Central Sound Regional Science & Engineering Fair

2012 Student & Teacher Guide

For High School Students in King and Snohomish Counties

March 10, 2012 at Bellevue College

www.bellevuecollege.edu/sciencefair

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This guide is adapted from the "Research Projects Guide" produced by the STEM Education Outreach Programs at the University of New Mexico, the "You want me to do WHAT?" Science Fair Guide from Cedarcrest High School, and the Washington State Science and Engineering Fair Student Handbook, along with inspiration from sciencebuddies.org.

Our many thanks to those science fair supporters who helped produce this document.

Last Revision 07/20/11, K. Souza

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Introduction

Congratulations on accepting the challenge of participating in the Central Sound Regional Science & Engineering Fair on March 10, 2012! The experience of conducting research, carrying out an experiment, and seeing a project to completion can be a lot of fun and is also an excellent learning experience. Your participation provides you with priceless experience in the scientific process and these skills will help you in both academic and real-world situations.

This guide is designed to help students, teachers, and parents understand the process of planning and executing science and engineering projects. A science or engineering research project can be based on almost any topic imaginable. This is **YOUR** opportunity to take a deeper look at a topic that interests you!

This guide will take you through the science fair process from start to finish. Remember, the best projects require careful planning and dedication on your part.

As you go through the guide you will see a number of icons that you will help direct you to the most important information. The legend below describes each icon and how to use each section.

	**Stop!** The stop sign icon is found next to important steps and steps that MUST be completed **BEFORE** students can continue their projects. Students who do not follow these instructions will be disqualified from the CSRSEF.
	**Examples** Read a section and still confused? The blue example boxes will walk you through specific examples, step by step.
	**Key Info** Don't have time to read the entire manual? That's OK, these key info boxes will provide a short summary of each section.
	**Checklists** The checklists at the end of each section allow students to keep themselves on track. Students should be able to answer "yes" to each question before moving on to the next section.

If you have any questions about the CSRSEF or would like additional copies of this guide, please visit the fair website at http://www.bellevuecollege.edu/sciencefair or contact the fair director at 425-564-3055.

Part I: Science and Engineering Fair Overview

Suggested Project Timeline

Good science and engineering fair projects take time. Below, you'll find a 9-week timeline to help keep you on track as you work your way through your project. Keep in mind it is always better to start early!

	Monday	Tuesday	Wednesday	Thursday	Friday
Week 1 Jan 8-14	Decide whether to do a team or an individual project	Brainstorm 3 topic ideas	Develop 3 research questions and share them with an adult	Think about how you would test each research question	Choose a testable research question and decide on a project category
Week 2 Jan. 15-21	Make a list of questions you have about your topic	Spend some time in the library reading and taking notes about your topic	Develop your hypothesis or design criteria		Finalize your hypothesis or design criteria
Week 3 Jan 22-28	Identify your adult sponsor	Develop your research methods	Make a rough draft of your materials and experimental procedure	Register for the CSRSEF and submit the following forms: Checklist for Adult Sponsor Form. Approval Form	Complete the ISEF form wizard at www.bellevuecollege.edu/sciencefair and submit any additional forms.
Week 4 Jan 29-Feb 4	Wait for SRC/IRB approval from the CSRSEF (if working with humans, vertebrates, potentially hazardous biological agents, etc.)	Write the introduction and background sections of your research paper		Format the references page for your research project. Be sure to have at least 3 sources!	
Week 5 **Feb 5-11**	Finalize your experimental procedure/prototype designs	**After IRB/SRC approval,** conduct experiments/build prototypes		Repeat your experiments/test your prototype	
Week 6 Feb 12-18	Conduct more experiments to fill holes in your data or modify your prototype		Analyze your raw data into graphs and charts		
Week 7 Feb 19-25		Redesign your engineering product and conduct more testing		Finalize all graphs and charts for your display board	
Week 8 Feb 26-Mar 3	Write the experimental procedure, results, and conclusion sections of your research paper		Write your official 250 word abstract on the official ISEF form	REGISTRATION DEADLINE FOR the CSRSEF: MARCH 1, 2011 www.bellevuecollege.edu/sciencefair	
Week 9 Mar4-10	Proofread your research paper		Create your display board		Practice talking about your project to friends and family!

….and take your project to the CSRSEF on Saturday, March 10, 2012!

Part II: Starting with the Basics

Start with the Basics: How do I choose a topic?

Selecting a science or engineering fair topic is often the most difficult part of the entire process. The key to completing a successful project is to think about it early and think about it often! Some questions you'll want to start asking yourself now are:

1. *Should I work on my project by myself or work with a team?*
2. *How do I choose a project topic?*
3. *Is my project a science project or an engineering project?*
4. *Which category is most appropriate for my project?*

Part I of this guide will walk you through the steps to answer these important questions. Keep in mind that it is up to YOU to make your project a success!

1. **Should I work on my project by myself or work with a team?**

   Before you choose a topic, you need to decide if you will work on your CSRSEF project by yourself or if you will work with a partner. Working with your BFF may seem like a good idea, but keep in mind that a big part of the team judging is how well you worked with your teammate. If you think that you will have problems working with someone or if it will be difficult for you to schedule time to work with your partner, it may be a good idea to stick with an individual project.

2. **How do I choose a project topic?**

   Choosing a science and engineering fair topic is often the hardest part of your research project, so start thinking about topics early! Use your research journal to keep track of topics that interest you. Pay special attention to things covered in school, conversations with friends and family, and activities that you'd like to explore further. Think about questions you have that you might be able to answer by doing a research project.

   See the Example on the following page for more information about how to choose a science and engineering fair topic.

Example: How do I choose a project topic?

Still stuck? Use the example below to help you brainstorm topic ideas. Remember to keep track of project ideas in your research journal!

You may be interested in:

People	Diseases Animals	Television	Plants
Electricity	Rocks	Pollution	Space
Solar Energy	Music	Weather	Computers

Inventing Things (there are infinite possibilities!)

A list like this is a great start, but the topics themselves are much too broad. You need to get more specific and decide what it is about the topic that is interesting to you. What do you ***really*** want to know about? Try phrasing your ideas in the form of questions, like:

- What makes a person an adult?
- How can plants be protected against pests?
- How does weather change?
- How does sickness affect people?

