Nuclear Power on the Battlefield (Ukraine)

Russian Invasion of Ukraine

February 24 2022

*Slide show presented by webinar**
February 26 2022

Gordon Edwards, Ph.D., President,
Canadian Coalition for Nuclear Responsibility

e-mail: ccnr@web.ca

www.ccnr.org

*webinar hosted by Dianuke, recording at https://www.youtube.com/watch?v=CM0FR4Eacmw

THE NATURE OF THE HAZARD

A nuclear power reactor is not just a machine for making electricity, it is also a warehouse of radioactive poisons – hundreds of varieties, created as a result of the fission process. Most of them were never found in nature before the discovery of nuclear fission in 1939.

Any event that causes the release of a substantial fraction of this inventory of poisonous materials can be catastrophic, leading to radiation exposures to millions of people and contamination that lasts for centuries – even millennia, in some cases.

Units 1 to 4 of Fukushima Daiichi Nuclear Power Station − before earthquake

. . . but the reactors looked exactly the same after the earthquake and tsunami

hydrogen gas explosions occur in the days following the earthquake and tsunami

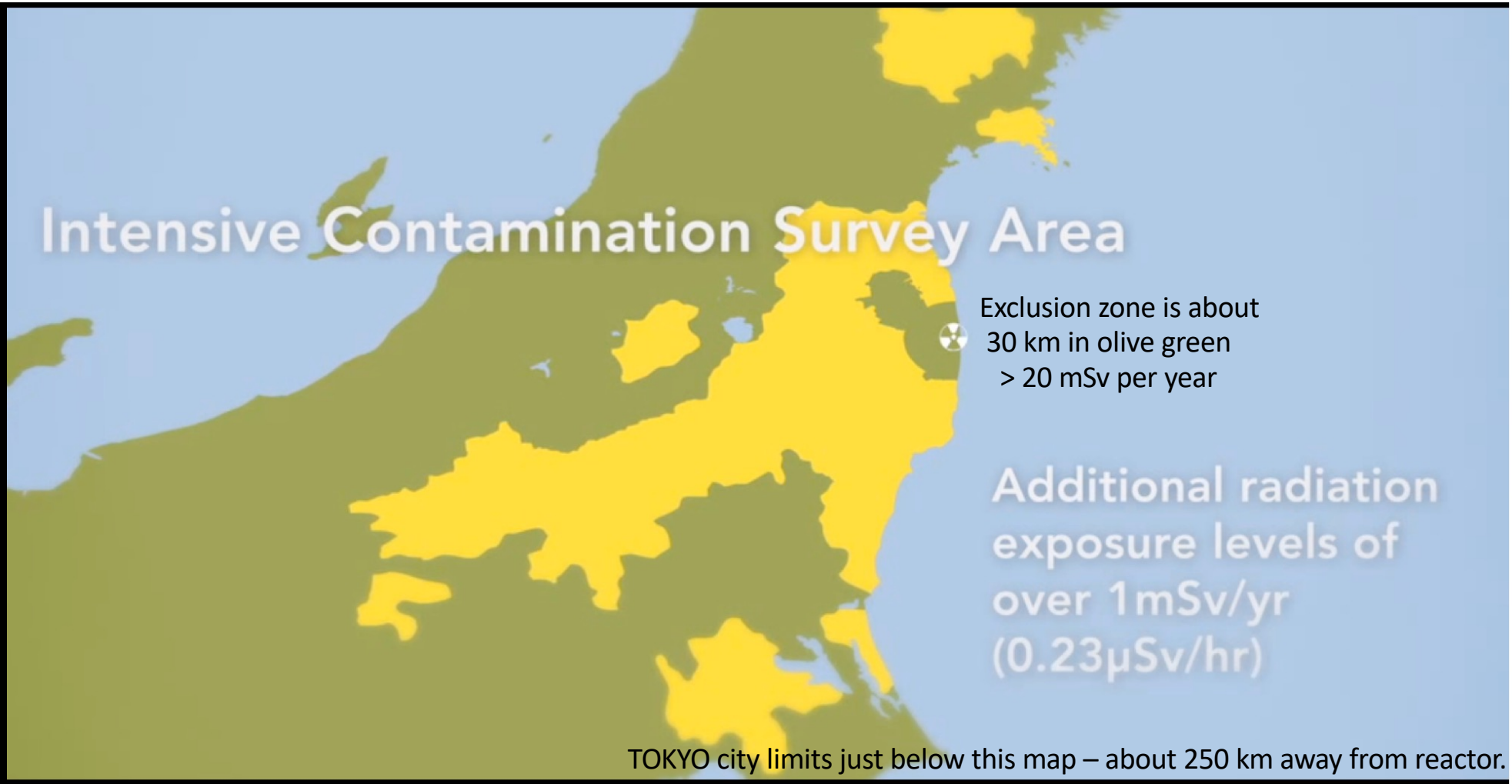
radioactive fission products carried by steam and smoke are spread abroad

FUKUSHIMA TRIPLE MELTDOwN

Radioactive heat led to hydrogen gas explosions, three core meltdowns and four demolished reactor buildings.
Without cooling*, the radioactive heat drives temperatures up to 2800 degrees Celsius.*

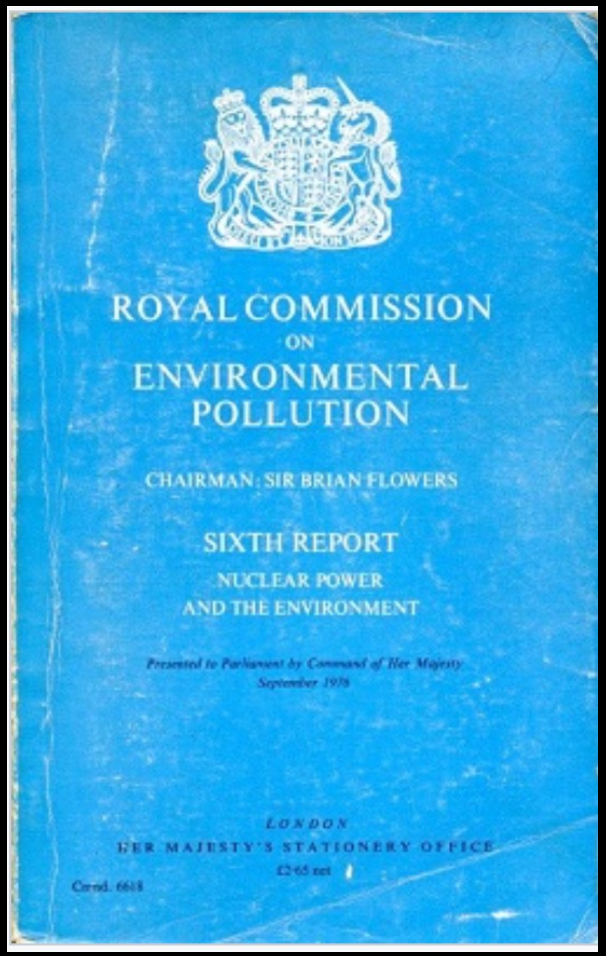
IAEA approves plan to dump more than one million tonnes of contaminated water into the ocean

Enormous inventory of radioactive materials remains in 4 pools + cores of units 1-3



Exclusion zone - radiation dose rate over 20 millisieverts per year; yellow zones - annual doses more than 1 millisievert.

1 millisievert per year is the maximum allowed for a member of the public in Canada



THE FLOWERS REPORT – 1976

Nuclear physicist Sir Brian Flowers chaired the UK Royal Commission of Inquiry into Nuclear Power and the Environment.

