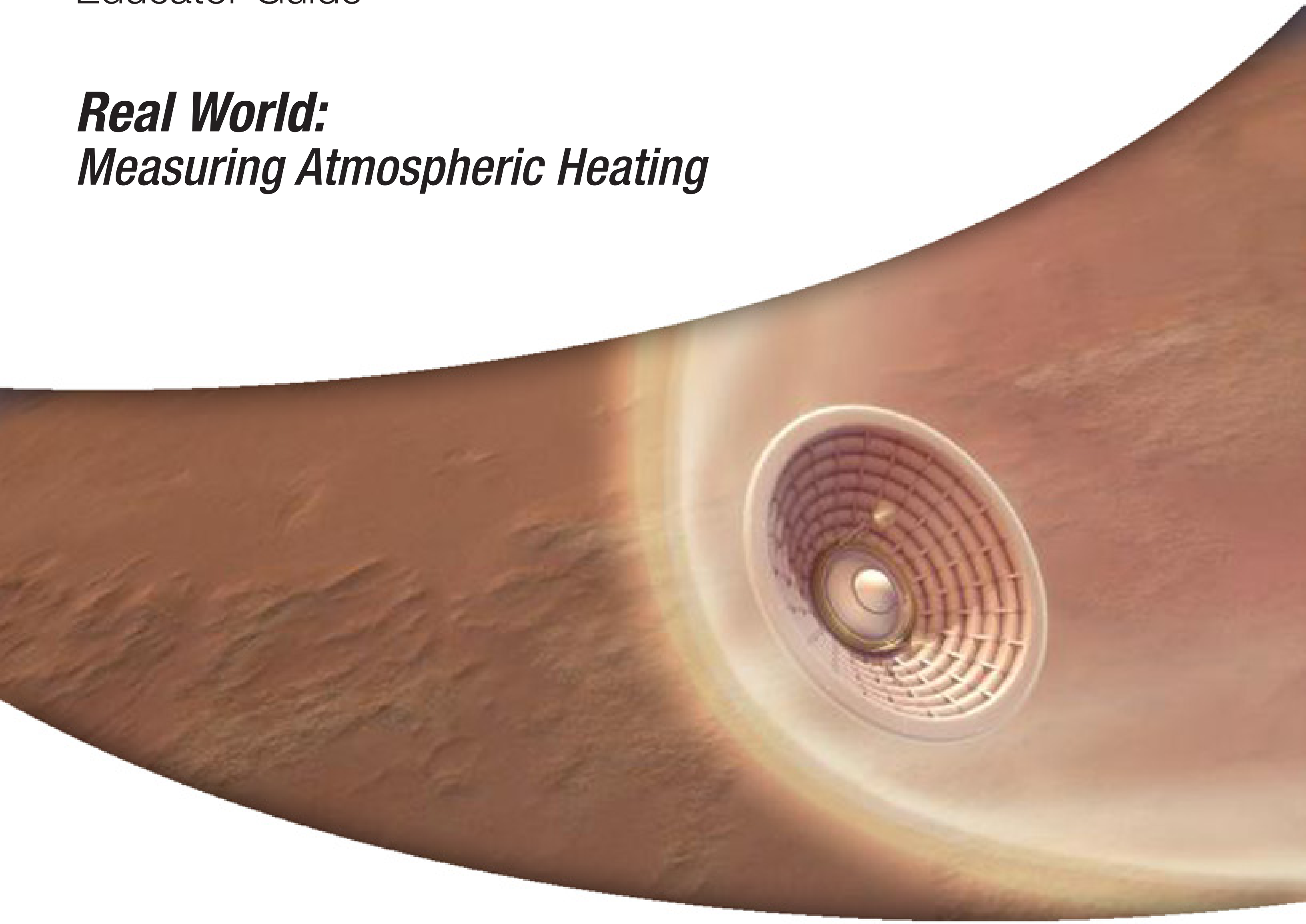
National Aeronautics and Space Administration

