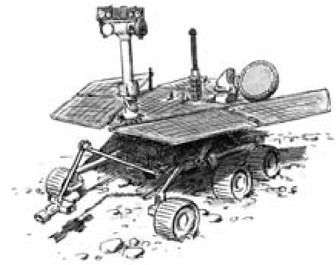
NOVA

Original broadcast: January 4, 2004

MARS Dead or Alive

PROGRAM OVERVIEW



NOVA describes the design and construction of the Mars Exploration Rovers (MERs).

The program:

- outlines the plan to land twin robots on Mars after they journey some 300 million miles to the Red Planet.
- describes some of the challenges the design team faces: the robots must land by themselves; they must function in cold, dusty environments; and they have to avoid landing in canyons or in places with too many rocks.
- presents one aspect of the robots' mission—to find evidence as to whether there was ever an environment on Mars that could have supported life.
- recalls the 1997 Mars *Pathfinder* mission, which safely landed a rover on Mars for the first time.
- describes the challenges of the new mission—to design a rover that can survive landing with the parachute and airbag system used by *Pathfinder*, but with a much heavier rover than the *Pathfinder* previously carried.
- reports that in the past 40 years, more than 50 percent of the missions sent to Mars have failed.
- documents the testing process used to design effective parachutes that have the necessary stability, strength, and braking power.
- discusses the process of selecting a landing site that is both safe and valuable in terms of the mission goals.
- explains that the rovers go through more than 200 tests to ensure that the mission will go smoothly.
- examines how engineers handle last-minute problems.
- shows the excitement and nervousness exhibited by all team members on launch.

BEFORE WATCHING

1 Ask students to imagine that they can visit Mars. What would they want to find out about the planet?

2 Review the solar system with your class. Discuss distances between planets, especially between Mars and Earth. (See NASA's "The Solar System" for more information: heasarc.gsfc.nasa.gov/docs/cosmic/solar_system_info.html)

3 Organize your class into three teams. Assign each team a different part of the Mars Exploration Rovers (instrumentation and power systems, parachute, landing system) to track during the program. They should take notes on how each part or parts work, problems that developed during testing, and how each problem was addressed.

AFTER WATCHING

1 Make a chart on the board that lists the three parts of the rovers. Have each team contribute examples of the problems affecting the parts that were tracked and how those problems were solved.

2 Ask students why scientists sent robots to Mars. What did they want to find out? How did what scientists want to find out compare with what students wanted to know?

3 Discuss the evidence scientists are seeking to help provide clues about whether an environment that could have supported life on Mars ever existed. Why are scientists interested in finding this out?

CLASSROOM ACTIVITY

Objective
To investigate three variables affecting a parachute's rate of descent and then design a parachute that will descend as slowly as possible.

Materials for teacher
- see Teacher Materials Preparation on page 3

Materials for each team
- copy of the "Slowing Things Down" student handout
- copy of the "Engineering Team Directives" student handout
- copy of the "Testing Your Parachute" student handout
- 113-L large plastic trash bag (0.9–1.1 mL thick)
- three 2.6-cm metal washers
- kite twine—Variable A teams: 12 m; B teams: 15 m; C teams: 10 m
- 25-cm compass—Variable A teams only
- tissue paper—Variable B teams only
- plastic grocery bag—Variable B teams only
- meter stick
- scissors
- clear tape
- fine-point marker
- 8-m measuring tape
- stopwatch
- calculator

Procedure
1. Discuss with students some uses for parachutes (to slow down human descent, to drop supplies and other materials into war zones, to slow down vehicles such as the space shuttle and the rovers). Ask students what variables affect a parachute's rate of descent (e.g., canopy surface area, canopy material, length of suspension lines, number of suspension lines, shape, payload weight, vent diameter, and wind). Write their answers on the board.
2. Tell students they have been hired to design, construct, and test a parachute that will bring a payload down to the ground as slowly as possible. In this activity, students will test three of the variables that affect descent rate.
3. Organize students into enough teams so that each variable outlined in the "Engineering Team Directives" student handout is tested by at least two teams.
4. Distribute the materials and student handouts to each team. Have each team make and record a hypothesis about how its variable will affect the descent rate of its parachute. Ask students to explain their reasoning.

STANDARDS CONNECTION

The "Slowing Things Down" activity aligns with the following National Science Education Standards and Principles and Standards for School Mathematics.

