Getting Prepared for an Electromagnetic Pulse Attack or Severe Solar Storm

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The science fiction writer Arthur C. Clarke once said:

Any sufficiently advanced technology is indistinguishable from magic.

This statement is commonly known as Clarke's Third Law. Many people have heard this quotation, but few people really think about its implications.

We now live in a world that is so completely immersed in advanced technology that we depend upon it for our very survival. Most of the actions that we depend upon for our everyday activities -- from flipping a switch to make the lights come on to obtaining all of our food supplies at a nearby supermarket -- are things that any individual from a century ago would consider ***magic***.

Very few people in industrialized countries do work that is not directly assisted by electronic computers, although that computerized assistance is often quite invisible to the average person. Few people think about things such as the fact that whenever we buy some food item at a supermarket (and many others are buying the same item), the next time we go to that same supermarket, they still have about the same supplies that they had before. There are invisible infrastructures all around us that are made up of advanced technology. Most of us just take the magic for granted.

Few people stop to consider what would happen if, in an instant, the magic went away. If our advanced technology were suddenly and completely destroyed, how would we manage to survive? A nuclear EMP could make the magic go away. I hope it never happens, and I don't think that it is at all inevitable. It makes no sense, however, to be blind to the danger. It is both much less likely to happen -- and also less likely to have a catastrophic impact -- if, both as a civilization and as individuals, we are prepared for an attack on our advanced technology. A nuclear EMP would be a seemingly magical attack upon our advanced technology, the technological infrastructure upon which our lives depend.

Among all of the kinds of electromagnetic disturbances that can occur, though, it is important to keep things in perspective. It is possible that a nuclear EMP may never happen where you live. On the other hand, a severe solar storm that will destroy most of the world's power grids appears nearly inevitable at this point. **Protection against the damage of a severe solar storm could be done easily and rather inexpensively by the electrical utilities; however it is *not* being done, and there is no sign that it will be done.** A severe solar storm poses little threat to electronics, but would take down the most important power grids in the world for a period of years. This is a special problem in the United States, and is a severe threat in the eastern United States. So, more important than preparing for a nuclear EMP attack is preparing for all of the ramifications of a severe solar storm which would cause an electrical power outage that would, in most areas, last for a period of years. Most standby power systems would continue to function after a severe solar storm, but supplying the standby power systems with adequate fuel, when the main power grids are offline for years, could become a very critical problem.

This is a page about some of the things that **individuals** can do to prepare for an electromagnetic pulse attack. I'm an electronics engineer who has been thinking about the EMP problem for more than 3 decades. I even have an ancient Radio Shack TRS-80 Model 4P that has been retrofitted with a complete electromagnetic shield. It's just a personal antique, useless for anything but a personal reminder of how long I've been thinking about this problem. That early-model personal computer didn't even have a hard drive.

I've spent much of my career working with radio and television transmitters on high mountaintops where there is a lot of lightning and other kinds of severe electromagnetic transients. Many engineers who spend their careers working in fairly benign electromagnetic environments don't realize the fragility of our technological infrastructure. On this page, I'm going to concentrate on a nuclear EMP attack, but much of this also applies to natural events such as unusual geomagnetic storms due to extremely large solar storms.

The threat of a sudden EMP attack that causes a widespread catastrophe is certainly nothing new. Consider this Cold War era quotation from a widely-read and highly-respected publication 30 years ago: "The United States is frequently crossed by picture-taking Cosmos series satellites that orbit at a height of 200 to 450 kilometers above the earth. Just one of these satellites, carrying a few pounds of enriched plutonium instead of a camera, might touch off instant coast-to-coast pandemonium: the U.S. power grid going out, all electrical appliances without a separate power supply (televisions, radios, computers, traffic lights) shutting down, commercial telephone lines going dead, special military channels barely working or quickly going silent." -- from "Nuclear Pulse (III): Playing a Wild Card" by William J. Broad in ***Science*** magazine, pages 1248-1251, **June**

12, 1981.

First: Another brief note about severe solar storms (and similar natural events), and then I'll get back to nuclear EMP. Solar storms would primarily affect the power grid, and are not likely to harm things like computers. Also, solar storms would only disrupt communications temporarily, and would not be likely to cause direct harm to communications equipment (except for satellites). An extremely large solar storm, though, would induce geomagnetic currents that could destroy a substantial fraction of the very largest transformers on the power grid (possibly over much of the world). If this happened, electric power loss due to a large solar storm would be out for a period of years and possibly decades. Unlike nuclear EMP, such a solar storm is an eventual inevitability.

The last solar storm that could have caused this level of damage happened in 1859, before the power grid was in place (although in 1921 a large solar storm, of briefer duration than the 1859 event, occurred which affected only a small area of the planet). The power grid has only been in place for a ***tiny*** fraction of one percent of human history, and a really large solar storm (of the size and duration of the 1859 event) has not happened in that time. There is a general assumption that any solar event that is similar to, or larger than, the 1859 solar superstorm will simply never happen again, although there is ***no*** justification for such an assumption -- in fact, we know that this assumption is false. There is a good possibility that such a solar storm will happen in this century. If it happens in the current situation without spares for our largest transformers, a large part of the worldwide power grid (including 70 to 100 percent of the United States power grid) will be down for years.

A 2008 study by Metatech found that the time required to obtain a replacement for any one of the 370 or so largest transformers in the United States was 3 years. In a solar superstorm that affects vulnerable areas of the entire world, delivery times could easily be much longer. The United States, which currently has no capability to manufacture those transformers, will be at the end of a very long waiting line. There are some companies in the United States that certainly have the capability of moving up from the ability to manufacture medium-sized power grid transformers to the capability of manufacturing even the largest transformers. So far, that capability has not been developed. Since such a expansion of manufacturing capability requires a lot of electrical power, the capability cannot be developed after an electromagnetic catastrophe. The capability has to be developed before there is an actual critical need. In the past year, at least two companies have expressed the intention of getting back into the large transformer business, but it will take a considerable length of time to develop this capability fully.

Because of the inevitability of a large solar superstorm, **we have to accept the fact that**

the current electric power grid upon which our lives depend is only a *temporary* infrastructure. This temporary infrastructure has served us very well, and we now have entrusted our very lives to it. The electric power grid began as a convenience, but has become a necessity for sustaining life through a process that has happened so slowly that most of us have not noticed this transformation. We do not know how long the current power grid will last; but if it not replaced by a robust permanent infrastructure in time, hundreds of millions of people will die when the electric power grid collapses simultaneously in many countries. How such a collapse occurs is well known, and the methods to either prevent it, or to have spare transformers in place to fairly quickly repair it, are also well known. Although these preventive measures would not be terribly expensive, they would take some time to put into place, and those things have never been done.

