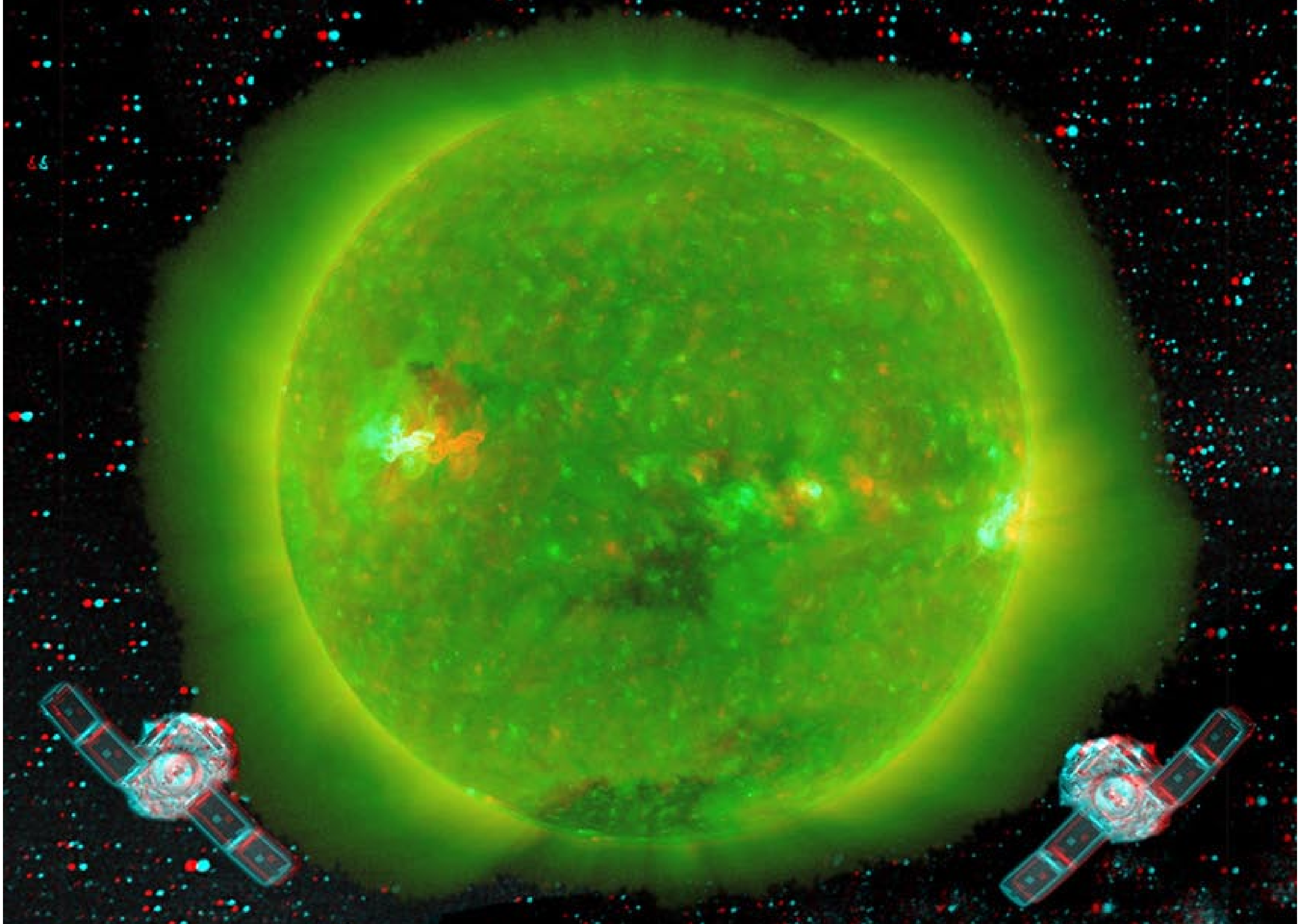
National Aeronautics and Space Administration

# The 3D Sun

from the Solar and TErrestrial RElations Observatory



The twin **STEREO** spacecraft observe the Sun from two locations to provide the first views of solar activity in 3D. In this image taken in extreme ultraviolet light, the brighter areas are active regions, often the sources of solar storms.

