# When Does Opportunity Knock?
## A Real World Science Lesson Plan

## BACKGROUND:
WWII was a time of unprecedented innovation. For example:
- Penicillin was developed into an antibiotic in 1944
- Radar was developed into a technology to identify incoming craft and missiles, and for vessels to use in identifying other craft and land masses by both American and British militaries
- Nuclear fission was developed into chain reactions both controlled and critical
- Mathematics and computational machines were developed to crack codes and estimate trajectories
- DDT was developed as an insecticide
- Ballpoint pens were developed by Hungarian refugees of war
- Electronic circuitry was developed to enable portable radio communication
- Synthetic plastics were developed as substitutes for many natural products
- The first jet engines were developed by the Germans
- The use of blood plasma and other methods for treating shock were developed by US scientists
- Pressurized cabins in aircraft
- Hand cranked flashlights

## OBJECTIVES:
Students will learn about the design process, and apply science and reasoning to solve problems.

Students will understand the role of technology in society, and how many social factors influence development of new technologies.

## GRADE LEVEL:
5-8 with enrichment activities for advanced students

## STANDARDS:
**3rd-5th grades:**
- Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost. **3-5-ETS1-1**
- Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. **3-5-ETS1-3**

**6th-8th grades:**
- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1-1**
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **MS-ETS1-2**


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## TIME REQUIREMENT:

**Mother of Invention** will take only part of an hour. **Necessity Cards** could take from one to several hours, depending on how far you take the work-product. **Break it Down** will take about one hour, and **Make a Timeline** will take about half an hour.

## MATERIALS:

**Student Handouts:** Mother of Invention, Necessity Cards, Break it Down, and Make a Timeline

For **Break it Down** you will need some mechanically or battery powered toys to take apart.

For **Make a Timeline** students will need some long skinny sheets of paper

## PRIOR KNOWLEDGE:

Students may need a review of the design process. Some students may not have had a lot of experience with tools and taking things apart, and may need some help.

## INFORMATION FOR TEACHERS:

You can send a letter home to ask for toys that are no longer in use. I have had great luck finding things at Dollar Stores and thrift stores.

## OUTLINE OF ACTIVITIES:

1. Students read **The Mother of Invention** and answer the questions about it. You could also read *What Color is My World?* by Kareem Abdul Jabar, *Build It: Invent New Structures and Contraptions* by Tammy Enz, *Imaginative Inventions* by Charise Harper, or *Girls Think of Everything* by Catherine Thimmesh.
2. Students use **Necessity Cards** to develop their own ideas for inventions. The cards present a challenge, and students develop an invention to meet the challenge.
3. Students use **Break It Down** to figure out how some inventions work. In this activity they take apart mechanically or electronically powered toys to see how they work.
4. Students **Make a Timeline** with important events in WWII and innovations to see how necessity and solutions interacted to create innovations and a successful war effort.

## ASSESSMENT:

Student responses on handouts will provide some data on their understanding of the design process and the role of technology and science in solving society's problems.
Student work-products from **Necessity Cards** will show how their understanding of these ideas is developing, and evaluate their ability to reason and provide evidence for reasoning.

## EXTENSION/ENRICHMENT:

You can differentiate in how far and how long students work on their **Necessity Cards** projects.

## REFERENCES:

*Tuxedo Park*. Jennet Conant, Simon and Schuster, 2002.
*The Invention That Changed the World.* Robert Buderi, Touchstone, 1996.
*Laboratory Warriors.* Tom Shactman, Perennial, 2002.

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# STUDENT HANDOUT

## The Mother of Invention

There are many things that have to come together to make an invention. The timing has to be right, and the inventor has to have a good vision of how the creation will fill an important need.

Here are two examples that illustrate how inventions work and come to be important.

Pharmacy window of medical detachment dispensary at Camp San Luis Obispo, California, 25 February 1945. The National WWII Museum, 2011.065.613.

**Penicillin**

In 1928 Alexander Fleming discovered that some fungus had accidentally gotten into a sample of bacteria he was growing. The fungus stopped the growth of the bacteria. He was a Scottish scientist working in London.

Fleming grew more of the fungus to find out what it was and to try to learn how it worked to kill the bacteria. He tried to isolate a chemical from the fungus that could be used as a treatment for infections, but he was much better at biology than chemistry. Fleming was also not a great communicator—either in writing or in speech. He did find with experiments that it was not toxic to animals or humans. However he was not able to convince anyone to help him develop penicillin into a useful treatment.

This was a time in which many people suffered and died from infections. Infections had been reduced in the late 1800's when doctors began to understand that hand-washing and disinfection with soap and bleach could reduce infections. In WWI improved techniques for washing wounds reduced infections, still deaths due to infection were very high.

Throughout the period after WWI medical researchers looked for ways to treat infections, but for a long time they found little success. In 1940, a team of scientists at Oxford University made a discovery.

Led by Australian Howard Florey, they discovered that penicillin injected in mice cured some bacterial infections. They followed these experi-


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# STUDENT HANDOUT

## The Mother of Invention

ments with tests in humans, most of which showed that penicillin cured infections. But they were having trouble making large quantities of penicillin. They needed to find a way to grow lots of the fungus, and to extract and concentrate the chemical that worked on the bacteria.