Provisions for insuring islands of power production within the country that would prevent millions of deaths could be put in place fairly quickly, and much less expensively, but this also has never been done -- or, until recently, even been seriously considered, except by the few scientists and engineers who have seriously studied the fragility of the electric power grid. There are finally signs, in 2011, that this situation is beginning to change.

Although solar storms primarily affect the power grid, customers can communicate the importance of EMP and solar storm protection to their local electric utilities. Devices such as the *SolidGround* system made by **Emprimus** can be installed by local electric companies on all of their large transformers that are connected to very long lines.

What just happened???

The most important piece of information you can have after any sort of unusual electrical event is information about ***what happened***. If there is a bright flash in the sky at the same time that the power goes off, and you've been thinking about nuclear EMP, your first reaction may be to assume the worst. It may, however, be just cloud-to-cloud lightning that happened at the same time that a distant cloud-to-ground lightning strike knocked out the power. Even if you thought the sky was clear outside, there may have been a distant thunderstorm, and lightning bolts sometimes travel remarkably long distances.

If it is a nuclear EMP, though, you will want to know about it right away, and the local radio and television stations are going to all be off the air. The internet will also be down. There might be some telephone service if you are ***very*** lucky, but anyone that you would call probably won't know any more than you. The only way that you will get any timely information will be by listening to broadcasts originating on other continents using a battery-operated shortwave radio.

If you have a shortwave radio, it is likely to be knocked out by the EMP unless it is adequately shielded. To be adequately shielded, it needs to be kept inside of a complete metallic shielded enclosure, commonly known as a faraday cage, and preferably inside **nested** faraday cages. A faraday cage is an **total** enclosure made out of a good electrical conductor such as copper or aluminum. Large faraday cages can get extremely complicated. For small portable electronics, though, completely covering the electronic equipment in aluminum foil makes an adequate faraday cage around the equipment. The foil covering needs to be complete, without any significant gaps. Wrap the device in plastic or put it in an insulated box before wrapping the covered device in foil. (Otherwise, the foil may simply conduct the EMP energy into the device more effectively.) A single layer of foil may not be adequate. In order to enclose the equipment in a **nested faraday cage**, place the foil-covered device in a plastic bag, such as a freezer bag, and wrap that bag completely in aluminum foil. If you really want to protect the equipment against a large EMP, add another layer of plastic and foil. The layer of plastic need to be the thickest plastic bags that you can easily find. (They don't need to be terribly thick, but do try to find some heavy-duty bags.)

Just adding many layers of foil directly on top of foil won't do as much good, due to what is called "skin effect." I won't bother to explain skin effect here, but you can look it up if you're curious. Don't worry too much about skin effect, though. I only mention it here because many people have the misconception that when it comes to shielding, the thicker the better -- and this is definitely not true after a certain thickness is reached. Layers of shielding separated by insulation works much better. As a practical matter, though, wrapping with 2 or 3 layers of foil helps to assure that you actually have a good shield around the equipment.

Of course, any antennas or power cords need to be either disconnected or contained completely within the faraday cage.

One question that arises frequently is whether a gun safe or a galvanized trash can makes an effective faraday cage. Technically, it may not be correct to call either of these a faraday cage because they are not constructed of the best electrical conductors. A galvanized metal trash can, though, can be a very effective electromagnetic shield. The interior of the body of the galvanized metal trash can should be lined with some material to electrically insulate items stored inside the container from the metal exterior. (Cardboard probably works better than any other inexpensive material for this. Liners such as plastic trash bags may be too thin for this because of the momentary high voltages that could be induced on the exterior during an actual EMP.) Do **not** place any insulation at a point where it would interfere with the electrical connection between the metal lid and the metal body of the trash can. It would be a good idea to wrap items placed inside the metal trash can with a layer of aluminum foil in the "nested faraday cage manner described above.

The question about using gun safes as an electromagnetic shield cannot be answered because there are so many variations in construction that would affect the shielding efficiency. In particular, the electrical connection between the door and the rest of the safe is usually not very good. Such a safe probably has some shielding effectiveness, but in most cases, the shielding is very minimal.

You'll need to keep plenty of batteries on hand for your radios. There are some models of shortwave radios that have hand-crank or solar power, but those "emergency radios" that I've tried don't have very good shortwave reception (although, as explained below, many inexpensive shortwave radios could suddenly become very adequate after an EMP event). A common complaint about radios that use hand-crank power is that the hand cranks are not very sturdy, however the radios will continue to function by using conventional battery power (or solar power if it is available.) If you do use the hand crank on an emergency radio, though, do not treat the hand crank too roughly. I still recommend keeping plenty of batteries on hand.

Energizer makes lithium batteries with a 15 year shelf life. Although small batteries were not damaged during the 1962 high-altitude nuclear tests, it would be wise to wrap each sealed package of batteries in a layer of aluminum foil. Future EMPs may be much larger than the 1962 events. Also, battery technology is evolving and the sensitivity of newer types of batteries to EMP is unknown (although the cylindrical batteries tend to provide a certain amount of shielding just due to the way that they are constructed.). I generally prefer ***Energizer*** batteries for cylindrical batteries (AA, AAA, C and D sizes) and ***Duracell*** for 9-volt batteries. The 9-volt batteries contain 6 internal cells in series. In the ***Duracell*** 9-volt batteries, the cells are spot welded together, whereas most other popular brands use a simple press-fit interconnect for the cells. The ***Duracell*** spot-weld method generally makes for a much more reliable connection in this type of battery.

The idea behind having a shortwave radio is to be able to directly receive radio stations on another continent that has been unaffected by the EMP. The radio that I like best of the portable, and not too expensive, receivers is the SONY ICF-SW7600GR. This model is not cheap, but you can usually find it for at least 25 percent below its "list price."

Another good shortwave radio for the price is the **Grundig Traveller II Digital G8**. This Grundig radio is much less expensive than the SONY ICF-SW7600GR. You can usually find the Grundig G8 for around 50 U.S. dollars. In using the Grundig radio recently, my only complaint was that it seemed to be much more susceptible to electrical noise than many other shortwave radios. Electrical noise is always a problem when listening to distant stations, but, of course, in a post-EMP situation, electrical noise would cease to be a problem.