He wrote that if nuclear power had been widely deployed in Europe before WWII, large parts of Europe would be uninhabitable today, BECAUSE of WWII – since nuclear plants would surely have been targeted.

Statute of the International Atomic Energy Agency

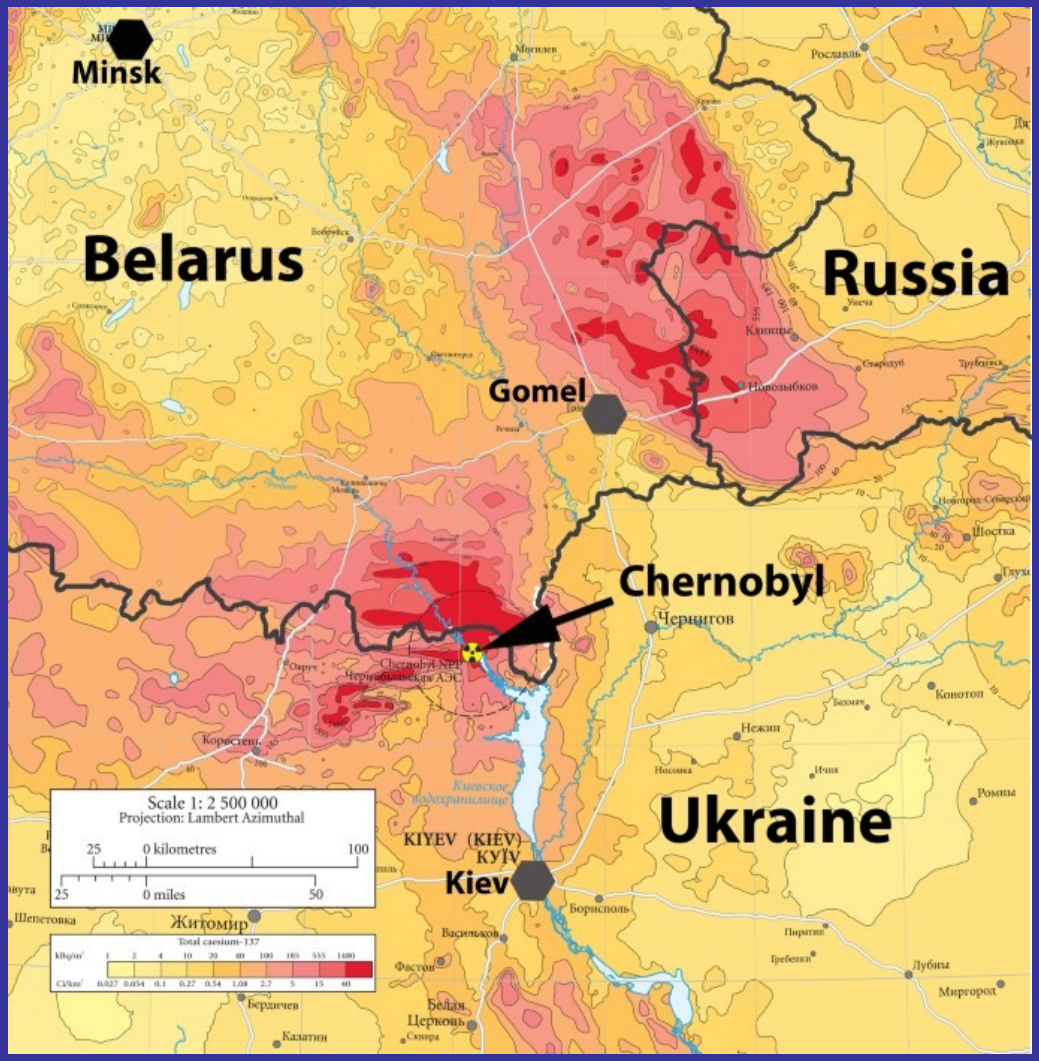
ARTICLE II: Objectives

The Agency shall seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world. It shall ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.

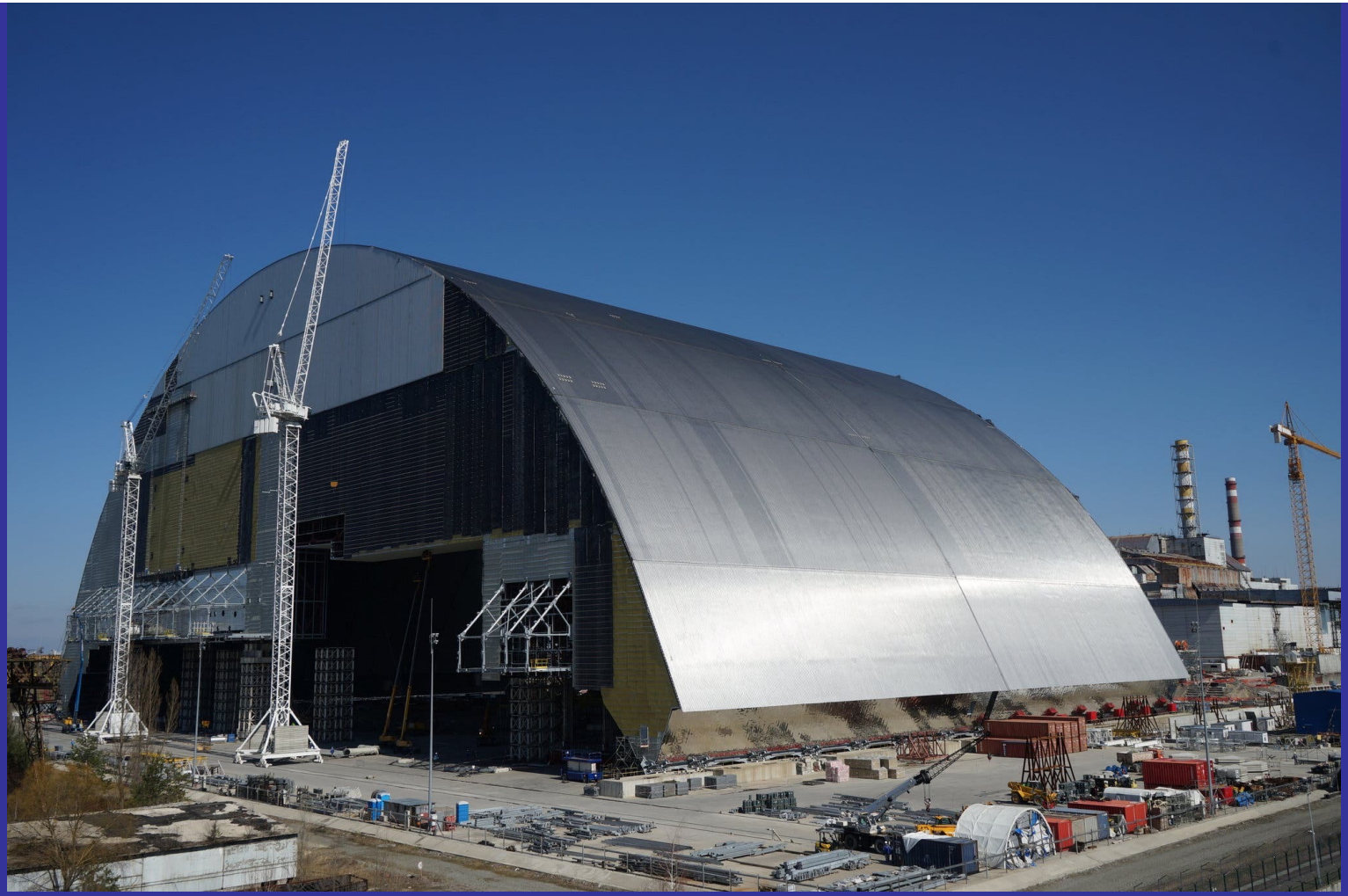
CONTROVERSIAL:
Agreement between IAEA and WHO of 1959 . . .
impossible for Health Organization to act alone

