Educating Space Age Environmentalists:

A Kindergarten-High School Standards-Based Curricular Approach

(Aligned to the Next Generation Science Standards for Earth and Space Science)

GRADE 7

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Grade 7

Introduction:

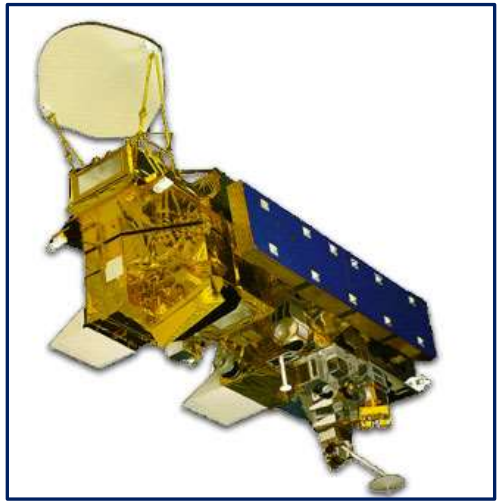
Outer space is a valuable natural resource because it is home to satellites such as Aqua and GOES-13 that give us a global look at Earth processes and cycles and how they change over time. To ensure that such spacecraft can continue to navigate space safely, we need to design technologies to remove large pieces of debris from orbit.

Students learn how energy from the sun and the force of gravity drive the water cycle through a lesson designed by NASA that aligns with **MS-ESS2-4.** As a culminating activity, students create their own model of the water cycle from the viewpoint of a water molecule.

Extension 1 materials include two video excerpts from NOVA's "Earth From Space" program that help students gain greater appreciation for the indispensable role played by satellites in understanding the water cycle and how it creates Earth's weather. The Aqua satellite and five weather tracking satellites, including GOES-13, are highlighted.

Extension 2 features a design team project—Engineering Designs for Active Debris Removal—that is aligned with **MS-ETS1-2** – Engineering Design. Basic educational materials in the form of readings and videos are used to inform students about the threat orbital debris poses to spacecraft and about several active debris removal technologies that are under investigation. Student teams are assigned to research one or another design and report back to the class on its strengths and limitations.

Grade 7

Next Generation Science Standards Alignment	Spacecraft Featured: *AQUA Satellite*	NASA Main Page for Featured Spacecraft: Click here for AQUA.
Disciplinary Core Idea/Sub-Idea: **ESS2. Earth's Systems** **The Roles of Water in Earth's Surface Processes – (ESS2.C)** Grade 7: Earth and Space Sciences MS-ESS2-4. Develop a model to describe the cycling of water through Earth's systems driven by energy from the sun and the force of gravity.	 **Credit: NASA**	*Aqua, Latin for water, is a NASA Earth Science satellite mission named for the large amount of information that the mission is collecting about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice…Aqua was launched on May 4, 2002, and has six Earth-observing instruments on board, collecting a variety of global data sets.* *-From NASA Website*

NSTA-Vetted Lesson Plans – NGSS@NSTA

Instructional Resource: "Exploring the Water Cycle" (NSTA-vetted lesson) – Designed to take at least two 45-minute class periods to complete. This resource is one in a series of Global Precipitation Measurement (GPM) Originals, a collection of educational resources and videos developed by the GPM staff, based on Global Precipitation Measurement, an international satellite mission created to unify and advance precipitation measurements from space for scientific discovery and societal applications.

Overview:

In this NASA lesson, students learn about the water cycle, and how energy from the sun – as well as the force of gravity – drive this cycle. To understand more fully the processes that take place in moving water through Earth's system, students observe and investigate the movement of water through the different stages of the water cycle, and determine what drives this cycle. First, students explore the meaning of "precipitation." Next, they view a video, showing why the water cycle is important, and take notes while observing a simple version of the water cycle. They are then asked what stages require solar radiation, which require water to give off heat, and which are driven by the force of gravity. As they view teacher demonstrations, students complete a worksheet in which they record their observations

of various processes in the water cycle, and how energy is involved. Throughout the duration of the lesson, students build their understanding of the water cycle through experiencing and seeing different models. As a culminating activity, students create their own model of the water cycle from the viewpoint of a water molecule, including the processes, the energy involved, and the gravity. (From website below.)

