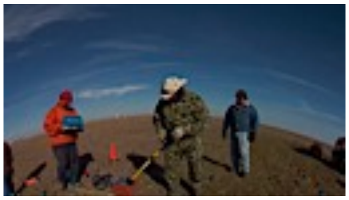
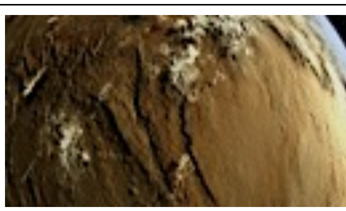
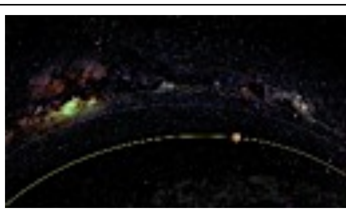
IMPACT EARTH

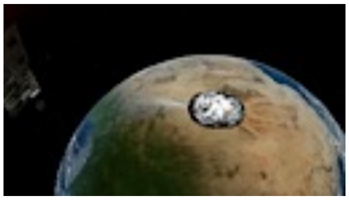
VERSION (SUBTITLES) REVISED: JULY 26, 2013

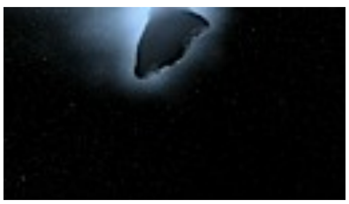
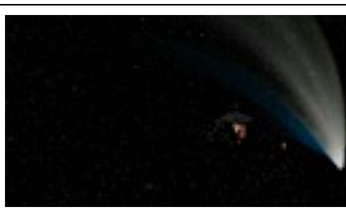
SCENE	TIME	SCRIPT
	00:01	Millions of asteroids and comets lurk among the planets - left over bits and pieces from the solar system's formation four and a half billion years ago. Asteroids and comets once delivered raw materials to a young, growing Earth. Now they may be the most attractive places near 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**
	01:26	IMPACT EARTH Featuring Astronaut Tom Jones
PART 1		**METEORITE HUNTING**
	01:43	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.
	02:55	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.
	03:14	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.

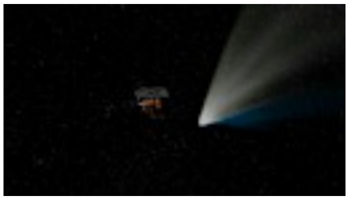
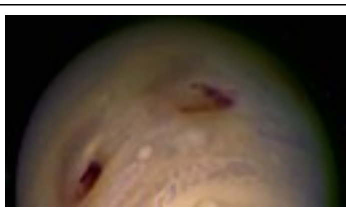
	03:25	In October 2006, a research team arrived to locate and excavate one of these buried meteorites - a rock that had not been seen or touched since impact over 10,000 years ago.
	03:40	To find a meteorite under the ground, the team used ground penetrating radar, which could detect an object below the surface. For days the team pulled the radar unit over grid patterns marked on the ground - above places where a magnetometer had identified buried metal, watching for reflections at the correct depth and then creating a 3D image of the buried object. The radar image allowed the team to rule out discarded farm equipment.
	04:11	Finally the diggers began to excavate a pit around the probable meteorite that the ground penetrating radar had identified. Soil layers in the pit indicate that this fall happened in the Pleistocene epoch, fixing the probable impact date over 10,000 years ago.
	04:32	Comparing the radar image with the real meteorite shows how accurately radar can depict a buried rock. The meteorite's composition reflects it origin inside an asteroid that broke apart millions of years ago. Most meteorites are made of stone or iron. In contrast, this meteorite is a mixture, a rare Pallasite, composed of olivine crystals in a nickel-iron matrix. Such a rock came from the boundary between the core and the mantle of a large asteroid, fragmented long ago in a violent collision. Meteorites like this one provide valuable information about the composition and history of the asteroids in our solar system.
	05:19	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**
	05:51	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.