AND NOW TO THE UKRAINE

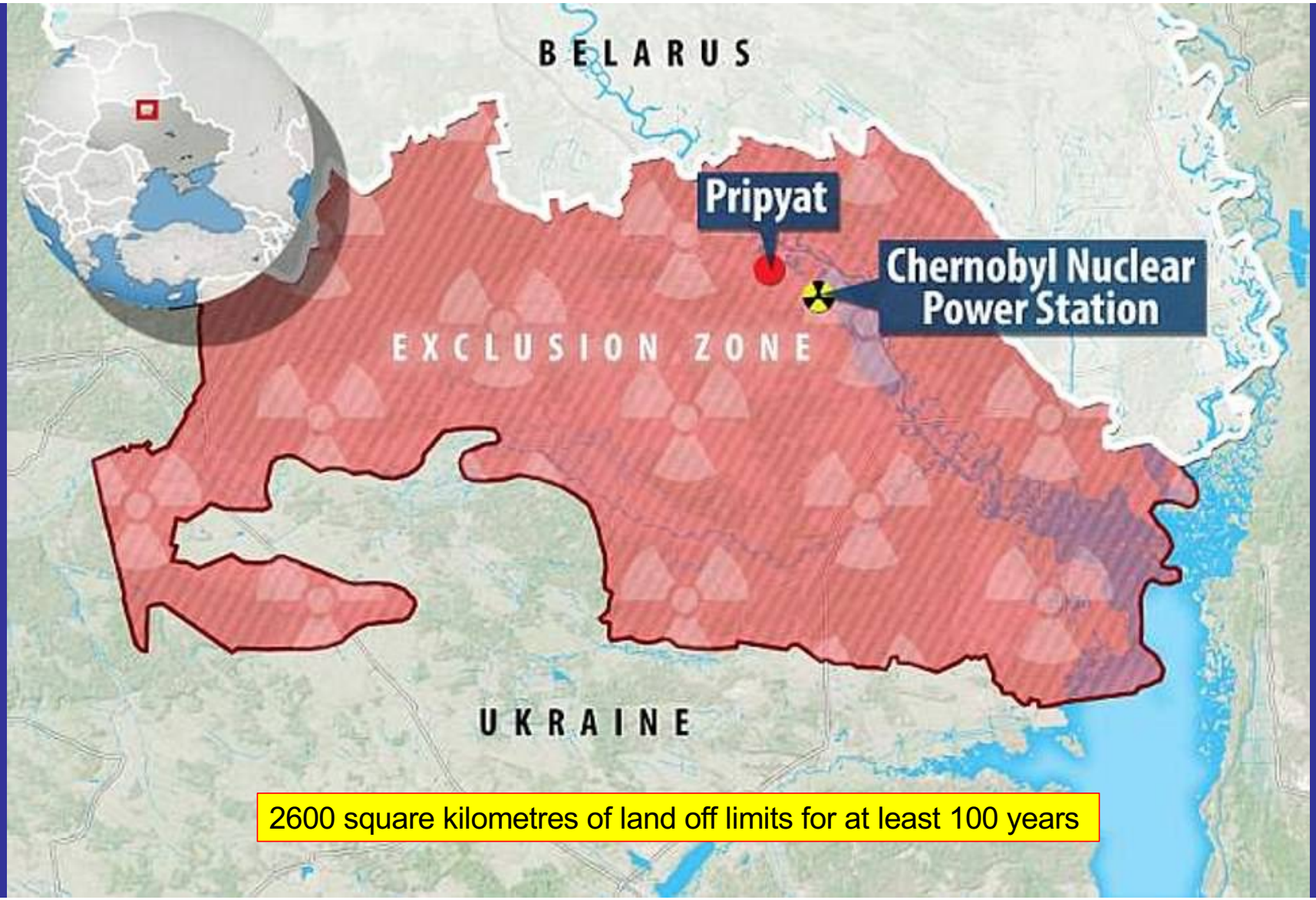
The remains of the Chornobyl reactor that exploded and melted down in 1986;
explosion caused in part by "positive void coefficient", a feature of all CANDUs



Ground contamination in Russia, Ukraine and Belarus



“Confinement” shelter for the crippled Chornobyl reactor installed in 2016 at a cost of US $2.3 billion

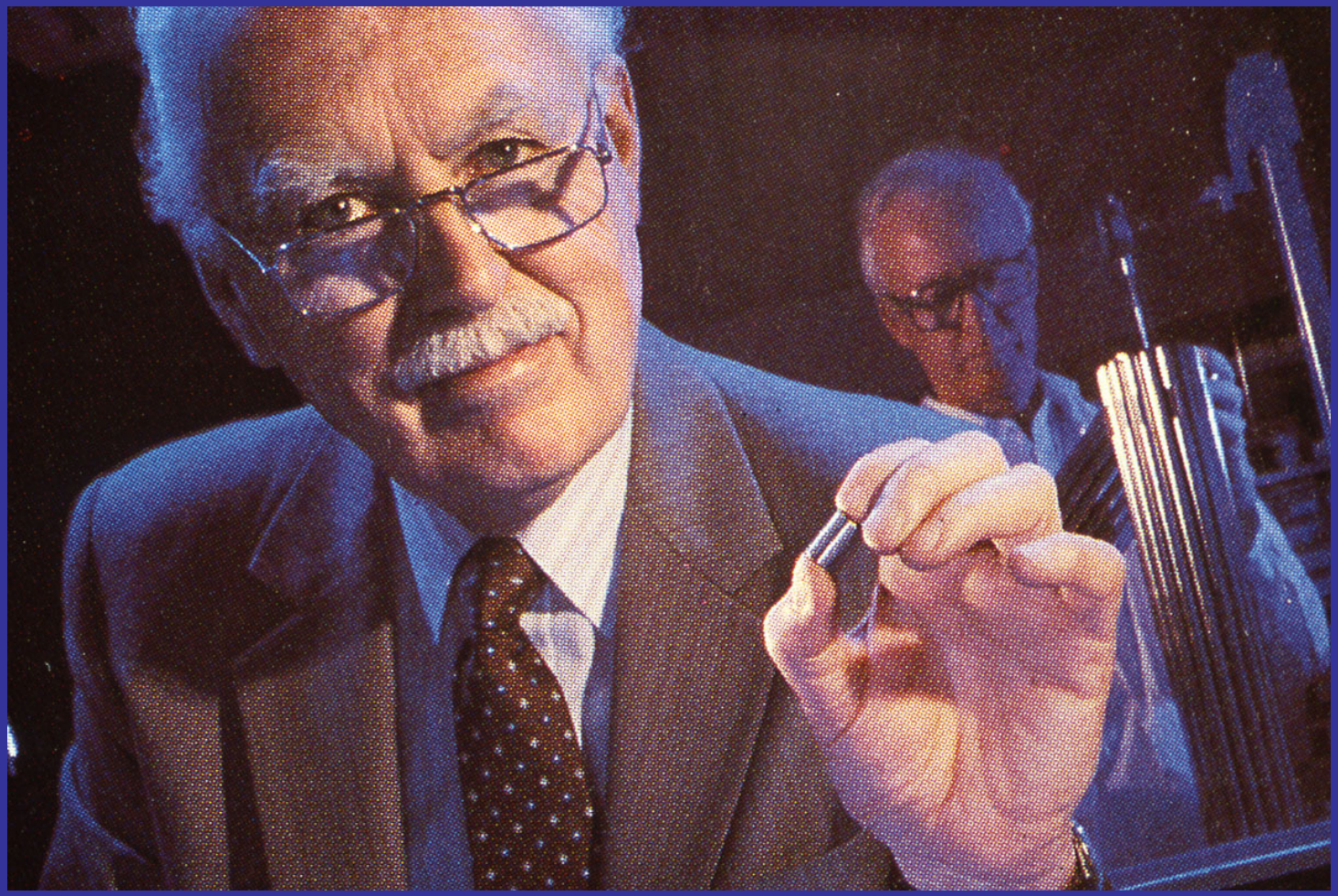

BELARUS
Pripyat
Chernobyl Nuclear Power Station
EXCLUSION ZONE
UKRAINE
2600 square kilometres of land off limits for at least 100 years