Click here for a description of the materials, a full listing of alignment to NGSS, and suggested modifications to more fully align with the NGSS.

Click here for the lesson plan and accompanying resources, including a teacher's guide, student capture sheet, PowerPoint presentation, and pre- and post-assessment are found at:

Following this lesson, students will be able to:

- Explain how energy from the sun and the force of gravity drive the water cycle.
- Understand the processes that take place in moving water through Earth's systems.

Extension 1: Outer space is a valuable natural resource, serving as home to spacecraft that provide essential information and perspective for understanding Earth's Place in the Universe, Earth's Systems, and Earth and Human Activity.

Instructional Focus: The Aqua satellite enables scientists to observe the global pattern of water vapor circulation and learn how it connects to the Sun, oceans, atmosphere, and life.

Two video clips from NOVA – "Earth from Space" are recommended for grade 7, and are excellent resources correlated with the NSTA-vetted lesson. Both video clips demonstrate the critical role played by satellites in understanding the water cycle and how this cycle creates Earth's weather.

- **Video: *Water Vapor Fuels Hurricanes* – NOVA: "Earth from Space" – WGBH Educational Foundation – 2013 – (5 min.)**

This video depicts data visualizations showing what water vapor evaporating from the ocean's surface might look like if one could see it. The video illustrates how NASA's Aqua satellite uses infrared wavelengths to monitor the oceans and the production of water vapor. Students learn how the Sun's heat warms ocean water and creates water vapor through the process of evaporation. They see that when water vapor condenses in the atmosphere, heat is released that helps to fuel storms. Simulations in the video show how large cloud formations can develop into powerful hurricanes that have a major impact on human life.
Click here for the video.

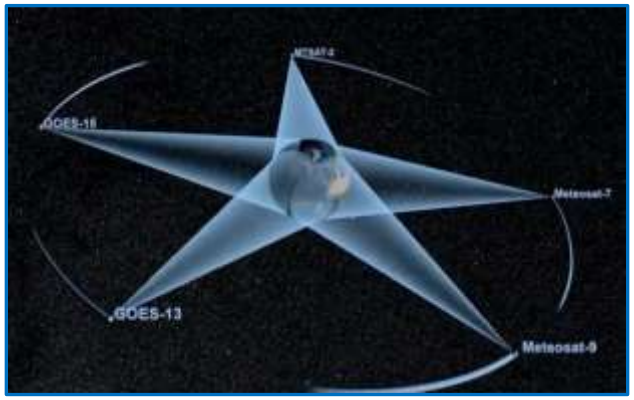
- **Video: *Monitoring Earth's Water Vapor* – NOVA: "Earth from Space" – WGBH Educational Foundation – 2013 – (5 min.)**

This video enables students to observe the global pattern of water vapor circulation, and learn how this circulation pattern connects the Sun, oceans, atmosphere, and life. Video animations show how satellites in geostationary orbit provide a global view of water vapor movement. Students see how water vapor produced near the equator travels toward Earth's poles, transporting energy and creating weather, as well as how variations in topography result in different weather outcomes.
Click here for the video.

Both videos also have accompanying helpful resources for teachers, including:

- A background essay that provides an overview for students.
- Learning points that describe the main ideas of the video.
- Discussion questions.
- Strategies for teachers on how to utilize the video.

After viewing one or both videos, a key point to emphasize with students is that outer space is a valuable natural resource, because it is "home" to the AQUA satellite (Latin for "water") that orbits the poles, monitoring the complex interaction between sunlight and water; and also home to the five weather-tracking spacecraft, including the Geostationary Operational Environmental Satellite (GOES) spacecraft, orbiting 22,000 miles above the earth. Combined data from these five satellites provide a picture of the entire earth, showing the impact of the sun on water, and how this impact varies in different locales.



