

# Comet and Asteroid Threat Impact Analysis

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*The great majority of asteroid and comet impacts produce only regional areas of devastation. They are not global killers. Our planet is huge and can absorb a fairly big hit. There is an exception. The Earth has several times in the past experienced massive impact events that have extinguished most of the life from the planet. In general, these massive impacts have been caused by inward falling comets from the Oort Cloud. In these rare cases, huge comet fragments penetrated the Earth's crust. The shock wave from these deep impacts traveled through the Earth and produced a very large zone of devastation on the opposite side of the globe. Vast quantities of magma were released, which result in global damage and a major extinction event. This process is described in greater detail in Reference 1. The deep impacts (impacts that penetrate the Earth's crust) are not random. Rather they occur quite regularly in geological time. The next deep impact event will occur in approximately 80 million years.*

Have you ever watched a **shooting star** in the night sky? In general, a shooting star is the size of a single grain of sand. As it hits the atmosphere at very high velocities, its kinetic energy is transformed into thermal energy, which produces the brilliant streak across the sky. When a large comet impacts the earth, the same process occurs. But a large comet or asteroid will not burn up in the atmosphere. Much of this force will be released as it impacts the earth sending shock waves over the surface of the earth and through the fragile earth's crust and into its mantle & core and by sending trillions of tons of debris into the air and into space.

The following equation gives the kinetic energy based on the diameter of a spherical comet or asteroid.

$$KE = 5.21 \times 10^{-5} \times (\text{diameter})^3 \times (\text{velocity})^2 \times (\text{density})$$

Where KE is expressed in Megatons of TNT

Where diameter is expressed in miles

Where the velocity relative to Earth is expressed in miles per hour

Where density is expressed in grams per cubic centimeter

Assuming 1 megaton of TNT is equivalent to  $4.185 \times 10^{22}$  ergs

In metric form:

$$KE = 6.256 \times 10^{-8} \times (\text{diameter})^3 \times (\text{velocity})^2 \times (\text{density})$$

Where KE is expressed in Megatons of TNT

Where diameter is expressed in meters

Where the velocity relative to Earth is expressed in kilometers per second

Where density is expressed in grams per cubic centimeter

Assuming 1 megaton of TNT is equivalent to  $4.185 \times 10^{22}$  ergs

The table below provides an estimate of Kinetic Energy for three categories of impactors: **Asteroids**, **Short Period Comets**, and **Long Period Comets**.

These rough estimates are based on the assumption that the impactor is spherical in shape and a non-binary system. Many asteroids and comets have irregular shapes, which can affect impact energy calculations. Approximately 16 percent of Near Earth Asteroids larger than 660 feet are binary systems.<sup>2</sup>

One of the variables in the equation is density. It is theorized that the density of comets range from that of a fluffy snowball (0.1 grams per cc) to the density of sheets of ice and dirt (2.0 grams per cc).<sup>3</sup> Delay Doppler radar is a tool that can be used to assess and measure asteroid & comet density. Dr. Steve Ostro (NASA- JPL) provided a closer estimate of the density range as 0.5 to 1.0 grams per cc based on radar data. The estimate contained in the table will use the midpoint (0.75 grams/cc) for the short period comet (SPC) and long period comet (LPC). According to Steve, asteroids range from 1 to 7 grams/cc, with the majority around 2 grams/cc. The estimate will use 2 grams/cc for asteroid density.

Another variable in the equation is speed. Here again, delay Doppler radar provides the most accurate estimates. In Dr. Ostro's judgment typical impact velocities are roughly 45,000 mph (20 km/sec) for asteroids and SPCs and roughly 110,000 mph (50 km/sec) for LPCs. These values were used in generating the table.

<b>Kinetic Energy (Equivalent Tons of TNT)</b>	<b>Asteroid Diameter</b>	<b>Short Period Comet Diameter</b>	<b>Long Period Comet Diameter</b>
1 Megaton	89 feet 27 meters	123 feet 38 meters	67 feet 20 meters
10 Megatons	192 feet 58 meters	266 feet 81 meters	144 feet 44 meters
100 Megatons	413 feet 126 meters	573 feet 175 meters	311 feet 95 meters
1,000 Megatons	890 feet 271 meters	1,235 feet 376 meters	670 feet 204 meters
10,000 Megatons	0.36 miles 585 meters	0.50 miles 811 meters	0.27 miles 440 meters
30,000 Megatons	0.52 miles 843 meters	0.73 miles 1.2 kilometers	0.39 miles 635 meters
100,000 Megatons	0.78 miles 1.3 kilometers	1.1 miles 1.7 kilometers	0.58 miles 948 meters
1,000,000 Megatons	1.7 miles 2.7 kilometers	2.3 miles 3.8 kilometers	1.3 miles 2.0 kilometers
10,000,000 Megatons	3.6 miles 5.8 kilometers	5.0 miles 8.1 kilometers	2.7 miles 4.4 kilometers
100,000,000 Megatons	7.8 miles 13 kilometers	11 miles 17 kilometers	5.9 miles 9.5 kilometers
300,000,000 Megatons	11 miles 18 kilometers	16 miles 25 kilometers	8.5 miles 14 kilometers
1,000,000,000 Megatons	17 miles 27 kilometers	23 miles 38 kilometers	13 miles 20 kilometers

Benny Peiser (CCNet) recently wrote, "In contrast to most other, more frequent natural disasters (such as earthquakes, volcanic eruptions, tropical storms, tsunami, etc.), we have very little empirical knowledge, let alone experience of NEO impacts and their secondary environmental and societal effects."<sup>4</sup> This is the reason why, when you researched asteroid and comet impacts, you will come across conflicting information. It is far from being an exact science.

The information provided below is my best assessment of the impact threat. Initially, I began summarizing the impact threat by solely relying on material extracted from related books and Internet articles. Unfortunately, some of this material exaggerates the magnitude of several effects, while totally ignoring others. More recently, I began to integrate two other elements in forming my opinion on the impact threat: nuclear explosion effects & eye witness accounts of past impact events. (1) An asteroid impact has been compared to a nuclear explosion

without the radiation. This is a fairly good analogy. The nuclear explosion effects are a well-studied science that can be directly applied to the study of impacts. (2) The earth has been struck by a number of impacts within recorded history. Eyewitness accounts of these impacts, in my opinion carry substantial insight and a means of validating the impact threat model.

In general, a comet or asteroid impact will only create a regional zone of devastation (defined as the area within the blast wave 1-psi peak overpressure). This zone of destruction is caused primarily by the shock wave with a contributing component from thermal radiation, debris and electromagnetic effects. On rare occasions a massive comet can deeply penetrate the Earth's crust. Deep penetrations can be modeled by underground nuclear explosions; with the major effect being ground shock. The impact shock wave can pass through the Earth rupturing the crust on the opposite side of the globe. Vast flows of volcanic magma are released. The gases generated from this magma release are the prime culprits of global mass extinctions.

An outline of these effects are provided below with a detailed discussion following.

### **Shock Wave**

**Air: Blast Wave**

**Ground: Ground Shock**

**Water: Water Compression Wave – Tsunami**

### **Thermal Radiation**

**Flash**

**Fireball**

### **Debris & Aerosols**

### **Electromagnetic Effects**

**Electromagnetic Pulse (EMP)**

**Ionizing Radiation**

**Electroponic Bursters**

### **Secondary Effects**

**Mass Fires**

**Earthquakes/ Landslides/Volcanoes/Lava Flows**

**Dust & Impact Winter**

**Gas Evolution & Acid Rain**

**Upper Atmospheric Effects**

**Oxygen Depletion**

**Magnetic Pole Reversals**

**Energetic Weather Conditions**

**Starvation and Plagues**

## **Shock Wave**

The kinetic energy released by the impact of a comet or asteroid with Earth will produce a continuously propagated pressure wave in the surrounding medium. There are three types of shock waves possible from an impact event. These are a function of the medium impacted: air, earth, and water. The shock wave in air is

referred to as the Blast Wave. The shock wave in the earth is referred to as Ground Shock. The shock wave in water is referred to as a Water Compression Wave. As a Water Compression Wave approaches a shoreline, it can result in the formation of a Tsunami.

### Blast Wave

The blast wave has incredible force near the impact point. Objects within the path of the blast wave are subjected to a short transient wave with very high peak overpressures and to extraordinarily severe transient winds. As the wave moves outward from the impact point, the overpressure and the wind speed drops significantly. Generally, the blast wave damage is a function of the peak overpressure (in psi – pounds per square inch).

*For impacts less than global extinction events, the atmospheric blast wave is the primary cause of damage & loss of life.*

The first table defines the peak overpressure as a function of the distance from the point-of-impact for various size impactors (kinetic energy). The second table describes the damage caused by the blast wave as a function of peak overpressure. The table also provides peak wind velocity as a function of peak overpressure. It is interesting to note that near the point of impact (100-psi overpressure), the blast wave is moving at an incredible speed of 2200 miles per hour, but further away (1-psi overpressure), the blast wave is moving only at 35 miles per hour. At a large distance from the impact, of the three types of shock waves, the atmospheric blast wave will be the last to arrive.

<b>KINETIC ENERGY</b>	<b>1 psi</b>	<b>3 psi</b>	<b>5 psi</b>	<b>10 psi</b>	<b>50 psi</b>
1 Megaton	8 miles 13 kilometers	4.6 miles 7.4 kilometers	3.4 miles 5.5 kilometers	2.4 miles 3.9 kilometers	1.0 miles 1.6 kilometers
10 Megatons	18 miles 28 kilometers	10 miles 16 kilometers	7 miles 12 kilometers	5.3 miles 8.5 kilometers	2.2 miles 3.5 kilometers
100 Megatons	38 miles 62 kilometers	22 miles 35 kilometers	16 miles 26 kilometers	12 miles 19 kilometers	4.8 miles 7.7 kilometers
1,000 Megatons	83 miles 134 kilometers	47 miles 76 kilometers	35 miles 57 kilometers	25 miles 40 kilometers	11 miles 17 kilometers
10,000 Megatons	182 miles 292 kilometers	103 miles 166 kilometers	77 miles 123 kilometers	55 miles 88 kilometers	23 miles 37 kilometers
100,000 Megatons	397 miles 638 kilometers	225 miles 363 kilometers	167 miles 269 kilometers	120 miles 193 kilometers	50 miles 81 kilometers
1,000,000 Megatons	866 miles 1,393 kilometers	492 miles 792 kilometers	364 miles 586 kilometers	261 miles 420 kilometers	109 miles 176 kilometers
10,000,000 Megatons	1,890 miles 3,040 kilometers	1,070 miles 1,730 kilometers	780 miles 1,280 kilometers	570 miles 920 kilometers	240 miles 380 kilometers
100,000,000 Megatons	4,120 miles 6,630 kilometers	2,340 miles 3,770 kilometers	1,740 miles 2,790 kilometers	1,240 miles 2,000 kilometers	520 miles 840 kilometers
1,000,000,000 Megatons*	< 9,000 miles < 14,500 kilometers	< 5,100 miles < 8,200 kilometers	< 3,800 miles < 6,100 kilometers	< 2,700 miles < 4,400 kilometers	< 1,100 miles < 1,800 kilometers

The table was derived by extrapolating Figure 3.1 *Weapon overpressure as a function of distance from a surface burst* contained in Oak Ridge National Lab "Civil Defense Shelters: A State-Of-The-Art Assessment - 1986".<sup>5</sup>

\* Comets of this size are deep impactors that can penetrate the Earth's crust and produce massive flood volcanic ruptures. These impacts will result in global extinction events. Atmospheric blast range will be dramatically less than depicted on this row of the table. Energy primarily converted to ground shock beneath the Earth's crust.

<b>BLAST WAVE PRESSURE</b>	<b>PEAK WIND VELOCITY</b>	<b>DAMAGE EFFECT <sup>6,7</sup></b>
1 psi	35 mph	Light damage to structures (i.e. houses). People endangered by flying glass and debris.
2 psi	65 mph	Severe damage to structures. Windows blown out. Interior walls of house blown out. Furniture and contents swept out to far side of house. Masonry walls collapse.
3 psi	95 mph	Walls of a typical steel frame building are blown away. Very severe damage to residences. Winds sufficient to kill people in open.
5 psi	160 mph	Houses collapse or are blown off foundations. People exposed to blast wave are thrown hard and if they impact a solid object, death likely to occur. Lightly constructed commercial buildings and typical residences are destroyed. Heavier construction is severely damaged. Automobiles are damaged to the point they can no longer be driven.
10 psi	290 mph	Most factories and commercial buildings collapse. Small wood framed and brick residences destroyed and distributed as debris.
20 psi	470 mph	Reinforced concrete structures are leveled. Damage to physical body is significant. The pressure ruptures the walls of the abdominal and thoracic cavities causing hemorrhaging. Air is actually forced into the circulatory system. Human soft tissue and skeletal structure suffers severe damage.
50 psi	1,000 mph	(This is about the limits of a good underground expedient shelter)
100 psi	2,230 mph	

(The distance from point-of-impact as defined by the overpressure (in psi) from the air blast wave will be used as a standard unit of measure to define affected areas for several of the following impact effects.)