By this time, WWII had started in Europe, and England was being bombed by Germany regularly. Hoping to find a better place to develop penicillin into a drug, Florey went to the US. They made some progress by 1942, but still had only enough of the drug to treat 10 patients.

By 1943 the US War Production Board realized that penicillin could be critical to treating infections in soldiers, and developed a plan to create large quantities of it. With the help of a government agricultural lab, and chemical engineer Margaret Hutchinson Rousseau, they found a very powerful strain of the fungus, and methods to grow lots of it. After that they developed effective ways to get the penicillin from the fungus. By the time the US and England were planning the D-Day invasion, they had all the penicillin they needed to treat the wounded.

Medical technicians in a laboratory at Cape Gloucester, New Britain, August 1944. The National WWII Museum, 2008.354.216.

Florey never patented penicillin, as he believed it would be unethical to restrict its use and profit from something needed so badly for the war effort. Florey and his colleague Ernst Chain shared a Nobel Prize in 1945 for their work in developing penicillin.

### Plastics

A plastic really means a material that is easy to shape. Today when we say plastic, what we mean is a synthetic polymer. A polymer is a chemical that is made of a repeated chain of smaller units.

Humans have been using polymers (wood, paper, horn, cotton, linen) for millennia. Rubber and other polymers from plant sap was used for many purposes for centuries until in the 1840s engineers learned to strengthen it by treating it with sulfur.

The first synthetic polymers were made in 1860, when John Wesley Hyatt treated cotton fiber with camphor to create celluloid. Celluloid was


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# STUDENT HANDOUT

## The Mother of Invention

meant to replace expensive and rare substances like horn, tortoiseshell, and ivory. Although celluloid was important in some manufacturing, in most areas natural polymers were still cheap and plentiful enough that they were used instead of human-made ones.

In the early 1900s chemical engineers were working with a new substance, called coal tar. Coal tar is a by-product of coal production, and engineers learned to make many products from it including dyes, and sulfa drugs which were used to fight infections before penicillin.

In 1907 Leo Baekeland made the first completely synthetic plastic. He made it from coal tar, and called it Bakelite. Throughout the decades before WWII more and more plastics were made from coal tar and oil. Radios, telephones, fancy furniture, jewelry, and sculptures were made from synthetic polymers. But still most manufactured products used natural materials.

That all changed with the beginning of WWII. Suddenly electronics systems were needed for tens of thousands of aircraft, boats, ships, radios, and radar systems. They all needed insulation around their wires and at the same time plant polymers commonly produced in the tropics were harder to get because of enemy activity in the oceans.

In 1935 nylon had been discovered, but it was more expensive than the silk and linen it was meant to replace. During wartime those natural materials were in short supply, and nylon was used to make parachutes, ropes, and parts of clothing. During WWII plastic production in the US increased 300%.

In the future, as fossil fuels get more expensive, the balance may change again. It is possible that we might return to using plant and animal products in place of synthetic polymers. Scientists have been investigating the use of waste agricultural products—like bean pods and feathers—to replace oil as a source for polymers.

You might be the next Leo Baekeland. Perhaps your research will lead us to a future of new materials that don't depend on oil or coal for their production.


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# STUDENT HANDOUT

## Necessity Cards

It doesn't take just smarts and creativity to make an invention work. It takes necessity. Unless there is a really strong need for change, a new idea won't be adopted. A new idea needs people to invest time and money, and so there has to be some sort of problem that forces them to make the change.

Radio controlled target plane at a training site at San Luis Obispo, California, April 1944. The National WWII Museum, 2011.065.1176.

WWII was a time when there was a lot of need for change. The US had to get ready really fast, to make a lot of stuff and prepare a lot of people, and send them around the world. We had to do all that without some of the resources that we were used to having—because those resources were now under the control of our enemies.

Your team will get a card with a problem, and a need for a solution. These all represent challenges the US faced in WWII. Your assignment is to develop a plan for a solution to the problem. In class you won't be able to actually make the solution, but you can develop a detailed plan using what you know to create a solution.

**Start by:**

- Making a list of what you know about the ideas in the problem
- Brainstorming a list of ways to solve the problem
- Evaluate that list for the ways that are best, easiest, cheapest etc.
- Pick one of the solutions to develop

Your teacher will help you with details about how your invention will be developed and presented, but it will certainly involve diagrams and some written explanation.


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# STUDENT HANDOUT

## Necessity Cards

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| **Remote Control**<br>Sometimes air missions were very dangerous, and risking a crew was not a good idea.<br><br>It would be great if there were a way to send aircraft on missions and control them from the ground with no crew on board. | **Portable Rations**<br>There were lots of rations for soldiers in the field, but they took up space and were heavy and needed heating up.<br><br>It would be great if there was a packaged food that could be eaten without heating, that had a lot of energy and vitamins and nutrients. | **Malaria**<br>There were lots of mosquitos biting troops, especially in the Pacific Theater. Many of these mosquitos carried malaria. Malaria is a disease caused by single-celled parasites. The drugs we used for malaria were not great, and caused lots of side effects.<br><br>It would be great to have a way to prevent mosquito bites, get rid of mosquitos, or cure malaria. |
| **Portable Pens**<br>Pilots had to make notes on maps, but the pens they used were fountain pens, and spilled ink and got clogged and smeared.<br><br>It would be great to have an easy-to-use pen that wouldn't leak much and had ink that dried fast. | **Portable Power**<br>There were often power outages on bases that depended on generators, or cities occupied by troops.<br><br>It would be great to have lights, radios, and other equipment that had a way for their users to generated electricity for them. | **Parachute Fabric**<br>Parachutes were made of silk. Silk was light and strong and performed well in this function. But silk comes from caterpillar cocoons, and is slow to make and expensive too. Silk also came from parts of Asia that the Japanese came to control.<br><br>It would be great to have a fabric that would be strong and light like silk, but was easier and cheaper to make. |


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# STUDENT HANDOUT

## Necessity Cards

### Stopping Infections

All through history more soldiers died of infections than anything else. Infections are caused by bacteria that reproduce exponentially and make people sick.

