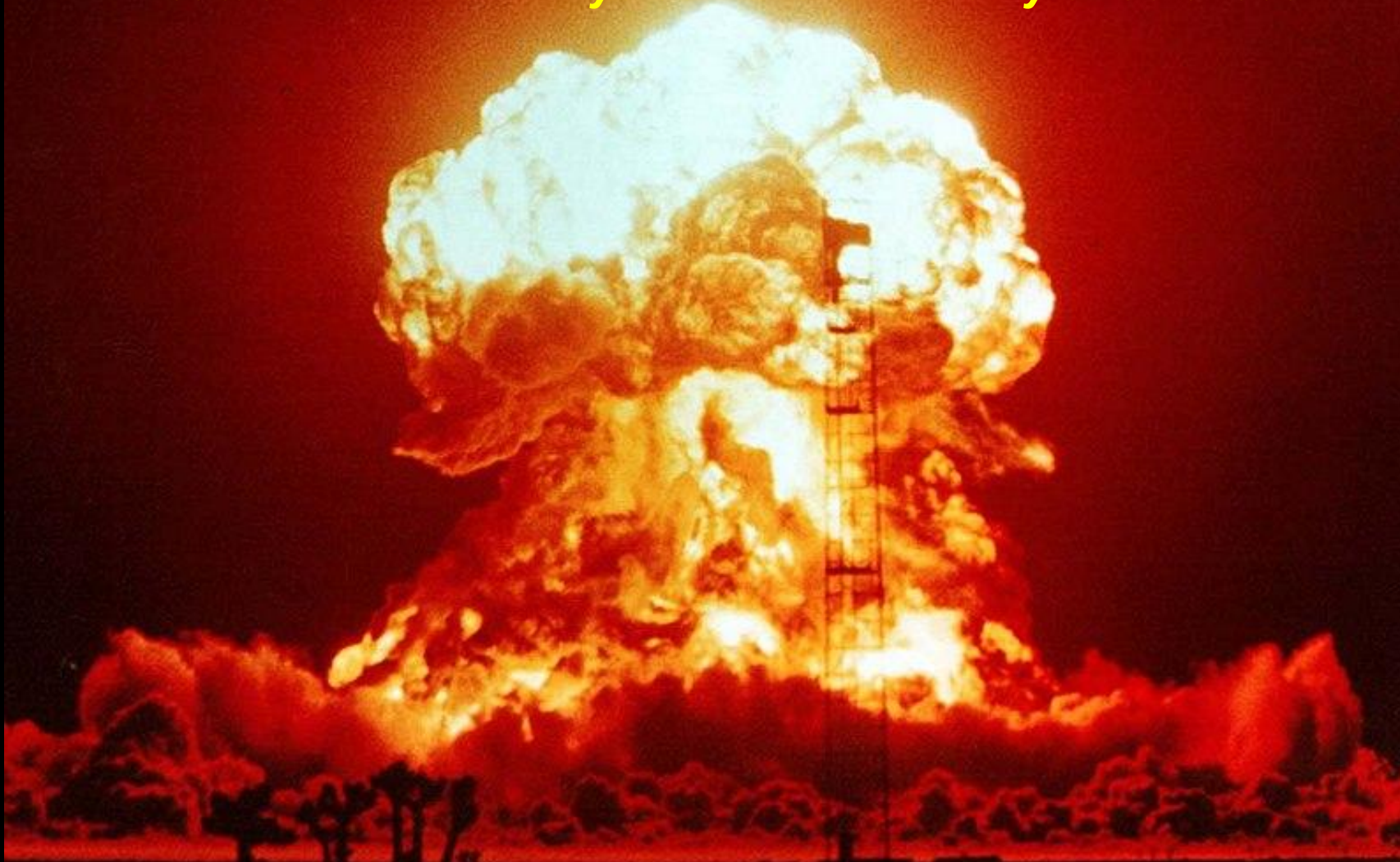


Radiological consequences of the attack with nuclear weapons

Paweł Olko

Institute of Nuclear Physics Polish Academy of Sciences



2022-10-12



ICRP Advice for Members of the Public on Protection in Case of a Nuclear Detonation



2022-10-12



ICRP Advice for Members of the Public on Protection in Case of a Nuclear Detonation



The Effects of Nuclear Weapons

Compiled and edited by
Samuel Glasstone and Philip J. Dolan

Third Edition

Prepared and published by the
UNITED STATES DEPARTMENT OF DEFENSE
and the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION



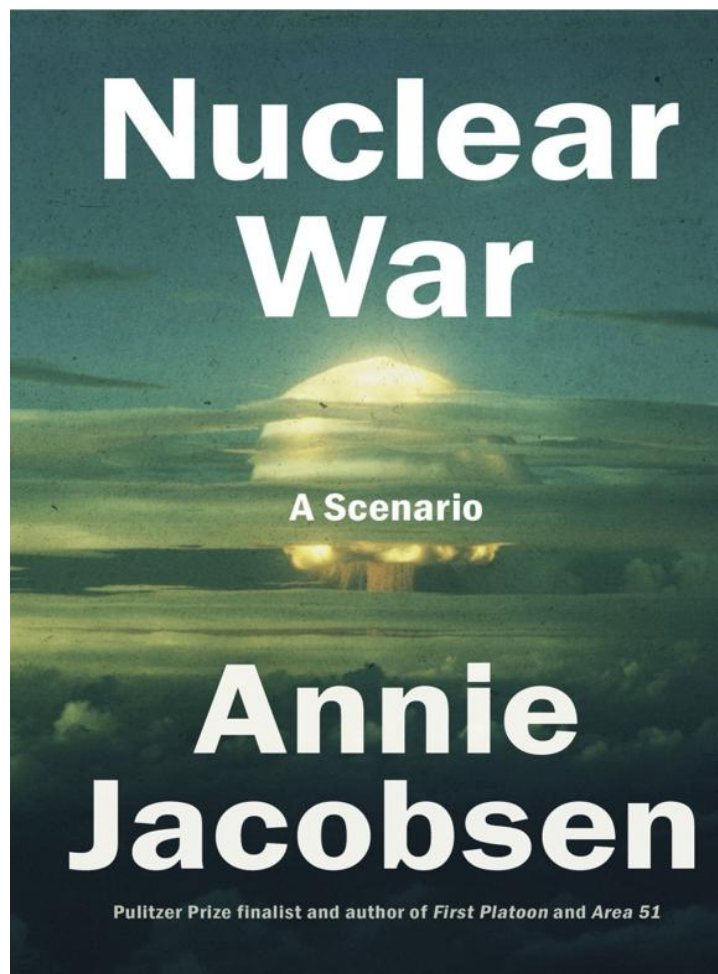
1977

Nuclear war is back in the spotlight

- Repeated threats of using nuclear weapons by Russian Federation
- Testing of new weapons with nuclear warheads :
 - 9M730 Buriewiestnik cruise missile** with nuclear reactor and
 - 2M39Poseidon torpedo** designed for destroying coastal cities

Increased public interest:

- movies "**Oppenheimer**", "**A house of dynamite**",
- book A. Jacobsen "**Nuclear War – Scenario**"



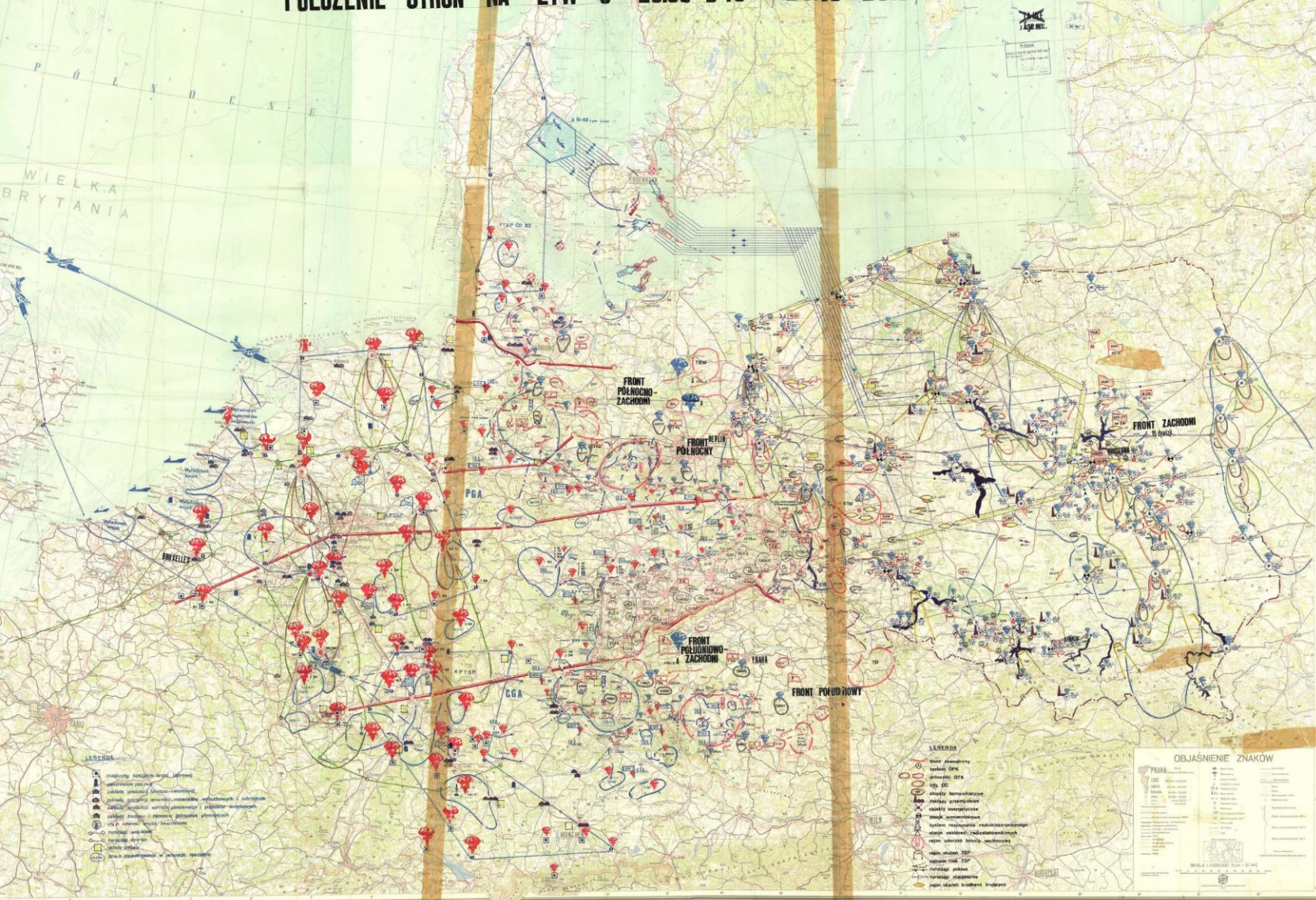
Cillian Murphy as
Oppenheimer



Plans of Nuclear War in Europe Between NATO and Warsaw Pact

POŁOŻENIE STRON NA ZTW O 20.00 D 18 20.00 25.5

ZALĄCZNIK DO ZAŁOŻENIA NR 2



Colonel Ryszard Kukliński
Chief of Staff of Polish Army
delivered battle plans to NATO
evacuated in 1981



Outline

1. Nuclear potential in Europe
2. Physics of nuclear explosion
3. Health effects of radiation exposure
4. ICRP leaflet : Advice for the Public on Protection in Case of a Nuclear Detonation



Craig Fritz – Sandia National Laboratories

Nuclear potential in Europe

Russian Federation

Strategic :

- 1166 warheads in 305 launchers
- 720 warheads on 12 nuc submarines

Tactical: 4000 warheads

Kaliningrad: two brigades of ISKANDER
(24 launchers), range 1000-2500 km, warheads 50 kT

United States (in Europe): apprx. 150 B61-12 bombs (0.3 -50 kT)
in frame of Nuclear Sharing in 5 centers

France:

50 bombs (Dassault Rafale aircrafts)
64 launchers in 4 nuc submarines

United Kingdom

120 warheads on 4 nuc submarines



Nuclear potential of Ukraine (1994)

2390 tactical nuclear warheads

1240 Strategic nuclear warheads

- 130 UR-100N intercontinental ballistic missiles (ICBM) with six warheads each
- 46 RT-23 Molodets ICBMs with 10 warheads each
- 33 strategic bombers

Well developed industry producing rockets oraz airplanes: industrial complex Piwdenmasz in Pawlograd, Kiev, Sarnach.



Medium range R-12 rocket with a megaton-class thermonuclear warhead constituted main offensive missile threat to Western Europe

Budapest Memorandum, December 5, 1994



Bill Clinton, Boris Jelcyn and Leonid Kuczma

January 14, 1994: Signing in Moscow of the Trilateral Declaration by the Presidents of Ukraine, Russia, and the USA on the elimination of Ukrainian nuclear weapons in exchange for security guarantees for Ukraine.

March 6, 1994: The transfer of strategic warheads to Russia began.

December 5, 1994: At the Budapest conference, the USA, the UK, and Russia provided security guarantees to Ukraine.

