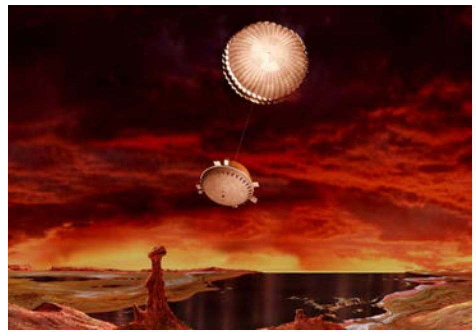
Activity 7
Drop Zone! Design and Test a Probe

Overview

During this activity, your youth:

- Build a parachute and probe that can descend and land safely from a high point.
- Creatively use the information learned in previous lessons to perform science and engineering techniques of design, construction, and testing.
- Learn the value of experimentation that allows testing, improvement, and refinement as a professional part of engineering.



Time/number of sessions	Activity Type	Space Needed
Four 40-minute sessions. Sessions 3 and 4 may be repeated.	Hands-on construction	Classroom or cafeteria for construction; gym or schoolyard for testing

Activity Goals

Youth will:

- Include data from readings in their experimental design.
- Use experiment and analysis to study, force, motion, and mass.
- Consider real-world challenges in their parachute/probe designs: proper descent, and on-target landing on varied surfaces using the "habits of mind" of engineers.

Where's the Science and Engineering?

- For engineers, experimentation to test, fail, learn, and improve is a natural part of the design–build–test process and is not considered a failure but an opportunity for progress and eventual success in space.
- Engineers design and build spacecraft and instruments as solutions for science objectives rather than for looks or for their own personal goals.

National Science Education Standards

K–4

Physical Science
- Properties of objects and materials
- Position and motion of objects

Science Inquiry
- Abilities necessary to do scientific inquiry

Technology
- Abilities of technological design
- Understandings about science and technology

5–8

Physical Science
- Properties and changes of properties in matter
- Motions and forces

Unifying Concepts and Processes
- Evidence, models, and explanation
- Systems, order, and organization
- Form and function

Equity/Leveling the Playing Field

- Students who don't have experience with building activities, or who need opportunities to increase their fine motor skills may need additional time or days to re-visit their structure. They may also need technical assistance from you.
- You can group students who have more experience with those who have less — remember, one child may take over and may require careful facilitation.
- Remind students that a "failed" probe is an opportunity to re-design and not a reflection of the team's potential or ability.

Getting Ready

For Session 1

- Find location for later testing parachutes and parachuting probes (Session 4)

For Session 2

- Copy the student *Parachuting Probe Packets* as in materials list.
- Set up a safe testing area from which to drop the probes. If it is not safe to use an elevated, protected, common traffic area, use a ramp or volleyball net. Draw a "target" landing area with chalk or place a hula-hoop.
- Make a clay ball for the probe drop, to use as a baseline time test.
- If you have access to a small portable wading pool, use this for the landing in liquid test. (Be sure the students understand that there will not be liquid water on Titan's surface, though there are lakes of liquid methane.)
- For the volleyball net drop zone, wrap the probe in its parachute and launch by throwing it over the net. The parachute must open and float to the ground without harming the probe. The net establishes a minimum height for the probe to climb before falling to Earth, and also a "safe zone" that is kept student-free until all probes have been thrown. They are retrieved after throwing.

Leader Tips

- Allow 20 minutes or more to make the probe packets and to set up construction materials for the parachutes and probes.
- To think like engineers, give the measurements for the parachute and string to students in metric units. To convert inches to centimeters (cm), multiply inches by 2.54. Example: 14 inches = 2.54*14 cm = 35.56 cm.
- Students may have "unlimited" or set distribution from the type and amount of materials you gather. You can set "prices" on the materials, and give students a limited budget or you can give them a set of supplies and a budget to buy more.
- If napkins or tissue paper are not available, opened sheets of 2-page newspaper are an option. Cut the 4 pieces of string the same length as the edge of the paper and use a heavier test object.