It would be great to stop infections somehow, either by removing bacteria, killing bacteria, or treating wounds differently.

### Insulating Circuits

Almost all the equipment in WWII used electrical circuits. Airplanes, tanks, ships, trucks, radios, radar…it all depended on electrical circuits. All those circuits used wires that needed to be insulated. Insulation of wires needs that doesn't carry electricity to be easily and cheaply wrapped around a wire.

It would be great to have a material that could be produced with the material we have that would insulate wire.

### Treating Trauma

When someone gets injured badly they often lose a lot of blood. This loss of blood has serious effects on the body—causing a condition called shock. Blood transfusions can be used to treat shock, but it is hard to get enough blood, preserve it, make sure it's the right type, and get it to wounded soldiers.

It would be great to have a way to treat trauma from shock, either by giving more fluid to the body, finding a way to treat symptoms of shock, or by preserving blood better.

### High Altitude Flight

Planes are vulnerable to being shot down when they fly at low altitude. But flying at high altitude is difficult because the air is so thin. At high altitude with the air pressure so low fight crews get very cold and have trouble getting enough oxygen. They can bundle up and use oxygen tanks, but that limits how long they can stay up in the air.

It would be great to have a way to fly at high altitude and have planes with more air pressure in them.

### Alternative Fuel

Fuel was in short supply. It was necessary to use gasoline for tanks, planes, cars, and generators. Rationing helped, but conflict prevented exploration and development of new oil wells.

It would be great to have a way to make fuel from some other resource that was readily available.

### Amphibious Vehicles

We had lots of great ships, and lots of great trucks and tanks. But it was hard to go from one to the other. Getting trucks and tanks and soldiers from transport boats to shore was hard. It was also hard to move stuff and people around on the islands in the Pacific where there was lots of rain and rivers and lagoons.

It would be great to have vehicles that could move from water to land more easily.


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# STUDENT HANDOUT

## Break it Down

Your teacher will give you one or more toys to examine.
Without making a mess take your toys apart one at a time. Answer the questions below for each toy.

**What does the toy do?**

**Draw a diagram of the toy's parts and how they work together:**

**Give an example of something else that works like this toy:**

Officer controlling radio target plane, San Luis Obispo, California, June 1944. The National WWII Museum, 2011.065.1179.


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# STUDENT HANDOUT

## Make a Timeline

In order to understand how necessity creates innovation, and how innovation solves problems, you need to see how everything lays out in time.

**Directions:** Take the dates below and use them to make a timeline. Your timeline should start in September of 1939, with the invasion of Poland by Germany. It should end in September of 1945 with the surrender of Japan. Put the historical dates and technological innovations in different colors.

### Historical Dates

- Soviet troops push Germans out of Soviet Union, June 1944
- Germany invades Soviet Union, June 1941
- British and US troops take Okinawa from Japan, June 1945
- France is occupied by Germany, June 1940
- British, French, and US troops liberate Paris, August 1944
- Great Britain begins air-bombing attacks on Germany, May 1940
- US drops a nuclear bomb on Hiroshima, August 1945
- Battle of Britain begins July 1940 and ends October 1940
- British and US troops enter Germany, October 1944
- US drops a nuclear bomb on Nagasaki, August 1945
- Japan bombs Pearl Harbor; US enters WWII, December 1941
- British and US forces stop Japanese in the Pacific at Midway, June 1942
- Allies take North Africa back from Germans, May 1943
- Japan formally surrenders, September 1945
- British, Canadian, and US troops land on beaches of Normandy (D-Day), June 1944
- Battle of the Bulge begins December 1944
- Germany surrenders, May 1945

Sherman tanks advance on a snowy road in Belgium, January 1944. The National WWII Museum, 2004.311.052.

A naval air transport flying past Gareloi Volcano in the Aleutians, October 1943. The National WWII Museum, 2011.102.347.


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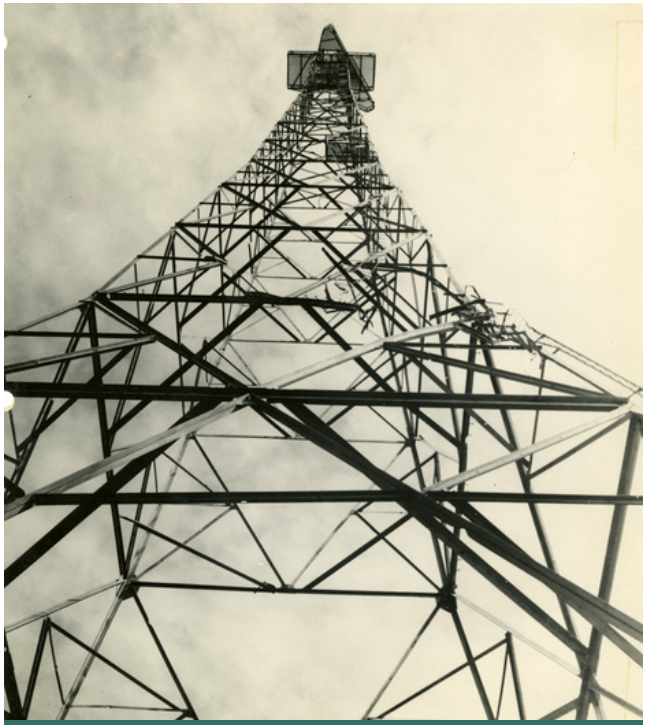
# STUDENT HANDOUT