GRADES 5–8
Science Standard B:
Physical Science
Motions and Forces
- If more than one force acts upon an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude. Unbalanced forces will cause changes in the speed or direction of an object's motion.

Science Standard E:
Science and Technology
Understandings about science and technology
- Perfectly designed solutions do not exist. All technological solutions have trade-offs, such as safety, cost, efficiency, and appearance.
- Technological designs have constraints.

Mathematics Standard: Measurement

Video is not required for this activity.

Classroom Activity Author
Margy Kuntz has written and edited educational materials for 20 years. She has authored numerous educational supplements, basal text materials, and trade books in science, math, and computers.

5 Emphasize the importance of constructing the parachutes as closely as possible to the specifications provided. This is important to ensure the consistency of results among both the parachutes tested within each team and the parachutes tested among teams.

6 After students have constructed their parachutes, locate a safe and suitable place to drop the parachutes, such as from a balcony, theater stage, gym bleachers, or window. Make sure the drop height is at least 4–5 meters and that there are as few drafts as possible. Emphasize to students the importance of conducting each trial the same way—dropping the parachute in a consistent manner and accurately timing the drop is critical to this activity.

7 Have each team report its results. Create a data table on the board for each variable listing the average descent rates. What contributed to slower descent rates for each variable tested? Once students have shared their findings, present students with another challenge: Based on the results of previous trials, design and construct a parachute that will have the slowest average rate of descent while carrying a 2.6-cm metal washer payload. You may want to give students the option of changing untested variables, such as number of suspension lines or canopy shape. Provide students with any additional materials they may need.

8 Have each team drop its parachute five times and determine the average rate of descent for the five trials. Once all teams have finished, compare the parachute with the slowest descent rate to the others. What about it might have contributed to its longest descent time? To conclude, discuss with students whether the slowest parachute would be the best parachute. What other considerations might affect parachute design?

9 As an extension, have students research different kinds of parachutes and their uses.

STANDARDS CONNECTION (CONT.)

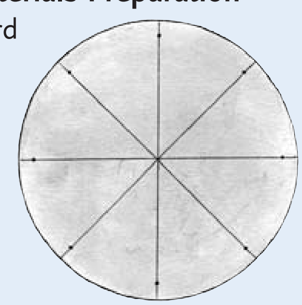
GRADES 9–12
Science Standard B:
Physical Science
Motions and Forces
- Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and inversely proportional to the square of the distance between them.

Science Standard E:
Science and Technology
Understandings about science and technology
- Creativity, imagination, and a good knowledge base are all required in the work of science and engineering.

Mathematics Standard: Measurement

Teacher Materials Preparation

- poster board
- scissors
- meter stick
- pencil
- compass



1 Draw a 36-cm diameter circle on the poster board. Use the meter stick to draw lines through the center of the circle to divide it into eight equal parts. Then, mark a point on each line approximately 2 cm in from the circle's edge.

2 Cut out the template and use the compass point to create a small hole in each of the eight places marked around the edge. Repeat this procedure for each team's template.

ACTIVITY ANSWER

A parachute helps reduce the speed of a falling object by providing air resistance, or drag. The upward force of the air on the parachute opposes the downward force of gravity on the payload. In addition, drag is produced when air moves through the small holes in porous canopy material, across the surface of the chute, or along the suspension lines. Parachutes that create more drag have a slower descent rate, while parachutes that create less drag have a faster descent rate.

A parachute with the slowest descent rate might not necessarily be the best parachute for any given task. Engineers also need to consider other aspects of parachute design, such as stability, weight, and materials cost.

Students tested the following:

Canopy Size: In general, parachutes with a larger surface area produce more drag, and therefore descend more slowly. There is a point where a larger canopy size yields no more added benefit.

Canopy Material: In general, lighter and/or less porous materials create more drag than heavier and/or more porous materials.

Suspension Line Length: Longer suspension lines allow the canopy to inflate fully and thus create more drag, slower descent rates, and more stability. They also add more weight. Shorter suspension lines create less drag, faster descent rates, and less stability. However, suspension lines that are too long may become tangled, while suspension lines that are too short may prevent the parachute canopy from fully inflating.

There are myriad additional variables that contribute to parachute descent rate, including number of suspension lines, payload weight, number and size of vent holes, number of canopy layers, and canopy shape. How these are combined, and the ratios of the materials used, all contribute to how slowly a parachute descends.

