Physics 280: Session 8

Plan for This Session

Conclusion of Module 2:
Nuclear Weapons

Definition:
Weapons of mass destruction

Module 3:
Effects of nuclear explosions

Plutonium Is Created in Nuclear Reactors

The fissile nuclide Pu-239 can be created by bombarding U-238 with neutrons in a nuclear reactor —

- U-238 + n → Pu-239 (via a two-step process)

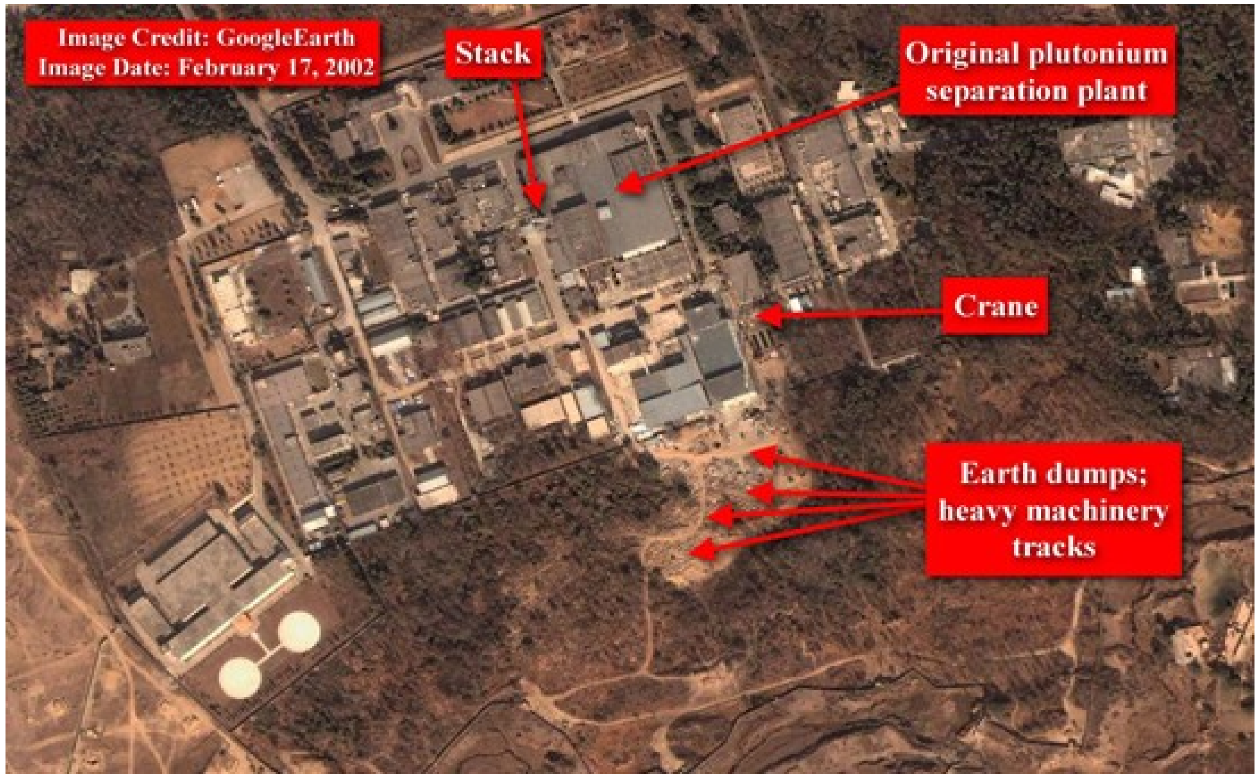
(non-fissile) (fissile)

N Reactor, Hanford, WA

Reactor, Yongbyon, NK

Plutonium Must Then Be Chemically Separated from Uranium and Other Elements

224-B Plutonium Separation Plant, Hanford, WA, 1985



Plutonium Separation Plant Rawalpindi, Pakistan, Feb 2002

Plutonium is extracted from the uranium fuel rods by first dissolving the rods to form a slurry and then extracting the trace amounts of plutonium in the slurry by chemically processing the slurry.

