National Aeronautics and Space Administration

Educational Program	
Educators & Students	Grades 5–8

EP-2003-08-401-HQ

NASA
Student Involvement Program
Aerospace Technology Engineering Challenge

NASA's mission is

- ❑ To understand and protect our home planet,
- ❑ To explore the Universe and search for life,
- ❑ To inspire the next generation of explorers as only NASA can.

Resource Guide
2003–2004 National Competitions

Welcome to **ATEC**, the NSIP **Aerospace Technology Engineering Challenge**!

This Resource Guide explains how to prepare a project for entry in the NSIP **ATEC** Competition. It also offers an introduction to the *Spacecraft Structures Design Challenge* of the NASA Earth-to-Orbit (ETO) program.

For more information on the NSIP competitions, as well as official rules and entry submission materials:

- download from the NSIP web site (www.nsip.net), or
- contact NSIP by e-mail (info@nsip.net), or
- telephone NSIP (1-800-848-8429), or
- write to:
  NSIP-TERC
  2067 Massachusetts Ave Ste 2
  Cambridge, MA 02140-1364.

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Competition Categories

Grades 5–8   Teams of 2–4 Students

Aerospace Technology Engineering Challenge (ATEC)

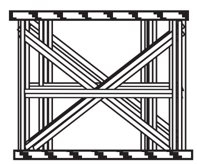
With some simple and inexpensive materials, you can lead an exciting unit that focuses on a specific problem that NASA engineers must solve and the process they use to solve it. In the classroom, teams of 2–4 students design, build, test, and revise their own solutions to problems that share fundamental science and engineering issues with the challenges facing NASA engineers.

This guide explains how teams can prepare entries for NSIP ATEC competition. It also provides an overview of the ATEC and student work sheets to help you collect meaningful assessment data in the classroom.

The ETO Teacher's Guide

Detailed instructions for all of the classroom activities referred to in this guide, as well as a wealth of supporting materials, are available for free in the Teacher's Guide for the ETO *Spacecraft Structures Design Challenge*. It is available at http://eto.nasa.gov (click on "The Challenges"), and is necessary for this Competition. (Specifics are available online regarding exactly which parts of the ETO guide are necessary.)

Once you and your students have done the ETO classroom activities of the Spacecraft Structures Design Challenges, prepare student team entries for submission to the NSIP ATEC Competition.



A heavily-built thrust structure

Standards

These activities help students achieve national goals in science, math, and thinking skills. Your students have the opportunity to use creativity, cleverness, and scientific knowledge to solve a challenge based on a real-world problem that is part of the space program.

Students have many opportunities to learn about forces, structures, and energy transfer during the activities. The storyboard, as explained in the ETO guide, and the NSIP Project give students opportunities to develop their presentation and communication skills.

A detailed view of the math and thinking skills developed by the activities and how the Structures Challenge relates to national science education standards is available on pages 7–10 of the full ETO Guide.

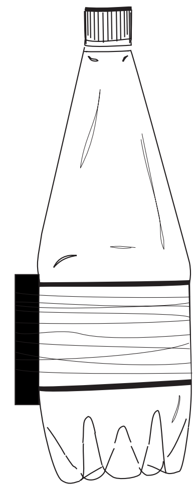
Introducing the ATEC Challenge

The challenge is for teams of 2-4 students to build a model "thrust structure" out of sticks, cardboard, and hot melt glue. In a rocket, the thrust structure connects the engine to the rocket body. It must be strong enough to withstand the engine's thrust without being damaged, and as lightweight as possible, so the rocket can have the largest possible payload. Similarly, the goal of the student models is to design and build the lightest possible structure which is capable of launching the test rocket into orbit three times.

