DOCUMENT RESUME

ED 458 135		SE 065 306

TITLE	The Measurement of All Things: Tools of the Aeronautics Trade. NASA Connect: Program 1 in the 1999-2000 Series.
INSTITUTION	National Aeronautics and Space Administration, Hampton, VA. Langley Research Center.
REPORT NO	EG-1999-09-01-LaRC
PUB DATE	1999-00-00
NOTE	32p.; Accompanying videotape not available from ERIC. For other documents in series, see SE 065 307-312.
AVAILABLE FROM	Web site: http://edu.larc.nasa.gov/connect/detect/norbert/lab.html.
PUB TYPE	Guides - Classroom - Teacher (052)
EDRS PRICE	MF01/PC02 Plus Postage.
DESCRIPTORS	*Aerospace Education; Astronomy; Elementary Education; Lesson Plans; Mathematics Activities; *Mathematics Instruction; *Measurement; Science and Society; *Science Education; Space Sciences; *Technology Education

ABSTRACT

This teaching unit is designed to help students in grades 4-8 explore the concept of measurement in the context of aeronautics. The units in this series have been developed to enhance and enrich mathematics, science, and technology education and to accommodate different teaching and learning styles. Each unit consists of a storyline presenting the context for the problems to be solved, lists of the mathematics and science concepts addressed, background notes for the teacher, a list of teacher resources, and an activity complete with blackline masters. Also included are suggestions for extensions to the problems and their relationship to national mathematics standards. The story line for this unit is students exploring the concept of measurement and the tools used in measuring while learning what and how engineers and scientists use measurement during the process of developing, designing, and testing airplanes. (MM)

National Aeronautics and
Space Administration
Langley Research Center
Hampton, VA 23681-0001

NASA CONNECT

Program 1 in the 1999-2000 Series

The Measurement of All Things:

Tools of the Aeronautics Trade

Story line: Students will explore the concept of measurement and the tools used in measuring things, while learning "what" and "how" engineers and scientists use measurement during the process of developing, designing, and testing airplanes.

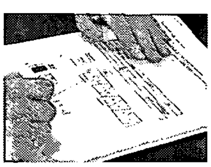
Math Concepts: Number and Number Sense, Units, Conversion, Tools

Science Concepts: Logic, Reasoning, Science as Inquiry

NASA Research: Fundamental Aeronautics, Measurement Science, Flight Research

■ *build and test objects in a wind tunnel*

■ *use computers to simulate and test an airfoil*



■ *graph, analyze, and present data*

Educator's Guide	
Teachers & Students	Grades 4-8

Publication Number
EG-1999-09-01-LaRC

PROGRAM SUMMARY

OBJECTIVES

In *The Measurement of All Things: Tools of the Aeronautics Trade*, students will investigate the U.S. Customary and metric systems of measurement. They will also learn about the tools and techniques used by NASA aeronautical engineers and scientists to measure two of the four forces of flight: lift and drag. To apply what they have learned about measurement and the metric system, students will work in groups to construct a wind tunnel, a fundamental tool of aeronautics. *(See Figures 1 and 2.)* This activity is taken from *Mission Mathematics: Grades 5-8* and involves using a wind tunnel to measure the wind resistance, or drag, of four polyhedrons (i.e., cone, cube, pyramid, and tetrahedron). For more information on *The Measurement of All Things: Tools of the Aeronautics Trade*, please visit the following section of the NASA CONNECT web site:
http://edu.larc.nasa.gov/connect/tools.html

While visiting the corresponding web page for this program, students can access FoilSim, the technology-based component of the program. FoilSim is the online activity and is located in "Norbert's Lab" at
http://edu.larc.nasa.gov/connect/tools/norbert/lab.html
With FoilSim, students will have the opportunity to use the computer, another fundamental aeronautics tool. FoilSim is an interactive simulation software package that can be used to determine airflow around variously shaped airfoils. Using FoilSim, students can manipulate camber, area, angle of attack, and thickness of an airfoil and measure the drag force of a wing.

Access to information is critical to making career decisions. Career Corner, located at **http://edu.larc.nasa.gov/connect/tools/ca1.html,** is a web-based component that highlights the professionals who appear in the program, *The Measurement of All Things: Tools of the Aeronautics Trade.* This web site includes pictures of the professionals; summarizes their duties and responsibilities; and includes details about the person, event, or situation that greatly influenced their career choice.

TEACHER BACKGROUND

MEASUREMENT

Measurement is essential to our daily lives. Actually, it would be hard to imagine a day when we did not use measurement and measuring instruments. Measurement is essential to commerce: the making, selling, and purchasing of goods and services. Measurement is a fundamental process of science and technology. We use measurement when we operate our cars, prepare our meals, and play sports. We use measurement in nearly everything we do. There are seven basic categories of measurement: length, time, mass (weight), volume, temperature, electric current, and luminous intensity. The concepts of uniformity, units, and standards are basic to the entire concept of measurement. The Babylonians, Chinese, Egyptians, Greeks, Hindus, Romans, and medieval English all contributed to the development of modern measurement. There are two systems of measurement: (1) the English system, which consists of two related systems, U.S. Customary and the British Imperial, and (2) the metric system. The English system evolved over centuries and drew heavily from the traditional practices (customs) of ancient and medieval civilizations. Basic units of measurement in the U.S. Customary system are the foot, gallon, pound, and mile. The metric system, one of the most significant results of the French Revolution, is used by the world's scientific community and by most nations. Basic units of measurement in the metric system are the gram, meter, liter, and kilometer.

WIND TUNNELS

Wind tunnels are machines for "flying" aircraft on the ground. They are tube-like structures or passages in which wind is produced, usually by a large fan, to flow over objects such as aircraft, engines, wings, rockets, or models of these objects. A stationary object is placed in the test section of a tunnel and connected to instruments that measure and record airflow around the object and the aerodynamic forces that act upon it. From information gathered in these observations, engineers can determine the behavior of an aircraft or its components at takeoff, while cruising, and during descent and landing.

Wind tunnels also help engineers determine the performance of, and eliminate "bugs" in, new designs of civil and military aircraft without risk to a pilot or costly aircraft. Responses to the flight condition of new materials and shapes for wings, ailerons, tails, fuselages, landing gear, power systems, and engine cowlings can be assessed before these designs are incorporated into aircraft.

Today, no aircraft, spacecraft, space launch vehicle, or reentry vehicle is built or committed to flight until after its design and components have been thoroughly tested in wind tunnels. Every modern aircraft and space rocket has made its maiden flight in a wind tunnel. Wind tunnels have been among the key tools that have made American aircraft and aeronautical equipment the most preferred and most widely used in the world.

THE ACTIVITY: MAKING AND USING A WIND TUNNEL

NATIONAL MATH STANDARDS

- Estimate, make, and use measurements to describe and compare phenomena.
- Select appropriate tools to measure the degree of accuracy required for a particular activity.
- Develop formulas and procedures for determining measures to solve problems.
- Apply the power and use of mathematical reasoning.
- Apply mathematical thinking and modeling to problem solving.

INSTRUCTIONAL OBJECTIVES

Students will (1) apply and use various measurement techniques and tools; (2) use measurement tools and techniques to construct a wind tunnel; (3) learn and use metric units of measurement; (4) measure and record the drag of four polyhedrons; and (5) graph, analyze, and present results.

TEACHER RESOURCES

Books

Nelson, David. (1998). *Dictionary of Mathematics.* NY: Penguin Group.

Seiter, Charles. (1995). *Everyday Math for Dummies.* Foster City, CA: IDG Books Worldwide.

How Things Work. (1990). "Flight." Lincolnwood, IL: Publications International, Ltd.

Jennings, Terry. (1992). *Planes, Gliders, Helicopters and Other Flying Machines.* NY: Kingfisher.

NASA. (1998). *Aeronautics: An Educator's Guide with Activities in Science, Mathematics, and Technology Education.* Washington, DC: NASA (EG-1998-09-105-HQ).

Web Sites

The Math Forum
http://forum.swarthmore.edu/paths/measurement/index.html

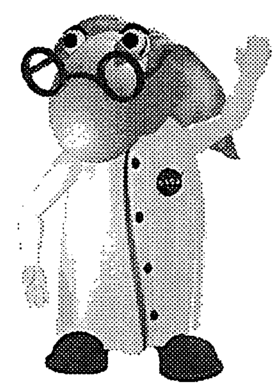
PBS Teacher Resource
http://www.pbs.org/teachersource/math/index.html

Measure 4 Measure
http://www.wolinskyweb.com/measure.htm

Wind Tunnels
http://www.quest.arc.nasa.gov

Foilsim
http://www.lerc.nasa.gov/www/K-12/aerosim/vufoil.htm

Norbert's Lab on the NASA CONNECT web site
http://edu.larc.nasa.gov/connect/tools/norbert/lab.html



Check out Norbert's Lab!