Left: Graphic showing geostationary orbit of the 5 weather-tracking spacecraft, orbiting 22,000 miles above Earth.

Right: A city scene after an Asian monsoon.

(Above: from video – *Monitoring Earth's Water Vapor*)

Extension 2: The growing problem of space debris requires us to clean up the space environment - utilizing new technologies and public advocacy - before it becomes too dangerous to navigate.

Instructional Focus: Students participate in a design team project entitled, "Engineering Designs for Active Debris Removal" that is aligned with MS-ETS1-2. After learning about ongoing research into several technologies, student teams research the various concepts and report to the class on their respective strengths and limitations.

Next Generation Science Standards Alignment

MS - ETS1 – 2. Engineering Design

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

Background: In 2011, the National Research Council (NRC) reported the debris problem had reached a tipping point in key Earth orbits. The density of debris is now so great that collisions among existing objects generate new pieces of debris faster than atmospheric drag remove them from orbit. Donald Kessler, who led the NRC study, said we have lost control of the space environment.

Because debris is growing exponentially, removing dead satellites and rocket bodies from orbits where collisions are most likely to occur is essential for stabilizing the space environment. Active Debris Removal (ADR) technologies reduce the volume of debris from which new debris can be created. Several ADR concepts are under investigation, but each poses technological challenges.

Two articles, two videos, a book, and a design team project are recommended for grade 6:

- **Article – "What is Orbital Debris" – from the *NASA Knows!* series for grades 5-8**

This article provides a helpful overview of the space debris issue. (*Protectouterspace.com* has updated this article, which is attached.)

- **Article – "Space Junk" – by Josh Adler - Readworks.org**

Click here for this article, as well as an accompanying vocabulary list, comprehension quiz, and answer key.

- **Video: *Tracking Space Junk - The Verge* - Jan. 16, 2017 – (6 min.)**

This video introduces students to the problem of orbital debris. From the website: *There is a whole bunch of debris zooming around our planet at more than 17,000 miles per hour. This space junk ranges in size from smaller than a marble to larger than a baseball, and it makes Earth orbit a whole lot more crowded — and dangerous.*

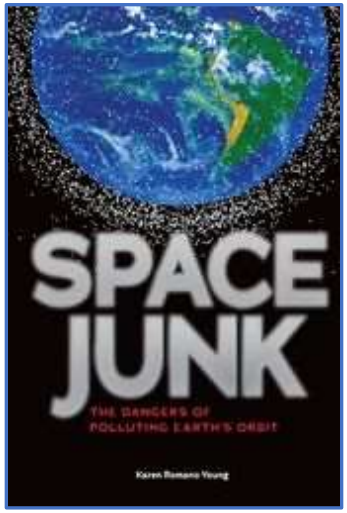
Click here for the video.

(Left: from video - *Tracking Space Junk* – Narrated by Lauren Grush)

- **Video: *5 Strange Ways to Clean Up Our Space Junk – Scientific American Space Lab* - Feb. 20, 2014 – (4 min.)**

This video introduces students to Active Debris Removal (ADR). From the website: *We look at some of the strangest proposals to combat the ever-growing cloud of space junk.* **Click here** for the video.

