The Nuclear Threat Today

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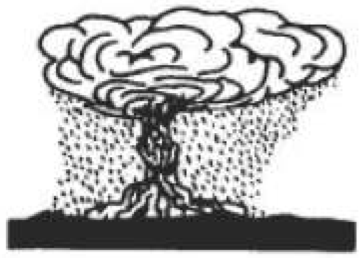

Section 7: Monitoring Fallout

As mentioned in preceding sections, fallout is created during a surface burst when the fireball from the warhead's detonation comes into contact with the earth's surface. Inside the fireball is where radiation is most intense. Neutron radiation within the fireball can actually radiate (cause non-radioactive materials to acquire enough energy from neutrons or captured neutrons to become radioactive) material on the surface. The materials on the surface that are radiated are dirt, concrete and glass from buildings, ash from wood structures and human bodies and dirt from the ground. Actually, this is any material within the intense initial radiation discharge of the fireball. Neutron radiation will not travel much farther than the expanse of the fireball.

The detonation of the warhead also results in the vaporization of tens of pounds of plutonium and/or uranium. These vaporized isotopes are absorbed into cooling particulates, which used to be materials on the ground. Buildings, earth and living beings on the ground are burned into ash and pounded into small particles by the weapon's initial effects. These particulates are super heated inside the fireball where neutron bombardment occurs. Due to superheating, the particulates rise from the ground in an updraft that forms the stem of a mushroom cloud. This is called the popcorn effect. So called because particulates are super heated to the point that they loose all moisture and seem to jump into the atmosphere. As these particulates rise in the updraft, they gradually cool. As they cool, they begin to absorb gasses present in the cloud. The cloud begins to cool and spread out, forming the classic mushroom shape.

Some of the gasses present in the cloud are the vaporized plutonium and/or uranium. Many of these are absorbed into the particulates and add to the radioactivity. As the cloud cools, it spreads out and is carried downwind. The particulates drift back down to the earth across the area the cloud is carried by the wind. These particulates are highly radioactive and known as fallout. Much of the column of smoke and particulates making the stem of the mushroom cloud will collapse after cooling. This will bring heavy fallout to the local area and areas close by that are downwind. The farther an area is away from ground zero, the less fallout will be experienced. Also, areas that are perpendicular to wind direction to ground zero will experience far less fallout.

Because fallout is highly radioactive, it releases it's energy very rapidly. Radiation levels start out extremely high during the first hours after detonation. Gamma and X radiations are intense, but this means that the high rate of energy loss will diminish quickly. Fallout undergoes one half life approximately every two hours. This means that the radiation emitted by a particle of fallout will diminish by one half it's level every two hours. An intense deposit radiating five hundred roentgens per hour will diminish to two hundred and fifty roentgens per hour within a two hour time span. Two hours after this, radiation levels will have diminished to one hundred and twenty five roentgens per hour. Radiation levels will continue to diminish by one half every two hours for many years, but radiation levels begin to diminish to safe levels after three weeks, assuming no further strikes deposit fresh fallout.

Most areas within the several States will experience fallout in a strategic exchange, but if a few weapons are detonated during a ‘terrorist’ incident, only areas downwind of the detonations will experience fallout of an immediate hazard. This will provide safe areas to evacuate to, however, tensions will be high after internal terrorist strikes and a nuclear war may proceed in the aftermath. See section 1 for details on this threat.

Preceding sections have detailed shielding a structure to shelter against the threat of radiation. You will now need to monitor radiation levels efficiently to maintain the safety of shelter occupants. You must first have the means to measure radiation levels. Ionizing radiation is the most common form of radiation released in a nuclear event and aside from neutron radiation it poses the greatest threat due to it's penetrating ability. Ionizing radiation gets it's name from the effect it has on the environment. When ionizing radiation interacts with molecules of gasses in the atmosphere, it imparts some of it's energy into electrons within the molecule's atoms. The electrons absorb enough energy from the radiation to break free from their orbit. This turns the atom into an ion, an atom devoid of one or more electrons and having a positive charge. This also causes the atmosphere to have a mild electrical charge.