In addition to these and other design factors, parachutes are affected by outside forces such as wind and atmospheric pressure. Because the atmospheric density of Mars is less than 1 percent of Earth's, a parachute alone cannot slow down the Mars Exploration Rover enough to ensure a safe, slow landing speed. Therefore, the MER parachute system includes rockets to help slow the descent of the lander and to help counteract the effect of strong Martian winds.

To help the rover land safely, the NASA team designed several systems, including an aeroshell to protect the lander carrying the rover from heat and forces during atmospheric entry, a parachute to slow the lander's speed prior to impact, and airbags to soften the landing. The Martian lander requires a parachute system that will slow the lander enough to prevent it from crashing into the surface, and stable enough to prevent the lander from striking the surface at an angle.

Sample Results

Variable A: Surface Area
Parachute 1: 18 cm canopy

	Height (m)	Time (s)	Rate (m/s)
Drop 1	4.5	2.14	2.10
Drop 2	4.5	2.23	2.02
Drop 3	4.5	2.23	2.02
Drop 4	4.5	2.28	1.97
Drop 5	4.5	2.04	2.21

18 cm
average descent rate: 2.06 m/s

27 cm
average descent rate: 1.25 m/s

36 cm
average descent rate: 1.04 m/s

Variable B: Canopy Material
Parachute 1: trash bag

	Height (m)	Time (s)	Rate (m/s)
Drop 1	4.5	4.09	1.10
Drop 2	4.5	4.20	1.07
Drop 3	4.5	4.48	1.00
Drop 4	4.5	4.56	.99
Drop 5	4.5	4.67	.96

trash bag
average descent rate: 1.02 m/s

plastic grocery bag
average descent rate: .87 m/s

tissue paper
average descent rate: .96 m/s

Variable C: Suspension Line Length
Parachute 1: 15 cm line

	Height (m)	Time (s)	Rate (m/s)
Drop 1	4.5	2.05	2.20
Drop 2	4.5	2.65	1.70
Drop 3	4.5	2.05	2.20
Drop 4	4.5	2.20	2.05
Drop 5	4.5	2.15	2.09

15 cm
average descent rate: 2.05 m/s

25 cm
average descent rate: 1.31 m/s

50 cm
average descent rate: .96 m/s

LINKS & BOOKS

Links

NOVA Web Site—MARS Dead or Alive
www.pbs.org/nova/mars/
In this companion Web site for the NOVA program, watch the program online, learn why water is necessary for life, investigate the rover's parts, explore Mars' landscape, and design your own parachute.

Mars Academy
www.marsacademy.com/
Features an international online collaborative project to find real-life solutions to problems involved with designing a manned mission to Mars, including landing site selection, trajectory calculations, rocket design, crew selection, and life support system plans.

Mars Daily
www.marsdaily.com/
Contains a collection of articles related to Mars exploration.

Mars Exploration Rover Mission
mars.jpl.nasa.gov/mer/
Includes short biographies of the scientists who worked on designing the rovers and background information about the mission.

Mars Exploration Rovers
athena.cornell.edu/
Provides information about the scientific instruments on board the rovers, the flight plan, and video simulations of the rovers landing on Mars.

Martian Invasion: Probing Lively Puzzles on the Red Planet
www.sciencenews.org/20031108/bob10.asp
Outlines the objectives of the European Space Agency's and NASA's missions to Mars.

NASA Center for Mars Exploration
cmex-www.arc.nasa.gov/CMEX/index.html
Presents hundreds of concept maps of Mars-related information, digital atlases of the Red Planet, a menu of human and robotic missions to Mars, educator resources, and more.

NASA Spacelink: Mars
spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Space.Science/Our.Solar.System/Mars/.index.html
Provides image libraries, resource guides, investigations, and more.

NSTA Web News Analysis: Mars Journeys
www.nsta.org/main/news/stories/nsta_story.php?news_story_ID=48395
Offers a digest of online news articles focusing on Mars journeys.

Slowest Model Parachute Challenge
www.cc.gatech.edu/projects/DITC/designTasks/parachute/index.html
Provides an in-depth investigation for a coffee filter parachute challenge, complete with video clips from three classrooms that completed the unit.

Books

Boyce, Joseph M.
The Smithsonian Book of Mars.
Washington: Smithsonian Institution Press, 2003.
Provides a firsthand account of the history of the planet's exploration by one of NASA's Mars program scientists. Includes explanations of Mars's atmosphere, climate, surface, and interior derived from NASA mission findings.

