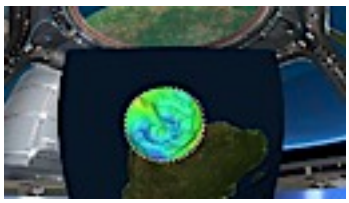
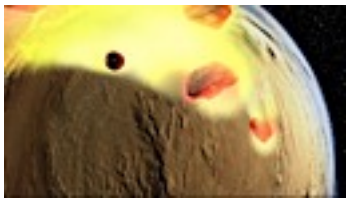
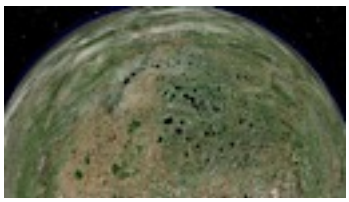
IMPACT!
Encounters with Comets, Meteors and Asteroids

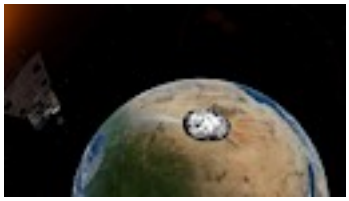
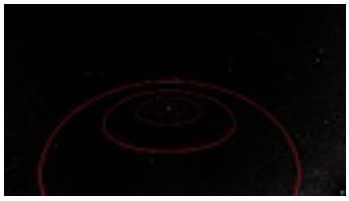
VERSION (SUBTITLES) REVISED: NOVEMBER 5, 2013

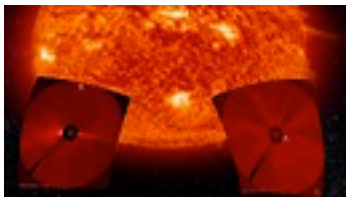
SCENE	TIME	SCRIPT
	00:01	Millions of asteroids and comets lurk among the planets - left over bits and pieces from the solar system's formation four and a half billion years ago. Asteroids and comets once delivered raw materials to a young, growing Earth. Now they may be the most attractive places near Earth for mining the minerals, water, and oxygen needed to sustain colonies on other worlds. I'm Tom Jones, a planetary scientist, and a four time shuttle astronaut. I will be your guide as we explore asteroids and comets - friends and foes, and discover the role they have played in our past and how they could affect our future in space and here on Earth.
TITLES		**OPENING TITLES**
	01:28	IMPACT! Encounters with Comets, Meteors, and Asteroids
PART 1		**METEORITE HUNTING**
	01:40	Each day, Millions of tiny meteors burn up in Earth's atmosphere. Those as small as a grain of sand look like "shooting stars" as they streak across the sky. Of the hundred tons of space rocks and pebbles swept up by Earth daily, only a few pieces are large enough to survive their fiery descent and strike its surface. Just over 10,000 years ago, the last Ice Age was releasing its frigid grip on the North American plains. The first humans had recently arrived, traveling over a land bridge exposed by the ice. These Native Americans of the Great Plains may have witnessed a spectacular meteorite fall.
	02:52	As the fireworks ended, hundreds of meteorites fell to the ground. Native Americans and then farmers collected these strange rocks from the sky and used them as a source of iron.
	03:10	Now meteorite hunters are returning to the wheat fields of southwestern Kansas to search for larger meteorites, buried at least a meter under the ground.

