Editor's Note:

We have probably all been amazed at the ingenuity of spacecraft engineers when we see some of the solutions they invent for such problems as landing a roving vehicle on Mars—as engineers at the Jet Propulsion Laboratory did for NASA's Mars Pathfinder project—without using retro-rockets or even putting a spacecraft in orbit first. This month, we bring you a simple, yet creativity-freeing, classroom activity designing a piece of space hardware to solve a real space exploration problem.

This activity relates to NASA's New Millennium Program ***Deep Space 2 (Mars Microprobe)*** *mission, set to launch in January 1999. This will be a great opportunity to involve students in a current NASA mission and let them share in the excitement of solving a real spacecraft engineering problem. More information about the Mars Microprobe mission can be found on NASA/JPL's web site for children,* ***The Space Place,*** *also supported by ITEA. Visit the* ***The Space Place*** *at* ***http://spaceplace.jpl.nasa.gov.*** *Information about other New Millennium Program missions is available at* ***http://nmp.jpl.nasa.gov.***

This activity was conceived by Sharon Mayeux, a fifth-grade teacher in La Crescenta, California. The article was written by Diane Fisher, Technology and Science writer at JPL and the designer and writer of ***The Space Place.*** *Appreciation also goes to Nancy Leon, Education and Public Outreach Manager for Deep Space 2 and other New Millennium Program missions.*

classroom activity
spacecraft design

Solving a Spacecraft Design Problem

Planetary spacecraft have usually been fairly delicate-looking contraptions. Most have had thin, dish-type antennas to communicate with Earth. Some have had long, flimsy-looking instrument booms. Some have had wide solar panels attached by delicate hinges. Although they may have looked fragile, these spacecraft have worked very well in space, designed as they were to withstand extreme temperatures and radiation, but not the extreme mechanical stress of smashing into a planet. Even spacecraft that have made highly successful soft landings (like the Viking Mars Landers in 1976 or the Apollo moon landers in 1969-72) had toothpick-like, albeit sturdy, legs and plate-like feet. Mars Pathfinder, which did a spectacular parachute-slowed, airbag-cushioned landing on Mars July 4, 1997, was built to withstand considerably more jostling than previous landers, since it was still expected to hit the surface at 25 meters per second (56 miles per hour). So far, the only spacecraft actually *designed* to crash land on an alien world were Rangers 7, 8, and 9 (1964-65). The Rangers were on "suicide" missions to the moon, transmitting back to Earth in real time several last gasp, close-up photos of their soon-to-be lunar grave sites.

Except for the Rangers, all previous lander designs only set the craft politely (well, maybe a little roughly in the case of Pathfinder!) down on the surface. Now the National Aeronautics and Space Administration (NASA) is ready to dive below the surface. One way to avoid the cost and complexity of designing for powered or otherwise soft landings is to just drop small, very rugged, probes onto the surface, let them hit at full speed creating their own "impact craters," and give them just enough instrumentation to analyze what lies at the bottom of the hole.

NASA's New Millennium Program was established to develop and test new technologies for use in future space missions. The Deep Space 2 Mars Microprobe project will test new planetary probe technology that will allow multiple, inexpensive probes to piggy-back on another, orbiting spacecraft and be dropped onto the planet's (or planetary moon's) surface. In the case of the Mars Microprobes, the probes must be able to withstand passage through the Martian atmosphere, land right-side up, and use the force of the impact (at 200 meters per second, or 400 miles per hour) to penetrate the surface to a depth that will give meaningful data. And without breaking! The probes' designers have come up with a container for the probes, called an "aeroshell," that will protect the probes from the heat of falling through the Martian atmosphere, keep the probes oriented properly, then shatter on impact, flying out of the way so the probes can do their work.

The activity described on the next three pages, which can be adapted for students from upper elementary through middle school, gives students the opportunity to creatively solve a real spacecraft engineering design problem. Using a pre-defined set of materials, and working in groups of three to five, students design an aerodynamically shaped probe container that will always land upright regardless of how it is dropped or thrown. The groups then join together to "test" (demonstrate) their designs under different conditions, observing which design attributes contribute most to success.

We suggest duplicating and giving the students the first two pages as an introduction and guide before they do the activity and the third page as a catalyst for discussion after the demonstrations are complete.

