LESSON 16

Machines Assessment: A Technological Design Challenge

Teamwork pays off in the technological design challenge.

INTRODUCTION

In the last several lessons, you have investigated different machines. In this lesson, you will use what you have learned about forces, work, and machines. You will also work on a problem identified earlier in the module. In Lesson 8, you found that the motor alone could not lift the K'NEX® sled loaded with 14 washers. In this lesson, you will be challenged to use a combination of the motor and a machine to lift the sled. To do this, you must design a machine-and-motor apparatus and then build it. You will then evaluate how well your design works. At the end of the lesson, you will share with your classmates the apparatus you designed and built, together with your evaluation of it.

OBJECTIVES FOR THIS LESSON

Develop a solution to a technological design challenge.

Implement your proposed solution.

Interpret data.

Evaluate your solution to the technological design challenge.

Communicate the results of your design solution to others.

Getting Started

1. If you have not done so, read "Science and Technology," on page 150.

2. Answer the following question in your science notebook. Then share your examples with the class.

What are some examples of human needs that can be solved through technology?

3. Review what you have learned about force, work, and machines in this module. Be sure to include mechanical advantage.

4. Discuss with your partners and then with the class why knowing mechanical advantage could help in your machine-and-motor design plans.

5. Make sure you have your student sheets from Lessons 11, 12, 13, and 14 ready to use.

MATERIALS FOR LESSON 16

For you

- Your copy of Student Sheet 11.1: Forces on a Cart on the Inclined Plane
- Your copy of Student Sheet 12.1: How Is a Pulley System Used To Do Work?
- Your copy of Student Sheet 14.1: The Mechanical Advantage of Machines
- 1 copy of Inquiry Master 16.1: Scoring Rubric for the Technological Design Challenge
- 1 copy of Student Sheet 16.1a: Planning Our Solution to the Technological Design Challenge
- 1 copy of Student Sheet 16.1b: Evaluating Our Solution to the Technological Design Challenge

For your group

- 1 sled (from Lesson 13)
- 1 pegboard assembly
- 1 knife switch
- 1 motor clamp
- 1 electric motor with wire leads and alligator clips
- 1 motor pulley with nail
- 3 large paper clips
- 3 D-cell batteries
- 3 D-cell battery holders
- 3 black insulated connector wires with alligator clips
- 3 red insulated connector wires with alligator clips
- 1 0- to 2.5-N spring scale
- 1 0- to 10-N spring scale
- 3 machine screws with wing nuts
- 1 20-cm piece of masking tape
- 1 2.0-m piece of string
- 1 meterstick
- One of the following:
  - 1 pegboard lever with pegboard bracket
  - 1 fixed pulley with 4 pegboard hooks and 1 movable pulley (from Lesson 12)
  - 1 inclined plane and double loop hook, with wheels for sled K'NEX® parts for wheel assembly:
    - 4 gray connectors (C1)
    - 2 red rods (R6)
    - 4 small wheels (W1)

SCIENCE AND TECHNOLOGY

You have conducted many scientific inquiries over the past few weeks. You learned how to control independent variables and how to measure dependent variables. You analyzed your data to discover relationships among the variables. In this lesson, you will do something different. You will design a solution to a technological problem.

How is science different from technology? People often talk about them together, but they are actually different.

Science seeks to discover the basic principles that govern the natural world. It tries to understand and explain the relationships among things. Scientific principles are usually expressed as theories or laws of science. Scientists develop and test their theories by conducting experiments. For example, in previous lessons, you experimented with machines. You learned the basic principles that tell you how machines work. You learned the science behind machines.

Technology, however, tries to meet human needs. Suppose you want to build a machine to do a particular task, such as lifting a load onto a platform. Building a machine is a technological design challenge. First, you must have the necessary materials. Next, you must assemble them to make a working machine. That requires technological understanding of machines and how they work. Based on scientific principles, technological designs create working solutions for people.

In this lesson, you will respond to a technological design challenge that will meet a human need. Your goal will be to build a working model. You must build your device to work within certain design constraints. Work with your teammates and share your ideas. Technological design gives you a chance to combine your creativity and your scientific knowledge.

Inquiry 16.1
Choosing the Machine for the Job

PROCEDURE

1. With your group, review Student Sheet 16.1a: Planning Our Solution to the Technological Design Challenge. The task and specifications for this challenge are described in the Project Brief on the student sheet. You and your fellow engineers will fill out this sheet as you complete your design. The K'NEX® sled with 14 washers is the piano for your model solutions.