Memorandum on Security Assurances in connection with Ukraine's accession to the Treaty on the Non-Proliferation of Nuclear Weapons

The Russian Federation, the United Kingdom of Great Britain and Northern Ireland, and The United States of America reaffirm :

- their commitment (...) to respect the independence and sovereignty and the existing borders of Ukraine.**
- their obligation to refrain from the threat or use of force against the territorial integrity or political independence of Ukraine, and that none of their weapons will ever be used against Ukraine (...)**

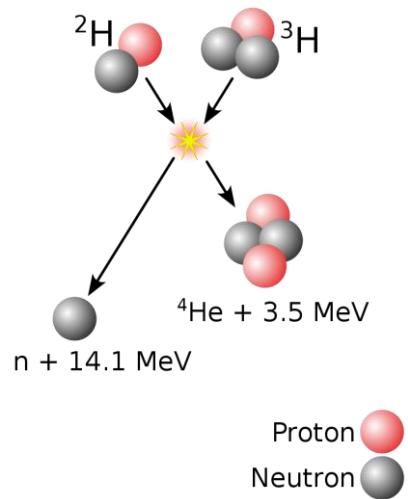
FOR THE RUSSIAN FEDERATION: (signature Boris Yeltsin)

FOR THE UNITED STATES OF AMERICA: (signature Bill Clinton)

FOR THE UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND: (signature John Major)

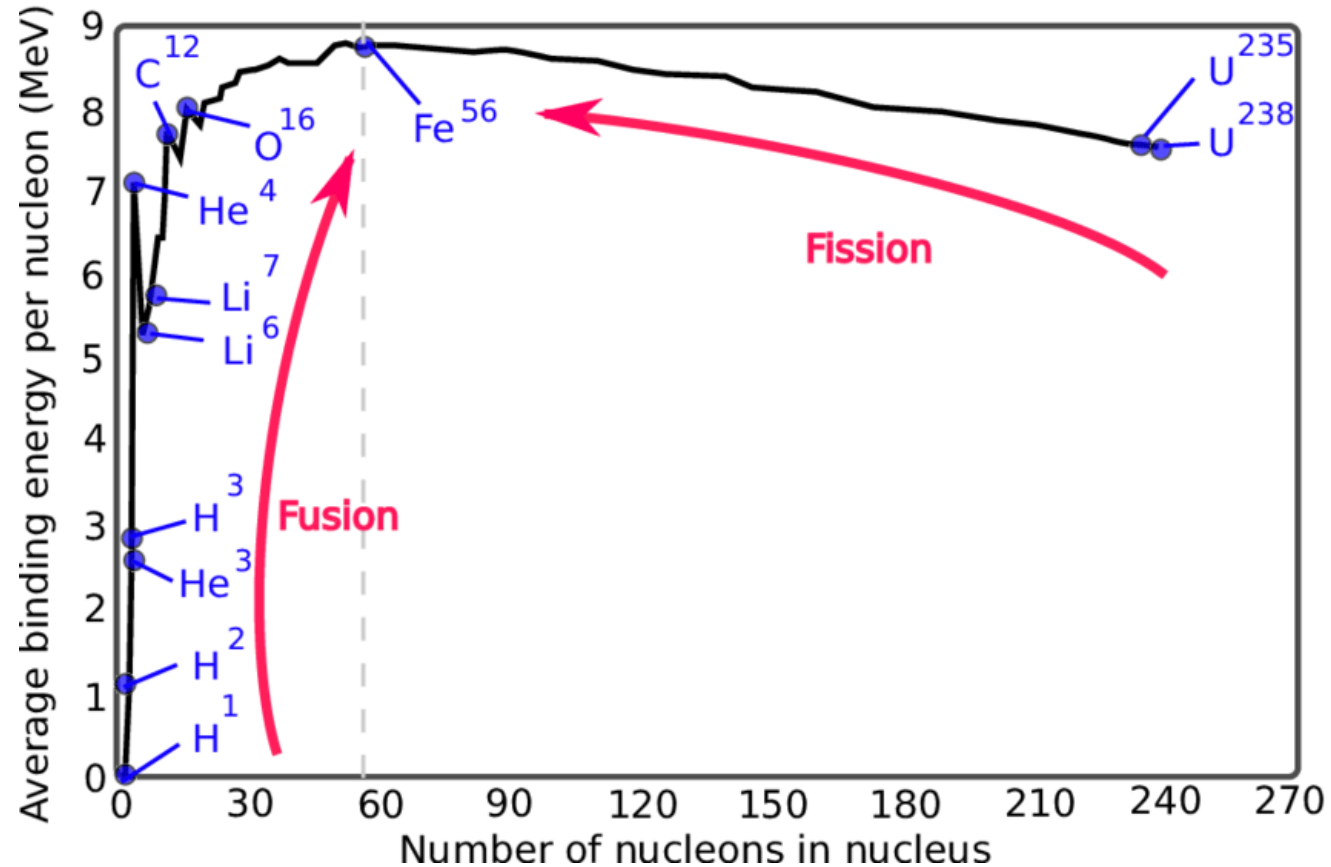
In April 2023, in an interview with Irish broadcaster RTE Tuesday, US president Bill Clinton expressed regret at pressuring Ukraine to give up nuclear weapons

Fusion and fission nuclear reactions

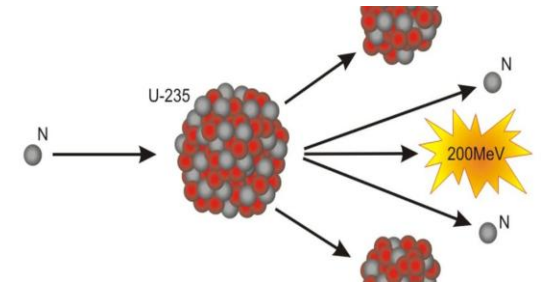


H-2

H-3 ($T_{1/2} = 12.3 \text{ y}$)



Adapted from Atzeni and Meyer-Ter-Vehn, 2004



U-233

U-235

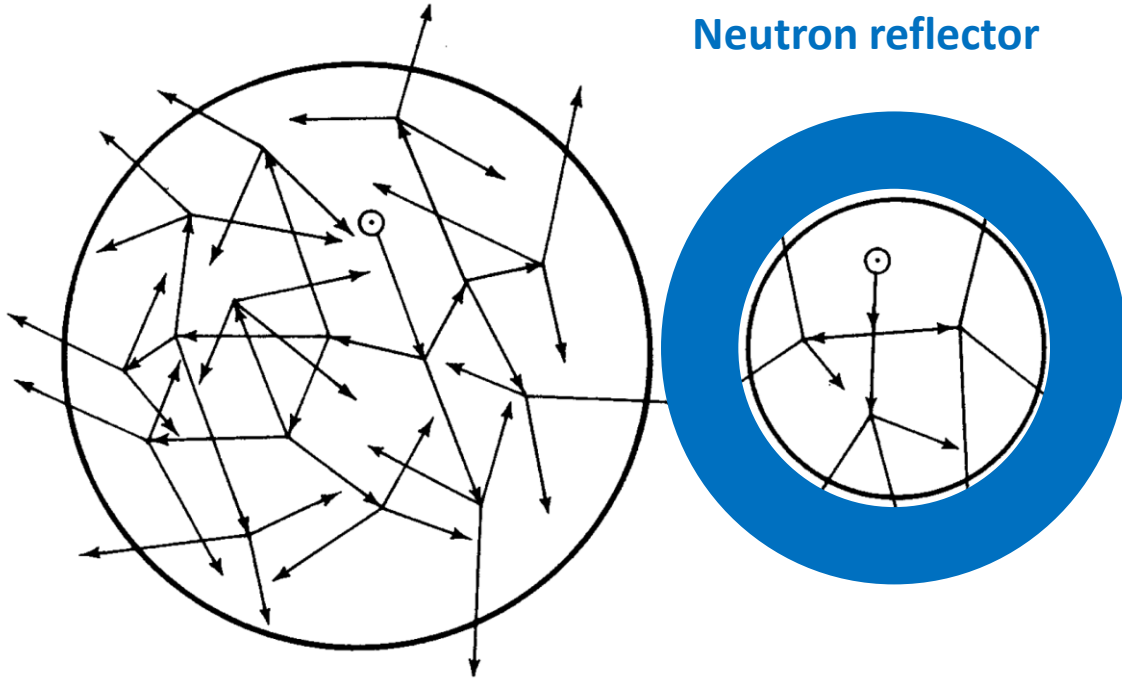
Pu-239

.....

Chain reaction possible

Critical mass and chain reaction

Neutron reflector



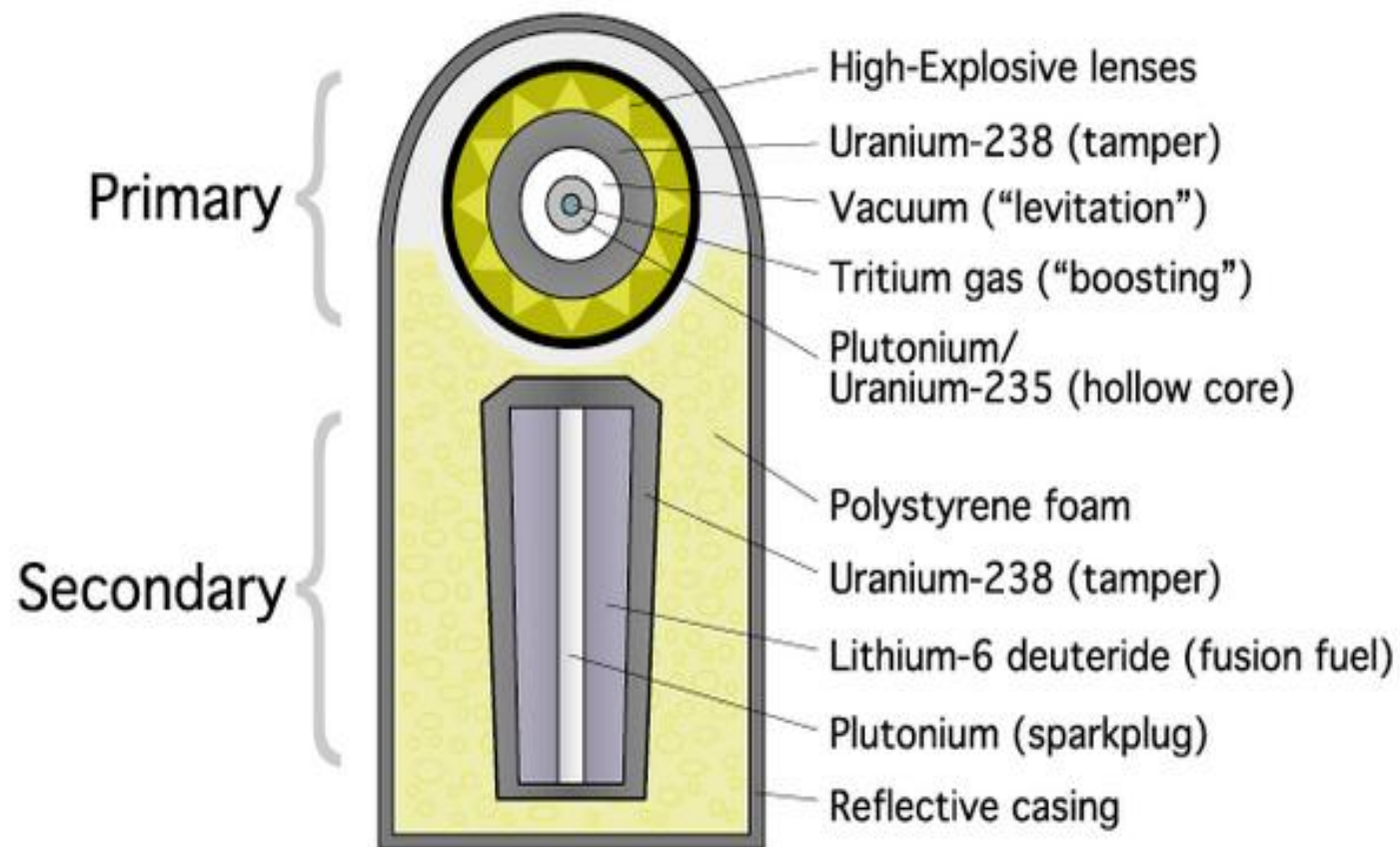
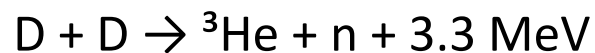
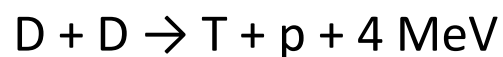
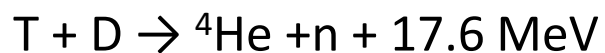
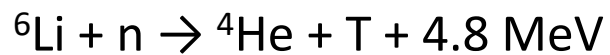
(Glastone & Dolan, 1977)

Nuclide	Half-life (y)	Critical mass (kg)	Diameter (cm)
U-233	159,200	15	11
U-235	704 E+6	52	17
Np-236	153,000	7	8.7
Pu-239	24,110	10	9.9
Am-241	432.6	55–77	20–23

Critical mass - minimum mass of the fissile material needed for a sustained nuclear chain reaction in a particular setup

Mechanism of nuclear and thermonuclear explosion

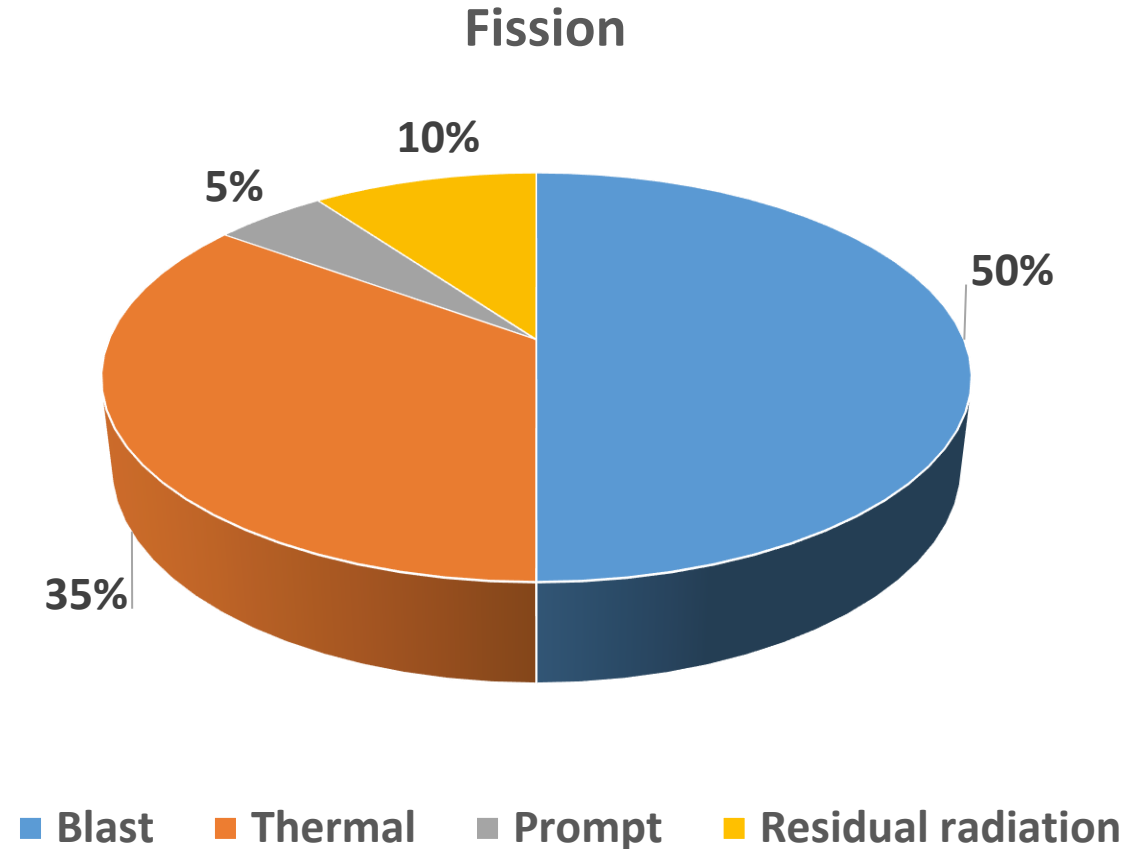
- The explosive lens compresses the plutonium and creates a critical mass – a fission explosion occurs
- Explosion creates a hot plasma that compresses the fuel and ignite a fusion
- ${}^6\text{LiD}$ is the source for tritium and deuterium