Fortunately, this effect allows us to measure the amount of ionizing radiation in the immediate environment. Expedient fallout meters like the Kearny Fallout Meter (KFM) or manufactured units like the CDV-715 measures the electrical charge in the atmosphere and calculates the amount of radiation being encountered in the immediate vicinity. I strongly suggest purchasing a surplus fallout meter that has been professionally calibrated. Calibrated and functioning Civil Defense survey meters can be purchased from www.radmeters4u.com. If you do not have the money for one of these units, get yourself a copy of Cresson Kearny's *Nuclear War Survival Skills* and obtain the supplies to build a KFM or even purchase all of the materials for a KFM below $20 at Ready Reserve Foods. You must have a radiation meter in working condition before the arrival of fallout and hopefully before the arrival of a crisis.

Tom from New England recommends a Russian unit called the RKCB-104. Purchased from www.excaliburmineral.com/equipment.htm, these units work as low level radiation monitors, so should probably be used only in your shelter. This unit also doubles as a dosimeter and will help you calculate your accumulated doses. I’ll be testing this unit myself sometime this summer.

You will need at least one meter. Two or more are better as they will confirm the readings from each of the meters. It is very important to gain accurate radiation readings to gauge the danger to your group. You will also want a backup if one unit should happen to fail. Two meters may confirm a correct reading if another meter has failed and giving a false reading. If you have only two meters and they are giving different readings, the meter whose readings are varying wildly is the malfunctioning meter, while the meter giving a more steady reading is the functioning meter. If you have only one meter and it’s readings are varying wildly, you may not be getting accurate readings. You’ll need to keep your meter operating for half an hour to an hour for the circuit to warm up. If the meter begins giving a steady reading after this, your trouble may have just been a cold circuit, but without another meter, you may not know if the readings are accurate. Since a KFM is so cheap, there is no excuse for not having a backup. If your KFM is not assembled and functioning, you should begin assembling the KFM immediately after sealing yourself into your shelter.

You will need to assign someone to monitor the radiation meters constantly. This person will be the radiation monitor and will be responsible for taking readings, keeping records of dose rates, estimating future radiation levels, estimating outside radiation levels, finding the protection factor of the shelter, estimating future dose rates, keeping the radiation logs, converting readings and maintaining safe exposure practices. The radiation monitor should have basic math skills and write legibly. An assistant should also be assigned which will learn to accomplish all of the tasks of the radiation monitor and take on his/her duties while the radiation monitor sleeps or should he/she become incapacitated.

Radiation readings are logged into a radiation log book. The log book should contain The date, time, the reading inside the shelter, the reading outside the shelter, the dose rates inside and outside the shelter and space for notes. Below is a good example of an entry.

Date	Time	Reading Inside	Reading Outside	Dose Inside	Dose Outside	Notes
8/29/1997 H+2hours	2:00PM	1R/hour	500R/hour	0 RAD	0 RAD	Shelter
H+3hours	3:00PM	.75R/hour	375R/hour	1.14 RAD	570 RAD	PF=500
H+4hours	4:00PM	.5R/hour	250R/hour	1.995RAD	997.5RAD	

The date and time entries are very important for calculating dose rates. H in the date entry refers to H hour or the time of weapon detonation. H+2hours is the first entry for the time fallout first arrives. This is two hours after H hour. By 2:00 PM in the time entry enough fallout to radiate at 500 roentgens per hour is deposited. Before this hour no fallout was present, so zero RADs of accumulated dose is recorded. You have divided the recorded reading of outside radiation levels by the recorded inside readings of radiation levels to arrive at your shelter's PF or protection factor. From now on, all outside radiation levels may be estimated by multiplying inside levels by the shelter's PF. This will protect occupants from the hazard of exiting the shelter to take readings.

At H+3 hours you can see that radiation levels are beginning to decay. The inside reading has fallen to .75 roentgens per hour and the outside reading will have dropped to 375 roentgens per hour. Your estimated dose inside your shelter will be based on the previous hour's reading. This will give you a high estimate, but will also force you to act more safely. Dose rates are calculated in RADs. A RAD is a (R)oentgen (A)bsorbed (D)ose. This estimates the amount of biological damage done to your body by absorbing radiation. Any amount of radiation you absorb will become part of your accumulated dose. This accumulated dose will add up as you can see by the example above. While radiation levels continue to drop, the doses for inside and outside the shelter continues to rise. Again the dose rate is based on the previous hour's radiation reading. This is converted to RADs and added to the previous dose to provide the accumulated dose.