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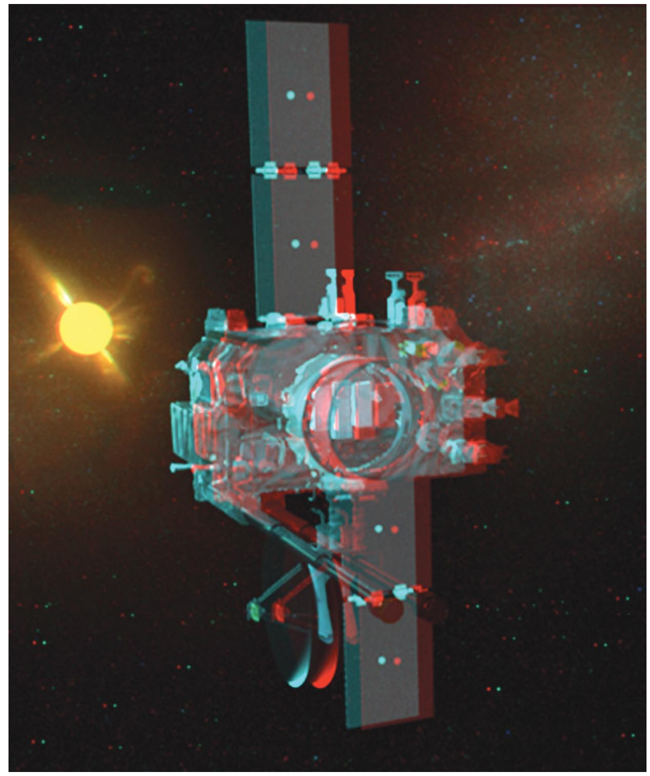
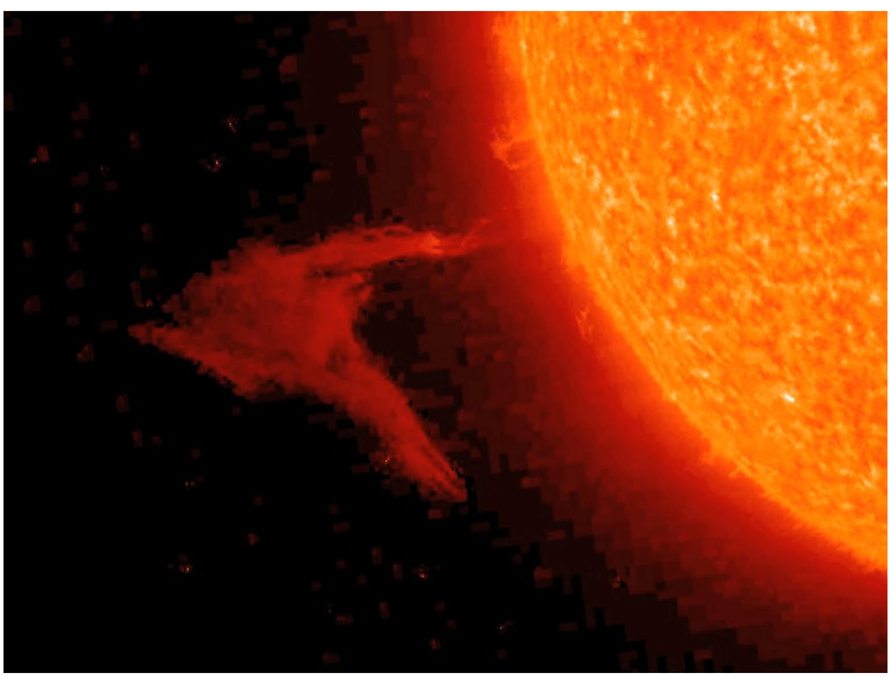
# The STEREO mission