CONCERNS AT CHORNOBYL

Because the fuel stored in onsite pools is at least 22 years old (the last of the four reactors was shut down in the year 2000) heat is generated slowly. But weaponry, especially incendiary devices, could expel the water and ignite a raging zirconium fire leading to massive radioactive releases.

If the stored fuel assemblies are crushed or distorted, an accidental chain reaction ("criticality") in the pool could perhaps start, triggering explosions and radioactive releases.

Soil in the exclusion zone is heavily contaminated with radio-active cesium, strontium and plutonium. Much of it is too close to the surface, ready to be resuspended by churning up the soil or triggering a wildfire in the highly flammable peat-like marsh.

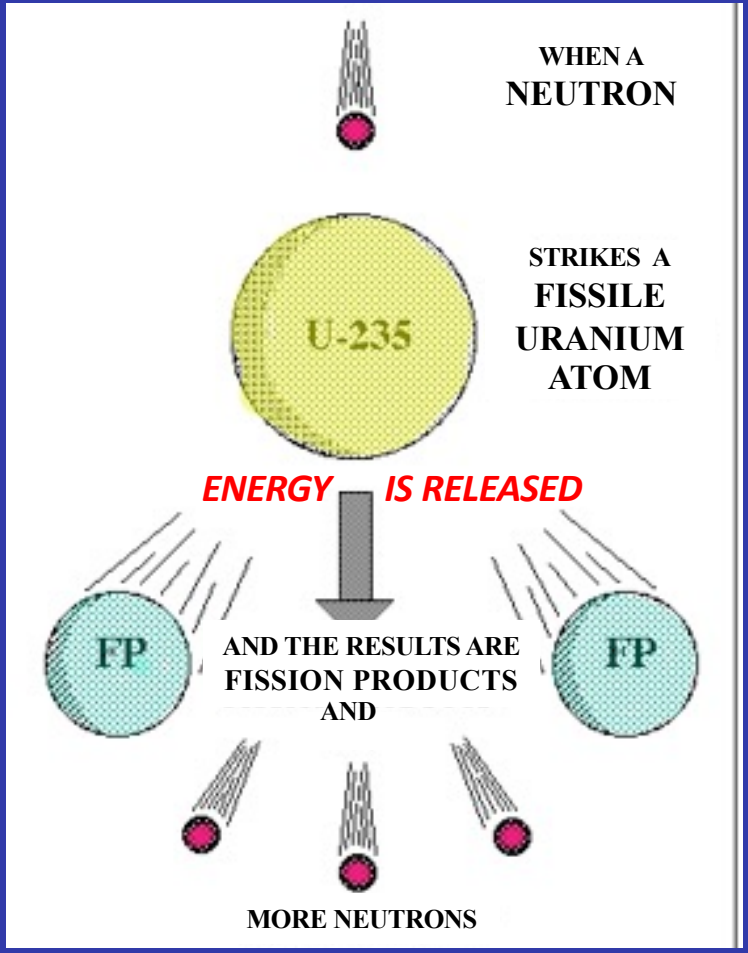


Canadian Nuclear Association advertisement: “Small Wonder”

Advantage: one uranium pellet has as much energy as a carload of coal - with no direct CO_2 emissions
Disadvantage: after using it you have to keep your eye on that pellet for the next ten million years

Nuclear Chain Reaction

The neutron is like the "magic wand" that makes things happen . . .

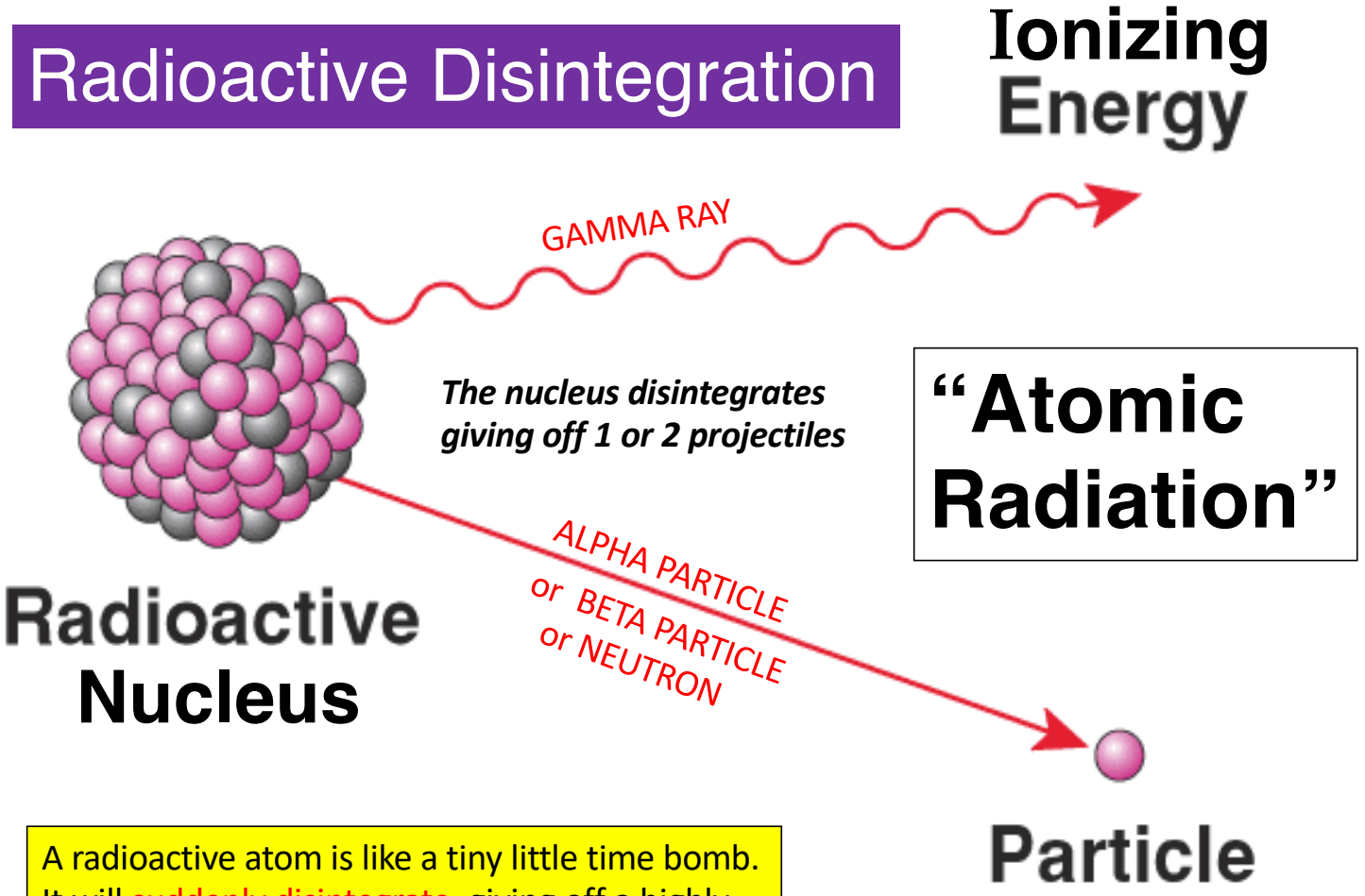


U-235 is the only naturally occurring element that can sustain a nuclear chain reaction

The fission products are new radioactive elements – unstable!