Grundig also makes a somewhat better radio known as the S350DL, that sells for about

100 U.S. dollars. This radio is larger, and many people find it easier to handle. It also has a number of features, such as bandwidth and RF gain controls, that are difficult to find on other radios in this price range. The tuning on the S350DL is analog, but it has a digital readout. Some of the annoying aspects of the tuning dial in earliest models of this radio have been corrected in current versions.

The National Geographic Store sells the Grundig S350DL radio, which is pictured at the bottom of this page.

Many people have legitimate complaints about nearly any shortwave radio that can be purchased for less than 300 U.S. dollars. Those complaints are often valid if the radio is to be used frequently in today's high levels of electrical noise and radio frequency interference. In a post-EMP situation, or any situation where the regional electric grid goes down, the situation will be very different.

Many people have bought or kept old vacuum tube radios for use after an EMP attack. Although vacuum tubes are thousands of times more resistant to EMP than transistors (and discrete transistors are much more resistant than integrated circuits), other components of vacuum tubes radios can be damaged by EMP. In fact, vacuum tube radios actually *were* damaged in 1962 high-altitude nuclear tests. Vacuum tube radios also have the disadvantage of requiring much more power than solid-state radios, and electric power will be a rare commodity after a nuclear EMP. Although a vacuum tube radio would have a high likelihood of coming through an EMP event undamaged as long as it was turned off and not connected to an antenna, a modern solid-state shortwave radio kept inside of a nested faraday cage is the best form of insurance for obtaining information after an EMP event. (Many people don't realize that most vacuum tube radios still in existence have an early solid-state device called a selenium rectifier that is quite vulnerable to EMP damage. Although replacement selenium rectifiers are still sold for old radios, they are difficult to find, and you would probably find them to be impossible to get after an EMP attack.)

One important misconception about electromagnetic shielding is the common belief that it should be "all or nothing." When it comes to critical small spare items like an emergency radio, it is important to go to some extra trouble to insure the best shielding possible. Simple small nested faraday cages are so simple and inexpensive that you might as well make sure that a few items are very well shielded. When it comes to less critical items, though, such as items that you use frequently, a less-complete electromagnetic shield could easily make the difference between having equipment that survives an EMP and equipment that does not survive. It is a very common misconception that certain items must have military-grade shielding and other items are nothing to worry about at all. Real world electromagnetic disturbances are much more messy than that.

A nuclear EMP will severely disrupt the upper atmosphere, so it could be several hours after an EMP before you get decent shortwave reception with any radio, but that will be long before you could get information from any other source. If you're in the United States, you may be able to get emergency information from a local NOAA Weather Radio station. I believe that a few NOAA emergency transmitters are EMP-protected, but most are not. Repairs to many of these transmitters may be able to be made by military personnel, who can also supply emergency power to them for a while, but that emergency power may not last very long. If you're in the United States, though, it is important to have a NOAA Weather Radio. These radios really are inexpensive, and whenever the NOAA transmitters are working, they can provide local information that is critically important. Like your shortwave radio, an emergency NOAA Weather radio needs to be kept in a nested faraday cage until you need it. NOAA Weather Radios could be especially important in the case of a large solar superstorm, where the radios would probably continue to work and give information, even though much of the power grid could be out for years.

If you have a spare laptop computer, it can also be stored in nested faraday cages, just like your radio.

LED and CFL lights: LED lights (and, to a lesser extent, compact fluorescent lights) can be very useful for post-EMP use because of their efficiency at a time when very little electricity may be available. Both LED lights and CFL lights, though, are **very** sensitive to EMP.

LED lights are solid-state diodes that are made to conduct electricity on one direction only. In the case of LED lights, the LED itself has a very low reverse breakdown voltage. Most LED lights will handle a fairly large voltage spike in the forward direction, but not in the reverse direction. LED lights are currently the most efficient form of lighting that is available. LED lights also can last for a very long time. I know of one case where a device that I built in 1980 has some of the older (1970s) type of LED indicator lights that have been operating continuously for more than 30 years.

Compact fluorescent lights can probably be stored without any kind of EMP protection because the base of the light is so small that they are unlikely to pick up enough voltage for the imbedded transistors to be damaged. CFL bulbs are almost certain, however, to be damaged if they are in a socket at the time of an EMP since they have two switching transistors embedded into the base of the CFL. These switching transistors, although they are out of sight, would very likely be damaged by high voltages picked up by any wiring external the the CFL device itself.

If you learn that you have been in an EMP attack, don't make any premature assumptions about how bad it may have been. It may have just hit a part of the country, or it may have been with a relatively small weapon so that the power grid may be back up and running in a few weeks. It also could be from a large weapon, or multiple weapons, that totally destroyed the infrastructure of the country. There is an enormous spectrum of possibilities for an EMP attack.

Much of what has been written elsewhere about faraday cages is based upon the assumption that the faraday cage is going to be a room or building sized structure. Large professionally-built faraday cages need to be well-grounded, but for smaller faraday cages, such as you would use to shield a radio or a laptop computer, any wire running to a ground is likely to just function as an *antenna*, and possibly as a very efficient antenna for gathering EMP. Grounding for EMP is a very specialized area of technology. In fact, grounding for just about any application other than simple static discharge or some basic kinds of electrical safety are also very specialized areas of technology.

As the Soviets learned in 1962, even large underground conductors (such as underground power lines) can absorb huge induced currents from nuclear EMP. The same thing can happen to underground conductors like cold water pipes, which are commonly used for more primitive types of grounding. In a nuclear EMP, a cold water pipe ground may become a large underground antenna if it is connected to a long underground pipe. Although these underground pipes probably won't pick up very much of the fast E1 pulse, they can pick up rather large DC-like currents, and you don't need unexpected electrical currents coming from what you thought was a ground connection.

For shielding small items like radios and other electronics equipment, use the **nested** faraday cage system of alternating foil (or screen) and plastic, and don't bother with the ground connection (unless you plan to physically bury your equipment). EMP grounding gets *very* tricky, and the ordinary rules for grounding do not apply. (Most high-power transmitter antennas are actually at a DC ground.)

I sometimes regret using the term ***faraday cage*** at all because that term has a very specific meaning in the engineering world, and few non-engineers understand the difference between a faraday cage and a partial (but possibly quite adequate) electromagnetic shield. A steel enclosure is not a good enough electrical conductor to be called a faraday cage, but it may provide enough electromagnetic shielding to protect its contents. A related popular myth is that there is a sharp and well-defined boundary between what is protected from EMP and what is not.