The STEREO (Solar TErrestrial RElations Observatory) mission consists of a pair of two nearly identical space-based observatories. One spacecraft moves ahead of Earth in its orbit; the other trails behind - to provide the first-ever stereoscopic measurements to study the sun and solar storms. The nickname for this kind of vision is “3-D” for three-dimensional. STEREO’s two spacecraft with identical instruments can view almost the entire sky from sun to Earth. This lets STEREO obtain a 3D view of solar storms when they occur and follow the changing shape of the clouds of particles called coronal mass ejections (CMEs) as they travel out and away from the sun. CMEs are the most powerful explosions in our solar system. The sun is an active star, like most stars, and it is capable of developing solar storms at almost any time. The mission is giving scientists for the first time the opportunity to observe and track the speed and changing structure of these storms from positions ahead of and behind Earth.

STEREO was launched from Cape Canaveral, Florida, in late 2006. The two spacecraft, with their identical set of instruments, are slowly separating so that by 2011 the two of them together will be able to view the entire sun at once. (As of mid-2008 they were about 65 degrees apart.) From there they will continue on around the sun. They will be able to identify active regions, which are areas of intense magnetic fields, before they rotate into view from Earth. Active regions are often the sources of solar storms. With the Behind spacecraft, we can see these earlier than ever before - a big help for inmproving predictions of solar storms.



*3D illustration of one of two STEREO spacecraft*



*A solar prominence in UV light taken by STEREO*

Each spacecraft is about the size of a golf cart, but its solar panels stretch out about 21 feet (6.5 m). STEREO has instruments that can detect and measure radio wave bursts associated with solar storms and others that gather information about the particles themselves as they pass by the spacecraft. Another instrument takes images of the sun in ultraviolet light (see image left). We cannot see UV light with our eyes, but it is a very useful way to observe features of the sun. Other instruments block out the sun so that we can observe the atmosphere surrounding the sun (called the corona). These coronagraphs can observe CMEs blasted out from the sun and into space. Finally, other telescopes on STEREO keep an eye on the remaining space from sun to Earth so they can track solar storms.

Though the STEREO mission is sure to produce more discoveries and new science, it is likely that STEREO will be best remembered as the first mission ever to produce true 3D images of the sun.

***Daily images and movies are available at stereo.gsfc.nasa.gov/***

# Learning about Space Weather

We are magnetically connected to the sun. Particles stream from the sun in all directions as solar wind and sometimes powerful solar storms blast out many more charged particles. One of the most important solar events from Earth's perspective is the coronal mass ejection (CME). A CME is the eruption of a huge bubble of plasma (ionized gas) from the sun's outer atmosphere, or corona. The corona is the gaseous region above the surface that extends millions of miles into space. Complicated magnetic fields extend from the interior to create great arches and loops above the surface. The buildup and interaction of these magnetic loops supplies the energy to produce the violent explosion of a CME. We call these solar storms space weather.

One theory is that the magnetic loops of the sun's field hold down the newer magnetic fields emerging from below the sun's surface. They also help restrain the hot plasma carried by those fields, much like a net holding down a hot-air balloon. Scientists suggest that this causes tremendous upward pressure to build until the magnetic field breaks apart, allowing a CME to escape at high speed. These events can occur almost daily, but most are rather small. We are most concerned about the largest solar storms.

A CME plasma cloud, which carries magnetic field along with it, races through space at speeds from near one million miles per hour (400 km/sec) to 5 million mph, so that one directed towards Earth can reach us in one to five days. A typical CME can carry more than 10 billion tons of plasma into the solar system, a mass equal to that of 100,000 battleships. The energy in the bubble of solar plasma is comparable to a hundred hurricanes. Its energy and magnetic fields associated with that plasma impact Earth's protective magnetic shield in space, the magnetosphere.