Producing a Nuclear Explosion Using Plutonium – 1

- **Virtually any combination of plutonium isotopes can be used to make a nuclear weapon.**

- Not all combinations, however, are equally convenient or efficient.

- Pu-239 is produced when the most common isotope of uranium, U-238, absorbs a neutron and then quickly decays to plutonium.

- Pu-239 is the most useful isotope for making nuclear bombs. It is produced in varying quantities in virtually all operating nuclear reactors.

Producing a Nuclear Explosion Using Plutonium – 2

- As fuel in a nuclear reactor is exposed to longer and longer periods of neutron irradiation, heavier isotopes of plutonium build up, as some of the plutonium absorbs additional neutrons, creating Pu-240, Pu-241, and so on.

- Pu-238 also builds up from a chain of neutron absorptions and radioactive decays starting from U-235.

- Plutonium with substantial quantities of Pu-238, Pu-240, Pu-241, Pu-242 is called “high burn-up” or “reactor-grade” plutonium.

- High burn-up plutonium can approach ~ 40% Pu-239, ~ 30% Pu-240, ~ 15% Pu-241, and ~ 15% Pu-242.

Producing a Nuclear Explosion Using Plutonium – 3

Producing a nuclear explosion is much easier if the plutonium is “weapon-grade” (defined as more than 93% Pu-239).

Producing a nuclear explosion is more difficult using reactor-grade plutonium —

•It is impractical to separate Pu-239 from Pu-240 (it has never been done on a large scale)

•Pu-240 and heavier Pu isotopes are highly radioactive (“hot”) and hence difficult to handle

•This radioactivity is likely to cause pre-initiation, producing a “fizzle” rather than a full-yield explosion

Even so, a bomb *can* be made using reactor-grade Pu. The U.S. tested such a bomb in 1962 to demonstrate this.

Producing a Nuclear Explosion Using Plutonium – 4

- Because of the preference for relatively pure Pu-239 for making bombs, **when a reactor is used specifically for creating weapons plutonium, the fuel rods are removed and the plutonium is separated from them after a relatively brief period of irradiation**. The resulting “low burn-up” plutonium has a higher concentration of Pu-239.

- However, brief irradiation is very inefficient for power production. Hence, **in power reactors the fuel is left in the reactor much longer, producing “high burn-up” ("reactor grade") plutonium, which is less suitable for bombs**.

A Nuclear Explosion Can Be Produced Using Reactor-Grade Plutonium – 1

Use of reactor-grade plutonium complicates bomb design for several reasons. One of the most important is that
Pu-240 has a high rate of spontaneous fission and therefore will continually produce many background neutrons.

- In a well-designed nuclear explosive using weapons-grade plutonium, a pulse of neutrons is released to start the chain reaction at the optimal moment, but there is some chance that a background neutron from spontaneous fission of Pu-240 will set off the reaction prematurely. This is called "pre-initiation”.

- With reactor-grade plutonium, the probability of pre-initiation is very large. Pre-initiation can substantially reduce the explosive yield, since the weapon may blow itself apart earlier, cutting short the chain reaction that releases energy.

A Nuclear Explosion Can Be Produced Using Reactor-Grade Plutonium – 2

- However, calculations demonstrate that ***even if pre-initiation occurs at the worst possible moment*** (when the material first becomes compressed enough to sustain a chain reaction), ***the explosive yield of even a relatively simple device similar to the Nagasaki bomb would likely be about 1—3 kilotons*.**

- While this yield is referred to as the "fizzle yield", a 1-kiloton bomb would still have a radius of destruction roughly one-third that of the Hiroshima weapon, making it a horrendous weapon.

- Regardless of how high the concentration of troublesome isotopes is, the yield would not be less than this. With a more sophisticated design, weapons could be built with reactor- grade plutonium that would be assured of having higher yields.

A Nuclear Explosion Can Be Produced Using Reactor-Grade Plutonium – 3

In short, *it would be quite possible for a potential proliferator to make a nuclear explosive from reactor-grade plutonium using a simple design that would be assured of having a yield in the range of one to a few kilotons, or more if a more advanced design were used*.