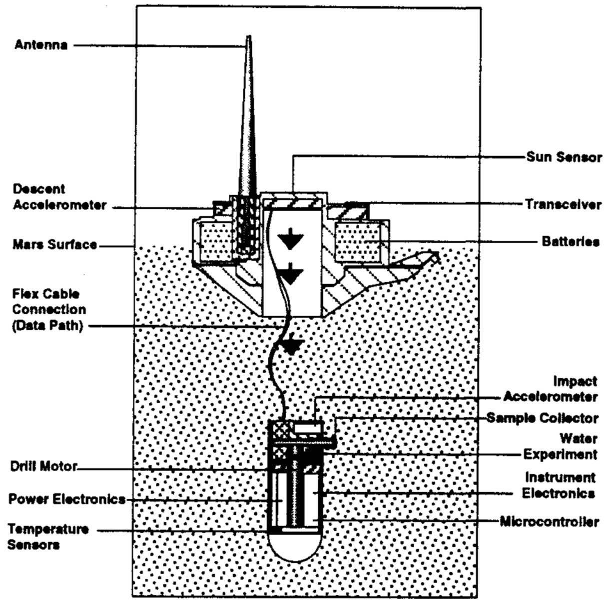
Designing for Impact!

Imagine looking up in the sky at night and seeing a glowing white object streaking across the sky. But instead of winking out quickly like a meteor (or "falling star"), it just keeps glowing and falling, lower and lower, closer and closer to where you are standing! You take cover under a tree and—bang! Whatever it is crashes just a few meters away. You cautiously approach, and, by the light of the moon, see dozens of broken pieces of some thin, eggshell-like material laying around the edges of a shallow, garbage-can-lid sized hole in the ground. In the middle of the hole is a saucer-sized metal disk with a short metal stick pointing toward the sky. All is quiet now, but you soon hear a tiny whirring noise coming from the ground below the disk. What would you think? What would you do?

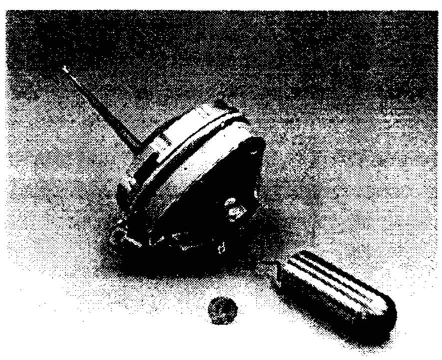
Anything that could get white hot, fall out of the sky and hit the ground at such speed, yet still make mechanical whirring noises, is very strange indeed! Is it some sort of alien technology? Is it a miniature spaceship? Is it full of miniature aliens?

Well, you probably won't see this happen here on Earth, but if you were in the right (or wrong!) place on Mars next December (1999), you might see this very thing—although you wouldn't have a tree to hide under!

The National Aeronautics and Space Administration (NASA) is sending two "microprobes" to Mars next year to test some new technologies for landing probes on other planets. The Mars Microprobes will arrive at Mars by piggy-backing on another Mars-bound spacecraft, the Mars Polar Lander, to be launched in January 1999. The Mars Microprobes (also called the Deep Space 2 mission) will crash land so hard that one part (called the "forebody") will plunge a couple of feet below the surface. There it will send out a tiny drill to



take a soil sample and test it for water. You see, we know there was once a lot of water on Mars, but we don't know where it went. Since it's extremely cold on Mars, we wonder whether some of the water might be frozen in the ground. The part of the probe that stays above the ground (called the "aftbody")—the part that looks like a metal disk with a little antenna sticking up—will send the measurements back to Earth, by way of another spacecraft (called Mars Global Surveyor) already in orbit around Mars.



But how will NASA make these probes land right-side up so the part that's supposed to plunge underground doesn't land on the top? What a problem!

Like the NASA engineers have done, see if you can design and build a probe system that, no matter how you drop it or throw it, will always land right-side up. A probe system is the probe and its container. For your design, just build the container, but take into account where the probe will ride inside it.