Once you have a list of broad questions, think about how you can rephrase the question to make it testable. For example, instead of asking, "What makes a person an adult?" You may want to ask, "How do eighth graders compare to adults?" Little changes like these can make a big difference. Remember to be as specific as you can. In science, information must be exact if it's going to matter.

Need more help? Use the examples below to get a better idea about how to turn your interests into testable questions:

How can plants be protected against pests?
becomes
Can companion planting protect beans from beetles?

How does weather change?
becomes
How do cloud formations predict weather?

***How does sickness affect people*?**
becomes
What influences the rate of recovery from the common cold?

Start a project notebook (a composition notebook works well!) and keep track of off of your project ideas. Once you have a list of specific, testable questions, you are ready to choose a research question. Be sure to choose a question that you have the means to investigate. For example, studying whether children in China learn English by watching cartoons may sound like a great topic, but is probably not a good choice for someone who lives in Washington State! Ask your teacher, parents, or an expert in the field to make sure your research question is testable and appropriate.

Topic Checklist

What Makes a Good Science and Engineering Fair Topic?	You Should Answer "Yes" to Every Question
Is your science or engineering topic a specific, testable question?	Yes / No
Will you be able to investigate your question of interest with supplies that you already have or that you will be able to get before the fair?	Yes / No
Will you be able to investigate your question before the CSRSEF takes place on March 10, 2012?	Yes / No

Helpful Hint: The internet can be a great resource for brainstorming ideas, but beware of websites that promise quick and easy science fair projects. Teachers and science fair judges can easily spot generic ideas downloaded from a website!

3. Is my project a science project or an engineering project?

Now that you've formulated a research question, you need to determine if your question addresses a problem in science or if it addresses a problem in engineering.

Science projects focus on **RESEARCH** and producing **KNOWLEDGE** about the world. **Engineering** projects focus on **DESIGN** and producing a **PHYSICAL PRODUCT**.

In real life, the boundaries between science and engineering projects are not always clear. Scientists often engineer tools to do their work, while engineers often use the scientific method to help them design their products. Much of what we often call "computer science" is actually engineering -- programmers creating new products. Your project may fall in the gray area between science and engineering, and that's OK. Many projects can and should use the scientific method.

However, if the objective of your project is to invent a new device, procedure, computer program, or algorithm, then it may make sense to follow the engineering process.

Examples of Science Questions vs. Engineering Questions:

Science Questions:

- How long does it take the heart to return to normal after exercise?
- How rapidly does a plant make starch?
- What is the best insulator to keep ice from melting?
- Which method of cooking destroys the most bacteria?
- Does listening to music while you study affect your ability to memorize facts?

Engineering Questions:

- How can you redesign a sandbag to better protect homes during a flood?
- What can you do with a swim cap to optimize its ability to decrease drag in water?
- What is the best propeller design for a wind generator?

If you are unsure whether your project is a science or an engineering project, please ask a teacher or parent for help.

4. Which category is most appropriate for my project?

Now that you've chosen a research question and determined whether you'll be doing a science or engineering project, you need to determine which category at the CSRSEF is most appropriate for your project. If your project is an engineering project, you must enter it into an engineering category. Full descriptions of each category can be found on the CSRSEF website (http://www.bellevuecollege.edu/sciencefair).

Science Categories:

Animal Sciences	Behavioral & Social Sciences	Biochemistry
Cellular & Molecular Biology	Chemistry	Computer Science
Earth & Planetary Science	Energy & Transportation	Environmental Management
Environmental Sciences	Mathematical Sciences	Medicine & Health Sciences
Microbiology	Physics & Astronomy	Plant Sciences

Engineering Categories:

Engineering: Electrical & Mechanical
Engineering: Materials & Bioengineering

If you are still unsure about which category is most appropriate for your project, ask a teacher or contact the CSRSEF director for more help.

Part III: Planning Your Project

Planning Your Project: Background Research

Before you start designing your science experiment or engineering product, you will need to learn as much background information as you can about your topic. Remember, you are probably not the first person to be interested in your science fair topic! It is important to learn from the work of others and to design your project so that it builds on their research. Use the tips below to get started!

Key Info: Background Research

Background research is necessary for both science and engineering projects. To gather background information for your project, follow these steps:

1. **Identify the keywords in the question for your science or engineering project.** Brainstorm synonyms, keywords, and concepts to investigate further. For example, if your project is about overcoming the common cold, you would want to learn about what causes the common cold, common remedies to help people get over a cold, and the types of experiments that others have done to see if these remedies actually work.

2. **Only use information from reputable sources!** Peer-reviewed journals, university and government websites, and reference materials are generally good sources. Don't be tempted to use open source material (like Wikipedia) to find background information! If you aren't sure if a source is trustworthy, ask a teacher or parent for help.

3. **Determine how researchers in your field of study interpret their data.** Take note of any mathematical formulas or equations that you will need to describe the results of your experiment (science project) or information that you will need to build your prototype (engineering project).

4. **Become familiar with the history of similar experiments or inventions**.

5. **Talk with a mentor, your parents, and teachers**. Ask them: "What should I study to better understand my science or engineering project?"

Background research is important to help you understand the theory behind your experiment or product. Science fair judges like to see that you understand why your experiment turns out the way it does.

Background Research Checklist

What Makes a Good Background Research Plan?	For a Good Background Research Plan, You Should Answer "Yes" to Every Question
Have you identified all the keywords in your science fair project question?	Yes / No
Do you have enough background information to help you design your science experiment and predict the outcome, or to help you design and develop your engineering product?	Yes / No

If you are working on a Science Project, continue on to "Developing a Hypothesis" on p. 12. If you are working on an Engineering Project, skip to the Engineering Project Guide on p. 20.

Science Project Guide: Developing a Hypothesis

After thoroughly researching your science topic, you should have some educated guesses about your project topic/question. This educated guess is called a hypothesis.

The hypothesis must be worded so that you can test it with your experiment. The easiest way to do this is to use an "If _________, then ___________" statement. In science, hypotheses must be testable. This means that researchers should be able to carry out an investigation and obtain evidence that shows whether the hypothesis is true or false.

Your hypothesis should also be relatively simple and concise. Don't make your hypothesis overly long and complicated. Be direct and to the point.

Key Info: Developing a Hypothesis

A hypothesis is an educated guess about how things work that is based on information found through background research.

A hypothesis is often written as an "If _____, then _____." statement.

Your hypothesis should be something that you can actually test; what's called a testable hypothesis. In other words, you need to be able to measure both "what you do" and "what will happen."