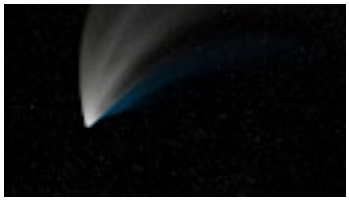
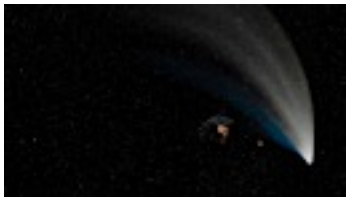
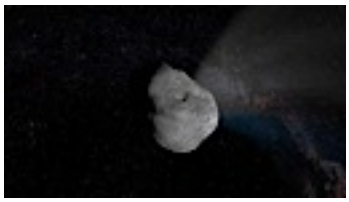
	03:22	In October 2006, a research team arrived to locate and excavate one of these buried meteorites - a rock that had not been seen or touched since impact over 10,000 years ago. Meteorites like this one provide valuable information about the composition and history of the asteroids in our solar system.
	03:48	The news media were fascinated with the idea of imaging a buried meteorite before digging it up. With the meteorite's dramatic formation as a remnant of an asteroid collision and with the possibility of using this technique in the future to explore below the surface of Mars. The European Space Agency has proposed installing ground-penetrating radar on a robotic rover to map the Martian subsurface for drilling and to reveal the location of meteorites buried under the Martian terrain.
PART 2		**ASTEROID IMPACT**
	04:21	We live in a dangerous cosmic neighborhood. Impacts still shape the surfaces of planets and moons. Most of our Moon's craters were created in the first half billion years of the Moon's history, ending with a cataclysmic heavy bombardment almost four billion years ago. On the Moon's southern highlands and on most of its far side, craters overlap craters so thickly that the original crust is almost completely obscured.
	04:51	Looking down from the International Space Station, we see small space rocks burn up in Earth's atmosphere. In the distant past, Earth, like the Moon, was hit hard, but crustal motions and weathering by wind and water have erased the evidence of most impacts. Still geologists have identified over 180 impact scars around the globe. Many are located through satellite imagery and photographed by astronauts orbiting on the International Space Station.
	05:23	In the early 1960s, Eugene Shoemaker, a geologist and astronomer, examined the kilometer-wide Barringer Crater near Winslow Arizona. The desert climate has preserved this crater's sharp outline, allowing us to compare it with similar craters on the Moon.
	05:48	Perhaps the most famous impact crater on Earth lies below the village of Chicxulub, on the northwestern tip of Mexico's Yucatan Peninsula. The Chicxulub crater is buried under layers of marine limestone with an arc of sink holes on the surface marking the crater's circular rim far below. It's central depression, buried rim, and outer rings match impact features on the Moon.
	06:15	We can imagine the impact that created this buried crater. Sixty-five million years ago, a 10 kilometer-wide asteroid blazed through Earth's atmosphere and struck a shallow sea. The asteroid became an intensely hot fireball. But Earth's atmosphere had little effect on the velocity of this enormous flying mountain of rock. Impact with the ocean floor created a crater over 150 kilometers wide and a giant tsunami. Millions of tons of dust from the sea floor were

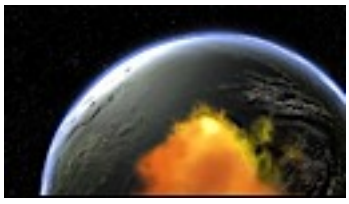
		hurled into the atmosphere. Global darkness followed, killing vegetation, while acid rain poisoned the upper oceans. Eighty percent of the planet's living species, including all non-flying dinosaurs, were wiped out.
	07:22	The search for evidence of impact cratering now extends to the Sahara Desert where shifting sands have buried the past, leaving only hints of ancient cratering events.
	07:35	We can imagine meteoroids falling toward the desert: some burning up in the atmosphere and others reaching the surface. Gradually desert sand has filled the craters. Only tools like air and space born radar can look below the exposed crater rims to see the buried features of an impact crater.
	08:06	A recent extraterrestrial encounter produced no craters at its impact site in the remote Tunguska region of central Siberia.
	08:15	On the morning of June 30, 1908, a 40-meter-wide asteroid fragment entered Earth's atmosphere traveling at a speed of over 50,000 kilometers per hour. During its quick plunge, the space rock heated the surrounding air to four times the temperature of the Sun's surface.
	08:34	Just after 7 a.m. local time, the few startled inhabitants observed a brilliant white fireball. At a height of 8 kilometers, pressure and heat caused the space rock to fragment and annihilate itself, producing a firestorm and releasing energy equivalent to hundreds of Hiroshima atomic bombs.
	09:13	Eighty million trees were blown down - a catastrophe powerful enough to destroy a modern city.
	09:24	Without warning on Feb. 15, 2013, another asteroid fragment struck Siberia.

