
FIREFALL
Teacher’s Guide/NGSS Alignment
Eastern Florida State College Planetarium & GeoGraphics Imaging
Present Firefall
Based on the original script by Philip Groce Directed By Mark Howard & George Fleenor
Narrated By Philip Groce, Mike Harvey and Rita Moreno
Original Score and Sound Design by Troy McClellan/Full Dome FX, Inc
Animations by Joe Tucciarone Additional Animations by Mark Howard
Distributed By GeoGraphics Imaging

**http://www.nextgenscience.org/**

***FireFall* covers almost <u>every</u> middle school (grades 6-8) Next Generation Science Standard in the Earth and Space Sciences, and additional topics in Physical Sciences, Forces and Interactions, and Energy. The same standards for high school also are covered, and higher-level students are given the opportunity to use mathematical and/or computational skills.**

**The topic and nature of the program is appropriate for students in grades 6-12, and also is appropriate for gifted and advanced learners in grades 4 and 5.**

**I chose to align the program to the NGSS instead of the 1996 National Science Education Standards, which it replaces. It is a favorite of middle school teachers in my area (northeast Ohio/western Pennsylvania), and also makes for a great public program. The various Scout groups enjoy the "make a comet" demo.**

**The following isn't an exhaustive teacher's guide, but one that encourages you to follow the links to great material already available on line.**

**-Sharon Shanks, retired from Ward Beecher Planetarium at Youngstown State University sharon.shanks@gmail.com**

## Synopsis

The program begins with an explosion to introduce the fact that Earth has been (and continues to be) bombarded by objects from the solar system. The objects are left over from the formation of the sun and subsequent formation of the solar system.

The visual evidence for this event (the late heavy bombardment) is present on the surfaces of Mercury, Mars, our moon, and the moons of the large gas planets. Some evidence remains on the surface of Earth, but weathering, erosion, and other geologic events have all but erased the craters.

Next introduced are shooting stars: their source, connection of some to comets, and the predictable nature of annual meteor showers by knowing the source comet's orbit. Although most meteors do not reach the surface of Earth, there are exceptions, and these are reviewed.

Comets also were formed during the solar system's birth; their nature is explained and the impact of Comet Shoemaker-Levy 9 on Jupiter is featured as the first (and so far only) comet observed to strike a planet. Scientific ways of knowing (observation, hypothesis, research) connects with the Tunguska event from 1908, and the comet that exploded over Chelyabinsk in 2013.

Asteroids also were produced during solar system formation. Many are gravitationally held in the asteroid belt, but there are others whose orbits cross the path of Earth's orbit. These are Near Earth Objects (NEOs); technology is the tool that observing programs use to scan the skies for NEOs that might possibly strike Earth.

Study of Earth's systems shows that a catastrophic event was responsible for the mass extinction about 65 million years ago; an example of the steps outlined in ESS-2 is provided by the work of Luis and Walter Alvarez in discovering the probable KT event boundary crater.

Finally, the still-debated theory that impacting comets brought large amounts of water to Earth, possibly along with amino acids that are part of life, briefly connects the program to the life sciences. This is an excellent chance to pull current exploration (i.e. the Rosetta Mission) and discovery into the classroom and/or planetarium programs.

## Demonstrations (more below)

The best practice to follow in conjunction with seeing the program is pre- and/or post-visit hands-on demonstrations in the classroom and/or the planetarium itself. Two of the most common demonstrations are still the best: making a comet and making impact craters.

## Meeting the Standards

Taken together, the program and the classroom and/or planetarium demonstrations easily meet the following **Disciplinary Core Ideas**:

| DCI | Title |
|---|---|
| MS-ESS1 | Earth's Place in the Universe |
| | ESS1-1, ESS1-2, ESS1-3, ESS1-4 |
| MS-ESS2 | Earth's Systems |
| | ESS2-1, ESS2-2, ESS2-3 |

Especially good are the connections to Science and Engineering Practices (developing and using models, analyzing and interpreting data); the Disciplinary Core Ideas (about the universe and its stars; Earth and the solar system; Earth's materials and systems; plate tectonics and large-scale system interaction; the roles of water; and the history of planet Earth); and Crosscutting Concepts (patterns; cause and effect; scale, proportion, and quantity; systems and system models; energy and matter; and the nature of science).

