
AIRCRAFT CARRIER
GUARDIANS OF THE SEA
EDUCATION GUIDE


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Welcome to the *AIRCRAFT CARRIER* Guide for Educators!

We cannot think of a better way to inspire students to explore science and engineering concepts than by climbing onboard an aircraft carrier through this suspenseful film. On the following pages you will find six open-ended inquiry activities for grades 4-8, all directly related to the film and exploring concepts in greater depth that the film introduces. Here are a few important things to keep in mind as you read on:

1. Each activity includes background information linking the science in the film to the activity, and a Challenge Question. There are multiple ways to address these challenges – not one right answer. We want to encourage students to think independently and solve problems like scientists and engineers.
2. All activities are addressed directly to the student so that you can easily photocopy and distribute the pages to your class. The amount of supplies you will need depends on the number of students in your classroom.
3. We know there's a big difference between a 4th grader and an 8th grader. You can add more specific instructions if you feel your students need that, or you can add extra challenges. We added a "Find out more" section to facilitate that.
4. All activities are linked to the Next Generation Science Standards. *Aircraft Carrier* has especially strong connections to the Engineering Design Standards, plus there's a lot of physics, materials science, and more.
5. We also have a selection of online resources to provide more background information for you and research opportunities for your students.

We hope you and your students enjoy these challenges. If you would like to share photos of any of their projects, please email **info@k2communications.com**.

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Special thanks to:
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Student Experiences, Museum of Science and Industry, Chicago, for their review of this guide.

1. FLOATING AND SINKING

Challenge Question #1:
How does an aircraft carrier stay afloat?

You will need:
- cardboard boxes and other recycled materials
- duct tape
- scissors
- popsicle sticks
- large tub filled with water
- measuring cups
- marking pen

1. Study the shape of the aircraft carrier in the photograph. What are the engineering design variables that need to be considered for a boat that carries heavy planes? (For example: What materials were used to build it? What shape is it? How heavy is it?)

2. Design an experiment to test one of the design variables on a model aircraft carrier made from cardboard boxes and duct tape. Choose one very specific question you will study and describe the plan for testing your hypothesis.

3. Build your aircraft carrier from the supplies listed above. Test it in the tub to make sure it floats and doesn't tip over easily. Then make alterations to the design to improve its buoyancy. What changes did you make and why?

4. Create a simulation for landing planes (made from popsicle sticks and duct tape) on your aircraft carrier. Study the size and weight of a real aircraft carrier and real airplane so that you can make your models to scale. How much weight does your aircraft carrier hold before it sinks?

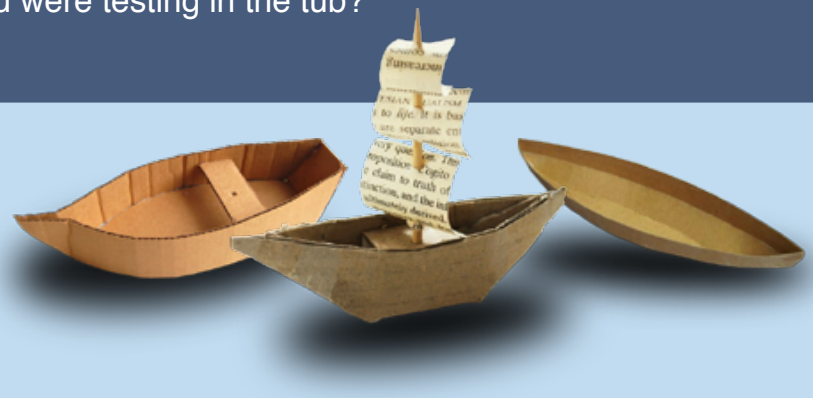
5. Based on your experiments, write a report to the US Navy with your recommendations regarding aircraft carrier design. If you email your report to info@k2communications.com, we will forward it to the Navy and with your approval, post it on the film web site and share it with other students nationwide.