NASA eClips™

Educator Guide

Real World:
Measuring Atmospheric Heating



Educational Product	
Educators & Student	Grades 8-10

EG-2012-11-019

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eClips

MEASURING ATMOSPHERIC HEATING

NASA's THE REAL WORLD MATHEMATICS

EDUCATOR GUIDE

Grade Level:
8–10

Subjects:
Physical Science;
Mathematics;
Engineering Design

Teacher Preparation Time:
15 minutes

Lesson Duration:
two and one-half 50-minute class periods

National Standards:

National Science Education Standards (NSES)

Science as Inquiry

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

Unifying Concepts and Processes

- Evidence, models and explanation
- Change, constancy and measurement

Physical Science

- Transfer of energy

Science and Technology

- Abilities of technological design
- Understandings about science and technology

2011 Framework for K-12 Science Education

Physical Sciences

- Matter and its interactions
- Energy

Engineering, Technology and the Applications of Science

- Physical Sciences with Engineering design

National Council of Teachers of Mathematics (NCTM)

Problem Solving

- Use problem solving strategies to investigate and understand mathematical content
- Verify and interpret results with respect to the original problem

Measurement

- Apply appropriate techniques, tools, and formulas to determine measurements
- Understand measurable attributes of objects and the units, systems and processes of measurement

Statistics

- Systematically collect, organize, and describe data
- Construct, read, and interpret tables, charts, and graphs
- Make inferences and convincing arguments based on data analysis

International Technology and Engineering Educator Association (ITEEA)

Design

- Students will develop an understanding of the attributes of design.
- Students will develop an understanding of engineering design.
- Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

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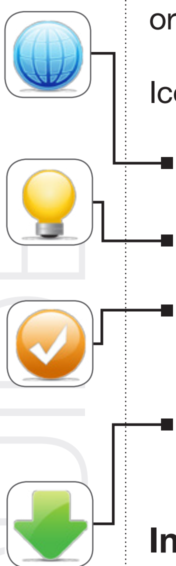
Lesson Overview:

Students think and act like engineers and scientists as they conduct an inquiry experiment about aerodynamic heating using everyday inflatables - balloons. Within this work, students discover the difference between qualitative and quantitative data; collect, organize and interpret data; and use their data to explain transfer of heat energy. Students view NASA eClips™ video segments and apply what they have learned to Hypersonic Inflatable Aerodynamic Decelerators, or HIAD, one of NASA's newest exploration technologies.

Icons flag areas of interest or opportunities for teachers.



- **Technology Icon** highlights opportunities to use technology to enhance the lesson.
- **Modification Icon** denotes opportunities to differentiate the lesson.
- **Connections Icon** identifies opportunities to relate the lesson to historical references and other topics or disciplines.
- **Check for Understanding Icon** suggests quick, formative assessment opportunities.

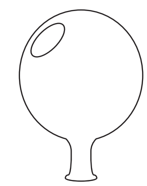
Materials List

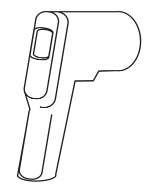
Per student

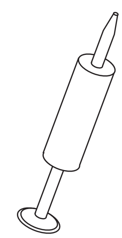
- Science notebook
- Safety goggles

Per group of four students

- (3-4) 30-cm round latex balloons
- 1 plastic balloon pump
- 1 handheld infrared thermometer
- Assorted latex balloons (different sizes and shapes)
- Optional: assorted materials to stabilize the balloons throughout testing.







Instructional Objectives

Students will

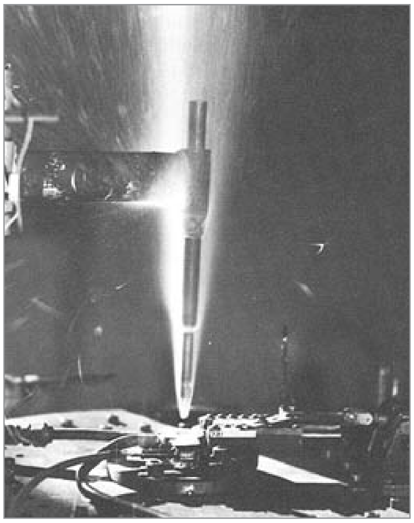
- Gather qualitative and quantitative data during balloon testing and observation.
- Organize data for statistical analysis.
- Visualize data looking for patterns.
- Calculate and justify measures of central tendency.
- Engineer solutions to gather more consistent data.
- Use a model to explain aerodynamic heating.