Military systems have very rigid specifications for electromagnetic shielding because they are trying to protect against a multitude of unknown factors. Unless an individual has a very large amount of available wealth, such a high level of protection is probably not going to be relevant for an individual. The level of shielding that is adequate in any particular case depends upon a great many factors, including the strength of the EMP, the distance and direction to the weapon and the electromagnetic sensitivity of the particular equipment that you are trying to protect. This electromagnetic sensitivity varies greatly with every electronic device, and the sensitivity changes rapidly as technologies change.

A few days after an EMP attack, a lot of people will become really terrified as their food and water supplies run out, and they discover that there is no way to obtain fresh supplies. Within two or three weeks, the military services will likely come to the rescue for many people. If the size of the attack has been very large, though, that period of relief will probably not last very long. An even larger problem for food distribution is that any kind of centrally-directed distribution, no matter how well-intentioned, is highly inefficient. If you drive into any very large city with enough food for everyone, no centralized organization has ever figured out how to devise a mechanism that is anything close to being as efficient as the marketplace to get the food to everyone. In any case, most people will soon simply begin to starve to death.

For many people, their first concern regarding an EMP attack or a solar superstorm is the protection of their personal electronics, or even their automobiles. For nearly everyone, though, the first **real** problem they will face will come from the loss of power to the pumps that supply their water -- and with the computers that maintain the only local food supplies. Although most individuals cannot do anything to protect critical infrastructure computers or to protect the power to critical central utility water pumps and sewage systems, some advanced planning can increase the chances that you will have an adequate supply of food and water.

Whatever the scope of the EMP attack, the longer that you can remain at home and be fairly self-sufficient, the better things will be for you. This is likely to be especially true during the first few weeks after the EMP event. In most industrialized countries, it is not customary for individuals to keep very much in the way of emergency supplies in their homes. In fact, many people who do keep many emergency supplies are regarded with some suspicion, thought to be "survivalists" or some other strange breed of humans. Disasters are frequent enough, though, that any prudent individual should maintain some basic level of self-sufficiency. Most people in industrialized countries see large-scale emergencies happening frequently on television, while maintaining the irrational and completely unwarranted assumption that it will never happen to them. It is the people who do not plan for personal emergencies who ought to be regarded with suspicion as a strange and irrational breed of human.

There are several very reliable companies that specialize in these emergency supplies. The MREs (meals ready to eat) used by military services, especially during emergencies, have to be made on an industrial scale, and they are available for sale to individuals during non-emergency times. The MREs are **not** the best choice for emergency supplies, though, because of the limited lifetime compared to canned dehydrated and canned freeze-dried food. Many of these same companies that make MREs also make freeze-dried food in cans, which have a far longer shelf life and a much lower daily relative cost. After any sort of large-scale disaster, these supplies are only going to be available from government agencies, and government agencies will only have a finite supply. Many basic emergency supplies can be purchased in advance of the emergency from reputable companies that have been making these emergency food supplies for years. The food that these companies sell normally has a shelf life of 5 to 25 years or more, depending upon exactly how it is prepared and packaged. Although I do not want to get into the process of naming companies, one that I believe to be one of the best, especially for those who have not thought about the subject before, is Emergency Essentials.

For any emergency food supplies that you do get, it is important to get food that you personally like and are actually likely to use, even if a personal emergency never happens. Then, if an emergency does happen, it will be you, not distant relief workers, who will determine what the content of your food supply is. If you get food that you actually like, you will be motivated to actually use it, and you won't have to throw it out as it approaches its maximum storable life.

Some people keep only grains as an emergency food supply. Although some raw grains have a very long shelf life and a high calorie density, they do not have an adequate spectrum of nutrients for long-term use. In any emergency situation where scarcity of food is a long-term problem, we are likely to see the return of long-forgotten nutritional diseases such as scurvy and various kinds of other vitamin deficiencies, especially of the B vitamins and vitamin D.

Don't forget about water. Few people keep an emergency supply of water, in spite of the fact that it is inexpensive and easy to do. **Almost every country of the world has a period of days every year where many people in some large area are without drinkable water.** In most countries, much of the water is pumped by electric motors. After a major EMP attack or a solar superstorm, electricity for most of those pumps is going to be unavailable for a very long period of time. It would be easy for most cities to have a protected emergency electrical supply in place for critical pumps; but, like most EMP protection activity, **although it is easy and could possibly save millions of lives, it is not being done**.

A good source of information and products in a situation where the electric grid is down, especially for obtaining well water in such a situation, is the Lehmans web site.

It is also a good idea to have plenty of fire extinguishers. The immediate aftermath of either a nuclear EMP attack or a large solar superstorm is likely result in a number of fires, along with the elimination of the water necessary to extinguish the fires. Both the E3 component of a nuclear electromagnetic pulse, as well as the DC-like currents induced by a large solar superstorm, are likely to overheat thousands of transformers that are connected to long wires. Although it is the destruction of the very large transformers in the power grid that could keep the power grid from being restored for many years, many much smaller transformers, such as those on utility poles, and spread throughout suburban neighborhoods, are at risk of overheating to the point that they cause fires. Although the great majority of the smaller transformers are likely to survive, many of these transformers are very old, and some of them are likely to severely overheat.

Medicine is another very important thing that must be considered. If there are medicines that are required by someone in your household, it is always prudent to have an extra supply on hand. In many countries, insurance restricts the amount of medicine that you can buy. It is often actually less expensive to pay the full price for prescription medicine, especially when generics are available. Buying prescription medicine out of your own pocket makes it much easier to stockpile a supply for emergencies. There is a fairly new web site operated by a physician that discusses the problem of medicine storage for use during disasters. See the Armageddon Medicine site.

If you want to really be part of the solution, instead of part of the problem, and increase the probability that the country can return to normal within a few years after an EMP attack, then you can be prepared to become part of the new infrastructure. The more electronics equipment that you can store under nested faraday shielding, the better. If you want to be able to use that electronics equipment after the batteries run down, you will need a personal power source. A simple small electric generator, one that does not depend upon electronics to start or run, is always a good idea. After an EMP attack, though, fuel for the generator will be a scarce commodity. Solar panels can be used to supply a small amount of electricity indefinitely, especially if you also have some good rechargeable batteries that match the voltage of your solar panel. I don't know how resistant solar cells are to EMP (the solar panel technology is ever-changing), but if you have something like a 50 watt solar panel, you can store it in a nested faraday cage. Only very rare individuals are going to be able to have full electric power after an EMP attack, no matter what advance preparations they might like to make. In a post-pulse world, though, any amount of reasonably reliable electricity is going to be a real personal luxury.