Examples of Hypotheses:

- If I open the faucet, then the flow of water will increase.
- If a plant receives fertilizer, then it will grow faster than a plant that does not receive fertilizer.
- If I put fenders on a bicycle, then the rider will stay dry when riding through puddles.
- Raising the temperature of a cup of water will increase the amount of sugar that dissolves.

Not every question can be answered by the scientific method. The hypothesis is the key. If you can state your question as a testable hypothesis, then you can use the scientific method to obtain an answer.

If you are having a hard time generating a hypothesis, you may be working on an engineering project. Go back to p.8 to see a list of criteria for an engineering project.

Science Project Guide: Planning your experiment

Now that you have decided on a hypothesis, you'll need to develop one or more experiments that will test to see whether your prediction (hypothesis) is correct. You must carefully plan your experiments so that you are only manipulating one thing, or variable, at a time.

Scientists use the scientific method to search for **cause and effect** relationships in nature. In other words, they design an experiment so that changes to one item cause something else to change in a way that can be measured.

These changing quantities are called **variables**. A variable is any factor, trait, or condition that can exist in differing amounts or types. An experiment usually has three kinds of variables: independent, dependent, and controlled.

Controlled Variables

All experiments contain variables that can unintentionally affect your experiment. These variables must be controlled by the scientist (YOU!) to make your experiment credible. These variables, called **controlled variables, or constant variables** are traits that a scientist keeps constant throughout the experiment. For example, if we want to measure how much light is released by different light bulbs, it is important to make sure that the voltage or the amount of energy that goes to each light bulb is held constant. That's because both the voltage and the light bulb have an impact on how much light is emitted. If we change both of them at the same time, we can't be sure how much of the change in light is due to the change in light bulb and how much of it is due to the change voltage. In other words, it would not be a fair test.

Independent and Dependent Variables

The second type of variable, the **independent variable or manipulated variable,** is the one that is changed by the scientist. A good experiment has only **ONE** independent variable. As the scientist changes the independent variable, he or she **observes** what happens.

The scientist focuses on the **dependent variable or responding variable** to observe and measure how it changes in response to manipulations of the independent variable. By definition, the dependent variable *depends on* the independent variable.

See the example on the following page for more help in understanding variables.

Example: Understanding Variables.

Variables can be tough to understand. Let’s use a simple example to better understand the relationship between ***controlled, independent, and dependent*** variables.

Take the following hypothesis as an example:

If I add fertilizer to a houseplant, then it will grow taller than a plant that does not receive fertilizer.

The ***Controlled Variables*** are the variables or conditions that are **kept the same in all of your samples**. Controlled variables allow you to claim that the effect you see in your experiment is because of the manipulations ***you made*,** and not due to external factors.

For example, if the plants in your experiment that received fertilizer also received more water, you would **NOT** be able to make the claim that an increase in the plant’s height was because you added fertilizer; it may have grown taller because it received more water. This is an example of a variable that must be controlled.

Other variables that must be controlled are the soil conditions for the plants and the amount of water, light, etc each plant receives. Controlling these variables ensure that any change you see in the height of the plant is solely due to the addition of fertilizer.

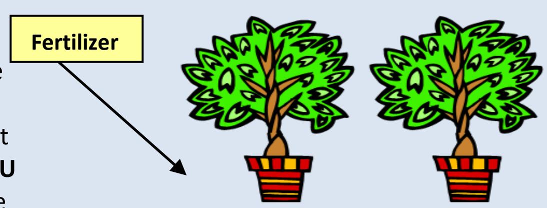
The ***Controlled Variables*** are kept the same in all samples. This means that all of your samples are IDENTICAL before you start manipulating the independent variable.

A **B**

Plants are grown under the same conditions

The **Independent Variable** is the variable that you plan to change in your experiment. For this example, it is the addition of fertilizer to your experimental plant.

The ***fertilizer*** is the ***Independent Variable*** because it is the trait that **YOU** are changing in the experiment

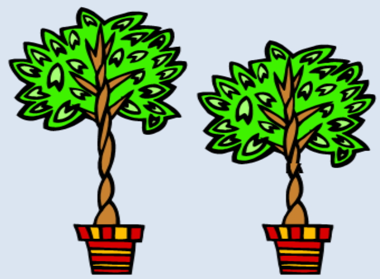


A **B**

Plant A gets fertilizer. Plant B does not.

The **Dependent Variable(s)** are the variable(s) that change in response to the independent variable. A scientist observes and/or measures the dependent variable to see how it responds to the independent variable. In this case, the *height* of the plants is the dependent variable because the *height* of Plant A changes in response to the addition of the fertilizer (independent variable).

The ***height*** of the plant is the **dependent variable** because it changes in response to the **independent variable** (the fertilizer).



A **B**

Plant A gets fertilizer. Plant B does not.

Plant B in this example is what is called a **control group. A control group is** a sample that has not been manipulated. In this case, plant B was grown under the same conditions as plant A, but did not receive fertilizer (the independent variable was not manipulated). The addition of a control group allows you to compare your experimental group to a sample that you didn't mess with.

Defining variables can be a tricky business. If you are having difficulty defining your experimental variables, ask a teacher, parent, or other adult for help.

Science Project Guide: Writing Your Experimental Procedure

Once you have determined what your controlled, independent, and dependent variables are, it's time to write out your experimental procedure. Use the steps below to guide you.

1. **Make a list of the Materials** you will need to conduct your experiment and be specific!

2. **Write the experimental procedure like a step-by-step recipe for your science experiment.** A good procedure is so detailed and complete that it lets someone else duplicate your experiment exactly.

   For example, "Add baking soda to vinegar" isn't very specific. "Add 2 tsp. baking soda to 1 cup vinegar" is much more descriptive and would allow someone else to repeat the step exactly.

3. **Define you variables.** Include a description of your controlled, independent, and dependent variables. Remember, controlled variables are kept the same, independent variables are manipulated, and dependent variables respond to changes in the independent variable.

4. **In most, if not all experiments, it is important to include a control group/sample.** The experimental group is the group that you manipulate, while the control is a sample that has not been manipulated. This allows you to compare your experimental group to a sample that you did not manipulate.

   For example, if your hypothesis was: "When plants receive fertilizer, they grow taller," it would be important to include one or more plants that receive no fertilizer. These plants provide a basis for comparison, and ensure that any changes you see when you add fertilizer are in fact caused by the fertilizer and not by something else.