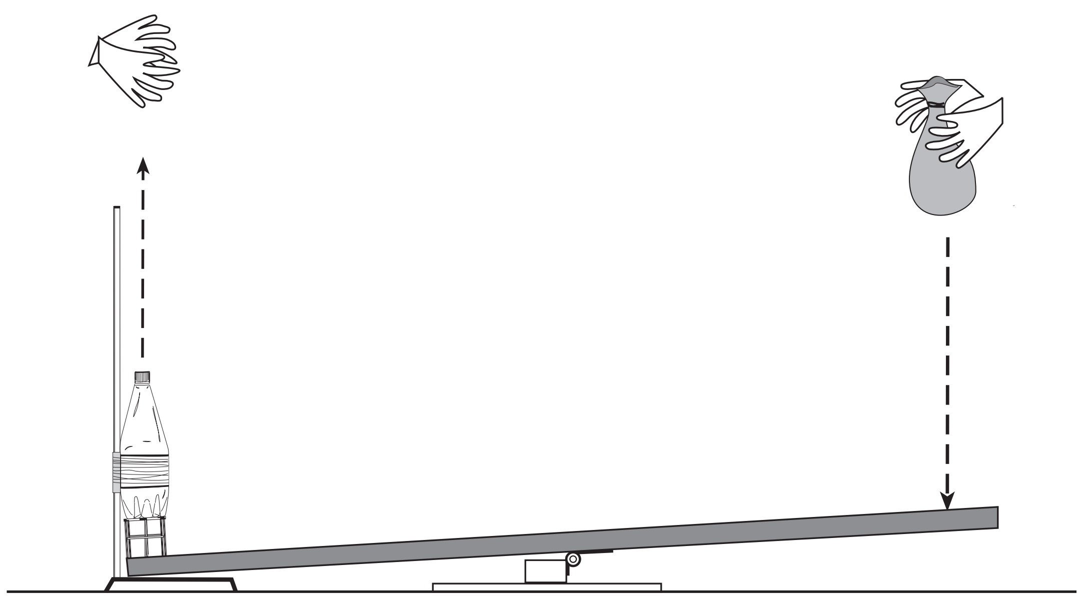
When a team has built a structure and completed a Design Specifications sheet for it, they will test the structure by using it to launch a 1 kg test rocket into "orbit." They will place their model under the test rocket, on the launch lever that will send the rocket about 1 meter high. A weight will be dropped (from a carefully chosen height) onto the far end of the launch lever, and the rocket will fly into "low earth orbit."

After each launch, the team will inspect its structure for damage. If the structure passes the first test, it will be tested to see whether it can withstand 3 launches. The team will fill out a Test Results sheet for each structure it tests.

Each team will make use of what it learns to build revised designs over the course of several sessions, trying to maintain or increase the strength and reduce the weight of their structure.



The "rocket" is a 1-liter plastic bottle filled with water. A brass guide tube is taped to the side.



The Design Specifications Sheet and the Test Results Sheet

The **Design Specifications** and **Test Results Sheets** are simple records teams fill out for each structure they design. The Sheets describe the structure before it is tested and the actual results of testing. Students must complete these Sheets before and after each test launch—the team is not ready for launch testing until the teacher has verified that the Design Specifications Sheet is complete, and that takes only a few seconds.

Besides being an integral part of a methodical scientific inquiry, these records both require students to communicate their ideas about what they are doing, and provide teachers with a visual and written story of each team's progress, which is invaluable data for student assessment. The "portfolio" is built into the inquiry.

In addition, the Design Specifications and Test Results Sheets are the basis of Entries to the NSIP ATEC competition. Because the students completed the Sheets during the activities, preparing their Entries to the NSIP ATEC competition is simplified.

Teaching Strategies

The ETO Guide offers Teaching Strategies for use in the classroom. Here are two examples:

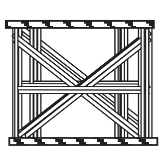
- ❑ Emphasize improvement over competition. The goal of the challenge is for each team to improve its own design. However, there should be some recognition for designs that perform extremely well. There should also be recognition for teams whose designs improve the most, for teams that originate design innovations used by others, for elegant design, and for quality construction.
- ❑ Encourage students to compare their designs with those of other groups. Endorse borrowing. After all, engineers borrow a good idea whenever they can. However, be sure that the team that came up with the good idea is given credit in documentation and in the pre-test presentation.

Time Required

The design challenge can be carried out in six 45-minute class periods. More time will be needed to complete the NSIP Entries. You will need to invest an additional 4–8 hours gathering the materials, building the test stand, trying out your own designs, reading the Guide, and preparing the classroom.