If you have solar panels that are now in use, you can obtain some EMP protection by proper shielding and transient protection on the wires going to the panels, and by surrounding the panels with aluminum wire cloth (also known as hardware cloth). Aluminum wire cloth is somewhat difficult to find, but it is available. Aluminum wire cloth with openings of 0.4 to 0.5 inches will not only supply a certain amount of EMP protection, but can provide some protection against larger hailstones that can cause damage in severe weather. The wire cloth will block some of the sunlight, but the right size of wire cloth will block less than 15 to 25 percent of the sunlight. If you are making a new solar panel system, some consideration should be given to putting the solar panels inside of a cage made of aluminum wire cloth. This is much easier to do during the original installation.

If you plan to use solar cells or battery power, you will probably want to keep a small inverter under shielding. Inverters that can step up ordinary 12 volt DC power to a few hundred watts of household AC are not terribly expensive. For people who own protected photovoltaic solar cells, a number of DC-powered appliances have recently become available. Transient protection (capable of reacting to the fast E1 pulse) must be supplied on the electronic components of any solar cell system, such as the inputs and outputs of charge controllers and inverters. Any wire runs of any length should be shielded.

If you're trying to protect an existing solar panel system, protecting the wiring (even if it is shielded) from transients will require the services of someone knowledgeable in EMP transient protection. In most cases, the most economical solution is to keep spare components, especially inverters and charge controllers, stored under electromagnetic shielding.

If you do have access to post-EMP electricity sufficient to run a microwave oven occasionally, that can be a very efficient way of cooking food in many situations. The problem is that most microwave ovens couldn't be turned on after an EMP event due to the sensitivity of the solid-state control circuitry. The magnetron that generates the heat in a microwave oven would probably survive an EMP just fine. Microwave ovens are heavily shielded, but the sensitive control circuits are outside of the shielding. A few microwave ovens are controlled by a mechanical timer, and these would probably be fully functional after an EMP (assuming that you can occasionally get enough electricity to operate them). You can still find mechanical-timer-controlled microwave ovens occasionally, although they are getting harder to find every year. I bought one about four years ago at K-Mart for $40 for post-EMP use. I have recently seen small microwave ovens with electro-mechanical controls come back onto the market.

The chamber of an older microwave oven is an efficient faraday cage for most purposes which can be used for shielding small electronic items. **It is important that any microwave oven used for this purpose should have its power cord cut off close the the body of the microwave oven.** This should be done both to prevent accidentally turning on the microwave oven with electronics inside and to prevent the power cord from acting as an antenna to conduct EMP into the interior of the oven. Some newer microwave ovens have a chamber that is designed to shield microwaves, but may not effectively shield some lower frequencies. Anything that you are hoping to use as an electromagnetic shield should be tested by putting a radio inside of the shield tuned to a strong FM station. If you can hear the FM station while the radio is inside of the shield, then the shield is not adequate. There are so many things that can go wrong with electromagnetic shielding that any shielding that you are using should be tested first using the FM radio test. (Be sure to remove the batteries from any equipment before putting it in permanent storage, though.)

Laptop computers are generally much easier to protect from EMP than desktop computers. This is true both because of the smaller size of laptop computers and the fact that desktop computers have numerous cables which act as antennas for EMP -- and which conduct the pulse directly to the very sensitive electronics inside the computer. Even laptop computers must be well-shielded and without any connections to unprotected wires. The U.S. military contractors have developed shielding devices so that laptop computers can continue to be used during EMP attacks. Devices such as these, however, are not available on the commercial market.

If you want to store larger items in a faraday cage, you can use copper screen or aluminum screen. Most commercial faraday cages use copper screen, but copper screen is expensive and is difficult for most individuals to obtain. Bright aluminum screen works almost as well, and aluminum screen can be obtained in rolls at many building supply stores such as Home Depot. Don't worry about the fact that this screen is not a solid material. The size of the tiny ventilation holes in the mesh of ordinary window screen is irrelevant to EMP protection. ***Aluminum*** screen can make a very effective electromagnetic shield. Ordinary ferrous (iron-containing) window screen is **not** a good material for a faraday cage because it is a poor electrical conductor.

Do keep in mind, though, that anything even approaching a room-sized faraday cage is likely to only be a partial shield unless it is carefully and professionally designed and maintained, something that is completely impractical for most individuals. A partial shield, though, can often reduce electromagnetic signals from the outside by a critical amount. When I was working at a broadcast transmitter site that had an unacceptable level of electromagnetic radiation from the FM broadcast antenna into the area at ground level where the vehicle was commonly parked, I had a carport built with copper screen imbedded into the roof of the carport. The reduction in electromagnetic radiation beneath the carport was quite dramatic -- as actually measured using professional equipment. Since nuclear EMP comes in from a fairly high angle, it is likely that a similar arrangement, but using aluminum screen, would reduce the EMP substantially, possibly enough to protect vehicles and other large items stored below the shielded structure. In the case of the carport that I had built, I grounded the imbedded screen because I knew that the wire leading to ground would not act as more of an antenna than a ground for the shield. (I also knew that the ground at the bottom of the carport was an extremely well-designed ground.) Although most small faraday cages should **not** be grounded because of the "accidental antenna" problem, if a carport shield can be well-grounded at all four corners, then a direct wire going to a ground rod at each corner would probably be a good idea.

One question that most people don't think about is how to test the shielding efficiency that you are using. Most people don't have access to professional electromagnetic field measuring equipment, and they certainly don't have any nuclear weapons laying around the house. The most damaging part of a nuclear EMP has frequency components that run roughly from the AM broadcast band to the FM broadcast band. The components that are most likely to damage ordinary small electronic items are near the FM broadcast band. Therefore, you can make a rough test of your shielding effectiveness by tuning a radio to a strong FM station and see if your shielding silences the radio so that you can't receive the FM station. You can try the same thing with AM. In general, the good electrical conductors like copper or aluminum will be better at shielding the higher frequencies in the FM range, while steel cases may perform better in the lower-frequency AM band.

It is important to have all of the computer data that is important to you backed up onto ***optical*** media, like CD or DVD. Paper printouts are fine, but after an EMP attack, most of the data on paper printouts will simply never get typed back into computers, so those paper printouts will just become your personal mementos.