BEFORE THE ACTIVITY

MATERIALS NEEDED

clear adhesive tape
transparency film
glue
colored pencils or markers
meter stick
box /window fan (3-speeds)
cardboard
strong scissors
string
duct tape or packing tape
2 chairs
pencil
safety goggles
window screen (optional)
elastic cord (from a party hat)

Ask students to share their thoughts or write their responses to the following questions. Encourage students to research measurement and related topics by using the library and the Internet.

What would the world be like without airplanes?
How did the Wright brothers design the wings for the "Wright Flyer"?
What will futuristic aircraft look like?
Why do we test models in wind tunnels?
Can we test things other than airplanes in wind tunnels?
What careers relate to the field of aviation?

VOCABULARY

drag - the surface force of air that slows down the plane as it moves forward
lift - the surface flow of air generated around the wings that keeps an airplane up
mass - an object's quantity of matter
mean - the average of all numbers in a data set
median - the middle number in a data set that is arranged from the lowest to the highest
meter - the standard unit of length used in the metric system
mode - the number that appears most often in the data set
polyhedron - any many sided figure (e.g., cone, cube, or pyramid)
thrust - the force of the engine that pushes a plane forward (opposite of drag)
wind tunnel - a tunnel-like passage through which air is blown at a known velocity to investigate or test airflow around an object (i.e., airplane model)

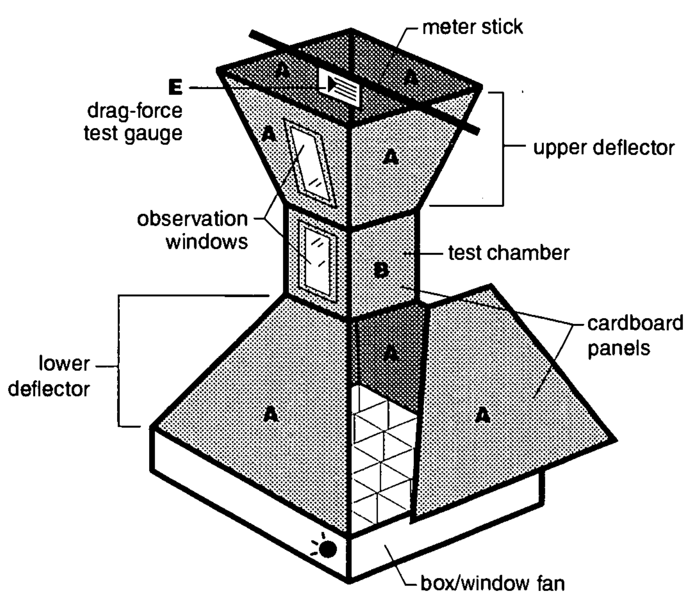


***Figure 1. Wind Tunnel Diagram** - refer to the drawing above when constructing each section.*

THE ACTIVITY

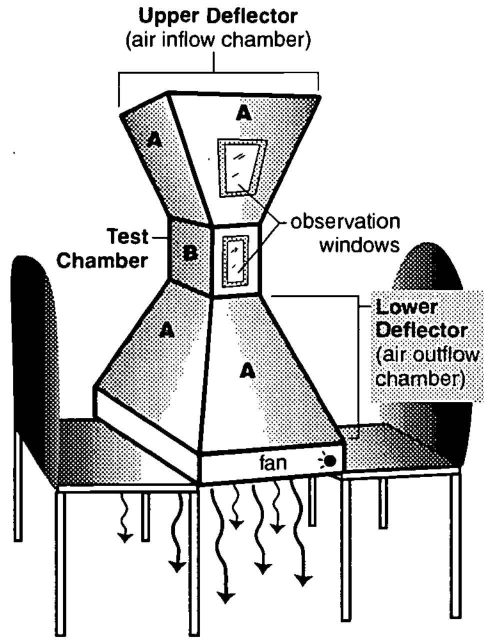
1. Divide the class into four groups:
- Engineering Team 1: structure (upper deflector)
- Engineering Team 2: structure (test chamber)
- Engineering Team 3: structure (lower deflector)
- Engineering Team 4: drag force test gauge

2. Make classroom copies of
- Cue Cards *(page 10) (1 copy per student)*
- Table A: Measured and Calculated Lengths *(page 11) (1 copy per student)*
- Patterns for Polyhedrons *(pages 12-15) (1 set per team)*
- Student Data Worksheet *(page 16) (1 copy per student)*
- Graph of the Drag (Mean) *(page 17) (1 copy per student)*

3. Teams 1, 2, and 3 should complete Table A: Measured and Calculated Lengths and give it to the teacher. *(page 11)*

4. Make Team Task Assignments:

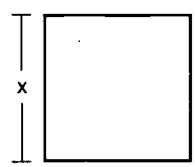
Figure 2. Completed Wind Tunnel - with fan on.



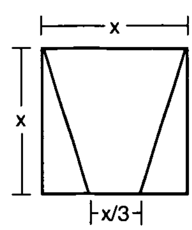
Engineering Team 1: Structure (upper deflector)
Section A of wind tunnel diagram *(see Figure 3)*

- Refer to Table A: Measured and Calculated Lengths to measure each panel of the upper deflector. Carefully cut out four panels.
- In the middle of **one** panel in the top section of the wind tunnel, cut out a window and tape a piece of transparency film over the window from the inside.
- Tape the four panels together to form the top section. This section is now ready for attachment to the middle section (test chamber).
- Using the polyhedron patterns, build a cone, a cube, a pyramid, and a tetrahedron *(see pages 12-15)*. Use tape to attach a string to each of these shapes.

Figure 3. Section A - Upper Deflector Panels.



box/window fan



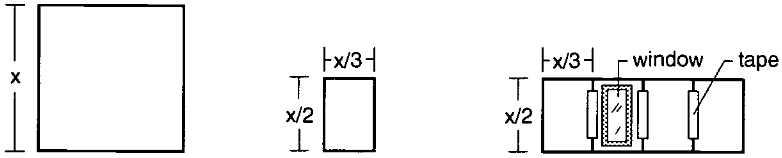
upper deflector panel

Note 1: For safety reasons, the teacher may precut panels (sections A and B) for construction of the wind tunnel after the students have measured and drawn the panels.

Note 2: Emphasize the importance of accuracy in measurement and that the wind tunnels need to be airtight to be effective.

Note 3: Address safety factors, such as not dropping items into the fan and not standing on chairs to look into the wind tunnel.

Figure 4. Section B - Test Chamber Section.

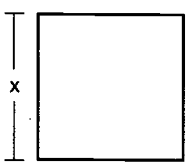


box/window fan *test chamber* *test chamber - open view with all four sides showing*

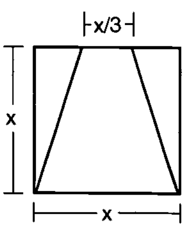
Engineering Team 2: Structure (test chamber)
Section B of wind tunnel diagram *(see Figure 4 above)*

- Refer to Table A: Measured and Calculated Lengths to measure each panel of the upper deflector. Carefully cut out four panels.
- In the middle of **one** panel of the test chamber, cut out a window and tape a piece of transparency film over the window opening from the inside.
- Tape the panels together. This section is now ready for attachment to the upper deflector *(see Figure 1)*.
- Using the polyhedron patterns *(pages 12-15)*, build a cone, a cube, a pyramid, and a tetrahedron. Use tape to attach a string to each of these shapes.

Figure 5. Section A - Lower Deflector Panels.



box/window fan



lower deflector panel

Engineering Team 3: Structure (lower deflector)
Section A of wind tunnel diagram *(see Figure 5 to left)*

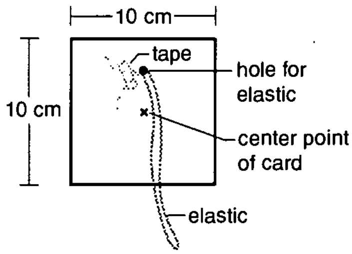
- Refer to Table A: Measured and Calculated Lengths to measure each panel of the upper deflector. Carefully cut out four panels.
- Tape the four panels together to form the bottom section. This section is now ready for attachment to the middle section (test chamber).
- Using the polyhedron patterns, build a cone, a cube, a pyramid, and a tetrahedron. Use tape to attach a string to each of these shapes.