1. FLOATING AND SINKING

Find out more:

a) Mark the water level in the tub before you add the aircraft carrier, and again after you add the aircraft carrier. How much water is displaced by your aircraft carrier before and after you add the planes?

b) Take your aircraft carrier to a body of water outdoors and try to simulate conditions, such as wind and waves, in the middle of the ocean. What new factors does this add that weren't present when you were testing in the tub?



What is buoyancy?

Buoyancy refers to how well an object floats. A heavier object does not float as well as a lightweight object, but it can be shaped in a way to improve its buoyancy. Because of its shape, an aircraft carrier has much better buoyancy than a ball of metal that weighs the same. A floating aircraft carrier is displacing the same volume of water as would fill the bottom half of the ship, the part that is underwater. When you add the weight of the heavy planes, the ship sinks further down, displacing more water.

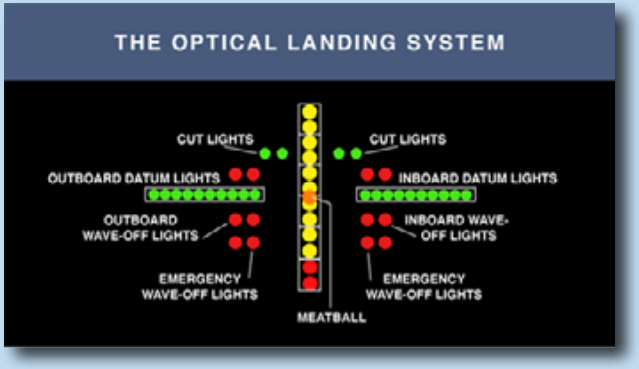
An aircraft carrier weighs over 100,000 tons (or 220,462,280 pounds!).

The airplanes they land there typically weigh 32,080 pounds each.

The 6,000 people on an aircraft carrier weigh a total of about 900,000 pounds.

2. LANDING ON AN AIRCRAFT CARRIER

Challenge Question #2:
Why do aircraft carriers need both Landing Signal Officers and Optical Landing Systems?



You will need:
1 page magnifier (aka a Fresnel lens), 3 small flashlights, red and green twinkle lights (1 string of each color), wire cutters/strippers, 4 batteries (D or stronger), duct tape, cardboard, scissors, a partner to work with you

1. Cut a section of 5 green bulbs from the twinkle lights. Strip the wire at each end. Do the same with a section of red bulbs.

2. Using the supplies above, build 2 separate circuits so that you can make both strings of bulbs light. It will take some experimenting to do this, but keep trying!

3. Assemble a model of an Optical Landing System including “datum lights,” “wave-off lights” and “the meatball.” Hint: To create the meatball, you will need the flashlights and page magnifier/Fresnel lens. A Fresnel lens is used in a real Optical Landing System. How does the light change when directed through the lens?

4. Choose one person to be the Landing Signal Officer (LSO) and one person to be the Pilot. Create two simulations for landing the plane on the aircraft carrier – one in which the pilot is able to land successfully in spite of choppy waves and one in which the pilot has to be “waved-off.” The LSO operates the Optical Landing System. Talk to each other as if you were the LSO and pilot using radios and headsets.

5. Write up a report from the LSO to your commanding officer explaining why you made the decisions you made.

6. When the Optical Landing System was first created in the 1950s, it was expected to eliminate the need for LSOs because it is designed to communicate information quickly and efficiently. But accident rates were significantly reduced when LSOs were involved. LSOs are skilled in operating the System, but what else can they do that the Optical Landing System cannot?

2. LANDING ON AN AIRCRAFT CARRIER

Who are the people who help planes land on an aircraft carrier, and how do they do it?

The 7 categories of jobs on an aircraft carrier are categorized by the color shirts the people wear. The chart will help you understand who is who. Things happen very fast when a plane is landing on an aircraft carrier. With 5,000 people working together, the shirts are a big help to keep up with what's going on. It is the LSOs, in white shirts, who help the pilot land the plane.