2. Read the Project Brief on Student Sheet 16.1a. In your science notebook, answer the questions that follow. Then discuss your answers with the class.

   A. What is the human need described in the brief?

   B. What will indicate that your design solution is successful?

   C. What are the constraints that you must work within when you design your solution?

3. Study the recommended time frame in Table 1: Production Schedule on the student sheet. Discuss this schedule with your team members. Note how much time is suggested for each part of the process. As you move through each step of the design challenge, be sure to record how much time you actually spend on each part.

4. Your teacher will give you a copy of Inquiry Master 16.1: Scoring Rubric for the Technological Design Challenge. Review it with the class.

5. You have worked with three simple machines—the inclined plane, the pulley, and the lever—in previous lessons. Now decide with your teammates which of these machines you will use to build your machine-and-motor apparatus.

6. Work with your team to plan your solution to the design challenge. Be sure to complete the Design Brief on Student Sheet 16.1a: Planning Our Solution to the Technological Design Challenge.

7. Implement your plan by setting up the machine you have selected and connecting it to the motor and batteries.

8. Test your setup. Record the result of the test in your science notebook. Keep in mind the criteria set by the challenge.

9. If the motor did not lift the load, analyze your design, modify it, and try again. Technological designs are often tested and modified to produce the best working model.

10. Evaluate your solution and complete Student Sheet 16.1b: Evaluating Our Solution to the Technological Design Challenge. Answer these questions on the student sheet: How successful were our plan and design ideas? How well were we able to follow our plan? What changes did we make to our original design? How close were we to meeting our proposed time frame as shown in the Production Schedule? In what ways is our final machine-and-motor design different from the design specifications provided? How successful is our final design? If we were to redesign our apparatus, what changes would we make?

TECHNOLOGY—IT'S NOT JUST COMPUTERS

Many people think that the word "technology" refers only to high-speed computers, digitized photography, two-way satellite communication, and the Internet. But technology is not just computers! The pulley, the wheel, and even the pencil are results of technological innovation. These devices have one important thing in common: They have all made life easier.

Although science and engineering are related, each has a different goal. The goal of science is to acquire a systematic knowledge of the world. The goal of engineering is to apply knowledge of science and mathematics in designing products that meet a need. The products might be objects, such as bridges or automobiles, or processes, such as a better way to recycle paper.

Engineers usually begin their work with a set of design requirements. These requirements are based on their expectations for the finished product. The design requirements for an automobile, for instance, might be that it have a maximum speed of 130 kilometers (80 miles) per hour and cost less than $20,000.

Often an engineer will create a prototype, or model, to test whether the final product is likely to meet the design requirements. For example, aeronautical engineers build models of aircraft and test the airflow around them in wind tunnels. Naval architects perform similar tests with models of boats in water tanks. For such tests, engineers create requirements appropriate for the small size of the model. If the model does not satisfy these requirements, the engineers search for ways to improve and modify it. If a particular design continues to fail, it's back to the drawing board! This process of evaluating a design through a repetitive process of testing and refining is the essence of a practice known as technological design.

The design process, in other words, does not always move forward in a predictable way. At any point, an engineering team may have to return to a previous step to make improvements. The design is refined again and again, until the engineers believe they have the best-possible product. In some cases, the finished product may not look anything like what was originally proposed!

The design technology loop

When do you use the processes of technological design? Almost every time you have to solve a problem. Planning, building, testing, refining, and retesting are the key steps in a cycle that can help you solve just about any problem, from the simplest to the most complex.

REFLECTING ON WHAT YOU'VE DONE

1. As a team, share your solution to the technological design challenge with the rest of the class.

2. On the basis of what you have done in this lesson, discuss with the class how technological design differs from scientific design.

LINKING A COUNTRY TO A CONTINENT

It's only 50 kilometers from Folkestone, England, to Calais, France, but traveling between these two points is harder than you might think. That's because the two cities are separated by the English Channel.

The island country of England has been separated from France and mainland Europe ever since the last Ice Age, some 10,000 years ago. The channel that divides them is not deep, but its waters are choppy. Boat crossings can be rough.

Until recently, the only way to travel from England to France was by boat or plane. Today, however, you can cross the channel by train.

