Questions:

EMP preparedness can be divided into categories:

a. Residential and small commercial property – that we individuals can protect on our own.
b. Privately owned large industrial property
c. Government owned property

The following address residential and small commercial property

1. What and where can I buy circuit protectors? Suppose I have a standby battery pack for my radios that needs to be plugged in to keep its battery up. What do I insert between commercial power and the pack? Assume I've already wrapped the battery pack in grounded copper screen wire.

   Answer:

   Surge Protectors are designed to protect electronics from the E2 type pulses produced by lightning. Some are better than others. Be careful even if you are buying them to protect from lightning EMP. If they are not designed properly they may not provide much protection. Buying cheap is not always the answer. Look up Surge protection on the internet for advice on protecting against lightning for the E2 component.

   Most E3 pulses will result in damage to the grid, but the transformers on the power pole will likely protect your house. It may protect your house at the expense of the transformer itself. A shorter line from the transformer to the house circuits is best for E3. Surge protectors may not help at these low frequencies since they are designed to protect equipment from lightning caused EMP. The issue here really does relate directly to Volts per meter.

   The E1 component is the higher frequency content. Here high frequency relates to short wave length. High frequency electronics may be quite susceptible. Cell phone antennas are designed to pick up high frequency (short wavelength) content.

   Currents at these high frequencies (E1 Component) do not build over length quite like the E3 component. Long transmission lines are designed to have low impedance for extremely low frequencies. At higher frequencies the current will flow on the surface and the large conductors used on the grid will represent a high impedance to these higher frequencies. This results in more losses over distance for the E1 component. The E1 damage is done because the effect is wide spread due to the high altitude burst and Compton scattering. Small circuits can still pick up these high power currents and most modern electronics are designed to operate at low voltages. A small trace can act like an antenna and couple large voltages onto low voltage circuits.

   A battery is probably pretty robust. The control circuitry that does charge control may not be very robust.

   RF devices are really susceptible. RF devices are designed to pick up very faint RF signals and amplify them for use. HEMP will not be faint or low power RF. It will be quite strong. Strong enough to affect street lamps designed in the early 1960s. (refer to Starfish Prime, a high altitude nuclear test caonducted July 9, 1962)

   The real question is:

   How do I survive when the electrical power grid goes down for months or even years?

   The question the EMP Task Force in Colorado is asking is:

What can we do to protect the Colorado electrical grid so that even if it does go down, we can recover it in a short period (hopefully days or less)?

2. What about semi-Faraday cages such as airplane, cars, trucks, metal buildings? What is the risk of damage? How do we prevent EMPs from entering through antennas and power cords?

   Answer:

   Think of a Faraday cage as a bottle. A bottle can be used to keep things in or to keep things out (A bottle keeps your wine in and it keeps the drying air out). If you have a hole on the bottle, good things can get out or bad things can get in. The smaller the hole the better it is, but any hole in your wine bottle (when you're not pouring) can be bad. A Faraday cage is much the same story. Any hole in the cage can let bad stuff in. The bigger the hole, the more bad stuff gets in.

   Outside wires such as power cords or antennas provide better paths for the bad stuff to get into your device. Power cords can be shielded but they are not doing much good if they are not hooked up to some power source. If the power source is propagating the fault into your power cord, shielding the cord will not help.

   Antennas are more problematic. What good is an antenna that does not pick up radio frequency? How then can one protect an antenna from radio frequency? (Put a spare in a Faraday Cage?)

   There are some buildings built for commercial or government work that are designed to be Faraday cages. It can be done. It will cost a lot of money. If you want to build a Faraday Cage, you can search the internet for design considerations.

3. Where can we acquire a catalog of protective devices?

   Answer:

   I would search the internet for my particular concern. There are not always catalog solutions. This is not the type of thing that has often happened so there is little commercial value in marketing it.

   Again, does this matter if the Power Grid goes down for months or years? If the power grid goes down, there may be no power for the device you just protected. The power generating system and the power transmission infrastructure may well go away if we are attacked.

4. What is the difference in a mile long wire and a 2 meter wire from a 2 nS pulse?

   Answer:

   The field strength of the electric field will be expressed in Volts/meter. A mile is approximately 1600 meters. So, if you have a low frequency pulse that has a field strength of 2Volts/meter, a 2 meter wire will have a difference in potential of 2V/m X 2m or 4Volts from one end to the other. For a 1600 meter wire (Approximately 1mile), the potential from one end to the other is 3200Volts (Wow!).

   That is pretty simple math, but as one might expect the answer is not that simple. You asked about a 2ns pulse. That is not a low frequency pulse (where I started my simple analysis). The answer for the 2 meter wire would still be about 4 Volts. The mile long cable however would look like a high impedance load to the 2ns pulse so very little current would flow and therefore the Voltage drop across the long wire would not be so great.

   In the high frequency range the HEMP field can be extreme. The graph in my presentation shows a field strength as high as 50,000V/m. For your 2 meter case that gives you 100,000 Volts!!!!