Teams 1, 2, and 3 should carefully tape their sections together to form the wind tunnel. Make sure the window on the upper deflector and the window on the test chamber are on the same side of the wind tunnel before attaching. Tape the wind tunnel to the window fan and place the fan onto two chairs. (See pages 4 - 5 for diagrams.)

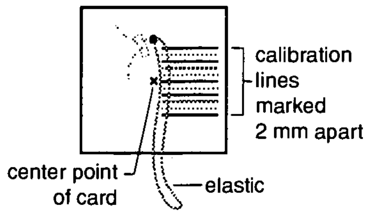
Engineering Team 4: Drag Force Test Gauge
Section E of wind tunnel diagram. *(See Figure 6, page 7.)*

- Cut a 10-cm x 10-cm square from cardboard.
- Punch a 1-mm hole in the cardboard, centered 3-cm from the top.
- Remove the elastic band from inside the party hat. (The elastic band should be approximately 15 cm long unstretched.) Double over the elastic to form a loop.

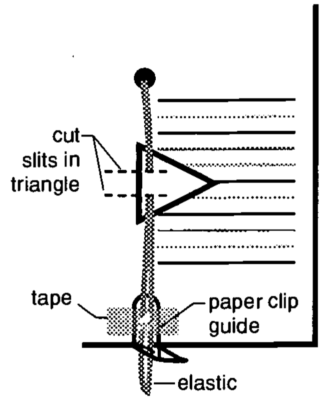
Figure 6. Drag Force Test Gauge.



Punch top hole and thread in elastic.



Add calibration lines.



Thread the elastic through 2 slits cut in the triangle gauge and then through the paper clip guide (which is taped to the square).

- Thread the two loose ends of the elastic through the hole in the card and hold them in place with a piece of tape.
- Mark the center of the card (find center point using diagonals).
- Beginning at the center point, draw a solid line to the right edge. At 2-mm intervals, draw 5 lines above and 5 below the centerline that was just drawn.
- Using cardboard, cut an equilateral triangle with each side equal to 2 cm. Cut two slits in the triangle, place the elastic through the slits, and center the point of the triangle on the centerline.
- Bend a paper clip 90 degrees to form a guide clip for the elastic. Attach the paper clip to the center of the bottom edge with tape. Slip the elastic through the loop of the paper clip.
- Tape the top edge of the card to the center of the meter stick.
- Using the polyhedron patterns, build a cone, a cube, a pyramid, and a tetrahedron. Use tape to attach a string to each of these shapes.

SUGGESTION:

Using the primary colors, alternate the line color (for ease of reading).

5. Testing the Shapes

Note: If you want to even out the wind flow, place two window screens 1/8 inch apart on top of the upper (intake) deflector.

Note: Students will test each shape **3 times** at each speed. *(See Table B, page 16)*

- Attach the tetrahedron to a string at the end of the elastic so it can be seen through the window of the test chamber.
- Note the position of the gauge.
- Start the fan on low speed. Read the amount of elastic stretch by using the gauge. The stretch measurement is the drag force exerted by the wind on the object.
- Record the drag in Table B on the Student Data Worksheet *(page 16)*. Turn off the fan and make sure the gauge is registered at the centerline. Test the tetrahedron 2 more times at low speed and record data.

CHALLENGE:

Can you predict which polyhedrons will have more or less drag than the tetrahedron?

- Continue to test each shape **3 times** at low, medium, and high speeds.
- Calculate the mean, median, and mode for each of the polyhedrons. (Record data on Table C on the Student Data Worksheet *(page 16)*)
- Using the data recorded in Table B, graph the mean of each polyhedron at low, medium, and high speeds using the Graph of the Drag (Mean) worksheet *(page 17)*.
- All groups should share their data and complete the graph.

6. Analyzing the Data

Can you answer these questions?

1. Do the shape, mass, and position of the objects in the wind tunnel affect the drag? How? *(Yes, because each will affect how much force is exerted on the object.)*

2. Which factor (shape, mass, wind speed, or drag) is the constant? That means it stays the same throughout the activity. Why is it important to keep the constant? *(Mass is the constant throughout the activity. Constants are needed to eliminate external factors and maintain the only two variables: The independent factor, the one that is changed, and the dependent factor, the one that is observed.)*

3. Which objects experienced the least and most drag? Why? *(See experimental data in Table A, page 11.)*

4. Do the direction and speed of the wind flow affect the drag on the objects? *(Yes, because the direction of the wind will hit different surface areas of the various shapes.)*

5. In which part of the wind tunnel is the wind speed the fastest? Why? *(The wind speed is fastest in the test chamber because the wind is passing from a larger chamber to a smaller one.)*

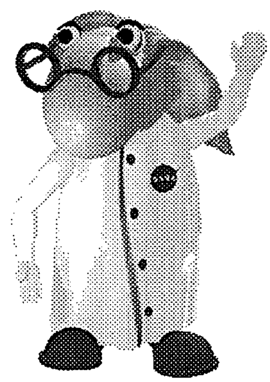
6. What is the importance of using a wind tunnel for the design of aircraft or lifting bodies? *(Wind tunnels are used to test the design and viability of aircraft and other objects before a full-scale version is built.)*

7. What other objects can be tested in a wind tunnel? *(Cars, wheelchairs, hurricane-proof homes, buildings, and parafoils can be tested in a wind tunnel.)*

8. Describe the relationship between the shape of the object and the drag created? *(Reducing the object's surface area in the wind flow lowers the drag value.)*

EXTENDING THE ACTIVITY

1. For extension activities, please visit "Norbert's Lab" on the NASA CONNECT web site at **http://edu.larc.nasa.gov/connect/tools/norbert/lab.html**



*Encourage students to visit **all** the rooms in Norbert's lab.*

2. Using the data collected and recorded from the NASA CONNECT Activity, have students make comparisons, predictions, and inferences *(see the examples below).*

Example: The following tables show the data collected by Prince William County, Virginia students.

	Low Speed			Medium Speed			High Speed		
	test 1	test 2	test 3	test 1	test 2	test 3	test 1	test 2	test 3
Tetrahedron	1.0	1.0	1.0	2.0	2.0	2.0	3.0	2.5	3.0
Pyramid	1.5	1.5	1.0	2.0	3.0	3.0	5.0	5.5	5.0
Cube	1.0	1.0	1.0	2.0	2.0	2.0	4.0	4.0	4.0
Cone	2.0	2.0	2.0	4.0	4.0	4.0	8.5	8.5	8.5

	Low Speed Mean	Medium Speed Mean	High Speed Mean
Tetrahedron	1.0	2.0	2.8
Pyramid	1.3	2.7	5.2
Cube	1.0	2.0	4.0
Cone	2.0	4.0	8.5

CUE CARDS, TABLES, PATTERNS, CHARTS, GRAPHS

CUE CARDS

Peninsula Fine Arts Center in Newport News, VA

How did the U.S. Standard system of measurement develop?

How was the metric system devised?

How are the two systems different?

Mike Logan, NASA Langley Research Center

Explain four forces which affect aircraft performance and tell how they relate to each other.

Hector Soto, NASA Langley Research Center

What is a wind tunnel?

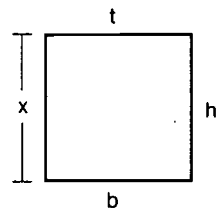
How is it used as a measurement tool?

Why is the SR-71 an ideal research test airplane?