More neutrons are needed to create a nuclear chain reaction

Radioactive Disintegration



A radioactive atom is like a tiny little time bomb. It will suddenly disintegrate, giving off a highly energetic particle and/or a photon of energy. These projectiles are damaging to living cells.

Atomic radiation cannot be seen – and cannot be shut off

In a “cloud chamber” you can see the unending tracks of all 3 types of emissions from uranium ore

A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
H (T)	Hydrogen (Tritium)	3	¥¥¥	¥	¥	
Be	Beryllium	10		¥	¥	
C	Carbon	14		¥¥¥	¥¥¥	
Si	Silicon	32		¥	¥	
P	Phosphorus	32		¥	¥	
S	Sulphur	35		¥		
Cl	Chlorine	36		¥		
Ar Ar	Argon Argon	39 42		¥ ¥	¥ ¥	
K K	Potassium Potassium	40 42		¥	 ¥	
Ca Ca	Calcium Calcium	41 45		¥	 ¥	
Sc	Scandium	46		¥		
Standard Chemical Symbol	**Common Name of element**	**Atomic Mass Number**	**F.P. Fission Product**	**F.I.A.P. Activation Product**	**Z.A.P. Activation Product**	**Actinide (includes progeny)**
V	Vanadium	50			¥	
Mn	Manganese	54		¥	¥¥¥	
Fe Fe	Iron Iron	55 59		¥¥¥	¥¥¥ ¥	
Co Co	Cobalt Cobalt	58 60		¥ ¥¥¥	¥ ¥¥¥	
Ni Ni	Nickel Nickel	59 63		¥ ¥¥¥	¥¥¥ ¥¥¥	
Zn	Zinc	65		¥	¥	
Se	Selenium	79	¥¥¥			
Kr Kr	Krypton Krypton	81 85	¥ ¥¥¥			
Rb	Rubidium	87	¥			
Sr Sr	Strontium Strontium	89 90	¥ ¥¥¥	 ¥	¥ ¥	
Y	Yttrium	90	¥¥¥	¥	¥	

F.I.A.P. = fuel impurity activation product Z.A.P. = zirconium cladding activation product [source: AECL]

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Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Y	Yttrium	91	¥		¥	
Zr	Zirconium	93	¥¥¥	¥	¥¥¥	
Zr	Zirconium	95	¥	¥	¥	
Nb	Niobium	92			¥	
Nb	Niobium	93m	¥¥¥	¥	¥¥¥	
Nb	Niobium	94	¥	¥	¥¥¥	
Nb	Niobium	95	¥	¥	¥	
Nb	Niobium	95m	¥		¥	
Mo	Molybdenum	93		¥	¥	
Tc	Technetium	99	¥¥¥	¥	¥	
Ru	Ruthenium	103	¥			
Ru	Ruthenium	106	¥¥¥			
Rh	Rhodium	103m	¥			
Rh	Rhodium	106	¥¥¥			
Pd	Palladium	107	¥¥¥			
Ag	Silver	108	¥	¥	¥	
Ag	Silver	108m	¥	¥¥¥	¥	
Ag	Silver	109m	¥	¥	¥	
Ag	Silver	110	¥	¥	¥	
Ag	Silver	110m	¥	¥	¥	
Cd	Cadmium	109	¥	¥	¥	
Cd	Cadmium	113	¥		¥	
Cd	Cadmium	113m	¥¥¥		¥	
Cd	Cadmium	115	¥			
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
In	Indium	113m			¥	
In	Indium	114	¥	¥	¥	
In	Indium	114m			¥	
In	Indium	115			¥	
Sn	Tin	113			¥	
Sn	Tin	117m	¥	¥	¥	
Sn	Tin	119m	¥¥¥		¥¥¥	
Sn	Tin	121m	¥		¥¥¥	
Sn	Tin	123	¥		¥	

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Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Sn	Tin	125	¥¥¥		¥	
Sn	Tin	126				
Sb	Antimony	124	¥		¥	
Sb	Antimony	125	¥¥¥		¥¥¥	
Sb	Antimony	126	¥		¥	
Sb	Antimony	126m	¥¥¥			
Te	Tellurium	123	¥		¥	
Te	Tellurium	123m	¥		¥	
Te	Tellurium	125m	¥¥¥		¥¥¥	
Te	Tellurium	127	¥		¥	
Te	Tellurium	127m	¥		¥	
I	Iodine	129	¥		¥	
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Cs	Cesium	134	¥			
Cs	Cesium	135	¥¥¥			
Cs	Cesium	137	¥¥¥			
Ba	Barium	137m	¥¥¥			
La	Lanthanum	138	¥			
Ce	Cerium	142	¥			
Ce	Cerium	144	¥¥¥			
Pr	Praseodymium	144	¥¥¥			
Pr	Praseodymium	144m	¥¥¥			
Nd	Neodymium	144	¥			
Pm	Promethium	147	¥¥¥			
Sm	Samarium	147	¥			
Sm	Samarium	148	¥	¥		
Sm	Samarium	149	¥			
Sm	Samarium	151	¥¥¥			
Eu	Europium	152	¥¥¥	¥		
Eu	Europium	154	¥¥¥	¥		
Eu	Europium	155	¥¥¥	¥		
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Gd	Gadolinium	152	¥	¥		
Gd	Gadolinium	153	¥	¥		
Tb	Terbium	157		¥		

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Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Tb	Terbium	160		¥		
Dy	Dysprosium	159		¥		
Ho	Holmium	166m	¥	¥		
Tm	Thulium	170		¥		
Tm	Thulium	171		¥		
Lu	Lutetium	176			¥	
Lu	Lutetium	176			¥	
Lu	Lutetium	176			¥	
Hf	Hafnium	175			¥	
Hf	Hafnium	181			¥	
Hf	Hafnium	182			¥	
Ta	Tantalum	180			¥	
Ta	Tantalum	182			¥	
W	Tungsten	181			¥	
W	Tungsten	185			¥	
W	Tungsten	188			¥	
Re	Rhenium	187			¥	
Re	Rhenium	188			¥	
Os	Osmium	194			¥	
Ir	Iridium	192			¥	
Ir	Iridium	192m			¥	
Ir	Iridium	194			¥	
Ir	Iridium	194m			¥	
Pt	Platinum	193			¥	
Tl	Thallium	206			¥	
Tl	Thallium	207				¥
Tl	Thallium	208				¥
Tl	Thallium	209				¥
Pb	Lead	204			¥	
Pb	Lead	205			¥	
Pb	Lead	209				¥
Pb	Lead	210				¥
Pb	Lead	211				¥
Pb	Lead	212				¥
Pb	Lead	214				¥
Standard	Common Name of	Atomic Mass	F.P.	F.I.A.P.	Z.A.P.	Actinide