The use of the Alvarez example is an apt connection to the nature of science, especially that scientific knowledge is open to revision in light of new evidence.

Additional topics in the program touch, sometimes to a large degree, are the Physical Sciences, Forces and Interactions, Energy

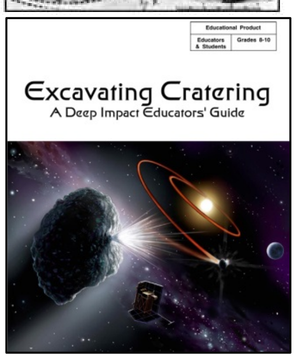
| | |
|---|---|
| [MS-PS1](#) | Matter and Its Interactions |
| | PS1-1, PS1-2 |
| [MS-PS2](#) | Motion and Stability: Forces and Interactions |
| | PS2-1, PS2-2, PS2-3, PS2-4 |
| [MS-PS3](#) | Energy |
| | PS3-1, PS3-2, PS3-5 |

The Science and Engineering Practices illustrated by *FireFall* include analyzing and interpreting data; obtaining, evaluating, and communicating information; and scientific knowledge is based on empirical evidence. Developing and using models and planning and carrying out investigations especially applies to the cratering activity.

Under Discipline Core Ideas, matter from space is part of structure and properties of matter and change of state; forces and motion applied to gravity, orbits, and kinetic and potential energy (including Newton's Third Law); types of interactions (gravity); definitions of energy; conservation of energy and energy transfer; and the relationship between energy and forces.

Crosscutting Concepts again include cause and effect; energy and matter (matter conservation); systems and system models; and scale, proportion, and quantity.

## Suggested Demonstrations


### Cratering

There are numerous online lessons and suggestions for making impact craters in the classroom. I have used several from NASA's *Exploring the Moon* teacher's guide and can endorse them.

To download the entire guide, go to www.nasa.gov/audience/foreducators/topnav/materials/listbytype/Exploring.the.Moon.html#.VbP3iflViko; you also have the option to download individual topics from the guide.

I also have used Lava Layering and Clay Lava Flows with success.

(My version of Word does not allow me to link directly to the guide. You can always copy and paste the above into your browser.)

An amazingly inclusive educator's guide from the Deep Impact mission called *Excavating Cratering* is available online. It pulls in almost every educational standard possible, along with math and technology.

## Make a Comet

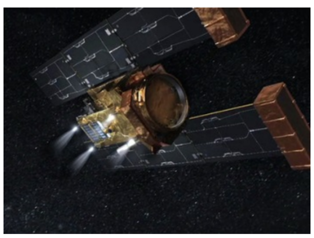
There are several good "recipes" online. One of the original and still one of the best is from Dennis Schatz at the Pacific Science Center: www.noao.edu/education/crecipe.html.

NASA's Jet Propulsion Laboratory has an excellent page called Create a Comet with Dry Ice that includes a helpful video from "Do It Yourself Space." There are many ways to mess up a making a comet demo (as I know from first-hand experience), so seeing it made correctly is worth the time it takes to watch the video.

Be sure to check out the other activities under Learn and Teach in the navigation menu on the JPL site.

Chuck Bueter at Nightwise.org presented a workshop on making comets at the 2013 Great Lakes Planetarium Association conference; learn tips from this pro at www.youtube.com/watch?v=syStSJa4lag. A little showmanship always makes this a fun demonstration. Personally, I like to hand out old lab coats to participants and I make a point of "tasting" the dark organic goo (molasses or dark Kayro) to make sure it's fresh.

## Additional Resources



Another interesting resource from NASA is called "Comet Mystery Boxes" from the Stardust mission, which introduces comets by using a tactile learning experience. I have not tried this one, but it sounds promising. You can find it at the Stardust-NExT site, along with links to a number of activities also appropriate to illustrate the science, math, technology, and engineering in *FireFall*.

For more about the KT boundary impact, read *T.rex and the Crater of Doom* by Walter Alvarez (1997, Princeton University Press). The title might be a bit dramatic, but the book is suitable for adult general readers and motivated high and middle school students.