TABLE A. MEASURED AND CALCULATED LENGTHS

Objects	Height (h)	Bottom (b)	Top (t)
A. Window fan			
B. Upper/lower deflectors			
C. Test chamber			

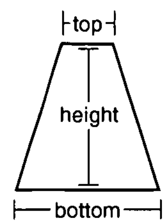
A. Window fan: The standard box/window fan is a square. Because the fan is the base of the wind tunnel, the tunnel dimensions or size will be based on the dimensions or size of the fan. Because the fan is square, you need only measure one side of the fan. This measurement represents x.



box/window fan

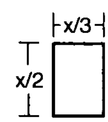
B. Upper/lower deflectors. The same pattern is used for the upper and lower deflectors. Each section requires four pieces. To find the dimensions for these pieces, substitute the measurement represented by x.

top measurement = x/3
height = x
bottom = x



upper/lower deflectors

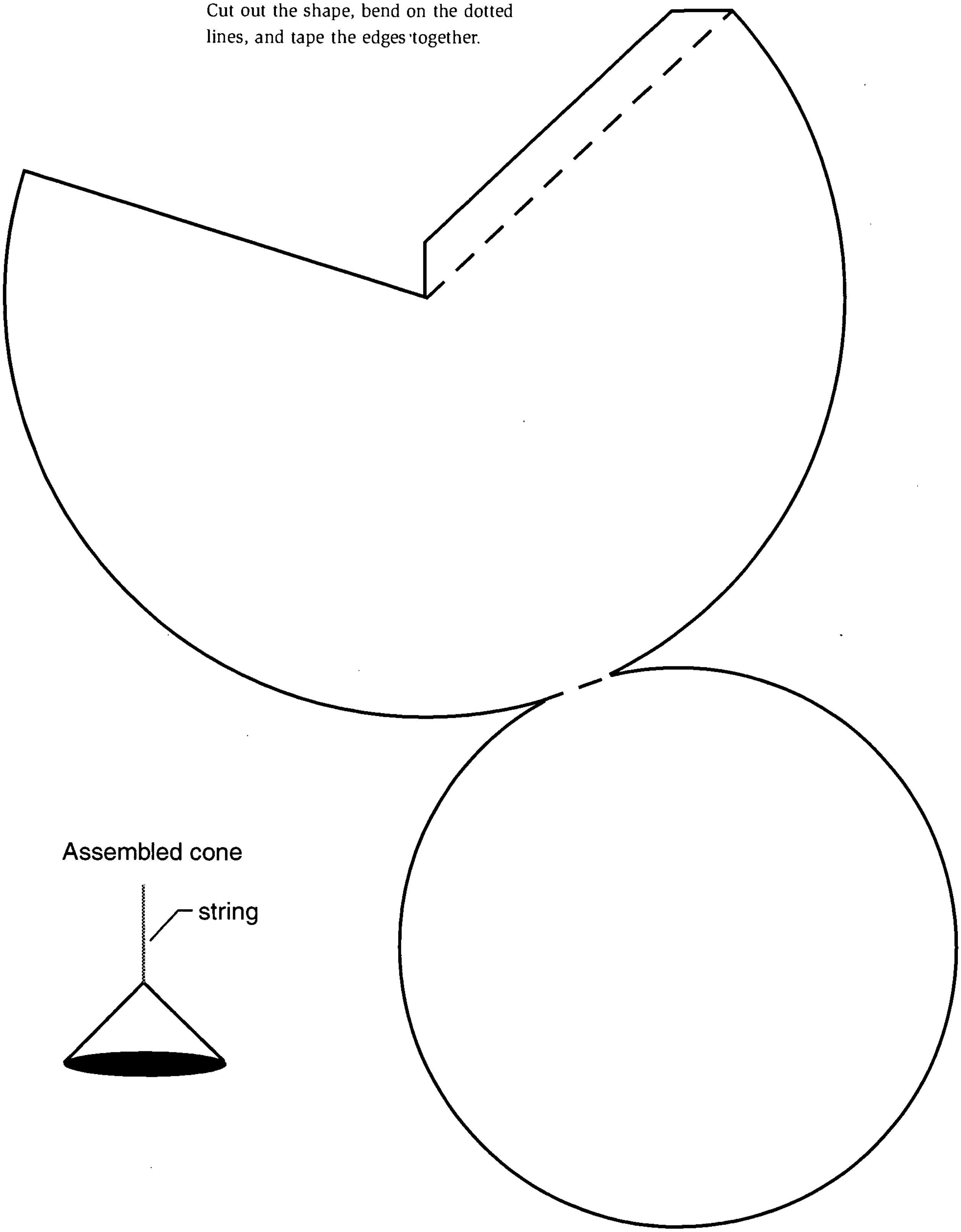
C. Test chamber. The test chamber is constructed of four pieces. To find the dimensions for these pieces, substitute the measurement represented by x.



test chamber

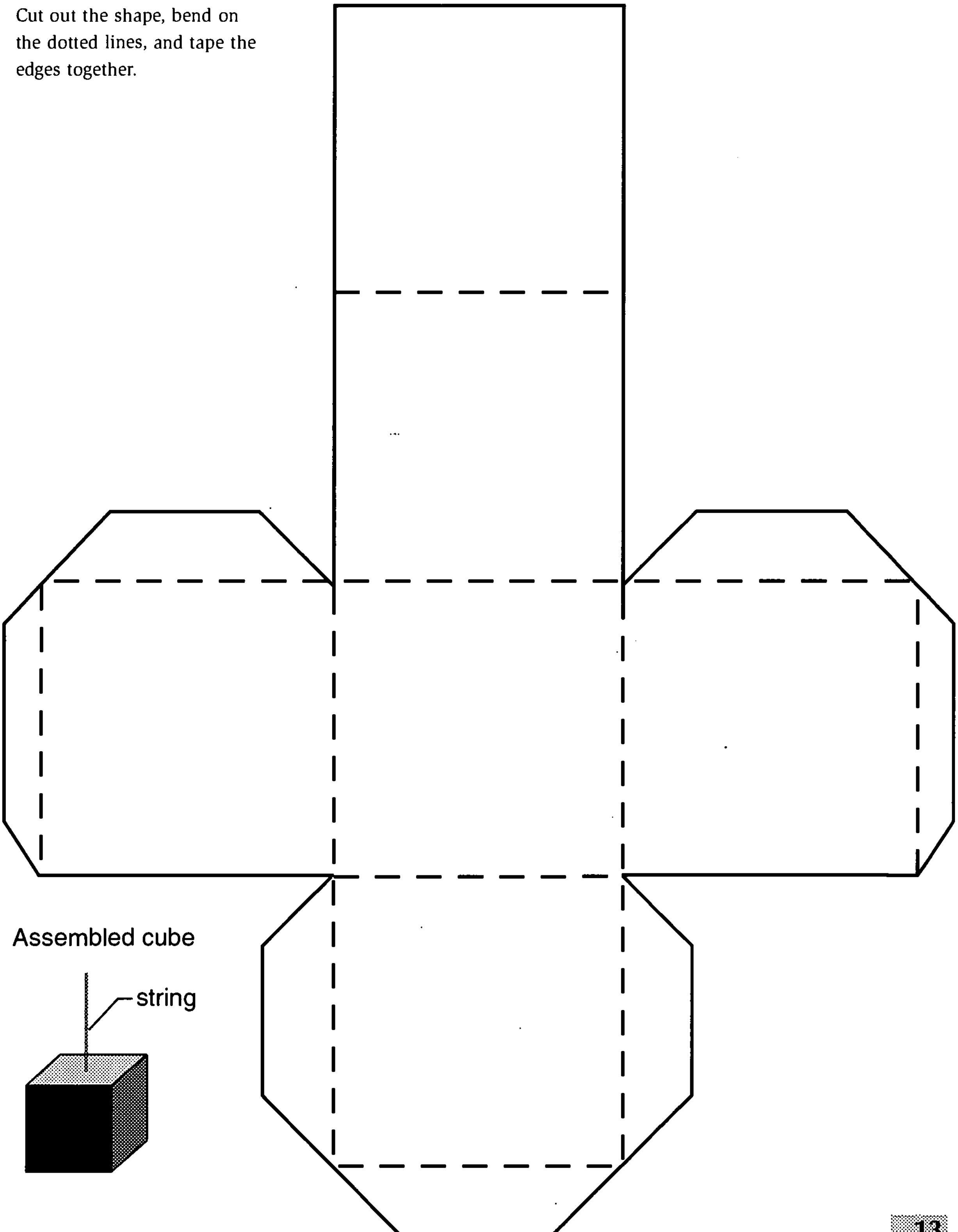
CONE

Cut out the shape, bend on the dotted lines, and tape the edges together.