Parent Involvement

The Masters section of the ETO Guide includes a reproducible flyer to send home to inform parents about the activity and includes suggested activities students and parents can do at home together.




Design Specifications Sheet

Design Number:

Thrust Structure Weight:

Date:

Class:

Team Name:

Do not put on this sheet the name of any student, teacher, school, city, etc. Give your team a name.

Sketch your design below. Identify materials used. Show glue points.

Describe the key features of your design:

NSIP Aerospace Technology Engineering Challenge

Preparing the NSIP Project

The NSIP project is a report of the work a team did to design, build, test, analyze, and improve its structures. The next three sections of this guide provide full details on preparing an NSIP project and how it will be evaluated by the judges.

In many ways, the NSIP Project is similar to the "storyboard" students create at the conclusion of the ETO activities, which is described in detail in the ETO Guide. The NSIP Project uses much of the same material as the ETO storyboard, but a written Narrative takes the place of the oral presentation. Suggestions in the ETO Guide on preparing good story-board presentations are directly relevant to preparing NSIP Entries.

The rest of the next four pages is addressed to your students so you can share it directly with them.

Components of the Project

1) Title

A brief simple title is fine. Distinctive titles help the judges keep track of Entries. You may also include your team name if it does not identify your school, city, or any person.

2) Summary

No more than 50 words to identify the specific approach you took to the Challenge. (These are the same words that go on the Entry Form.)

3) Narrative

Tell the story of the work you did on your designs and how you improved them. Include just what you would want to say to anyone looking at the rest of your Project. Tell the story in order from beginning to end, referring to the other parts of your Project when appropriate. The ETO Teacher's Guide offers numerous suggestions to help your team prepare its storyboard to present your work to others. Most of the NSIP Project is like the story-board, except that a project can't include any models, and a written Narrative takes the place of the ETO oral presentation.

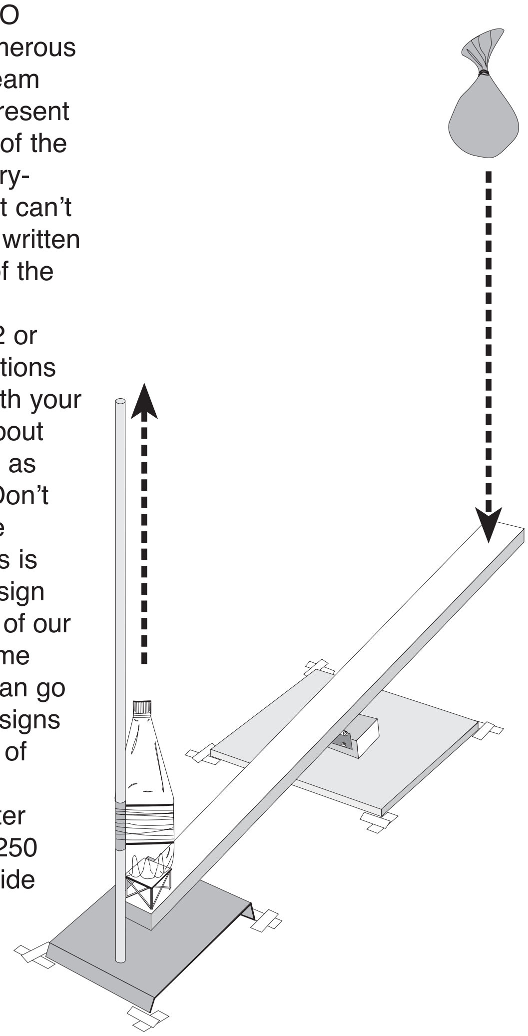
You may include only 2 or 3 pairs of Design Specifications and Test Results sheets with your Project, but you may tell about as many designs and tests as you like in the Narrative. Don't leave the failures out of the story! Reporting on failures is a very important part of design and testing, because many of our most important lessons come from learning about what can go wrong. Also, all of your designs should appear in the Table of Test Results.

A brief Narrative is better than one that is too long. 250 to 500 words is a rough guide to a good length. Do not exceed 800 words.