## Make a Timeline

**Technological Innovations**

- Factories to produce weapons-grade uranium and plutonium begin operation in the US, January 1945
- England starts research to develop nuclear bomb, October 1940
- Great Britain erects Chain Home, a radar system surrounding their country, September 1939
- US has large stockpile of penicillin for use with troops, June 1944
- Roosevelt creates National Defense Research Committee to get ready for war, September 1940
- FDR approves in principle Manhattan Project, October 1941
- US begins production of its first large computer (ENIAC), June 1943
- British capture and begin studying Enigma machine, February 1940
- Germany cuts its nuclear weapons program, January 1942
- Great Britain starts using radar jamming, July 1943
- First pressurized bomber, B-29, September 1942
- Test of nuclear bomb at secret site in New Mexico, July 1945
- Biro, who fled Nazi forces in Hungary, begins selling ballpoint pens, February 1944
- US military begins using dried plasma to treat shock, March 1944
- Great Britain begins investigating nuclear weapons, April 1940
- Germans launch first V-1 attacks, June 1944
- Great Britain and US commit to develop nuclear weapons, June 1941
- Colossus computer begins use in code-breaking, December 1943
- Germans begin using first jet fighter plane, July 1944
- British take their radar research to US, September 1940
- US starts using radar to locate ground targets, March 1944
- British can reliably crack German Enigma code, May 1941
- Enrico Fermi creates first sustained chain reaction with uranium, December 1942
- Germans begin using V-2 rockets against England, September 1944



Deserted Japanese radar tower at Carlson Island, Kwajalein Atoll, June 1944. The National WWII Museum, 2011.075.028.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# Operations and Calculations
## A Real World Science Lesson Plan

## BACKGROUND:
WWII was a time when operations and statistics first came into prominence as fields of importance. Delivering supplies and soldiers to the right place at the right time was very important, especially as the US was relatively unprepared for war. Operations is the name of the field that specializes in this kind of thing—getting things made and moved and completed. Statistics is a field that is important to operations, because it provides tools to measure quality and indentify when and where things go wrong. Measurement is something that all scientists and engineers use, but in operations people use lots of measurement, so that they can calculate effectiveness. Calculations for statistics and other purposes were harder in WWII because they didn't have calculators and computers like we do. However, they did have their own kind of calculators. These were mostly different versions of slide rules.

## OBJECTIVES:
- Students will learn about logistics, operations, quality control, and statistics.
- Students will use statistics to evaluate the quality of a finished product.
- Students will make their own calculator for a specific purpose.
- Students will make calculations from provided data, and will find ways to display data that communicate it most effectively.
- Students will learn about forces and how them determine the motion of objects
- Students will learn about gravity and trajectory
- Students will practice collecting and analyzing data

## GRADE LEVEL:
5-8 with enrichment activities for advanced students

## STANDARDS:
**3rd-5th grades:**
- Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation. **CCSS Math 5.G.A.2**
- Represent data in graphical displays (bar graphs, pictographs and/or pie charts) to reveal patterns that indicate relationships. **NGSS Science and Engineering Practices-Analyzing and Interpreting Data**
- Define a simple design problem reflecting a need or a want that includes specified criteria for

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success and constraints on materials, time, or cost. **3-5-ETS1-1**

- Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved. **3-5-ETS1-3**
- The effect of unbalanced forces on an object results in a change of motion. Patterns of motion can be used to predict future motion. **3-5 PS2-A**
- The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center. **3-5 PS2-A**

**6th-8th grades:**

- Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. **CCSS Math 6.EE.C.9**
- Graphs, charts, and images can be used to identify patterns in data. **NGSS Crosscutting Concepts-Patterns**
- Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions. **MS-ETS1-1**
- Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem. **MS-ETS1-2**
- The role of the mass of an object must be qualitatively accounted for in any change of motion due to the application of a force. **6-8 PS2-A**

## TIME REQUIREMENT:

**Inspected By** will take only part of a hour. **Rationale for Rationing** will take about the same amount of time. Younger students make take a whole period for **Calculating Forces. Production for Victory** will take less than an hour. Both **Assembly Line** and **Making a Calculator** will take about an hour each.

## MATERIALS:

For **Inspected By** you will need a bag of candies (M&Ms, Skittles, etc) for each group, and a balance for weighing the candy.

For **How Big Was WWII?** students will need graph paper.

For **Make a Calculator** students will need some measuring tape, graph paper, and a ruler. They'll also need space to measure their paces.

For **Assembly Line** each team of students will need 6 clickable ball point pens, 6 paper plates, and a stopwatch.