CUBE

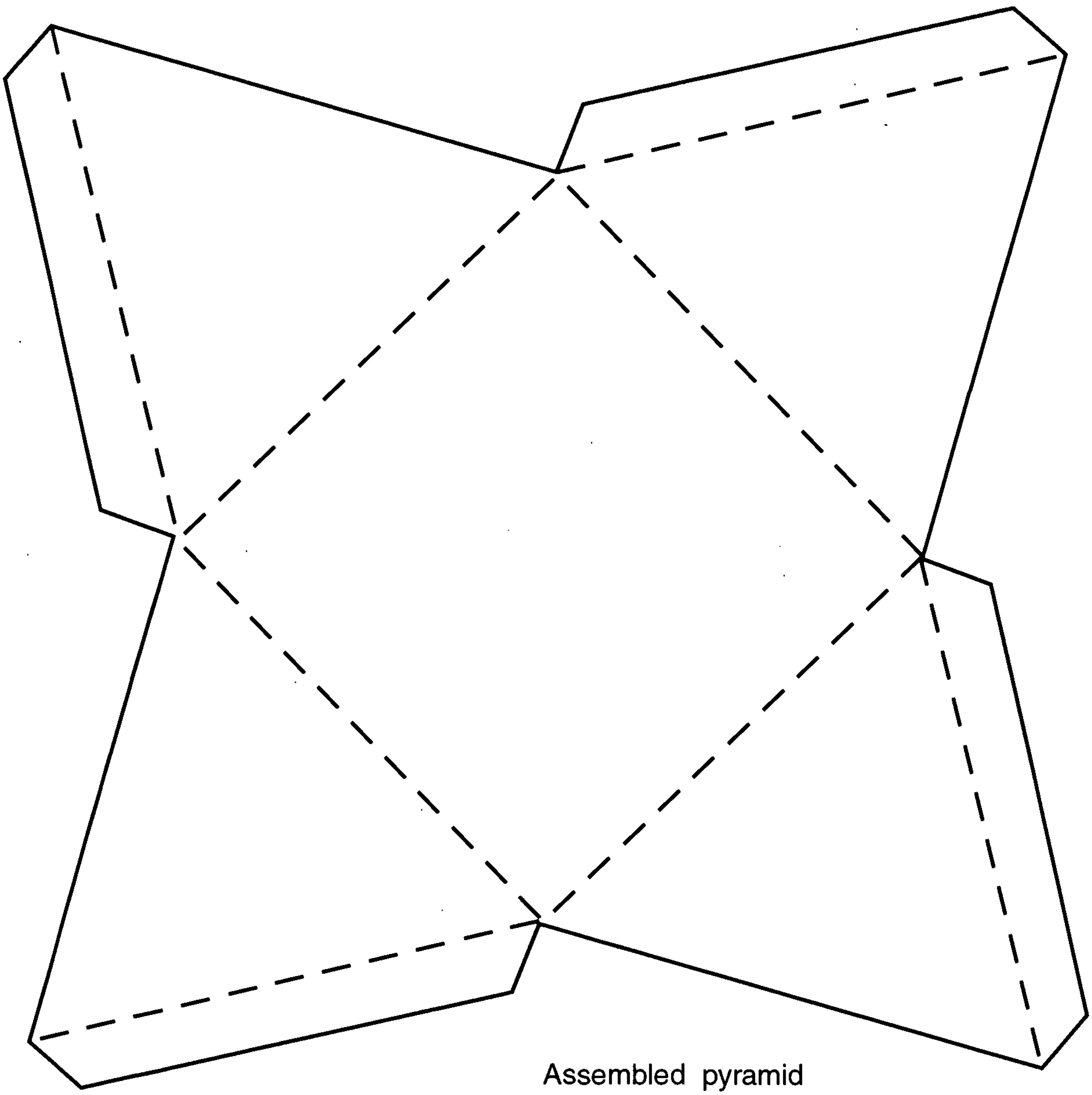
Cut out the shape, bend on the dotted lines, and tape the edges together.



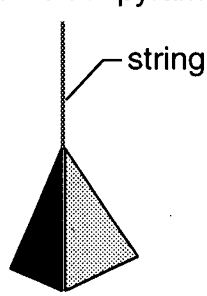
Assembled cube

PYRAMID

Cut out the shape, bend on the dotted lines, and tape the edges together.

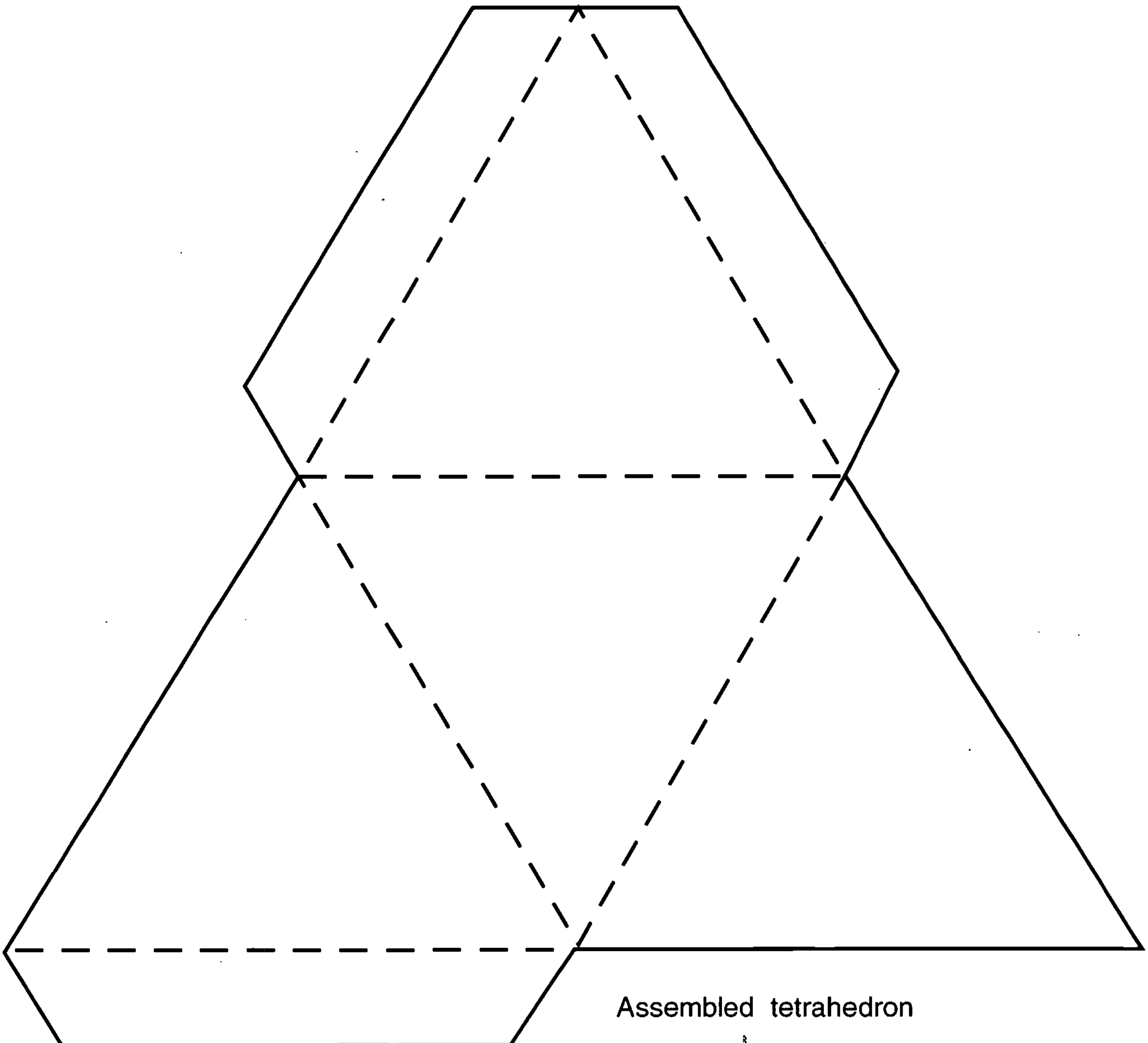


Assembled pyramid

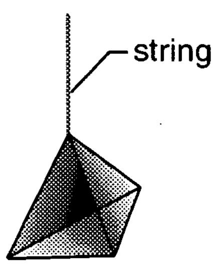


TETRAHEDRON

Cut out the shape, bend on the dotted lines, and tape the edges together.