4) Concepts We Applied and How We Discovered Them

This section asks you to show what you learned. What is it about your best design that makes it so strong and light? How did you figure out a way to make it like that? Some of the ways you might have found to improve your designs include examining other structures, learning from other teams, research on structures and forces, and just trying something different. Did you discover any general rules about how to make a structure strong and light?

100 to 250 words is about right for this section. Do not exceed 400 words.



Example of the First Page of an Project
by Team Name Optional

Summary
This example shows a good way to format your Project. Use your team name if it does not identify your school, city or any individual. Put the summary from your Entry Form next. Note the generous margins and 12-point type in a basic font. (Do not exceed 50 words!)

Narrative
Simple formatting makes it easy for the judges see the good work that your team did. Good choices for fonts include Times New Roman, Courier, and Palatino. Be sure to leave 2 inches blank at the top of the first page and pay close attention to all the details in the NSIP Competition Rules.

5) Design Specifications and Test Results Sheets
Include these for 2 or 3 structures only. Choose sheets for structures from which you learned something, for your best structure, and for tests that show useful information. Please see the related section under "Making Your Project the Best it Can Be" (next page) for further guidance about which sheets to include and how to make them communicate clearly.

If you have carefully and thoroughly filled out your sheets, they will contain much of the information asked for in the preceding two sections. That will help keep those sections brief and interesting.

6) Test Set-up, Materials, and Table of Test Results
Use the diagram provided and fill in the lengths and heights of your test set-up. Fill in the box to tell how heavy your weight is. Be sure to include the units with your measurements!

Use transparent tape to attach two of the craft sticks you used where indicated to each of three copies of the Background Sheet.

Use the table provided to list all your structures by design number, weight, and how many launches each survived.

If you made any particular alterations to the materials or the launcher compared to those described in the ETO Guide, please describe very briefly the changes you made.

7) Resource Credits
Where did you find helpful information or other kinds of assistance? It's smart to learn from others and it's correct to thank them by listing them here.

Remember that no name of any student, teacher, school, city, etc. may appear anywhere in the Project. You can give other teams credit by using their team name, and you can refer to teachers as, for example, "our science teacher."

The official NSIP Entry Packet, which is required to enter the NSIP ATEC Competition, as well as additional information about other NSIP competitions, can be obtained from the NSIP web site (www.nsip.net), or by email request (info@nsip.net), or by telephone request (1-800-848-8429).

Please pay close attention to the rules detailed in the Entry Packet, as well as the Judging Rubrics on pages 10-11, in preparing and submitting a competition entry.

Making Your Project the Best It Can Be

Review the points listed here in order to submit the best possible project. Remember to study the judging rubrics carefully.

Design Specification and Test Results Sheets

Choosing the Right Sheets

Choose sheets that best help tell the story of how you improved your structures. You'll score extra points (see the rubrics) if you include sheets for two models that each survived all three launches.

An excellent way to document your team's progress is to include the sheets for the first structure that survived undamaged and for your lightest successful structure. You can score extra points for including sheets for a design that failed if you also report a lesson you learned from the failure and used it to improve a later design.

Preparing the Sheets

You are welcome to recopy your sheets to make them easier to understand, as long as you do not alter any of the facts related to your design or test results. For example, you might improve the drawings or the lettering so that they reproduce well when photocopied, or make complete sentences out of abbreviated original notes.

The goal is to make your original sheets clear and complete enough to be part of your Project. Don't be discouraged if you find that you need to neaten things up in order for the sheets to communicate clearly.

Anonymity and Format of Entries

No name of any student, teacher, school, city, etc. may appear anywhere in the Project. Other NSIP materials list specific requirements for the format of the Project. Here are some key points:

- ❑ Leave the first page blank for 2 inches from the top of the page. Then place the Title, your Team Name if it does not identify your school, city or any individual, the Summary, and the beginning of the Narrative.
- ❑ Do not use any cover sheet, binder, etc. Please number the pages consecutively starting with page 1.