The Optical Landing System is a group of lights – horizontal green lights that the pilot uses to see the plane's relationship to the horizon, vertical red lights that flash if it is unsafe to land, and, in the middle, a series of amber Fresnel lenses (like the light you'd find in a lighthouse). When the Fresnel lenses line up correctly and the plane is at the correct angle to land, the pilot sees one round amber light nicknamed the meatball. If the meatball turns red, that means that the pilot is too low to land; the LSOs will flash the red wave-off lights and the pilot will have to circle around again. The LSOs communicate with the pilot by radio and also use hand signals and, at night, flashlights. LSOs adjust the Optical Landing System and turn it on or off with a control device nicknamed the "pickle."

Find out more: Why is the nickname for the LSO "Paddles?" What is a "pickle" and how is it used?

How do you build a circuit?
If you have tried and tried and can't get those bulbs to light, check out "Christmas Light Circuit" by More than a Worksheet at **https://www.youtube.com/watch?v=cBKzKZRpsVQ** (but don't cut all of your bulbs apart!). Once you can light 1 bulb, you can go on to lighting a string of 5.

3. BUILDING THE STRONGEST WIRE

Challenge Question #3:
How do you design a cable strong enough to stop a speeding jet?

You will need:
- 2 large binder clips
- string
- 2 straight-back chairs
- 10” long pieces of “cable” made from very thin materials, such as nylon fishing line, cotton string, wire, long rubber bands, and 2 sizes of spaghetti
- 1 small paper cup
- sharp scissors
- 1 pipe cleaner
- measuring tape
- 20 pennies

1. Tie one clip to the back of each chair by wrapping string around one side of the clip as shown in the photograph. Position the chairs back to back, about 10-11” apart.
2. Use the scissors to poke 2 small holes in the top part of the paper cup. Run the pipe cleaner through the holes so that it loops above the cup, like a basket. Twist the ends of the pipe cleaner so that it stays attached to the cup.
3. Clip each end of the cable you are testing to one of the clips, so that it is parallel to the floor with the cup hanging in the center as shown in the photograph.
4. Add pennies to the cup, one at a time. Watch what happens to the material. Measure the material when you start and at different intervals, graphing the number of pennies compared to number of inches for each material.
5. Repeat this tensile strength test (steps 3 and 4) with the different cable materials.
6. Select 2 materials that, based on your testing, you recommend for the cable that stops the planes on an aircraft carrier. What qualities of this material did you consider in making your recommendation?

3. BUILDING THE STRONGEST WIRE

What is tensile strength?
Tensile strength is the amount of force required to stretch a material to the point where it breaks. Steel cables and spider webs both have excellent tensile strength. If the cable on an aircraft carrier broke, the plane would fly into the ocean. If the spider web broke, the spider wouldn't be able to catch her food. While tensile strength is about pulling something apart, compressive strength is about pressing it together. Concrete has excellent compressive strength and, when used to build roads, can withstand the traffic of heavy vehicles without breaking.


A jet plane catches the arresting wire on landing

Find out more: How are the results of your testing changed if you braid three strands of material together?

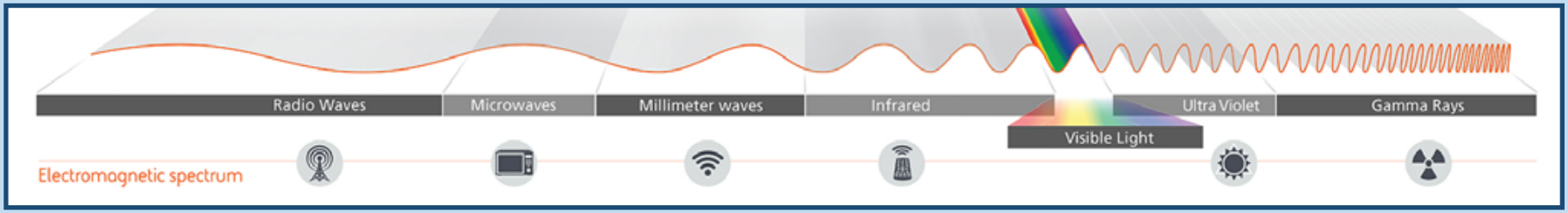
What are the steps for safely landing a plane on an aircraft carrier?
After the Landing Signal Officers clear the pilot to land, the pilot releases the "tailhook" from the back of the plane, which grabs on to one of four arresting wires, or "cables," across the runway on the ship. The cable pulls on the plane and, with the help of a system of pulleys below, slows it down. The cables are steel ropes designed for tensile strength, as a cluster of wires (see illustration) woven together similarly to the way a spider builds its web.