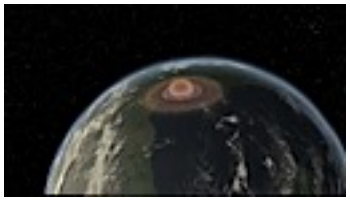
	09:32	Dozens of building- and car-mounted video cameras captured the meteor's descent and the shadows it cast, making it the most documented meteor event in history. There were no deaths, but about 1,500 injuries occured, mostly cuts from glass that broke due to the force of the shock wave produced when the meteor broke up in the atmosphere. Sound waves from this explosion circled the Earth several times. Seventy-two hundred buildings were damaged and many small fragments have been recovered.
PART 3		**ASTEROID SEARCH**
	10:23	Earth's history of impacts show that we still face the potential for global devastation from space. If an asteroid larger than a couple of kilometers across struck the Earth, the explosion could throw enough dust into the atmosphere to shut down agriculture for a year or more, destroying natural ecosystems and possibly leading to a collapse of modern civilization. NASA has funded several survey teams to find objects wider than a kilometer that could impact the Earth. Each evening, observers from Massachusetts to Arizona and Hawaii search the sky for asteroids on paths that cross Earth's orbit. None of the potential civilization killers found thus far are on a collision course with Earth.
	11:11	Amateur astronomers also volunteer their time and equipment to search for new asteroids, working at facilities like Houston's George Observatory. Asteroid hunters photograph sections of the sky through large telescopes taking images of the same starfield about 15 minutes apart. They compare the photos as they look for an object that has moved against the background starfield.
	11:43	The orbits of most asteroids lie in a region called the asteroid belt, between the paths of Mars and Jupiter. Like the rest of the solar system, the asteroid belt is almost empty, with millions of asteroids spread over the entire area. The total mass of these asteroids is much less than the mass of Earth's Moon.
	12:06	Collisions and the gravitational tugs of nearby planets can nudge asteroids out of the asteroid belt and perhaps send them sunward. In such a collision, a large asteroid might shatter into many smaller asteroids. These impacts create the meteoroids that become meteors in Earth's atmosphere and meteorites if they survive to reach Earth's surface.
	12:31	Astronomers are now tracking an asteroid named Apophis that will soon come very close to Earth. Apophis is a stony asteroid 270 meters wide.

	12:44	On Friday, April 13, 2029, Apophis will come within 33,000 km of the Earth - reaching a lower altitude than the geostationary satellites monitoring the weather and carrying television signals.
	13:00	The impact of an asteroid the size of Apophis could wipe out a city or cause a devastating tsunami. The Earth can expect an impact of this size as often as once every 50,000 years on average.
	13:13	Apophis serves to warn us that dangerous asteroids are close by and that it is only a matter of time until we find one on a collision course with Earth.
	13:26	We have also launched robotic spacecraft to study asteroids up close. In 1991, the Galileo spacecraft imaged Gaspra and in 1993 it approached Ida and discovered that this asteroid has a tiny moon called Dactyl. In 1997 the NEAR-Shoemaker spacecraft flew past the dark asteroid Mathilde, over 50 kilometers wide. In 2000, the NEAR-Shoemaker spacecraft went into orbit around the asteroid Eros, the first discovered Near-Earth Asteroid. In 2001 it landed on the asteroid's irregular surface. The Hayabusa spacecraft visited the asteroid Itokawa which looks more like a loose pile of rubble than a solid rock. In 2005 Hayabusa actually touched down on the asteroid.
	14:29	Data from these encounters help scientists design ways to deflect an asteroid like Eros or Itokawa that could someday hit Earth. Suggestions range from lasers and solar sails to a nuclear blast at close range. A kinetic impactor could hit the asteroid and nudge it forward or backward along its orbit. A gravity tug with its small, but persistent, gravitational attraction could gradually pull a threatening asteroid from its impact trajectory.
PART 4		**COMETS UP CLOSE**
	15:05	Comets also threaten Earth, especially a comet as large as Comet Hale-Bopp, with a nucleus over 7 times as wide as an average comet. If it were to hit Earth, the impact would be over 40 times more powerful than the asteroid impact that killed the dinosaurs. It could destroy all life on the planet.
	15:33	Like many comets, Comet Hale Bopp's story began in the Oort Cloud, a distant spherical shell of icy particles far beyond the planets. Impacts within this cloud can propel one of these dirty ice balls sunward to become a comet.

	15:50	After leaving the Oort Cloud, Comet Hale Bopp reached the orbits of the planets and passed closest to Earth during the reign of Pharaoh Pepi I over 4,000 years ago.
	16:03	Inside the pharaoh's pyramid at Saqqara, there is a text describing a star with long hair. Perhaps this is the brilliant Comet Hale-Bopp on its first visit.
	16:14	On its sunward journey, Jupiter's gravity altered its orbit so the comet would return to Earth's skies at the end of the 20th century.
	16:26	In 1995 Alan Hale and Thomas Bopp rediscovered this comet, just after it passed the orbit of Saturn. The sun's heat had begun to vaporize the comet's ices, forming a gas shroud called a coma.
	16:41	Comet Hale Bopp's coma grew larger and its tail grew longer as it came closer to the Sun. It grew a blue gas tail pointing straight away from the Sun and a yellowish dust tail curving away along its orbital path -- both stretching across a quarter of the sky.
	17:02	Jupiter's gravity may ultimately bring this comet close to the sun, turning it into a sungrazer, like Comet Ison. As these videos show, the sun's energy can make a sungrazer very bright, break it apart into several comets, or destroy it completely.
	17:21	In addition to long period comets journeying far beyond the planets, there are also short period comets, like Halley's Comet. The orbit of Halley's Comet extends beyond Neptune with a period of just over 75 years.
	17:36	Halley's Comet has been documented throughout history from the Norman Conquest in 1066 to Giotto's painting, The Adoration of the Magi. Halley's Comet appeared low in southern skies in 1986 while the Giotto spacecraft gave us a close-up view of its nucleus. We must wait until 2061 for next return of this famous comet.