Because radiation is measured in different units, it will be necessary to convert those units in order to convert to RADs and to know the correct radiation levels reported in other areas in respect to the unit of measurement you are measuring radiation in. There are several different units you will need to be familiar with. These are the Roentgen, RAD, REM, Gray and Sievert.

Since most equipment used by Americans will use the roentgen (R) as the unit of measure, we'll base other units as comparative to the roentgen. Because of it's ionizing ability, Gamma and X radiations create an electrical charge in the atmosphere. This electrical charge is measured in coulombs and calculated to read as roentgens. One coulomb is the amount of electrical charge carried in a current of 1 Ampere maintained for 1 second. This charge is measured in a cubic kilogram of air. A roentgen is the measurement of enough ionizing radiation to create 1 electrostatic unit charge in this kilogram of air which converts to 1 electrostatic unit of charge = 2.58 X ^10-4 coulombs = 1R. The charging chamber of a fallout meter will calculate the electrostatic unit charge and convert the reading into roentgens on it's readout.

Despite the small electrical charge this ionization produces in air, the penetrating ability of ionizing radiation and it's effect on living tissue makes this very dangerous. To equate the measurement of roentgens to damage accumulated in living tissues, scientists have established two units of measure to consider this.

The RAD as mentioned above is the Roentgen Absorbed Dose. It measures the accumulated dose of roentgens to living tissue. The roentgen is measured by the electrostatic charge it produces by bumping into electrons in the air. Your body is much more dense than the air and ionizing radiation will impart more energy into your living tissues than empty air. For this reason you must record your accumulated dose in RADs rather than roentgens as RADs reflects more correctly the amount of damage inflicted to your body by that accumulated dose. The energy imparted into your body is on the order of fourteen percent above that of empty air, therefore a very simple formula for converting roentgens into RADs can be used for conversion. Take your reading in roentgens (R) and multiply by 1.14. (R X 1.14=RADs.)

In the example log you will notice that the inside and outside doses always accumulate. To estimate your dose, use your reading in roentgens from the previous hour (R) and multiply by 1.14. The first inside dose reading was based on 1R per hour. This gives us a dose of 1.14 RAD. During the second hour radioactive decay gave us a reading of .75R per hour. Applying the formula R X 1.14=RAD we have a RAD reading of .855 RAD. This latest dose must be added to the previous dose of 1.14 RAD to give us an up to date accumulated dose of 1.995 (1.14+.855) RAD. You must add your accumulated doses every hour in this manner for reasons we will explain in a few paragraphs.

Another unit of measurement is the REM. A REM is a (R)oentgen (E)quivalent (M)ammal. The REM also measures the amount of damage done to body tissues by radiation. The REM differs from the RAD in that it uses a qualifier to gauge each type of radiation's effect on living tissue. This qualifier (Q) is then multiplied by the dose in RAD to arrive at the dose in REM. Fortunately, the Q for ionizing radiation is 1 making a REM measurement of Gamma and X radiation the same as the RAD measurement. (RAD X Q=REM). For all intents and purposes, a REM reported from other areas is the same as a RAD.

A REM varies from a RAD when Q is not valued at 1. Radiation forms exist that do give a different value for Q. The value for Q when the radiation present is in the form of alpha particles is 20. If your Geiger counter or RKCB-104 unit gives you a reading of .5R/hr near a radiation source giving off alpha particles you would convert your reading to RAD giving you .57. You would then multiply this by the REM Qualifier (Q) in this case Q=20 for alpha particles giving you a REM reading of 11.4. Other factors where Q differs from 1 is in the presence of neutron radiation which also varies with the energy of the neutron particle. Neutron particle energy is measured in Milli-electron Volts (MeV) or Kili-electron Volts (KeV). Neutrons with an energy of less than 10KeV has a Q of 5. Neutrons with an energy between 10 and 100KeV has a Q of 10. For neutrons between 100KeV and 2MeV Q=20. Because energy for neutrons equals speed you will have a spike in the graph where neutrons of a greater energy will actually decrease the value for Q. This is because neutrons of such energy may zip through your body without completely "thermalizing" or being captured. Though these neutrons will still impart some of their energy into your body, so Q is still greater than 1. Neutrons with an energy between 2MeV and 20MeV will have a Q of 10. Neutrons greater than 20MeV posses a Q of 5. Beta particles are high speed electrons and can damage uncovered skin and internal organs if ingested. Beta particles have a Q of 1.