<b>BLAST WAVE PRESSURE</b>	<b>DAMAGE EFFECT <sup>6,29</sup></b>
1.5 psi (unobstructed)	Second degree burns.
1 to 2 psi	25% injuries.
2 psi	Fine kindling fuel ignites.
2.5 psi	30% trees blown down.
2 to 5 psi	5% fatalities, 45% injuries.
5 to 12 psi	50% fatalities, 40% injuries.
10 psi	Most combustible materials will ignite and burn.
> 12 psi	98% fatalities, 2% injuries.

## Ground Shock

The shock wave that passes through the earth is referred to as Ground Shock. During the impact, the kinetic energy of the asteroid/comet is transmitted directly into the ground, producing compression and shear motions, which propagate radially outward from the impact.<sup>5</sup> Ground shock is similar to an earthquake. Ground shock propagates very quickly. At greater distance from the impact, ground shock will be the first shock wave to arrive. I have estimated the speed of the ground shock using earthquake formulas. Earthquakes are broken down into two categories: Primary and Secondary.

Primary earthquakes move at 13,500 mph to 29,000 mph (6 to 13 km/sec). These earthquakes not only travel through the crust of the earth but through the molten mantle. A large ocean impact will produce a ground shock similar to a Primary earthquake because the Earth's crust is very thin under the ocean. I expect the Primary ground shock from a large ocean impact to be the main trigger in producing the following secondary effects: earthquakes, volcanoes, lava flows and underwater landslides.

Secondary earthquakes move at a speed of 8,000 mph to 12,000 mph (3.5 to 5.5 km/sec). These earthquakes will travel horizontally through the earth's crust. A large land impact will produce a ground shock similar to a Secondary earthquake. Experience from nuclear weapons testing shows this Secondary ground shock is an extremely damaging shock wave near the impact site. The ground shock at the equivalent 75-psi blast overpressure is sufficient to snap an individual's legs in two if they are standing on a concrete floor within a blast shelter.<sup>5</sup> But this shock wave effect rolls off very quickly, such that at the equivalent 50-psi range, the effect is minimal.

*Ground shock is the primary threat of deep impacts that produce global extinction events.*

## Water Compression Wave – Tsunami

Since 72 percent of the Earth's surface is covered with oceans, there is a 72 percent probability that a comet or asteroid impact will occur in the ocean.<sup>3</sup> An ocean impact would excavate a large transient cavity approximately 20 times the diameter of the impactor.<sup>8,9</sup>

An ocean impact will create a **compression wave in the water**. The compression wave may be sufficient to implode deeply submerged objects, such as submarines.

A large ocean impact would produce a large **tsunami**. Tsunami is Japanese for "harbor wave". Tsunami generally travel very fast across the ocean, typically 380 miles per hour.<sup>10</sup> In deep water the impact tsunami height might be several thousand feet high for a K/T size impactor, but the height will increase dramatically as the waves reach the shoreline because the wave slows in shallow water and the energy becomes more concentrated.<sup>8</sup> The impact tsunami may produce several mile high waves that could travel several hundred miles inland.<sup>11,12</sup> Tsunamis are of concern because they propagate over great distances and much of the world's populations are centered around the coastal areas.

The following equation (by Jack Hills from Los Alamos National Laboratory) predicts the height of a deepwater wave (tsunami) 1,000 kilometers (621 miles) from an asteroid/comet point-of-impact.

$$h = 1.0081 \times 10^{-5} \times [(\text{diameter})^3 \times (\text{velocity})^2 \times (\text{density})]^{0.54}$$

Where "h" is the deepwater wave amplitude expressed in meters

Where comet/asteroid diameter is expressed in meters

Where impactor velocity relative to Earth is expressed in kilometers/second

Where impactor density is expressed in grams per cubic centimeter

The following table provides results of this formula based on a spherical non-binary asteroid with a density of 2 grams/cc, and a velocity of 20 km/sec. This table defines wave height at 1,000 kilometers from the impact.<sup>8</sup>

<b>Asteroid Diameter</b>	<b>Deepwater Wave Height</b>	<b>Asteroid Diameter</b>	<b>Deepwater Wave Height</b>
200 meters	2 meters	660 feet	7 feet
300 meters	4 meters	980 feet	12 feet
400 meters	6 meters	1,310 feet	20 feet
500 meters	9 meters	1,640 feet	29 feet
600 meters	12 meters	1,970 feet	39 feet
700 meters	15 meters	2,300 feet	50 feet
800 meters	19 meters	2,630 feet	62 feet
900 meters	23 meters	2,950 feet	75 feet
1 kilometer	27 meters	0.6 miles	89 feet
2 kilometers	83 meters	1.2 miles	272 feet
3 kilometers	160 meters	1.9 miles	525 feet
4 kilometers	255 meters	2.5 miles	837 feet
5 kilometers	366 meters	3.1 miles	1,200 feet
6 kilometers	490 meters	3.7 miles	1,600 feet
7 kilometers	630 meters	4.4 miles	2,100 feet
8 kilometers	780 meters	5.0 miles	2,600 feet
9 kilometers	950 meters	5.6 miles	3,100 feet
10 kilometers	1.1 kilometers	6.2 miles	3,700 feet
11 kilometers	1.3 kilometers	6.8 miles	4,300 feet
12 kilometers	1.5 kilometers	7.5 miles	5,000 feet
13 kilometers	1.7 kilometers	8.1 miles	5,600 feet
14 kilometers	1.9 kilometers	8.7 miles	6,400 feet
15 kilometers	2.2 kilometers	9.3 miles	7,100 feet

The deepwater wave amplitude is a function of the distance from the impact point. The closer to the impact, the higher the deepwater wave amplitude and vice-versa.

The deepwater wave amplitude is the maximum height of the wave above sea level when in deep water. The run-up height is the vertical height above sea level of the tsunami at its furthest point inland. The run-up height will help to determine how far the tsunami will travel inland. The run-up factor is the run-up height divided by the deepwater wave amplitude. The run-up factor will vary significantly by local topography and wave direction. Crawford and Mader (1998) estimated typical run-up factor as only 2 to 3. But measure run-up factors as high as 40 have been observed in Hawaii.<sup>8</sup>

Hills & Mader (1995) estimated that for a typical coastal plain a 10 meter (33 feet) tsunami (deepwater wave height) would penetrate about 1 kilometer (0.6 miles) inland and a 100 meter (328 feet) tsunami would penetrate about 22 kilometers (14 miles) inland.<sup>8</sup>

Significant variability exists in deepwater wave amplitude predictions made by experts in the field.

A recent paper by H. J. Melosh indicates the tsunami impact threat is exaggerated.<sup>13</sup> An earlier Office of Naval Research Report studying the tsunami hazard from nuclear explosions showed the wave structure had short wavelengths and significant wave harmonics. This significantly reduced the deepwater wave amplitude.

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## **Thermal Radiation**

An asteroid or comet impact will produce high levels of thermal radiation when it strikes the Earth. This radiation will come from the Flash and the Fireball.

### **Flash**

As the comet or asteroid enters the atmosphere, it will produce a flash of very intense ultraviolet light. The light will be many times brighter than the sun. The flash lasts only several millionths of a second. Indirect exposure can produce temporary injury called flash blindness. This effect will last a few minutes. Direct exposure can cause permanent damage to the retina; by producing choriretinal burns.<sup>7</sup> The curvature of the Earth will limit this effect significantly. In general, anyone outside 100 miles from point of impact would not directly see the flash. Individuals in aircraft or spacecraft may be affected at far greater distances.

The ultraviolet thermal radiation from the flash can result in very intense heating of the skin, called "flash burns". Shielding of even the most insubstantial type (for example, sheets of paper or thin cloth) is effective at minimizing the effects of "flash burn".<sup>14</sup>

When the impact occurs, the sound of the flash will begin to make its way around the world. The sound has been described as a thunderclap or as a gun being fired. In general, this sound will travel at approximately 764 miles per hour.

### **Fireball**

The fireball will produce large quantities of visible and infrared thermal radiation that can produce instantaneous fires. Air is essentially transparent to thermal radiation. The thermal radiation affects exposed surfaces, producing instantaneous damage by rapid heating. The effects of thermal radiation can be reduced dramatically (65%) if the atmosphere is foggy or cloudy. At blast wave overpressure greater than 10-psi, most combustible material will ignite and burn. Easily ignitable, dry materials (such as, dry leaves, dry grass, old newspapers, thin dark flammable fabrics, tar paper, etc.) can be ignited at overpressures as low as 2 to 3 psi and produce fires.

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## Debris & Aerosols

At impact, the comet or asteroid will be instantly vaporized along with material from the impact crater/cavity. The diameter of crater/cavity created will typically be 20 times the diameter of the impactor.<sup>8</sup> This debris at temperatures greater than 9,000 degrees Fahrenheit will be ejected into the atmosphere and into space in a ballistic trajectory.<sup>15</sup> Whereas an ocean impact will create a vast amount of superheated steam, an impact on land will eject significantly more solid debris into the atmosphere.

The blast will fling large amounts of debris over short distances within the atmosphere. The area around the impact will become a major debris field. Some of this debris may be the size of large boulders. Much of the debris will be very hot and cause significant damage.

As the asteroid or comet strikes the Earth, the tremendous heat produced by the impact will melt and vaporize rock. The blast will also eject debris into the upper atmosphere and into space in a ballistic trajectory. It will take 45 to 60 minutes for the debris to reach the other side of the globe.<sup>3</sup> The debris from a large impactor will blot out the sun, the moon and the stars and turn the Earth dark as night. This vaporized rock cloud will rapidly cool and condense in space and form droplets that solidify into spherules (tiny glass beads about 1mm in diameter). Over the next several hours and days, much of this debris will rain back down over the entire surface of the Earth.<sup>15</sup> This returning debris will be fairly light and will be slowed significantly as it falls through the atmosphere and should not present a significant secondary impact hazard.

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## Electromagnetic Effects

In general, electromagnetic effects will not directly harm people but the effect can be deadly to electronics and inhibit electronic communications.

### Electromagnetic Pulse (EMP)

I theorize that an impact can produce a very high Electro-Magnetic Pulse (EMP). The pulse would occur almost instantaneously after the impact. This pulse is typically of a very short duration, approximately 1 microsecond and is caused by Compton-recoil electrons and photoelectrons from photons scattered in the surrounding medium. The resulting electric and magnetic fields may couple with electrical/electronic systems to produce damaging current and voltage surges. This pulse is not harmful to humans but it is deadly to electronics, especially transistors, semiconductors and computer chips. The scope of this effect has been only minimally studied. Comparing a surface impact to a nuclear weapon EMP can provide a crude measurement of the effective range of this effect. A ground-level nuclear explosion will produce a Source Region Electro-Magnetic Pulse [SREMP] as far as the distance at which the peak overpressure is 2 psi.

The types of equipment damaged or destroyed by an EMP includes:

Energy Infrastructure: electrical power grids, power generating stations, the control systems in nuclear power plants, charge controllers & voltage converters in solar & wind generating electrical systems, oil and gas delivery systems, advance computer control systems.

Communications Infrastructure: television and radio broadcasting facilities, radios, cell phones, televisions, computers and networks, Internet, digital telephone switching systems, commercial telephones, microwave and satellite communications, police scanners.

Automobiles – cars manufactured after 1985 contained a variety of electronics including engine computers, electronic ignition, fuel injection systems, anti-lock breaking systems, electronic automatic transmissions, computer controlled active suspension, and four wheel steering.

Transportation Infrastructure: other forms of transportation (airplanes, buses, trucks, rail, ships), road and rail signaling, gasoline pumps, global positioning systems, radar systems, navigational aids.

Economic Infrastructure: automated machinery, banking, finance industry, stock market, computer systems in factories and offices, inventory maintenance, medical pumps and monitors, medical systems, government and corporate databases, electronic controllers used in manufacturing, chemical, petroleum product industries and metallurgical industries.

Long conductors such as power lines, communication cables, radio towers, railroad tracks, large antennas, pipes, cables, metal fencing and the electronic equipment attached to them are particularly susceptible to EMP.

