AIAA

AEROSPACE MICRO-LESSON

Easily digestible Aerospace Principles revealed for K-12 Students and Educators. These lessons will be sent on a bi-weekly basis and allow grade-level focused learning. - AIAA STEM K-12 Committee.

THE SOLAR DYNAMICS OBSERVER

The Solar Dynamics Observer was launched on February 11, 2010 to study the "weather" in space that is caused by the Sun. After launch it climbed up to a geostationary orbit in which it goes around the earth exactly once per day. You can find an overview of the project at NASA's Mission Pages.

Next Generation Science Standards (NGSS):

- Discipline: Motion and Stability: Earth's Place in the Universe
- Crosscutting Concept: Patterns
- Science & Engineering Practice: Analyzing and Interpreting Data

GRADES K-2

1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.

The sun is something that all of us notice. We comment on whether it is a sunny or cloudy day, whether it is too hot or too bright. And we have all been warned not to stare directly at the sun. Even though humans cannot look directly at it without hurting their eyes, NASA has something that can watch the sun without even blinking. It is the Solar Dynamics Observer, or the SDO. Just as your name tells who you are, so does the SDO's name. Solar means that it deals with the sun. Dynamics means that it studies changes and motion. Observer means that it watches; formally speaking, it holds science machinery that is used to study things that happen in nature. Put that all together and you have a satellite that is full of equipment to watch and record what is happening on the sun, all day, every day.

Why do we need to study the sun? Even though people have always noticed the sun, there are still many things we don't know about it. The sun is important to us because it provides light and heat to Earth, but it can also cause problems. For instance, too much sun on someone's skin can cause a sunburn. The sun can also cause trouble for machines like cell phones and GPS systems. If the scientists at NASA gather enough information, they will be able to predict when the sun is going to act up and we can be prepared. To do that, there are several different kinds of equipment built into the SDO. Some take images of the sun's atmosphere, others measure the extreme ultraviolet (UV) light that the sun releases, and still others measure magnetic fields on the sun's surface. You can see some of the incredible pictures from the SDO in the gallery of images. The next time you draw a

Grades K-2 (continued)

picture of the sun, you may want to use some of the colors the SDO uses; you can tell everyone you are making a scientific picture.

For information about the sun itself, you may wish to read *The Sun: Our Nearest Star* by Franklyn M. Branley, *The Sun: All about solar flares, eclipses, sunspots and more!* by Seymour Simon, or *Sun! One in a Billion* by Stacy McAnulty.

Grades 3-5

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from the Earth.

We all know that there are cycles in nature. Life cycles, day and night, the seasons, and the water cycle are just a few. But did you know that there are cycles within the sun and on its surface? NASA's Solar Dynamics Observer (SDO) studies the sun constantly to gather information about those cycles. It may be hard to imagine that something as far away as the sun can interfere with cell phones or even the supply of electricity to our homes, but it can. At least we have the atmosphere to protect us from some of the sun's effects, but astronauts working out in space are very vulnerable. By studying things like solar flares, NASA will be better able to protect our astronauts and satellites.

There is a short video explaining the science of the mission. (The video was made before the SDO was launched so it speaks in the future tense. Some of the specific numbers given in the video have also changed since the mission began.) It explains the basic purpose of the observatory and the equipment it uses. Most of it is similar to things we use, just much more sensitive and more of it. For instance, the cameras take images with 4,000 x 4,000 pixels (very high resolution). This allows the scientists to take very clear pictures of the entire disc of the sun, rather than only a small portion of it. They are able to take a picture every few seconds instead of every 3 minutes. Imagine how much they are learning about all those cycles with that much information!

For more detailed explanations of the equipment and mission, you may read the SDO Guide, which includes photos of the spacecraft and its components and descriptions of their intended purpose. The AIA page includes a pattern and instructions for folding a trihexaflexagon based on the SDO. The students may enjoy making and "flexing" it.

Grades 6-8

MS-ESS1-1.Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

One of the instruments on the Solar Dynamics Observer is the Helioseismic and Magnetic Imager (HMI). The HMI includes two cameras, each creating images 4,096 pixels across, taking pictures "at a 4-second cadence for each camera" and sending data at a rate of 55 Mbits/sec. Let's do a little arithmetic.