Where the Q for calculating REM is greater than 1, you should note this in your log and use the reading from REM as your accumulated dose. Because damage to your body by any radiation is accumulative the dose must be added to previous doses. Notes must be made when you add a dose from a REM rating that is greater than it's RAD equivalent. By adding a REM dose to your accumulated dose you will more accurately gauge the damage done to your body and give greater caution to working safer in a radiated environment.

The Gray is the Standard International (SI) equivalent of the RAD. The Gray (Gy) is easily converted to the RAD and Roentgen. One Gray is the equivalent to 100 RADs. If you have a unit such as the Gamma Scout which measures radiation in Grays, you may need to convert to RADs and Roentgens to compare readings from reports of other areas or if you are using a KFM or other unit which gives reading in roentgens you may have to convert roentgens to Grays. Not to mention FEMA will report radiation levels using Grays and how will you know how that relates to your readings without converting?

Grays are divided into units like the centiGray (cGy). This is one, one hundredth of a Gray. Since one Gray is 100 RADs, one cGy would equal one RAD. That was an easy conversion to RAD, now you may have to convert to roentgens. Remember that a RAD is expressed as the energy of a roentgen plus 14 percent the roentgen's energy. That is arrived at R X 1.14=RAD. With this knowledge, we can reverse the process and take that 14 percent of energy away from the RAD reading to give us the roentgen reading. This is done with the formula RAD/1.14=R. Convert your cGy to RAD. 2 cGy=2 RAD. Now divide by 1.14 to arrive at 1.755 roentgens. Now you can convert RAD to roentgen and Gray to roentgen. To convert roentgen to Gray, first use the formula to convert roentgen to RAD. Once you have your RAD it will the same as a cGy.

The Seivert (Sv) is the SI unit based on the REM. Like the Gy=100 RAD, the Sv=100 REM. Again, 1centiSeivert (cSv) =1 REM Just as 1cGy=1 RAD. Conversions here are easy as well, as long as you know what form of radiation is being monitored. Most radiation in the aftermath of a nuclear detonation will be emitted by fallout, which will mostly take the form of gamma radiation. Remember, to arrive at the reading for REM the qualifier Q is necessary. Q is a variable based on the type of radiation being measured. If reports are not qualified as to ionizing radiation, alpha particles or beta particles, Q will remain unknown and a conversion will not be possible. However, unless otherwise instructed, it would probably be safe to assume that the radiation being measured is gamma radiation. In this case, Q will equal 1 and the reading in cSv will equal the reading in RAD.

Should you wish to convert a cSv reading to roentgens where Q does not equal 1, the formula is (cSv/Q)/1.14=R. An example of the need to convert Sv to R could present itself in a terrorist incident. For example, should terrorists acquire a quantity of pulonium-210 which is an alpha emitter and the terrorists build a dispersal bomb. This bomb is set off at a mall. Reports of the situation are given over the news with radiation readings of about 1Sv/hour. You know that pulonium-210 is an alpha emitter with a known qualifier of 20. Further, your daughter is close to this area visiting a friend and you decide the situation warrants that you must pick her up and drive to a safe area due to the possibility of further terrorist incidents. You have a Geiger counter that gives readings in roentgens and will rely on that to warn you of radiation fields as you pass close to the area. At what reading in roentgens can you expect to encounter the high readings of 1Sv if you should encounter the most dangerous areas? One Seivert is the equivalent of 100cSv or 100RAD, so in this case, the formula given above will translate as (100/20)/1.14=4.39R. Should you encounter a reading of 4.39 roentgens per hour from your Geiger counter, you have encountered an alpha emitter source of 1Sv/hour.

The above may also be useful if terrorists were to disperse radiological materials including alpha emitters by aircraft or car over an urban or suburban area. You can also convert your roentgen reading to RAD and multiply by Q to arrive at a reading in REM or Sv. Because alpha and beta particles lack in their ability to penetrate, if you have sealed your shelter well and filter your air, alpha and beta particles will not be present inside and they will not register on your meter or Geiger counter in the shelter. As mentioned, most radiation reports after a nuclear incident will concern ionizing radiation. Other forms of radiation with the exception of neutron radiation will be easily shielded against. We will discuss neutron radiation in a future section.