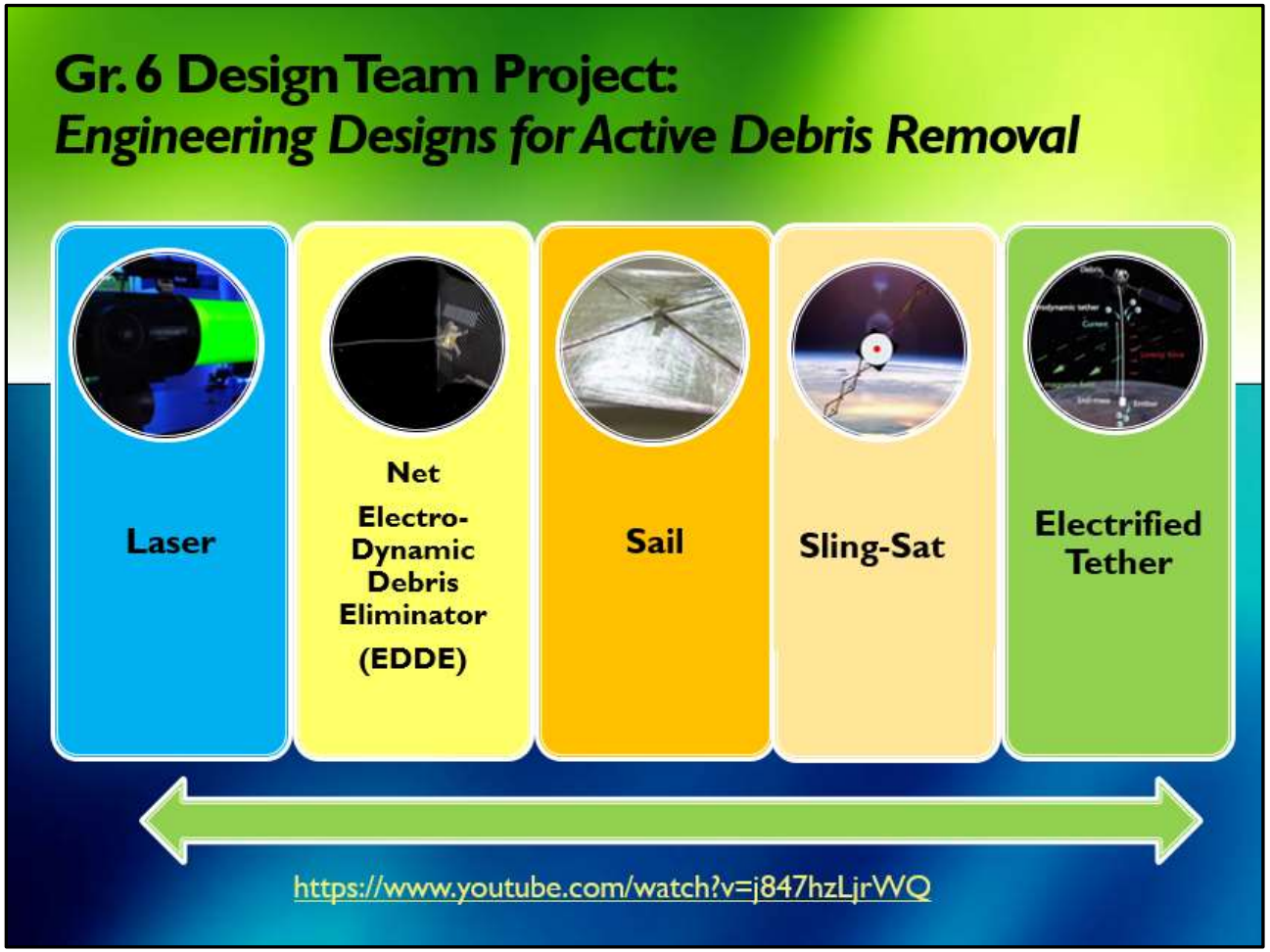
- **Book: *Space Junk – The Dangers of Polluting Earth's Orbit*, by Karen Romano Young (Recommended for ages 12-18)**



This book provides excellent background reading for the design exercise, particularly the sections entitled, "House Cleaning" and "The Time Has Come" – p. 46-51. "Taking Out the Trash" on p. 40-51 covers different types of methods for active debris removal, such as the CubeSail, the electrodynamic tether, the ElectroDynamic Debris Eliminator (EDDE), the Space Debris Elimination (SpaDE), the TAMU Sweeper, the e.DeOrbit, and CleanSpace One. Quote: "It's not only economically sound to clean up space. Satellites are vital to our modern way of life" – (p. 50). The book could be read by the entire class, or, it could be used as an enrichment/challenge activity for selected students to read.