   If you are not sure if your project should include a control group or what your control group should be, please ask a teacher or other adult.

5. **Lather, rinse, repeat!** Another important part of your project is repeatability. Scientists ***ALWAYS*** conduct experiments multiple times to verify that their results are consistent. This shows that the answer to your question is not just an accident. When writing your experimental procedure, make sure to include how many times you will repeat your experiment. Most teachers and judges want you to **repeat your experiment a minimum of three times**. Repeating your experiment more than three times is even better, and may be required to measure very small changes in some experiments.

   If you are doing something like growing plants, then you should do the experiment on at least three plants in separate pots (that's the same as doing the experiment three times).

   If you are doing an experiment that involves testing or surveying different groups, you won't need to repeat the experiment three times, but you will need to test or survey enough people to insure that your results are reliable. You will almost always need many more than three participants!

Key Info: Planning your Experimental Procedure

- An experimental procedure is a step-by-step list of everything you must do to perform your experiment. Think about all the steps that you will need to go through to gather data for your project, and record exactly what needs to be done in each step. **This list should be made in your research notebook!**

- Your experimental procedure must explain how you will change your independent variable and how you will measure the change in the dependent variable.

- Your experimental procedure should explain how the controlled variables will be maintained.

- Your experimental procedure should specify how many times you intend to repeat your experiment, so that you can verify that your results are reproducible.

- A good experimental procedure enables someone else to duplicate your experiment exactly!

BEFORE YOU CONTINUE, you MUST register for the CSRSEF, submit the Checklist for Adult Sponsor Form, Approval Form, **and complete the Intel ISEF form wizard at** http://apps.societyforscience.org/isef/students/wizard/index.asp**!**

Experimental Procedure Checklist

What Makes a Good Experimental Procedure?	For a Good Experimental Procedure, You Should Answer "Yes" to Every Question
Have you included a description of your experimental and control groups?	Yes / No
Have you included a specific, step-by-step list of all procedures?	Yes / No
Have you described how to the change your independent variable and how you will measure that change?	Yes / No
Have you explained how the controlled variables will be maintained at a constant value?	Yes / No
Have you specified how many times you intend to repeat the experiment (should be at least three times), and is that number of repetitions sufficient to give you reliable data?	Yes / No
The ultimate test: Can another individual duplicate the experiment based on the experimental procedure you have written?	Yes / No

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Some experiments, including those that involve human subjects, animals, and hazardous materials, MUST be approved by the CSRSEF's Scientific Review Committee and Institutional Review Board (SRC/IRB) BEFORE you begin your experiment. Use the Intel ISEF form wizard (http://apps.societyforscience.org/isef/students/wizard/index.asp) to determine if your project needs SRC/IRB approval and submit all of the appropriate forms to the fair director. If your project requires SRC/IRB approval, you **MUST WAIT FOR APPROVAL** before beginning any part of your experiment!

Key Info: Conducting Your Experiment

BEFORE YOU CONTINUE, you MUST register for the CSRSEF and submit the Checklist for Adult Sponsor Form, Approval Form, **and complete the Intel ISEF form wizard at** http://apps.societyforscience.org/isef/students/wizard/index.asp.

If SRC/IRB approval is required, you MUST wait for approval before starting your experiment!

- If you haven't already, start a research notebook to keep track of your methods and observations during your experiment.
- Create a data table to help you organize measurements and other observations as they happen.
- Think about any safety concerns. Make sure you use the proper safety equipment (gloves, goggles, lab coat, etc.).
- Read through your experimental procedure BEFORE you start.
- Follow your experimental procedure EXACTLY. If you need to make changes (scientists often do), make note of the changes in your research notebook.
- Take measurements and notes as accurately as possible.
- Take pictures of your experiment to put on your display board.

During the Experiment

It is very important to take very detailed notes in your project notebook as you conduct your experiments. In addition to your data, record your **observations** as you perform the experiment. Write down any problems that occur, anything you do that is different than what you wrote down, and any ideas that come to mind, or interesting occurrences. Be on the lookout for the unexpected. Your observations will be useful when you analyze your data and draw conclusions.

Take care to only manipulate your independent variable. Remember, it is up to you to keep all of your controlled variables constant.

If possible, take **pictures** of your experiment along the way. You can use these on your display board to help you explain your experiment at the fair.

Remember to use numerical measurements as much as possible. If your experiment also has qualitative data (not numerical), then take a photo or make a sketch to put on your display.

Try to be as exact as possible about the way you conduct your experiment, and follow your experimental procedure EXACTLY. If you need to make changes along the way, be sure to note them in your research notebook. Failures and mistakes are part of the learning process, so don't get discouraged if things do not go as planned the first time.

Remember to stay organized and be safe! Keep your workspace clean and organized as you conduct your experiment. Keep your supplies within reach. Use protective gear and adult supervision as needed.

Experiment Checklist

What Makes a Good Science Experiment?	For a Good Science Experiment, You Should Answer "Yes" to Every Question
Did you take detailed notes about your observations and record everything you did in your project notebook?	Yes / No
Were you consistent, careful, and accurate when you made your measurements?	Yes / No
Were you able to keep controlled variables constant and only manipulated your independent variable?	Yes / No
If you ran into any unexpected problems, did you adjust your experimental procedure accordingly and make note of any changes in your project notebook?	Yes / No

Now that you have completed your experiment and collected your raw data, continue on to p. 24 for information about how to analyze your data, write your research paper, and create your display board!

Engineering Project Guide: Bigger, Faster, Stronger!

While scientists study how nature works, engineers and computer programmers create new things that fill a need. Because engineers and computer programmers have different objectives than those of scientists, they follow a different process to do their work.

This guide will describe the engineering process in detail and highlight how it can be applied to a CSRSEF engineering fair project.

Key Info: Overview of the Engineering Process

1. **Define a Need**: Think of something that YOU can make that will fill a need that is not currently being met. This is called defining a need. Do your target customers need a new version of an existing product that has more speed, lighter weight, or lower cost? Or, do you need to design a new product with a combination of features that has never been seen before?
2. **Do Background Research**: Investigate what others have already learned about your idea. Gather information that will help you design your invention. Don't reinvent the wheel.
3. **Establish Design Criteria**: Design criteria are requirements you choose for your design that will be used to make decisions about how to build your product. For example, you might set out to design a baseball bat that has design criteria calling for the same strength and size as an aluminum bat, but half the weight.
4. **Prepare Preliminary Designs**: Good engineers look at a number of designs before moving creating a prototype, or functional model, of your finished product. It's much faster and cheaper to evaluate designs on paper before actually building something. Each preliminary design is likely to have some good points and some bad. As you continue to generate new designs you will incorporate more and more of your best ideas until you have designed a product that best meets your customer's needs.