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Chemical Symbol	element	Number	Fission Product	Activation Product	Activation Product	(includes progeny)
Bi	Bismuth	208			¥	
Bi	Bismuth	210			¥	¥
Bi	Bismuth	210m				¥
Bi	Bismuth	211				¥
Bi	Bismuth	212				¥
Bi	Bismuth	213				¥
Bi	Bismuth	214				
Po	Polonium	210			¥	¥
Po	Polonium	211				¥
Po	Polonium	212				¥
Po	Polonium	213				¥
Po	Polonium	214				¥
Po	Polonium	215				¥
Po	Polonium	216				¥
Po	Polonium	218				¥
At	Astatine	217				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Rn	Radon	219				¥
Rn	Radon	220				¥
Rn	Radon	222				¥
Fr	Francium	221				¥
Fr	Francium	221				¥
Ra	Radium	223				¥
Ra	Radium	224				¥
Ra	Radium	225				¥
Ra	Radium	226				¥
Ra	Radium	228				¥
Ac	Actinium	225				¥
Ac	Actinium	227				¥
Ac	Actinium	228				¥
Th	Thorium	227				¥
Th	Thorium	228				¥
Th	Thorium	229				¥
Th	Thorium	230				¥
Th	Thorium	231				¥
Th	Thorium	232				¥

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A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Th	Thorium	234				¥¥¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Pa	Protactinium	231				¥
Pa	Protactinium	233				¥¥¥
Pa	Protactinium	234				¥
Pa	Protactinium	234m				¥¥¥
U	Uranium	232				¥
U	Uranium	233				¥
U	Uranium	234				¥¥¥
U	Uranium	235				¥
U	Uranium	236				¥¥¥
U	Uranium	237				¥¥¥
U	Uranium	238				¥¥¥
U	Uranium	240				¥
Np	Neptunium	237				¥¥¥
Np	Neptunium	238				¥
Np	Neptunium	239				¥¥¥
Np	Neptunium	240				¥
Np	Neptunium	240m				¥
Pu	Plutonium	236				¥
Pu	Plutonium	238				¥¥¥
Pu	Plutonium	239				¥¥¥
Pu	Plutonium	240				¥¥¥
Pu	Plutonium	241				¥¥¥
Pu	Plutonium	242				¥¥¥
Pu	Plutonium	243				¥
Pu	Plutonium	244				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)
Am	Americium	241				¥¥¥
Am	Americium	242				¥¥¥
Am	Americium	242m				¥¥¥
Am	Americium	243				¥¥¥
Am	Americium	245				¥
Cm	Curium	242				¥¥¥
Cm	Curium	243				¥¥¥

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A LIST OF SELECTED RADIONUCLIDES IN IRRADIATED NUCLEAR FUEL

Cm	Curium	244				¥¥¥
Cm	Curium	245				¥
Cm	Curium	246				¥
Cm	Curium	247				¥
Cm	Curium	248				¥
Cm	Curium	250				¥
Bk	Berkelium	249				¥
Bk	Berkelium	250				¥
Cf	Californium	249				¥
Cf	Californium	250				¥
Cf	Californium	251				¥
Cf	Californium	252				¥
Standard Chemical Symbol	Common Name of element	Atomic Mass Number	F.P. Fission Product	F.I.A.P. Activation Product	Z.A.P. Activation Product	Actinide (includes progeny)

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This list of 211 man-made radionuclides contained in irradiated nuclear fuel is by no means complete! (AECL)

[AECL = Atomic Energy of Canada Limited]

Radioactive elements are chemical substances which are also radioactive.

They all have their own unique pathways through the environment and through the human body.

RADIOACTIVE CONTAMINATION

THYROID
iodine–131
beta (gamma) ; 8 days

SKIN
sulphur–35
beta ; 87 days

LIVER
cobalt–60
beta (gamma) ; 5 years

OVARIES
iodine–131
beta (gamma) ; 8 days
cobalt–60
beta (gamma) ; 5 years
krypton-85
gamma ; 10 years
ruthenium–106
gamma ; 1 year
zinc–65
gamma ; 245 days
barium–140
gamma ; 13 days
potassium–42
gamma ; 12 hours
cesium–137
gamma ; 30 years
plutonium–239
alpha ; 24 000 years

MUSCLE
potassium–42
gamma ; 12 hours
cesium–137
gamma ; 30 years

LUNGS
radon–222 (and whole body)
alpha ; 3,8 days
uranium–233 (et os)
alpha ; 162 000 years
plutonium–239 (and bone)
alpha ; 24 000 years

SPLEEN
polonium–210 (and whole body)
alpha ; 138 days

KIDNEYS
uranium–238 (and bone)
alpha ; 4 500 000 years
ruthenium–106
gamma (beta) ; 1 year

BONE
radium–226
alpha ; 1 620 years
zinc–65
gamma ; 245 days
strontium–90
beta ; 28 years
yttrium–90
beta ; 64 hours
promethium–147
beta ; 2 years
barium–140
beta (gamma) ; 13 days
thorium–234
beta ; 24,1 days
phosphorus–32
beta ; 14 days
carbon–14 (and fat)
beta ; 5 600 years

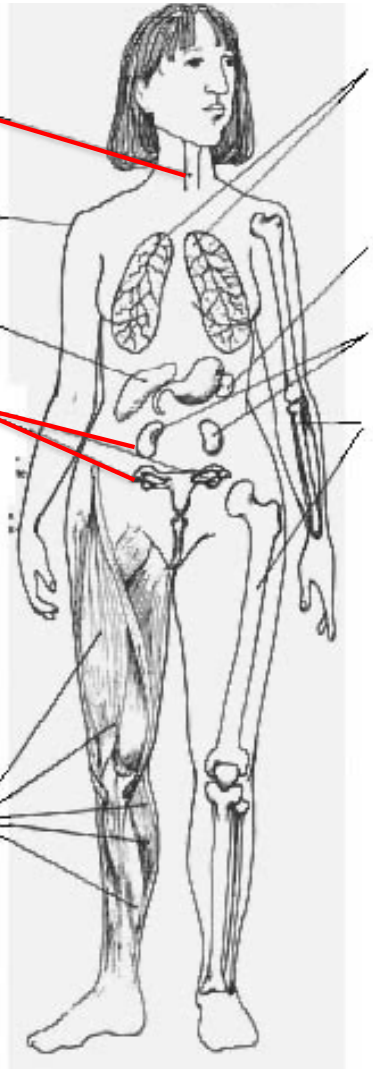
Iodine-131 goes to the thyroid gland (in the throat) and damages it.

Thyroid cancer, mental retardation, stunted growth, can be caused.

Young children are especially at risk.

5000 kids in Belarus had to have their thyroids removed after Chornobyl….