NASA's Hypersonic Inflatable Aerodynamic Decelerator (HIAD) Project

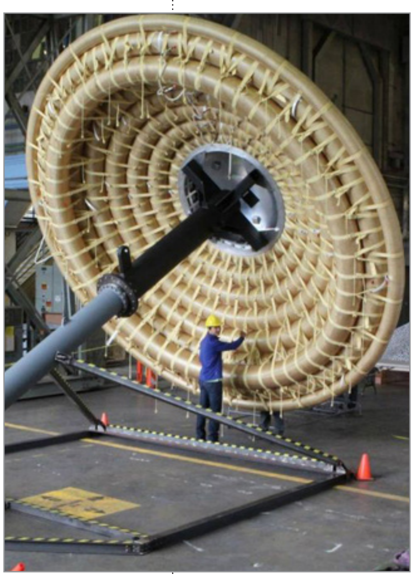
Vehicle Shape

NASA has studied how to land spacecraft on planetary bodies since the 1950s -- and as engineers know entry, descent and landing can be the greatest challenge for destinations with an atmosphere. The first atmospheric entry tests used ballistic missiles that featured long nosecones with narrow tips. That shape cut through the air easily, but high speeds and low drag led to overheating and the melting of the rockets' surfaces. So NASA researchers began testing blunt-nose reentry vehicles. They found that a blunt body with its greater drag transferred far less heat to the spacecraft than traditional shapes. For that reason, the first astronauts flew in space capsules, such as Mercury, Gemini and Apollo, with that blunt body shape.

Mercury capsule model in the Langley Full-Scale Tunnel, January 1959. Credit: NASA



Hot-air jets employing ceramic heat exchangers played an important role at Langley in the study of materials for ballistic missile pose cones and reentry vehicles. Here a model is being tested in one of these jets at 4000 degrees Fahrenheit in 1957. Credit: NASA



The inflatable structure is a series of rings made of braided Kevlar that are stacked together. Credit: NASA

Blunt body designs work well, but engineers and scientists, led by a team at NASA's Langley Research Center, have what they think is an even more versatile idea -- a Hypersonic Inflatable Aerodynamic Decelerator or HIAD. The inflatable spacecraft technology looks like a giant cone of inner tubes assembled like a child's stacking ring toy. The inflatable heat shield offers reduced mass and increased size, both crucial in space travel. During launch, the uninflated stacked rings are packed inside a bag. Before the spacecraft is ready to enter the atmosphere, a compressed gas system pumps up the volume of the inflatable structure. The inflatable structure is made up of incredibly strong, yet flexible fabric that is designed to maintain its shape and withstand the heat and force of rushing through an atmosphere.

Inflatable Technology

Inflatable technology could give NASA more options for future planetary missions. On Mars, for example, a larger vehicle would allow more mass (larger, heavier scientific instruments or other tools for exploration) to be landed at the same altitude; or allow the same mass to be landed at higher altitudes. This new technology can be used on any planet or object in space that has an atmosphere. These places include Earth, Mars, Venus, Titan, and the gas giants - Jupiter, Saturn, Uranus and Neptune. The technology could also be used to return payloads to Earth from the International Space Station or other low Earth orbit locations. This new technology will advance space exploration, both robotic and human, allowing new scientific discoveries, and quite literally, change the way we explore new worlds.

For more information about HIAD visit, *www.nasa.gov/hiad*.

Entry, Descent, and Landing

Entry, descent and landing of any spacecraft to a destination with an atmosphere create some unique, but common problems. First the vehicle must be slowed down enough to safely land. The Mars Science Laboratory, for example, traversed the atmosphere of Mars at a high velocity of 5.5 to 7.5 kilometers per second. At a speed of more than 20,000 kilometers per hour (12,400 miles per hour) as the spacecraft made its downward plunge, the craft was moving at supersonic speeds. A person running that fast would be able to go from Washington, DC to Los Angeles, California in about 10 minutes.