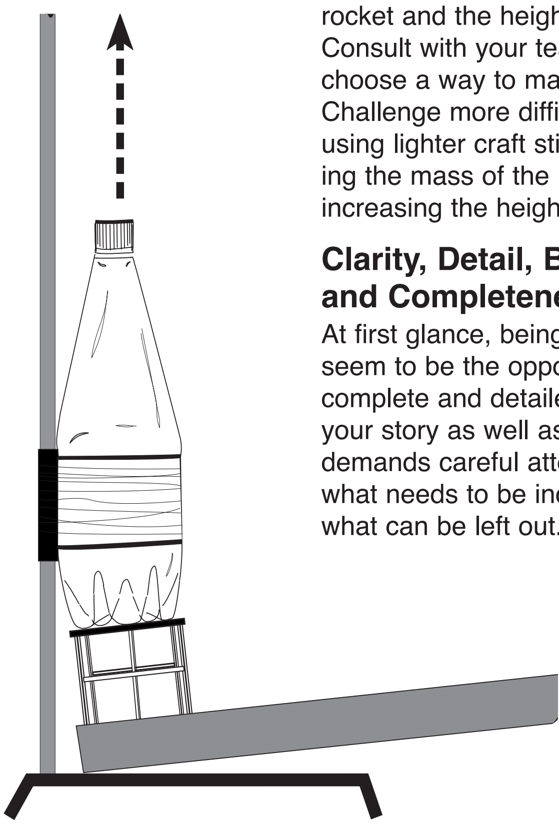
This photo shows the lower end of a Titan rocket on horizontal display. The top of the rocket is way off the page to the right. On the left you see the engine, and in the center you see the structure that transmits the thrust of the rocket engine to the cylindrical body of the rocket.

What About Grammar and Spelling?

Careful attention to these and other details will result in higher scores, even though they are not explicitly mentioned in the rubrics. Serious deficiencies will detract from the quality of an Project and result in lower scores. Review your Project carefully.

Take Time to Keep Track of Your Work

The Challenge is really a lot of fun, and many students find that building the next design right away is the most fun part. They don't want to take time to record an improved technique or the purpose of a test; they just want to build. ("Give me that glue gun now, please!") But when the time comes to tell the story of what you did and what you learned, there's nothing better than a careful record created as you did your work.



Should We Include Photos?

No. The drawings and descriptions should be enough to give the judges a clear picture of the designs. Photos may be useful in the classroom if students find that looking at a photo helps them make better drawings.

How Can We Improve If Our First Structure Was Truly Excellent?

When you build a very good structure, you may find it hard to imagine that anyone could build a better one. However, the history of engineering is filled with surprising improvements. In extensive field testing of this Challenge, it hasn't happened yet that a team built the best structure first.

If no other team working on the Challenge in your classroom is able to make a lighter structure after several rounds of redesign and test, it may mean that the craft sticks you are using are too strong for the weight of the rocket and the height of launch. Consult with your teacher to choose a way to make the Challenge more difficult, such as using lighter craft sticks, increasing the mass of the rocket, or increasing the height of launch.

Clarity, Detail, Brevity, and Completeness

At first glance, being brief may seem to be the opposite of being complete and detailed. Telling your story as well as you can demands careful attention to both what needs to be included and what can be left out.

How the Entries Will Be Scored

Qualified NSIP Entries will be judged according to the rubrics on the next two pages. The goal of the rubrics and of the judging process is to evaluate the Entries according to:

1) How well the team tells the story of the development of its designs, with special concern for the clarity, detail, brevity, and completeness of the explanation;
2) The quality of the effort the team made to design, build, test, analyze, and improve its structures;
3) The progress the team documents in improving its structures; and,
4) The concepts and techniques the team used to improve its designs.

When questions arise about how to interpret or apply the Rubrics, please consult the four points listed above

Aerospace Technology Engineering Challenge

Judging Rubric

Grades 5–8

Teams of 2–4

Entries must meet the following minimum standards to qualify for judging.

¤ Entries must follow all competition rules detailed in the Entry Packet.

¤ Projects must meet specific minimum standards (see pp. 6-7)..