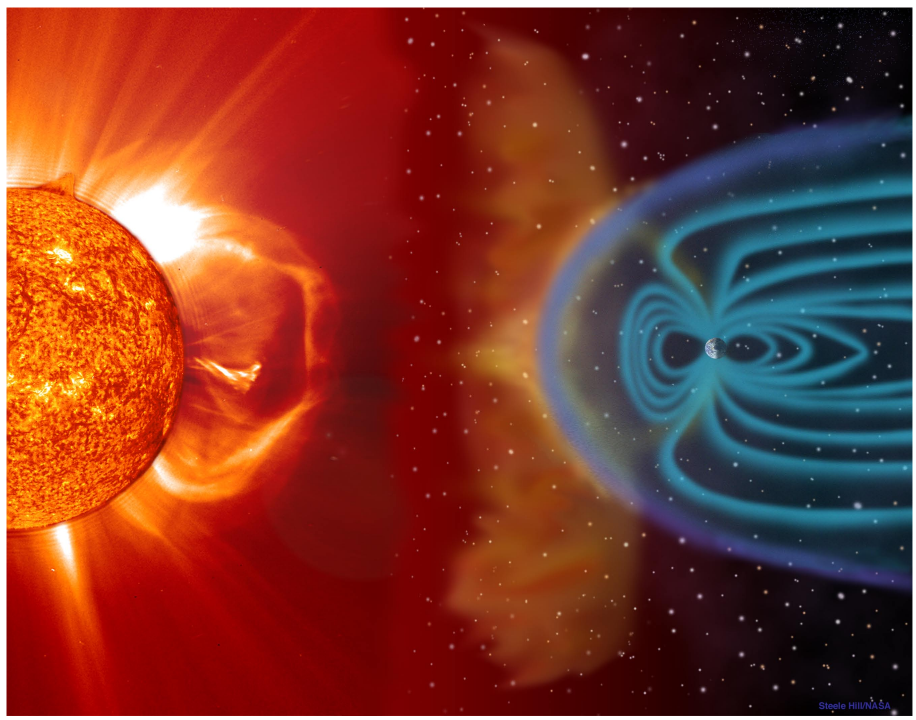
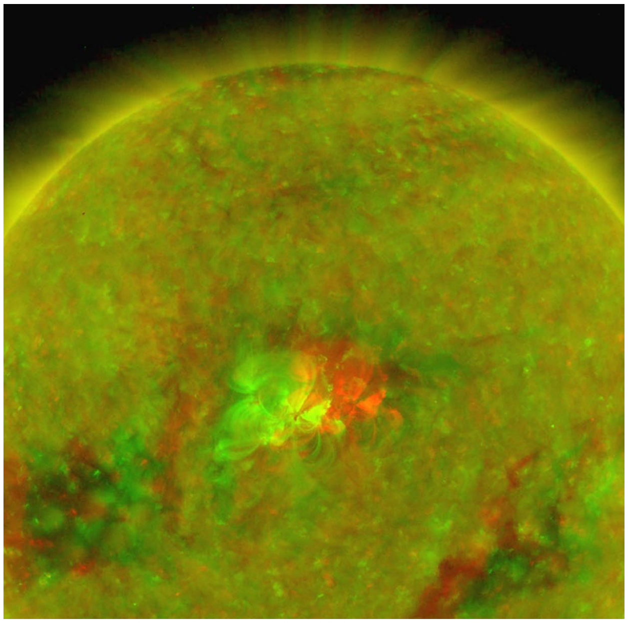



*Illustration of a CME exploding from the Sun and heading towards Earth*

How does this affect Earth and its people? The energy from a CME does not directly reach the surface of Earth. The cloud is blocked by Earth's magnetosphere, then slides around to the back side of Earth, where it can inject energy into the magnetosphere (*in blue at right)*, exciting particles trapped there. Under certain conditions, the particles follow the magnetic field lines down to Earth near the Poles. The visible signs of this activity are beautiful aurora (often called Northern and Southern lights), shimmering curtains of colorful, glowing lights in the night sky. However, at times a range of technological equipment suffers harmful effects: satellites fail, electric generators get overloaded; and communication and navigation equipment become disrupted. Astronauts can even become ill by solar storm radiation.