In order to use the atmosphere to slow the vehicle, engineers have to increase the aerodynamic drag on the vehicle. Drag is a function of the vehicle's area. To land twice the mass, the vehicle must have twice the drag area. By increasing the diameter of the vehicle, scientists and engineers are able to deploy larger vehicles.

Aerodynamic Heating

But the second problem, heat, requires that vehicles have some sort of thermal protection system. As a vehicle traverses the atmosphere, a large amount of friction is created. The impact of the air molecules on one another transfers a great deal of heat to the surface of the entry vehicle, in a process known as aerodynamic heating. The diameter of a HIAD, however, is much larger than a traditional aeroshell. Specific spots on the inflatable heat shield do not get as hot because the heat is spread over a larger surface area. In a HIAD, several materials are combined together in layers to insulate the larger inflatable heat shield, providing effective heat resistance and making HIAD a unique solution for the problems of entry, descent and landing.

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DEFINITIONS

Aerodynamic heating – Aerodynamic heating is the heating of a solid body produced as air or other fluid passes over the body.

Convection – Convection is the movement of molecules within fluids, such as air or water.

Forced convection – Forced convection occurs when a pump or other mechanism moves a heated fluid.

HIAD – HIAD, or Hypersonic Inflatable Aerodynamic Decelerators, are inflatable heat shield structures made up of incredibly strong, yet flexible fabric designed to maintain shape and withstand heat during atmospheric reentry.

Infrared thermometer – Infrared thermometer is a tool that measures the heat being given off by an object.

Molecules – Molecules are particles with more than one atom that combine to form unique properties.

Qualitative data – Qualitative data are sets of information that describe attributes.

Quantitative data – Quantitative data are values that can be counted or measured.

Thermal protection system – A thermal protection system is a combination of materials used to insulate and reduce the amount of heat transferred to a spacecraft as it enters an atmosphere.

Velocity – The speed and the direction of travel of an object is the object's velocity. Velocity is similar to speed, but whereas an example of speed would be, "the wind was blowing at 40 miles per hour," velocity would be expressed as "40 miles per hour from the SE." Direction becomes important when dealing with navigation of boats, aircraft, wind and water currents, etc.

5E INQUIRY LESSON DEVELOPMENT

ENGAGE – Qualitative Data (15 minutes)

1. Give a 30-centimeter (12-inch) balloon to each group. Ask students to describe the physical attributes of the balloon in their science notebooks. *(Attributes may include color, size, flexibility, etc.)*
2. Using a balloon pump, one student in the group should begin inflating the balloon. Ask other students to safely use their senses to gather information about changes in the balloon as it inflates. *(Students should note a change in size, an increase in surface temperature of the balloon, lighter color, etc.)*
3. In a large group, ask students to share their findings. Did the students note any similarities? Did all balloons change in the same way?
4. Introduce the concept of qualitative data. Explain to students that qualitative data is information that describes or defines characteristics. Qualitative data requires that the observer draw inferences and discover patterns.

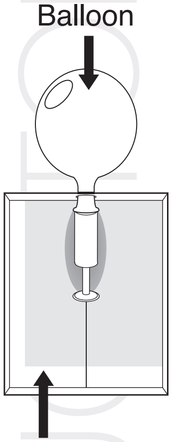
EXPLORE – Quantitative Data (30 minutes)

1. Introduce the concept of quantitative data. Quantitative data can be counted or measured. Counted data is also known as discrete data; measured data is known as continuous data. Ask students to give examples of quantitative data. *(Answers will vary, but may include counting money, temperature readings, or the number of students in the class.)*
2. In small groups, ask the students to brainstorm ways they might count or measure the qualitative data they collected about their balloons. Share ideas with the large group. *(Students may consider counting the number of times they pumped air into the balloon with the pump, measuring the increase in diameter of the balloon, etc.)* Give students an opportunity to collect some of their quantitative data and add it to their science notebooks.
3. **(Check for Understanding)** Ask students how they might measure the increase in warmth they felt as the balloon was inflated. *(Students should understand that temperature is measured in degrees and that tools to measure temperature include thermometers.)*
4. **(Connections)** In addition to the traditional thermometers students may recognize, explain that infrared thermometers are tools that measure the heat given off by an object. The thermometer includes a laser light to help the user point the thermometer. Students may wish to conduct research to find out more about infrared wavelengths or how an infrared thermometer actually works. Brainstorm a list of careers/jobs that might use an infrared thermometer.