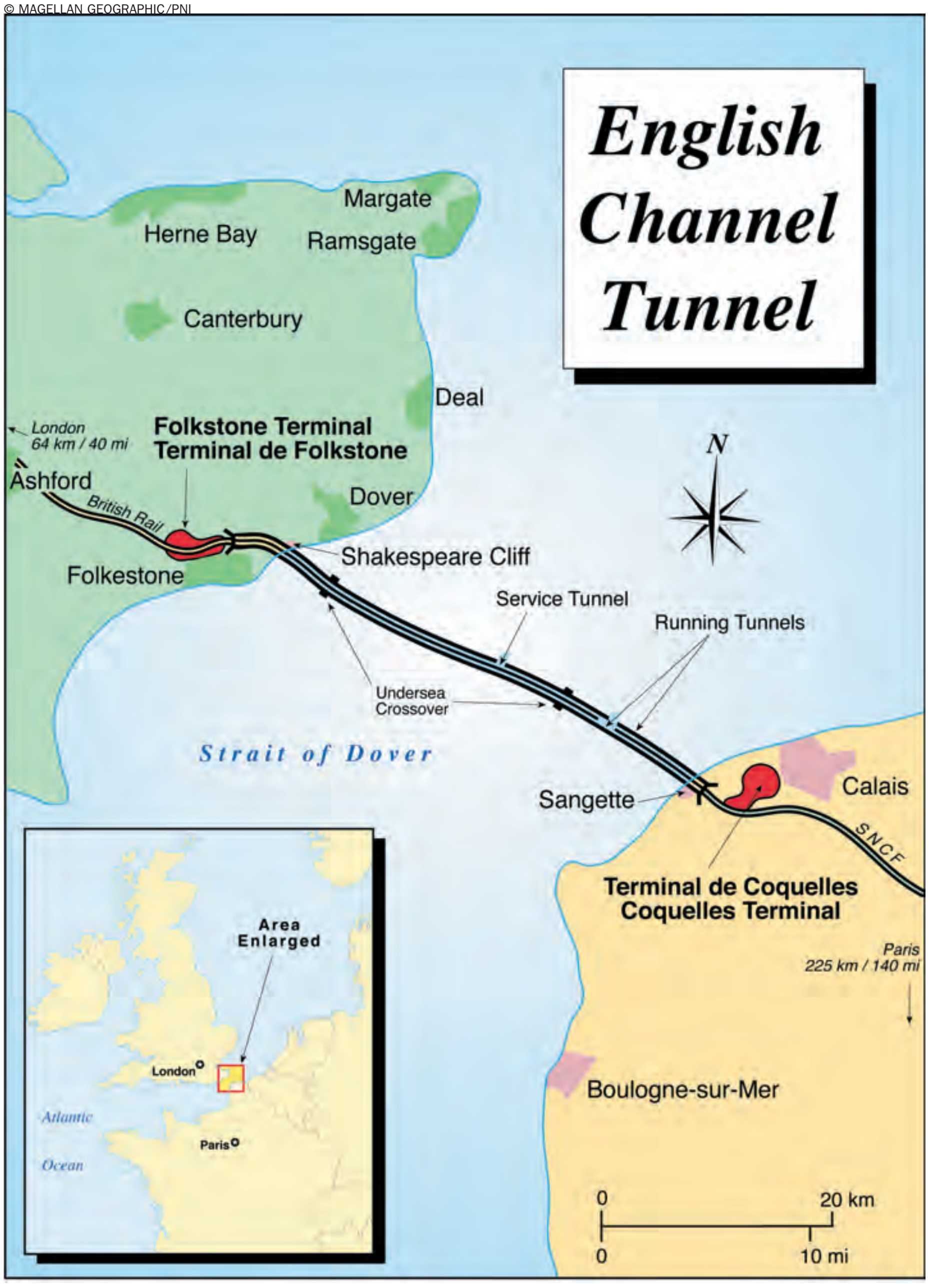
The train goes through a tunnel that was carved out beneath the waters of the English Channel. It is called the Chunnel (short for "Channel Tunnel"). The Chunnel is one of the greatest engineering feats of modern times.

CORBIS/HULTON-DEUTSCH COLLECTION

A 300-Year-Old Dream Come True

People have thought about building a tunnel beneath the English Channel for nearly 300 years. In the early 19th century, Emperor Napoleon Bonaparte even had plans drawn up for how it might be done.