### **Ionizing Radiation**

Large quantities of ionizing radiation will be produced by the impact and can severely change the environment of the upper atmosphere, producing heavily ionized regions, which can disrupt electromagnetic waves passing through those zones. The trapping mechanism for these high-energy electrons may be similar to that which produces the Van Allen radiation belts. This radiation will cause significant interruption of communications. This will interfere with all telephone, television, computer and radio traffic. There will be so much static in the signal that it will be almost unintelligible. For a large impact, these disturbed regions can easily be global in size and can persist for tens of hours. This would essentially shut down all worldwide communications.

### **Electroponic Bursters**

An impact can produce phantom sounds similar to a crackling or clicking sound. These strange sounds can be heard by one individual and yet another individual a few feet away will hear nothing. These sounds are commonly called electroponic bursters. These sounds occur instantaneously at impact. It is theorized these sounds come from very low frequency (VLF) radio waves at frequencies of 10 hertz to 30 hertz that are produced during impact. These radio waves require a suitable transducer that will act as a loudspeaker to convert the electromagnetic signals into audible vibrations. Several items have been shown to work including aluminum foil, thin wires, pine needles, dry frizzy hair, and even a pair of eyeglasses.<sup>18</sup> In another theory, they are caused by the generation of short-lived transient pulses in electric field strength.<sup>19</sup>

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## **Secondary Effects**

Secondary effects (mass fires, earthquakes, volcanoes, lava flows, underwater landslides, impact winter, acid rain, stratospheric effects, oxygen depletion, magnetic pole reversal, energetic weather patterns, starvation and plagues) are triggered by the Primary effects (shock waves, thermal radiation, debris and electromagnetic effects) of a large comet or asteroid impact.

### **Mass Fires**

It has been theorized that a large comet or asteroid impact (such as the Chicxulub impact) would produce a global firestorm. The large impact would instantly vaporize several hundred cubic miles of water, earth and other debris at temperatures greater than 9,000 degrees Fahrenheit and eject this superheated material through the atmosphere and space in a ballistic trajectory.<sup>15</sup> Over the next several hours after the impact, much of this debris would rain down over the entire surface of the Earth.<sup>10</sup> The heavier debris would fall like burning rocks from the sky, killing and destroying almost everything exposed above ground. The heat would incinerate cities and forests. Approximately 50 to 100% of the forest in the world will be burned up simultaneously.<sup>3</sup> The air temperature will rise significantly, to the temperature of an oven set on broil. A global firestorm would result in the combustion of much of the organic material present on the surface of the Earth.<sup>20</sup> The global firestorm

theory is an interesting theory but I believe that in time this theory will be thrown out because geological evidence and impact modeling will prove this theory lacks merit.

There are the two types of mass fires: conflagration and firestorms. In a conflagration, fire spreads along a moving fire-front driven by ambient winds. The San Francisco Earthquake Fire is an example of a conflagration. Many forest fires are conflagrations. Conflagrations take several hours to develop and inflict few immediate or direct casualties because there is adequate time for populations to flee. In a firestorm, the violent inrushing of winds creates an extremely hot fire. Temperatures can reach 1,500°F – 5,400°F (800°C – 3,000°C). The winds prevent the fire from spreading outward. The fires continue until all combustibles are exhausted. An example is the Hamburg firestorm in World War 2. A firestorm is extremely deadly to individuals because of the very high temperatures generated, the inability to evacuate, and the threat of asphyxiation.<sup>6</sup>

I feel that the potential for a global firestorm is overstated. I believe that thermal radiation from the impact fireball will spawn massive fires in the vicinity of the impact. At the distance defined by the blast wave overpressure greater than 10-psi, most combustible material will ignite and burn. Easily ignitable, dry materials can be ignited at overpressures as low as 2 to 3 psi and result in fires.<sup>5</sup>

Most of the superheated ejecta material that is flung into the atmosphere and into space in a ballistic orbit will fall back to Earth. The initial wave of debris will be very hot indeed. Most of this debris will fall near the point of impact, well within the zone of destruction defined by the 1-psi overpressure area. But some of this debris will be flung into the stratosphere and into space and that debris will take several hours or days to return to the Earth surface. That debris will have cooled down substantially. The longer this material spends in space, the colder the material will become, because this ejected debris will radiate heat. As the ejected material is drawn back to Earth by gravity, the material will have significantly less kinetic energy, than the original asteroid or cometary mass, because it now has a much lower velocity and this slow returning debris will not produce radically heating of the Earth's atmosphere.

This belief is supported by impact modeling conducted by V.V. Shuvalov, Institute of Dynamics of Geospheres, Moscow, Russia which showed that the mass of high velocity ejecta from the Chicxulub impact appears to be rather small, a few percent of the impactor mass, and could not be responsible for global wildfires. The critical ignition value of incident radiation energy is estimated to be 20-100 joules/cm<sup>2</sup> and is a function of forest type, moisture and other conditions. In general, firestorms could only arise up to a distance of 1,250-1,900 miles (2,000-3,000) kilometers from the impact site.<sup>21</sup> Refer to the following [research article](#).

Another indicator that a global firestorm did not occur during the K/T Boundary comes from the study of fossilized fern spores. A global firestorm would have destroyed nearly all plant life. After the total devastation from the K/T impact, the first plant to rebound would have been the fern. One would expect the total pollen/spore count to rise sharply in the years immediately following the impact. According to "K/T Boundary Impact Hypothesis" by Ralph E. Taggart, that was the case, but only for the area within 2,100 miles (3,400 kilometers) of the Chicxulub impact site.<sup>22</sup> That zone did show a "fern spike" which peaked at 70-100% of the total pollen/spore count immediately after the impact. In general, areas outside the 2,100 miles did not exhibit this "fern spike". A global firestorm would have produced a global "fern spike" and that was not the case. The 2,100-mile radius corresponds roughly to the 3-psi overpressure from a blast wave created by an impact that produced a kinetic energy equivalent of 100,000,000 megatons of TNT (the K/T impactor).

Looking at this from another angle, spherules are small beads of melted rock, ejecta from the impact. Spherules are present in and define geological boundary layers for an impact event. This debris was rapidly cooled prior to being deposited all over the world. If the debris had been in a melted state when it returned to the surface of the planet, it would have fused with whatever it came in contact with. Spherules would not have their characteristic round shape. Therefore this impact debris was cool and did not ignite worldwide firestorms.

I believe scattered fires will occur after an impact outside the area defined as the zone of destruction. Some of these may even become mass fires. Most will be a conflagration, but a few may become firestorms. Generally these fires will be a result of secondary effects, such as volcanic and earthquake damage. A gas line is broken and natural gas is ignited by a flame. Communications is down. The fire department is not alerted and cannot

respond. The fire burns down one house and spreads to the next. Soon an entire neighborhood is ablaze. Or a lightning strike sets a field ablaze, soon the unchecked fire grows into a massive fire that consumes many acres of farmland.

A short while ago, I was asked the question: "Will the oceans burn during a global firestorm?" I thought what a strange question. Let me broaden the question and discuss mass fires for 6 zones: ocean, desert, grassland & farmland, cities, forest, fuel reserves.

Ocean: The obvious answer is "no". Oceans represent 72 percent of the Earth's surface.

Desert: The sand in the deserts will not burn. They represent approximately 5 percent of the Earth's land area.

Grassland & Farmland: To assess this, I will call on my own experience. I have a 5-acre field in front of my home. I burned the shrub in the springtime to clear the land (a common practice in the countryside). I would factor in the wind direction and light the fire at the downwind end to create a firebreak and then I would light the fire from the upwind side. The fires would burn from both ends towards the middle. One year the fire almost got away from me. The flames shot up 30 to 40 feet in the air. The fire spawned a whirlwind (baby tornado). The interesting observation is that the fire only lasted approximately 30 minutes. And 30 minutes after the fire burned out, you could freely walk among the ashes. In summary, a fire in grassland and farmland could turn into a conflagration if unchecked but not a firestorm and the fire would be short-lived.

Cities: The effects of a large comet impact have been compared to the effect of a very large nuclear bomb. A report titled "The Effects of Nuclear War" by the Office of Technology discusses the probability a nuclear weapon could produce a firestorm. The report summarizes their assessment as follows: "Some believe that firestorms in the U.S. or Soviet cities are unlikely because the density of flammable materials (fuel loading) is too low – the ignition of a firestorm is thought to require a fuel loading of at least 8 lbs/sq. ft. (Hamburg had 32), compared to fuel loading of 2 lbs/sq. ft. in a typical U.S. suburb and 5 lbs/sq. ft. in a neighborhood of two story brick rowhouses." In summary, most cities lack the fuel density to create a firestorm. Most fires within cities if unchecked could grow into conflagrations.

Forest: If a fire occurs in a forest and is left unchecked, it could develop into a forest fire, which is a type of mass fire called conflagration.

Fuel Reserves: Mass fires could occur in reserves of fuel including coal, oil and natural gas. I might lump large tire dumps also in this category. The fuel loading of these reserves can exceed 8 lbs/sq ft. Thus there is the potential of creating a localized firestorm. But in general many of these reserves are buried underground, therefore the release of fuel will be limited and a fire similar to the oil field fires at the end of the Kuwaiti war is more likely.

Vast quantities of methane hydrate are located under the sea floor. The methane was formed from decomposing organic matter in ocean sediment. The amount of carbon contained in these deposits exceeds the amount in all of the known coal, oil and gas reservoirs. It has been suggested that an impact could release large volumes of methane gas, that would rise to the surface, ignite and burn.<sup>23</sup> Referring back to the study of fern spore, the data implies that a global firestorm did not result in the K/T boundary.

Summary: The area within the zone of destruction defined by the 1-psi overpressure will be subjected to significant thermal radiation and to the fallout from very hot debris. This will spawn very energetic fires including firestorms. The area outside this zone of destruction will be subjected to scattered fires generally as a result of secondary effects such as earthquakes, lightning strikes, etc. Many fires will spread because of lack of emergency responders. These fires could develop into mass fires, most of the type called conflagrations.

## Earthquakes/Landslides/Volcanoes/Lava Flows

A large impact can trigger a variety of secondary effects including earthquakes, landslides, volcanoes and lava flows. Most of these events will be triggered by the Primary Ground Shock. Although we have experienced during the course of human history many large disasters of this type, we have not experienced the depth and breath of simultaneous disaster events that can be triggered by a large impact. Various disasters will sweep across the globe. They will generate great devastation, which will further compound the problems during recovery efforts. Volcanoes and lava flows can produce vast amount of debris and aerosols and propel this material into the upper atmosphere and stratosphere. The aerosols, and sulfur dioxide in particular, can result in global cooling that can impact crop production.

A massive deep ocean impact will produce two areas (not one) of extensive damage on the surface of the Earth. The first is at the site of the impact. The second is at the exit vector on the opposite side of the globe, where the Earth will be turned into a jumbled debris field from which lava and deadly gases (such as sulfur dioxide) will spew forth for decades. These lava flows represent the major cause of extinctions from an asteroid or comet impact because they result in long-term global ecological damage. (There was a massive episode of lava flows in what is now India, producing huge sheets of volcanic material known as the Deccan Traps at the end of the Cretaceous Period. There was also a very massive episode of lava flows called the Siberian Traps at the end of the Permian Period.) This phenomenon is even observed on other planets. On the planet Mercury, a very large comet or meteorite impact formed the Caloris Basin. The shock wave from this impact traveled through the planet and produced a jumbled terrain on the opposite side.<sup>20</sup>

The thickness of the Earth's crust is around 3 miles under the ocean and 20-35 miles on the continents.<sup>24</sup> [USGS Map](#) The ocean impact of a large comet or asteroid could puncture a hole through the Earth's crust into the molten mantle beneath producing massive lava flows. This impact will generate a compression wave through the molten mantle and core of the Earth. Massive earthquakes will resonate across the crust of the earth for several years after the impact. These compression waves will result in increased volcanic activity. The core of the Earth may develop an oscillation or ring and as a result the pattern of earthquake/volcanic activity will have a repetitious burst cycle (33-70 minutes).

This theory is supported by recent research findings that uncovered a strong correlation between major impact events and secondary volcanic activity. During the last 4 billion years on Earth, scientists have identified 10 major impact events caused by collision with comets/meteors. Nine out of ten of these Earth impacts also correlate with intense periods of mantle plume volcanism.<sup>25</sup>

Just as a massive earthquake will produce aftershocks, an impact from a large comet or asteroid will produce a sizeable increase in earthquake and volcanic activity. Some of this activity will occur in or near the oceans. An impact can also induce underwater landslides. These events can produce secondary tsunamis. Although these will not be of the size of the comet "impact tsunami", they will still be of a magnitude that can cause great destruction along the coastline. Because they will occur in many areas of the globe, they represent a considerable threat to all coastal areas around the world for several months.