For time limitations, students can conduct a parachute inquiry only. The questions in the *Parachuting Probe Packet* can be applied to parachutes rather than probes. You can still design/re-design for a slow descent in a targeted area. Discuss "controlled testing" where only one design factor changes at a time: material type, string length, or washer size.

Materials — From Your Supply Closet

Session	For Leader	For Students
1		For student teams of 4 — For Parachutes • Tissue paper or paper napkins (about 14 inches on a side when opened up) • Self-adhesive, 1/4-inch hole reinforcements or clear tape • Lightweight string (such as kite string) or packing string, cut into four 14-inch lengths • Metal washers or a number of large-size paper clips At a separate table, additional materials for experimentation • Hand-held hole punchers • 14 by 14 inch sheets of sturdy plastic material (cut from garbage bags) • Several large sheets of plastic to be cut into various sizes • Plenty of additional (uncut) string for adaptations/ variations • Masking tape; clear tape • Several metal washers, can be of various sizes • Boxes of large-size paper clips; rubber bands • Drawing paper
2	• Long-arm stapler • Chart paper/whiteboard/ chalkboard and markers/chalk	
3		At a separate table — For Probes • Paper cups/plates of various sizes • Clean pint-size milk cartons • Paper cylinders (e.g., paper towel or toilet paper tubes) • Pipe cleaners; straws; Popsicle™ sticks • Foil • Tissue paper • Corks • Tape • Stapler • Whatever you can scavenge and/or students can bring in • Optional: materials for decoration • Student's *Saturn Discovery Log*
4	• Clay to make small ball • Stop-watches or watches with timers (2–3) • Sidewalk chalk or hula hoop • (Optional) small inflatable wading pool and water	

From a Photocopier/Printer

Session	For Leader	For Students
2	Leader Reference *Huygens Probe Components*	• Back-to-back photocopy of the student *Parachuting Probe Packet* for each student team of 4. Nest the pages, and fold (check to make sure the pages are in order). Staple into booklets (5-1/2 by 8-1/2 inch) using a long-arm stapler.

Drop Zone! Design and Test a Probe

Student Activity

Session 1 • Building and Testing a Parachute

1. Prepare the students to build and test their parachutes using the following conversation guide.
    - Once engineers understand the challenges of landing a probe in space like the one that the Cassini and Huygens engineers landed on Titan, they often build models and experiment with testing. First, they start with a model they think will work. If it does not land successfully, they don't call it a failure but rather an opportunity to improve and draw closer to success.
    - There may only be one thing that isn't working: the material, the size, measurements of the parachute, etc. So they only change one thing at a time and then test again. That's called "controlled testing." The engineers "control" changing one thing that might work and then if it doesn't, they go back to the original model and change something different until they have a successful landing.
    - At some point, they may begin to combine some of the successful parts of the experiment and they may end up with a very different model from the original parachute and probe.
    - Think of these things as you work to make a team parachute and later a probe.
    - Remember to include your whole team in the design and the construction. Everyone should have an engineering task to do.
    - When you feel you may have your best parachute design built, try it out in a clear area of the classroom to see how it does.
    - If you find you need to do some controlled testing, decide as a team which one thing you believe should change and then test again.

2. Assign the students to small teams of 3 to 4.
3. Have the students use tissue paper or paper napkins (approximately 14 inches square) to create a parachute. Use a paper punch to make one hole in each of the four corners as far into the paper as possible. Strengthen with a self-adhesive binder paper hole reinforcement, or 4 short pieces of tape surrounding the hole.
4. Attach 14-inch lengths of string to each corner, and tie these to a small washer or other light object (such as several large-size paperclips arranged side-by-side and held together with a rubber band). Each team should use the same kind of items.
5. Students need to figure out how to fold and toss the parachutes so that they open and slow the fall of the washer/object. These experiments can be done in the classroom.
6. Once students have mastered this, they can experiment with different lengths of string, different-size washers, and/or different parachute materials. Be sure they understand that they should only change one variable at a time in order to have a true controlled test!
7. Collect the parachutes to save for the coming sessions.