Croswell, Ken.
Magnificent Mars.
New York: Free Press, 2003.
Discusses what is known about Mars and what is still to be discovered.

Hartmann, William K.
A Traveler's Guide to Mars: The Mysterious Landscapes of the Red Planet.
New York: Workman Publishing Company, 2003.
Discusses the three major eras of Mars's 4.5-billion-year history and compares the geologic processes on the Red Planet with those on Earth. Includes many photographs.

Morton, Oliver.
Mapping Mars: Science, Imagination, and the Birth of a World.
London: Fourth Estate, 2002.
Examines scientists' efforts to map Mars and profiles researchers and science fiction writers who have contributed to how Mars has been viewed.

Raeburn, Paul.
Mars: Uncovering the Secrets of the Red Planet.
Washington: National Geographic, 1998.
Chronicles the history of human exploration of Mars, describing each Mars mission and its key players. Includes a pair of 3-D glasses to view a foldout landscape of Mars.

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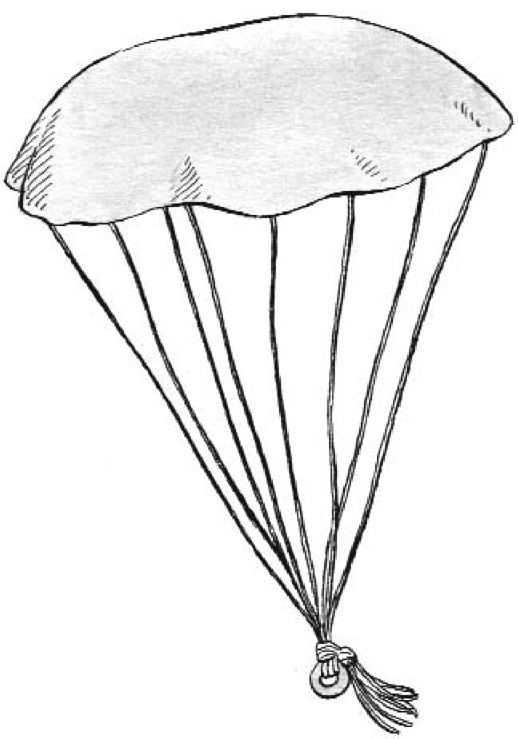
Slowing Things Down

A parachute system has been designed to slow the landers down when they enter the Martian atmosphere at speeds of up to 20,000 kilometers per hour. The Mars rover teams have the added challenge of a thin atmosphere that makes slowing the landers down even harder. There are many variables that affect how much a parachute can slow an object down. In this activity, each engineering team will test one variable that affects descent rate in a normal Earth atmosphere.



Procedure

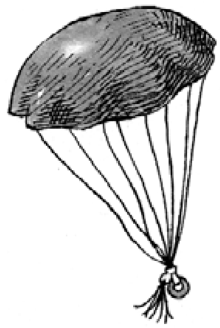
1 Construct the three parachutes assigned to your team. Trace the template your teacher has provided on a flattened garbage bag, which will be your parachute's canopy (since the bag has two layers, each template will result in two canopies). Cut out the canopies. Variable A teams will alter the size of their canopies; variable B teams will also cut canopies out of additional materials.

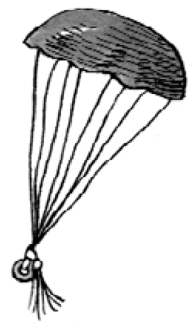
2 Center your template over the canopy and use your pen to mark each of the eight holes on the edge of the template.

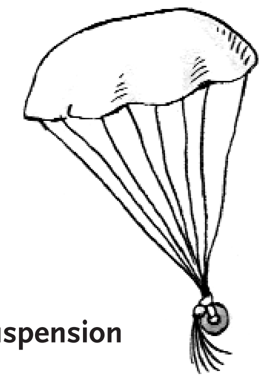
3 Further modify or attach suspension lines and the payload to your parachute according to the instructions listed on your "Engineering Team Directives" handout.

4 Repeat the steps for your next two canopies.

Engineering Team Directives







Variable A: Surface Area
Your team will test the effects of surface area on descent rate. Your specifications will be:

Parachute 1: 18-cm canopy. Use the compass to draw an 18-cm circle on your canopy. Cut it out and mark eight equidistant points 2 cm from the circle's edge. Cut eight suspension lines 35 cm long and attach to canopy according to the instructions below. Mark and tie off at 25 cm. Attach one washer as described below.