An impact can trigger a very intense earthquake. In a large earthquake, the land will take on the appearance of the ocean during a storm with large rolling waves. A deafening roar will precede by a few seconds each quake. Large areas of land will be uplifted or sunk. Landslides will occur. Deep fissures will open up in the earth. Sand blows or eruptions will cover some areas with sand and mud. Above ground and underground rivers will be rerouted. Some new ponds and lakes will form while others disappear.

The following are examples of secondary effects that might follow a large asteroid or comet impact in the Atlantic Ocean.

A large ocean impact can break through the Earth's crust. This would expose the ocean to the molten lava beneath. The lava could flow up forming a new large volcanic island. The volcano would spew significant amounts of sulfur dioxide into the atmosphere.

The Hawaiian Islands were formed from massive volcanoes. If the water in the ocean were removed, the Hawaiian Islands would be the tallest mountains on the surface of the Earth, over 5 miles high. Geological evidence has shown that over time, individual islands will break apart through large landslides. Great chunks, the size of New York City, can break off and tumble 5 miles to the bottom of the ocean floor. When this landslide occurs, it displaces a large volume of water. This would create a large tsunami that would affect the entire Pacific Rim. A large crack with several feet of separation has already formed in the Big Island of Hawaii. The Primary Ground Shock from a large ocean impact (even though it occurred on the other side of the United States) would travel through the molten mantle and could trigger this landslide resulting in a tsunami that would devastate the cities along the west coast of the United States, including Los Angeles, San Diego and San Francisco along with coastal areas of Japan, Asia, and Australia.

The impact could trigger a landslide and volcanic activity on the Teide volcano on Tenerife in the Canary Islands. This is the 3rd largest volcano on Earth. If the asteroid impact triggered this landslide, the result would be a tsunami that will primarily affect Northwestern Africa and Western Europe. The volcano would erupt and send significant amounts of sulfur dioxide into the atmosphere.

The impact could also wake up the Yellowstone volcano. This is the largest volcano in North America. The impact could also produce large earthquakes in the Reelfoot Rift that is commonly called the New Madrid fault. This is a large earthquake fault line that runs down the center of the U.S. A large earthquake in this fault would generate significant earthquake damage from Chicago to New Orleans. The impact could also produce large earthquakes in the San Andreas Fault system in California.

### **Dust & Impact Winter**

It has been theorized that the impact of a large comet or asteroid and the resulting fires would throw up so much dust and ash in the stratosphere that it would shut off sunlight from the surface of the planet. This would plunge the Earth into a period of darkness lasting many months and even years. In the absence of sunlight, solar heating of the Earth's surface would come to a halt. This will lead to a severe cooling of the continents approximately 70°F below normal and lead to an "impact winter".<sup>3</sup> An "impact winter" is similar to a "nuclear winter" but more severe, and could lead to a new Ice Age.

I feel that the threat of a dust generated "impact winter" is vastly overstated and that any dust generated "impact winter" produced will not be anywhere near as severe nor last as long as some predict.

\* Just as dust that is kicked up into the atmosphere will block sunlight from hitting the earth, the dust will also act as an insulator trapping heat at the Earth's surface. This includes the heat from (1) the impact and fireball, (2) firestorms, (3) fuel fires – oil, natural gas, coal, timber, methane hydrate, and (4) lava flows and volcanoes. This trapping effect will slow the decent of the temperature fall, and retard the onset and depth of the "impact winter".

\* Some of my reasoning comes from reverse logic. The dust cloud is a global threat. It shuts off light from the entire surface of the Earth. It brings photosynthesis to a grinding halt. Several mammals and reptiles survived the asteroid that slammed into Mexico's Yucatan Peninsula 65 million years ago. We know this because the event did not result in total and complete extinction of all complex lifeforms. How long could these creatures survive without food? Several years seems like a very, very long time to go without food.

\* The oldest tropical honeybees, *Cretotrigona prisca*, were studied by Jacqueline M. Kozisek. These honeybees survived the K/T extinction. The bees share a common ancestry tree with modern tropical honeybees making them an ideal subject for study. These bees rely on pollen for their energy source and do not store honey. They must have a constant source of blooming angiosperms to survive. They also require a temperature of 31-34°C to maintain their metabolism. These insects are very sensitive to the environment changes. Covering the outer atmosphere with a dust layer, blocking off photosynthesis, and dropping tropical temperatures by 7-12°C would have meant certain death for this species. If a

global “impact winter” occurred, these honeybees could not survive years in the dark and cold without the flowering plants they lived off of. But they did survive!<sup>30</sup>

\* According to a geologist, Kevin Pope, the impact would not generate the quantities of fine dust needed to block the Sun completely and choke off photosynthesis. Approximately 99% of the debris produced will be in the form of spherules, which are too coarse and heavy to remain suspended in the upper atmosphere for very long. Only 1% of the debris is fine dust generated from pulverized rock. If this fine dust were spread out across the entire globe, it would represent a thickness of approximately 0.03 millimeters. Therefore the hypothesis of an "impact winter" is vastly overstated.<sup>26</sup>

I believe the entire world will be dark within one hour of a large impact. The impact debris flung high into the stratosphere will cause this darkness. It will take several days for this debris to fall back to Earth's surface. I believe at about the third day after impact, some light will start to get through.

## **Gas Evolution & Acid Rain**

The ionization of the air during the impact event, and the subsequent firestorms and increased volcanic activity will produce large volumes of hazardous or poisonous gases including nitric oxide, nitrogen dioxide, carbon dioxide, sulfur dioxide, carbon monoxide, hydrogen sulfide, hydrogen chloride and hydrogen fluoride.<sup>16, 17</sup> Breathing several of these gases can result in severe lung damage, lung edema and death.<sup>3</sup> Fortunately, many of these very deadly gases will react quickly with moisture in the air and convert to a less dangerous acid mist. In normal to high humidity environments, this conversion will take place within 1 - 4 miles. But under the following conditions, the range will be significantly greater:

- \* Dry, arid desert environments.
- \* Winter freezing environments that produce very low humidity levels.
- \* High up in the atmosphere where the temperature is below freezing.
- \* Very dense gas clouds.

As these gases combine with the moisture in the air, strong acids will form. This intense acid rain including carbonic acid, nitric acid, hydrated sulfur dioxide, and hydrochloric acid will fall to earth.<sup>3, 12, 16, 17, 27</sup> Some of the most intense periods of acid rainfall may occur within the few days immediately following the impact. These acid rainfalls may be very intense localized concentrations and a function of prevailing wind patterns.

Acid rain can harm vegetation. Acid rain can pollute the waters in rivers, streams, lakes and oceans. This rainfall can contaminate drinking water for humans, mammals, amphibians, reptiles and birds. Slight acidification of the ocean can destroy calcareous nannoplankton.<sup>22</sup> It can also produce large fish kills.

A deep impact that produces a massive release of volcanic magma on the Earth's surface will also produce a very complex climate model. The released light sulfur gases will rise high in the sky and produce a very reflective atmosphere. The volcanic area will be very dark and these acid clouds will wrap around the affected hemisphere, turning half the Earth dark. But the carbon dioxide being heavier than air will cling to the planet's surface acting like a thermal blanket, holding in trapped heat. One million cubic kilometers of magma releases the equivalent of 1 year of solar heating on Earth. Several past impacts that produced global extinction events vented 5 times this amount of magma. This is a significant quantity of thermal heat if the magma was released during a short interval. The magma heat will turn the area thousands of miles near the exit vector into a dark inferno. Water will act as a natural heat transport mechanism. The evaporated moisture will move heat above the carbon dioxide layer venting the thermal energy into deep space. This will quickly turn the forest in this region into tinder. Volcanic induced lightning will ignite these forests producing great mass fires.

*The evolved gases from the magma release and the acidification of the terrestrial and marine environments and the draw down of oxygen levels are the primary killer of life forms during past mass extinction events.*

## Upper Atmospheric Effects

The fireball composed of very hot gases will rise very high into the atmosphere (stratosphere, mesosphere, thermosphere) and radiate heat into outer space. In general, hot gases expand. I believe the fireball when it reaches the stratosphere will result in an expansion of the stratospheric envelope, which can increase the orbit disrupting drag on spacecraft.

The debris ejected from a large impact, thermal radiation and the expanded upper atmosphere can create a hazard for satellites. Satellites have two types of orbits.

Satellites in a Geostationary or Geosynchronous Equatorial Orbit are high above the Earth. Typically these are 22,300 miles above the surface of the Earth. These satellites are used for, telephone transmissions, television and radio program feeds, computer communications, maritime navigation, GPS, and military command & control. In general, these satellites will survive the effects of the impact.

Satellites in a Low Earth Orbit including Polar Orbit are close to the Earth. Typically these satellites are 200-500 miles above the surface of the Earth. They travel at high speeds ~17,000 mph. These satellites are used for remote sensing and weather. These satellites will be particularly vulnerable to collisions with impact debris blasted into space. The collision of this debris field and these low earth orbit satellites will disable or destroy these satellites within a few hours. The International Space Station and Space Shuttle will also fall into this category.

A large comet or asteroid impact will produce large volumes of nitric oxide and carry it well up into the stratosphere, where this aerosol will severely damage and destroy the ozone layer.<sup>27</sup> As a result; high levels of ultraviolet radiation, that is normally shielded by the ozone layer, will reach the surface of the Earth. Ultraviolet radiation can cause serious sunburn, increased incidences of skin cancer and eye damage. Ultraviolet radiation can cause some genetic damage in plants, but the damage will be limited. The ozone molecules will be steadily regenerated by solar radiation after the impact. Complete regeneration and recovery could take several years.<sup>28</sup>

## Oxygen Depletion

The oxygen in the atmosphere is 20.946% by volume.<sup>24</sup> An atmosphere containing less than 19.5% oxygen is considered oxygen-deficient. Loss of consciousness, asphyxiation and, death can also occur in a matter of minutes due to oxygen starvation.

Atmospheric Oxygen by Volume	Symptoms or Effects
16% - 12%	Breathing and pulse rate increased, muscular coordination slightly disturbed.
14% - 10%	Emotional upset, abnormal fatigue, disturbed respiration.
10% - 6%	Nausea and vomiting, collapse or loss of consciousness.
Below 6%	Convulsive movements, possible respiratory collapse and death.

*This threat only materializes for a deep impact, which produces a massive release of magma at the Earth's surface.*

Deep impact events can produce reduced oxygen levels. During several past mass extinction events, the oxygen levels have dropped approximately 20%. This is a huge drop. The "Russian-Ukrainian Theory of Deep Abiotic Petroleum Origin" explains why the atmosphere suffered a dramatic decline in oxygen levels and why the oceans became anoxic/superanoxic. According to the Russian-Ukrainian Theory, petroleum is not a fossil fuel. Petroleum comes from hydrocarbons that were basic components in planet creation. These hydrocarbons exist in a stable form under extreme pressures and temperatures on the underbelly of the Earth's crust. If the Russian-Ukrainian Theory is applied to volcanic eruptions, it produces an interesting observation. Small amounts of these hydrocarbons bleed into the magma during volcanic eruptions. The hydrocarbons in the magma burn when they are exposed to the oxygen in the atmosphere. Several gases released during volcanic eruptions, such



as carbon dioxide and monoxide, rather than originating as compressed gases from deep within the Earth, are in reality, a product of a combustion process at the Earth's surface. The combustion process, not only injects acidic gases into the atmosphere, but bleeds oxygen from the atmosphere, which in turn removes oxygen from the oceans.

### **Magnetic Pole Reversals**

A deep impact could shift the Earth's magnetic pole and may produce a pole reversal.<sup>3, 20</sup> Earth has undergone magnetic pole reversals in the past and a large impact could trigger this type of event. The Earth's magnetic pole deflects cosmic radiation. When the magnetic pole is weak or non-existent, such as at the mid-point of a pole reversal, charged particles from space can penetrate to the Earth's surface.<sup>20</sup> This cosmic radiation can cause direct harm to life on the planet and can also create genetic damage.

### **Energetic Weather Conditions**

Years ago when I was young, living in Dallas, Texas, I witnessed an unusual weather phenomena, a mud storm. As I remember it, the storm rained mud for about 20 minutes. When it was done, everything was coated with a ¼ inch thick layer of mud. This unusual event was caused when a dust storm collided with a rainstorm. This type of weather phenomena will become more like the norm after a large impact. A similar weather phenomenon that will occur after an impact is called "black rain". In this phenomenon, rain is mixed with the debris and ashes from the impact. This rain is very black and very sticky. The residue coats everything exposed on the outside and is very difficult to wash off.

If a large comet or asteroid impacts the ocean, I believe the heat of the fireball would evaporate large amounts of water. I feel that there will be significant rainfall immediately after the impact. The largest amounts will fall in the region near the impact and this storm path will be determined by the prevailing winds.