	18:03	Comet Tempel 1 is a good example of a short period comet. With each return, the Sun heats up the comet's dirty snowball-like nucleus, causing it to shed material into its gossamer tail.
	18:19	The Deep Impact spacecraft reached Comet Tempel 1 on July 4th, 2005. The larger "flyby" spacecraft carried a small "impactor", which it released into the comet's path for a planned collision.
	18:34	To observe the impact, the flyby spacecraft maneuvered into a new orbit that passed just 500 kilometers from the comet.
	18:51	From this mission we discovered that Comet Tempel 1 is a fragile icy dirtball covered with powdery dust, and that the ice deep inside its nucleus may be unchanged from the early days of the solar system.
	19:10	Six years later, the Stardust spacecraft flew past Comet Tempel 1 and photographed the crater we had made on the comet's surface.
	19:21	Stardust also captured thousands of particles of comet dust during a daring close encounter with Comet Wild 2, a comet that has only recently ventured close to the Sun.
	19:33	After landing in the Utah desert, the Stardust sample container was taken to a clean room at the Johnson Space Center in Houston, Texas. This room has a cleanliness factor 100 times that of a hospital operating room to ensure that the comet dust is not contaminated.
	19:57	The grids in the circular collector brought back samples that formed at hot temperatures near the sun as well as organic compounds that formed at cold temperatures far from the sun. Astrobiologists also found the amino acid, glycine, in the Stardust samples. Amino acids are the building blocks of life.

	20:26	At Mt. Palomar in March 1993, astronomers Gene and Carolyn Shoemaker and David Levy discovered a very unusual comet orbiting Jupiter. Comet Shoemaker Levy 9 had come too close to Jupiter in 1992 and the giant planet had torn it apart, leaving comet fragments arranged like pearls on a string in an orbit destined to impact Jupiter.
	20:51	Hour after hour the fragments plunged into Jupiter's atmosphere, producing a band of dark blotches in Jupiter's cloud tops and Earth-size soot rings that marked the cloud tops for weeks. These bruises gradually dissipated in the planet's atmosphere. Comet Shoemaker Levy 9's longest-lasting effect is its demonstration that our Earth orbits in a cosmic shooting gallery.
PART 5		**COMET COLLISION**
	21:19	Comets are friend and foe. Comet impacts probably brought water and organic material to the early Earth and perhaps ice to the Moon's poles. Unlike asteroids, comets come from distant regions that we cannot search from Earth. After its discovery, we would have at most a few years to assess the threat and prepare for a comet encounter. To understand the hazard, let's see what would happen if a comet the size of Shoemaker Levy 9 hit Earth.
	21:56	Earth does not have Jupiter's thick atmospheric cushion so a 2-kilometer wide comet would rush quickly through the atmosphere creating an enormous glowing fireball.
	22:09	Let's suppose that the comet crashes into the shallow Gulf of Mexico just south of Houston, Texas - releasing a million megatons of energy on impact.
	22:31	The impact would gouge out a crater about 30 kilometers wide and generate a shock wave that almost instantaneously converts the energy of the impact into heat and vaporizes the comet. The same pulse melts the surrounding rock and produces a rapidly expanding fireball. The blast raises a gigantic tsunami that races inland.
	22:57	A decompression wave follows, hurling molten and shattered debris away from the impact site. Wood and concrete buildings topple. Glass windows shatter. Bridges collapse and cars become flying projectiles. Debris reaches the stratosphere and blocks sunlight for months.

	23:23	From the lunar surface, astronauts see Earth as a fragile and vulnerable world. Earth supports a delicate biosphere, with life forms that adapt poorly to dramatic changes. Even if humans do survive the actual impact, the loss of agriculture and the complex structures of civilization would put human society at risk.
	23:48	Because we have so much to lose, we must step up our search for comets and asteroids. We can find and track them, even use our space technology to shift their orbits. What we still lack, and must find, is the will to act together to ensure our survival.
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