Cross section of arresting wire

4. LIGHT, HEAT AND SOUND WAVES

What are the different types of waves and how do they relate to stealth technology?

These activities explore light, sound and heat waves in air and water. Infrared waves are part of the spectrum of visible light and, although people can't see them, we feel them as heat. Infrared waves and sound can be detected by the F-35 jet (pictured here) and Virginia Class submarine. The electronic periscope on the Virginia includes cameras with infrared and low-light technology allowing them to see things that people cannot. Radar and sonar find aircraft and subs by sending out electromagnetic and sound waves that reflect back to the transmitter. To be stealthy, the sub and airplane are built with their engines inside so that their "heat signature" (infrared waves) is harder to detect. The F-35 and Virginia detect and neutralize threats by intercepting energy signals across the full electromagnetic spectrum, jamming the signals and directing energy toward the threat.



Challenge Question #4:
What characteristics can you detect for different kinds of waves?

COLORFUL LIGHT WAVES

You will need:

- CD
- White paper
- Sunlight or flashlight
- Colored pencils

1. Use the back of the CD to reflect and focus light rays, either from sunlight or a flashlight, onto white paper. The CD is separating all of the colors that make up that single ray of light.
2. Position the CD at different angles and light sources to see how the spectrum changes.
3. Use the colored pencils to reproduce the rainbow spectrums. Make drawings of the changes you see when you experiment with angles, distance and light source.
4. Tonight, take a moment to go outside when the sun is setting. Observe the colors around you. Can you see colors blending together? How would the spectrum look different if you only drew the colors you can see at night?

4. LIGHT, HEAT AND SOUND WAVES

VISIBLE SOUND WAVES
You will need:
- Large bowl
- Stretchy plastic wrap, like Saran Wrap
- Uncooked rice
- Metal spoon and cookie sheet

1. Stretch the plastic wrap tightly across the top of the bowl.
2. Put about a teaspoon of rice on the plastic.
3. What happens to the rice when you bang on the cookie sheet with the spoon next to the bowl?
4. Now experiment with how hard you're hitting the cookie sheet. How does the volume of the sound or the sound's closeness to the bowl affect the rice?

INVISIBLE THERMAL WAVES
You will need:
- Magnifying glass
- Thermometer
- Sunlight
- Styrofoam cup
- Room temperature water

1. Add about 2 inches of water to the Styrofoam cup. Make sure the water is at room temperature to avoid false results for the experiment.
2. Place the thermometer in the water and record the temperature.
3. Use the magnifying glass to focus the sunlight on the water.
4. Observe the change in temperature on the thermometer. What is happening?
5. How would you redesign the activity so that the Styrofoam cup prevented the thermometer from detecting the change in the water?

Find out more: You can't see infrared light waves, but you use them all the time. Your remote control uses these waves to send signals to your TV. You can test this by putting transparent and opaque things in front of the remote to see if they block the waves.

5. READY FOR TAKE OFF

Challenge Question #5:
How can you generate enough energy to launch an F-35 jet plane that goes from 0 to 170 miles/hour in just 2 seconds?

You will need:
- Masking tape
- Oblong-shaped balloon
- 2-inch section of plastic drinking straw
- 6-foot piece of string
- Scissors
- Desk or table
- Friend or activity partner

1. Tape one end of the string to your desk.
2. Thread the other end of the string through the straw.
3. Blow up the balloon and hold it closed so that the air doesn't escape.
4. Tape the straw to the side of the inflated balloon with the opening of the balloon pointing towards the desk.
5. Have your partner hold the other end of the string above your desk, at an angle.
6. Pull the balloon down to the desk and release your hold on the balloon's opening, allowing air to escape.
7. Did your balloon travel from your desk up towards your partner? If not, what adjustments do you need to make?
8. Experiment with different variables to make your balloon launch more successful. How does the angle of the string affect the launch of the balloon? What happens if you make the string more taught, or tighter? Does the balloon go farther when it's blown up more?