Why didn't anything happen? The answer lies in technology. Even though he was the leader of France, Napoleon did not have the equipment or resources to complete such a huge engineering feat. It would have first required drilling through tons of rock. Then all that rock would have to be taken out of the tunnel. Engineers also said they would need to build chimneys that stuck up through the water so that the



Far left: *A man emerges from the tunnel dug before the Chunnel was built. Although early attempts to dig a tunnel did not succeed, hopes for a tunnel beneath the English Channel remained alive.*

Left: *The shallow waters of the English Channel separate France and England.*

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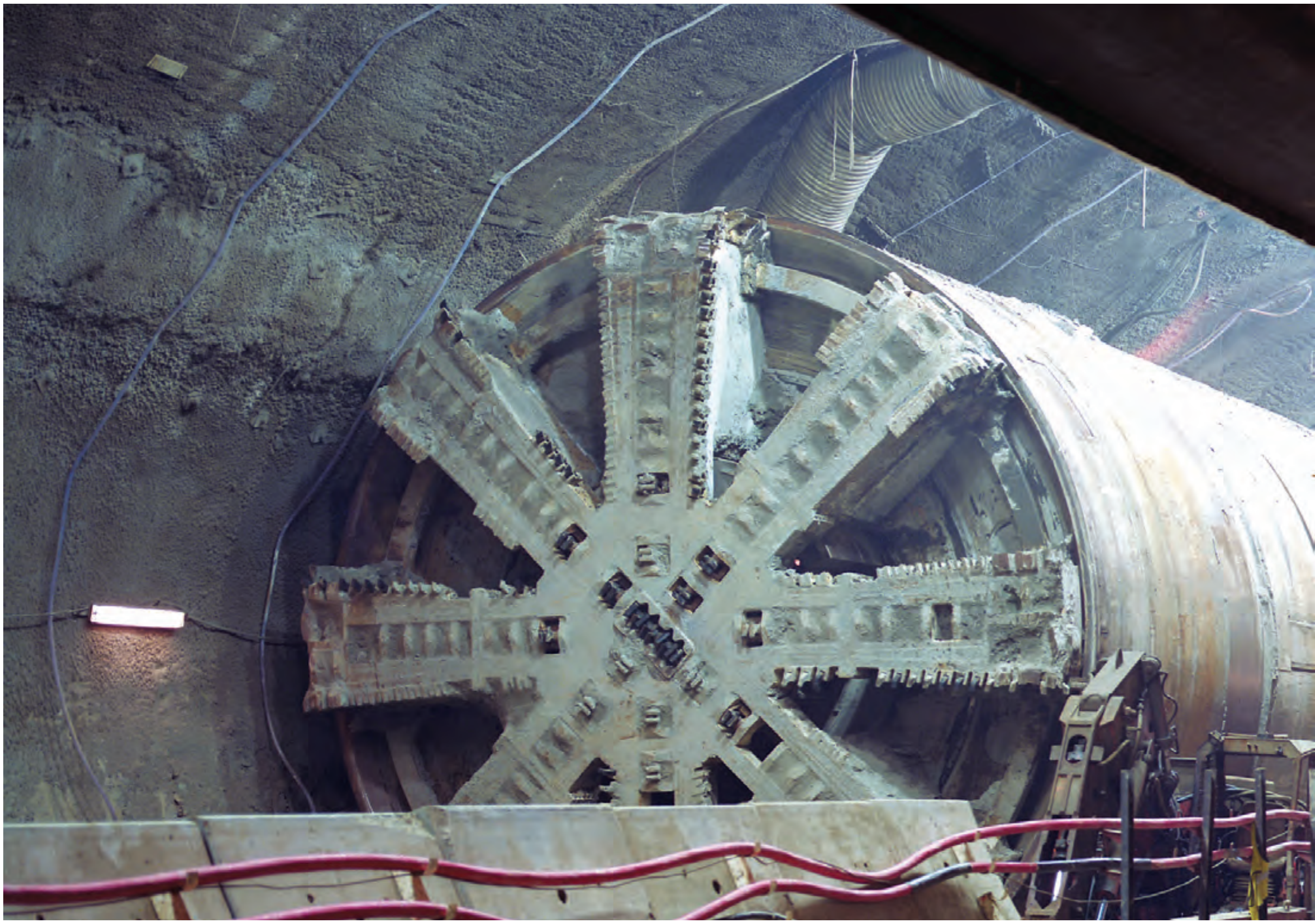


workers would have air. All in all, it would have been a pretty challenging project.

