in this next Design Journal section—Mindstorm.

Mindstorm

Convenient name for this section, huh? The Lego Mindstorms NXT robotics kit uses that unique word, Mindstorms. For us, to mindstorm (or brainstorm) is our chance to use our creativity and start developing ideas for how this bot will be designed and built. This is an easy section to complete. What I want you to do is simply write down your questions, observations, and ideas that have been popping into your head since you became aware of the challenge. There are no incorrect items to place in this section except for sketches—those come last. So, to get you started, take a look at Figure 2-7. You'll see some of my initial thoughts on this challenge, this bot, and the direction I want to take for my initial design.

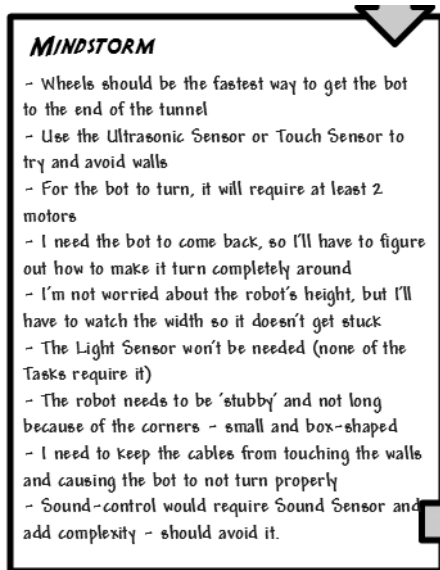


Figure 2-7. The Mindstorm section contains my initial thoughts.

I'm not going to cover all my Mindstorm items here, but I would like to mention a couple and explain how and why I wrote them.

One of my observations was “For the bot to turn, it will require at least 2 motors.” This might seem like common sense, but then again, maybe not. In order for a bot to turn, it has to have a force that makes it turn. Two wheels, connected to a single motor, only give forward and backward motion. For the bot to turn left and right, it requires another motor. By spinning one motor (and its wheel) in one direction and spinning the other motor in the reverse direction, we can cause the bot to turn. This can also be accomplished simply by locking the second motor in place and keeping it from spinning. One wheel will spin, the other wheel will not spin, and the bot will turn.

Another observation was “Sound-control would require Sound sensor and add complexity—should avoid it.” One of my initial ideas was to control the bot by using different sounds and tones. One tone would stop the bot, another tone would make it turn right, and yet another would make it turn left. Then it occurred to me that this would be just too much trouble. My goal is to make the bot as independent as possible and allow it to find its way down the tunnel and back. So the Sound sensor was eliminated.

Your main objective here is simply to have some fun and write down some of your initial thoughts on what you'd like to do with your bot design. You might have to take a completely different direction after some testing. You might find you exhaust your supply of a particular component. What you write down isn't going to lock you in to a particular design. You can change the design anytime—even start over completely. Print out another Design Journal page and try a different design. It's supposed to be fun, so make it fun. Go crazy with your ideas—the crazier, the better!

Now you're done with the Robot Description and the Task List is full. You've identified some Limitations/Constraints and your Mindstorm items section is overflowing with your thoughts and observations. It's now time to finish up with the Design Journal's final section—Sketches.

Sketches

When I draw stick figure people, they tend to have very short legs and very long arms. I still color outside the lines with crayons. I guess what I'm trying to say is that if you're a professional artist, you don't have to worry about any competition from me.

I can, however, draw shapes that are fairly close to squares, circles, rectangles, and triangles. And that's good enough for what I'm going to ask you to do in this section. I want to give you some suggestions before starting on the building of your bot, and I'm going to take my own advice and show you my actual sketches for the ExploroBot.

I'm going to reference some of the ideas I wrote down in the Mindstorm section and show you how I came up with the size and shape of the ExploroBot. First, I'll start with the shape. Take a look at Figure 2-8 and notice that I started with a basic shape to help determine the placement of sensors, motors, and other parts.

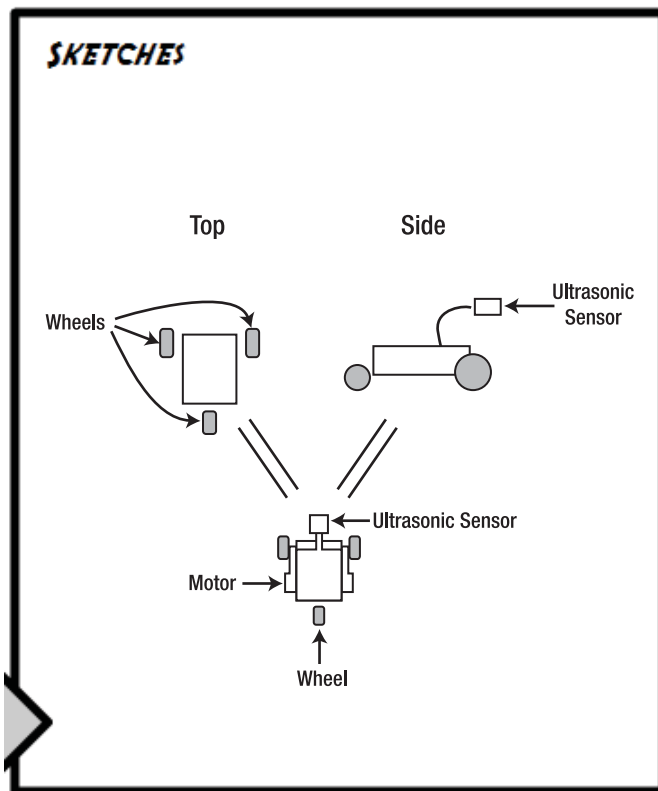


Figure 2-8. In the Sketches section, try and start with placing basic shapes.

First, I need to decide between the Touch sensor or the Ultrasonic sensor for detecting an approaching wall or obstacle. If I use the Touch sensor, it will need to be placed far in front of the bot, possibly on a long neck or pole, to allow it time to stop the bot and give it room to turn. But if I use the Ultrasonic sensor I can place it closer to the bot's body because it can detect a wall or an obstacle from a distance and it doesn't require an impact with the wall or

obstacle. Because my goal is to keep the ExploroBot as short in length as possible, I'm going to use the Ultrasonic sensor.

My ExploroBot will require two motors (for turning), the Ultrasonic sensor, and the Intelligent Brick. And unless I want the Brick to scrape the ground while it moves, I'll need to give it one or two extra wheels. I'll try to save some weight and keep the size down by using three wheels.

What I'm envisioning is using the Intelligent Brick as the main body. Two motors, one on each side of the Brick, will spin the two wheels used for forward and backward motion and for turning. I'll configure a small third wheel that will pivot to make the bot's turning a little smoother and give less resistance.

What do your sketches look like? Have you taken a different approach to the design of the ExploroBot? Remember, there is no *right* or *wrong* solution. If your ExploroBot reaches the end of the tunnel, lands on the pressure plate, and then returns to the tunnel entrance, you've succeeded in opening the tomb door.

In Chapter 3 I'm going to walk you through the assembly of my version of the ExploroBot. Feel free to change it up! Move the Ultrasonic sensor to the back or simply change it to the Touch sensor. Try giving it four wheels instead of three. Chapter 4 will show you how to program the ExploroBot; at the end of the chapter I'll also give you some ideas on how to set up the challenge and test your bot.

Now, let's build the ExploroBot!