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5. **Build and Test a Prototype**: A prototype is a full-scale and functional model of your invention. You build it from the preliminary design that best meets your design criteria. Many times it is impossible to meet all your design criteria and you need to choose a design that fulfills most, but not all, of your design criteria.
6. **Redesign & Retest as Necessary**: Almost every prototype has unanticipated flaws, things you overlooked, and design features that did not work the way you intended. Engineers test their products (and generate data) to determine how well their products work. Then, they redesign their products to improve its flaws, and then submit them to a new round of tests. This process is called redesigning and retesting and should be done several times.
7. **Present Results**: Engineers working in industry present their results by putting the product into manufacturing so that others can buy it. For the CSRSEF, you will show your engineering process on a display board and describe how you determined the best design for your product.

Engineering: Where to Start?

If you have chosen to do an engineering project, you should decide on a topic and begin your background research just like if you were doing a science project. However, in order to design a successful product, you will need to ask additional questions while conducting your background research. In addition to understanding the science of how your invention will work, you will also need to:

1. **Define your target user or customer**. Think about who will use your product, and make a list of traits that belong to your ideal customer. These can include your customer's:
   - Age
   - Gender
   - Occupation
   - Hobbies/Interests, etc.
2. **Research what already exists to fill the need you defined**. Once you've defined your customer, do research to determine if a product you are interested in designing already exists.

   Remember, there is no need to start from scratch and create an entirely new product (although you can!). It is perfectly acceptable to think of ways that you can modify a product to make it better. The possibilities are endless!

3. **Determine your design criteria. Think about your customer and what they want from a product.** In your project notebook, make a list of the criteria (or attributes) that will make your product appealing to them, and what it is about your product that will be different from products that are already on the market.

Example: Design Criteria

Cost
- Cost to purchase - Cost to use

Physical characteristics
- Weight - Density - Elasticity - Hardness - Strength

Inputs
- Energy consumption - Fuel consumption

How it looks (we call this aesthetics)

Performance characteristics
- Accuracy - Reproducibility

Environmental requirements
- Resistance to corrosion - Compatibility with ___________

WARNING: This is just a brief list to get you thinking about design criteria. Keep in mind that there are dozens of other criteria that may be important for your engineering project. Be sure to talk to others about your criteria to make sure you didn't miss any!

4. **Rank your design criteria.** Once you have your list, decide which design criteria are most important for your product. If you have too many design criteria, it can become very difficult to actually design and build a product. Imagine having a friend whose parents have set ten times as many rules as your parents. Such an imaginary friend might have difficulty doing things because he or she would always be violating one of the rules. Having too many design criteria (criteria are a type of "rule") creates a similar situation.

   Too few design criteria can also be a problem. If you have too few criteria you might get a result that you don't really want. Let's say you design a lightweight, high-strength baseball bat, but it cost $10,000 for the prototype. A baseball bat that costs more than a car would only be marketable to a few wealthy people.

5. **Consider your design tradeoffs.** What's a design tradeoff? Sometimes you will have design criteria that "fight each other" or tend to move in opposite directions. For example, materials to make our baseball bat lighter in weight are probably more expensive the lighter they are. You can't have the lowest weight and the lowest cost at the same time; therefore, when we design our bat we will have to make a tradeoff between cost and weight. Design tradeoffs are very, very common. Almost every project has some.

6. **Make a Materials List & Preliminary Designs.** Engineering projects have a materials list, programming projects probably don't. While both engineering and programming projects *could* have a procedure, it makes more sense to prepare several preliminary designs at this stage of the process.

   A preliminary design is a detailed drawing of the finished product. Each preliminary design should include the dimensions of the finished product, materials used, a description of any mechanical components, and any other details that would allow someone else to build your prototype using only your drawing as a guide. Try to create a number of preliminary designs that incorporate features that satisfy different design criteria. Once you have several ideas, carefully evaluate each design and determine which one meets the most of your design criteria with the fewest design tradeoffs. This is the preliminary design that you will use to build a full size model of your project.

Some projects, including those that involve human subjects, animals, and hazardous materials, MUST be approved by the CSRSEF's Scientific Review Committee and Institutional Review Board (SRC/IRB) BEFORE you begin your experiment. Use the Intel ISEF form wizard (http://apps.societyforscience.org/isef/students/wizard/index.asp) to determine if your project needs SRC/IRB approval and submit all of the appropriate forms to the fair director. If your project requires SRC/IRB approval, you **MUST WAIT FOR APPROVAL** before beginning any part of your experiment!

7. **Build & Test a prototype**. After you decide on a preliminary design, it is time to build a full-size functional model, or prototype, of your product. Make sure you build your prototype to the exact specifications you have defined in your preliminary design. If you make any changes during the building process, make a note of it in your research notebook.

8. **After you build your prototype, it is time to test it** with some of your targeted users to see if it meets the design criteria you outlined for your product. For example, if your goal was to design a baseball bat that has the same strength and size as an aluminum bat but half the weight, you would want to compare

the strength, size, and weight of your prototype to the strength and weight of an aluminum bat. These tests will provide data that you can use to show whether or not your prototype has met your design criteria.

9. **Redesign & Retest**. After testing your first prototype, you may find out that it is not meeting your design criteria as you had expected. This is a natural part of the engineering process, and gives the engineer a chance to redesign their prototype to fix any unanticipated flaws. For example, if you find that your prototype is much heavier than you had anticipated, you may decide to redesign your prototype to use lighter materials. Once you have modified your design, you should retest your prototype to see if you were able to fix the flaws of your product while maintaining the positive aspects of your design.

   This part of the engineering process is called "Redesigning and Retesting." Engineering typically go through multiple cycles of redesigning and retesting before they settle on a final product. Keep in mind that the data that you generate during this phase of your engineering project will be an important part of your final CSRSEF display. Almost always, you will want to present the results of your testing and retesting in charts or graphs. See more about graphs and data analysis on p. 24.