CD and DVD data (in other words, *optical media*) is not affected by EMP. Even if your computers are destroyed, if the country's economy can get re-built after an EMP attack, then new computers can be purchased from other continents. If all the computer data is gone, then recovery is going to be many years later than it would be if the data could just be reloaded from optical media. Computer data runs our modern world. It is a major part of the invisible magic that I mentioned at the top of this page. If you own a small business, that computer data can be especially important. (It is probably not a good idea to use double-sided DVDs, though, since there is the possibility of arcing between layers during electronic attacks. It is best to just use single-sided single-layer media.) For long-term storage of data, ***archival grade*** CD-R and DVD-R media are available at a reasonable price from manufacturers such as Verbatim and Memorex. The archival grade media are much more likely to last for many years or decades, and they don't cost that much more than standard media. Most stores don't carry archival grade media, but they aren't that difficult to find, especially on larger electronics stores on the internet.

Protecting most of the electronic appliances in your house against EMP, if they are plugged in and in use, is probably hopeless. There is always the possibility, though, that you will be near the edge of an area that is affected by an EMP attack. For this possibility, the combination of ordinary surge suppressors and ferrite suppression cores could be very valuable. There is at least one company that makes surge suppressors that look much like ordinary retail store surge suppressors, that are designed to be fast enough for nuclear EMP.

Ferrite suppression cores are those imbedded cylindrical things that make the cylindrical protrusion in the power cords on sensitive electronics equipment. They can be very effective to protect your equipment against ordinary transients -- such as the type that occur constantly on the power lines and slowly damage your electronics equipment. The ferrite suppressors on power cords (and inside of many surge protectors) are usually the common type 43 ferrite material, which offers a considerable amount of protection against ordinary transients, but would do only a little to protect against the very fast **E1** component of a nuclear EMP. You can buy separate snap-on ferrite suppressors, including snap-on ferrite suppression cores with type 61 ferrite, which will absorb much faster pulses. The ferrite cores with material 61 don't cost all that much more than the older ferrite, and they should attenuate the spike from a nuclear EMP much better than type 43 material. If you're in an area where there is a strong EMP, it won't attenuate it enough to do any good at all, but if you're at the edge of the affected area, or just get a nearby lightning strike, or have a lot of ordinary voltage spikes on your power line, these snap-on ferrite cores with material 61 could be extremely valuable. They are sold by companies such as Mouser Electronics. Look for items such as Fair-Rite part number 0461167281 or 0461164281.

Items like surge suppressors and ferrite suppression cores are only going to be effective against relatively small pulses that come in through the power line. A large EMP will totally and completely fry your large screen television by directly inducing currents in the equipment itself that are far too large for it to handle. The same is true for much of the other electronics in your home. There is no reason to assume, though, that any EMP attack will be maximally effective -- or that you will never be right at the edge of the affected area. **Also, even if an EMP attack never happens, an endless barrage of small voltage spikes is eating away at your electronics equipment every day unless you are doing something to protect against it.**

There are all kinds of EMP attack scenarios. There are many situations one can imagine where the area around the edges of the EMP zone is extremely large. There could be entire large cities where even the unshielded equipment with minimal protection mostly survives, but everything unprotected is fried.

There is actually quite a lot that can be done to protect your electronics from a small EMP attack or if you happen to be at the edge of the EMP-affected area. If you live in a lightning-prone area, many of these things will give your electronics equipment a much longer lifetime. **Repeated hits from small electrical transients is a major cause of electronic failures, ranking second only to heat as a cause of most types of electronic failure.**

It is important to read the EMP Commission Report on Critical National Infrastructures, so you'll have some idea of the scope of the EMP problem. Note: This is a 200-page report (7 megabytes), and could take a half-hour or more to download if you are on a slow dial-up connection.

This EMP Commission report is the best information, but definitely not the last word, on likely EMP effects on today's infrastructure and equipment. The EMP Commission relied heavily on data from simulators, and this data does not explain all of the effects that were actually seen in the 1962 nuclear tests, especially in the Soviet EMP tests over Kazakhstan.

One thing that you'll discover in that **Critical National Infrastructures Report** is that automobiles and trucks seem to be more resilient against EMP attacks that what is portrayed in most fiction. Although many vehicles **would** be rendered inoperative, and it will be a regular "demolition derby" on streets and highways, many (but not all) vehicles that are *not running at the time of an EMP* will be likely to run after they are started (although there is a very high probability that your car will experience electronic damage outside of the electronic ignition system, and your car may have to be started in an unconventional way. It is also possible that you may have to momentarily disconnect the battery so that electronic modules can recover from an EMP-caused latch-up condition, a situation unique to EMP.) It may be necessary to have a maintenance manual for your car so that you, or someone you know, can figure out how to bypass the damaged modules in your car.

Vehicles, especially gasoline vehicles, have to have a robust amount of electromagnetic shielding around the entire electronic ignition system. Otherwise, the ignition noise from all the automobiles would render radio and television sets unusable (especially car radios). Today's automobiles have published standards for electromagnetic shielding, but there is not much consistency in shielding requirements. You can check this list from Clemson University for a partial list of the many and varied standards for electromagnetic shielding of automobiles.

Some additional information on vehicles may be found on the EMP Effects on Vehicles Page.

The most difficult part of operating a car after an EMP event (or even a solar superstorm) is likely to be obtaining gasoline. It is very foolish to ever let the level of gasoline in your tank get below half full. In a wide range of emergencies, one of the most valuable things to have is a full tank of gasoline. A solar superstorm will **NOT** damage your automobile; but by knocking out the power grid, it can make fuel almost impossible to find.

It is important to remember that the last time an automobile was **actually** tested against nuclear EMP was in 1962. Everything since then has been in simulators that we hope are close to the real thing.

One common question people ask is about grounding the frames of cars. If you have a car parked in a location where there is a very short and direct connection straight down into a **high-quality** ground, then grounding the frame of a car *might* help, but I doubt it. In most situations, attempts to ground the frame of a car are more likely to just make matters *worse* by providing an accidental antenna for EMP. The safest way to provide a modest amount of EMP protection for a car is to keep it parked inside a metal shed.