Presentation of the Team's Work (Maximum: 20 + 20 + 12 = 52 points)			**Progress and Concepts** (Maximum: 12 + 12 = 24 points)	
A *Does the Narrative (when read with attention to other parts of the Project) tell a clear story of the structures, the ideas, the concepts, and the techniques the designs are based on?*	**B** *Are the Design Specifications and Test Results Sheets informative and complete? Are the drawings good enough to allow a team of judges to build a structure just like the one the student team tested?*	**C** *Are the other components of the Project carefully completed?*	**D** *Do the designs show evidence of improvement?*	**E** *Are the concepts and techniques that led to improvement clearly spelled out?*
Just as described above, including focus on ideas, concepts, and techniques 20	The sheets practically tell the story themselves 20	As requested, with evidence of extra thoroughness 12	Later successful designs are much lighter, and also economical, very strong, or otherwise superior 12	Two or more concepts or techniques definitely related to improvement 12
It is a good story of the work, but lacks focus on ideas, concepts, and techniques 15	They are clear enough when studied with other parts of the Project 15	All requirements met 9	Later successful designs are much lighter than original ones or somewhat lighter and otherwise improved 9	One concept or technique definitely related to improvement 9
The narrative is too long, too brief, hard to follow, disorganized, or missing key parts 10	They show good effort, but some aspects are vague 10	Signs of carelessness 6	Later successful designs are somewhat lighter than original ones or otherwise improved 6	Good discussion of relevant concepts, but, unrelated to improvements 6
Fails to tell the story of the development of the designs 5	Considerable information is missing or illegible 5	Something important is missing or incorrect 3	The structures eventually become strong enough, but not lighter 3	Consideration of relevant concepts 3
Very seriously deficient or absent 0	Very seriously deficient or absent 0	Multiple serious deficiencies 0	No 0	No description of relevant concepts 0

Subtotal points from this page __________

Aerospace Technology Engineering Challenge

Judging Rubric

Grades 5–8

Teams of 2–4

Entries must meet the following minimum standards to qualify for judging.

¤ Entries must follow all competition rules detailed in the Entry Packet.

¤ Projects must meet specific minimum standards (see pp. 6-7)..

Quality of Effort (Maximum: 8 + 8 + 4 + 4 = 24 points)			
Judges will take into account the quality of the team's effort throughout the process of scoring each project. The categories below help to assess the thoroughness of the team's effort.			
F *Are there Design Specifications and Test Results Sheets for at least 2 structures that survived undamaged through 3 launches?*	**G** *Are test results reported for more than just a few structures?*	**H** *Is there an example of something learned from a design that failed?*	**I** *Is there evidence of research the team did that led to an improved design?*
Report of two structures that survived undamaged through 3 launches AND were quite different 8	6 or more structures 8	A good lesson from a failed structure is reported clearly and detailed on included Design and Test Sheets 4	Yes; research shows clear connection to improved designs 4
Report of two structures that survived undamaged through 3 launches 6	5 structures 6	A good lesson from a failed structure is reported clearly 3	Good research, but with unclear connection to improvement 3
Report of only one structure that survived undamaged through 3 launches 4	4 structures 4	A failed structure and a lesson of slight value are reported 2	Good research unrelated to improvement 2
Missing information or only partially successful structures 2	3 structures 2	Story of a failed structure, but no lesson 1	Some research 1
Structures unsuccessful or sheets missing 0	2 or fewer structures 0	No example 0	No evidence 0

Subtotal points from this page __________

Total points __________

Design Specifications Sheet

Design Number: ______ Thrust Structure Weight: ______

Date:________________ Class:________________________ Team Name: ____

Do not put on this sheet the name of any student, teacher, school, city, etc. Give your team a name.

Sketch your design below. Identify materials used. Show glue points.