### **Starvation and Plagues**

A massive comet impact can produce a global catastrophe. Unfavorable weather conditions following a large impact will retard food production. Acid rain will also contribute by destroying crops. The infrastructure will take a big hit from a large impact. Broken transportation lines will inhibit transport of grains to processing centers and then to population centers. Other damaged infrastructure (government, finance, communications, energy) will place most recovery efforts into shambles. The inability to quickly recover from the damaged infrastructure will lead to starvation and famines in the general population. A weakened population from starvation is vulnerable to disease, epidemics and plagues.

### **Summary**

The great majority of asteroid and comet impacts produce only regional areas of great devastation.

Global extinction events are rare and are caused by deep impactors, one's that penetrates the Earth's crust. This type of impact produces two zones of destruction: one at the point of impact and one on the opposite side of the Earth at the exit vector. The destruction at the point of impact produces a local area of devastation that for a short period of time (several days) wrecks havoc. The area of devastation on the opposite side of the Earth is significantly greater and the devastation is long-term extending tens of thousands of years or longer. It is this component that produces global devastation by releasing of massive quantities of volcanic magma, which in turn release acidic and poisonous gases. The acidic gases combine with moisture to form acids that destroy life across the entire globe. The gas generation is also responsible for the drawdown of oxygen levels below minimally acceptable levels. A very large impactor is required to produce a global extinction event. Generally this is not an asteroid but rather a comet from the Oort Cloud. The energy released by a deep impactor is split between surface effects and interior effects. The surface effects can be modeled by comparable energy release

from a surface nuclear burst. The interior effects can be modeled by an equivalent underground nuclear explosion. The main underground component is ground shock.

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**Appendix A**  
**Impact Scenario**

## SCENARIO

An asteroid strikes the Earth without warning. The asteroid 3.6 miles (5.8 kilometers) in diameter crashes into the Atlantic Ocean at Longitude 72° 49' West, Latitude 28° 0' North, at the edge of the Bermuda Triangle. The asteroid is traveling at a velocity of 20 km/sec, has a density of 2.0 grams/cc. The asteroid is spherical in shape. It is not a binary asteroid. The impact occurs at 9:45 PM Eastern Time in the middle of June. The asteroid hits the Earth nearly head-on (2 degrees from true vertical) heading slightly East to West.

The asteroid will impact with the kinetic energy equivalent to 10,000,000 megatons of TNT. This amount of energy is equivalent to 333 times the energy of all the nuclear weapons that existed in the world during the height of the cold war in the 1970's.

### Secondary Effects:

I have introduced a number of secondary effects to interject some realism into the scenario. That is not to say that a 3.6-mile diameter asteroid impact will produce these exact effects, but rather they will produce effects like these. These just happen to be on scientist minds at the moment, events that are likely to occur even without an impact.

\* There is a crack that has formed on the Big Island of Hawaii. The gap is presently a few feet wide. If you remove the water from the ocean, Hawaii would be one of the tallest mountains in the world, over 5 miles high. The islands were created from underwater volcanoes. In time as the islands age, they will fracture producing a large landslide. Part of the Big Island will break away and fall to the bottom of the ocean. This landslide will displace many square miles of water and produce a very large tsunami. This tsunami will destroy much of the coastal areas of the West Coast of the U.S., Japan, Asia, and Australia. Within this scenario, the asteroid impact will trigger this landslide.

\* The impact will also wake up the Yellowstone volcano, one of the largest volcano in North America.

\* The impact will stress the Reelfoot Rift producing several earthquakes along the New Madrid fault line. This large earthquake fault runs down the center of the U.S. It will generate significant earthquake damage from Chicago to New Orleans.

\* The impact will produce large earthquakes in the San Andreas Fault system in California.

## Bermuda

Jim Pidelo had completed his law degree at Harvard and took a detour to Bermuda for a little needed R&R before returning home to take the New York bar exam. He knew from the moment he stepped off the plane; this was a good decision. The ocean water was a deep blue and the weather was balmy. He settled in at the Elbow Beach Hotel. After registering at the front desk, he went up to his room, dropped the suitcases on the bed. Rummaging through his bags, he found his swim trunks and a bottle of sun tan lotion. The rest of the unpacking could wait until later. He made his way to the beach, found a chair and settled down for some serious sunbathing. This was paradise.

He woke up two hours later. His back was on fire. He looked up and before his eyes stood a beautiful angel. She was smiling "Your back looks like a boiled lobster." He replied, "I feel like one." She opened her beachbag, "I have some Aloe Vera. It will take some of the sting away. Would you like me to put some on your back?" He thought he remembered her from someplace. Oh, yes, he had caught a brief glimpse of her as he boarded the plane in Boston. He said, "My name is James, what's yours?" She said "Elizabeth. You can call me Beth." He said, "I will forever be grateful if you spread some of that magic lotion on my back."

Jim invited Beth to dinner and she accepted. They spent their meal discussing Boston, college life and what the future held in store for them. Darkness fell and they continued to lazily chat for hours while sipping elegant glasses of dry white wine in the lounge. He was dazzled by her looks. He felt comfortable with her, like they might have been made for each other, soul mates. He proposed a walk along the beach in the moonlight. She said that would be romantic.

The stars shined brightly in the crisp night's sky. They walked along the sandy beach hand-in-hand. The salty air was mixed with a blend of scents from tropical flowers. Her eyes sparkled in the moonlight. Her hands were small and soft. Jim found a path leading through a small forest of palm trees. They strolled through the trees until the darkness completely enveloped them. He paused. She turned. He could see the thin outline of her eyes. He moved closer and pressed his lips against her. He held her close.

The sky became bright with intense light that filtered through the palm leaves. It took a few seconds before Jim realized something very strange was afoot. A whistling sound joined a chorus of off-key whistling sound producing an eerie wail. This sound grew to ear splitting intensity. It sounded like an ancient creature crying out in great pain. White ash drifted down from the sky. There was the sound of wind and small whirlwinds danced through the trees. It began to get hot, very hot. And then the ground shook so violently, they were both knocked off their feet. Beth was knocked headfirst into the base of a tree. She lay unconscious on the ground. Jim pulled himself up off the ground. He felt the scrapes on his knees and the wet blood oozing from the wound. Ash and small fragments of burning branches fell to the ground. The heat was becoming almost unbearable. A thick haze began to fill the forest. He decided to make a dash towards the ocean. He felt his way to Beth. He grabbed her hand and lifted her up over his shoulders in a fireman's carry. The ground was still moving. He swayed back-and-forth as he rushed to the shoreline. He reached the edge of the trees. The heat was intense. He ran until the ocean engulfed them. The cold water felt good.

His mad dash to the ocean was like walking through the fires of Hell. His clothes were burnt. He stood in the ocean half-naked where chunks of his clothes dissolved away in the surf. Some fused to his body. Although the ocean felt refreshing, his body began to absorb the seawater through his skin. Several large water blisters formed where his flesh had been exposed. He suddenly felt sick to his stomach. His hair had also been aflame and only blotches remained. Elizabeth was in worse shape. Her body had shielded his in the dash.

Elizabeth woke up and began talking incoherently, still in shock. Even though he knew it was the middle of the night, he couldn't fathom where or why the sun was there. Then it began to sink in that maybe this wasn't the sun. It was brighter, more intense than the sun. Whatever it was, it was set in a backdrop of black violent clouds.

Five minutes after they first kissed, the sky went dark. The only light was from the island, where vast fires raged out of control. The island was engulfed in a cloud of smoke. The winds picked up and rushed to shore. Elizabeth eyes grew large; she became lucid and coherent for a moment “What’s happening?” He looked at her and could see she was in a lot of pain. He responded, “Something big, maybe an atomic bomb!”

Elizabeth turned and faced him. Her stare was that of a person in a strange trance. She spoke softly “Hold me!” He wrapped his arms around her and they stood alone at the edge of the world. He pressed his body against hers tightly, so close that he could feel her heart beating. It was rapid like a quivering sparrow. He realized she was not holding him out of sense of romance but out of a ghastly fear and desperation. He knew this because he felt the same way.

Several minutes went by. He heard the earth groan and then he felt the sand beneath his feet rise abruptly upward. The fires picked up in intensity. A vast lightning storm approached the island from a distance. Another ten minutes passed in the blackness at the edge of the burning island. He felt the cool wind blowing against his back. Perhaps it was safe to return to the shore. The lightning storm had grown to an immense size and was about to swallow up the island. If they stayed in the ocean, he worried about being electrocuted. He took Beth by the hand and they returned to the beach. The sand was still very warm, too warm to stand on with his bare feet. Suddenly several loud deafening cracks of thunder echoed across the island.

He heard what he thought was a strong wind and then suddenly he was flying through the air. When he gained consciousness, his arm was intense pain. He could see by the reflected light from the fires that his right arm was dislocated from its socket. He tried to steady himself and get back on his feet. Beth had disappeared. He wandered about trying to locate her. Then he followed the edge of the island shoreline, trying to find other survivors. Almost forty-five minutes passed and he noticed the ocean water was receding from the shoreline. Then he heard a sound. He couldn’t quite make it out at first. It was the roaring sound. In the final seconds of his life, he saw a giant wave bigger than any mountain on Earth wash ashore.

*[The forest of palm trees provided an organic shelter that temporarily protected James and Elizabeth from the intense thermal radiation from the fireball. The heat turned the palm leaves into white ash. It also removed the moisture from the trees. During the drying, small cracks opened in the trees and the released moisture whistled, like steam from a teakettle. The thermal radiation also formed small whirlwinds. The primary ground shock knocked Elizabeth into a tree where she went unconscious. When they were in the ocean, the uplift was a reflected ground shock. The impact unleashed a massive magnetic storm hundreds of miles across that will last for over 6 hours and produce numerous lightning strikes. The loud cracks of thunder were the sound of the impact. The strong wind that dislocated Jim’s right arm was the blast wave. The giant wave was the tsunami that completed the island’s destruction.]*

## Location: Bermuda

Distance from Point-of-Impact: 570 miles

Time of Impact: 10:45 local

Event	Timing of Event	Effect
Flash	Impact	Minimal. Someone would have to be facing the impact to receive indirect exposure and be injured by flashblindness.
Electroponic Bursters	Impact	If outside at Impact, might hear a series of loud clicking or crackling sounds.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting) Automobiles are dead, back-up power generators in hospitals are dead. Most electronics are destroyed by the EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	The fireball will emit intense thermal radiation for over 5 minutes. Most combustibles will ignite and burn.
Ground Shock	Impact + 1.6 minutes	Very violent ground shock that will level most buildings. The impact will produce a shock 11.9 on the Richter scale at the point of impact. The largest earthquake ever recorded is 8.9 on the Richter scale. Rocks are not strong enough for more. The ground shock will consist of several shock waves. The Primary wave will strike at 1.6 minutes after impact. Another strong shock, a reflected shock wave off the Earth's solid core, will arrive 20 minutes after impact.
Oxygen Depletion	Impact + 2 minutes	A thick haze (a product of numerous fires) will engulf the island shortly after impact. Due to dust, debris fallout and released aerosols, breathing will be difficult.
Mass Fires	Impact + 5 minutes	Thermal radiation will produce massive fires throughout the island within minutes, which will be extinguished by the tsunami.
Debris & Aerosols	Impact + 5 minutes	Several firerocks will fall from the sky. The fireball will light up the sky. Debris will block some of this light. The debris will also create a backdrop to the fireball. The effect will be very eerie, like the end of the world. The debris will blot out the moon and the stars. The sky will appear ripped in two.
Sound of Impact	Impact + 42 minutes	The impact will sound like a series of thunderclap or guns being fired.
Blast Wave	Impact + 46 minutes	Would cause the damage of a 10-psi overpressure blast.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Tsunami	Impact + 1.5 hours	The deepwater wave height will be approximately 1,700 feet high. The tsunami would totally destroy the island. Massive damage, massive destruction.
Triggered Earthquakes		Nil.
Triggered Landslides		Nil
Triggered Volcanoes		Nil
Triggered Lava Flows	Long Term Effect	The impact crater opens up a hole in the ocean floor that would take years to reseal. From this hole, lava, steam, sulfur dioxide and other aerosols will spring forth. Energetic storms and gas clouds will form and be carried by prevailing winds up the Eastern Seaboard.
Gas Evolution & Acid Rain	Impact + 1 day	Very high levels of acid rainfall and black rain. For several weeks after the impact, drinking surface water can result in sickness and death.
Energetic Weather Conditions	Impact + 3 days	Large amounts of water evaporated by the fireball, carried by prevailing winds up the Eastern Seaboard. This would produce very intense storms that would deposit unusually high amounts of rainfall.
Magnetic Pole Reversals		Nil
Starvation		No survivors left to starve.
Plagues		No survivors left to become sick.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.