Session 2 • Designing a Probe

1. Tell the students that they now have the opportunity to put themselves in the shoes of spacecraft designers and engineers. Distribute the *Parachuting Probe Packets* and read the text aloud.
2. Ask students to summarize the activity aloud and ask them what questions they have. Show the students the materials that will be available for them to use for building the probes.
3. Regroup the students into their small teams of 3 to 4. Recombine teams as needed to accommodate new or missing students.
4. Have a member of each team collect their parachute from Session 1.
5. Explain to the students that they will be doing an illustrated plan of their probe before they start building. The illustration should be carefully labeled and detailed. Use the Leader Reference *Huygens Probe Components* as an example, and as a reference for yourself in guiding the students' designs. Encourage the students to include design notes for the illustration. They should use the guidelines set forth in the probe packets. Remind them to record information in their *Parachuting Probe Packets*.
6. When students have completed their plans, reviewed them as a team, and everyone is satisfied, you may allow them move on to building the probe as in Section 3.
7. Collect the *Parachuting Probe Packets*.

Session 3 • Building the Probe

1. Regroup the students into their small teams of 3 to 4. Recombine teams as needed to accommodate new or missing students. Redistribute the *Parachuting Probe Packets*.

2. Have materials available for probe construction, and for an appropriate sized parachute if needed. Allow students to select materials and construct probes (and parachutes if needed) as a team.

3. Explain to the group that the next session will be the testing day for the probes. Provide time for students to share their designs with one another, and the whole group. Each design team can explain their choices and designs BEFORE testing begins.

4. (Optional) If time allows, provide a test area each day for the students to test their progress and allow for modifications to their design, based on the information from the testing.

Session 4 • Testing the Probe

1. Remind the students about the definition for controlled testing using the following conversation guide:
   - As we test our parachutes and probes, we have a controlled test. Remember what that means? What is the same about this test? What will all your tests have in common? (You are looking for: They are all dropped from the same height and in the same way. The landing surface is the same). What do we have that is different? (Their parachute probes are different.) If you make any changes to your parachute probe between your tests, your team should make note of it in your packets
   - We need to figure a baseline time of descent from our drop point. To do this, we'll drop an object, of similar weight to the probe that does not have a parachute attached. We'll use this clay ball and we need to record the time it takes for it to drop. Then we need to estimate how much slower we think the parachute probes will fall and that will become our target time for your teams to meet. Record all of this in your *Parachuting Probe Packets*.

2. Each team drops its own probe (or throws it over the volleyball net). They should try to drop the probes in the same manner each time. If possible, have two or three students timing the descent of each probe, and average the times. Also, if possible, there should be three trials for each probe — the test page in the *Parachuting Probe Packets* is set up for three trials.

3. Have students write their observations of the group's experiments in their *Saturn Discovery Logs*. This will help them in recalling this information during the whole-group discussion. It also reinforces the idea that the group is a community of learners, and that we learn from one another.

Questions for the Youth (Informal Assessment)

Give the students time to complete the last page of the *Parachuting Probe Packet* — "Questions for Spacecraft Engineers." Bring the group together, and ask each question and get responses from the students. It is a good idea to chart their responses.

Sharing the Findings (Informal Assessment)

Ask the following questions, and record student responses on the board or on chart paper:

- Which designs or design elements seemed the most stable, or added stability?
- Which parachutes seemed to take the longest to land?
- Which designs or design elements seemed to hit the target, or closest to the target, most often?
- Is there a "best weight" the probe needs to be in order to land accurately?
- Is there a relationship between parachute size and probe weight?
- What do you like best about working like a spacecraft engineer?
- What do you think are the biggest challenges they face?
- What questions do you still have?