Assembled tetrahedron



STUDENT DATA WORKSHEET

Table B. Drag Force Value

Fan Speeds									
	Low Speed			Medium Speed			High Speed		
	test 1	test 2	test 3	test 1	test 2	test 3	test 1	test 2	test 3
Tetrahedron									
Pyramid									
Cube									
Cone									

Observations: ____

____

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Table C. Drag Force Value Calculations

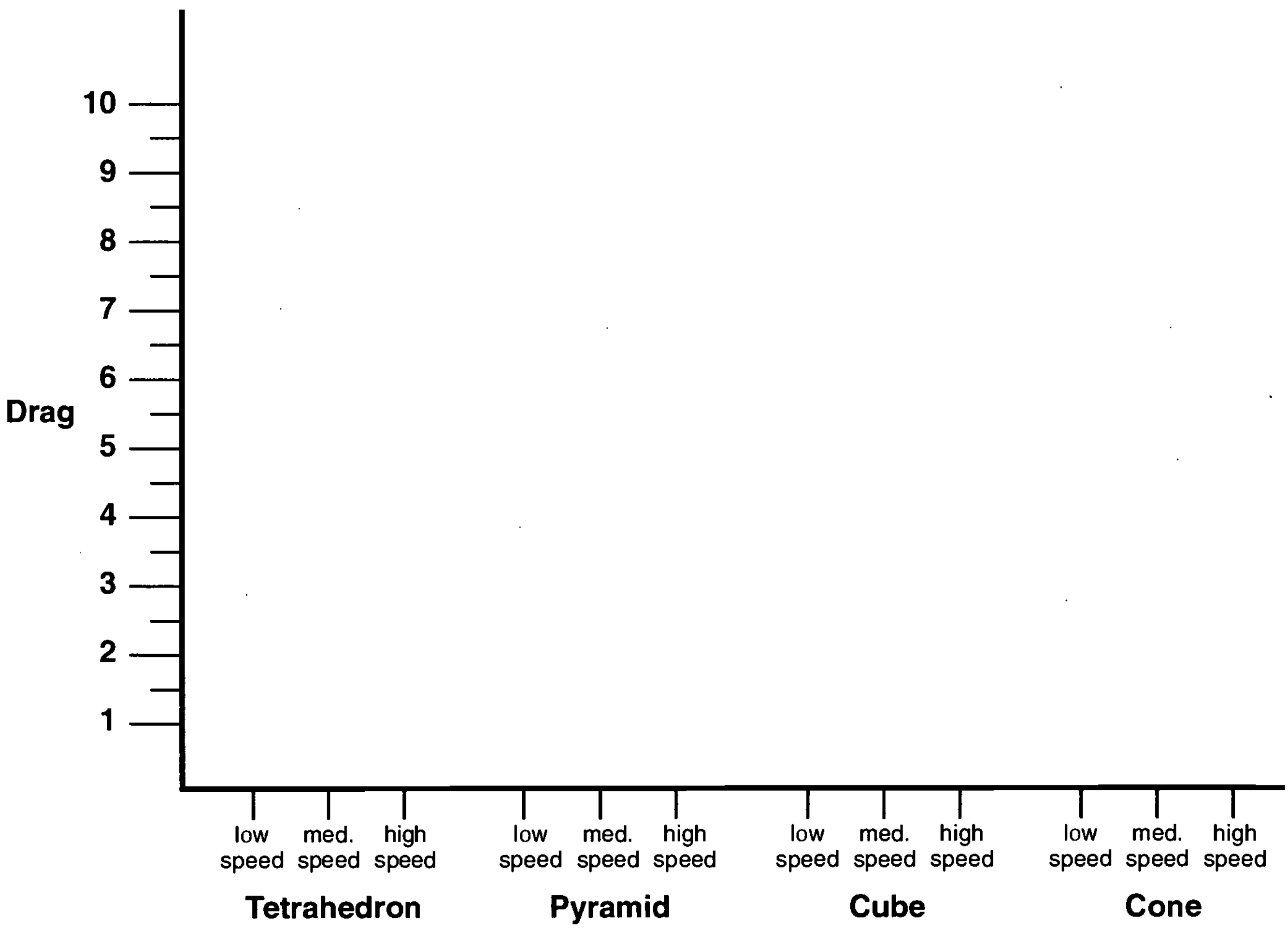
Fan Speeds									
	Low Speed			Medium Speed			High Speed		
	mean	median	mode	mean	median	mode	mean	median	mode
Tetrahedron									
Pyramid									
Cube									
Cone									

GRAPH OF THE DRAG (MEAN)

Directions: Use bars to graph the mean of each shape at low, medium, and high speeds. Use a different colored pencil for each speed.

KEY

low speed = green
medium speed = blue
high speed = red



1999-2000 NASA CONNECT PROGRAM OVERVIEW

INTRODUCTION TO THE 1999 - 2000 NASA CONNECT SERIES

NASA CONNECT is an award-winning instructional series produced by the NASA Langley Research Center's Office of Education and is designed to enhance the teaching of math, science, and technology in grades 4-8. This standards-based, distance learning program originates in Hampton, Virginia, is broadcast via Ku- and C-band satellite (television), and is web cast via the Internet through NASA's Learning Technology Channel. NASA CONNECT is carried by many PBS-affiliated stations across the country. By using a steerable dish, NASA CONNECT can also be downlinked using the satellite coordinates posted on the NASA CONNECT web site.

NASA CONNECT is informative and educational. Each program in the series uses NASA programs, projects, and researchers to illustrate the workplace application of math and science. Programs are 30-minutes long and seek to establish a "connection" between the math, science, and technology concepts taught in the classroom and the math, science, and technology used everyday by NASA researchers. The connection is further established by introducing students to the tools and methods used by NASA engineers and scientists who perform innovative research. NASA CONNECT programs include a lesson guide for educators and parents, a classroom (hands-on) activity or experiment, and web-based activities, all of which are designed to complement and extend the lesson and establish a connection between the home, the classroom, and the community.

The lesson guide includes the relevant national math and science standards, a teaching protocol, instructions for preparing and conducting the activity or experiment, and suggestions for extending the activity or experiment. Students are encouraged to use the data provided in the charts and graphs to make comparisons, predictions, and inferences. The web-based activities permit students to interact with NASA engineers and scientists, and are easily integrated into local, regional, and statewide technology initiatives. Two schools are featured in each NASA CONNECT program: students from one school perform the classroom activity or experiment, and students from the other demonstrate the web-based (computer) technology activities. Museums and science centers are often included as program partners.

Developed to enhance and enrich math, science, and technology education, NASA CONNECT accommodates different teaching and learning styles. Through the use of the classroom activity or experiment, NASA CONNECT allows educators to (1) demonstrate workplace math and science as a collaborative process and (2) present math and science as a process requiring creativity, critical thinking, and problem-solving skills. By using the teaching protocol, programs in the NASA CONNECT series can be easily integrated into the existing curriculum. They can also be used to introduce or reinforce a curriculum topic, objective, or skill. Programs can be viewed live or taped for later use.

NASA CONNECT is a U.S. Government product and is not subject to copyright. NASA CONNECT is FREE to educators; however, they must register to obtain the teacher (lesson) materials. There are no fees or licensing agreements. Off-air rights are granted in perpetuity. Educators are granted unlimited rights of duplication, dubbing, broadcasting, cable casting, and web casting into perpetuity, with the understanding that all NASA CONNECT materials will be used for educational purposes. Neither the broadcast nor the teacher (lesson) guides may be used, either in whole or in part, for commercial purposes without the expressed written consent of NASA CONNECT. For additional information about the series, the broadcast schedules, and the satellite coordinates, visit the NASA CONNECT web site at: **http://edu.larc.nasa.gov/connect/**

ABOUT THE 1999-2000 NASA CONNECT SERIES

The 1999-2000 NASA CONNECT program season uses aeronautics and space technology (A-ST) as its organizing theme. This theme forms the creative basis for a series of seven programs that demonstrate the problem-solving focus of NASA A-ST research. NASA A-ST goals are grouped into three areas or "Three Pillars": Global Civil Aviation, Revolutionary Technology Leaps, and Access to Space. These goals reflect national priorities for the NASA Aero-Space Technology Enterprise and require taking risks and performing the long-term research and development programs needed to keep the United States the global leader in aeronautics and space exploration.