Hence theft of separated plutonium, whether weapons-grade or reactor-grade, poses a grave security risk.

Categories of Nuclear Explosive Materials (Very Important)

- Uranium —
  - –LEU: < 20% U-235
  - –Weapons-usable HEU: > 20% U-235
  - –Weapons-grade HEU: > 80% U-235

- Plutonium —
  - –Reactor-grade: < 80% Pu-239 (e.g., light-water)
  - –Fuel-grade: 80% to 93% Pu-239
  - –Weapons-grade: > 93% Pu-239

Physics 280: Session 8

Plan for This Session

Conclusion of Module 2:
Nuclear Weapons

Definition:
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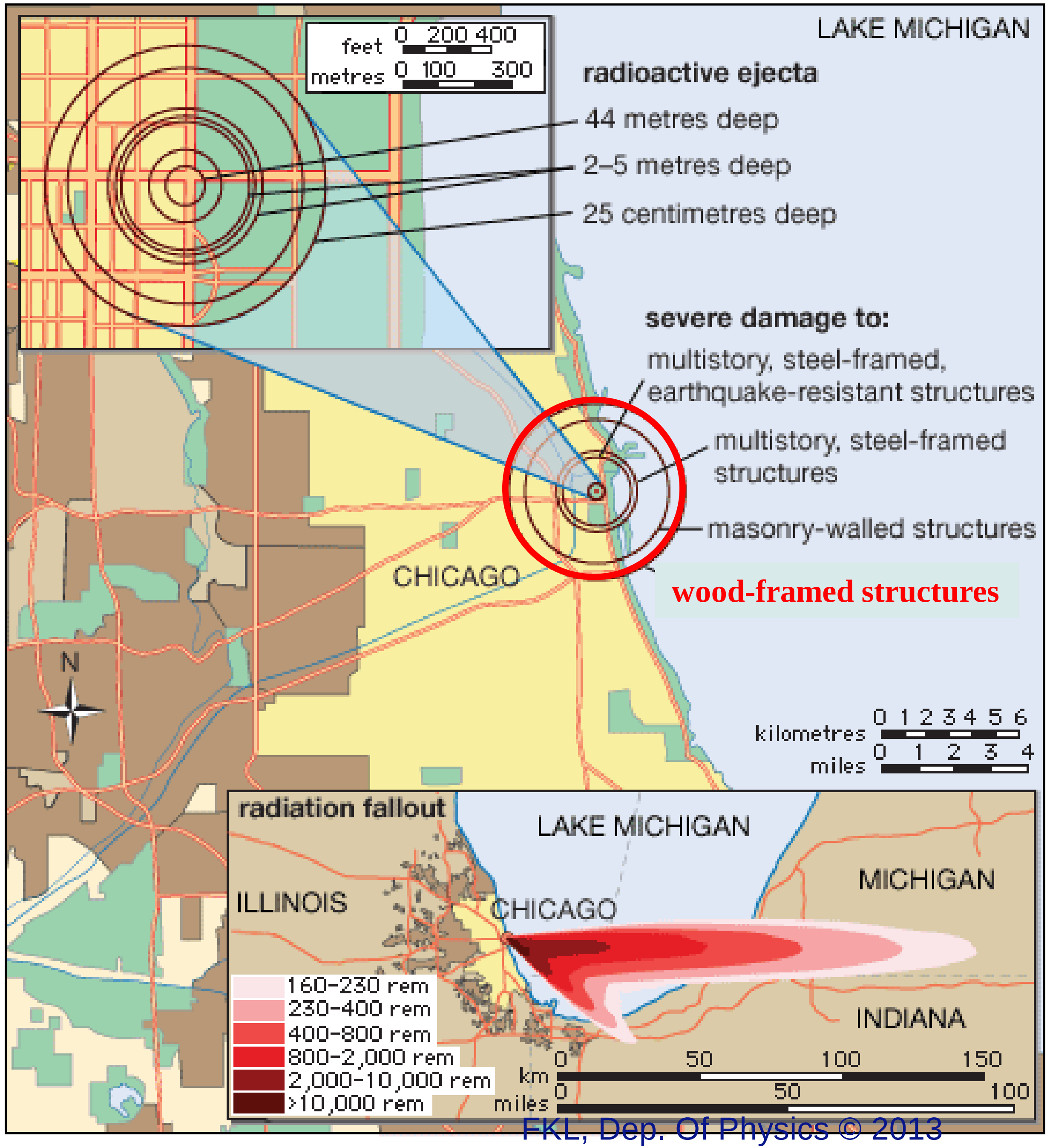
Effects of nuclear explosions