For a 2ns pulse, 1 wavelength is $3X10^8$ meters/s (Speed of light) divided by $2X10^9$ cycles/s (2ns) or 15 centimeters (cm) (5.9 inches). At this length your 15cm trace or wire can pick up 7,500Volts. 15cm is only slightly longer than the average cell phone. Even a 1cm (less than ½ inch) trace can pick up 500Volts from this pulse. On a modern electronic devices the supply voltages can be anywhere from 0.9V to 5V. Take a typical 3.3Volt circuit and couple in 500Volts for 2ns and you can do a lot of damage. It will occur so fast that you might not even see the flash when the weakest part is destroyed.

5. What do buried wires do to an EMP, such as a buried yard line to a house, telephone also?

   Answer:

   Buried wires are in affect shielded by the Earth. A very shallow trench will not shield as well as a deeper trench. Covering the trench also helps. The Earth then becomes your Faraday Cage. If the wire comes out from under the ground (as telephone wires most certainly will at some point), the wire can pick up the unwanted field and transmit it under ground. You would want to protect the wire as it entered the protected shielding to ensure the undesirable pulse does not propagate onto your buried wire.

   If the electrical power grid is down, there will be no one sending power to your protective trench.

   Also if the coupling is before the trench but on the wires accessing the trench, your protective trench will not completely avoid the problem. The destructive pulse will enter on the wires that also bring power (or signal) into the trench. This is why one would somehow need to condition the signal that enters the trench.

6. Hurricanes have ratings. Category 3 contains winds up to 129 MPH. Architects can design buildings to withstand 129 winds and so much vacuum associated with hurricanes. Are there similar ratings for EMPs and electronic hardening?

   Answer:

   Yes, but only for the Solar variety. NOAA has ratings for Solar activity that they use to help predict the effects on terrestrial equipment such as the Power Grid as well a space equipment such as weather satellites, GPS, Communications satellites and even Deep Space Missions.

   See: http://www.swpc.noaa.gov/communities/space-weather-enthusiasts

   There may be some military ratings for nuclear weapons but those are likely classified. Nuclear weapons are typically rated by equivalent weight of TNT (i.e. 20 Mega Ton). This is difficult to relate directly to EMP although the energy converted to Gamma rays or X-Rays which produce Compton Scattering has been studied. The percentage of the energy converted to the electromagnetic energy is very dependent on the design of the weapon. As such, much of this data is classified. (Starfish Prime was 1.4 Mega Tons, Hiroshima (Little Boy) was 13 kilo Tons and Nagasaki (Fat Man) was 22 kilo Tons.)

7. Tell us about the lab in Colorado Springs.

   Answer:

   I do not have much personal experience with this lab. I have talked to a person that works there.

   They do normal EMI/EMC testing as well as EMP. The difference is that most EMI/EMC testing is not so much the large scale pulse as determining how terrestrial systems interact. Most folks are concerned with how their system might be affected by other systems and there are often regulations on

the noise a system is allowed to produce. For example, an aircraft system needs to be able to operate while the aircraft is being “painted” by several radar systems all operating at different frequencies. Likewise a CB radio can only produce a certain amount of RF power in band and is also regulated on the allowed power it generates out of band.

The following are the categories b. and c.

1. Would it help anything to twist power transmission line wires like 1920 vintage telegraph wires?

   Answer:

   Typically twisted pairs are used to maintain externally generated noise as common mode (The same signal waveform on the positive and return wire). Common Mode Noise is often easier to deal with than differential noise. With Common Mode Noise you have the same noise signal on both lines so at the receiver it does not look like signal. Differential Noise looks like signal and can be difficult to remove from the signal.

   Power lines are typically three phase in long transmission lines. In order to keep the noise common mode, I think you would have to twist the three phases with ground. This could cause implementation issues. Someone will also have to twist the wires. They will likely want to be paid for that effort therefore it could be cost prohibitive. I believe the problems would outweigh the benefits, but it may be worth looking into.

2. Which of the 33 Colorado power plants can do a black start? … especially, how about Comanche III?

   Answer:

   I have not done a survey of the Colorado power plants for black start capability.

   Typically small hydro systems should be capable of black or cold start. Larger Hydro and Coal Systems may require emergency generators to black start. Hydro is not difficult to design as black start. In addition Colorado is fortune to have a large number of relatively small hydro plants. This will likely be a huge asset for us if we ever do need black start over a large portion of the state.

   Coal plants are not difficult to design as black start systems. Some may need emergency generators to get started, but it is not difficult to black start. I think most of our coal plants in Colorado support black start.

   Most nuclear plants cannot start without the grid. Some even need the grid to remain safe. Many are now designed with emergency generators to black start. If the grid is gone for an extended time, safety could become a concern.

   Many Solar systems require the grid to regulate the output voltage. So if there is no grid they a not able to provide a regulated output. This can prevent a black start. Storage batteries to allow large scale solar plants to regulate the output are not practical. If it is your only source and the sun goes away, so does the newly established grid. Solar is really not practical for black start.

   Wind turbines are also difficult to design as black start systems. First you need to overcome the inertia of the large turbines. Next the wind is unpredictable which could be difficult for the black start. Wind turbines are not practical for black start.