For **Trajectory**, you will need for each group:

- Stiff paper
- Tape
- Protractors (with angle arms is best)
- Tape measures or yard sticks
- Small marshmallows

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For **Slide Rules,** you will need for each student:

- Stiff paper
- Ruler

## PRIOR KNOWLEDGE:

Students may need a review of the design process. Some students may not have had a lot of experience with tools and taking things apart, and may need some help. Some of them may not have used a scale or a stopwatch before.

Students may already know about forces and motion, but they may not yet have learned about trajectory. They have experienced it—who hasn't thrown something by 4th grade?—but not analyzed the mechanics of it.

## INFORMATION FOR TEACHERS:

Students in this age band need to practice proportional reasoning, and seeing the interrelationship between math and science. This may be hard for them, but it is important for them to practice this. This reviews conversion of units and basic principles of science and engineering practice.

Show students how to build the device in **Trajectory**. Illustrate how to use it. For accurate results they will need to try to blow with the same force each time, and to launch from the same height. I would suggest you try the activity yourself before you do it with them, so that you can estimate how much space they will need. With low ceilings or small rooms you may need to take this to the hallway or playground. I would suggest they label their marshmallows with a marker so that they don't get mixed up when the kids are all firing at the same time (and to discourage unwanted marshmallow consumption). You may want to show them models or pictures of Graphical Firing Tables after you do **Slide Rules**.

## OUTLINE OF ACTIVITIES:

1. Students read **Rationing Rationale** and answer the questions.
2. Students use **Inspected By** to evaluate the quality of a completed product.
3. Students use **Production for Victory** to practice estimation and unit conversions while learning about war production.
4. Students use **How Big Was WWII?** to practice calculations and making and interpreting graphics that represent quantities.
5. Students use **Making Calculators** to learn proportional reasoning, and to see how analog calculators worked.
6. Students use **Assembly Line** to review the design process, discover some engineering terms, and to practice systems engineering.
7. All of these activities could be used separately as parts of other lessons and units to review science and engineering practices and quantitative skills.
8. Students use **Trajectory** to learn about patterns and predicting motion, then make sure they know how to label the forces acting on the marshmallow.
9. **Slide Rules** reinforces the concepts and processes in **Making Calculators**.
10. You might read *The Hundred Dresses* by Eleanor Estes, *Don't You Know There's a War On?* by Avi, or *Rosie the Riveter* by Penny Colman.

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## ASSESSMENT:

Student responses on handouts will provide some data on their understanding of the design process and the role of technology and science in solving society's problems.

You could test their understanding of the concepts and methods with other models of trajectory, including catapults and straw rockets.

## EXTENSION/ENRICHMENT:

In **Making a Calculator** there is a lot of room for extension. You could bring in slide rules, or use a slide rule simulator or app. You could also have students graph their stride length against height, and see that the data should form a line with a slope of about 0.41. The can try to find that proportional relationship between the values on the two lines of their calculators.

## REFERENCES:

*Freedom's Forge*. Arthur Herman, Random House, 2013.
*The Girls of Atomic City*. Denise Kiernan, Touchstone, 2012.
History of slide rules and calculators in the military: **http://www.ardec.army.mil/organizations/wsec/fcstd/ftab/FTaB_History.pdf**

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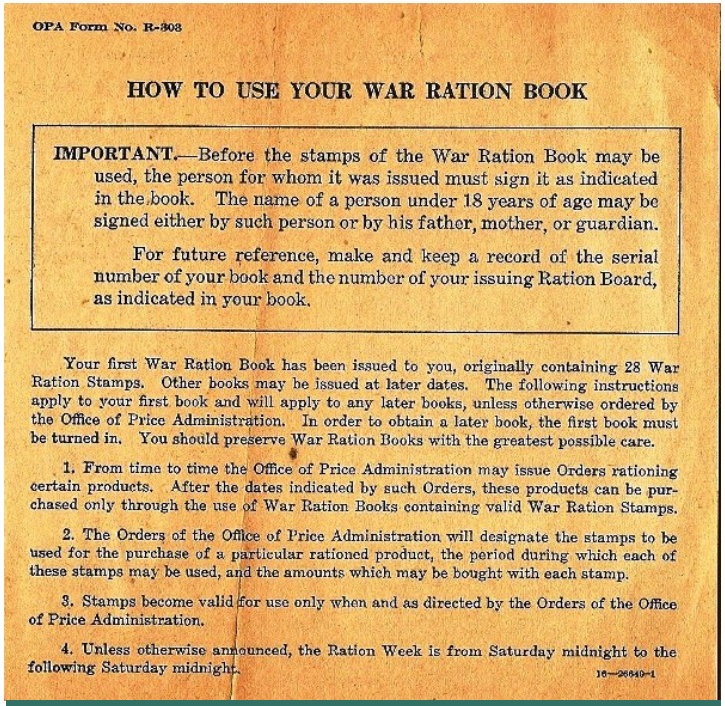
# STUDENT HANDOUT

## The Rationale for Rationing

Materials and energy were in short supply during WWII. There were 16 million troops fighting for victory, and the 117 million people on the home front were working hard to support them. Posters all around told people how important it was to support the war effort. People grew their own food, saved and reused material as much as possible, and went without in order to aid the war effort.