Impact of a 500 kiloton device detonated in Chicago



Impact of the 15 kiloton detonation in Hiroshima on wood-framed structures

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Module 3: Effects of Nuclear Explosions

Topics covered in this module —

- Weapons of mass destruction
- Overview of weapon effects
- Effects of thermal radiation
- Effects of blast waves
- Effects of nuclear radiation
- Possible effects of nuclear war

Effects of Nuclear Explosions

Definition:
“Weapons of Mass Destruction”

“Weapons of Mass Destruction”

Even a simple fission device can release *a million times* more destructive energy per kilogram than conventional explosives.

Nuclear weapons are the only weapons that could —

- Kill millions of people almost instantly
- Destroy the infrastructure and social fabric of the United States

Chemical and biological weapons do not have this capacity.

Only nuclear weapons are “weapons of mass destruction”

Only nuclear weapons threaten the survival of the U.S.

Chemical Weapons

A chemical weapon is a device that releases toxic chemicals.

Release of toxic chemicals in a city would not cause mass destruction but would —

- create fear
- disrupt normal activities
- possibly cause a large number of casualties.

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If dispersed effectively, a chemical agent could contaminate a substantial area.

If toxic enough, it might cause 100s or even 1,000s of casualties, but it would not destroy buildings or vital infrastructure.

Precautions before and rapid medical treatment and decontamination after such a release would reduce substantially the number of casualties, especially for less deadly agents.

Chemical Weapons

gas attack during World War I, 190,000 tons of Gas caused less than 1% of all combat deaths, ~100,000 deaths 1915-1918

Biological Weapons

Release of a biological agent would create fear and disrupt normal activities, but would not cause mass destruction.

In order to cause mass casualties, substantial amounts of agents such as anthrax, smallpox, and plague would have to be converted into tiny particles and then dispersed in an aerosol.

Because these agents are so deadly, the required forms and the equipment needed to disperse them are difficult to come by.

A complex long-term effort would be needed to develop and effectively deliver such an agent.

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A complex long-term effort would be needed to develop and effectively deliver such an agent.

A pathogen such as anthrax that does not produce contagious disease could be used to attack a particular building or area.

A pathogen such as smallpox that produces a deadly contagious disease would be a “doomsday” weapon, because it could kill millions of people worldwide, including the group or nation that released it.

In countries with an effective public health service, prompt quarantine, vaccination, and other measures could reduce greatly the number of casualties, the area affected, and the time required to get the disease under control.

In less-developed countries, a contagious deadly disease could be devastating.

Biological Weapons


Small pox > 300 millions deaths world wide 1900 to 1979 mortality ~ 30%

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Nuclear Weapons

In contrast to a chemical or biological agent, a “small” (10 kiloton) nuclear weapon detonated in a major city would kill more than 100,000 people and reduce tens of square kilometers to rubble almost instantly.

Even a crude nuclear device that fizzled would destroy many square kilometers of a city and kill tens of thousands of people.

A large (1 megaton) nuclear weapon could kill millions of people and destroy hundreds of square kilometers within a few seconds.

Those who survived a nuclear explosion would have to deal with severe physical trauma, burns, and radiation sickness. Vital infrastructure would be destroyed or damaged, and radioactivity would linger for years near and downwind of the explosion.

Unlike the effects of a chemical or biological weapon, the devastating effects of a nuclear weapon on a city cannot be reduced significantly by actions taken before or after the attack.