5. READY FOR TAKE OFF

How do you overcome the force of gravity?

On an airport runway, a typical airliner accelerates for about 5,300 feet before it lifts into the air. On an aircraft carrier, the F-35 has to do it in only 310 feet. To get it moving that fast, the F-35 jet is launched with a steam catapult. You may not be able to move a plane yourself, but you can launch a balloon and overcome the force of gravity and friction like the F-35 does. In this activity, your lungs will blow up the balloon to build pressure. On the carrier, the pressure built up by steam creates the powerful force that launches the jet. Just as your launch string is at an angle, the flight deck is at a 9-degree angle, pointing the jet slightly up in the air. On an aircraft carrier, the person who is in charge of this activity is called the Shooter because she or he "shoots" the jet off the end of the ship by triggering the release of the holding cable.

Steam from the previous catapult launch blowing back toward the next F/A-18 getting ready to launch

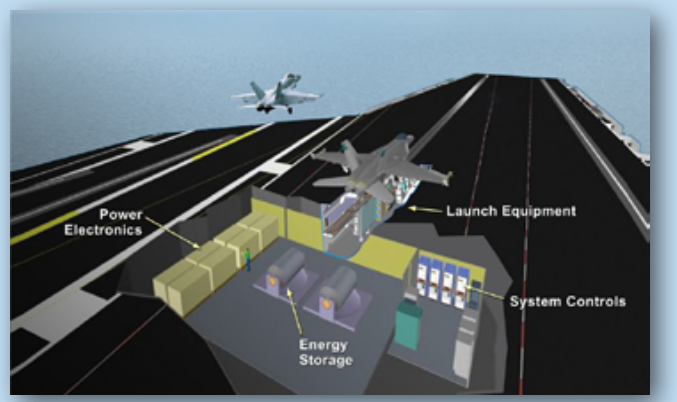
A shooter guides an F/A-18 for take-off

Find out more: What other ways can you create enough energy to blow up a balloon? Ask an adult to help you try this on a stovetop: Fill a pot with an inch of water. Put a small amount of water in the bottom of a glass bottle. Put a balloon tightly over the neck of the bottle and set the bottle in the pot. What happens when you turn on the stove and the water boils?

6. ELECTROMAGNETS

Are electromagnets the wave of the future for Aircraft Launch Systems?

The next Aircraft Carrier (the USS Gerald R. Ford) will use the Electromagnetic Aircraft Launch System (EMALS). It will replace the steam catapult system. Let's take a look at the science behind this new launch system. Running an electric current through a wire coil surrounding a ferrous metal, creates an electromagnet which produces a magnetic field. The more current running through the coil, the stronger the magnetic field and the more powerful the magnet will be. In the future, the F-35 will be launched with a series of electromagnets that are turned on and off, faster and faster, to accelerate the plane sufficiently to take off. Imagine magnets under the ship's deck that will essentially be pulling the plane along at high speeds before takeoff. You may not be able to move a plane yourself but in these two activities, you can make other things move using electricity and magnetism.



Artist's concept of the Electromagnetic Aircraft Launch System (EMALS)

Challenge Question #6:
How can magnetic forces launch an F-35 jet plane?

PICKING THINGS UP

You will need:
- 3-inch iron nail
- 3 feet of thin-coated copper wire
- Wire cutters
- D battery
- Paper clips

1. Hold the nail near the paper clips. Can you pick any of them up?
2. Strip an inch of coating off of each end of the wire.
3. Wrap the coated portion of the wire around the nail, leaving 8" free at each end.
4. Now connect the wires to the battery, one end of the wire at each terminal (end) of the battery. Try to pick up paper clips with the nail now.
5. How many paper clips can you pick up? How could you change your electromagnet to be able to pick up more paper clips? Can you figure out how to channel more than one battery's electricity to your electromagnet?