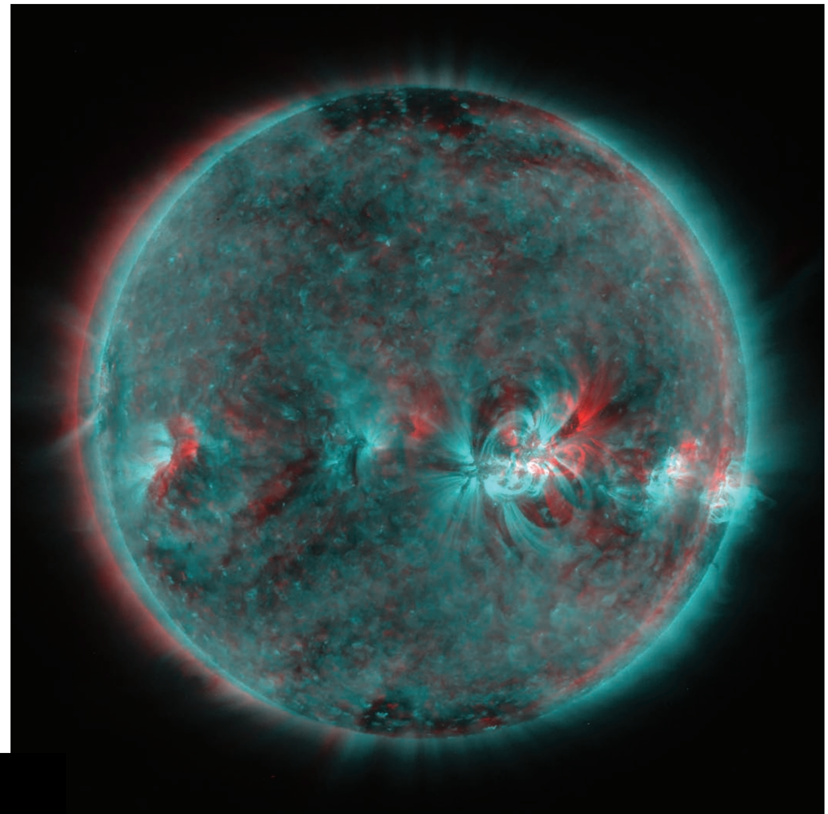
Scientists are working hard to find ways to better observe and then predict when these solar storms will occur and how Earth will respond. The SOHO spacecraft (launched 1995) has been a major workhorse for solar study, observing the sun 24/7 with 12 instruments. TRACE (1999) studies small areas of the sun's surface in great detail. Hinode (2007) captures detailed images and data on the sun. And the Solar Dynamics Observatory (late 2008) is taking over part of SOHO's role, bringing to bear new and greatly enhanced instruments. With a fleet of spacecraft in place, NASA will be able to model all types solar activity and impacts from the sun to Earth and even beyond. If human spaceflight is going to carry astronauts to the Moon, Mars, and even further, we need to know much more about predicting solar storms.