By the 1870s, drilling machinery had improved. The governments of France and England decided to give the tunnel a try. The French started on their side and the British dug in on the other. The plan was to meet halfway. Each country dug for about a mile and then gave up their shovels. Why? The leaders of the two

Above: *It took huge machines like the one seen here to bore through rock and dirt and create the Chunnel.*
Right: *Today, fast trains such as the one seen here carry people and goods back and forth through the Chunnel.*

CORBIS/DAVE BARTRUFF

countries suddenly began to worry about national security. The project was called off.

Making It Happen

Almost a century later, in the 1950s, Frank Davidson, a British attorney, and his wife were crossing from Britain to France on a ferry. The waters were rough, and Mrs. Davidson became seasick. Both of them wished that there was a better way to travel between the two countries.

Mr. Davidson had read about earlier efforts to build a tunnel beneath the waters of the channel. He convinced people in England and France that it was time to try again.

It took the cooperation of the governments of France and England, 10 contractors, and the support of 220 banks to make it happen. Workers started to dig on both sides of the channel simultaneously, as they had in the 1870s. This time, however, the effort was much larger. Nearly 250,000 engineering drawings were made. Monstrous machines were used to burrow 50 meters beneath the waters of the channel. The operators had to bore through rock and sediment that were under tremendous pressure from the waters above.

The Chunnel, which opened in 1994, is 50 kilometers long. It accommodates two-way traffic. Its endpoints are Folkestone and Calais, and a one-way trip takes about 30 minutes. Travelers can drive their cars aboard the Chunnel train and remain in them for the crossing. Trucks also ride the train through the Chunnel. Freight trains use the Chunnel to carry goods back and forth between England and the rest of Europe.

The Chunnel is a real success story that shows how technology can be used to meet human needs. People had dreamed of building a tunnel beneath the English Channel for centuries. Technology made it happen. □

QUESTIONS

1. What human need did the Chunnel meet?
2. What cities are at the ends of the Chunnel?
3. Why did people have to wait until the last half of the 20th century to build a tunnel beneath the English Channel?
4. Explain this statement: Building the Chunnel required the cooperation of many people.

REPORT TO THE PHARAOH

Memorandum

TO: Faruk, Chief Civil Engineer, Giza
FROM: Khufu, Pharaoh of Egypt
DATE: 2600 B.C.
RE: New Work Assignment

I hereby order you to build me a most impressive tomb—a tomb that is truly fit for a king. I want a tomb that will make future generations marvel—a tomb that will last for thousands of years. The site of the tomb will be in the desert at Giza.

I want my tomb to be the tallest building in all Egypt—at least 146 meters high. It must be large enough to house my remains and all my treasures. It also should have chambers for my queen, Henutsen, and for our furniture and other possessions. You must also include secret passageways so that grave robbers cannot steal our treasures.

Please get back to me as soon as possible with your plans for the tomb. How much will it cost? How many workers will be needed? How long will it take to complete the project?

Memorandum

TO: The Honorable Khufu, Pharaoh of Egypt
FROM: Faruk, Chief Civil Engineer, Giza
DATE: 2599 B.C.
RE: Plan for Building The Great Pyramid of Khufu

We are honored that you have requested that we build a tomb to remind future generations of the glory of the reign of the great Pharaoh Khufu.

I have discussed your request with our engineers, designers, and builders. Here are our ideas.

(continued)

Building a pyramid takes careful planning.

Page 2, Memo From Chief Civil Engineer

We will begin by consulting the high priests, who will tell us how your pyramid should be positioned. We will then pick the construction site, using the sun and stars to align the sides of the pyramid precisely to the north, south, east, and west. We will level the site and make sure your pyramid has a firm foundation. Each side will be 230 meters long. We estimate that the site will cover about 50,000 square meters.

The pyramid will be built of limestone and granite, which are found in abundance in the desert surrounding Giza. The exterior surface of the pyramid will be made of a smoother rock, which we will mine from a quarry that is about 700 kilometers from Giza on the other side of the Nile River.