One of the most dramatic ways this affected people's lives was rationing. Tires (and anything else made of rubber), sugar, meat , butter, cheese, milk, eggs, tea, chocolate, cloth, wood, metal, leather, paper, ink, bicycles, cars, fuel, and shoes were all rationed.

In the spring of 1942 all families registered for rationing through their local schools. On a trip to a grocery store, you had to take not just money but your ration book. Without your ration book you couldn't buy any of those things. Some foods (meat, dairy, oils) required red stamps, and others (canned goods) required blue stamps. Fresh fruits and vegetables were not rationed, but there were not many of them. The stamps had to be torn out in front of the grocer at the time of sale so that people wouldn't try selling stamps. Families were encouraged to can their own food. Since canning needs sugar, families who were canning could apply for more rations of sugar. Otherwise you could get one pound of sugar every 2 weeks for each person in the house.



OPA Form No. R-303

HOW TO USE YOUR WAR RATION BOOK

**IMPORTANT.**—Before the stamps of the War Ration Book may be used, the person for whom it was issued must sign it as indicated in the book. The name of a person under 18 years of age may be signed either by such person or by his father, mother, or guardian.

For future reference, make and keep a record of the serial number of your book and the number of your issuing Ration Board, as indicated in your book.

Your first War Ration Book has been issued to you, originally containing 28 War Ration Stamps. Other books may be issued at later dates. The following instructions apply to your first book and will apply to any later books, unless otherwise ordered by the Office of Price Administration. In order to obtain a later book, the first book must be turned in. You should preserve War Ration Books with the greatest possible care.

1. From time to time the Office of Price Administration may issue Orders rationing certain products. After the dates indicated by such Orders, these products can be purchased only through the use of War Ration Books containing valid War Ration Stamps.

2. The Orders of the Office of Price Administration will designate the stamps to be used for the purchase of a particular rationed product, the period during which each of these stamps may be used, and the amounts which may be bought with each stamp.

3. Stamps become valid for use only when and as directed by the Orders of the Office of Price Administration.

4. Unless otherwise announced, the Ration Week is from Saturday midnight to the following Saturday midnight.

16—26649-1

Ration book instructions. The Education Collection of the National WWII Museum.

If an adult had to commute to work, they got a B sticker to put in the car window. This allowed them to buy enough gas to get to and from work. If you could take the bus to work, or if you worked at home, you got an A sticker, and you got about 3 gallons of gas a week.

Supplies got even tighter in early 1945. As the Allies began to liberate parts of Europe, the US took responsibility for providing food to refugees. The war had caused a great deal of damage to farms and manufacturing in Europe, and supplies to clothe and feed the people there had to be brought in. Rationing didn't last long in the US after the war, but in England, which suffered a great loss of production of food and goods from the war, rationing lasted until 1954—9 years after the end of WWII.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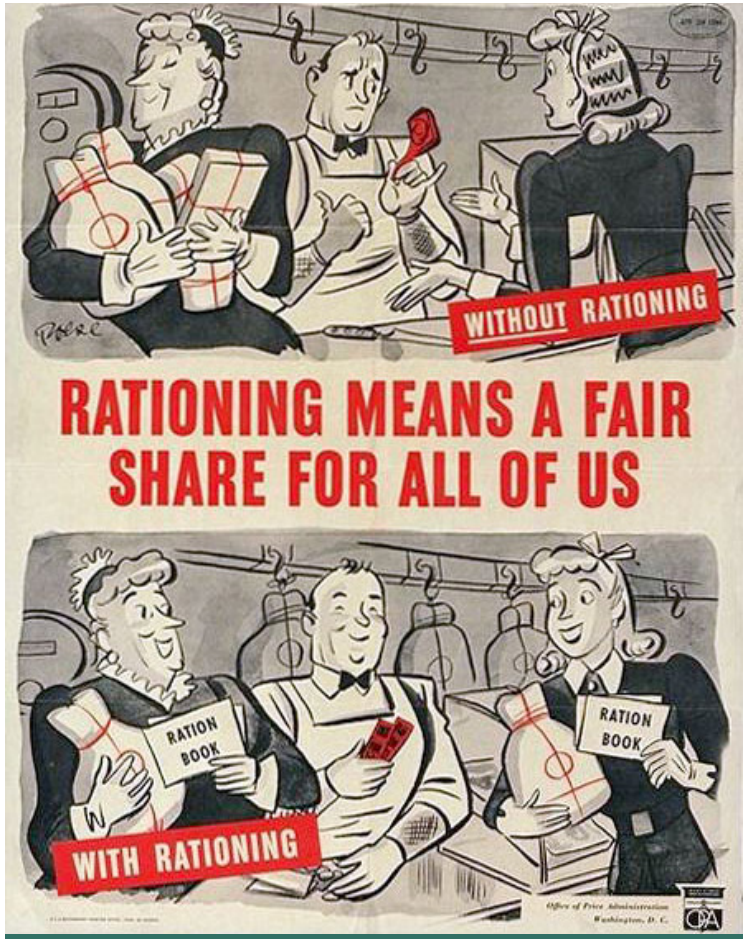
# STUDENT HANDOUT

## The Rationale for Rationing Questions

**There are about 2 cups in every pound of sugar. How much sugar do you think you eat every 2 weeks? (to help you evaluate your sugar intake—10 cans of soda hold 1 pound of sugar, 12 candy bars hold 1 pound of sugar.**

**Use your imagination. What do you think might cause the US to have rationing of food and other goods again? How would people handle it?**