Radiological Weapons

A radiological weapon is a device that spreads radioactive material
(most likely isotopes used would not be nuclear explosive nuclides!)

Such a weapon is a weapon of mass *disruption*, not mass *destruction.*

Dispersal of a substantial quantity of highly radioactive material in a city would *not* —

- physically damage structures
- immediately injure anyone

It could —

- contaminate a few city blocks with highly radioactive material
- contaminate a larger area with more weakly radioactive material

If explosives were used to disperse the material, the explosion could cause a small amount of damage and some injuries.

Depending on their exposure to radiation and how they were treated afterward —

- 100s or perhaps even 1,000s of people could become sick
- a larger number could have a somewhat higher probability of developing cancer or other diseases later in life

The main effect would be to create fear and disrupt normal activities.

Origin of the Term “Weapons of Mass Destruction”

In recent years some have sought to lump together as “WMD”—

- radiological weapons (“dirty bombs”)
- chemical weapons
- biological agents
- nuclear weapons

Broadening the definition of “WMD” and using it in this way had two main purposes:

- To make nuclear weapons seem no different from other weapons
- To make chemical and biological weapons seem as dangerous as nuclear weapons and therefore a justification for war or even nuclear war

This language was politically motivated and obscures the profound differences in

- the lethality and destructiveness of these weapons
- the timescales on which their effects are felt
- the possibility of protecting against them (or not)

In Physics 280, we will avoid the term “WMD”. Instead, we will say what we mean: “nuclear weapons”, “chemical weapons”, or “biological weapons”.

Question for Discussion

Which of the following countries once had nuclear weapons but gave them up?

(A) Belarus

(B) Kazakhstan

(C) Ukraine

(D) South Africa

(E) All of the above

iClicker Question

Which nuclear processes are important in the *primary* of a modern two-stage bomb?

fission

fusion

fission and fusion

iClicker Answer

Which nuclear processes are important in the *primary* of a modern two-stage bomb?

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iClicker Question

Which nuclear processes are important in the *secondary* of a modern two-stage bomb?

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iClicker Question

Could a terrorist group construct a workable bomb using reactor-grade plutonium?

No

Yes, but with difficulty

Yes, easily

iClicker Answer

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Effects of Nuclear Explosions

Overview of Nuclear Explosions

Effects of Nuclear Explosions (Overview)

- Effects of a single nuclear explosion
  - — Prompt nuclear radiation
  - — Electromagnetic Pulse (EMP)
  - — Thermal radiation
  - — Blast wave
  - — Residual nuclear radiation (“fallout”)
  - — Secondary effects (fires, explosions, etc.)
- Possible additional effects of nuclear war
  - — World-wide fallout
  - — Effects on Earth’s atmosphere and temperature
  - — Effects on physical health, medical care, food supply, transportation, mental health, social fabric, etc.

Credit:

Nuclear Energy Released in a Nuclear Explosion

The total energy released is the “yield” Y

Y is measured by comparison with TNT

By definition —

- 1 kiloton (kt) of TNT = 10^{12} calories
- 1 Megaton (Mt) of TNT = 1,000 kt = 10^{15} calories

1 calorie = the energy required to heat 1 gram of H_2O by 1 degree Celsius (C) = 4.2 J

(1 dietary Calorie [Cal] = 1,000 calories = 1 kcal.)

The nuclear energy is released in less than 1 micro second!

Initial Distribution of Energy From Any Nuclear Explosion (Important)

After ~ 1 microsecond —

- Essentially all of the energy has been liberated
- Vaporized weapon debris has moved only ~ 1 m
- Temperature of debris is ~ 10^7 C (~ center of Sun)
- Pressure of vapor is ~ 10^6 atmospheres

The energy is *initially* distributed as follows —

• Soft X-rays (1 keV)	~ 80%
• Thermal energy of weapon debris	~ 15%
• Prompt nuclear radiation (n, γ, β)	~ 5%