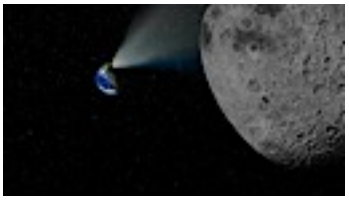
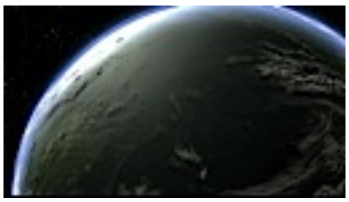
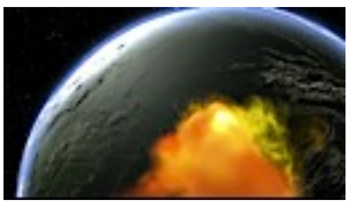
	06:21	Looking down from the International Space Station, we see small space rocks burn up in Earth's atmosphere. In the distant past, Earth, like the Moon, was hit hard, but crustal motions and weathering by wind and water have erased the evidence of most impacts. Still geologists have identified over 180 impact scars around the globe. Many are located through satellite imagery and photographed by astronauts orbiting on the International Space Station.
	06:53	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.
	07:18	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.
	07:45	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.
	08:52	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.
	09:05	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 exposed crater rims to see the buried features of an impact crater.
	09:36	A recent extraterrestrial encounter produced no craters at its impact site in the remote Tunguska region of central Siberia.

	09:44	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.
	10:03	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.
	10:43	Eighty million trees were blown down - a catastrophe powerful enough to destroy a modern city.
PART 3		**ASTEROID SEARCH**
	10:53	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.
	11:41	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.
	12:14	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.
	12:37	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.

	13:02	Astronomers are now tracking an asteroid named Apophis that will soon come very close to Earth. Apophis is a stony asteroid 270 meters wide.
	13:15	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.
	13:31	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.
	13:44	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.
	13:57	We have 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 - twice the size of Ida and four times as large as Gaspra. 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 trying to collect samples.
	15:24	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. Space agencies may test these methods on nearby asteroids in the near future.
PART 4		**COMETS UP CLOSE**

	16:08	Comets also threaten Earth. On July 23rd, 1995, Alan Hale and Thomas Bopp became the discoverers of Comet Hale Bopp - the most widely observed comet in history. As Comet Hale Bopp approached the Sun, its nucleus and atmosphere continued to brighten, with a blue gas tail pointing straight away from the Sun and a yellowish dust tail curving away toward its orbital path.
	16:33	Comet Hale Bopp last visited the inner solar system over 4,200 years ago, during ancient Egypt's golden age. In 1996, Jupiter altered the comet's orbit and it will return again in about 2,400 years.
	16:52	Like asteroids, comets are time capsules that hold clues about the history of the solar system. Formed around four and a half billion years ago, they are made of ice and dust: primitive debris from the solar system's most distant and coldest regions. Comets like Hale Bopp have spent most of their lives in deep freeze, beyond Neptune. Other short-period comets follow paths that remain inside Neptune's orbit and bring them back into view on a regular schedule.
	17:22	Comet Tempel 1 is a good example of a short period comet.
	17:28	With each return, the Sun heats up the comet's dirty snowball-like nucleus, causing it to shed material into its gossamer tail.
	17:38	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.
	17:53	To observe the impact, the flyby spacecraft maneuvered to a new orbit that passed just 500 kilometers from the comet.

	18:10	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.
	18:27	In the future, we may have to use the same technique to change the orbit of a comet or asteroid, preventing a collision with Earth.
	18:37	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 along the comet's orbital path.
	19:02	In 1994 the Hubble Space Telescope resolved Comet Shoemaker-Levy 9 into a train of 21 icy fragments stretching over three times the distance between the Earth and Moon. The fragments were on course for an impact with the giant planet in July.
	19:20	These impacts would occur on Jupiter's night side, out of view from Earth, but so close to the day-night terminator that each impact site would soon rotate into view.
	19:32	The Shoemakers and David Levy stared at the huge spots their comet made in the atmosphere of this giant world. The fate of Comet Shoemaker-Levy 9 was a graphic reminder that the impact process is alive and dangerous in our solar system.
	19:49	Hour after hour the impacts continued, producing a band of dark blotches in Jupiter's cloud tops and Earth-size soot rings that marked the cloud tops for weeks.
	19:59	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**
	20:15	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.
	20:52	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.
	21:05	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.
	21:27	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.
	21:53	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.
	22:19	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.
	22:44	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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Narration		Tom Jones

		Jim Bratton
Writer and Director		Carolyn Sumners
Score and Audio-Post Production		Shai Fishman Fish-I Studios
Animation		Tom Casey – Home Run Pictures Adam Barnes Tony Butterfield Gerry Crouse Phillipe Velasquez
Executive Producer		Patricia Reiff
Content Review		Bruce Caron Clark Chapman Alan Harris Essam Heggy Thomas Jones Donald Yeomans
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Meteorite Field Team		Steve Arnold Johnny Castillo Chris Flis Phil Mani Andy Smith James Talmage David Temple Barbara Wilson Buster Wilson Gary Young
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