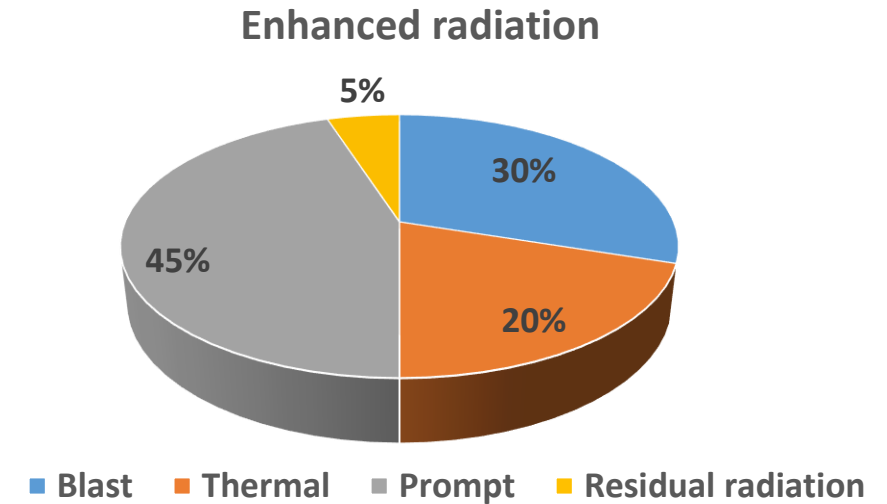
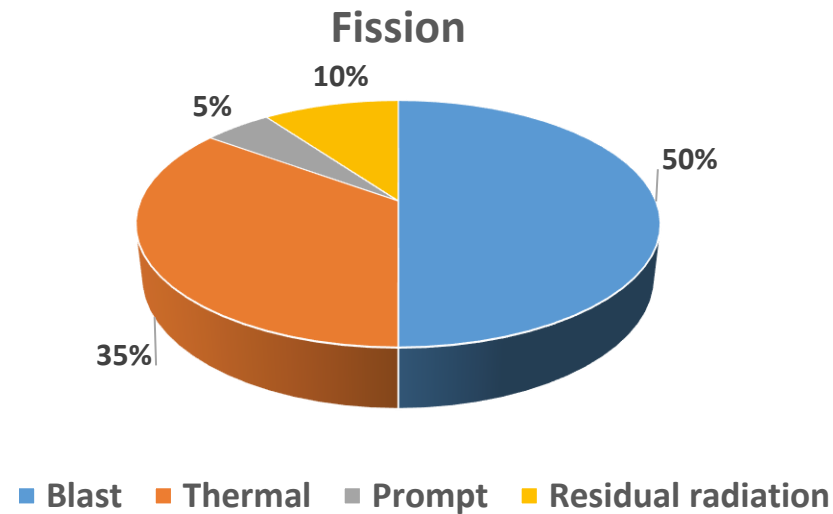
<https://ahf.nuclearmuseum.org/ahf/history/hydrogen-bomb-1950/>

Damaging factors of a nuclear explosion

- **blast (shock wave),**
- **thermal radiation (heat),**
- **prompt nuclear radiation**
- **radioactive fallout,**
- **electromagnetic pulse (EMP)**

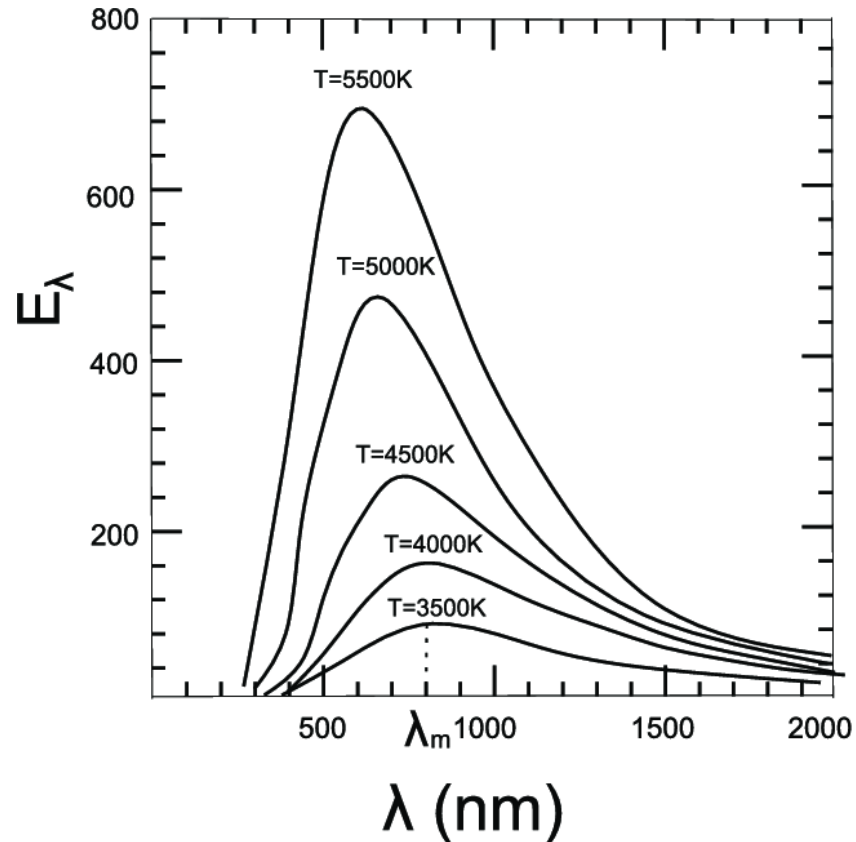


"Neutron bombs" – enhanced radiation (ER) weapon

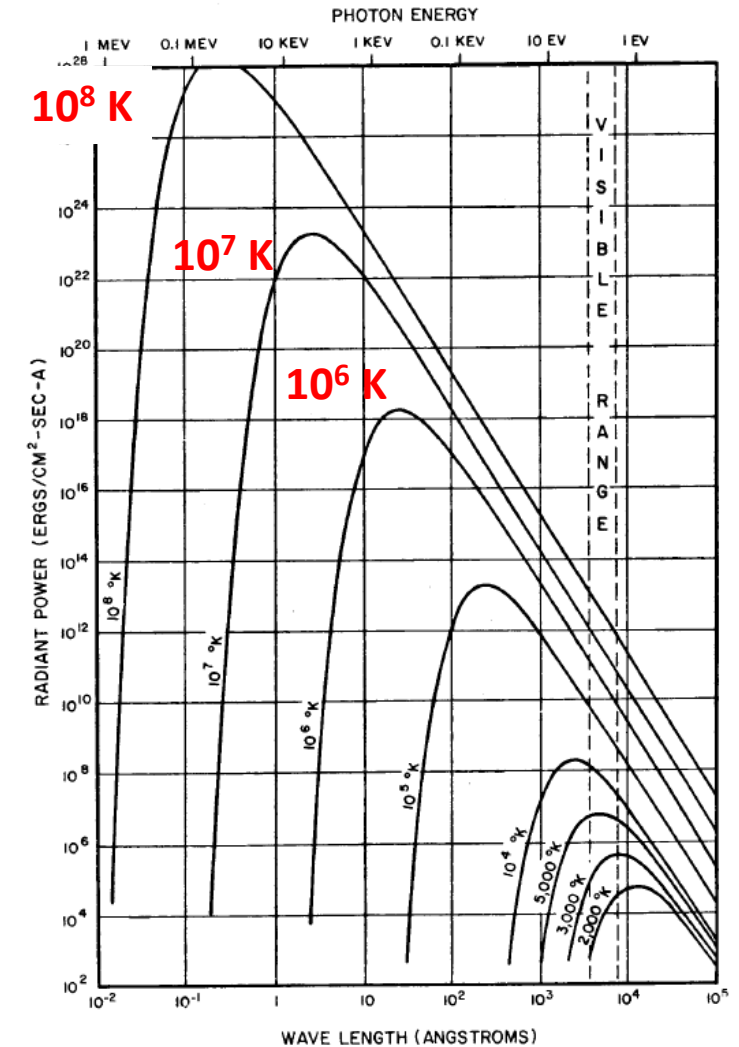


- 80 Gy to a T-72 tank crew at a range of 690 m (1 kT ER)
- 6 Gy exposure for unprotected men up at 1350 m
- NATO destroyed their neutron enhanced warheads before 1992

Electromagnetic radiation emitted by a black body – the Planck radiation law



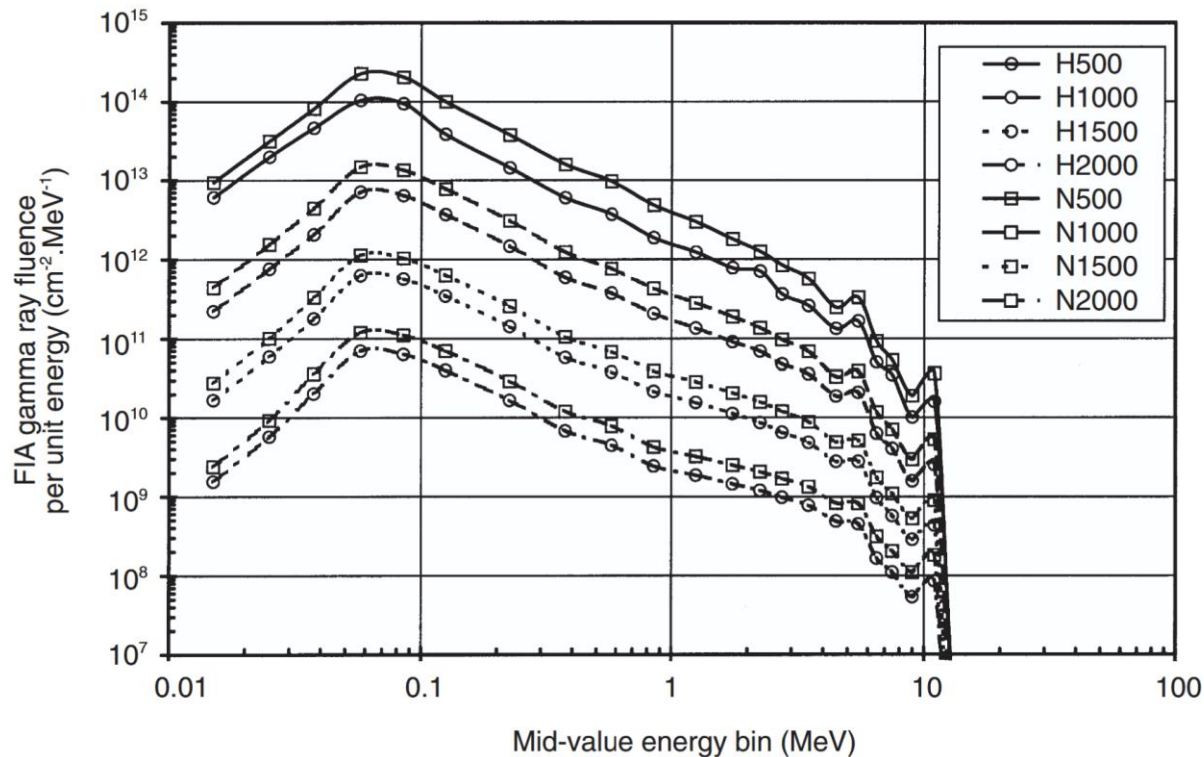
The spectral density of electromagnetic radiation emitted by a black body in thermal equilibrium at a given temperature T



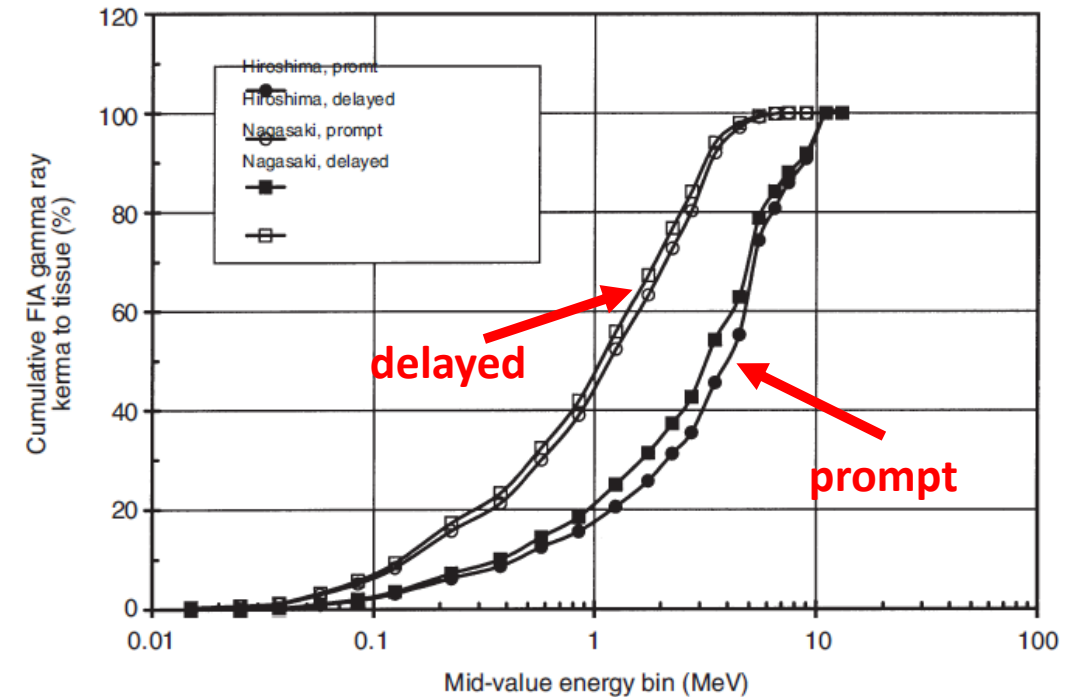
At temperatures of millions K
X-rays are emitted

(Glastone & Dolan, 1977)

Photon energy spectrum after A-bomb explosion: prompt and delayed



Total free-in-air gamma ray fluence per unit energy spectra for Hiroshima (H) and Nagasaki (N) at ground ranges of 500, 1000, 1500 and 2000 m.