A propaganda poster about rationing, printed by the Office of Price Administration, 1943. The National Archives, 44-PA-611.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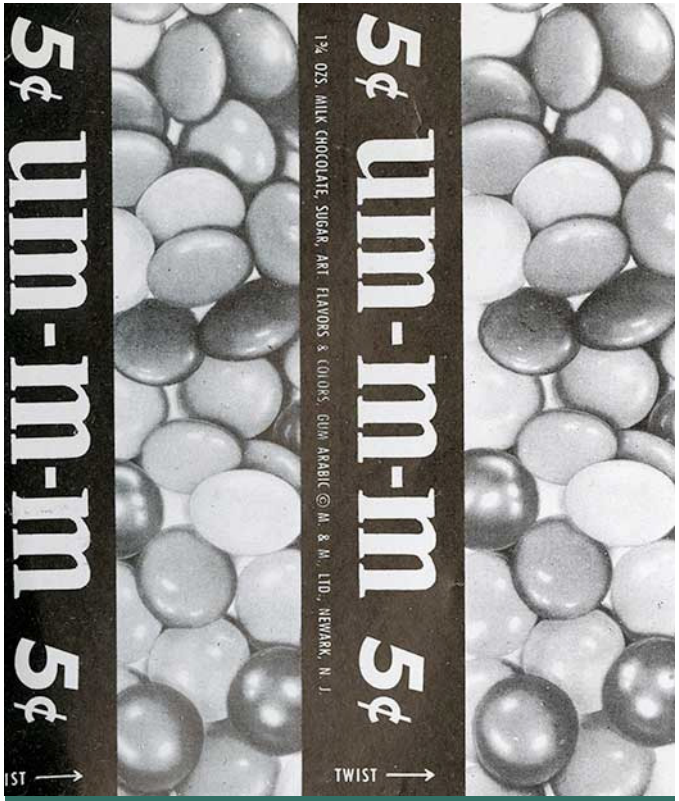
# STUDENT HANDOUT

## Inspected by...

Take the package of candy your teacher gives you, and open it.

**Make a data table to record information about the contents—**
How many pieces there are, and what colors they are. Find the mass of the candies as well.



M & M's were a World War II Innovation. Courtesy of Mars Incorporated.

**Calculate the percent of each color of candy in your bag:**


©The National WWII Museum

# STUDENT HANDOUT

## Inspected by...

**Pool your data with the class. What are the percents of each color across the whole class?**

**Was anyone's bag very different from the rest? Were the masses of the candies in the bag the same across the whole class? Were the numbers of candies in each bag the same across the whole class?**

**If you had a giant container of these candies that held 5,000 of them, how many of each color would you expect to find? How much would 5,000 of these candies weigh?**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# STUDENT HANDOUT

## Production for Victory!

Socks were made of wool in 1941—most clothes were made of natural fibers at the time. How much wool would it take to make socks for the 16 million soldiers the US had in WWII?

**One pair of socks has about 2.0 oz of wool in it. If a soldier has 7 seven pairs of socks, how much wool is needed (use estimation)?**

**There are 16 oz in a pound, so how many pounds of wool is that (use estimation)?**

**So how many pounds of wool will it take to make a week of socks for all 16 million soldiers (use estimation)?**

**If one sheep produces 20 pounds of wool in a year, how many sheep will be needed to get all that wool in one year (use estimation)?**

South African Infantry men drying and warming themselves and their gear in the sun, Veggio, Italy, November 1944. The National WWII Museum, 2007.048.432.


©The National WWII Museum

# STUDENT HANDOUT

## Calculating Forces

In Fall of 1939 when the Germany invaded Poland, and WWII started in Europe, there were less than a million men in the US Armed Forces. At the same time the number of troops in the German and Japanese military were much larger.

There is a display at The National WWII Museum that shows dramatically how different the numbers were. For each nation there are shelves holding toy soldiers in rows. Each toy soldier in the case represents 2,000 actual soldiers.

81st Infantry Division soldiers marching in training at San Luis Obispo, February 1944. The National WWII Museum, 2011.065.397.

The Japanese case has 13 rows of soldiers. Each of these rows has 3 lines of soldiers, and has 59 soldiers in each of those lines.
**Using estimation, about how many toy soldiers are in that case?**

**Using estimation, about how many men were in the Japanese military in 1939?**

The German case has 12 rows of soldiers. Each of these rows has 3 lines of soldiers, and has 59 soldiers in each of those lines.
**Using estimation, about how many toy soldiers are in that case?**

**Using estimation, about how many men were in the German military in 1939?**

The US case has 5 rows of soldiers. Each of these rows has 3 lines of soldiers, and has 21 soldiers in each of those lines.
**Using estimation, about how many toy soldiers are in that case?**

**Using estimation, about how many men were in the US military in 1939?**

**Using estimation, about how many more soldiers did the Japanese and Germans have than the US?**


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# STUDENT HANDOUT

## How Big Was WWII?

There are many different ways of estimating the human cost of the war, and the chaos caused by the conflict can lead to different estimations of the number of casualties. This table represents a very good estimate of the deaths due to WWII.

| Country | Lives Lost |
|---|---|
| Great Britain | 449,500 |
| United States | 418,500 |
| Japan | 2,700,000 |
| Germany | 7,233,000 |
| China | 20,000,000 |
| Rest of Europe | 11,015,600 |
| Soviet Union | 23,100,000 |
| **TOTAL:** | **65,000,000** |