Parachute 2: 27-cm canopy. Use the compass to draw a 27-cm circle on your canopy. Cut it out and mark eight equidistant points 2 cm from the circle's edge. Cut eight suspension lines 48 cm long and attach to canopy. Mark and tie off at 38 cm. Attach one washer.

Parachute 3: 36-cm canopy. No canopy changes necessary. Cut eight suspension lines 60 cm long and attach to canopy. Mark and tie off at 50 cm. Attach one washer.

Variable B: Canopy Material
Your team will test the effects of canopy material on descent rate. Your parachute specifications will be:

Parachute 1: 36-cm canopy made out of the plastic trash bag. Attach eight 60-cm suspension lines to canopy according to the instructions below. Mark and tie off at 50 cm. Attach one washer as described below.

Parachute 2: 36-cm canopy made out of the plastic grocery bag. Attach eight 60-cm suspension lines to canopy. Mark and tie off at 50 cm. Attach one washer.

Parachute 3: 36-cm canopy made of the tissue paper. Attach eight 60-cm suspension lines to canopy. Mark and tie off at 50 cm. Attach one washer.

Variable C: Suspension Line Length
Your team will test the effects of suspension line length on descent rate. Your specifications will be:

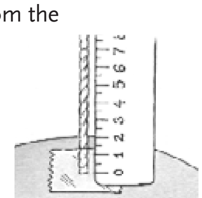
Parachute 1: 15-cm lines. Cut eight lines 25 cm long and attach to canopy according to the instructions below. Mark and tie off at 15 cm. Attach one washer as described below.

Parachute 2: 25-cm lines. Cut eight lines 35 cm long and attach to canopy. Mark and tie off at 25 cm. Attach one washer.

Parachute 3: 50-cm lines. Cut eight lines 60 cm long and attach to canopy. Mark and tie off at 50 cm. Attach one washer.

ALL TEAMS

Attaching Suspension Lines
For each line, touch the end of the string to the mark you made 2 cm from the edge of the canopy. Attach each line to the canopy with a 3-cm piece of tape. Start from the *top of the string,* where it is taped to the canopy, when measuring the length where you will mark to tie off. Do not stretch the string as you are measuring it.



Adding Payload
Bring your lines together where they have been marked and tie a half knot with the lines so that the marked areas all appear in the same place on the outside of the knot. Add your washer payload and tie another half knot over the washer. Tighten the knot. Trim the remaining strings to 5 cm. Your parachute is ready to launch!

Testing Your Parachute

To test your parachute, you will drop it from a certain distance and time its descent. Then you will use the drop height and descent time to calculate the descent rate, which is the amount of time it takes the payload to fall a certain distance.

Procedure

1 Make three charts like the one below for your trial data.

2 Prepare your parachute for launch. Turn the parachute over, and while holding the washer, find its center point (see illustration at right). Turn the parachute back over while holding the center point. Smooth out the folds of the parachute so that they drape smoothly. Be especially careful when doing this with the non-plastic canopies.

3 Position the parachute over the drop zone and wait for the payload to stop moving. Measure the distance (in meters) from the payload to the floor and record this height. Drop *all* of your parachutes from this height.

4 Have the person with the stopwatch count down from three, saying "drop" at zero. At that moment, the timer should start timing and the person holding the parachute should drop the parachute. Timing should stop when the payload hits the floor. Conduct two practice trials before performing your actual trials.

5 Perform five drops, making sure to drop the parachute from the same height each time.

6 Repeat the test for the other two parachutes you built. Calculate and record the average descent rate for the five drops.

Questions

Write your answers on a separate piece of paper.

1 Which of your parachutes had the slowest descent rate? Explain why.

2 What, if any, patterns do you see in your data? How would you explain these patterns? Which patterns do you think are important? Explain your reasoning.

3 What are the lowest and highest descent rates in each of your three parachute trials? If there are any large differences, what do you attribute them to?

4 How confident are you of your results? Explain your level of confidence.

preparing the parachute for drop

dropping the parachute

Variable: *surface area*

Parachute 1: *18 cm*

	Drop Height (m)	Drop Time (s)	Descent Rate distance (m)/time (s)
Drop 1	4.5	2.14	2.10
Drop 2			
Drop 3			
Drop 4			
Drop 5			

Average Descent Rate:___________