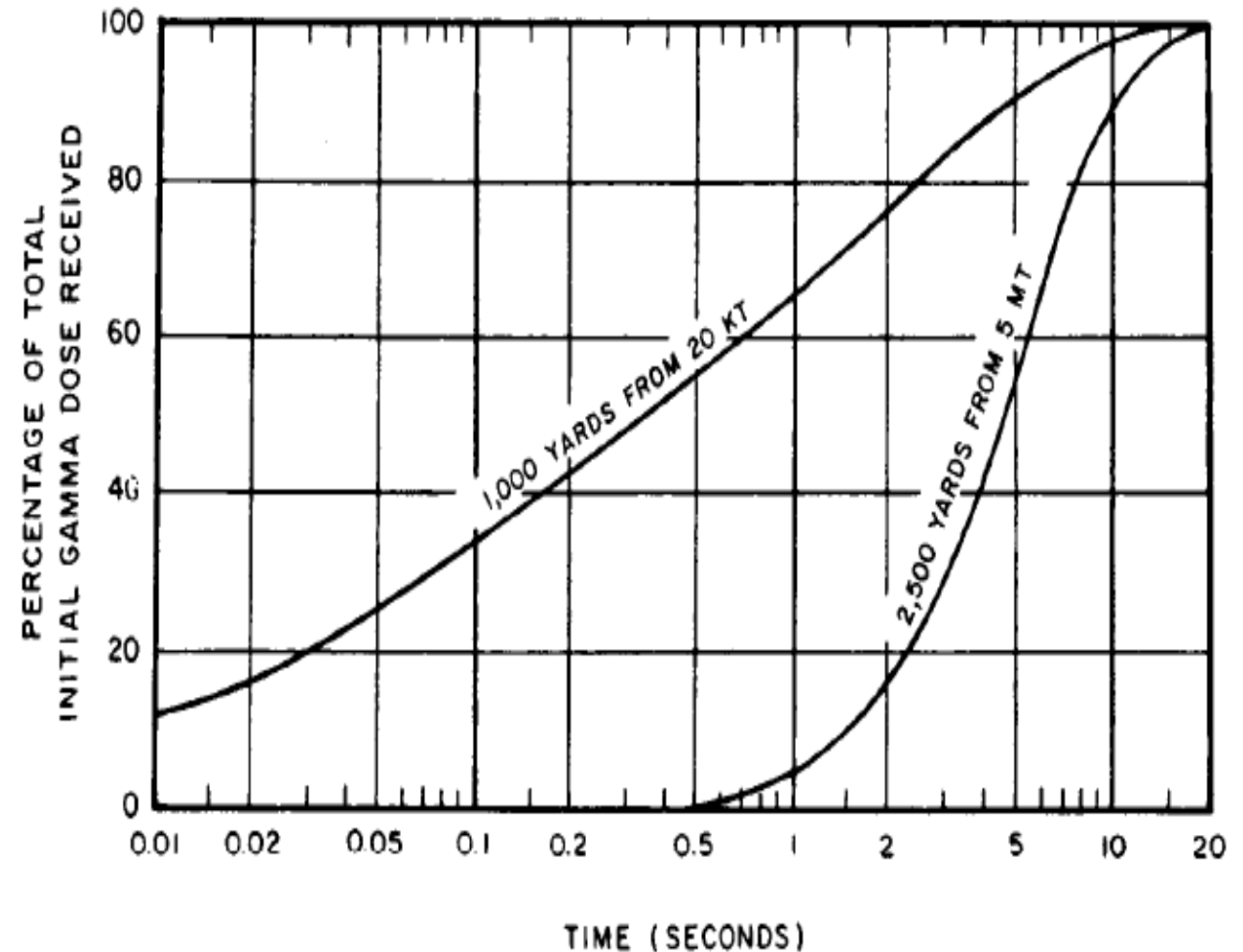
Cumulative energy distributions for free-in-air gamma ray kerma to tissue for Hiroshima (H) and Nagasaki (N) at 1000 m ground range.

Time distribution of delayed gamma-rays

Prompt gamma radiation is absorbed mostly in the bomb itself.

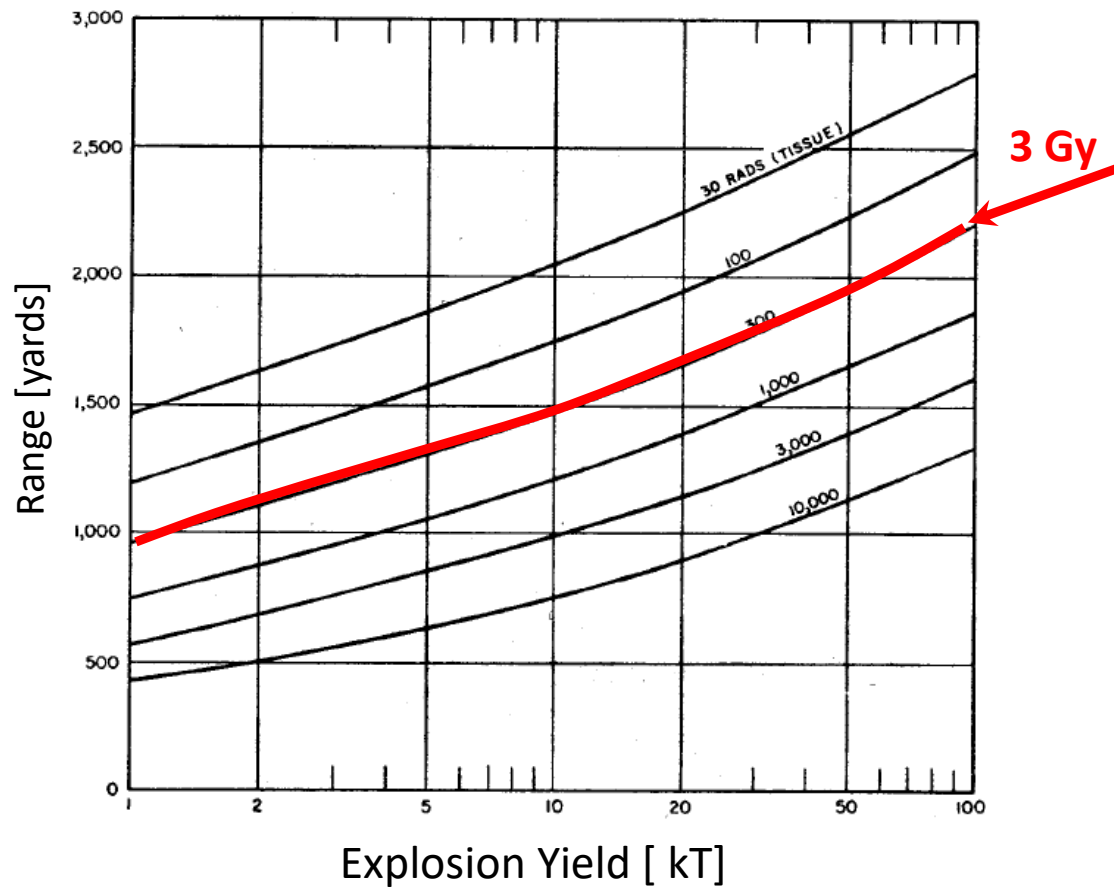
Dose from the prompt radiation is about 1% only of that what is emitted in the first minute

The emission is prolonged to several seconds - hiding under cover can significantly reduce the dose