Describe the key features of your design:

Test Results Sheet

Design Number: ____ Thrust Structure Weight: ____

Date:________________ Class:__________________________ Team Name: ____

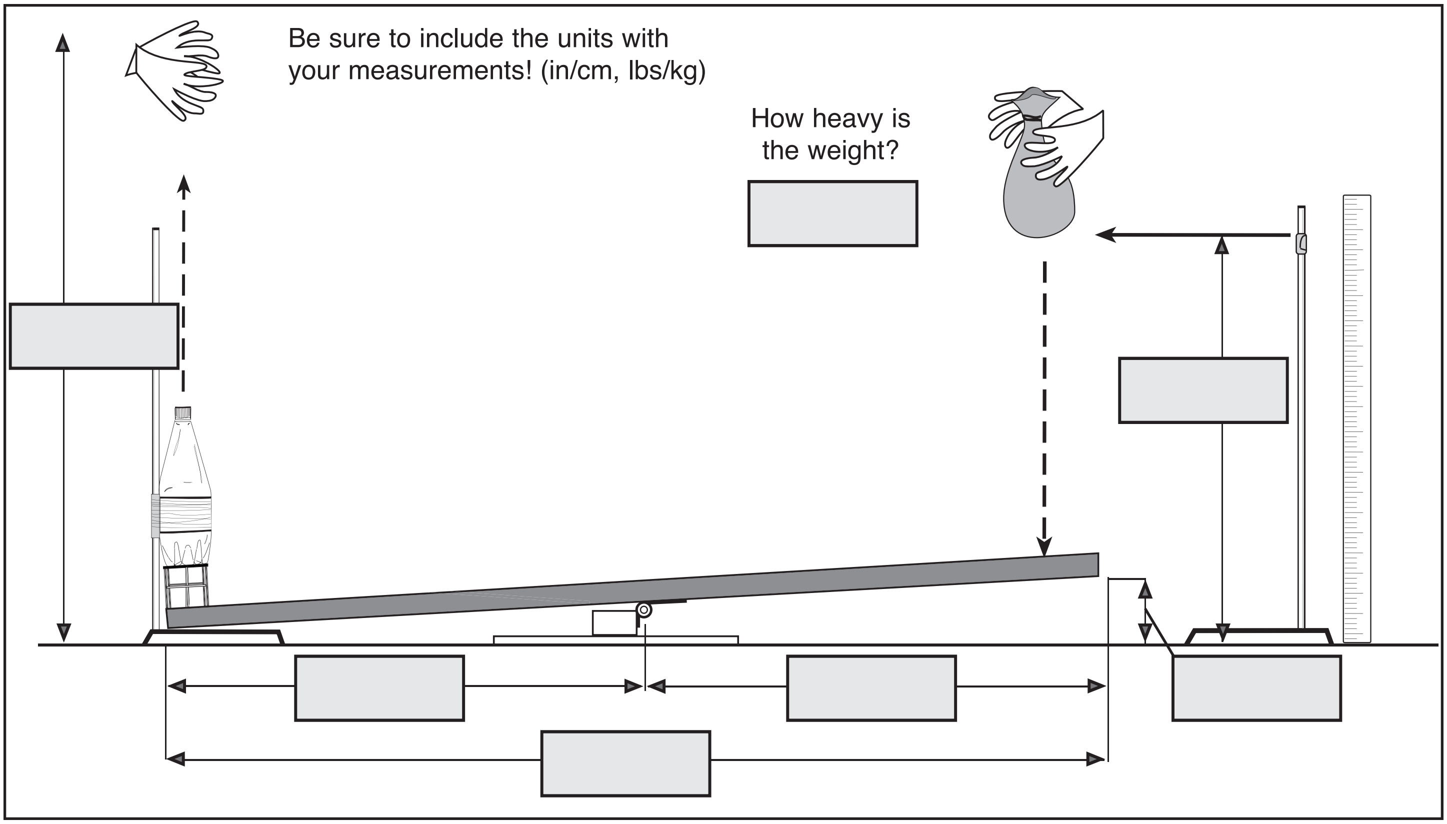
Do not put on this sheet the name of any student, teacher, school, city, etc. Give your team a name.

Sketch your model after testing. Show failure points, if any.

Test #	Damage (yes/no)	Results

Describe the results of the testing. Explain which features seemed effective and which did not.

Test Set-up, Materials, and Table of Test Results



Sample Sticks

In the space below, tape two of the sticks you used to build your structures. Remember to attach sticks to each of the three copies of your project. (It is best to do this after you make the copies!)