Description provided by the publisher: *This book examines the proliferation of space debris in outer space and discusses methods of retrieving and disposing of the material.* School Library Journal Review: *"A great cover beckons readers inside what should be a fascinating tour of the space around Earth—and it is … There is little else available for students about this important topic for future space engineers."*

- **Design Team Project** – ***Engineering Designs for Active Debris Removal***



After viewing the *Scientific American* video, divide the class into five teams, one for each of the designs discussed in the video: lasers, nets (ElectroDynamic Debris Eliminator or EDDE), sails, Sling-Sat, and electrified tether.

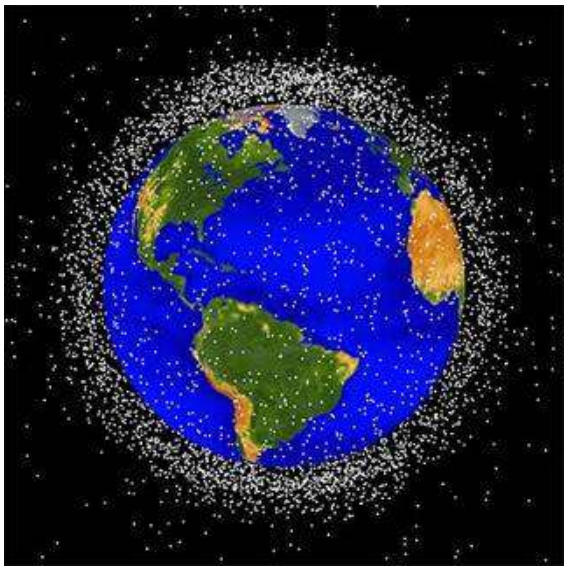
Have each team research its assigned design, and report back to the class on the design's strengths and limitations. If possible, invite a local STEM professional, ideally an aerospace engineer, to attend and participate in the discussion.

June 8, 2010

https://www.nasa.gov/audience/forstudents/5-8/features/nasa-knows/what-is-orbital-debris-58.html

What Is Orbital Debris?

This article is part of the NASA Knows! (Grades 5-8) series.



Most orbital debris is in low Earth orbit, where the space station flies.
Credits: NASA

Orbital debris (duh BREE) is "junk" that is circling Earth. It is pieces from spacecraft. Humans have been launching objects into space for more than 50 years. Most of those objects have fallen back to Earth. A piece of debris falls back to Earth about once a day. These objects either land or burn up in the atmosphere. Most objects that return to Earth end up in water, since it makes up 70 percent of Earth's surface. But many of the objects sent into space are still in orbit around Earth.

How Big Is Orbital Debris?

On one extreme, debris can be as small as tiny flecks of paint or bits of metal that have come off spacecraft. On the other, large debris could be an entire satellite that is no longer working. The most common source of orbital debris larger than 1 centimeter (0.39 inches) is the explosion of objects orbiting Earth. These are often rocket upper stages. They can contain fuel or high-pressure fluids.

Why Is Orbital Debris Important?

Most "space junk" is moving very fast. It can reach speeds of 4.3 to 5 miles per second. Five miles per second is 18,000 miles per hour. That speed is almost seven times faster than a bullet. And if a spacecraft is moving toward the debris, the total speed at which they collide can be even faster. The average impact speed of a piece of orbital debris running into another object is 22,370 miles per hour. Since it is moving so quickly, a tiny piece of orbital debris can cause a lot of damage. Being hit by a piece of debris smaller than half an inch around - traveling at about six miles per second - would be like being hit by a bowling ball moving at 300 miles per hour.