RADIOACTIVE CONTAMINATION



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carbon–14 (and fat)
beta ; 5 600 years

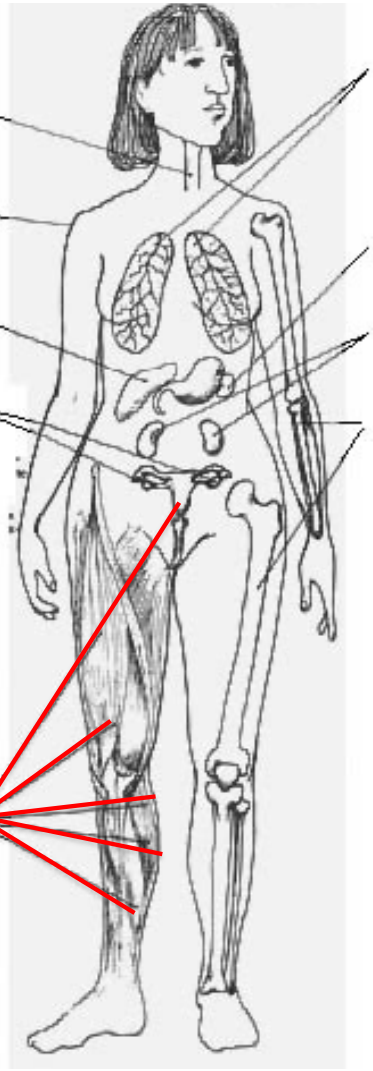
RADIOACTIVE CONTAMINATION

Cesium-137 behaves like potassium, going to the blood and soft tissues

It makes meat unfit for human consumption

It stays in the food chain for decades

For 30 years after Chornobyl sheep in England and boars in Europe are still contaminated



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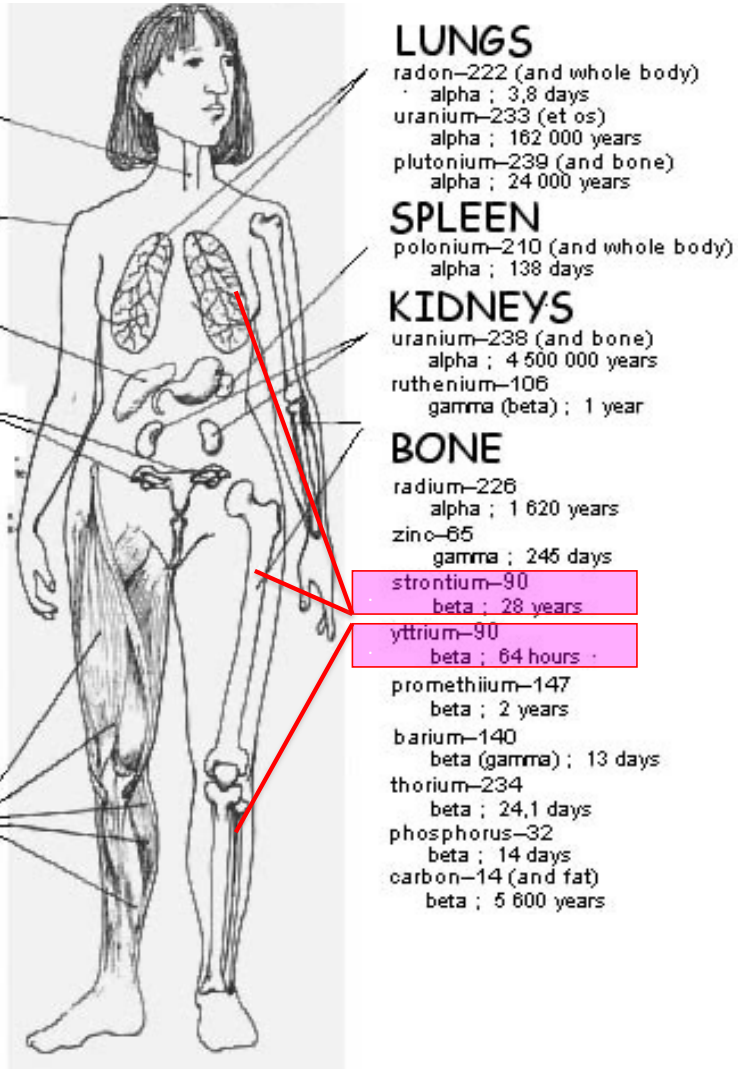
beta ; 5 600 years

RADIOACTIVE CONTAMINATION

Strontium-90 behaves like calcium; it goes to the bones, the teeth and mother´s milk

Bone cancer or blood diseases may result

Much harder to detect but even more dangerous than other nuclides



Health Effects

chronic exposure
increases the incidence of
cancer, leukemia, genetic damage,
strokes, heart attacks & other blood diseases,
stillbirths and teratogenic effects such as
low intelligence in young children
(following prenatal exposure)

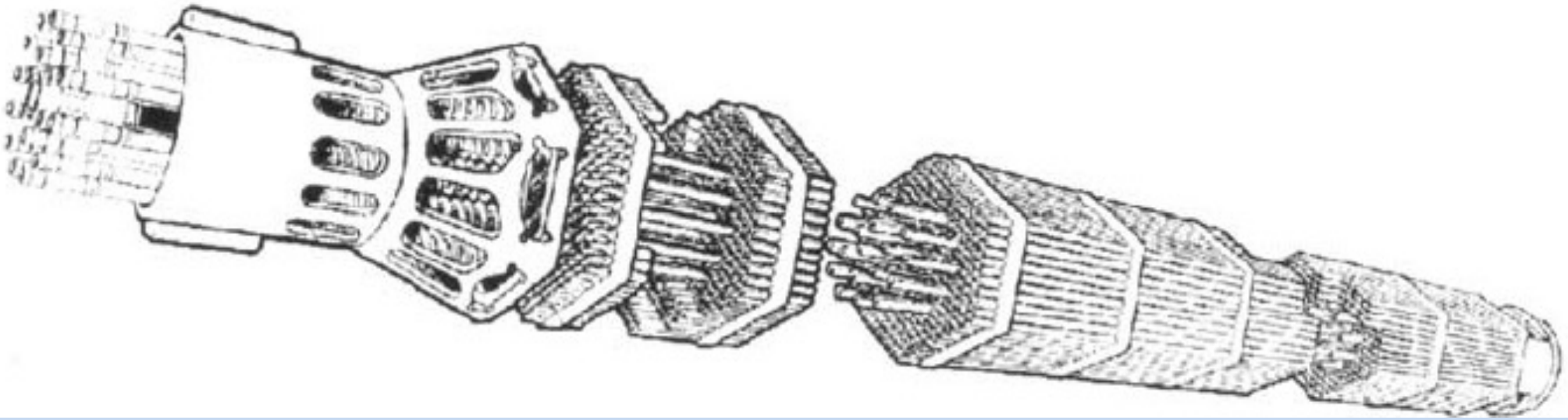
…but there is a time delay; the
onset of disease may occur years
or decades after exposure

. . . BACK TO THE UKRAINE

Ukraine has 15 nuclear reactors at 4 sites in addition to the shut-down Chornobyl site. Nuclear power provides 20 percent of Ukraine's energy and up to 50 percent of electricity. Chornobyl's reactors are RBMK design, all others are stronger VVER design (PWR's)

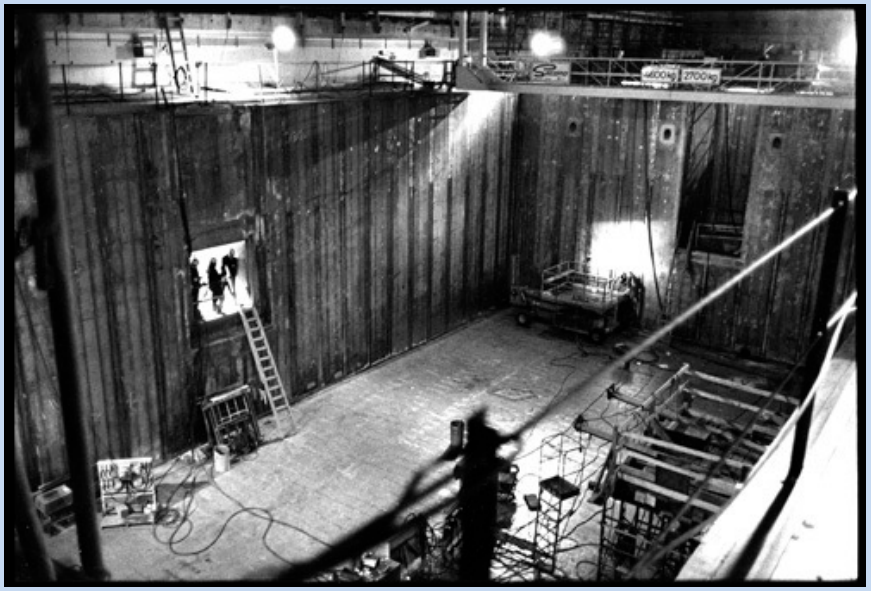
ZAPORIZHZHIA NPP ON THE DNEIPER RIVER IN SOUTH-EAST UKRAINE

Zaporizhzhia Nuclear Plant – 6 VVER-1000 reactors, 5700 Megawatts (electrical), largest in Europe
Units 5 & 6 shut down on February 25; Russian attack involved heavy fire for two hours March 3-4.