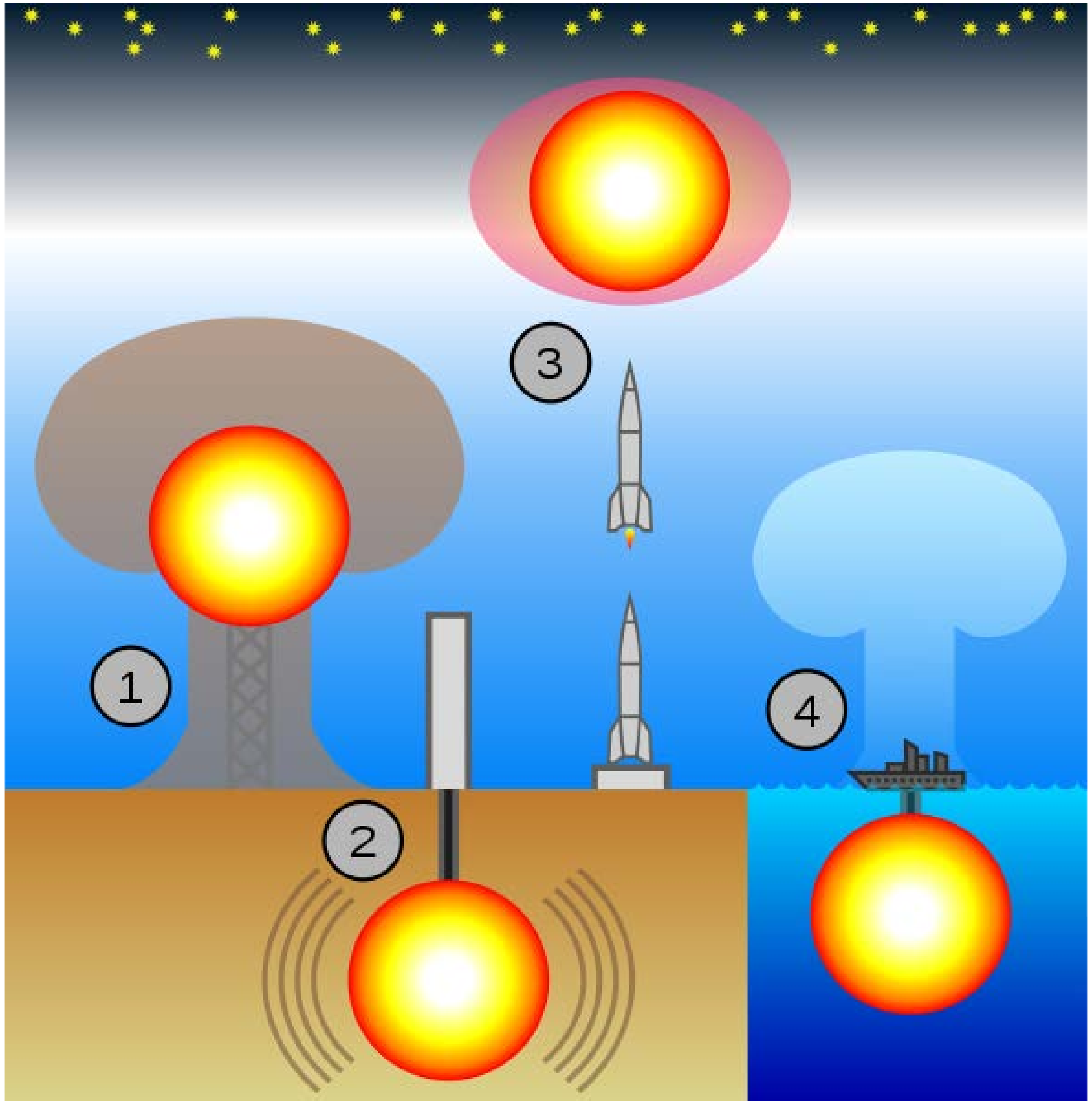
Subsequent Evolution of Nuclear Explosions

What happens next depends on —

- The yield of the weapon
- The environment in which the energy was released

It is largely independent of the weapon design.