Leader Reflection/Assessment

As you circulate and look at the students' writing, ask yourself the following questions:

1. Is the experimental plan clear and sequential?
2. Has the data been recorded in an organized way?
3. Does the reflective writing show evidence of critical and creative thought?

Glossary

Control — In an engineering experiment, a condition that doesn't change.
Controlled Test — An experiment where only one condition changes from trial to trial, so that the effects of that condition are clear.
Engineering Design Process — Consists of these steps: identify problem; brain-storm; iterate the design: build, test and evaluate, and redesign; share solution
Impulse — Impulse is the force of an impact multiplied by the amount of time the force is exerted. There are two types of impulse: hard and fast, and soft and slow.
Variable — What changes in an engineering experiment.

Information for Families

In the week prior to this activity, alert the students that they will be building a model of a probe — encourage them to describe to their families what a probe does, to get their family's ideas about what kinds of household recyclable material to use, and to ask them to contribute to the collection of materials.

Tired of the same old home videos? Check out videos from another world — Saturn!
saturn.jpl.nasa.gov/video/
www.jpl.nasa.gov/video/index.cfm?search=cassini&submit.x=0&submit.y=0

NASA Resources

Careers at NASA

Putting a probe into space around another planet takes a team of dedicated scientists, engineers, and others at NASA working together. Learn about some of the people who make space exploration possible.

Role Model Resource

Ayanna Howard is a robotics engineer at Georgia Tech University. She designs, builds, and programs robots to help scientists (and humans) perform jobs that are either too dangerous, tedious, or currently impossible for humans. Her interest in engineering and NASA was sparked one day in junior high school, when people from the Jet Propulsion Laboratory came to her school to judge the students' parachute egg-drop contest. "I decided at age 11 that I wanted to create artificial limbs for people. I planned to go to medical school, but discovered I hated biology in high school — especially dissecting frogs. Then I heard about robotics and realized that, if I became an engineer, I could do exactly what I wanted to do — and no frogs!"

When talking to young students, Ayanna says, "It's really rewarding when you hear people say, 'Maybe I can do that,' or 'I want to hear more.' I look at their eyes and think: Wow, I really do have a cool job."
More about Ayanna:
www.ece.gatech.edu/personnel/bio.php?id=135

Hear students share their stories of "My (High School) Summer at JPL"
www.jpl.nasa.gov/video/index.cfm?id=862

Resources

Are there volcanoes on Titan?
www.jpl.nasa.gov/video/index.cfm?id=951

Find lots of solar system educational resources
solarsystem.nasa.gov/educ

Taking Science to the Next Step

Special thanks to Dr. Jean-Pierre Lebreton and Dr. Ralph Lorenz, Cassini mission scientists, for the extension activities offered here.