6. ELECTROMAGNETS

MAKING THINGS MOVE

You will need:
- 25 feet of uncoated copper wire
- 2 to 6 neodymium magnets
- AA battery & AAA battery

1. Wrap the wire around the AA battery until you have made a long coil.
2. Attach 1 to 3 neodymium magnets to each end of the AAA battery and watch what happens when you put it inside the coil. Adjust the positions of the batteries if necessary.
3. Design your own experiments to see how the tightness of the coil or the number of magnets affects the movement of the battery.

Find out more: In this activity, your electricity travels from your battery through the copper coil due to electromagnetic waves. How can you re-design either of your electromagnets to make them stronger? Consider how tightly wound your coil is. Does that affect the strength of your battery?

*Images on this page are from FrugalFun4Boys.com

Selection of Next Generation Science Standards for Grades 3-8 related to the Activities and Film

Energy
4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

4-PS3-4. Apply scientific ideas to design, test, and refine a device that converts energy from one form to another.

MS-PS3-3. Apply scientific principles to design, construct, and test a device that either minimizes or maximizes thermal energy transfer.

Engineering Design
3-5-ETS1-1. Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.

MS-ETS1-1. 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.

3-5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.

MS-ETS1-2. Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

3-5-ETS1-3. 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.

Forces and Interaction
MS-PS-2. Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.

Motion and Stability: Forces and Interactions
MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

Structure, Function and Information Processing
MS-LS1-8. Gather and synthesize information that sensory receptors respond to stimuli by sending messages to the brain for immediate behavior or storage as memories.

4-LS1-2. Use a model to describe that animals receive different types of information through their senses, process the information in their brain and respond to the information in different ways.

Structure and Properties of Matter
MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

5-PS1-3. Make observations and measurements to identify materials based on their properties.

Waves and Their Applications
4-PS4-2. Develop a model to describe that light reflecting from objects and entering the eye allows objects to be seen.

MS-PS4-2. Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

For further information,
visit **www.nextgenscience.org**

To find out more about the giant screen film ***Aircraft Carrier***, please visit:

www.aircraftcarrierfilm.com

Aircraft Carrier is produced & distributed by K2 Communications and Giant Screen Films

RESOURCES

General:

http://www.navystemfortheclassroom.com/
http://www.navy.com/about/equipment/vessels/carriers.html
http://www.navy.com/navy-life/life-on-a-sub.html#why-live-on-a-sub
http://www.navy.com/navy-life/winr.html
"Rise of the Machines: Aircraft Carrier": https://www.youtube.com/watch?v=gV7bOZOo-h0
Life on a carrier: https://www.youtube.com/watch?v=lMwzHrrf0bw
Life on a sub: https://www.youtube.com/watch?v=8vyaFMbPWNo

Activity #1:

http://adventure.howstuffworks.com/outdoor-activities/water-sports/life-jacket1.htm
http://www.pbs.org/wgbh/nova/lasalle/buoyancy.html
https://www.schooltube.com/video/7100de854a0a40fead91/Bill%20Nye%20-%20Buoyancy

Activity #2:

http://www.airspacemag.com/how-things-work/the-meatball-8421491/?no-ist
http://www.navy.mil/navydata/ships/carriers/rainbow.asp
http://carrierlandingconsultants.com/
https://en.wikipedia.org/wiki/Modern_United_States_Navy_carrier_air_operations

Activity #3:

http://www.mtu.edu/materials/k12/experiments/tensile/
http://www.azom.com/article.aspx?ArticleID=3426
http://science.howstuffworks.com/aircraft-carrier4.htm

Activity #4:

https://www.f35.com/about
https://mynasadata.larc.nasa.gov/science-practices/electromagnetic-diagram/

Activity #5:

http://illumin.usc.edu/142/taking-off-and-landing-on-an-aircraft-carrier/
http://science.howstuffworks.com/aircraft-carrier3.htm

Activity #6:

Electromagnetic Aircraft Launch System: http://www.ga.com/emals
World's Simplest Electric Train: https://www.youtube.com/watch?v=J9b0J29OzAU