## Miscellaneous: Discussion topics, for more research

The following are thoughts I had while reading the script. Some are simple "find out more" questions, while others are just for discussion and have no correct answers.

### Chapter 1

*The time: fifty thousand years ago. The place: Canyon Diablo – the Canyon of the Devil – in a desert now called Arizona.*

*Nothing could have been more terrifying. In less than a minute, a detonation as powerful as a hydrogen bomb leveled three hundred square kilometers of savannah. The blast sent a supersonic gust of wind raging across the wilderness, killing every living thing in its path. And when the wind died and the dust cleared, a crater appeared…. a crater more than a kilometer wide and nearly two hundred meters deep . . . a silent remnant of this cataclysmic event.*

- Where is Canyon Diablo? What is the site called today?
- Do you understand the comparison of a detonation as powerful as a hydrogen bomb? Is the fact that it's a really big blast enough, or do you want to know exactly how much energy was expelled? How would you find out?

*Thousands of years later, the ancestors of Native Americans migrated to this region and settled on the surrounding plains. The presence of this enormous, bewildering hole in the grassland fired their imaginations. It was a sacred place they were forbidden to visit. Tribes told stories of a god falling from the sky bearing lighting and thunder, and burying himself in the crater. However, it was no god that descended to Earth that day, but a visitor from outer space – a meteor.*

- Can you think of other examples of cultural mythology that compares to the explanation of the formation of the crater? For another geological explanation, check out the native story of the creation of Devils Tower in Wyoming.
- Write your own myth that explains the presence of the crater.
- How does cultural mythology differ from empirical evidence?

*By far, the biggest and most dominant planet in the solar system is Jupiter. Once it formed, its restless motion and relentless gravity brought chaos to the other developing planets. Small, embryonic worlds known as planetesimals were violently hurled by Jupiter through the crowded solar nebula.*

- How could Jupiter bring chaos to the early solar system?

*Mercury…and the Moon still bear the marks of their wounds. Their airless, pockmarked surfaces have remained virtually unchanged for billions of years – a stark reminder of a tumultuous, distant time.*

- What explains why the surfaces have not changed over billions of years?
- How do astronomers use visual evidence to date the formation of craters?

*The red planet Mars also suffered heavy damage. Named for the mythological Roman god of war, Mars became a casualty of an epic attack from space. A prehistoric volley of mountainous rocks transformed its barren surface into a battleground. War had been waged on the god of war.*

- What do you think of the anthropomorphism in this paragraph?
- Is it appropriate for a science program?
- How would you rewrite it?

Tiny Mimas, one of Saturn's smaller moons, was nearly demolished by a powerful impact. The vast crater from this blow earned it the name of the "Death Star."

- What is the Death Star?
- Why was Mimas given this nickname?

**Chapter 2**


*Each ends its existence as a brilliant streak of light, plunging through the upper atmosphere at ninety times the speed of sound. At such speeds, friction with the air heats the particles to temperatures approaching 11 thousand degrees, vaporizing them in a flash of light lasting a mere fraction of a second.*

- Ablation from friction is one cause of the flash of light. There is a second cause. What is it? (Atmospheric ionization.)

You can download this poster at the American Meteor Society: www.amsmeteors.org.

*As the Earth goes around the sun, it travels nearly a billion kilometers each year at an average speed of a hundred and six thousand kilometers per hour. Because the Earth is so big and it travels so far, it encounters as much as fifty tons of cosmic debris each day.*

- What does this mean to the mass of Earth? Find a way to mathematically illustrate the mass of cosmic debris and the mass of Earth.
- Make a poster illustrating the same thing.

*As the nucleus approaches the Sun, its frozen surface is vaporized and some of the dusty meteoroids escape into space.*

- What are the three states of matter?
- Is vaporized the best term here? Would sublimation work better?
- How would the word sublimation be used correctly in the above paragraph?

*The richest and most reliable meteor display is the Perseid Shower in the constellation Perseus. This shower is most active in the pre-dawn hours around August 12th each year, producing as many as 100 meteors an hour. The Perseid meteor shower owes its existence to the torrent of dust left behind by Comet Swift-Tuttle.*

- Research major meteor showers and produce a hand-out for the rest of the class.
- Make a poster illustrating the process that produces annual meteor showers.