Engineering Project Checklist

What Makes a Good Engineering Project	For a Good Engineering Project, You Should Answer "Yes" to Every Question
Have you researched the needs of your users and selected the appropriate design criteria?	Yes / No
Did you make several preliminary designs before building a prototype?	Yes / No
Did you build your prototype to the exact specifications you outlined?	Yes / No
Did you test your prototype to see if it met your design criteria? Have you collected enough data to show that your prototype meets your design criteria?	Yes / No
Have you redesigned and retested your prototype so that it meets the majority of your design criteria?	Yes / No
Can you describe any unexpected results or design tradeoffs that you encountered while building your product?	Yes / No

Now that you have successfully engineered a new product, continue on to p. 24 for information about how to analyze your data, write your research paper, and create your display board!

Part IV: Putting it All Together:

Data Analysis

After you have completed your science experiments or designed and redesigned your engineering product, take some time to carefully review all of the data you have collected and make sure that you have enough data to come to a conclusion about the validity of your hypothesis. Often, you will need to perform calculations on your raw data in order to get the results from which you will generate a conclusion. If you are using a mathematical formula to analyze your data (for example, PV=NRT or $E=MC^2$) make sure that all of the units for a measurement are on the same metric scale– (keep L with L and mL with mL, do not mix L with mL!).

Many scientists use Microsoft Excel to organize their data, run statistical analyses, and make graphs. Think about the best way to summarize your data in graphs and charts to make it easy for the judges to see the results of your experiment. Do you want to calculate the average for each group of trials, or summarize the results in some other way such as ratios or percentages? Or, is it better to display your data as individual data points?

Think about the best way to present your data to make it easy for others to understand. Use charts and graphs to help you analyze the data and patterns.

Did you get the results you had expected? What did you find out from your experiment? Really think about what you have discovered and use your data to help you explain why you think certain things happened.

Key Info: Data Analysis

Take a look at your data.

- Is it complete?
- Do you need to collect more data to support or disprove your hypothesis? Do you need to redesign your product?
- Did you make any mistakes?

- Make your data easy to understand by organizing it into charts and/or graphs. Label each graph clearly with a title and legend, and be sure to label each axis!
- Place your independent variable on the x-axis of your graphs and the dependent variable on the y-axis (for science projects).

Graphs are often an excellent way to display your results. In fact, most good science fair projects have at least one graph.

For any type of graph:

- Generally, you should place your independent variable on the x-axis of your graph and the dependent variable on the y-axis.
- Be sure to label the axes of your graph— don't forget to include the units of measurement (grams, centimeters, liters, etc.).
- If you have more than one set of data, show each series in a different color or symbol and include a legend with clear labels.

Different types of graphs are appropriate for different experiments. For more help on graphing your science fair data, visit http://www.sciencebuddies.org/science-fair-projects/top_research-project_data-analysis.shtml.

Statistics

Competitive CSRSEF and Washington State Science & Engineering Fair projects will utilize statistics in addition to graphs and charts. Check out Science Buddies for short tutorials on several commonly used statistics: http://www.sciencebuddies.org/science-fair-projects/top_research-project_data-analysis.shtml

Data Analysis Checklist

What Makes for a Good Data Analysis Chart?	For a Good Chart, You Should Answer "Yes" to Every Question
Do you have enough data to know whether your hypothesis is supported or rejected?	Yes / No
Is your data accurate?	Yes / No
Have you summarized your data in graphs or charts?	Yes / No
Have you analyzed the validity of your data using statistics?	Yes / No
Have you verified that all calculations (if any) are correct?	Yes / No

Conclusions

Once you have enough data to support your hypothesis or to evaluate your prototype, it is time to write a conclusion.

Your conclusions will summarize whether your data supports or contradicts your original hypothesis. If you are doing an Engineering or Computer Science programming project, then you should state whether or not you met your design criteria. You may want to include key facts from your background research to help explain your results. Do your results suggest a relationship between the independent and dependent variable?

Key Info: Conclusions

- Your conclusion summarizes your data and explains how your results support or contradict your hypothesis or how your prototype met your design criteria.
    - Be sure to briefly summarize the background data to help explain your results.
- If you can, state the relationship between the dependent and the independent variable.
- Suggest changes in your experimental design and describe new hypotheses to test in the future.
- State the significance of your project. Why is your data important?

If Your Results did not support your hypothesis

If the results of your science experiment did not support your hypothesis, **DO NOT** change or manipulate your data to fit your original hypothesis. Scientists commonly find that results do not support their hypothesis, and they use those unexpected results as the first step in constructing a new hypothesis. If you think you need additional experimentation, describe what you think should happen next.

Scientific research is an ongoing process, and by discovering that your hypothesis is not true, you have already made huge advances in your learning that will lead you to ask more questions that lead to new experiments. Science fair judges do not care about whether you prove or disprove your hypothesis; they care how much you learned.

Part V: Making your project Stand out!

Completing Your Project

Now that you have finished your science or engineering project, it is time to write your research paper and make your display board.

A complete Project consists of the following:

1. A Project Notebook (highly recommended, but not required)
2. A Research Paper (highly recommended, but not required)
3. A Display Board with an abstract

Project Notebook:
Your project notebook should contain accurate and detailed notes of EVERYTHING you did for your research project. It includes dates, times, activities, notes, drawings, and observations. Good notes will not only show your consistency and thoroughness to the judges and will help you write your research paper. All competitive projects will have a project notebook.

Research Paper:
Your research paper is your chance to show your teacher and the judges all that you have learned. A big part of science and engineering is being able to write a report and summarize your results. Use the key info box to help your organize your paper. Again, all competitive projects will have a research paper.

Key Info: The Research Report

A good research paper includes the following sections:

- Title page: Project title, name, address, school, and grade
- Table of contents: Includes the title of each chapter and page numbers.
    - **Chapter 1:** State your research project. This chapter should give an introduction to your project and give reasons why the project is interesting and/or important.
    - **Chapter 2:** Background Research. This section will describe what the scientific literature says about your topic, what is known, what is not known, and what your project will add to the body of knowledge.
    - **Chapter 3:** Methods. Describe in detail your list of materials and the experimental procedure you used for your project. Explain how you collected the data and how it was analyzed.
    - **Chapter 4:** Results. Present your data in graphical form and summarize your results in words. Explain trends, any problems with the data, and how you interpreted the results.
    - **Chapter 5:** Conclusion. Your conclusion summarizes your data and explains how it supports or contradicts your hypothesis or how your prototype met your design criteria. If your hypothesis was not supported, form a new hypothesis to explain what you saw. Also, explain the significance of your project and what you learned.