## Washington D.C.

The President of the United States was attending a State Dinner at the White House. The food was prepared and the aroma drifted into the historically elegant dining room. The waiters stood patiently in the corridors for the queue to commence serving. The President was giving a short humorous speech when the room lunged into darkness. After a few seconds of mumbled silence, a flashlight moved into the room. The aide holding it approached the President and whispered something into his ear. The President said, "Please excuse me" and he left with the aide and the room was once again plunged into darkness. As the President made his way through the narrow corridor, he stumbled into a tray of succulent roast beef that crashed into the floor. He kept moving. They wound their way through the narrow corridor and then dropped three flights of stairs to a secured Comm Room. Technicians were busy changing out a fiber optic converter attached to a network hub.

The President asked "Status!" The technician turned around and was a little startled. "All systems are down. The backup generators are off-line. We are operating on battery power. Computer systems were fried. Network is off-line. Satellite Comm links are down. Phones are dead along with most of the radios. The few radios that are alive are overdriven with static. Other than that everything is fine. Give me 3 minutes. I am trying to reestablish communication with Cheyenne Mountain."

An advisor had quietly entered the room. He said, "Mr. President, I believe we have been hit with an EMP." The President said "Nuclear?" The advisor responded, "Need more data." The President said "Where?" The aide responded, "There's a fireball lighting up the sky in the South. The heat is fairly intense outside."

The President turned to his FBI security agent and said, "Would you please bring my wife downstairs."

The FBI agent responded, "It is already being done Mr. President as we speak." At that moment the ground shook violently. It became impossible to stand or walk. Objects fell from shelves and rattled across the floor. The motion lasted for a full 60 seconds.

An aide stumbled into the room a few moments after the earthquake stopped and said, "The west wing has collapsed."

A few seconds later, the President's wife entered. The President turned to her and took her by the hand. She said, "I'm O.K. Get on with your work."

A few minutes passed and network communications was reestablished with Cheyenne Mountain. As the President spoke, an operator keyed in the narrative.

President, "Who am I speaking with?"

Cheyenne Mountain Air Force Base, "General Ken Allison. I also have General Stevens and General Atwater by my side."

President, "What happened?"

Gen. Allison, "A large asteroid impacted in the Atlantic Ocean between the Bahamas and Bermuda."

President, "What's your present status?"

Gen. Allison, "Difficult. RF Interference raising havoc with communications, satellite reception." "Mr. President your life is in danger. I advise you evacuate White House immediately."

President, "Understood." "Ken, how big was this thing?"

Gen. Allison, "Large. Large enough to destroy the entire Eastern Seaboard."

President, "Understood."

The President turned to the FBI agent; "I need to evacuate the area. Arrange transportation to Air Force One."

The agent said, "I'll get right on it." He rushed out of the room.

President, "General, can you give me a damage report?"

Gen. Allison, "Interference on RF communications is extensive. Our ability to analyze the situation is degraded, very degraded. Satellite imagery shows extensive fires in Florida, the Carolina's and Cuba. A minute ago, we received unconfirmed reports of the destruction of the Hawaiian Islands."

President, "Your recommendations for evacuation point?"

Gen. Allison, "Recommend you establish command center at Northern Command."

The FBI agent reappeared, "Mr. President, follow me sir."

The agent led the President, his wife and his aides up the stairs. The sight was chaotic as individuals suddenly appeared on their route to fight fires or engage in search and rescue operations. The agent led them out to the back where several Washington policemen were lined up on their Harley Davidson motorcycles. When the agent came to a stop and turned around, the President asked, "Where is the transportation?"

The agent responded, "This is the transportation. The vehicles in your motorcade are inoperative."

The policeman took off his helmet and handed it to the President. "Put this on sir."

The convoy of cycles made their way slowly towards the airport. The earthquake shattered many buildings. Fires were burning everywhere, many out of control. Those that survived were on the streets, terrified of the aftershocks. Stalled automobiles littered the streets. Smoke was pouring into the sky. Except for the burning fires, the entire area was enveloped with total and complete darkness. It was an end of the world disaster being played out in slow motion. The motorcycle convoy came to a halt. The bridge in front of them had collapsed. The President looked down at the pavement. The pavement was so soft due to the heat that the tire tracks left depressions in the asphalt. Thirty minutes later the convoy arrived at Air Force One. The plane was readying for take off.

They were quickly escorted aboard the plane. The runway was dark. The President took his seat and the plane took off. The plane flew in a westerly direction. The impact produced a large magnetic storm that interfered with the plane's magnetic compass. Many of the instruments onboard Air Force One were inoperative. RF static degraded communications. In addition air traffic control systems on the ground were knocked out. The pilot was essentially flying blind. Many hours passed. Debris from the asteroid impact was sucked into the jet engines and the engines were heating up. The fuel began to run low. The ground below was dark. Before the plane crashed, the few parachutes on board were distributed. The hatch was opened and the President jumped into the darkness below. The chute opened. A few minutes later, the President was on the ground, alone in the darkness. It was cold. He reached down and touched the ground. It was ice.

*[The EMP destroyed most computer and communications equipment. Fiber optic lines remained intact but the fiber optic converters needed replacement. The EMP destroyed integrated circuits and computer modules within most vehicles effectively disabling them. Generally, motorcycles were unaffected unless they possessed electronic ignition systems. Shortly after Air Force One took to the skies, the city of Washington D.C. was hit with a strong blast wave that leveled much of the buildings throughout the city. There were very heavy casualties. Thirty minutes later, the city was hit with a tsunami, which completed the destruction. Although Air Force One successfully took off, it never arrived at its destination. It crashed landed in the far North. The President and Vice President along with most members of Congress failed to survive. The administration of the government passed onto the Northern Command, which coordinated recovery efforts with military precision for 3 years until the government could be reconstituted.]*

## Location: Washington D.C.

Distance from Point-of-Impact: 780 miles

Time of Impact: 9:45 Eastern

Event	Timing of Event	Effect
Flash	Impact	Minimal. Someone would have to be facing the impact to receive indirect exposure and be injured by flashblindness. (For example, someone looking out of a tall highrise building.
Electroponic Bursters	Impact	Too much traffic noise to detect this effect.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting) Automobiles are dead, back-up power generators in hospitals are dead. Most electronics destroyed by EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	The fireball will emit intense thermal radiation for over 5 minutes. Many combustibles will ignite and burn triggering numerous fires.
Ground Shock	Impact + 2.2 minutes	Violent ground shock. In general, earthquakes don't kill, the collapse of building do. The ground shock will consist of several shock waves. The Primary wave will strike at 2.2 minutes after impact. Another strong shock, a reflected shock wave off the Earth's solid core, will arrive 20 minutes after impact.
Debris & Aerosols	Impact + 8 minutes	The fireball will light up the sky. Debris will block some of this light. The debris will also create a backdrop to the fireball. The effect will be very eerie, like the end of the world. The debris will blot out the moon and the stars. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 1 hour	The impact will sound like a series of thunderclap or guns being fired.
Blast Wave	Impact + 1.7 Hours	Would cause the damage of a 5-psi overpressure blast.
Mass Fires	Impact + 2 hours	Many fires will ignite houses and buildings. They will quickly grow into massive fires that will threaten to engulf the entire city, due to the inability of the fire department to respond.
Tsunami	Impact + 2.1 hours	The deepwater wave height will be approximately 1500 feet high. North Carolina and Virginia absorb a good degree of the tsunami wave damage but it fails to prevent the cities total destruction. Massive damage, massive destruction.
Triggered Earthquakes		Nil.
Triggered Landslides		Nil.
Triggered Volcanoes		Nil.
Triggered Lava Flows	Long Term Effects	The impact crater opens up a hole in the ocean floor that would take years to reseal. From this hole, lava, steam, sulfur dioxide and other aerosols will spring forth. Energetic storms and gas clouds will form and be carried by prevailing winds up the Eastern Seaboard.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 Day	Very high levels of acid rainfall and black rain. For several weeks after the impact, drinking surface water can result in sickness and death.
Energetic Weather Conditions	Impact + 3 days	Large amounts of water evaporated by the fireball, carried by prevailing winds up the Eastern Seaboard. This would produce very intense storms that would deposit unusually high amounts of rainfall.
Magnetic Pole Reversals		Nil
Starvation		No survivors left to starve. The tsunami will devastate the entire East Coast of the U.S. For several years after the impact, the land will be unable to support crops due to salt-water contamination, high concentrations of acid rain and heavy metal pollution.
Plagues		No survivors left to become sick.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.

## Location: New York City, New York

Distance from Point-of-Impact: 885 miles

Time of Impact: 9:45 Eastern

Event	Timing of Event	Effect
Flash	Impact	Nil. Local rainstorm blocks the effect.
Electroponic Bursters	Impact	Too much traffic noise to detect this effect.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting) Automobiles are dead, back-up power generators in hospitals are dead. Most electronics are destroyed by the EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	The local rainstorm above NYC will minimize the ignition of combustibles.
Ground Shock	Impact + 2.5 minutes	Violent ground shock.
Debris & Aerosols	Impact + 9 minutes	The rainstorm will reduce visibility so much of this effect will be hidden. The fireball will energize the rainstorm. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 1.2 hours	The impact will sound like a series of thunderclap or guns being fired.
Mass Fires	Impact + 2 hours	Several fires will engulf houses and buildings primarily due to inability of fire department to respond.
Tsunami	Impact + 2.3 hours	The deepwater wave height will be approximately 1,400 feet high. The tsunami would destroy New York City completely. Massive casualties/massive destruction.
Blast Wave	Impact + 2.4 hours	Would cause the damage of a 4-psi overpressure blast.
Triggered Earthquakes		Nil.
Triggered Landslides		Nil.
Triggered Volcanoes		Nil.
Triggered Lava Flows	Long Term Effect	The impact crater opens up a hole in the ocean floor that would take years to reseal. From this hole, lava, steam, sulfur dioxide and other aerosols will spring forth. Energetic storms and gas clouds will form and be carried by prevailing winds up the Eastern Seaboard.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 day	Very high levels of acid rainfall and black rain. For several weeks after the impact, drinking surface water can result in sickness and death.
Energetic Weather Conditions	Impact + 3 days	Large amounts of water evaporated by the fireball, carried by prevailing winds up the Eastern Seaboard. This would produce very intense storms that would deposit unusually high amounts of rainfall.
Magnetic Pole Reversals		Nil.
Starvation		No survivors left to starve. The tsunami will devastate the entire East Coast of the U.S. For several years after the impact, the land will be unable to support crops due to salt-water contamination, high concentrations of acid rain and heavy metal pollution.
Plagues		No survivors left to become sick.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.

## Small Town outside Indianapolis, Indiana

Debbie McCalister was out on the porch relaxing in the cool night's air. She was resting on a lawn chair. The day had been a hot humid June day. A storm had blown through and cooled the air off. The storm moved on and the wind cleared away the clouds to reveal a canopy of stars. Her husband, George, was inside the house watching television from one of those satellite stations.

They lived in a small town in Indiana about 50 miles from the capital, Indianapolis. The northern half of the state was flat like smooth peanut butter spread on bread. The southern part of the state was hilly, think peanut butter chunky style. They lived in the hilly part.

They lead a quiet life. They had been married for a quarter century and still held true to each other and the vow they took to be faithful. They raised one daughter, Tasha, who married a year ago. She lived in a suburb of Indianapolis called Greenwood.

Debbie heard a series of loud clicks and then all the lights in the house went dark. The dogs began to bark and howl. Suddenly, the sky lit up as if it was daylight. George appeared at the doorway. "What's happening?"

Debbie said, "Something" she paused for a moment "strange."

"Powers out!" George walked outside and stared at the sky for a few moments. In the southeasterly direction the sky was glowing red. It grew brighter and became awash in colors.

Debbie said, "What is it?"

George said, "Don't know yet." He ran inside and found a flashlight and his car keys, ran to the car and tried to start the engine. It was dead. He tried the truck. It too was dead. He got out of the truck and ran to the large 500-gallon propane tank next to the house. He lifted the metal lid and shut the valve off. He ran back to the house.

Debbie said, "What is it?"

He looked up at the sky. It looked fierce and threatening. Colors were swirling. George said, "I don't know for sure. Too big to be a nuclear bomb! I'm guessing an impact."

Debbie said, "What kind of impact?"

George said "An asteroid or maybe a small comet."

Debbie said, "Well, what should we do?"