# 3D Images from NASA



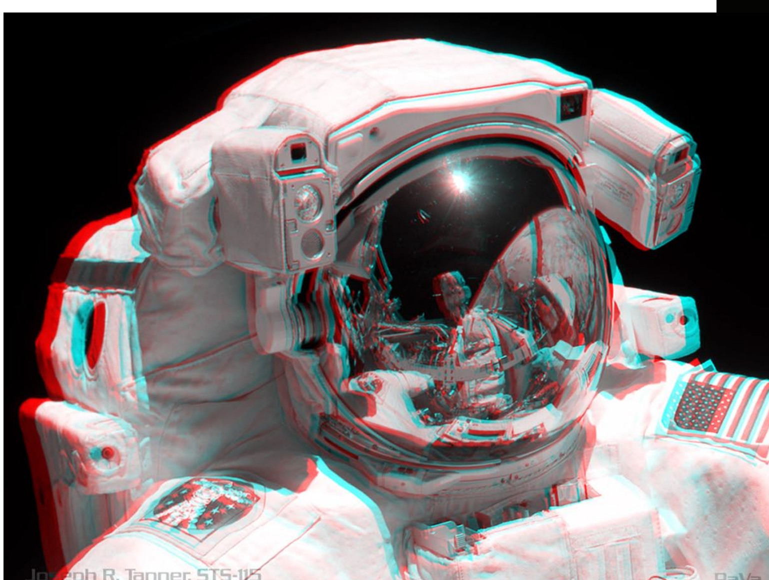
Credit: STEREO/NASA

*Loops of charged particles arc above the sun's surface*



Credit: STEREO/NASA

*Several active regions in UV light*




*NASA astronaut Joe Tanner on the International Space Station*

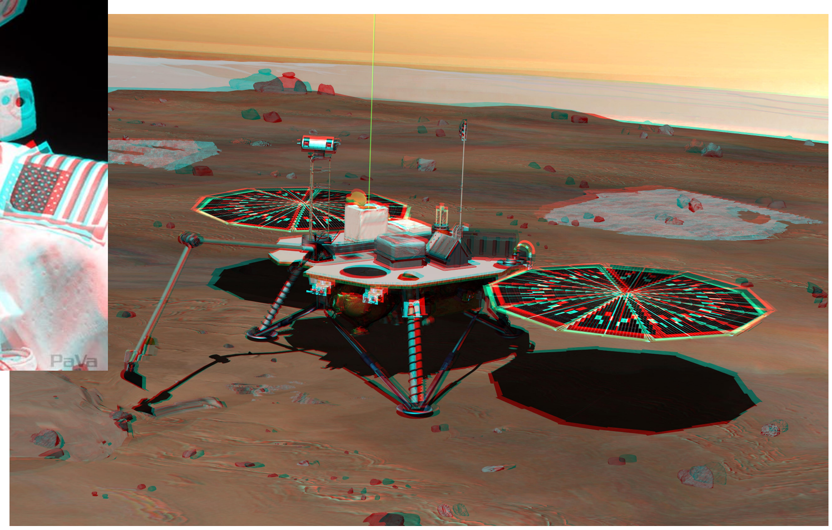
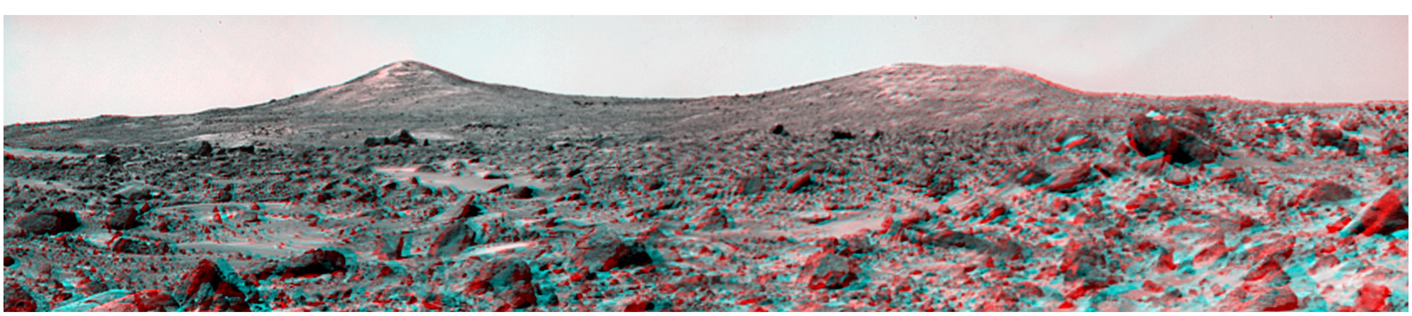