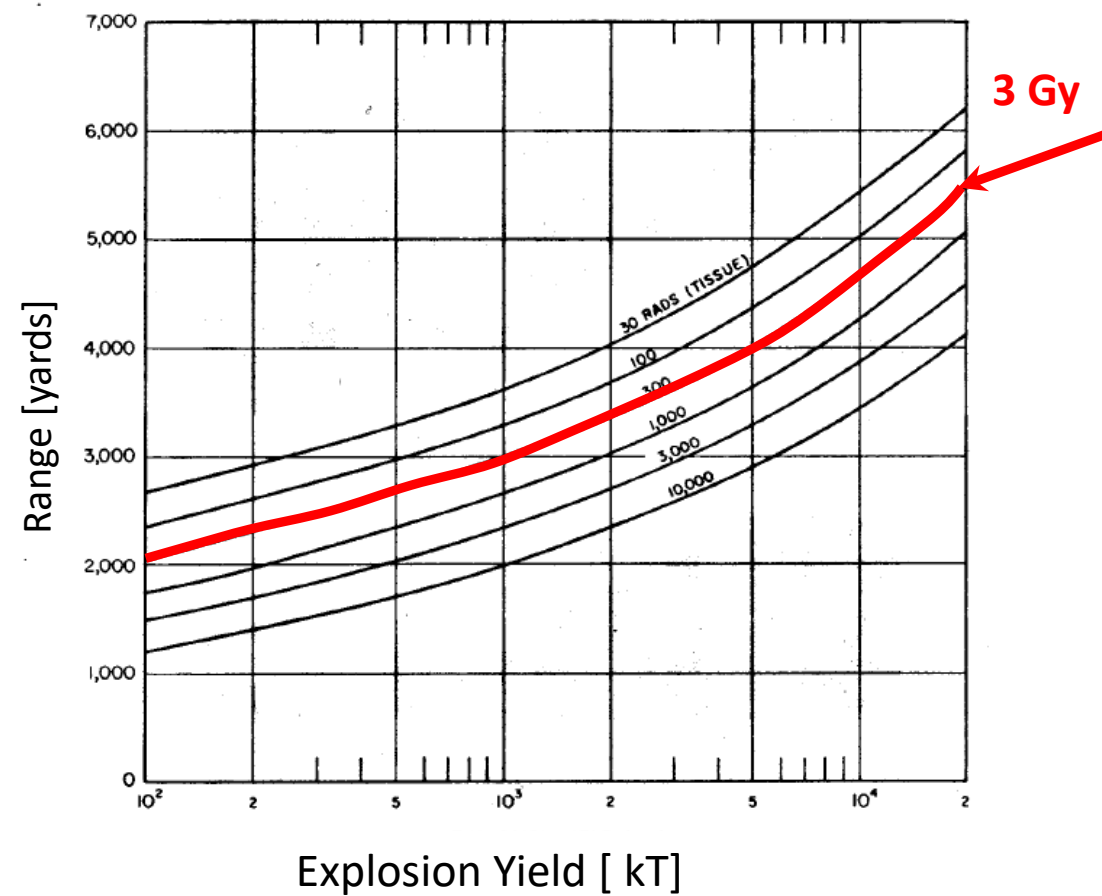


Gamma-ray doses after nuclear explosion

Fission warhead

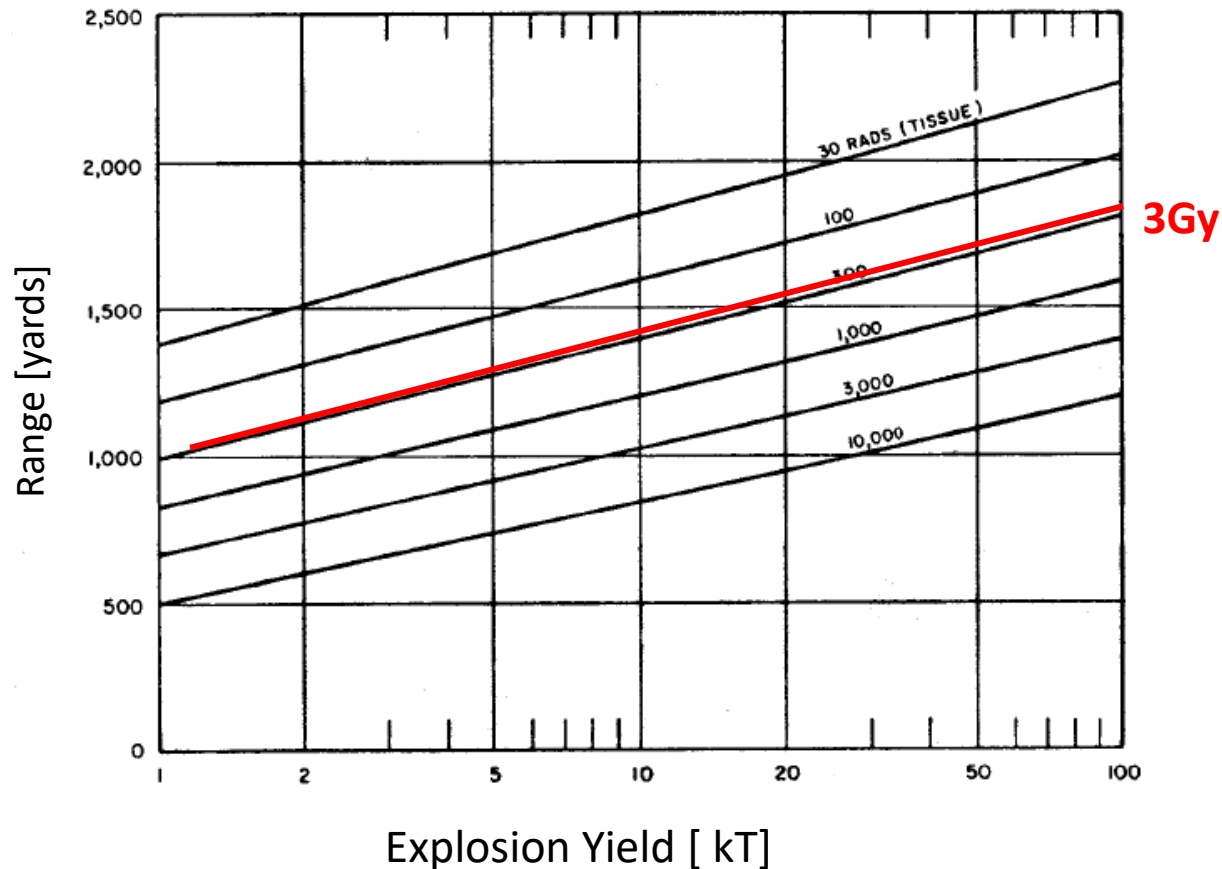


Fusion warhead

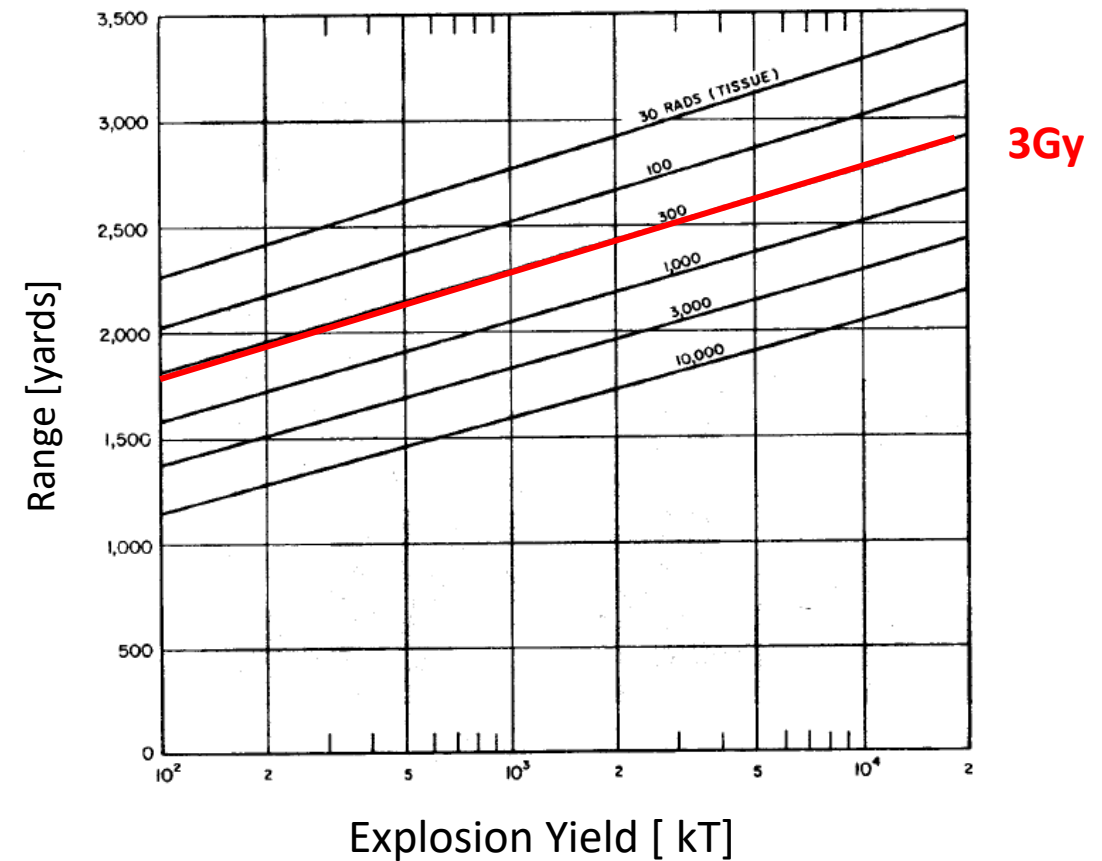


Neutron doses after nuclear explosion

Fission warhead



Fusion warhead



Neutron doses in Gy not in Sv (w_R valid for stochastic effects)

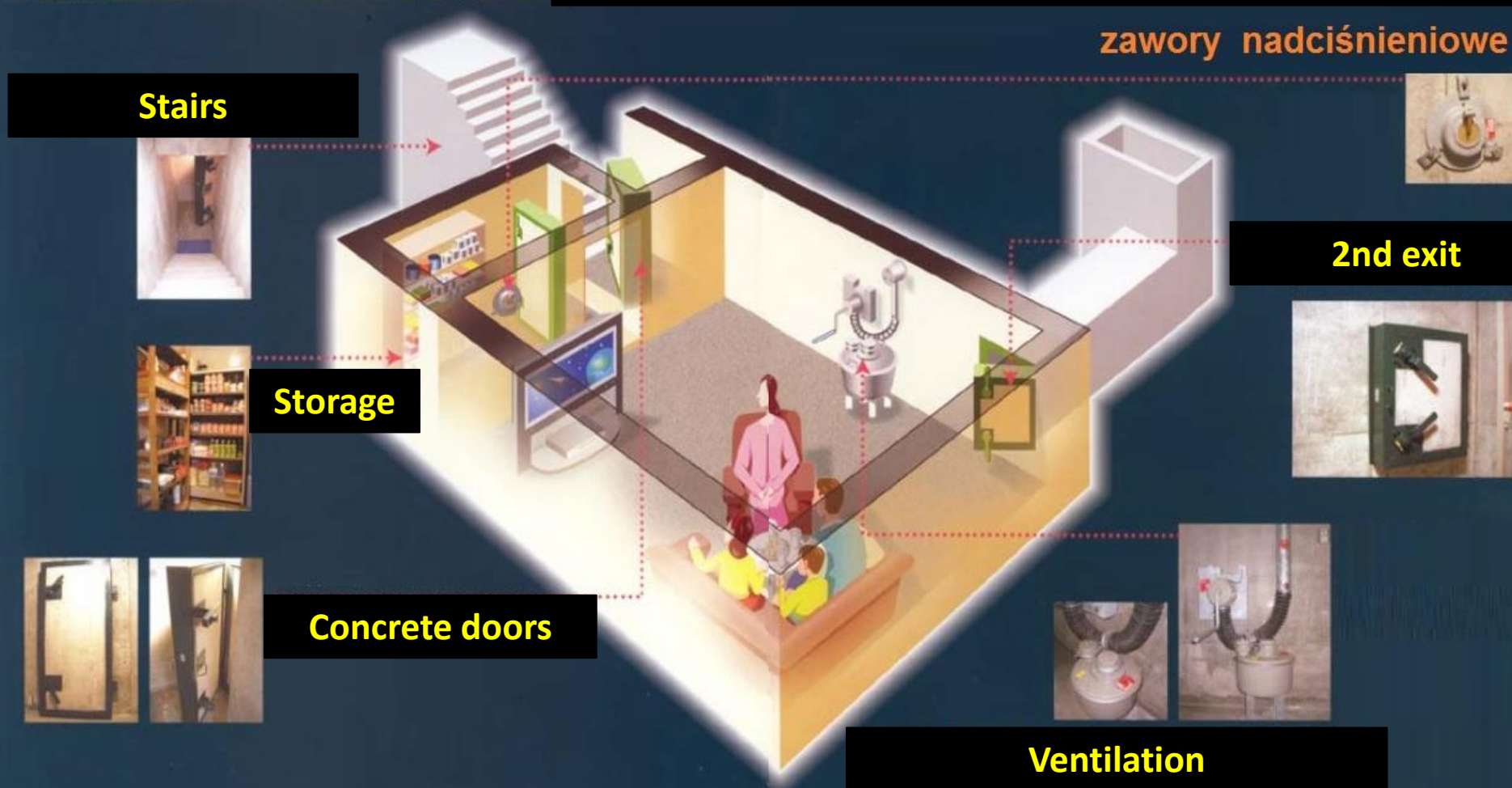
(Glastone & Dolan, 1977)

Dose transmission factors for various structures

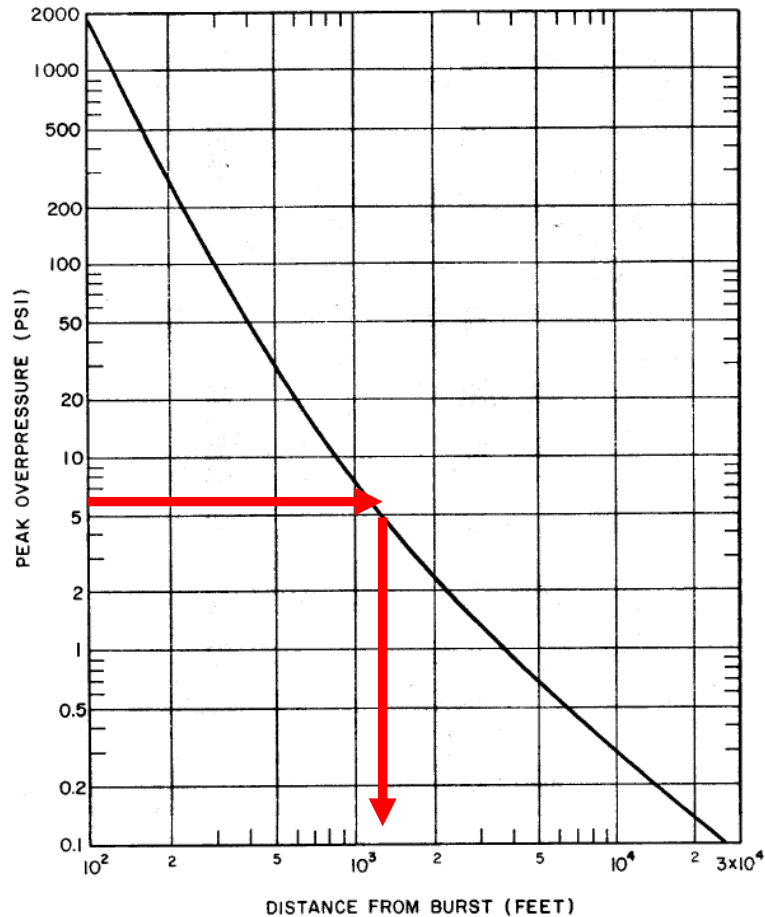
Structure	Delayed γ-rays	Neutrons
Basement	0.1- 0.6	0.1 - 0.8
Multistore building		
Upper stories	0.8-0.9	0.9-1.0
Lower stories	0.3-0.6	0.3-0.8
Concrete shelter (30 cm)	0.05 -0.1	0.2-0.4
Shelter with		
60 cm earth cover	0.03-0.07	0.02 - 0.08
100 cm earth cover	0.007-0.02	0.01- 0.05



Shelters



Damaging factors of a nuclear attack – blast (shock wave)



Peak overpressure from 1kT free burst at the ground

Total destruction of buildings

5 psi = 0.35 kg/cm² = 3500 kg/m²



The 5psi region of destruction after airblast 800 kT at 500 m,
radius of 4.8 km

<https://nuclearsecrecy.com/nukemap/>



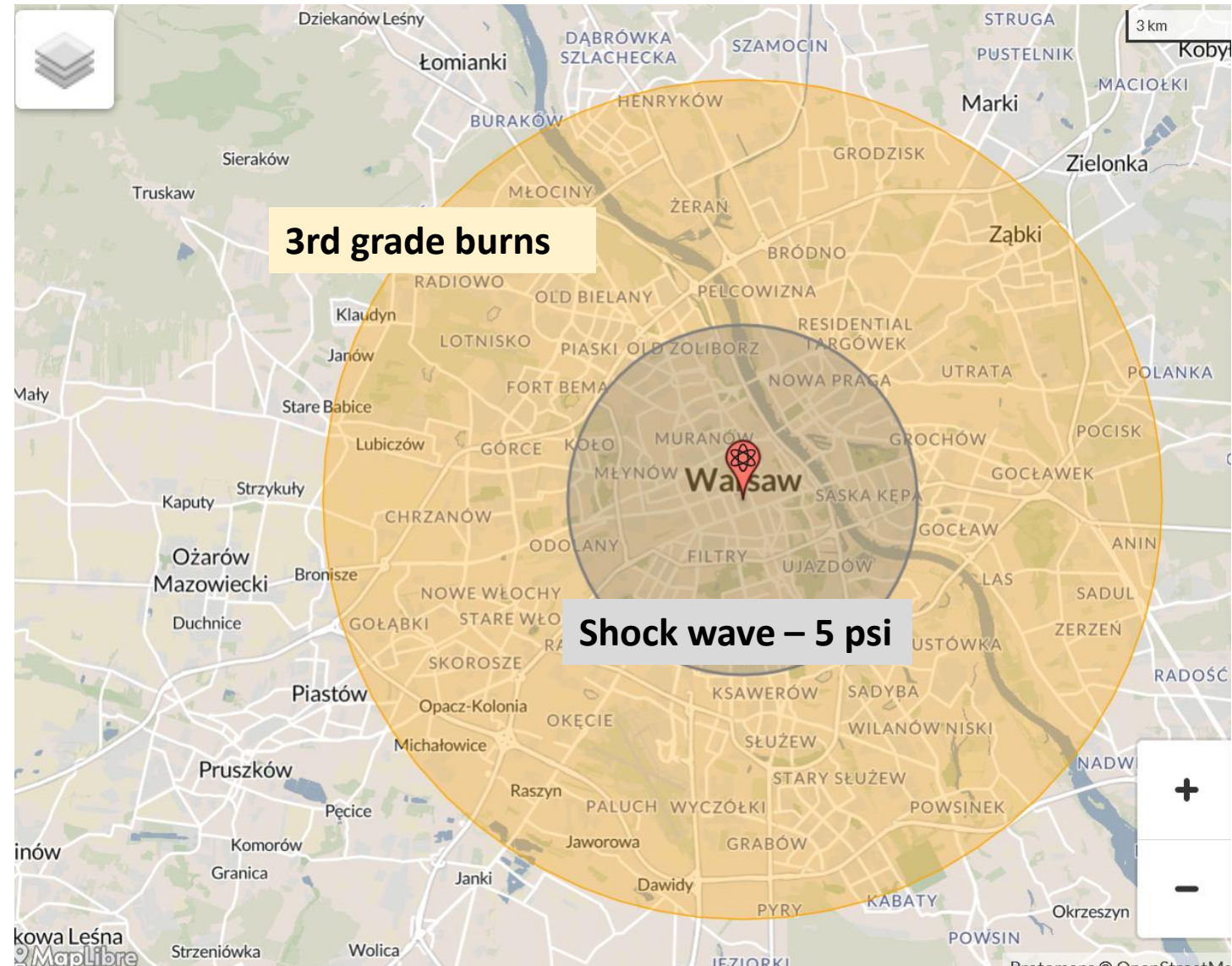
Damaging factors of a nuclear attack - thermal radiation