"Ground shock, the first thing that will hit is a ground shock. We need to get everything down." They started towards the door but before they took two steps, a low subsonic subterranean growl followed by a strong lateral ground shock occurred. It seemed to last forever. After the motion finally stopped. They got back on their feet and peered inside the house. It was a mess. The refrigerator was completely emptied. A large mound of food and broken jars formed a large heap on the floor. He shined the light at the cabinets. The doors stood open and the cabinets were bare. He walked into the house and then he could see the heap of broken dishes.

George was never a Boy Scout. But he could have been a darn good one. He had one motto in life and that was "Be Prepared!" He took potential disasters seriously, perhaps too seriously. When his daughter went off to college and they put her in the twelfth floor in the dormitory, he bought her a long rope. He told her "What would happen if the place caught on fire? I just want you to be safe." She landed up taking rappelling lessons in her freshman year. After that she joined an off campus Sorority whose house was a one-story building. But that was the way he was, he took everything too seriously.

He said "Debbie, come give me a hand." They headed to the pole barn. There were a few loose sheets of plywood inside. "We need to get these to the house."

She said, "Why?"

George said, "We're going to get hit with a blast wave. All that money we spent a couple years ago on those two sliding glass doors will go down the drain if we don't do something and I'll be darn if I see them destroyed."

They were hit with another large earthquake. This one was more powerful than the first one.

They took several trips, each time retrieving a sheet of plywood and nailing it to the wooden sliding glass doorframe. It was starting to get dark. The stars and the moon were disappearing. Sometimes they could see a streak of fire in the sky like a shooting star. The silence was interrupted by low rumble followed by a small aftershock.

After they finished nailing up the plywood, Debbie took a side trip and tried to call their daughter. She came back disappointed "Phones dead."

George checked the water pressure. It was gone. He checked the utility room. The water heater had cracked and water had flooded the room. He went to the circuit breaker panel and shut off the main breaker.

The house was protected on several sides with hills. When the blast wave finally hit about four hours after impact, the hills and the trees took the brunt of the blast. A few trees were uprooted. Several branches broke off. A particularly large branch fell on the house and punctured a hole in the roof. Several singles were blown off the house. One window was broken. George thought to himself that it could have been worse. George went over and inspected the damage to the pole barn. The wind had blown off part of the roof and the sides took some major damage also.

George took a ladder and climbed up onto the roof of the house with the chainsaw. He cut the branch apart and pulled the imbedded section from the roof. He did a quick patch job on the hole.

They spent the next several hours covering and protecting what they could in the pole barn and moving much of it into the house. Every now and then another aftershock would strike. Then they began the clean up. Much of the mess in the kitchen had to be thrown away. It was a shame because from now on food would be hard to come by. They organized and stacked into piles on the floor everything that survived the earthquakes.

One of the items they moved into the house was a large metal barrel. It looked like an ordinary 55-gallon steel drum except larger. It was marked "EMP Faraday Cage". George believed in labels. It as a modified 80-gallon salvage barrel. George undid the lid from the barrel and rummaged through the contents. He removed a 20-meter mobile transceiver from inside. He bought a pair of them a couple a few years back. One he placed inside a metal ammo can and gave to his daughter to store inside her car. He told her it was for emergencies. He never took the time to obtain a ham license. But he thought if there ever was a nuclear war or if an asteroid impact, at least he would be able to talk to his little girl. And since a large EMP would destroy almost all the transceivers in the world; who would care or even know if he broke the rules a little. George took the transceiver and installed it into the Jeep Wrangler. He dug out a whip antenna and screwed it into the mounting post. He connected the wiring and turned the unit on. He scanned the channels but all he received was static. He programmed the prearranged frequency and powered the unit down.

They worked until they were exhausted. The aftershocks came and rattled their nerves. But a gloom had set in. It was the dread of not knowing whether their daughter and their son-in-law were alive or dead. When they could work no more, they collapsed on the couch.

Several hours past and they woke up. Time lost its meaning. It was still pitch black. He woke his wife and they went outside and powered up the transceiver. "Kiddo, are you there?" He waited – silence. "Kiddo, are you there?" More silence.

"Daddy-O, I'm here. How are you and how is Mom?"

"We're O.K. A little shaken up but we're O.K. How are you and your husband?"

Tasha said, "We're O.K. The apartment is totaled but we're alive. Cars won't start.

George said, "Kiddo! We will be up in a couple days after it starts to get a little bit lighter. Can you manage till then?"

Tasha said, "No Problem!"

"Stay away from the surface water."

Tasha said, "Don't worry, the hot water tank has about 40 gallons left in it. We should be O.K. for awhile."

"Your car battery won't last forever. When it starts to get weak, switch it with the battery from your other car. Kiddo, Mom wants to say something."

Debbie said, "How do you work this contraption?"

George said, "Press this button here when you want to talk and hold it down. When you're done talking, release the button."

He went back inside the house and retrieved a replacement Micro Computer Unit (MCU) he had stored away in his EMP barrel. It took him several hours to install it in the passenger side of the Jeep. He put the key in the ignition and turned the key. This time it started. He said "Thank you Lord!"

Prologue: Recovery is a slow process. It happens one step at a time. The next several years were rough. The days were dark and gray. Crops wouldn't grow. Many people resorted to drinking untreated surface water in the days immediately following the impact. Many became sick and died. The corn and the soybeans stored away in farm silos kept most people from starving at least until the fields could be replanted. City folks had it rougher than country folks. Eventually pockets of electricity were restored. A local mechanics figured out how to hotwire around the imbedded computer systems in most cars and trucks bringing them back to a minimal

level of operation. Most people made do, thankful that they were alive. But a few never recovered. They were walking ghosts, afraid of any loud noises. Unable to understand or comprehend the events which transpired. They lived in constant fear.

## Location: Small Town Outside Indianapolis, Indiana

Distance from Point-of-Impact: 1112 miles

Time of Impact: 8:45 Central

Event	Timing of Event	Effect
Flash	Impact	Nil.
Electroponic Bursters	Impact	If outside at Impact, might hear a series of loud clicking or crackling sounds.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting) Automobiles are dead, back-up power generators in hospitals are dead.) Most electronics are destroyed by the EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	Dry leaves, dry grass, old newspapers, thin flammable fabrics (for example, curtains), tarpaper can ignite and burn. Numerous small fires will occur.
Ground Shock	Impact + 3.1 minutes	Violent ground shock.
Triggered Earthquakes	Impact + 5.2 minutes	The ground shock triggers a very large earthquake in the Reelfoot Rift fault system, commonly referred to as the New Madrid fault system. Modified Mercalli Intensity Scale of VII. Difficult to stand during the earthquake. Furniture broken. Slight to moderate damage in ordinary structures, considerable damage in poorly built or badly designed structures. Weak chimneys broken at roofline. Fall of plaster, loose bricks, stones, tiles, cornices and unbraced parapets. Small landslides and caving along sand and gravel banks. Significant damage to structures, roads, dams, bridges and infrastructure.
Debris & Aerosols	Impact + 11 minutes	The fireball will light up the sky. Debris will block some of this light. The debris will also create a backdrop to the fireball. The effect will be very eerie, like the end of the world. The debris will blot out the moon and the stars. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 1.5 hours	The impact will sound like a series of thunderclap or guns being fired.
Blast Wave	Impact + 4.4 hours	Would cause the damage of a 3-psi overpressure blast.
Mass Fires	Impact + 1 day	The ground shock and earthquake will rupture gas lines. Numerous small fires will occur from thermal radiation. Several fires will engulf houses and buildings and then spread primarily due to inability of fire department to respond.
Tsunami		The Appalachian Mountains would restrict damage from the Atlantic tsunami.
Triggered Landslides		Nil.
Triggered Volcanoes		Nil.
Triggered Lava Flows		Nil.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 day	Acid rainfall and black rain. Will result in fish-kills. Several plants and trees will die and the remainder will be weakened. Drinking surface water can cause sickness.
Energetic Weather Conditions	Impact + 3 days	Large storms will menace the area for several months. Tornadoes, large hailstorms, and very energetic lightning storms occur.
Magnetic Pole Reversals		Nil.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.
Starvation	Impact + 1 month	Due to infrastructure damage and lack of grain transportation and processing, individuals will have to adapt or starve. Grain process may be done locally, using hand operated grain mills.
Plagues	Impact + 3 months	Population weakened by starvation, drinking contaminated water, eating contaminated food supplies, and stressed by shock & fear will open door to plagues, sickness and disease.



## Location: Chicago, Illinois

Distance from Point-of-Impact: 1293 miles

Time of Impact: 8:45 Central

Event	Timing of Event	Effect
Flash	Impact	Nil.
Electrophonic Bursters	Impact	Too much traffic noise to detect this effect.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting). The power grid will be restored after a few hours but unstable. Intermittent black outs and brown outs. Most emergency back-up generators will be functional. Some electronics will be destroyed by the EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	Dry leaves, dry grass, old newspapers, thin flammable fabrics (for example, curtains), tarpaper can ignite and burn. Several small fires will occur.
Ground Shock	Impact + 3.7 minutes	Violent ground shock.
Triggered Earthquakes	Impact + 5.4 minutes	The ground shock triggers a very large earthquake in the Reelfoot Rift fault system, commonly referred to as the New Madrid fault system. Modified Mercalli Intensity Scale of V. Some dishes & windows broken. Cracks in plaster. Unstable objects overturned.
Tsunami	Impact + 6 minutes	The Appalachian Mountains would restrict significant damage from the Atlantic Ocean Tsunami. The ground shock would produce a small tsunami in Lake Michigan that will impact the Chicago shoreline.
Debris & Aerosols	Impact + 12 minutes	The fireball will light up the sky. Debris will block some of this light. The debris will also create a backdrop to the fireball. The effect will be very eerie, like the end of the world. The debris will blot out the moon and the stars. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 1.7 hours	The impact will sound like a series of thunderclap or guns being fired.
Blast Wave	Impact + 6.5 hours	Would cause the damage of a 2-psi overpressure blast.
Mass Fires	Impact + 1 day	The ground shock and earthquake will rupture gas lines. Several fires will engulf houses and buildings and then spread primarily due to inability of fire department to respond.
Triggered Landslides		Nil.
Triggered Volcanoes		Nil.
Triggered Lava Flows		Nil.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 day	Acid rainfall and black rain. Will result in fish-kills. Several plants and trees will die and the remainder will be weakened. Drinking surface water can cause sickness.
Energetic Weather Conditions	Impact + 3 days	Large storms will menace the area for several months. Tornadoes, large hailstorms, and very energetic lightning storms occur.
Magnetic Pole Reversals		Nil.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.
Starvation	Impact + 1 month	Large city populations will be particularly vulnerable to starvation threat. Grain transportation and processing will be the significant issue in a very damaged infrastructure.
Plagues	Impact + 3 months	Population weakened by starvation, drinking contaminated water, eating contaminated food supplies, and stressed by shock & fear will open door to plagues, sickness and disease.

## Location: Dallas, Texas

Distance from Point-of-Impact: 1445 miles

Time of Impact: 8:45 Central

Event	Timing of Event	Effect
Flash	Impact	Nil.
Electroponic Bursters	Impact	A few people will report hearing a series of loud clicking or crackling sounds at the time of impact.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting). The power grid will be restored after a few hours but unstable. Intermittent black outs and brown outs. Most emergency back-up generators will be functional. Some electronics will be destroyed by the EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	Dry leaves, dry grass, old newspapers, thin flammable fabrics (for example, curtains), tarpaper can ignite and burn. Several small fires will occur.
Ground Shock	Impact + 4.1 minutes	Violent ground shock.
Triggered Earthquakes	Impact + 7.1 minutes	The ground shock triggers a very large earthquake in the Reelfoot Rift fault system, commonly referred to as the New Madrid fault system. Modified Mercalli Intensity Scale of VI. Some heavy furniture moved. A few instances of fallen plaster and damaged chimneys. Windows, dishes, glassware broken. Weak masonry cracked.
Debris & Aerosols	Impact + 14 minutes	The fireball will light up the sky. Debris will block some of this light. The debris will also create a backdrop to the fireball. The effect will be very eerie, like the end of the world. The debris will blot out the moon and the stars. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 1.9 hours	The impact will sound like a series of thunderclap or guns being fired.
Blast Wave	Impact + 8.6 hours	Would cause the damage of a 2-psi overpressure blast.
Mass Fires	Impact + 1 day	The ground shock and earthquake will rupture gas lines. Several fires will engulf houses and buildings and then spread primarily due to inability of fire department to respond.
Tsunami		Florida will absorb most of the tsunami damage and protect the Texas coastline from severe damage.
Triggered Landslides		Nil.
Triggered Volcanoes		Nil.
Triggered Lava Flows		Nil.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 day	Acid rainfall and black rain. Will result in fish-kills. Several plants and trees will die and the remainder will be weakened. Drinking surface water can cause sickness.
Energetic Weather Conditions	Impact + 3 days	Large storms will menace the area for several months. Tornadoes, large hailstorms, and very energetic lightning storms occur.
Magnetic Pole Reversals		Nil.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.
Starvation	Impact + 1 month	Large city populations will be particularly vulnerable to starvation threat. Grain transportation and processing will be the significant issue in a very damaged infrastructure.
Plagues	Impact + 3 months	Population weakened by starvation, drinking contaminated water, eating contaminated food supplies, and stressed by shock & fear will open door to plagues, sickness and disease.