*How Much Debris Is in Orbit?

To keep astronauts safe, scientists use radar to keep track of all the debris in orbit. They classify it by its size. About 13,000 known objects are bigger than 10 centimeters in diameter. Scientists believe that there are more than 100,000 pieces of orbital debris between 1 cm and 10 cm. And tens of millions of pieces are smaller than 1 cm. All pieces of debris larger than 10 cm are carefully tracked using radar and telescopes. That information is used to estimate the number of small pieces of debris. Even though they cannot detect every piece, scientists have an idea of the amount of debris that is out there.

Experiments like the Long Duration Exposure Facility helped scientists learn more about orbital debris.
Credits: NASA

To determine how many pieces of very small debris - smaller than 1 millimeter - are in orbit, scientists study the space shuttle when it returns from orbit. They look for damage from debris impacts. When the space shuttle returns from missions, scientists count the number of impacts it experienced. They then compare the number of dents or holes to the amount of space the shuttle traveled through. These comparisons help them estimate how many of the tiny objects are in orbit around Earth.

NASA also has performed experiments in space to learn more about orbital debris. Satellites like the Long Duration Exposure Facility are brought back to Earth. Scientists then count the number of objects that hit the satellite. The LDEF was a satellite that was left in space for over five years. It tested what happened to materials exposed to space.

**Note from protectouterspace.com editor: Some figures are outdated. Here are the updated figures from the European Space Agency:*

Today 23,000 known objects are in the catalogue.

The European Space Agency says that as of January 2017, the number of debris objects estimated by statistical models to be in orbit is:

29 000 objects >10 cm
750 000 objects from 1 cm to 10 cm
166 million objects from 1 mm to 1 cm

How Do Astronauts Stay Safe From Orbital Debris?

Since NASA keeps track of larger debris, spacecraft with crews are able to dodge it. When an object is expected to come within a few miles of the International Space Station, NASA can slightly change the station's path to avoid the object. Plus, the space station is the most heavily shielded spacecraft ever. It can survive impact with smaller pieces of debris. The debris would hit panels that serve as shields instead of vital parts of the station.

Spacesuits also help protect crew members from orbital debris and micrometeoroids when the astronauts are outside the space station. The suits include a layer of strong, thin material that protects astronauts from impacts. This layer is made from the materials used in bulletproof vests.

Multiple layers of material in a spacesuit protect astronauts from being hurt by orbital debris impacts while on spacewalks.
Credits: NASA

Since the smallest pieces of debris cannot be tracked, collisions with them are bound to happen. The space shuttle often returns to Earth with tiny impact craters. Impacts have even created small cracks in the front windows. Windows are replaced after almost every mission. The shuttle has three layers of windows to protect the crew.

What Is NASA Doing About Orbital Debris?

As humans launch more and more objects, will Earth orbit turn into a dangerous, crowded junkyard? Space agencies around the world are working to make sure that does not happen. Since 1988, the United States has had an official policy to keep the creation of new orbital debris to a minimum. NASA even has an Orbital Debris Program Office at Johnson Space Center in Houston, Texas. This office looks for ways to create less orbital debris. It also looks for ways to get rid of debris that is already in space. Many U.S. aerospace companies also follow guidelines to reduce the creation of debris. The Russian, Japanese, French and European space agencies are keeping the creation of new debris low, too.

NASA and other space agencies are doing many things to reduce the problem of orbital debris. The upper stages of launch vehicles, and some satellites, are being placed in lower orbits. This location will cause them to re-enter the atmosphere and burn up sooner. Debris in orbits below 373 miles usually falls back to Earth within a few years. Objects at heights of more than 621 miles can stay in orbit for more than a century.

Words to Know

stage: one of two or more sections of a rocket that have their own fuel and engine

micrometeoroid: a tiny (size of a grain of sand) particle of space debris, natural or artificial, traveling through space at high speeds