Table of Test Results

List the weight of each structure (in grams) in the appropriate column.

Design Number:	How Many Launches It Survived:			
	0	1	2	3
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				

Resources

❑ NSIP Web Site

The NSIP Web site provides additional information, learning activities, and linkages to sites with images, data, and other resources (including all Web sites listed here):
http://www.nsip.net/

❑ About the Space Shuttle

http://www.nasa.gov/qanda/space_shuttle.html

NASA Facts On Line:
http://www-pao.ksc.nasa.gov/kscpao

❑ About the Space Shuttle Structure

Introduction to the Space Shuttle: Shuttle Systems
http://science.ksc.nasa.gov/shuttle/technology/sts-newsref/sts_coord.html

❑ About Space Vehicles

International Reference Guide to Space Launch Systems. Steven J. Isakowitz. AIAA Press, Washington, D.C., 1995.

The History of Developing the National Space Transportation System. Second Edition. Dennis R. Jenkins. D.R. Jenkins, Harbor Beach, Fla., 1996.

Halfway to Anywhere: Achieving America's Destiny in Space. New York: M. Evans and Co. 1996.

Stine, G. Harry. Handbook of Model Rocketry. New York: Prentice-Hall Press. 1987.

❑ About New Space Vehicles

"A Simpler Ride Into Space" by T.K. Mattingly. Scientific American, October 1997, pp. 121–125.

"The Way to Go in Space" by Tim Beardsley. Scientific American, February 1999, pp. 80–97.

❑ About Engineering and Careers

www.discoverengineering.org
A new web site, Discover Engineering Online, lets adolescents investigate a host of engineering achievements. Aimed at inspiring interest in engineering among America's youth, the site is a vast resource. Among the many features of the site is information on what engineers do and how to become one. Designed specifically for students in grades six through nine, the site has links to games, downloadables, and powerful graphics, as well as to web sites of corporations, engineering societies, and other resources. One section, for example, lists several "cool" things tied to engineering, such as the mechanics of getting music from a compact disc to the ears of a teen, how to make a batch of plastic at home, or learning how to fold the world's greatest paper airplane.

http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Careers/

❑ NASA Web Sites

http://spacelink.nasa.gov/
SpaceLink: An Aeronautics and Space Resource for Educators

http://core.nasa.gov/
The worldwide distribution center for NASA-produced multimedia materials

http://education.nasa.gov/
A link to the many education resources provided by NASA

http://www.dfrc.nasa.gov/
Dryden Flight Research Center: has a photo gallery of more than 1,000 digital images of research aircraft

http://www1.msfc.nasa.gov/
Marshall Space Flight Center: contains many science, technology, and education resources in aeronautics, space and Earth science, and microgravity.

❑ Additional Reading

P primary	I middle school
E elementary	A advanced 9-12+

Girls Think of Everything: Stories of Ingenious Inventions by Women. Catherine Thimmesh. Illustrated by Melissa Sweet. Houghton Mifflin. 64 pp. Trade ISBN 0-395-93744-2. (I) Women have changed our lives with their inventions from windshield wipers to bulletproof vests. Thimmesh show us their inspirations and path to innovation. We learn how the inventors overcame obstacles and used creative thinking to solve problems. Resources, Index, List of Women Inventors.

The Technology Book for Girls and Other Advanced Beings. Trudee Romanek. Illustrated by Pat Cupples. Kids Can Press. Trade ISBN 1-55074-936-6; Paperback ISBN 1-55074-619-7. (E, I) Focusing on the fun aspects, this book shows how relevant technology is in the world and tries to entice girls to explore career fields. In-depth explanations with suggested activities complement science fair project ideas. A good choice to show girls how exciting the world of science and technology can really be. Bibliography, Index.

Building Big. Written and illustrated by David Macaulay. Walter Lorraine Books/Houghton Mifflin. 192 pp. Trade ISBN 0-395-96331-1. (A) This companion to the PBS series "Building Big" provides insight into the forces architects take into account as they design structures and the techniques used to overcome the challenges of building big. Clear, well-labeled illustrations show the reader details of the structures explained in the text. Glossary.