## Location: Lincoln, Nebraska

Distance from Point-of-Impact: 1634 miles

Time of Impact: 8:45 Central

Event	Timing of Event	Effect
Flash	Impact	Nil.
Electroponic Bursters	Impact	Several people will report hearing a series of loud clicking or crackling sounds at the time of impact.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting). The power grid will be restored after a few hours but unstable. Intermittent black outs and brown outs. Most emergency back-up generators will be functional. Most electronics will survive EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	Nil.
Ground Shock	Impact + 4.6 minutes	Minor ground shock.
Triggered Earthquakes	Impact + 6 minutes	The ground shock triggers a very large earthquake in the Reelfoot Rift fault system, commonly referred to as the New Madrid fault system. Modified Mercalli Intensity Scale of VI. Some heavy furniture moved. A few instances of fallen plaster and damaged chimneys. Windows, dishes, glassware broken. Weak masonry cracked.
Triggered Volcanoes	Impact + 10 minutes	The impact will wake up the Yellowstone volcano, the largest volcano in North America. The volcano will spew forth lava, ash and a variety of gases including sulfur dioxide. This will affect the ecology near the volcano and spread over the northern hemisphere. The ash and aerosols will depress the temperature. High concentrations of acid rainfall produced near the volcano. Volcano will be active for several years.
Debris & Aerosols	Impact + 16 minutes	The fireball will light up the sky. Debris will block some of this light. The debris will also create a backdrop to the fireball. The effect will be very eerie, like the end of the world. The debris will blot out the moon and the stars. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 2.1 hours	The impact will sound like a series of thunderclap or guns being fired.
Blast Wave	Impact + 11.6 hours	Would cause the damage of a 2-psi overpressure blast.
Mass Fires	Impact + 1 day	Nil (Exception will be in large cities where fires will be caused by broken gas lines and grow into conflagration due to ineffectiveness of emergency response.)
Tsunami		Nil.
Triggered Landslides		Nil.
Triggered Lava Flows		Nil.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 day	Acid rainfall and black rain. Produces fish-kills. Several plants and trees will die and the remainder will be weakened. Drinking surface water can cause sickness.
Energetic Weather Conditions	Impact + 4 days	Large storms will menace the area for several months. Tornadoes, large hailstorms, and very energetic lightning storms occur.
Magnetic Pole Reversals		Nil.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally. Lincoln will experience greater stress due to proximity to Yellowstone volcano and it's release of debris, smoke and aerosols.
Starvation	Impact + 1 month	Due to infrastructure damage and lack of grain transportation and processing, individuals will have to adapt or starve. Grain process may be done locally, using hand operated grain mills.
Plagues	Impact + 3 months	Population weakened by starvation, drinking contaminated water, eating contaminated food supplies, and stressed by shock & fear will open door to plagues, sickness and disease.

## Los Angeles, California

It was almost 7 PM. Thomas was wrapping up work at the art department of an advertising firm, when the power suddenly went out. He mistakenly figured it was a power blackout caused by the California energy shortage (probably due to manipulation from some large energy company trying to increase their profit margin). It was impossible to complete his work without electricity, so he decided to call it quits for the day. He exited the office and made his way to the asphalt parking lot next door. He unintentionally glanced up for a second and noticed something strange. A circular halo was forming around the setting sun to the West. But then he glanced to the East where the red glow of a rising sun began to take shape. He moved quickly to his car, opened the door and climbed inside. He started the car and turned on the radio. It crackled with static. He tried another, more static and another, more static. "What is happening around here!"

He headed off to his home in Woodland Hills, normally a one-hour drive in rush hour traffic. It was hot and smoggy, the end of a California summer day. Normally traffic made the commute home miserable. But today he sensed it was going to take a little longer than usual. The stoplights were out. Traffic was snarled in gridlock. Several minutes passed and he was still working his way through the first stoplight, when the ground shook violently. The stoplight swung from side to side. People ran outside into the open. Someone got out of their car and began directing traffic. Finally, Tom drove through that intersection. He thought to himself only three more stoplights to the freeway onramp and then he would be safe. The next earthquake hit two minutes later. This was not aftershock. This was THE earthquake, the one that everyone dreaded. The one that would split California in two and send it tumbling into the sea. The building to his left collapsed. As he passed the liquor store on his right, he could see rivers of alcohol winding its way to the gutter. He was watching as a woman and her child stood along the side of a brick building, and then the wall came down on top of them and they were gone. He thought of his wife and kids. He rummaged for his cell phone and dialed home. When he placed the phone to his ear all he heard was static.

The sky was beginning to get very dark. Suddenly, there was a flash of bright light and an explosion. He stared in the darkness where the flash used to be and finally made out the outline of a power transformer on a pole. The power company must be working to get the power up. A few minutes passed, and the stoplight in front of him came on. He moved slowly through the two remaining stoplights and onto the "405" freeway onramp. Traffic on the freeway was bad, but at least the cars were moving. As he drove at the snails pace, he would play with the radio trying to get any intelligent signal. Once and a while he thought he could pick up a word or two. He thought he heard "earthquake" and "electrical" and "emergency" and "freeway overpass". He kept trying to dial home but to no avail, so he finally gave up trying. Now and then he would hear a siren. He felt a degree of comfort that the police and firemen were responding to emergencies, getting us back on our feet again. Several hours went by and he passed the Santa Monica freeway and headed north past Westwood and through the pass. He heard several strikes of loud thunder echo off the canyon walls. He scanned the sky. No sign of lightning.

A few more hours and he made it through the pass. He felt comforted that the San Fernando Valley stretched out beneath him and it was all lit up. He went west on the "101" and exited onto Balboa Boulevard figuring he could make better time on the side roads. Tom noticed a pay phone next to the side of a minimart. He pulled over and called home. His wife answered, she was hysterical. From the way she talked he could tell she had been in tears. She said "Tom, Keep your windows down. I had this dream. You need to keep your windows down." He tried to find out if the house was O.K. What about his two sons? Why didn't the radio work? Had she heard any emergency broadcast? What was happening? But she was hysterical and all she did was to continue to babble about her dream and the stupid car windows.

He got back into the car and slammed the door. The car was beginning to overheat because of the hours of stop-and-go traffic. He shut off the air conditioner. He thought, "I'll give the car a break." He rolled down the electric windows. He thought "I hope that makes you happy!" He took off his jacket and tie. Suddenly, the car was being tossed about. Water was everywhere. The car headlights went dead after a few seconds. Water began pouring into the car. It was cold, very cold. It tasted like saltwater. And now it was completely dark. He undid his seatbelt. He removed his shoes. He reached up and gobbled a breath from the air bubble that formed at the ceiling and pulled himself through the window and up from the bottom of the sea.

When he reached the surface, he was in black water and black sky. There was current. He began to swim in the dark not knowing where he was or where he was headed. There was a significant amount of debris floating in the water. He encountered a few boards and held onto them for flotation. He heard people

screaming. He bumped into something. He reached over and felt it with his fingers. It felt like a body. Without thinking if the person alive or dead, he pushed away from it. He reflected, it wasn't moving. It was probably dead. After 30 minutes of floating, he could feel something under him. It was hard. He held on. After a few minutes the water level dropped slightly and he realized he was on the roof of a house. He waited. A few hours past. He lowered himself to the ground. He trudged through knee-deep water making his way as best he could onto dry land. He climbed up until he found what appeared to be a roadway. In the distance the headlights from a car was slowly making its way in his direction. When the car turned the last bend, it came to a dead stop. He was wet from head to toe and covered in slime and dirt. The woman inside the car look frightened as he approached. She held the steering wheel so tight that her knuckles were turning blue. He said, "Can you give me a ride home?"

[Although Tom was spared from the main brunt of the Hawaii landslide induced tsunami, he did encounter the backwash that flowed through the Los Angeles basin and then back up the San Fernando Valley. Added to this calamity was the loss of a major dam.]

## Location: Los Angeles, California

Distance from Point-of-Impact: 2712 miles

Time of Impact: 6:45 Pacific

Event	Timing of Event	Effect
Flash	Impact	Nil.
Electroponic Bursters	Impact	Too much traffic noise to detect this effect.
Electromagnetic Pulse	Impact	Loss of electrical power grid. (No stoplights, no TV, no radios, elevators dead, gasoline stations without power, no indoor/outdoor lighting). Power grid will be restored after a few hours but unstable. Intermittent blackouts and brownouts. Most emergency back-up generators will be functional. Most electronics will survive EMP.
Ionizing Radiation	Impact	Communications jammed for tens of hours.
Fireball	Impact + 30 seconds	Nil.
Ground Shock	Impact + 7.7 minutes	Very minor ground shock.
Triggered Earthquakes	Impact + 10 minutes	The ground shock triggers a very large earthquake in the San Andreas fault system. Modified Mercalli Intensity Scale of VIII. Considerable damage to ordinary buildings with partial collapse. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, and elevated tanks. Frame houses moved on foundation if not bolted down; loose panel walls thrown out. Significant damage to structures, roads, dams, bridges and infrastructure. Decayed pilings broken off. Branches broken from trees. Cracks on wet ground and on steep slopes. Several power transformers destroyed. Major dam breaks in the San Fernando Valley.
Debris & Aerosols	Impact + 26 minutes	The debris will blot out the sun. The effect will be very eerie, like the end of the world. Little heavy fallout.
Upper Atmospheric Effects	Impact + 1 hour	Low earth orbit satellites destroyed. Ozone layer destroyed.
Sound of Impact	Impact + 3.5 hours	The impact will sound like a series of thunderclap or guns being fired.
Triggered Landslides	Impact + 6 hours	The ground shock will hit Hawaii 15 minutes after impact. This will trigger a large landslide on the Big Island sending an area the size of NYC down 5 miles to the bottom of the ocean. A large tsunami will result that will destroy large areas of the Pacific Ocean shoreline. This Pacific Tsunami will slam into Los Angeles 5 hours and 45 minutes later and drive 30 miles inland.
Mass Fires	Impact + 1 day	Nil (The fire department will find it difficult coordinating response to small fires that break out due to loss of communications and earthquake damaged infrastructure. They will adapt quickly to prevent mass fires.)
Impact Tsunami		Nil.
Blast Wave		Nil.
Triggered Volcanoes		Nil.
Triggered Lava Flows		Nil.
Oxygen Depletion		Due to dust, debris fallout and released aerosols, breathing will be difficult.
Gas Evolution & Acid Rain	Impact + 1 day	Acid rainfall and black rain. Will result in fish-kills. Several plants and trees will die and the remainder will be weakened. Drinking surface water can cause sickness.
Energetic Weather Conditions	Impact + 5 days	Large storms will menace the area for several months. Tornadoes, large hailstorms, and very energetic lightning storms occur.
Magnetic Pole Reversals		Nil.
Dust & Impact Winter	Several weeks	Food crop destroyed for current year. Food crops environmentally stressed for a couple years thereafter. Overall temperature drops of 5 to 10 degrees F. Effects will vary regionally.
Starvation	Impact + 1 month	Large city populations particularly vulnerable to starvation threat. Grain transportation and processing will be the significant issue in a very damaged infrastructure.
Plagues	Impact + 3 months	Population weakened by starvation, drinking contaminated water, eating contaminated food supplies, and stressed by shock & fear will cause plagues, sickness and disease.

## **The Philippine Sea**

The container ship “MV Arafura” was on route to Australia with 23 crewmembers and 4 passengers onboard. The ship was heading south in the Philippine Sea. The waves were choppy and a storm was developing. Fifty minutes after the asteroid impact (10:35 AM local time), the ship shook and the crew felt a strong uplift. The force was so strong that most crewmembers were knocked off their feet. Most objects, not nailed down, fell and rattled around the floor. Several crewmembers rushed to the top deck to uncover the cause. Several containers had broken loose and fell into the ocean. As they hung on the railing, they witnessed the ocean boiling. The air was foul, smelling like rotten eggs. They found it difficult to breathe and they lost consciousness. A week later the ghost ship ran aground in Indonesia with all onboard missing or dead.

*[Small impact damage zone on the opposite side of the globe.]*