An intense flash of heat and light:

- blind people
- ignite fires
- of 3rd degree burns (50%), radius of 11 km

Firestorms:

injure or kill people trapped in shelters by lack of oxygen



airblast 800 kT at 500 m

<https://nuclearsecrecy.com/nukemap/>

Damage zones after nuclear explosion: shock wave, thermal and ionizing radiation

Parameters of the explosion

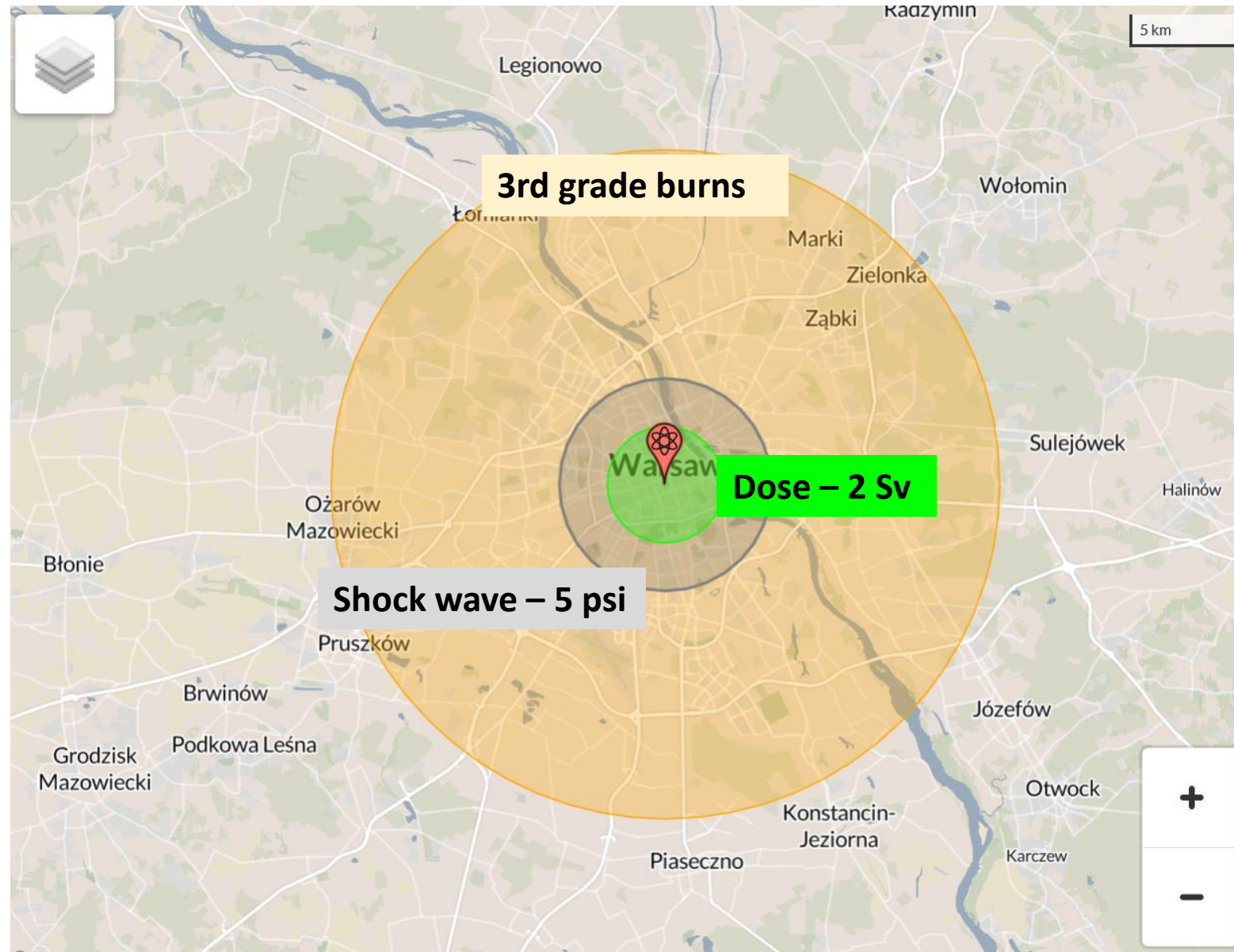
- Fusion warhead 800 kT
- Burst in air at 500 m

Radiation radius (2 Sv) – 2.6 km

Shock wave – (5 psi) - 4.8 km

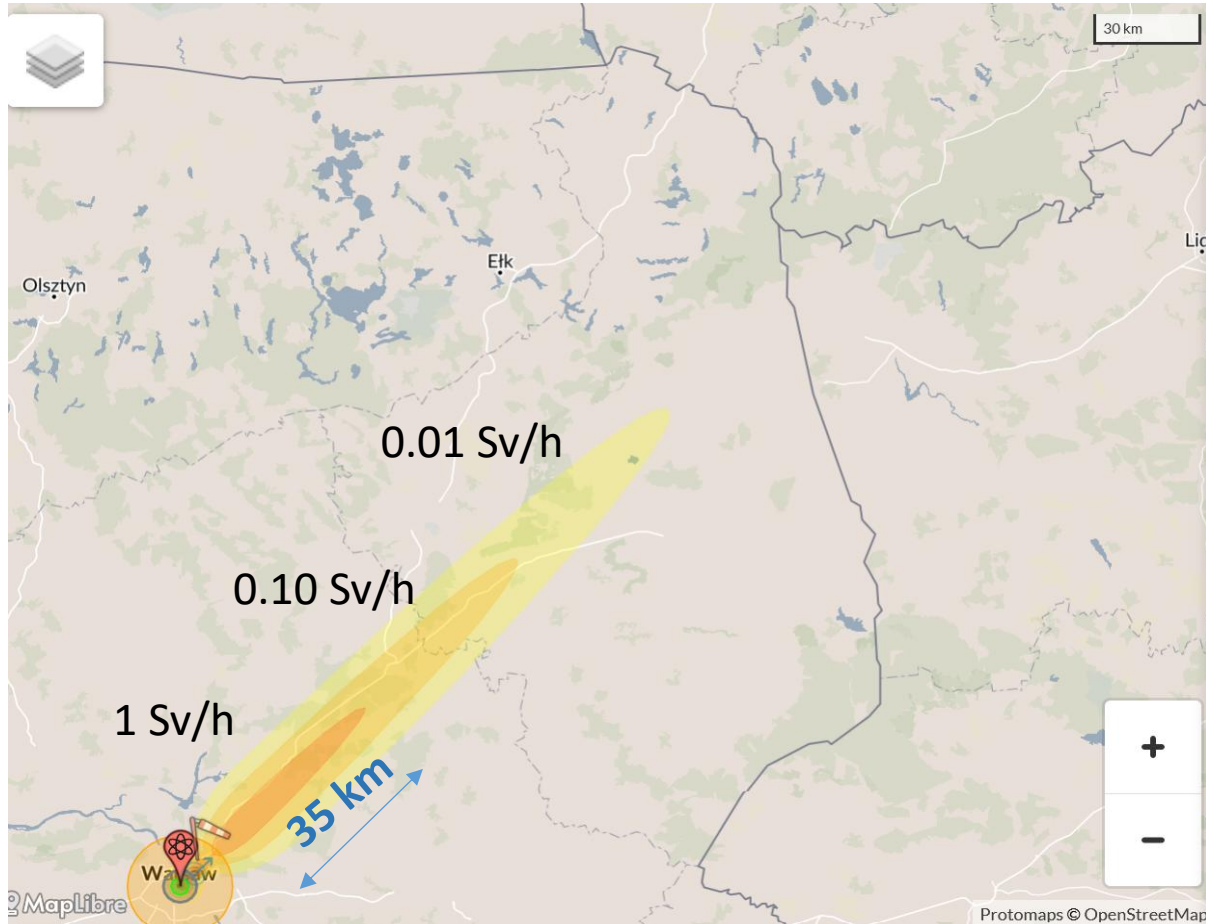
3rd grade burns (50%) - 11 km

At distances where exposure leads to lethal doses, shock wave and thermal radiation are the main risk factors.

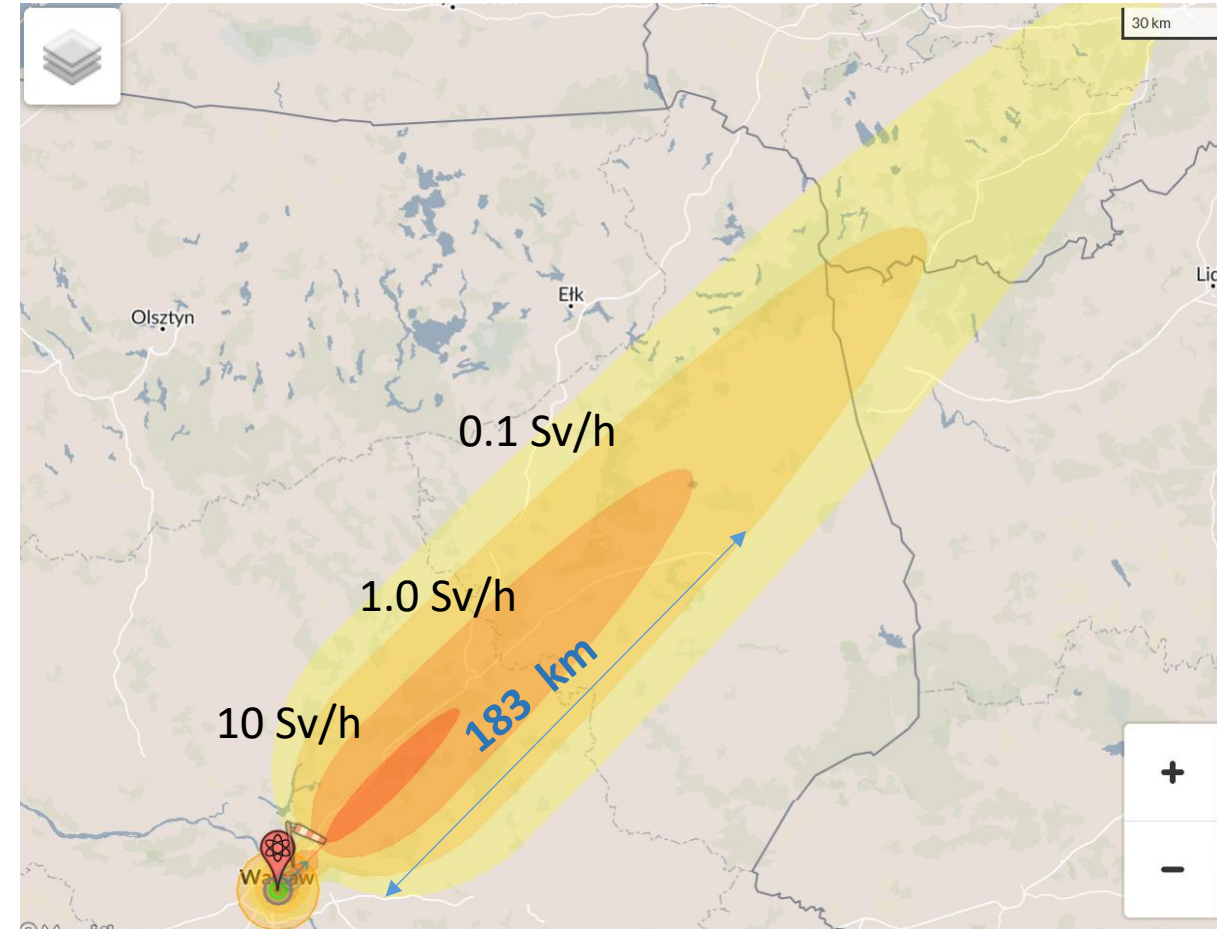


Radioactive fall-out depends on the height of the explosion

800 kT, **burst at 500 m in air**



800 kT, **burst at 0 m**



The explosion on the ground activates a vast amount of material, leading to radioactive fallout consisting primarily of short-lived beta isotopes. Radiation doses in open space are significant.