3. Does an EMP ruin transformers structurally as well as electrically? Does it just burn up the insulation, melt the wire, explode, or what?

   Answer:

Yes, the transformer will likely be structurally damaged. The EMP will likely saturate the core of the transformer. This will distort the electrical waveform as well as the magnetic waveform and can cause the core to heat up. I have actually heard the effect of the magnetic current distortion in a transformer. I think the noise is due to the distorted magnetic current setting up oscillations in the magnetic core.

The current draw can change, the output voltage and current may also change drastically. The losses internal to the device increase which cause excessive heat. The insulation on the windings can melt. The transformer oil that is used to lower internal capacitance and keep the transformer cool can overheat.

There are a number of videos on the internet showing power transformers blowing up or catching fire. It's fun to watch on U-Tube but I'm guessing it would be quite scary in person.

As you might expect, once the degradation starts, the heat form the event just causes acceleration of the destruction.

4. How self-sustaining are our oil fields, natural gas processing plants, natural gas transmission lines?

   Answer:

   This is a good question. I would doubt that the entire supply chain would work without the electric grid. We have all seen oil pumps out in very desolate rural areas. I would guess that electricity is used to run the pump to pump oil from the well, but I am just not certain.

   Let's suppose that the pumps would run without electricity from the grid. The rest of the supply chain uses the electric grid. Tanker trucks run on refined gasoline. That gasoline must be trucked to the gas stations. The gas stations will have no power to pump gasoline to the trucks from the underground tanks.

   If the tankers are modern vehicles with computer systems, those computers may have been disabled by the E1 Pulse. Cell phones used to communicate with drivers use repeaters that are powered by the electrical grid. Radio gear such as CB radios and even cell phones may have been damaged by the E1 Pulse.

   Pipelines for natural gas need pumps to move the gas through the pipeline. This power likely comes from the otherwise very reliable power grid.

5. How self-sustaining are the two Suncor refineries? Will they tell you?

   Answer:

   I am not certain. I have some guesses if you are interested in my uninformed guess.

   I know there is a substantial electric substation right next to the refinery in Commerce City. I suspect this station handles the power needs for the refinery. I would bet that Suncor has some backup power capability for safety critical areas. My guess is that these capabilities would be good for their limited capability for several hours to a few days. That backup capability most likely would not be to produce products.

   These refineries were built to produce product for sale. These are for profit organizations and as such they must produce for the benefit of their stock holders. Costly investment into backup for what has become a very reliable source of energy (the local power company), would not be in the best interest of their stock holders. They would likely not plan for the worst case scenario.

   If the worst does happen and the electrical power grid fails for months or even years, the infrastructure that supports us and Suncor will be devastated. There will be no electricity to pump water. There will be

no electricity to pump fuel. Pipe lines will likely stop since the pumps likely operate on the grid. Trucks to transport fuel may not start. If they do, there will be no electricity to pump fuel into the tankers.

6. Can diesel generators burn Jet-A?

   Answer:

   I'm not a chemical or mechanical engineer, but my guess is no. One could probably convert from diesel to Jet, but I am not certain there is a great benefit. However you generate the power you will need some energy source to do it.

7. How many GPS satellites will an EMP destroy? What's the total?

   Answer:

   There are many unknowns here. The initial blast would only affect those satellites with line of sight. The resulting radiation field could produce long term affects but these would depend upon the orbit of each satellite, the altitude and location of the blast and the design of the weapon.

   These satellites are designed to operate in space, so normal radiation might be of little consequence. Given that the military relies upon these systems around the world, I would expect them to be designed with some level of hardening. How much hardening is probably classified.

8. What is the DoD's criteria for fuel storage in days?

   Answer:

   I don't know and I don't think they will tell you. It may also depend upon the installation. In the worst case scenario, you might have fuel stored but no infrastructure to distribute it to where it is needed.

Notes:

GMD = Global Magnetic Disturbance
HEMP = High Altitude Electrical Discharge
MAD = Mutual Assured Destruction
L-3, White's old company
Most advances civilizations will suffer the most
Test bed is Los Alamos or White Sands
EMPs have been 1859, 1882, 1972, 1989, 2003, 2006, 2012
1962 was an atomic test off Hawaii
1 – 2 meters is wave length of highest energy
The shorter the antenna, the less energy.

*Significant electromagnetic pulse (EMP) threats occur when: *

*1.A nuclear weapon is detonated *
*2.An extreme solar storm occurs *
*3.A non-nuclear EMP (Radio Frequency) weapon is used *

*Three major types of nuclear EMP *

*1.Source Region EMP (SREMP) - observed since our first nuclear test *

*•Mainly a problem with surface detonations *

*•Can disrupt power and communications throughout an entire city/region *

*•Physics are well understood/modeled, but effects are widely misunderstood *

*2.High Altitude EMP (HEMP) – from balloon or missile nuclear burst *

*•1 burst can disrupt U.S. power/communications over many states or continent *
*•May take months or years to repair damage *
*•Controversy over strength of electric fields *

*3.System Generated EMP (SGEMP) *

•Disrupts/damages satellites