These numbers are from The National WWII Museum's estimates in *Beyond All Boundaries*

**Make a bar graph of these numbers on graph paper.**

### How big was it compared to other wars in which the US was involved?

Another way to examine this is to look at the actual cost of the war, not the number of human lives lost.

| War | Millions of Dollars (calculated in 2011 value) |
|---|---|
| American Revolution (1775-1783) | 2,407 |
| War of 1812 (1812-1815) | 1,533 |
| Civil War (1861-1865) | 79,742 |
| World War I (1917-1921) | 334,000 |
| World War II (1941-1945) | 4,104,000 |
| Korean War (1950-1953) | 341,000 |
| Vietnam War (1965-1975) | 738,000 |

These numbers are from the Congressional Research Service report RL32492 of 2015

**What kind of graph would best represent these numbers? Make a graph on graph paper.**

**What does this graph tell you about the size of WWII?**


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# STUDENT HANDOUT

## How Big Was WWII?

### How did the types of military service change up to and after WWII?

| War | Army | Navy | Marines | Airforce |
|---|---|---|---|---|
| Civil War* | 2,128,948 | 84,415 | | |
| World War I | 4,057,101 | 599,051 | 78,839 | |
| World War II | 11,260,000 | 4,183,466 | 669,100 | |
| Korean War | 2,834,000 | 1,177,000 | 424,000 | 1,285,000 |
| Vietnam War | 4,368,000 | 1,842,000 | 794,000 | 1,740,000 |

These numbers are from the Congressional Research Service report RL32492 of 2015
*only Union troops

**What kind of graph would best represent these numbers? Make a graph on graph paper.**

**What generalization can you make about this pattern?**


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# STUDENT HANDOUT

## Make a Calculator

### Step One: Find your Pace

1. Measure out a distance of 200 cm. Get a partner to observe and help you count out how many normal strides it takes you to cross that distance. Make sure that you are walking normally and not at all trying to change your stride.

2. Divide the number of strides by the distance to find your stride length:

**_____ / 200 cm = _____ stride length**

3. Help your partner to do the same thing for themselves.

4. Measure your height in cm, and record it here:

**_____ height**

### Step Two: Make your Calculator

1. On graph paper, make two lines of 24 cm. Make them parallel to each other and about 2 cm away from each other.
2. Put tick marks on each line every 2 cm.
3. On the top line number the tick marks starting with 32, and increasing by 4 for each (32, 36, 40, 44…). Label this line 'Stride in cm
4. On the bottom line number the tick marks starting with 80, and increasing by 10 for each (80, 90, 100…). Label this line 'Height in cm."
5. Find your stride length on the top line. Using a ruler, find the same spot on the bottom line. It should be the same as your height. Is it? Does it work for your partners?


©The National WWII Museum

# STUDENT HANDOUT

## Make a Calculator

### Step Three: Answer Questions

Soldiers are tracking some footprints in the woods. The prints have a stride length of 36 cm. Is the person who made the footprints a grown-up?

A scientist enters his lab, and finds footprints of mud on the floor. They might have been made by her fellow scientist, who is very tall (195 cm). If it was her friend, how long would the stride be?

10th Mountain Division soldiers and their tank traveling through snow in Italy, January 1945. The National WWII Museum, 2007.048.526.


©The National WWII Museum

# STUDENT HANDOUT

## Trajectory

Use the paper your teacher gives you to roll a tube just barely larger than one of the small marshmallows your teacher gives you. Tape the roll tight.

Next, tape the roll to the arm of a protractor. Mark the marshmallows in a way that lets you identify it as yours.

Set the protractor upright on a table or chair so you can hold it steady and at a constant height. Aim it in a direction with plenty of space. Be sure that when you launch the marshmallow you use the same amount of force each time.

Starting at 10º elevation, launch 3 marshmallows, and record how far away they landed. Record these distances in the table, and then find their average and record it too. Repeat up to 70º elevation

| Elevation | Distance 1 | Distance 2 | Distance 3 | Distance 4 |
|---|---|---|---|---|
| 10º | | | | |
| 20º | | | | |
| 30º | | | | |
| 40º | | | | |
| 50º | | | | |
| 60º | | | | |
| 70º | | | | |

Briefly describe the relationship between elevation of your projectile's launch point and the distance it traveled:


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# STUDENT HANDOUT

## Slide Rules

Make a Slide Rule to quickly calculate the elevation required to shoot a small marshmallow a given distance. Enter elevation in the top of each column, and the distance you would expect a marshmallow to travel at the bottom of each column.

| 5º | 10º | 15º | 20º | 25º | 30º | 35º | 40º | 45º | 50º | 55º | 60º | 65º | 70º | 75º |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | | | |

## Graphical Firing Table

In WWII soldiers used Graphical Firing Tables to quickly calculate the elevation they needed to use to launch artillery at a target. These were based on slide rules, with two bands of data and a rule to help them move along it. Often they had multiple bands so that they could be used with different kinds of artillery.

Slide rules were commonly used for all sorts of calculations before electronic calculators became common.

A gunner checking range duriong mountain maneuvers at Hunter Liggett Military Reservation on 24 March 1944. The National WWII Museum, 2011.065.1853.


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