My men will use copper and bronze tools to cut the stone. They are hard workers, but you must realize, Your Excellency, that this is a huge job. We will need 2.5 million cubic meters of rock for the basic structure. The workers will cut the rock into 2-ton blocks. To complete this task, we will need thousands of workers.

After the blocks have been cut, they must be moved to the construction site. Because some of the stone will come from across the Nile River, we will need a fleet of barges to float the rock across the river to Giza. For ground transport, we will place the chunks of rock on sleds or rollers and pull them to the building site. But before we can begin to move the rock over land, we will need to construct roadways over which to transport the rocks. Otherwise, the heavy sleds would sink in the sand. You see, Your Excellency, that this is a most complicated project!

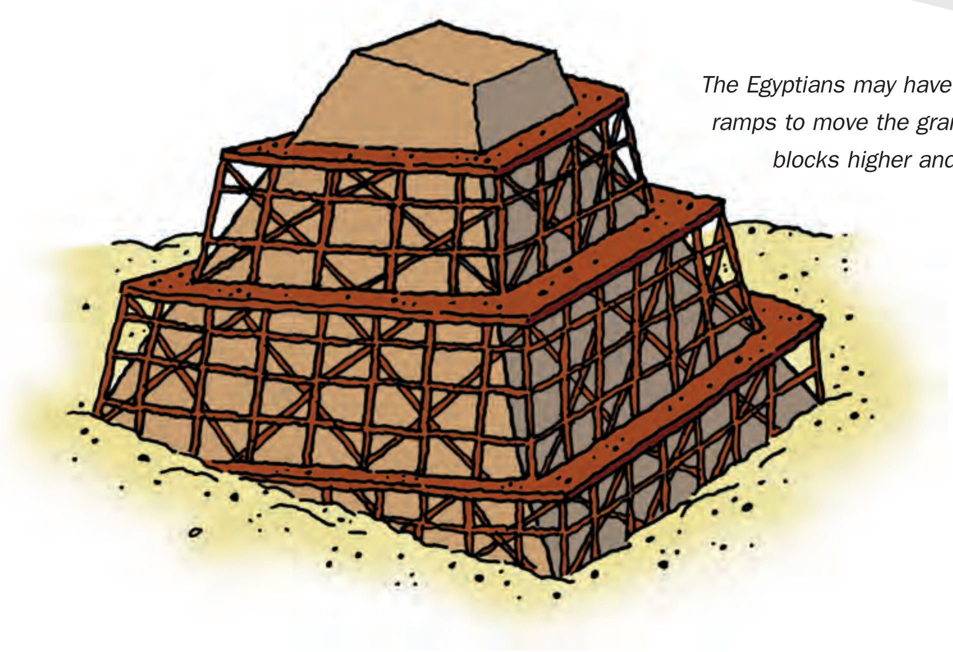
(continued)

Page 3, Memo From Chief Civil Engineer

Let us now look at what will happen when the pyramid is under construction. How will we get the rocks up to the top as the pyramid gets higher and higher? At first, we thought of constructing a long ramp or inclined plane. The slope of such a ramp could be no more than 10 degrees. If we wanted to haul rocks to a height of 146 meters at an incline of only 10 degrees, our ramp would have to be 1.5 kilometers long! Since the main quarry is only 300 meters away from the construction site, this would not be practical.

Instead, we propose to wrap the ramp *around* the pyramid—like a spiral staircase. The ramp will be made from mortar and stone chips. We will place wooden ties on the ramp. We will lubricate the ties with wet clay to make it easier for the blocks to slip over them as they are pulled up the side of the pyramid. When the block gets to the spot where it is needed, we will use a lever to move it into place. When the pyramid is finished, we will remove the ramp.

I hope you can understand, Your Excellency, that this project will take many years and millions of hours to complete. We estimate that it will take at least 20 years, maybe more. We are ready to begin when you say the word. We promise that your tombstone will truly be a wonder of the world. □



The Egyptians may have used ramps to move the granite blocks higher and higher.

CORBIS/ROGER RESSMEYER

More than 4600 years after its construction, Khufu's pyramid, built with simple machines and millions of hours of manpower, stands as a monument to this pharaoh. Until the 19th century, Khufu's pyramid was the tallest building in the world!

CORBIS/KEVIN R. MORRIS

Today, workers build skyscrapers more than 100 stories tall. What machines do they use?