THE SEVEN PROGRAMS

The Measurement of All Things: Tools of the Aeronautics Trade
Thursday, October 21, 1999, 11:00-11:30 AM (ET)

Story Line: Students will explore the concept of measurement and the tools used in measuring things, while learning "what" and "how" engineers and scientists use measurement during the process of developing, designing, and testing airplanes.
Math Concepts: Number and Number Sense, Units, Conversion, Tools
Science Concepts: Logic, Reasoning, Science as Inquiry
NASA Research: Fundamental Aeronautics, Measurement Science, Flight Research

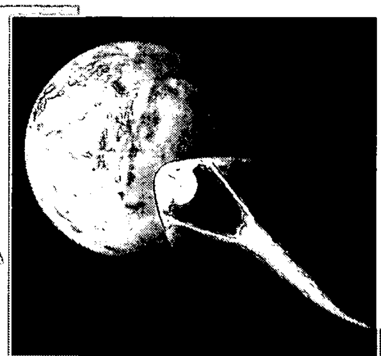
The Measurement of All Things: Atmospheric Detectives
Thursday, November 18, 1999, 11:00-11:30 AM (ET)

Story Line: Students will learn how scientists use satellites, lasers, optical detectors, and wavelengths of light to measure the presence of certain elements and compounds in the Earth's atmosphere.
Math Concepts: Volume, Computation and Estimation, Patterns, Tools
Science Concepts: Earth/Space Science, Chemistry, Physics, Electromagnetic Spectrum
NASA Research: CERES, LASE, SAGE II, and PICASSO

Geometry of Exploration: Water Below the Surface of Mars?
Thursday, December 9, 1999, 11:00-11:30 AM (ET)

Story Line: Students will learn how engineers and scientists will use geometry to navigate a spacecraft to Mars.
Math Concepts: Angles, Graphic Methods, Geometric Shapes, Inference, Reasoning
Science Concepts: Data Collection and Analysis, Experimentation, and Physics
NASA Research: Mars Microprobe

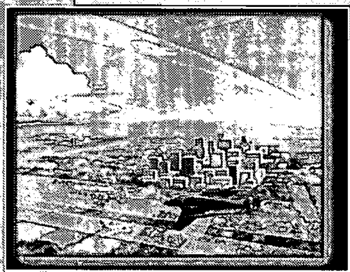
Geometry of Exploration: Wings over Mars
Thursday, January 20, 2000, 11:00-11:30 AM (ET)



Story Line: Students will learn about the geometric shapes and materials of the Mars Airplane, how the atmospheres of Mars and Earth compare, and how the aerodynamic forces of the Mars Airplane differ from those of the Wright Flyer.
Math Concepts: Measurement, Geometric Shapes, Data Collection and Analysis
Science Concepts: Force, Motion, Energy, Space Systems, Physical Changes
NASA Research: Mars Airplane

Proportionality: The X-Plane Generation
Thursday, February 17, 2000, 11:00-11:30 AM (ET)

Story Line: Students will learn why scaling and proportion are important factors in spacecraft design.
Math Concepts: Computation, Ratios, Estimates, Measurement
Science Concepts: Systematic Investigation, Force, Motion, Energy, Heat, Sound
NASA Research: X-Planes



Proportionality: Modeling the Future
Thursday, March 16, 2000, 11:00-11:30 AM (ET)

Story Line: Students will continue to learn why scaling and proportion are important in the design of small, affordable transportation systems.
Math Concepts: Computation, Ratios, Measurement, Data Visualization
Science Concepts: Force, Motion, Energy, Temperature, Heat, Sound
NASA Research: Small Affordable Transportation Systems (SATS)

Algebra: Mirror, Mirror on the Universe
Thursday, April 20, 2000, 11:00-11:30 AM (ET)

Story Line: Students will learn how algebra is used to explore the universe.
Math Concepts: Estimations, Expressions, Solving Equations, Word Problems
Science Concepts: Matter, Temperature, Chemical and Physical Changes, Light
NASA Research: Next Generation Space Telescope

PROGRAM FORMAT

Each NASA CONNECT program includes the following:

GUESTS

The program features program partners and a NASA engineer, scientist, or technician to illustrate the application of classroom lessons to the workplace.

ACTIVITIES

Students perform hands-on activities drawn from NASA educational products, including the National Council of Teachers of Mathematics (NCTM) math activity books, *Mission Mathematics*, developed in collaboration with NASA.

STUDENTS

Middle school students who have conducted the program's experiment are highlighted, as well as students who have completed the web-based component. The results of the experiment are shared with viewers.

DATA ANALYSIS

After the classroom activity, students are encouraged to perform analysis and data interpretation and engage in class discussion.

E-MAIL

Students can e-mail questions to the program guests two weeks following the live broadcast.

LESSON GUIDES

Lesson guides are provided for registered educators. Each guide includes a program summary, teacher background, national math and science standards, instructional objectives, teacher resources, and the classroom activity. Master copies of student data worksheets are also included for copying and distributing to students.

WEB SITE

Throughout the program, the NASA CONNECT URL (**http://edu.larc.nasa.gov/connect**) will be displayed to indicate points where further details and/or interactive activities relating to the video presentation can be examined.

WEB FORMAT

The broadcast and the Internet are closely interwoven in the NASA CONNECT series. The series uses the Internet in several ways to enhance the teaching and learning process.

INQUIRY INSTRUCTION

Students are provided with questions and investigations that require them to discover the generalities of the subject on the basis of practice examples. Feedback and elaboration are provided. Students gain new insight by making observations, developing inferences, making comparisons, and interpreting data.

HOME CONNECTION

Parents are encouraged to be partners in the explorations and activities. The web site provides a means for the parent and child to share in the learning process. Educators are encouraged to make parents aware of the web site and to encourage this one-on-one discovery between the parent and child about the mathematics and science concepts.

INTERNET WEB CAST

Each NASA CONNECT program is webcast in real time through the Internet. Educators are encouraged to check the NASA Learning Technologies Channel (**http://quest.arc.nasa.gov/ltc/special/connect**) schedule for further details on technology requirements and the broadcast schedule.

REGISTRATION AND FEEDBACK

Educators can register on-line for NASA CONNECT, can obtain broadcast schedule information for their state, can download print materials, and can evaluate the program through the NASA CONNECT web site (**http://edu.larc.nasa.gov/connect**).

NASA CONNECT TEACHING PROTOCOL

There is a definite difference between "doing science" and doing science activities. Classroom teachers have few opportunities to work with scientists to develop an understanding of the nature of scientific inquiry. The model proposed to educators through the NASA CONNECT series is a shift from "activitymania"— a collection of hands-on activities that are often disconnected from each other — to inquiry, in order to introduce students to the process of searching for patterns and relationships and to better develop higher order cognitive skills. Below is a six-step teaching protocol designed to prepare students for more active mental engagement with the video program so that they can make stronger connections between the NASA CONNECT program activities and appropriate mathematics and scientific concepts.

The six-step protocol includes reflective discussion, video engagement, dialogue notes, NASA CONNECT activity, journal writing, and NASA CONNECT web. This protocol is consistent with constructivist theory. A learning environment that promotes rich discourse among students is central to the approach. Student teams that engage in discovery, decision making, and problem solving give students opportunities to develop and present their findings to the entire class. The proposed format is flexible and is an effective way to teach students complex math and science concepts, to model science inquiry, and to emphasize connections.

STEP 1: REFLECTIVE DISCUSSION

Prior to viewing the NASA CONNECT program, list on the chalkboard the following questions to help students form their own theories and to give them a place to start constructing their knowledge about the show's topic. Have students share their thoughts or write their responses. Keep these questions on the board during the video. In addition to helping students prepare for the program, these questions can also serve as a pretest for assessment purposes. The following are sample questions:

1. How are math and science involved in studying ______?
2. What is the relationship between science and technology?
4. What role do mathematics and mathematical tools have in scientific inquiry?
5. What value might collaborations and partnerships play in conducting research?

STEP 2: VIDEO ENGAGEMENT

NASA CONNECT is not designed for passive viewing. NASA CONNECT actively engages students in the program. Several suggestions are provided to help teachers focus student attention on the video program.

CUE CARDS

Throughout each program, students observe the NASA CONNECT hosts trying to resolve a problem. Special guests and researchers use NASA projects and programs to assist students in solving the problem. Cue Cards are provided with each lesson guide, listing questions for the students to answer. Teachers should copy the Cue Cards and distribute them prior to the video showing. Students are encouraged to take notes during the video and answer the questions on the cards.

DATA ANALYSIS

After the classroom activity, the NASA CONNECT host will suggest that teachers pause the tape, encourage students to perform data analysis and interpretation, and engage in a class discussion. Students will be asked to respond to questions related to the data. More questions and their answers can be found in the lesson guide.

STEP 3: DIALOGUE NOTES

1. Immediately after the video, students should spend five to ten minutes reviewing the questions in "Step 1: Reflective Discussion Section." Teachers should ask students to give examples from the video presentation that support their responses to each question.