SAFETY NOTE: *Remind students that any kind of laser can damage human eyes, so the light beam should never be pointed at or near the eyes.*

5. Give each group of students a hand-held infrared thermometer. These tools are relatively inexpensive and can be purchased at local hardware or home improvement stores.
6. **(Modification)** The infrared thermometers do not need to be the same style or brand, so thermometers could be borrowed for this activity.
7. Give the students a few minutes to practice using the thermometer to gather accurate temperature readings of objects around the room, such as the desktop, a person’s hand, or a bottle of water.
8. Tell the group to assign roles to each member. One person will inflate the balloon using the balloon pump. One person will operate the infrared thermometer. The thermometer operator must be sure to keep the laser pointed at the same place on the balloon as it inflates and keep the thermometer pointed at that spot as the balloon deflates. One person will call out the numbers registering on the thermometer. One person will record the data.
9. Based on the qualitative data the students collected earlier, ask students to make a prediction about the pattern they will see with the temperature readings as the balloon inflates and deflates. Students should record their predictions in their science notebooks.

10. Tell the students to inflate the balloons, pumping as quickly as possible. Do not overinflate so the balloon pops. What happens to the temperature reading as the balloon is inflated? When the balloon is full of air, maintain a firm hold on the balloon and quickly allow the air to escape. What happens to the temperature reading as the balloon deflates? Allow students to conduct several trials.
11. **(Check for Understanding)** Ask students to create a data chart to represent the data collected for each trial. Identify the range of temperatures recorded for each trial. For example, students may record data similar to the following: the balloon temperature was 72 degrees Fahrenheit before inflating; reached 78 degrees Fahrenheit while inflating; and dropped to 69 degrees when it was deflated. The temperature range for that trial would be 69 to 78, or 9 degrees. Students may then calculate the mean, median and mode for each range. Ask students to determine which measure of central tendency best explains the situation. Ask students to make inferences about what patterns they are seeing. Why does the temperature change? What factors might influence the change? Identify any outliers in the data collected. *(Teacher Note: students will see a more dramatic difference in temperature readings if Fahrenheit units rather than degrees Celsius are used with the infrared thermometers. For comparison, students may wish to collect both Fahrenheit and Celsius data.)*
12. **(Technology)** Students may use graphing software to represent their data.
13. **(Modification)** Students may discover that keeping the infrared thermometer pointed at a specific spot on the balloon while someone is inflating the balloon is not easy. Just as NASA engineers solve problems while testing and developing new technologies, challenge students to think and act like engineers to solve this problem. Discuss the engineering design process with students. A graphic of the design process can be found in the NASA eClips™ Secondary Design Packet *http://www.nasa.gov/pdf/324206main_Design_Packet_II.pdf*. Teachers may use the questions in the Design Packet to help students organize their thinking. The design process graphic and packet may be accessed electronically or printed to best meet class needs.



Following the steps of the **engineering design process**, design a system or apparatus that would stabilize the balloon while it is being inflated, allowing a more accurate temperature reading. *(Designs may be as simple as a box lid with a hole punched through the end to insert the mouth of the balloon or a more complicated structure made of materials such as wood or clamps. Encourage students to be creative.)*

After students have finalized their designs, gather the materials for students to build and test their prototypes. Some designs may be eliminated due to constraints such as the availability or cost of materials. Which designs worked best? How might designs be changed after testing? How might designs be combined to create the most effective design? In their science notebooks, ask students to reflect on how their process of designing and modifying their stabilizing apparatus parallels the design process used by NASA engineers as they develop new technologies.