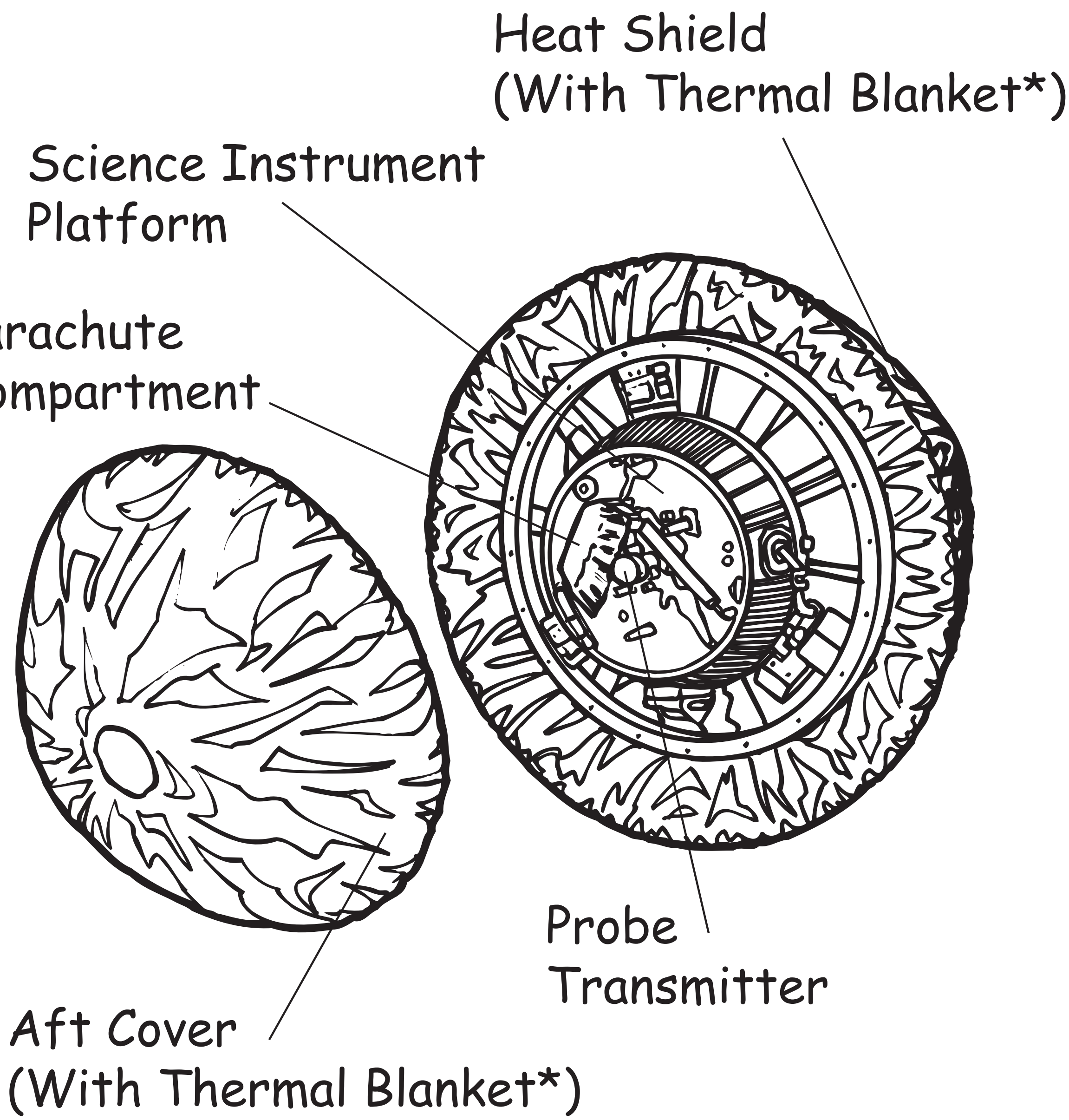
Optimization Exercise. Students can experiment with parachuting paper or cardstock cone-shaped "shields." A broad cone gives more drag (slows you down more) while a narrow cone is more stable, given the same amount of material. Students can first measure the time it takes a washer or ball of clay to fall from a given height. Parachuting shields earn points based on how much more slowly they fall. They also earn points for stability — specifically for how close they fall to a target drawn on the ground. Points can be "charged" for how much material is used to construct the shields. There should be some optimum where the cone is sharp enough to fall in a stable fashion and to land close to the target, but not so sharp it needs lots of material to have enough drag.

Characterizing an Unknown Surface. One of the Huygens Probe's responsibilities was to characterize the surface of Titan from the impact as recorded with onboard instruments to measure the probe's acceleration and deceleration. You can model this for the children by creating different surfaces hidden enclosed in cardboard boxes: for example, sand, gravel, brick, and water. Students can make a hole in the box top, and drop a "probe" (marble) into the hole at the top of the box, and try to guess what the surface is from the sound it makes. If a facilitator had a microphone/computer hook up, students could even "look" at the sound.