The ability to jot down the figures and convert radiation readings has a purpose. These figures will tell you about your survival and your future prospects to survive through the crisis. To tell you how you and your group are doing, researchers have calculated the damage these figures means to human and livestock bodies. Your accumulated dose, measured in RADs will be compared to what is referred to as the LD-50. LD stands for Lethal Dose. 50 stands for 50%. The figure means that 50% of those with a set accumulated dose within a month will die from the exposure. For human beings, this set accumulated dose is 400 RADs. The LD-50 is an accumulated dose for a one month figure.

You will see in the example entry log and the paragraphs above how to calculate and log an accumulated dose for inside and outside the shelter. This will give you an overall estimate of general dose rates for your group in the shelter and for anyone who might be exposed on the surface. This is good for a general estimation of safety hazards, but lacks for individual dose rates. To change air filters or make repairs inside or outside your shelter, individuals may have to exit the shelter or hardened areas for a time. This will result in varying dose rates for each occupant of the shelter. Each individual will need a separate sheet for accumulated doses.

The sheet for each individual will have each individual's name, hourly dose rates and special dose rates with notes. An example of this would follow:

John Doe

Date	Time	Dose	Spec. REM Dose	Notes
8/29/1997 H+2hours	2:00PM	0RAD	0	
H+3	3:00PM	1.14 RAD	0	
H+4	4:00PM	1.995 RAD	0	5 min. outside to replace
H+5	5:00PM	26.315 RAD	0	filter.

John Doe has just received an alarming accumulated dose because the air filter needed to be replaced which is why you should protect the open end of the filter with a larger protective box as described in section 5. Until John needed to exit the shelter, he was absorbing the same dose rate as everyone else inside. Once outside at 4:00PM, he was absorbing 285RADs per hour. This must be logged on his personal sheet. The formula to calculate John's true accumulate dose reading is simple. Take RAD per hour (RADhr) and divide by 60 to arrive at RADs per minute (RADmn) (RADhr/60=RADmn). Multiply RADmn by how many minutes John spent outside (Tm) to arrive at the accumulated dose of John's excursion outside (ADE). RADmn x Tm=ADE.

In John's case RADhr=285. 285/60=4.75RADmn. John spent 5 minutes outside (Tm), so 4.75 x 5=23.75 ADE. This is added to his inside hourly dose for the next hour as shown in John's sample sheet. John has a 5 minute accumulated dose of 23.75 RADs. His hourly inside rate from 4:00PM to 5:00PM was 2.565 RADs calculated from previous doses and the radiation decay rate of .57 RAD inside reading (1.995+.57=2.565). Add this inside dose to John's outside dose of 23.75 to arrive at his hourly accumulated dose of 26.315RADs. John must not exit the shelter again for the remainder of the crisis.

In John's case, calculation was easy because he wore protective clothing and an NBC rated mask before exiting the shelter. This means that he did not encounter alpha particles which are extremely limited in their penetrating ability. No special REM dose was necessary to calculate John's overall dose. In the scenario where you are able to seal up in a shelter, REM doses will be unnecessary to calculate, but in the case where our father must drive through an area contaminated with alpha emitters to rescue his daughter, you will need to calculate this dose. Merely convert your hourly REM dose (REMhr) to REMs per minute (REMmn). This is done in the same way as RADhr is converted to RADmn. The formula is the same, it is REMhr/60=REMmn. After that find your dose by REMmn x Tm. This will give you your ADE in REMs. Add your REM dose to your regular dose, but mark the REM dose separately under the special REM dose column and make a note under the notes column. An example might be as follows:

Dad

Date	Time	Dose	Spec. REM Dose	Notes
5/19/2007 H hour	5:00PM	25.04 REM	25.04 REM	4.39Rhr/60=.0732Rmn 15mn drive through area 1.098R ADE=1.252RAD alpha emitter Q=20 1.252RAD x Q=25.04REM

In this case, the dispersal bomb was not followed up with a device which could create fallout and therefore no ionizing radiation. If this had occurred, RAD doses would have been added to the REM dose under the dose column and marked as RAD. The one reading under REM and the notes would denote the difference in radiation forms, but the damage to the body created by the REM dose is real and needs to be added to the accumulated dose.