Retrofitting an automobile to make it EMP-resistant is a project that would be too difficult and expensive for most people. For those who want to try, the only authoritative document that I know to be available is one called "EMP Mitigation - Protecting Land Mobile Vehicles from HEMP Threat Environment" which was just published in March, 2011. To find this document, go to the Protection Technology Group page, then click on the Knowledge Base link at the top of the page. Scroll down on the Knowledge Base page until you get to the article that you want. The article specifically applies to military vehicles, but has relevance to commercial vehicles as well. Note that the part of the referenced article that refers to bonding of "all metallic structures to a single point ground system" is referring to an **electrical chassis ground** on the vehicle, **not** to an earth ground.

(I'm not giving a direct internal link to that page on protection of vehicles because the Protection Technology Group has been making extensive changes to its web site in recent months, and the exact location of the article on their site may change.)

I highly recommend any of the articles on the Protection Technology Group Knowledge Base page as an excellent source of information about EMP and/or lightning protection.

In the 1962 Soviet high-altitude nuclear tests over Kazakhstan, even military diesel generators were damaged. This process was apparently started by a large voltage spike from the fast E1 component of the pulse punching through the insulation on the wiring at a single point. According to Vladimir M. Loborev, one of the chief scientists who studied this phenomenon, "The matter of this phenomenon is that the electrical puncture occurs at the weak point of a system. Next, the heat puncture is developed at that point, under the action of the power voltage; as a result, the electrical power source is put out of action very often." (From his report at the 1994 EUROEM Conference in Bordeaux, France.)

This should be a warning to anyone who is planning to use any very old vehicle for possible use after an EMP event. If you have a pre-electronic-ignition era vehicle, it is important that you also have an electrical wiring diagram for the vehicle, and plenty of fuses (and I do mean **plenty** of fuses) and some critical electrical spare parts. My own personal experience in maintaining a 1959 model RCA high-power television transmitter until the year 2000 tells me that it is very easy for high voltages to punch through old insulation. Although post-EMP repair of these older vehicles may be easier than repair of a modern vehicle, it can be very frustrating, since very old insulation on electrical wiring can become extremely brittle.

To protect small generators from the kind of insulation puncture in the windings that was experienced in the 1962 Soviet tests, it is likely that simple MOV transient protectors (wired across one of the 120-volt outlets) on most generators would provide sufficient protection. The MOVs are not fast enough to capture the leading edge of the EMP spike, but it takes a lot more energy to punch through enamel insulation than to damage microelectronics, so it is likely that these MOVs would provide adequate protection for the insulation. Small MOVs are readily available from companies such as Radio Shack (part number 276-568). (It is unlikely that these MOVs would be fast enough to protect any microelectronics that may be in the generator, though.)

If you are constructing any kind of EMP protection that does need a ground connection, make sure that it is a good-quality ground. If the soil is dry, rocky, or otherwise likely to be of poor conductivity, proprietary commercial grounding compounds are available to enhance the conductivity of your ground rod to the earth. **Bentonite** is a material that is widely used in drilling industries that can also greatly enhance conductivity between the grounding system and the earth. I have found bentonite to be *very* effective as a grounding material. For most people, bentonite is easier to obtain and much more practical than the proprietary commercial grounding compounds. If it is not feasible to bury a ground rod vertically, a fairly good ground can be made by digging a trench as long and deep as is feasible, then placing flexible copper tubing (such as is used in plumbing) in the trench, covering the copper tubing with bentonite or other grounding compound, covering with topsoil, then using the above-ground part of the copper tubing for the ground connection.

I have the first draft on-line now of a separate page on this web site about grounding for EMP, and how to easily construct a ground that is likely to avoid the "accidental antenna" problem that is so common when non-engineers try to construct an electrical ground for EMP. (If you think that a water pipe or the ground wire on an AC outlet is a good ground for EMP, then you should definitely forget about grounding. Neither of these connections is close to being an effective EMP ground.)

Steel enclosures of various kinds are often suggested for use as an EMP shield for storing electronics equipment. Although steel can be a good electromagnetic shield for lower-frequency components, I have found it to be considerably inferior to better electrical conductors such as copper and aluminum in actual measurements in intense electromagnetic environments. Steel has *different* characteristics from better electric conductors such as copper and aluminum, so the best situation if you are using an steel enclosure is to add a layer of copper or aluminum screen or foil as an additional layer of shielding. (Steel tends to be better at shielding lower frequency components, but aluminum and copper are better at shielding the higher frequency components that are more likely to damage smaller items.) Actually, there is evidence that the very best EMP shields would be alternating layers of steel and aluminum or copper, with an insulating material separating the layers of metal. (This is how many electromagnetically shielded buildings are actually constructed.)

One very effective means for isolating disturbances on the power line from electronics equipment is the use of a "double-conversion" type of "true online" UPS (uninterruptable power supply). Any very large E1 pulse coming in on the power line would destroy the UPS, but the UPS would have isolated the equipment from the power line transient before failing. It is important to note that most uninterruptable power supplies on the market are **NOT** the "true online" type, and are of very limited usefulness for isolating the equipment from the power line (even for ordinary voltage spikes). Most inexpensive uninterruptable power supplies let much of the voltage spike hit the equipment before switching to internal battery power after the AC line power has failed.

The best of the small true online UPS units are those made by SOLA, but they are also rather expensive. Tripp-Lite makes a series of true-online double-conversion UPS units that are less expensive and are easier to for most people to find. (Many major UPS manufacturers have been rather deceptive in the past about whether their UPS units are actually the true-online double-conversion type, although most companies are becoming more honest about the architecture of their UPS units since the difference in actual equipment protection is quite considerable.)

The true online UPS units can also isolate equipment from the effects of the solar-storm-like E3 pulse or the effects of an actual solar superstorm. Although the principal effects of E3-type events for the individual is total loss of power from the power grid, these events could cause extreme distortions in the AC power waveform for a short amount of time until the grid collapses. This extremely-distorted AC could burn out motors and damage electrical and electronics equipment in a very short amount of time unless measures are taken to isolate the equipment from the power line by using a true online UPS or a ferro-resonant transformer. Certain types of ferro-resonant transformers, such as the SOLA CVS series, can isolate equipment from power line distortions by insuring that the equipment gets either a pure sine wave or nothing at all. The SOLA CVS transformers are also extremely effective at blocking most voltage transients from getting into equipment, although they won't completely block extremely large and fast transients such as those from the fast E1 component of a nuclear EMP.

One very important consideration for anyone using a UPS or a ferro-resonant transformer for protection any equipment containing a motor of any size (even a refrigerator) is that motors have very high start-up currents, and neither UPS units nor ferro-resonant transformers are designed for motor operation. If you are trying to use either a UPS or a ferro-resonant transformer to protect any appliance where a motor is a significant part of the load, you have to select a UPS or ferro-resonant transformer that has several times the rated load of the appliance.