Literacy

Give each team of students time to write a set of step-by-step directions to go with their drawing to facilitate construction of a probe. Have teams exchange plans and build.

Huygens Probe Components



*The protective thermal blanket is a layered material known as multi-layered insulation or MLI.

Questions for the Spacecraft Engineers

1. What did you find most surprising or interesting?

2. What problems did you encounter as you built and/or tested your probe? What changes did you make, and why?

3. Based on your trials, and observations of your class-mates' designs and tests, what changes, if any, would you make to your design?

4. What questions do you have now?

5. What questions would you like to ask of the Huygens Design Team?

6. What would you like to try next? Why?

Parachuting Probe Packet

The ____________________ Probe

Design Team/Spacecraft Engineers

____

____

Date______________________________

Engineering and Design Team Challenge:

Design a parachuting probe that will land upright on both solid and liquid surfaces, remain intact (not break apart), weigh as little as possible (while still meeting the other criteria), and meet the requirements for time of descent (how long it takes the parachute to land after being dropped).

Background information for Design Team:

Spacecraft engineers face many challenges. They design machines that survive the forces of being launched into outer space and operate there with little assistance from Earth.

Once in space, the spacecraft must protect its delicate instruments throughout the journey. We are counting on Cassini to protect Huygens on its seven-year journey from Earth to Saturn.

Any heat absorbed or produced by the spacecraft must be managed to prevent the instruments from overheating or getting too cold. The probe must be strongly anchored to the spacecraft, yet able to separate in a controlled fashion at the right time. Both spacecraft and probe must be protected from dangerous radiation and from high-speed dust particles.

The probe must remain able to operate after many months or even years of inactivity. It must also be able to respond to commands and to radio its data back to Earth as accurately as possible.

Testing the ___________________________________Probe

Trial Number	Condition Upon Landing	Time of Descent	Notes, Observations, Questions
1			
2			
3			

Idea 3 — Final Plan (draw and write):

Weight of Probe:

Your Task:

You will design and build a parachuting probe. Given an assortment of materials commonly found at home or in the classroom, you will construct a parachuting structure that will:

1. Land upright on a solid or liquid surface. (To simulate the requirement for the Huygens instruments — camera and other instruments — to be able to take pictures and measurements)

2. Land undamaged. (To simulate the requirement for the instruments to be able to work — they must not break on impact.)

3. Take as long as possible to land, but land within in a designated area. (Huygens' parachute size will control its descent time. Huygens will be collecting data as it descends.)

4. Weigh as little as possible. (A fourth property to consider is weight. The more a spacecraft weighs, the more it costs to launch it and maneuver it in space. So, you want your probe to be as light as possible.)

Imagine the possibilities! Wonder! Create!

Helpful Science Hints

Scientists use the word “impulse” to describe an impact.

Impulse is the force of impact multiplied by the amount of time the force is exerted. There are two types of impulse: hard and fast, and soft and slow. Hard and fast is usually not the way you would like to experience a change in speed. That’s when you run into a brick wall at full speed, going from fast to stopped in a fraction of a second. The great amount of force you experience over the short amount of time can result in broken bones, or worse. So, soft and slow is the way to go.

If the wall you run into is padded like a mattress, you will enjoy the result more than if you run into bricks. To give your probe the best chance for survival, you need to think about how to give it the soft and slow type of impulse. Anything you can do to increase the amount of time the probe spends slowing down before hitting the ground will increase its chances of landing intact.

Your parachute will be central in this endeavor. You may want to do some initial experimenting with parachutes. Think about these questions:

- What happens if you change the size of the parachute?

- What happens if you change the length of the strings that attach the parachute to its load?

- What happens if the parachute is attached in different places?

Idea 1 (draw and write):

Idea 2 (draw and write):