A camera with 4,096 pixels in each direction has 16,777,216 pixels (or 16 megapixels) in all. The word "pixel" is short for "picture element" and is one "dot" on the camera's image. It may be instructive to work the multiplication on the board:

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     4,096
   x 4,096
----------
    24 576
   368 640
        00
16 384 000
----------
16,777,216
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Each pixel will have some brightness; it is the differing brightnesses of the pixels that make up the image as a whole. In the simplest form, a pixel can be either on or off - light or dark. With the SDO cameras, however, a pixel can have an intermediate brightness. If - and this is a guess - each pixel is represented by an eight-bit number, it can record 256 different levels of brightness. Multiplying the eight by the number of pixels means that each image has 134,217,728 bits of information in it. At a data transfer rate of about 55 Mbits per second, each image takes a little longer than two seconds to transmit. With two cameras, each camera downloads one image every four seconds or so.

By way of comparison, a CD contains about 700 MB of data. Forty of these images, comprising about three minutes' worth of data, would pretty much fill up a CD. (In fairness, data compression techniques would reduce considerably the amount of storage space required for the data.)

We can also do some arithmetic with the angles and distances on the Sun. The HMI imager specification states that the field of view shall be greater than 2,000 arc-seconds.

GRADES 6-8 (CONTINUED)

Dividing by 60 and by 60 again to convert to degrees gives a field of view of at least 0.55 degrees. The Sun encompasses an angle of about half a degree as seen from the earth; thus the HMI is guaranteed to be able to take a picture of the whole Sun at once.

The angular resolution, which is the angular size of the smallest feature that the HMI can distinguish, is specified to be less than 1.5 arc-seconds. With a field of view of at least 2,000 arc-seconds and a camera size of 4,096 pixels, one pixel will cover an angle of about 0.5 arc-seconds. (This is an excellent exercise in using rounded numbers.) The smallest feature that the camera can detect will therefore be no more than three pixels wide.

We can divide the angular resolution by 60 twice to convert it to degrees to get 0.000417 degrees. From this angle, and from the distance between the Earth and the Sun, we can calculate the width of the smallest feature the HMI can distinguish on the Sun. We use a ratio. A full circle is 360 degrees; the circumference of a circle is "$2\pi R$", where "R" is the radius of the circle. In this case the radius is the distance between the Earth and the Sun, or 93,000,000 miles (150,000,000 kilometers). The width "w" of the smallest feature is the ratio of the angular resolution to 360 degrees, multiplied by "$2\pi R$":

$$\frac{w}{2\pi R} = \frac{0.000417\,\text{deg}}{360\,\text{deg}}$$

From this ratio we find that the smallest feature that the HMI can distinguish is about 680 miles (1,090 kilometers) across.

GRADES 9-12

[HS-ESS1-1. Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy that eventually reaches Earth in the form of radiation.]

The Solar Dynamics Observer was placed in a geostationary orbit, meaning that it stays above the same point on the earth at all times. By contrast, the Solar and Heliospheric Observatory (a predecessor mission also aimed at studying the Sun) was placed in a position between the Earth and the Sun where the gravity of the two bodies balances out. Why the difference? A large part of the answer lies in the amounts of data that the two observatories send back to the Earth. The SOHO spacecraft sends little enough data—

GRADES 9-12 (CONTINUED)

about 200 Kbits/second—that it can share receiving stations with other space missions. The SDO spacecraft, on the other hand, has a receiving station dedicated to itself. The HMI instrument on the SDO spacecraft, as mentioned in the Grades 6-8 lesson, sends data at a rate of 55 MBits/second. Other instruments on the SDO send more data, giving a total data download rate of 150 MBits/second. This is 750 times as much data per second, 24 hours per day, as the SOHO spacecraft. This larger data rate caused mission planners to place the SDO in earth orbit where it is always in the same place in the sky relative to its ground station and much closer than the SOHO spacecraft.

Sixty Years Ago in the Space Race:

Oct. 24, 1960: To rush the launch of a Mars probe before the Nov. 7 anniversary of the Bolshevik Revolution, Field Marshall Mitrofan Nedelin ignored several safety protocols and 126 people are killed when the R-16 ICBM explodes at the Baikonur Cosmodrome during launch preparations. There is a short clip from the History Channel available here: The Nedelin Catastrophe.