Because electronics equipment is becoming more vulnerable to voltage transients all the time, the surge suppressors that are sold for protecting expensive consumer electronics are getting better all the time. Today's consumer AC plug-in transient suppressors are much faster than those sold just a two or three years ago, and many of the newer units will absorb much larger voltage spikes. Although none of the consumer-type surge protection devices are likely to be completely effective against EMP, they may be helpful in protecting some types of household appliances.

If you have a small business with too much critical data to routinely back up onto optical media, you should consider looking for a data center with EMP protection and plenty of backup power. Many data centers are actually quite fragile, and many have proven to lack even the ability to survive a severe rain storm. Some data centers occupy former military facilities and claim to be EMP-hardened. You may want to consider backup data centers such as Infobunker and Cyberbunker.

For anyone with two-way radio equipment or radio receivers that are already extremely well-shielded and also well isolated from the power line, but left with the vulnerability of a connection to an external antenna, EMP protection devices can be obtained that are made by Polyphaser. The Polyphaser EMP protection devices for antenna connections generally use only type N connectors (so you may need an adapter), and the cost is generally about $125. Polyphaser does not sell these devices directly to the customer in small quantities, but they can be purchased through companies such as Richardson Electronics if you know *exactly* what model number of Polyphaser device that you want.

For conveniently protecting small electronics, such as laptop computers, when they are not in use, an aluminum briefcase should be very useful, but there are large differences in the shielding ability among different metallic briefcases. First, the briefcase needs to be a solid metal aluminum briefcase (**not** the less expensive "aluminum briefcase" that is actually made largely of aluminum-colored plastic). (The aluminum-colored plastic briefcases are useless as an EMP shield unless a considerable amount of additional electromagnetic shielding is added.) If you are unsure of the electromagnetic integrity of your aluminum briefcase, a layer of electromagnetically shielding metallic spray paint can be added to the exterior of the briefcase. The cans of electromagnetically shielding spray paint tend to be rather expensive, but they can be purchased from companies such as Mouser Electronics. For maximum effectiveness, there needs to be good electrical contact between the two halves of the briefcase, especially at the hinges and the latches. A well-shielded briefcase should be able to completely eliminate reception of an FM radio receiver that is tuned to a strong FM station and placed inside the briefcase with the latches secured.

Many lessons about what to expect after an electromagnetic event can be learned from the aftermath of the March 2011 tsunami in Japan. Unfortunately, the information about these events after the initial earthquake and tsunami by the news media in the United States has ranged from horrible to non-existent. Nearly all of the deaths and suffering after the first hour of the tsunami have been due to the absence of electricity and electronic communications. Just about the only place to get accurate information about the aftermath of the tsunami is from **NHK World**. NHK has shown things like what happens when you try to open the grocery stores after power is restored after a prolonged outage, and the difficulties of supplying the grocery stores from the food warehouses when the inventory control and computerized ordering systems are not working.

It should also be noted that the problems experienced in Japan by certain nuclear power plants are likely to be serious problems for any country in the aftermath of a severe solar storm or nuclear EMP. This has been discussed in connection with EMP long before the tsumani in Japan. Nuclear reactors require a reliable external source of electricity for cooling systems after any sort of scram shutdown.

The aftermath of the 2011 tornados in the United States has exposed the vulnerability of the cellular telephone system. Most cell phones are too small to intercept enough EMP to damage them; but the cellular repeaters, which are necessary to the operation of the cellular telephone system, are very vulnerable in a wide range of disaster situations. Unfortunately, the cellular telephone system was not designed with any peer-to-peer (direct cell-phone-to-cell-phone) capability. This means that if the cellular repeater stations go down, your cell phone becomes useless.

Some cellular telephone companies have developed mobile repeater stations for use in disaster situations. These have proven themselves to be mostly for show, and quite inadequate in any real-life large-scale emergency situation.

Your personal EMP and solar storm protection plan is likely to be very different depending upon where you live, and how many other people live with you. The only way to make an effective plan is to try to imagine an unpleasant future where you are suddenly thrust back into the middle ages. One thing that an EMP or a severe solar storm won't destroy is the knowledge of how to re-build effectively. Hopefully, even if we don't get an robust and permanent infrastructure built in time to prevent a catastrophe, the rebuilt post-pulse electrical and electronic infrastructure will be something that is permanent, and that all of us can finally trust, unlike the very fragile infrastructure that we have today.

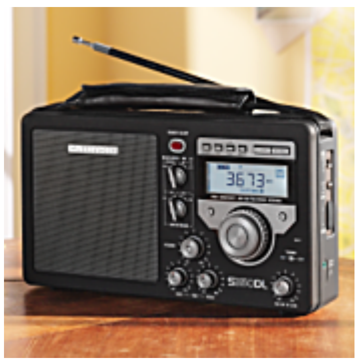
Other EMP pages at this web site:

- For a general introduction, see the **Futurescience Main EMP page**.
- There is a comprehensive and well-referenced page at this site with extensive details about the **1962 Soviet nuclear EMP tests over Kazakhstan**, which resulted in extensive damage to the electrical and communications infrastructure.
- There is a separate page with additional details about **EMP effects on motor vehicles**.
- **Notes and Technical References on Nuclear Electromagnetic Pulse** (and on solar storms).
- Also see my article about the **Operation Fishbowl** series of high-altitude nuclear tests
by the United States in 1962 over the mid-Pacific. This article includes extensive references.
- There is also a heavily-referenced page about **General EMP History**, including details on the balloon-launched Hardtack-Yucca nuclear test. A link to the video of the helium-balloon-launched nuclear weapon is included.
- Another page on EMP explains the critical difference between the **E1, E2 and E3**

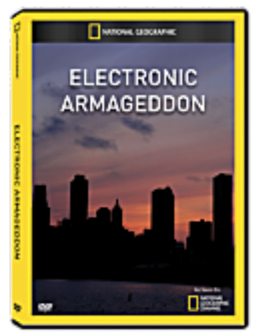
components of nuclear EMP.

- Also at this site, there is a page on common **EMP Myths**.

For additional information on preparedness, especially as it relates to electromagnetic pulse, there were a special series of excellent internet radio programs on the subject produced by EMPactAmerica in September, 2011. Those radio programs are available free at **http://www.empactradio.org**.



National Geographic Shortwave Radio



National Geographic EMP Documentary DVD