Dose rate from early fallout decreases very fast

After the explosion you have 10-60 minutes to hide

This delay depends on atmospheric conditions

- after 24 h - decrease of dose rate 500 times
- after a week - decrease of dose rate 5000 times

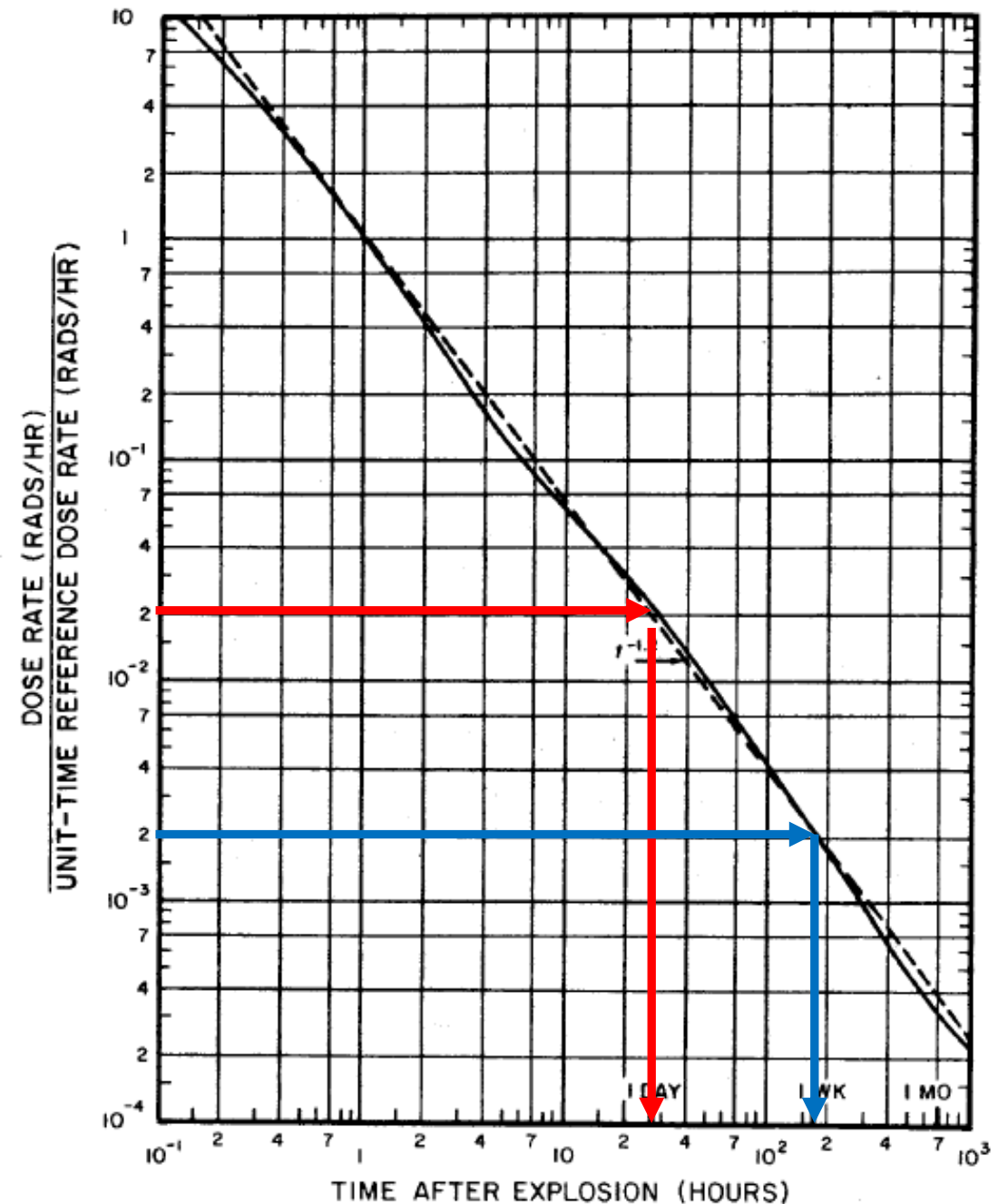


Figure 9.16a. Dependence of dose rate from early fallout upon time after explosion.

Fallout – what is more dangerous: external or internal exposure?

- Contamination with radioactive fallout is NOT immediately life-threatening (...)
- The hazard from external exposure - YES
- Never delayed urgent medical treatment due to contamination concerns.
- Shelter should never be denied due to contamination concerns.
- External decontamination can be self-performed e.g., brushing off clothes and skin.
- Mass decontamination (i.e. fire hose wash down) in colder climates can result in more casualties from hypothermia than would have occurred from contamination.

HOW TO STAY SAFE IN THE EVENT OF A NUCLEAR EXPLOSION

**WHAT TO DO:
NOW
Prepare**

Identify shelter locations. Identify the best shelter location near where you spend a lot of time, such as home, work, and school. The best locations are underground and in the middle of larger buildings.

While commuting, identify appropriate shelters to seek in the event of a detonation.

Outdoor areas, vehicles and mobile homes do NOT provide adequate shelter. Look for basements or the center of large multi-story buildings.

Make sure you have an Emergency Supply Kit for places you frequent and might have to stay for 24 hours. It should include bottled water, packaged foods, emergency medicines, a hand-crank or battery-powered radio to get information in case power is out, a flashlight, and extra batteries for essential items. If possible, store supplies for three or more days.

FEMA
FEMA P-2148
Catalog No. 17235-10

**WHAT TO DO:
DURING
Survive**

If warned of an imminent attack, immediately get inside the nearest building and move away from windows. This will help provide protection from the blast, heat, and radiation of the detonation.

If you are outdoors when a detonation occurs take cover from the blast behind anything that might offer protection. Lie face down to protect exposed skin from the heat and flying debris. If you are in a vehicle, stop safely, and duck down within the vehicle.

After the shock wave passes, get inside the nearest, best shelter location for protection from potential fallout. You will have 10 minutes or more to find an adequate shelter.

Be inside before the fallout arrives. The highest outdoor radiation levels from fallout occur immediately after the fallout arrives and then decrease with time.

Stay tuned for updated instructions from emergency response officials. If advised to evacuate, listen for information about routes, shelters, and procedures.

If you have evacuated, do not return until you are told it is safe to do so by local officials.

**WHAT TO DO:
AFTER
Be Safe**

Immediately after you are inside shelter, if you may have been outside after the fallout arrived:

Remove your outer layer of contaminated clothing to remove fallout and radiation from your body.

Take a shower or wash with soap and water to remove fallout from any skin or hair that was not covered. If you cannot wash or shower, use a wipe or clean wet cloth to wipe any skin or hair that was not covered.

Clean any pets that were outside after the fallout arrived. Gently brush your pet's coat to remove any fallout particles and wash your pet with soap and water, if available.

It is safe to eat or drink packaged food items or items that were inside a building. Do not consume food or liquids that were outdoors uncovered and may be contaminated by fallout.

If you are sick or injured, listen for instructions on how and where to get medical attention when authorities tell you it is safe to exit.

Where to go in a Radiation Emergency

● NOT SAFE
● SAFER
● SAFEST

Take an Active Role in Your Safety

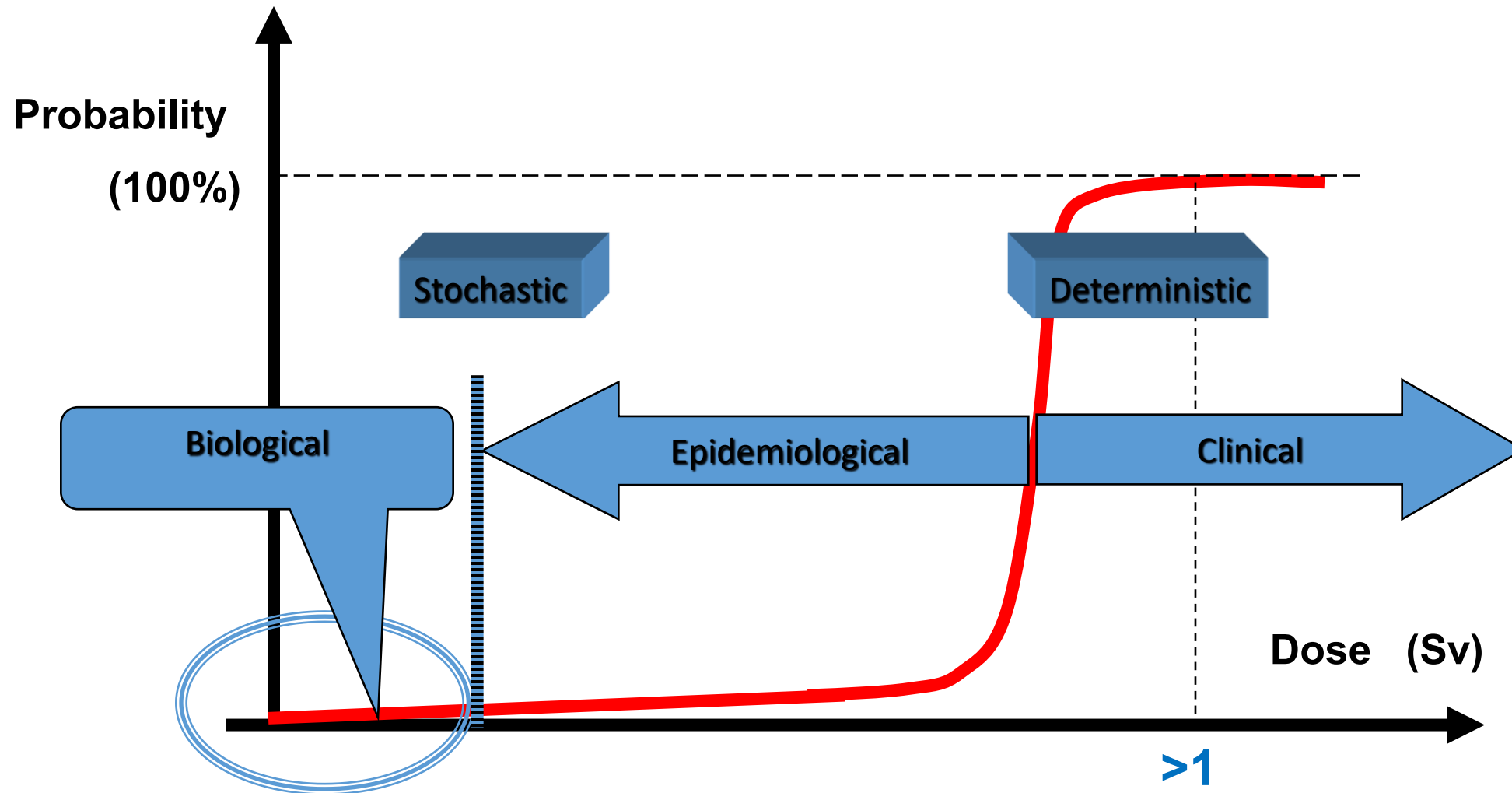
Download the **FEMA** app to get more information about preparing for a nuclear explosion.

Go to **Ready.gov**: <https://www.ready.gov/nuclear-blast>

Go to the **Centers for Disease Control**: <https://emergency.cdc.gov/radiation>

Go to **Health & Human Services**: <https://www.remm.nlm.gov/nuclearexplosion.htm>

Health Effects After Exposure to Ionizing Radiation



Deterministic effects of acute irradiation

Absorbed dose [Gy]	Effects
0.25-0.50	First symptoms (white cells)
1.00	Vomiting (after few hours after exposure)
3.20 – 3.60	~ 50% dies in 60 days (by limited medical support)
4.80 – 5.40	~50 % dies in 60 days (with advanced medical treatment)
10.00	~ 100% dies in 30 days

. Howard Matis - hsmatis@lbl.gov

Dose thresholds for selected tissue/organ damage

Table 2.1. Dose thresholds for selected tissue/organ damage. Information given in parentheses indicates timeline of occurrence of effect.

Effect	Threshold
Fatality (within weeks)	2–3 Gy acute dose to the whole body with good medical care 4–8 Gy protracted over 1 week 10–14 Gy in 1–3 months assuming good medical care
Skin burn on large areas (2–3 weeks)	5 Gy acute dose to the skin
Permanent sterility (males) (3 weeks)	6 Gy acute dose to the gonads
Permanent sterility (females) (<1 week)	3 Gy acute dose to the ovaries
Increased risk of circulatory disease (>10 years)	0.5 Gy to the heart or brain
Cataract induction (>20 years)	0.5 Gy to the lens of the eye

ICRP 146 (2020) *Radiological Protection of People and the Environment in the Event of a Large Nuclear Accident*

Dose assesment after the explosion?

Accidental dosimetry:

- biodosimetry
- physical dosimetry: EPR, TL, OSL

Supplementary methods:

- bioassays,
- neutron activation,
- radiation field mapping.

After large scale attack the immediate assessment of absorbed dose in a big population is fairly impossible

Journal of the ICRU

ICRU REPORT 94

Methods for Initial-Phase Assessment of Individual Doses Following Acute Exposure to Ionizing Radiation

Paola Fattibene
Werner Ruehm
Antonella Testa
François Trompier
Clemens Woda



Dose assesment after the explosion?