*The surface of the Earth is scarred with many such formations. Almost two hundred have been identified all over the world. Meteor Crater in Arizona is a well-known example but it is very small compared to others. Larger structures include the Manicouagan and Clearwater craters, in Quebec, Canada. The largest known crater on Earth is the Vredefort Crater in South Africa.*

- Why is it so difficult to find large craters on Earth?

**Chapter 3**

*Perhaps the most famous of them all is Comet Halley. Depicted in historical writings, tapestries, and famous works of art, this repeat celestial visitor has figured prominently throughout the ages. It was the first comet ever predicted to return. Its next encounter with Earth will be in 2061.*

- Who discovered this comet? Write a report on the man and the significance of his prediction.
- Research and make a chart of all the known sightings of Comet Halley.
- Does Comet Halley produce a meteor shower?

*Every other comet orbits the Sun, but Comet Shoemaker-Levy 9 was orbiting Jupiter. Once it was captured by the Jovian planet's powerful gravity, the comet was destined for destruction. A year before the discovery, the comet had passed very close to Jupiter, where immense tidal forces tore the nucleus apart, leaving a trail of debris.*

- Understand this paragraph enough to explain it to an imaginary group of first graders.

*The Tunguska region is so remote that it was almost twenty years before an expedition was organized to photograph and study the site. Upon arriving the explorers found that a forest the size of a large city had been leveled by the blast. Yet mysteriously, there was no crater and only a few traces of meteorites were ever found.*

- Tunguska is remote. Find it on a map.
- Look at the date of the impact. There is another explanation about why it took so long to investigate the site. Can you think of it?
- Compare and contrast the Tunguska event with the explosion over Chelyabinsk. Could the Chelyabinsk explosion also be caused by a comet?

**Chapter 4**

*These so called NEOs include comets, meteoroids and asteroids that periodically approach the Earth and pose a significant threat of impact. The Catalina Sky Survey in Arizona together with observing programs like the Siding Springs Survey in Australia carry out nightly searches for these potentially threatening objects.*

- Research the Catalina Sky Survey and the Siding Springs Survey. How do their methods compare?
- What is the current status of the Siding Springs observatory?
- Are there other surveys watching for NEOs?

*One of the early successes of these sky surveys was the discovery of the asteroid Apophis in 2004. Named for the Egyptian god of darkness, Apophis weighs six times more than the Great Pyramid of Giza.*

- How do astronomers know how much Apophis weighs?

- How much does the Great Pyramid of Giza weigh?

Then, 65 million years ago, in the twinkling of a geologic eye all of the dinosaurs mysteriously vanished. They perished in a mass extinction that abruptly wiped out three-fourths of *all* species. Known simply as the K-T Extinction, its cause remained a mystery for decades.

- What do the authors mean by the phrase "in the twinkling of a geologic eye"?
- What does K-T mean?
- Have there been other mass extinctions?

*They based their theory on the discovery of large amounts of Iridium in a geologic formation known as the "K-T layer."*

- What other visual evidence did the Alvarez team have? (Shocked quartz, shatter cones)
- What other effects of a massive asteroid impact contributed to the extinction of the dinosaurs?

*Near the center of the crater is the village whose Mayan name, means "the tail of the devil". On a fateful day at the end of the Cretaceous Period, a devil came from the sky, bearing lightning and thunder. It was a monstrous asteroid the size of Mount Everest and it raced toward Earth at breathtaking speed, striking what is now the Gulf of Mexico. The force of the impact was more than a million times stronger than the Tunguska detonation.*

- What is the name of the Maya village?
- How do astronomers know the size of the asteroid?
- How do they know the force of the impact?

*During the infancy of the solar system, Earth was showered with more than just rocks and water. Amino acids, the building blocks of DNA and all living things, have been discovered in both meteorites and comets. As they pelted the Earth with dust, rocks, and water, they may have also delivered the raw materials necessary for the origin of life.*

- The theory that comets might have brought water and amino acids to earth is still being debated. Research the question and write a position paper arguing your stand on the question.
- Why are astronomers, geologists, chemists, and other scientists so interested in studying meteorites?
- Why can't scientists study 4.6-billion-old Earth rocks?