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EXPLAIN – Understanding Aerodynamic Heating (20 minutes)

1. Show the NASA eClips™ video segment, Launchpad: The Heat Is On! (5:01) to the students. This segment can be found on the NASA eClips™ page of the NASA website: *http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=%22The%20Heat%20Is%20On%22&category=0010&disp=grid*

   The video may be streamed or downloaded from the nasa.gov website; a captioned version is also available at the nasa.gov site. This video may also be streamed from the NASA eClips You Tube™ channel: *http://www.youtube.com/watch?v=14zMq78EUgc&feature=share&list=PLD7BEC5371B22BDD9*

2. Share background information with the students about NASA's Hypersonic Inflatable Aerodynamic Decelerator (HIAD) project. As a group, discuss aerodynamic heating. Help students understand the process of forced convection. As an object, like a spacecraft, traverses an atmosphere, friction between the spacecraft and the air molecules creates heat. This heat is then transferred from one molecule to another. Spacecraft require some kind of thermal protection system to protect them from the intense heat. The velocity with which the craft passes through the atmosphere creates forced convection. As the heat is transferred between molecules, the spacecraft acts as a pump, moving the heated air and displacing the cold air in its path. The effect of this movement can be quantitatively measured. As students pumped air into the balloon, they created a similar, but less intense scenario.

EXTEND – Size Matters (30 minutes)

1. Three additional NASA eClips™ videos give students background information about the importance of size and shape of an inflatable heat shield. Divide the class into three groups. Ask each group to watch one of the video segments:

NASA eClips™ video, Real World: Changing the Way We Explore New Worlds
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=%22Changing%20the%20Way%20We%20Explore%20New%20Worlds%22&category=0100&disp=grid or *http://www.youtube.com/watch?v=VI9AQSQGiTg&feature=share&list=PL887C1C3BAAD53F17*

NASA eClips™ video, Launchpad: Mission Infusion – A Look at What's Ahead
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=%22Mission%20Infusion%22&category=0010&disp=grid or *http://www.youtube.com/watch?v=OYik792SjYY&feature=relmfu*

NASA eClips™ video, Launchpad: Descent and Landing – It's a Matter of Control
http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms=%22Descent%20and%20Landing%22&category=0010&disp=grid or *http://www.youtube.com/watch?v=ap8p5OjOdIE&list=PLD7BEC5371B22BDD9&index=0&feature=plcp*

2. **(Check for Understanding)** In their science notebooks, students should record any information they learn about the size and/or shape of inflatables. In a large group, students should then jigsaw their information, sharing what they have learned with the class.
3. Ask students to test other balloon shapes and sizes. Were temperature patterns the same with other balloons? Did students see more or less temperature differences between the inflation and deflation of balloons of different sizes? Did students see the biggest difference between the inflation and deflation temperatures in the largest balloons? Were the round balloons, those most like a blunt-shaped body, or long balloons more thermodynamically efficient? *(The balloons that have the greatest temperature difference between the inflation and deflation stage are those that are the most efficient because the heated air is distributed over a larger surface area, lowering the temperature more quickly.)*
4. **(Check for Understanding)** In their science notebooks, ask students to explain their findings based on what they have learned about aerodynamic heating. Go back to previous inferences and correct any misconceptions.
5. **(Connections) (Technology)** If students have access to online computers, tablets, or mobile devices, they may download the HIAD Application (App) to practice landing their own inflatable vehicle. The app is available on the NASA HIAD website, *http://www.nasa.gov/hiad*.

EVALUATE – Verify Results (30 minutes)

1. Ask students to create an illustration that explains aerodynamic heating.
2. Students should label the illustration with appropriate terms, such as boundary, forced convection; and include both qualitative and quantitative data collected.
3. **(Technology)** Students may choose to create a digital documentary or a computer-generated graphic illustration to explain aerodynamic heating.

Safety in the Educational Classroom and Laboratory

Safety is an important goal for all curricular areas of education. It is the responsibility of the school's administration for providing a learning environment that is safe, up-to-date and supportive of learning. Additionally, teachers are responsible for their students' welfare in the classroom and laboratory.

Read more on Safety in the Classroom and Laboratory
http://www.nasa.gov/audience/foreducators/plantgrowth/joinchallenge/Safety_in_the_Classroom.html