You can see by the example above, the father drove into a contaminated area registering 4.39R on the Geiger counter, spent 15 minutes driving through a contaminated area to rescue his daughter and accumulated 25.04 REMs from alpha particle radiation.

As mentioned, these figures add up and denote real damage to living bodies. To correlate the accumulating dose figures in RADs to the LD-50 dose rates mentioned in preceding paragraphs follow the LD-50 chart for the following species.

Table of LD-50 for animals and humans dose rate estimated at 30 days

animal	LD-50
humans	400 RADs
Dogs, pigs	300 RADs
Goats	350 RADs
sheep	540 RADs
cattle, horses	630 RADs
rabbits	800 RADs
chickens	1000 RADs
turtles	15000 RADs

Fifty percent of animals listed that receive an accumulated dose of RADs listed for their species in a thirty day period will die from the exposure. That is for healthy animals and humans in their prime. Elderly, infant and sick humans and animals will be effected worse and a higher percent of those will die from the exposure.

Because you now know the accumulated dose that you can receive, you will know if your shelter will provide you with enough protection to keep you safe for the duration of the crisis. Because radiation from fallout decays at a constant rate, you can estimate the accumulated dose you will receive within any set period of time.

An estimated dose rate and radiation count should be begun by the radiological monitor immediately upon logging current radiation counts after sealing the shelter and getting a true shelter PF. Logs for estimated dose rates may be logged in two hour intervals for ease of estimation. Radiation from fallout's half life is every two hours. Just divide the previous two hour's reading by 2 to arrive at the estimated reading for the next half life. To estimate an hourly rate divide the next two hour's reading by 2, then subtract this sum by the previous reading. Example: previous reading=500R/hr. 500/2=250. 250/2=125. 500-125=375. The next hour's reading will be 375R/hr. This example is from the outside reading, but may be applied to the inside reading as well. Convert roentgen readings into RADs and add to accumulated doses as demonstrated in previous paragraphs.

If for convenience you are estimating accumulated doses in RADs for every two hours, convert your reading from roentgen to RAD and multiply the reading by two. This will give you a slightly lower dose rate, but you can correct for the estimated readings when you log the actual readings. Example of estimated two hour reading: Inside reading in roentgen at H+10=.03125R/hr.
.03125 x 1.14=.035625 RAD. .035625 x 2=.07125 RAD over the next two hours. Add .07125 to the previous accumulated dose RAD reading from H+8 and you will have your estimated accumulated dose for the next two hours.

Using a chart for the decay rate of every two hours, if John Doe does not exit the shelter again, he will accumulate an estimated dose of 26.707 RADs in 24 hours. A dose of 30 RADs in 24 hours can cause a healthy human in his/her prime to become ill. If John is healthy, he is just under this dose, but not all people will react to exposure in the same way. This dose is close enough to be a concern and John should be monitored throughout the crisis should he become ill. Also John should not exit the shelter again until radiation levels have greatly diminished to non-crisis levels.

You must keep the accumulated doses of all occupants well below the LD-50 from the chart above. A radiation monitor's ability to calculate, measure, convert and log radiological readings will alert the group/family to danger and give them the opportunity to take actions to lessen or negate the dangers.

You will need to estimate accumulated doses for at least several days in advance and hopefully for a month in advance. Estimated accumulated doses should be well below the LD-50s. The occupants of a shelter should receive not over 100 RADs in a one month period of the crisis. This dose can make some people sick. It is the monitor's job to alert the group should estimated doses become dangerous. Should that become the case, evacuation of your area will become necessary.

The above examples were given as simple scenarios for ease of learning. In reality fallout will not be deposited at full strength within several minutes to give sudden hourly readings. Readings will start small and rise steadily for up to hours before leveling off to full strength. You will need to take readings for every 15 minutes at the minimum to monitor the deposit of fallout, but it probably won't be necessary to log doses at the minimum time interval readings. Logging doses for hourly accumulations will serve well enough.

Do not assume that a single fallout deposit is all that will be collected in your vicinity. Even if the detonation is reported to be a single terrorist incident, later terrorist weapons may be detonated in various targets or a limited to full scale war may result. This could result in further fallout being deposited in your area that will change your estimates. Should this occur calculate new estimates from the newer radiation readings. Should those new estimates become dangerous, you'll need to alter or make new plans for survival.