Typical VVER fuel assembly, about 500 kg.

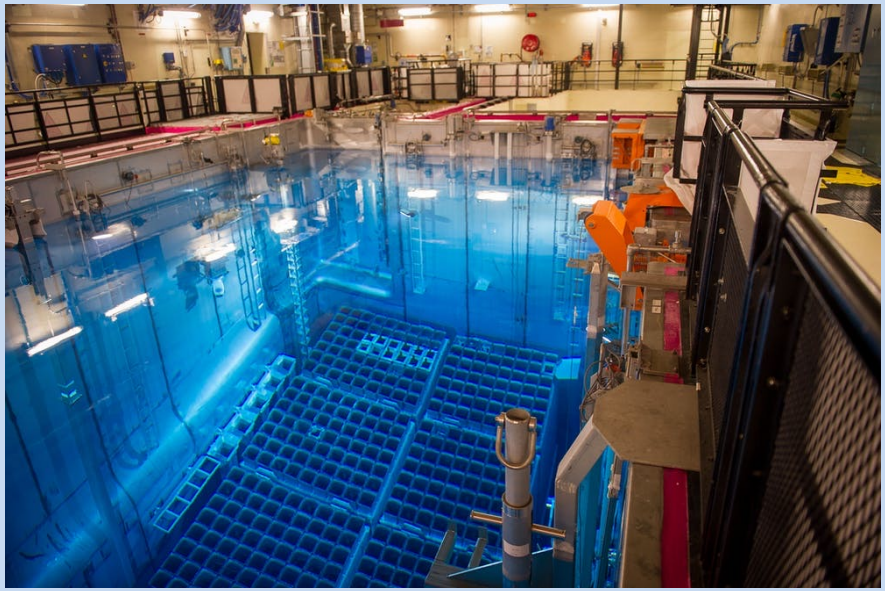
A freshly discharged fuel assembly would give an unshielded human one metre away a lethal dose of radiation in a few seconds.



Darlington (Canada) spent fuel pool under construction – photo by Robert Del Tredici

Irradiated nuclear fuel must be cooled for years (overheat → damage → releases)

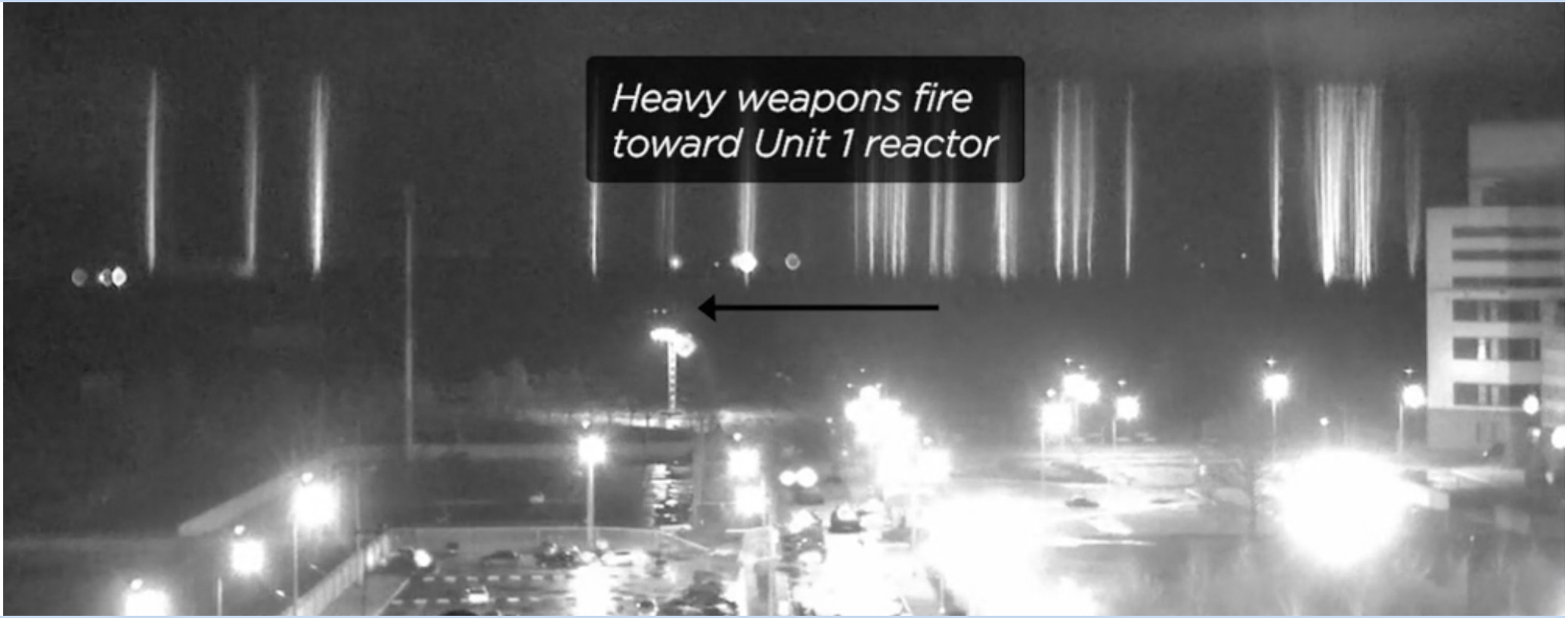
Radioactivity is a form of nuclear energy that can't be shut off – produces heat



Zaporizhzhia spent fuel pool in operation

Dry storage of used nuclear fuel at Zaporizhzhia NPP – air cooled

Overhead view of Zaporizhzhia Nuclear Site – units 1 to 6, left to right



Heavy fire, artillery, two hour battle – this security camera picture taken about 1 am March 4 2022

CONCERNS AT ZAPORIZHZHIA

A core meltdown could be triggered by a combination of equipment failure and operator error made more likely by operators having to operate at gunpoint.

Total station blackout – loss of both offsite power and backup diesel power – at Fukushima this led to disaster.

An uncontrolled power surge destroying the reactor core as at Chernobyl in 1986, brought about by fatigue and anxiety.

Massive radioactive releases from the Irradiated fuel pools or dry storage containers in the midst of battle, with reckless use of artillery and/or rocket-propelled grenades.

AFTERWORD: SMALL REACTORS ARE MUCH MORE VULNERABLE TO ACTS OF WAR

EBR-II produced 62.5 megawatts of heat and 20 megawatts of electricity
It operated from 1964 to 1994. *(EBR-I had a small meltdown in 1955.)*

The End

web site: www.ccnr.org

e-mail: ccnr@web.ca