*Illustration of the Phoenix explorer on Mars*



*Mars landscape taken by one of NASA's Mars Rovers*

# Making your own 3-D images

You can create your own red/blue 3D images to print, or view on a computer screen, using a normal digital camera and some image processing software. For this activity we explain how to use Adobe Photoshop, but you should be able to get the same results using similar programs by playing around with similar tools and settings. To recreate this 3D effect, we need to simulate binocular vision. In short, we need to take two photos of our subject, separated by a short distance (the distance between your eyes: about 3 inches), then make it so your left eye only sees the left image and your right eye only sees the right. We will use red/blue 3D glasses and when viewed through the glasses, our photo will appear three-dimensional!

You will need:

- A digital camera
- Photo editing software (Such as Adobe Photoshop, but others will work as well. An alternative for PCs is the online freeware program called GIMP.)
- Red/blue 3D glasses (You can make your own: http://stereo.gsfc.nasa.gov/classroom/glasses.shtml)

Step 1 - Pick a subject. It is easier to take photos of objects or landscapes because we need to take two photos that are as identical as possible. Shots of people can work if they stay still for the time it takes you to snap two photos. Take your first photo, then try to slide the camera over 3 inches and take the same photo again. (You can take one photo looking through your left eye and the second while looking through your right.) A common mistake is to take the pictures too far apart. Take several pairs of photos and select the best pair later on.

Step 2 - Download the photos to your computer and open them up in a photo-editing software such as Adobe Photoshop. Any program will work if it allows for red, blue, and green color channels to be manipulated independently.

Step 3 - Once both pictures are open, convert them both to grayscale by clicking on IMAGE in the menu bar and selecting MODE then GRAYSCALE. [Image>Mode>Grayscale]

Step 4 - Convert the right photo back to red, green, and blue (RGB) by clicking IMAGE on the menu bar and selecting MODE, then RGB (the image will still appear gray). [Image>Mode>RGB]

In the Channels tab (in the layers palette between the LAYERS and PATHS tabs), select the red channel by clicking on the word RED - NOT the little eye next to it (eyes indicate which channels are displayed, not selected). Only that channel should appear highlighted.

Step 5 - Go back to the left photo and select the entire photo [Ctrl-A] for PC or [Command-A] for Mac. Then copy the image [Ctrl-C] for PC or [Command-C] for Mac, and return to the right photo and paste the image [Ctrl-V] for PC or [Command-V] for Mac.

Step 6 - Now you are ready to complete the merging of the left and right images. Go back to the channels palette. Click on the little box next to RGB. An eye should appear in all four channels but still only the red channel is highlighted. You should now have a mostly black and white image with red and blue halos.

Step 7 - Next, the left and right eye images need to be better aligned to remove as many of the halos as possible. This is achieved by centering the two images on the subject of your photo (typically what is in front and center - the easiest part of the 3D photo for people to focus on). Select the move tool [press V] then use the arrow keys to move the red image until you see the best alignment. We are trying to remove the halos from around our subject, though objects towards the edges will still be quite haloed.

Step 8 - The final step is to crop the image down to the size you want using the crop tool located in the tool bar (left hand column, third tool down). Once you have selected the area of the image you want to keep hit ENTER to crop the image. Now that you are done, don't forget to save!

When you look at your image using red/blue 3D glasses, you should see the scene appear in 3D. If your 3D image seems to move away from you, you probably have the right and left images reversed. Start over. Try experimenting for a while with taking photos and creating the images to get the best results.

Credit: Steele Hill, NASA

*Home-made 3D photo using a hand-held camera*

*Adapted from Ethan Hurdus and Jacob Noel-Storr, Science Camp Watonka, CAPER Team*