- References: List all of your sources in alphabetical sources. APA style is encouraged.
- Appendix: Any information that is critical to your project but does not fit into one of the above chapters. This can include additional information about instruments, additional graphs/tables, etc.

Ask a parent or peer to proofread your paper. Check for spelling and grammar mistakes, and be sure to cite your sources properly!

Display Board

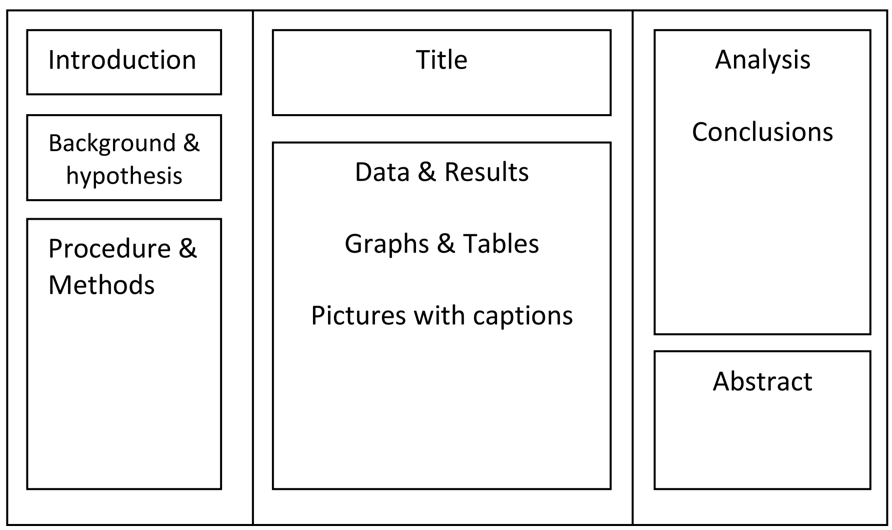
The display board is a visual representation of your entire project, from hypothesis to conclusion. Typically, a display is created on a tri-fold display board. According to CSRSEF rules, your display must not be larger than 48 inches wide, 30 inches deep (front to back), and 9 feet tall (from the floor to the top of the display board).

Keep your exhibit neat, uncluttered, and to the point. All photos and illustrations must include captions and photo credits. No living organisms (including plants), taxidermy specimens, preserved vertebrate or invertebrate animals, human/animal food, human/animal parts or body fluids, chemicals, or drugs are allowed at the CSRSEF.

The illustrations below are meant to guide you as you plan your display board. Be creative with your display, but be sure to include all of the important information about your project.

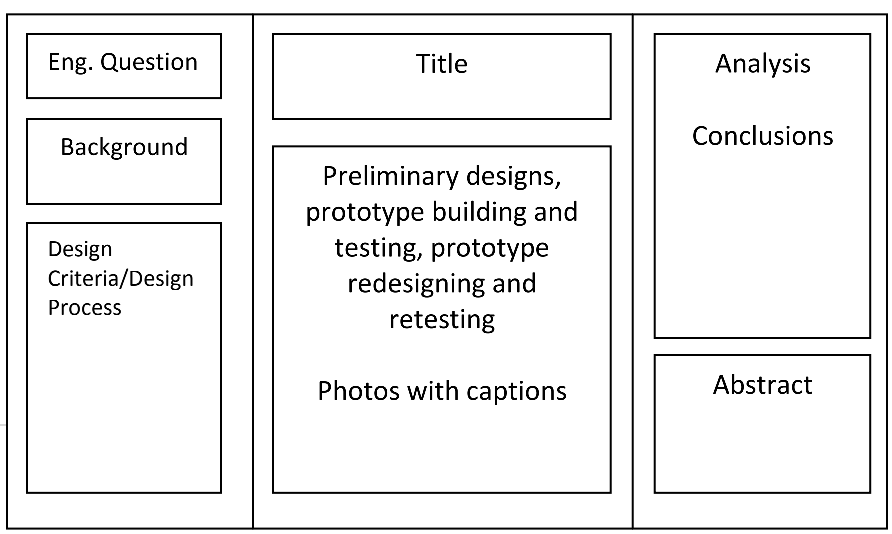
Your **SCIENCE** display board should include the following:

- Title of the Project
- Purpose
- Hypothesis
- Materials
- Procedure
- Data
- Results
- Conclusions
- Abstract



Your **ENGINEERING** display board should include the following:

- Title
- Engineering Question/ Goals
- Design Criteria/Design Process
- Materials
- Prototype Development
- Testing, Redesigning, Retesting
- Data Analysis and Conclusion
- Abstract



Abstract:
In order to participate in the CSRSEF and the Washington State Science and Engineering Fair, you must write a 250 word (maximum) abstract on the Official ISEF form which can be downloaded here: http://www.societyforscience.org/Document.Doc?id=24 .

An abstract is a short summary of your entire research project. The following elements should be included in an abstract:

- Title
- Statement of the Problem
- Purpose of the Study
- Hypothesis
- Procedure/Summary of the Experiment
- Results & Conclusions

Be brief and concise. For more information about constructing an abstract, visit http://stemed.unm.edu/PDFs/TEACHER%20RESOURCE%20CD-ROM/ABSTRACTS/Good%20Abstracts%20-%20HANDOUTS.pdf.

Final Display Checklist

What Makes for a Good Display Board?	For a Good Display Board, You Should Answer "Yes" to Every Question
Does your display board include all of the appropriate sections, including an abstract?	Yes / No
Is your display less than 48 inches wide, 30 inches deep (front to back), and 9 feet tall (from the floor to the top of the display board)?	Yes / No
Is your research paper complete and free of spelling, punctuation, and grammatical errors?	Yes / No
Have you removed prohibited items such as living organisms (including plants), taxidermy specimens, preserved vertebrate or invertebrate animals, human/animal food, human/animal parts or body fluids, chemicals, or drugs from your display?	Yes / No
Have you included captions and photo/illustration credits for all graphics on your display board?	Yes / No

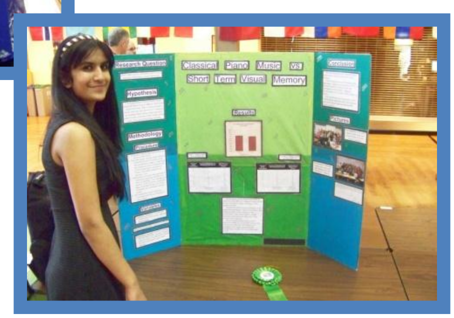
Preparing for the science fair:

To make the best impression at the CSRSEF, make sure you practice talking about your science or engineering project before you arrive at the fair. Plan your presentation so that it has an introduction, description of your project, and a conclusion. Practice in front of your display board and with any additional visual aids. Become comfortable describing your methods, data, and graphs, and try to keep your entire presentation to less than 10 minutes.