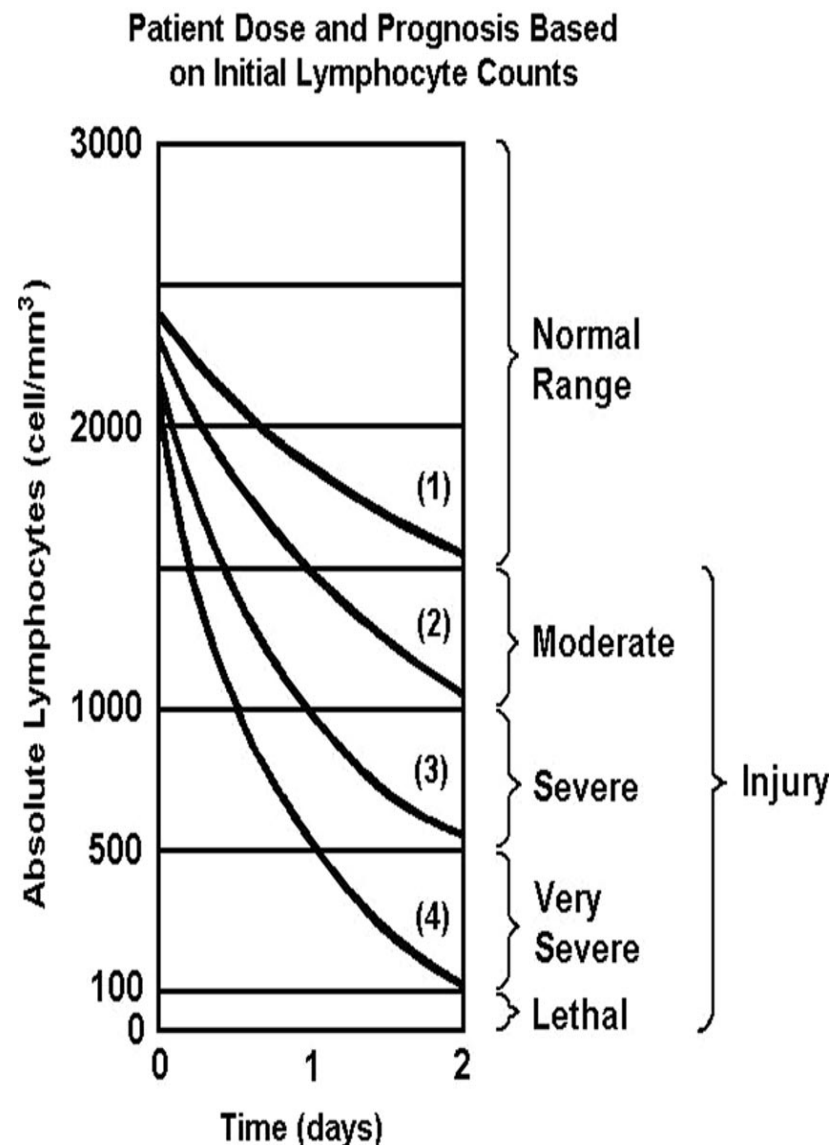
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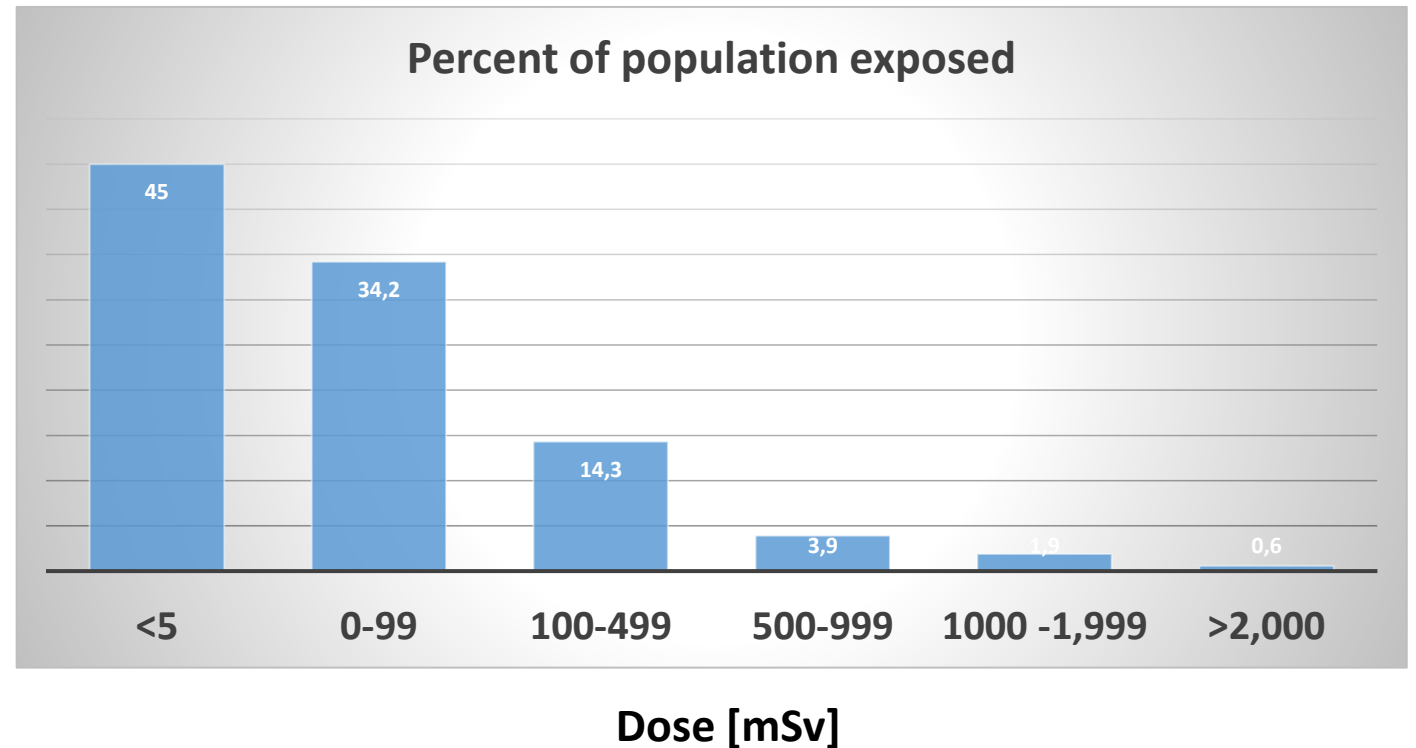
After large scale attack the immediate assessment of absorbed dose in a big population is fairly impossible



Effects of exposure: population of Hiroshima and Nagasaki

Population of Hiroshima and Nagasaki

Known doses:	86 720
Unknown:	7 021
Not in the city:	26 580
Total:	120 321



Preston et al, Radiat Res 160:381-407, 2003)

Almost 80% of population received relatively low doses below 100 mSv

Effects of exposure: mortality and the resulting risk factors

Mortality

Expected: ~ **8895 deaths**

Observed : **9355 deaths**

440 deaths attributed to radiation exposure

47 years of observation (1950-1997)

Preston et al, Radiat Res 160:381-407, 2003)

Risk factors (ICRP 60, 1990)

After 1 Sv of effective dose

~0.9% for leukemia

~9% solid cancer (men)

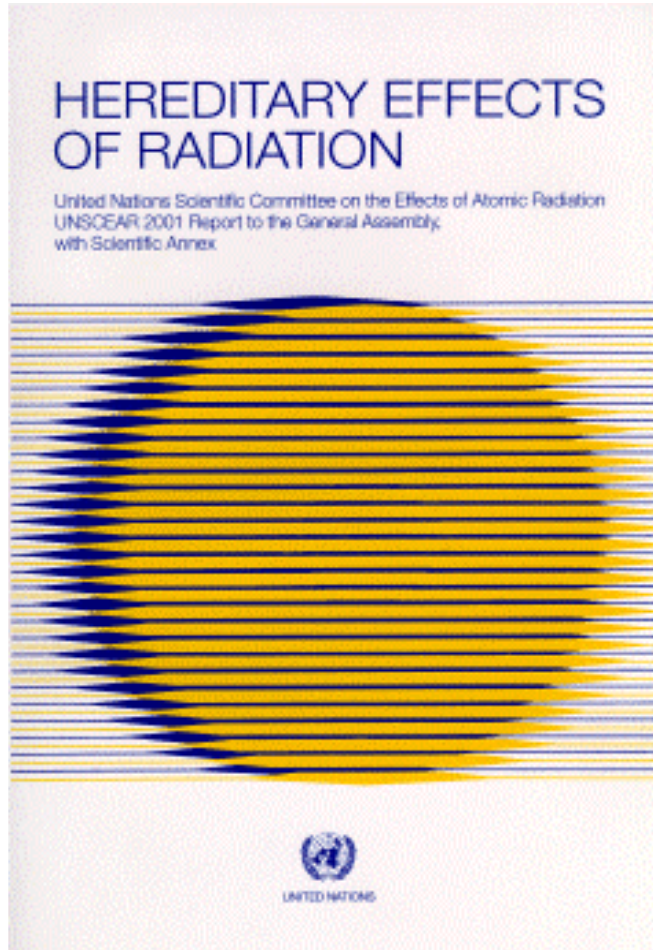
~13% solid cancer (women)

mean: ~11%

Dose and Dose Rate Effectiveness Factor (DDREF) = 2

~5% na 1000 mSv

Hereditary effects of radiation



Ionizing radiation damages the genetic material in reproductive cells and may result in mutations that are transmitted from generation to generation.

Risk of hereditary effects after exposure of parents:

0.3 - 0.5% on 1 Sv

"natural background" of genetic changes 0.4-0.6%

Prenatal exposure – the most significant effect

Exposure of fetus leads to increasing the risk of:

- small head size
- mental retardation,
- lower intelligence quotient (IQ)

Effect of fetus exposure (8-15 week of pregnancy):

**A significant shift of IQ : up to 30 IQ units per 1 Sv
in 50 % of children**

but observed only for doses > 0.2 Sv



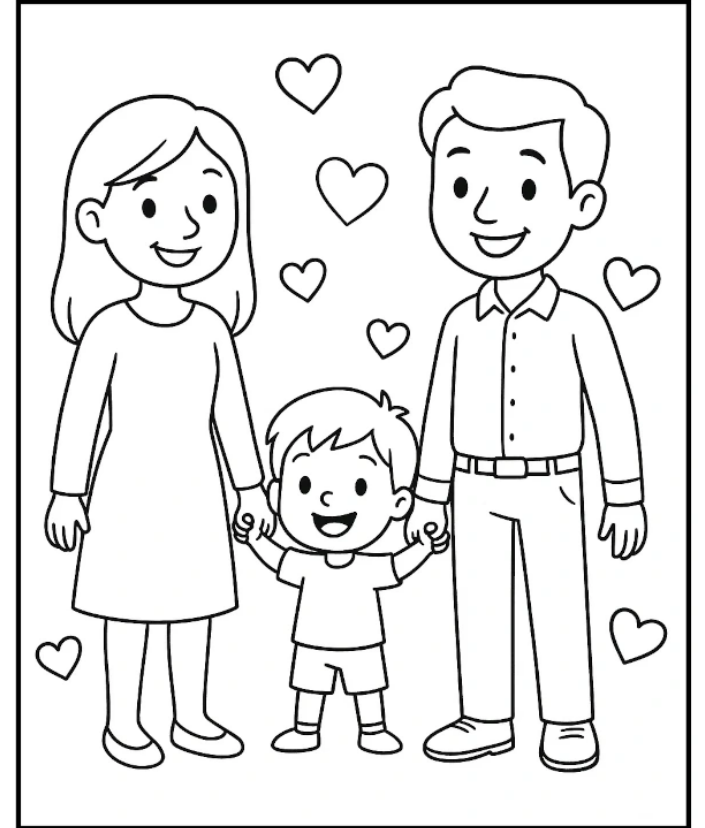
Childhood cancer incidence following parental exposure

No association was found between parental gonadal exposure and an increased risk of childhood cancer or other types of death.

No such association was found in adults whose parents were exposed to radiation.

“Risk of Death among Children of Atomic Bomb Survivors after 62 Years of Follow-up: A Cohort Study”

Eric J. Grant, Kyoji Furukawa, Ritsu Sakata, Hiromi Sugiyama, Atsuko Sadakane, IkunoTakahashi, Mai Utada, Yukiko Shimizu, Kotaro Ozasa
Lancet Oncol 2015 (October); 16(13):1316-23
(doi:10.1016/S1470-2045(15)00209-0)



Summary of the risk coefficients

Deterministic effects observed $D > 1.0 \text{ Sv}$

Stochastic effects observed for $D > 0.2 \text{ Sv}$

- $\sim 50\%/\text{Sv}$ for prenatal exposure
- $\sim 5 \text{ } \%/ \text{Sv}$ for solid cancer (for short exposures $11\%/\text{Sv}$)
- $\sim 0.5 \text{ } \%/ \text{Sv}$ for hereditary effects



EURADOS

The risks associated with exposure to ionizing radiation are much lower than those associated with exposure to blast (shock wave) and thermal radiation.

Advice for the Public on Protection in Case of a Nuclear Detonation

A nuclear detonation may occur without warning. It may result in mass casualties.

There are steps you can take to protect yourself and your family from the radiation after a nuclear detonation.

Go inside and stay inside. Get inside the center of a building or basement to put as much material between you and the radioactive material outside.

[THE FIRST 10 MINUTES](#)

[THE FIRST 24 HOURS](#)

[THE NEXT 48 HOURS](#)

[UNDERSTAND THE HAZARDS](#)

[HOW TO BE PREPARED FOR A NUCLEAR
DETONATION](#)

[RESPONDING TO ALERTS](#)

www.icrp.org

How to be prepared for a nuclear detonation?

Identify potential shelters

Agree with your family and friends about your actions

Add name tags to the clothes of small children

Prepare and store the following items in your shelters:

- A survival kit (flashlight, power banks, a battery-powered AM radio)
- A first aid kit with tools and medication
- A stock of water (2 L per day per person) for 2 weeks
- Several days of long-life food
- Spare clothes and footwear.



The first 10 minutes



The best thing you can do after a nuclear detonation is go inside. Put as much material as possible between you and the radioactive material outside.

The best way to protect you and your family before, during, and after a nuclear blast is getting inside the centre of a building or basement. Be inside before the fallout arrives

The first 24 hours

Outer layers of contaminated clothing and footwear should be removed, and any exposed skin and hair wiped off or washed.

Food, drink, and medicine already in stores (shops) or in your shelter are safe to consume.

Tune in to any available media, such AM/FM stations using a battery-powered radio, for updated instructions. Stay inside unless instructed otherwise.

Remain in the most protective location (basement or centre of a large building) for the first 12 – 24 hours unless threatened by an immediate hazard

Self-evacuation is strongly discouraged



Summary

The nuclear attack brings a devastating destruction due to blast (shock wave) and thermal radiation.

The area of high (lethal) radiation doses are well within area of a total devastation by shock waves (blast) and thermal radiation.

Sheltering during and some days after attack (radioactive fall-out) leads to significant reduction of absorbed doses.

Sheltering will mostly prevent clinical effects and significantly reduce risk of stochastic effects.