2. Review the Cue Cards with students. Teachers should ask students to share what they recorded and learned from each guest and NASA researcher. Students should also discuss what they believe are the important math and science concepts these individuals use in their work.

3. Return to the student data worksheets and, if necessary, provide students with additional time to complete the mathematical calculations and the data analysis. Educators should challenge students to think of different kinds of investigations that can be created from the experiment.

STEP 4: NASA CONNECT ACTIVITY

Students learn from direct teaching, engaging in classroom discussion, conducting research, and taking notes. During the NASA CONNECT video, an experiment is described. This activity is provided for the classroom teacher to use as a math/science lab. When using the NASA CONNECT Activity, introduce students to the vocabulary, guide students toward connections, and explore possible misconceptions associated with the topic. Data collected from the classroom activity can then be compared with the data collected by the featured middle school students and highlighted in the video. Finally, have your students relate the results of their classroom activity to the NASA research presented in the video.

STEP 5: JOURNAL WRITING

Journal writing supports students' reflective thinking processes. Students should reflect on what they learned from the video and from their own experimentation. Educators can also ask students questions that relate to the real-life applications of the concepts in the video and their lab experiment. Educators might use journal questions to assess student understanding of the concepts presented in the lesson guide.

STEP 6: NASA CONNECT WEB

The web site uses the inquisitory instruction strategy to place students in a contextual environment and encourages them to understand the math, science, and technology concepts and skills presented in the program. The web site also presents multiple perspectives to specific questions raised in the video. A series of activities is incorporated into the NASA CONNECT web site for each program to augment the video theme and to provide additional opportunities for students to perform multiple trials and share their data with others. Also, from the web site, students might submit E-mail questions to the program guests up to two weeks following a live broadcast. Teachers might use this site to establish a connection between the classroom and the family by sending home a notice about the NASA CONNECT program and its Internet URL and by encouraging parents to explore this site and complete the activities with their children.

NASA AERONAUTICS EDUCATOR RESOURCES

The NASA Aero-Space Technology (A-ST) Enterprise and educational communities are partners in developing materials to stimulate student interest and enthusiasm for mathematics and science. By augmenting learning environments with ideas and experiences that use mathematics and science, we share with students and educators the excitement of how these tools can be used and how their power can change the world. NASA on-line aeronautics projects follow these on-line links to more aeronautics-related projects that provide the curriculum, interactive materials, activities, and more, as developed by the NASA A-ST Centers and Learning Technologies Project (LTP) Offices and by external partners through LTP-funded electronic projects.

Aeronautics and Aviation Science Careers and Opportunities
(Massachusetts Corporation for Educational Telecommunications)
http://mcet.edu/nasa

Aeronautics Learning Laboratory for Science, Technology, and Research
(ALL STAR) (Florida International University)
http://allstar.fiu.edu/aero

Internet-Based Curriculum on Math and Aeronautics for Children with Physical Disabilities (InfoUse, Inc.)
http://planemath.com/

K-8 Aeronautics Internet Textbook (Cislunar Aerospace, Inc.)
http://wings.ucdavis.edu/

Kids Corner (NASA Langley)
http://kidscorner.larc.nasa.gov/

Lego Data Acquisition and Prototyping System (Tufts University)
http://ldaps.ivv.nasa.gov/

NASA Aeronautics Enterprise Web Ground School (NASA Headquarters)
http://www.hq.nasa.gov/office/aero/edu/

Sharing NASA (NASA/Ames)
http://quest.arc.nasa.gov

Wright Flyer On-line (NASA/Ames)
http://quest.arc.nasa.gov/aero/wright/

NASA ON-LINE RESOURCES FOR EDUCATORS

NASA Spacelink (http://spacelink.nasa.gov) is one of NASA's electronic resources that is specifically developed for use by the education community. This comprehensive electronic library offers teacher guides, wall sheets, and listings of videos, computer software, and other materials that have been developed to meet national education standards. Educators can search specific curriculum materials by grade level and subject matter. Current and historical information related to NASA's aeronautic and space research can be found from Spacelink. Links to NASA Educator Resource Center (ERC), CORE, news releases, current state reports on agency projects and events, and television broadcast schedules for NASA Television are also provided.

Quest (http://quest.arc.nasa.gov) is the home of NASA's K-12 internet Initiative. The electronic resource specializes in providing programs, materials, and opportunities for teachers and students to use NASA resources as learning tools to explore the Internet. One of its unique projects is "Sharing NASA," a series about on-line, interactive units where students can communicate with NASA scientists and researchers to experience the excitement of real science in real time. During the 1999-2000 academic year, Aero Design Team On-line will be a featured project of "Sharing NASA." Learning Technologies Channel (LTC) **(http://quest.arc.nasa.gov/ltc/)** is a NASA location on the Internet that allows you to participate in on-line courses and to remotely attend some NASA workshops and seminars. A primary focus of the LTC is to broaden the uses of the Internet to include in-service teacher training and to bring new internet experiences into the classroom.

NASA Central Operation of Resources for Educators (CORE)
NASA's CORE is a worldwide distribution center for NASA multimedia educational materials. Educational materials include videotape programs, slide sets, and computer software. For a minimal fee, NASA CORE will provide educators with materials through its mail order service. A free NASA CORE catalog is available.

NASA CORE
15181 State Route 58 South
Oberlin, OH 44074
phone: (440) 775-1400
fax: (440) 775-1460
E-mail: nasaco@leeca.esu.k12.oh.us
URL: **http://core.spacelink.nasa.gov**

NASA EDUCATIONAL PROGRAMS AND MATERIALS

The widest possible distribution and use of NASA educational programs and materials is encouraged. Specifically, there is no claim of copyright by the U.S. Government concerning the NASA CONNECT series. Therefore, permission is not required to either tape each broadcast or to copy the associated print materials for classroom use and/or retention in your school's library. Additional on-line resources can be found on SpaceLink (**http://spacelink.nasa.gov**)

NASA EDUCATOR RESOURCE CENTERS (ERC)

The NASA ERC Network is composed of Educator Resource Centers located at or near all NASA installations and ERCs located at planetariums, universities, museums, and other nonprofit organizations nationwide. These centers supply instructional activities, videotapes, slides, and computer software generated by NASA programs, technologies, and discoveries. These materials are designed for educators of all disciplines and are aligned to the national education standards.

For more information on NASA education programs and aeronautics-related materials, educators may contact the ERC at the following NASA Centers. The NASA field centers that have leading roles and responsibilities in the Aero-Space Technology (A-ST) Enterprise are in **boldface**:

AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY
NASA Ames Educator Resource Center
Mail Stop 253-2
Moffett Field, CA 94035-1000
(650) 604-3574

CA cities near the center
NASA Dryden Educator Resource Center
45108 North Third Street East
Lancaster, CA 93535
(661) 948-7347

CT, DE, DC, ME, MD, MA, NH, NJ, NY, PA, RI, VT
NASA Goddard Educator Resource Center
Mail Code 130.3
Greenbelt, MD 20771-0001
(301) 286-8570

CO, KS, NE, NM, ND, OK, SD, TX
Space Center Houston
1601 NASA Road One
Houston, TX 77058-3696
(281) 244-2129

NASA JPL Educator Resource Center
Village at Indian Hills Mall
1460 East Holt Blvd., Suite 20
Pomona, CA 91767
(909) 397-4420

FL, GA, PR, VI
NASA Kennedy Educator Resource Center
Mail Code ERC
J.F. Kennedy Space Center, FL 32899-0001
(407) 867-4090

KY, NC, SC, VA, WV
NASA Langley Educator Resource Center
Virginia Air and Space Center
600 Settlers Landing Road
Hampton, VA 23669-4033
(757) 727-0900, ext. 757

IL, IN, MI, MN, OH, WI
NASA Glenn Educator Resource Center
21000 Brookpark Road, MS 8-1
Cleveland, OH 44135-3191
(216) 433-2017

AL, AR, IA, LA, MO, TN
NASA Marshall Educator Resource Center
U.S. Space and Rocket Center
One Tranquility Base
Huntsville, AL 35758
(256) 544-5812

MS
NASA Stennis Educator Resource Center
Building 1200
Stennis Space Center, MS 39529
(228) 688-3220

VA's and MD's Eastern Shore
NASA Wallops Educator Resource Center
Education Complex - Visitor Center
Building J-17
Wallops Island, VA 23337-5099
(757) 824-2298