Here are the rules:

- The top and bottom of the probe container have to be different.
- The probe container can be no larger than 20 centimeters (or 8 inches) in any dimension.
- Your probe container can be any shape, or combination of shapes.
- You may use only the following materials and tools:

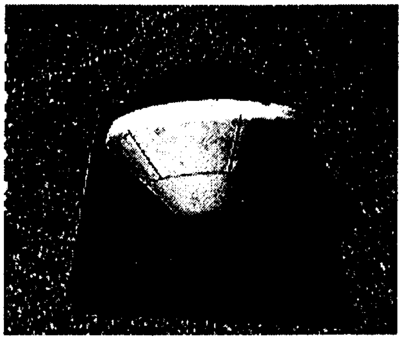
  Index cards or card stock
  Notebook paper
  Tape
  Scissors
  Paper clips
  Ruler
  Protractor

Here's what to do:

1. Get together with two to four others.
2. Figure out what your space mission will be. Where do you want to go? You can invent your own planet or moon if you like. Hint: The shape of the probe container makes no difference in its speed or orientation (which side is up) unless it is falling through an atmosphere.
3. Get everyone's ideas about what possible problems you might have to deal with and what kinds of designs might work.
4. Use some of your materials to test out a few sample designs.
5. Choose one design and assign the various tasks of construction to different members of the group. Make sure everyone has a job!
6. Once your probe system is complete, label which is the top and which is the bottom.
7. Test your probe system to see that it always lands bottom down. If it doesn't, adjust the design and test again.
8. Join in a circle with the other groups in your class. Watch as each group demonstrates its design. If you can, try to vary the heights from which you throw or drop the probe system. For example, first stand on the floor, then on a chair, then on a ladder or some height on the jungle gym.
9. Keep track of which designs are successful and which ones are not.
10. When all demonstrations are complete, examine the two groups of probe systems—the successful ones and the not-so-successful ones. What are the attributes (that is, size, shape, weight, placement of different materials, etc.) of the successful probe systems?

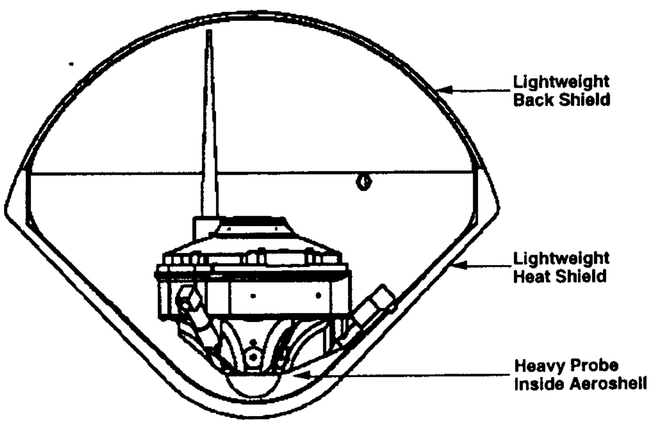
Draw a picture of the most successful probe system design

The NASA Engineers' Design



Here is what the NASA engineers decided was the best design for the containers that will protect and keep the Mars Microprobes' right-side-up as they fall through the Martian atmosphere. It is called an "aeroshell." The aeroshells are pointed on one side like the nose of an airplane. This shape helps the aeroshell to pass through the air more easily, which makes it "aerodynamic." The probes are placed in their aeroshells so that most of the weight is in the aeroshell nose--sort of like a badmitten birdie. This way, no matter how the aeroshell is pointed when it enters Mars' atmosphere, it always straightens itself out and lands nose side down. This is important since the nose side of the aeroshell is covered with a heat shield that protects the probes from the heat of entry. The heat shield must be pointed along the direction of travel to do any good.

The probe itself rides in the pointed end of the aeroshell, thus putting the greatest weight in the downward-pointing part of the container.



How might the design attributes you found most workable have influenced NASA's engineers when they designed the Mars Microprobes and their containers?

The aeroshells are made of a very thin, brittle material that will shatter upon impact with the Mars surface, allowing the forebodies of the probes inside to penetrate the ground.

If you were dropping a probe onto a planet with no atmosphere at all, the shape would make no difference and you would have to use retro-rockets to keep it from crashing too hard. Even though the atmosphere of Mars is only 1/100th as thick as the atmosphere on Earth, it is still thick enough that we can use parachutes and aerodynamic shapes to slow down a Martian lander or probe.

Of course, the container is only the beginning. Spacecraft engineers designing a planetary probe also have to consider what the surface of the planet might be like. How hard or soft will it be? What if the probe lands on a rock? What if the probe lands on top of a mountain and rolls down into a valley before coming to rest? We know it is very cold on Mars. How can they make the electronic and mechanical parts so they will work even at temperatures far colder than even the north pole on Earth? How can they design a power drill so tiny it can fit crosswise inside a probe only 4 centimeters (1-1/2 inches) across?

All these things, and many more, are the conditions and challenges the spacecraft engineers must plan for. Engineers must have great imaginations!

This activity is provided through the courtesy of the Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California.