Most importantly, have fun! Remember that the judges are real people who are genuinely interested in your project and that they want to help you succeed!

Good luck, and we look forward to seeing you at the Central Sound Regional Science and Engineering fair at Bellevue College on March 10, 2012!

And remember, please visit the website at www.bellevuecollege.edu/sciencefair for the latest CSRSEF updates.



Appendix

Selected Resources

Note: the guidelines on these web sites may differ slightly from the CSRSEF guidelines. Be sure to follow only CSRSEF or ISEF guidelines for your project!

American Psychological Association Guide to Psychological Research
URL: http://www.apa.org/education/k12/science-fairs.aspx
Provides a guide to Psychological Research as well as mentors for science fair projects.

100 Extremely Useful Search Engines for Science
URL: http://www.onlinecourses.org/2009/11/08/100-extremely-useful-search-engines-for-science/
A comprehensive list of science search engines, grouped by discipline.

Energy Quest
URL: www.energyquest.ca.gov/projects/index.html
The California Energy Commission's website with ideas for projects, an explanation of what makes a good project, and links to other useful sites.

Internet Public Library's Science Fair Project Resource Guide
URL: http://www.ipl.org/div/projectguide/

Science Buddies
URL: http://www.sciencebuddies.com/mentoring/science-projects.shtml
Contains project ideas, how-to section, and information on engineering projects.

Science Fair Central
URL: http://school.discovery.com/sciencefaircentral/
Discovery Channel's science fair site that includes a handbook and some project ideas.

Science Fair Projects @ NASA
URL: http://www.hq.nasa.gov/office/hqlibrary/pathfinders/fairs.htm
A list of science fair resources, both books and web sites.

Science Fair Zone
URL: www.sciencenewsforkids.com/articles/ScienceFairZone.asp
Through Science News for Kids, this site offers info specifically on science fair projects. Includes tips, science fair topics, profiles of students, and winning projects.

Successful Science Fair Projects
URL: http://faculty.washington.edu/chudler/fair.html
Basics of doing a science fair project following the scientific method.

Links to other WA State Science Fairs:
Washington State Science and Engineering Fair: http://www.wssef.org
South Sound Regional Science Fair: http://www.plu.edu/~scifair/
Mid Columbia Regional Science & Engineering Fair
Southwest Washington Science & Engineering Fair

Judging Criteria

Evaluation Criteria for CSRSEF Category Judging

The criteria and questions below are used by the Grand Awards Judges of the Intel ISEF. Please use this as a guide for category judging at the CSRSEF. Scientific Thought and Engineering Goals are separated into IIa. and IIb. to be used appropriately by category. There are also added questions for team projects.

I. Creative Ability (Individual—30, Team—25)

Does the project show creative ability and originality in the questions asked?

• the approach to solving the problem?, the analysis of the data?, the interpretation of the data?

• the use of equipment?, the construction or design of new equipment?

Creative research should support an investigation and help answer a question in an original way.

A creative contribution promotes an efficient and reliable method for solving a problem. When evaluating projects, it is important to distinguish between gadgeteering and ingenuity.

II a. Scientific Thought (Individual—30, Team—25)

For an engineering project, or some projects in categories such as computer science and mathematical sciences, the more appropriate questions are those found in IIb. Engineering Goals.

Is the problem stated clearly and unambiguously?

Was the problem sufficiently limited to allow plausible approach? Good scientists can identify important problems capable of solutions.

Was there a procedural plan for obtaining a solution?

Are the variables clearly recognized and defined?

If controls were necessary, did the student recognize their need and were they correctly used?

Are there adequate data to support the conclusions?

Does the Finalist or team recognize the data's limitations?

Does the Finalist/team understand the project's ties to related research?

Does the Finalist/team have an idea of what further research is warranted?

Did the Finalist/team cite scientific literature, or only popular literature (i.e., local newspapers, Reader's Digest).

II b. Engineering Goals (Individual—30, Team—25)

Does the project have a clear objective?

Is the objective relevant to the potential user's needs?

Is the solution workable? acceptable to the potential user? economically feasible?

Could the solution be utilized successfully in design or construction of an end product?

Is the solution a significant improvement over previous alternatives?

Has the solution been tested for performance under the conditions of use?

III. Thoroughness (Individual—15, Team—12)

Was the purpose carried out to completion within the scope of the original intent?

How completely was the problem covered?

Are the conclusions based on a single experiment or replication?

How complete are the project notes?

Is the Finalist/team aware of other approaches or theories?

How much time did the finalist or team spend on the project?

Is the finalist/team familiar with scientific literature in the studied field?

IV. Skill (Individual—15, Team—12)

Does the finalist/team have the required laboratory, computation, observational and design skills to obtain supporting data?

Where was the project performed (i.e., home, school laboratory, university laboratory)? Did the student or team receive assistance from parents, teachers, scientists or engineers?

Was the project completed under adult supervision, or did the student/team work largely alone?

Where did the equipment come from? Was it built independently by the Finalist or team? Was it obtained on loan? Was it part of a laboratory where the Finalist or team worked?

V. Clarity (Individual—10, Team—10)

How clearly does the Finalist discuss his/her project and explain the purpose, procedure, and conclusions? Watch out for memorized speeches that reflect little understanding of principles.

Does the written material reflect the Finalist's or team's understanding of the research?

Are the important phases of the project presented in an orderly manner?

How clearly is the data presented?

How clearly are the results presented?

How well does the project display explain the project?

Was the presentation done in a forthright manner, without tricks or gadgets?

Did the Finalist/team perform all the project work, or did someone help?

VI. Teamwork (Team Projects only—16)

Are the tasks and contributions of each team member clearly outlined?

Was each team member fully involved with the project, and is each member familiar with all aspects?

Does the final work reflect the coordinated efforts of all team members?