Nuclear Explosions



Credit: Wikipedia (nuclear weapons testing)

Possible environments —

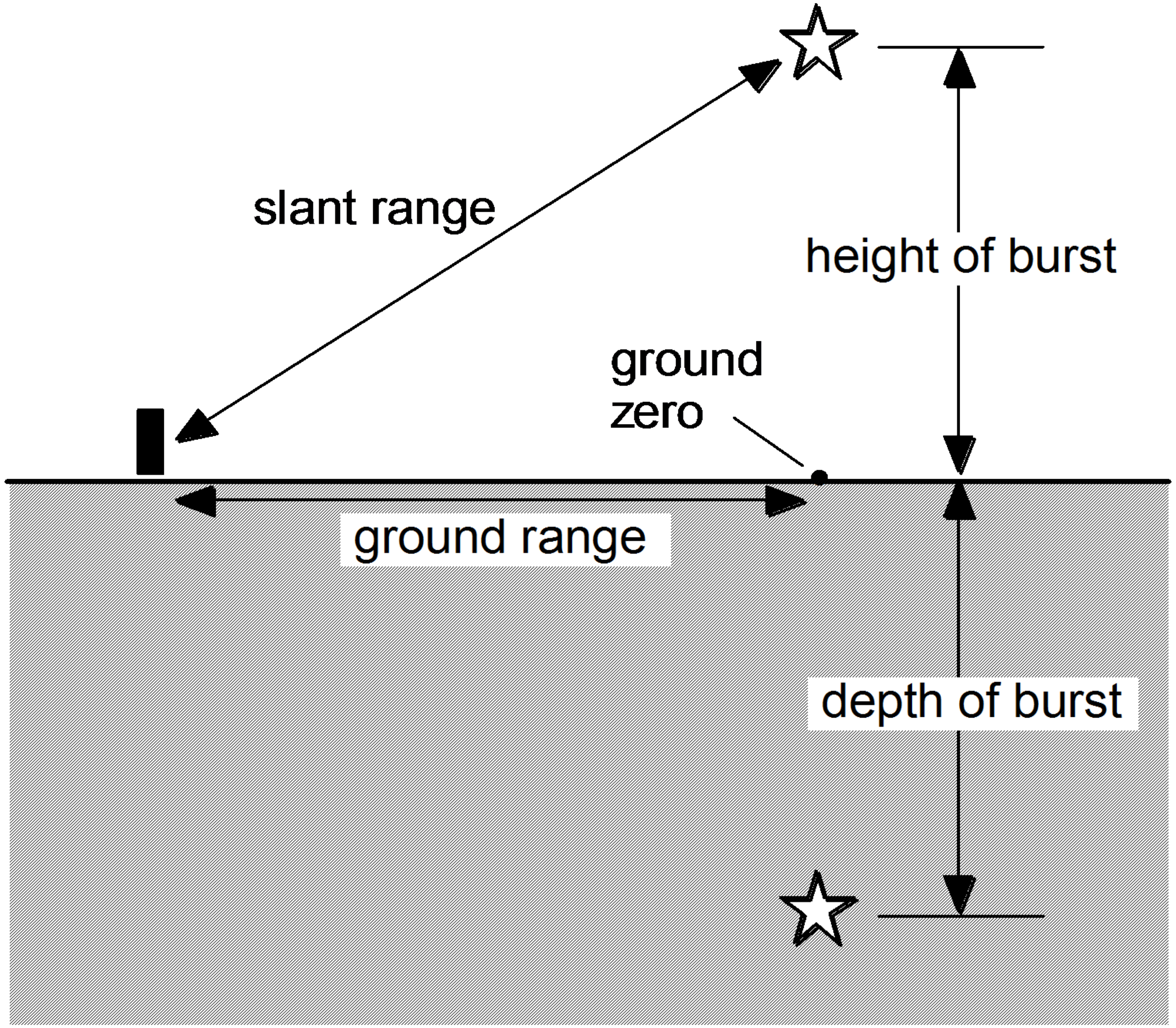
1. Air and surface bursts
2. Underground bursts

3a. Explosions at high altitude (above 30 km)

3b. Explosions in space

4. Underwater bursts

Nuclear Explosion Geometries

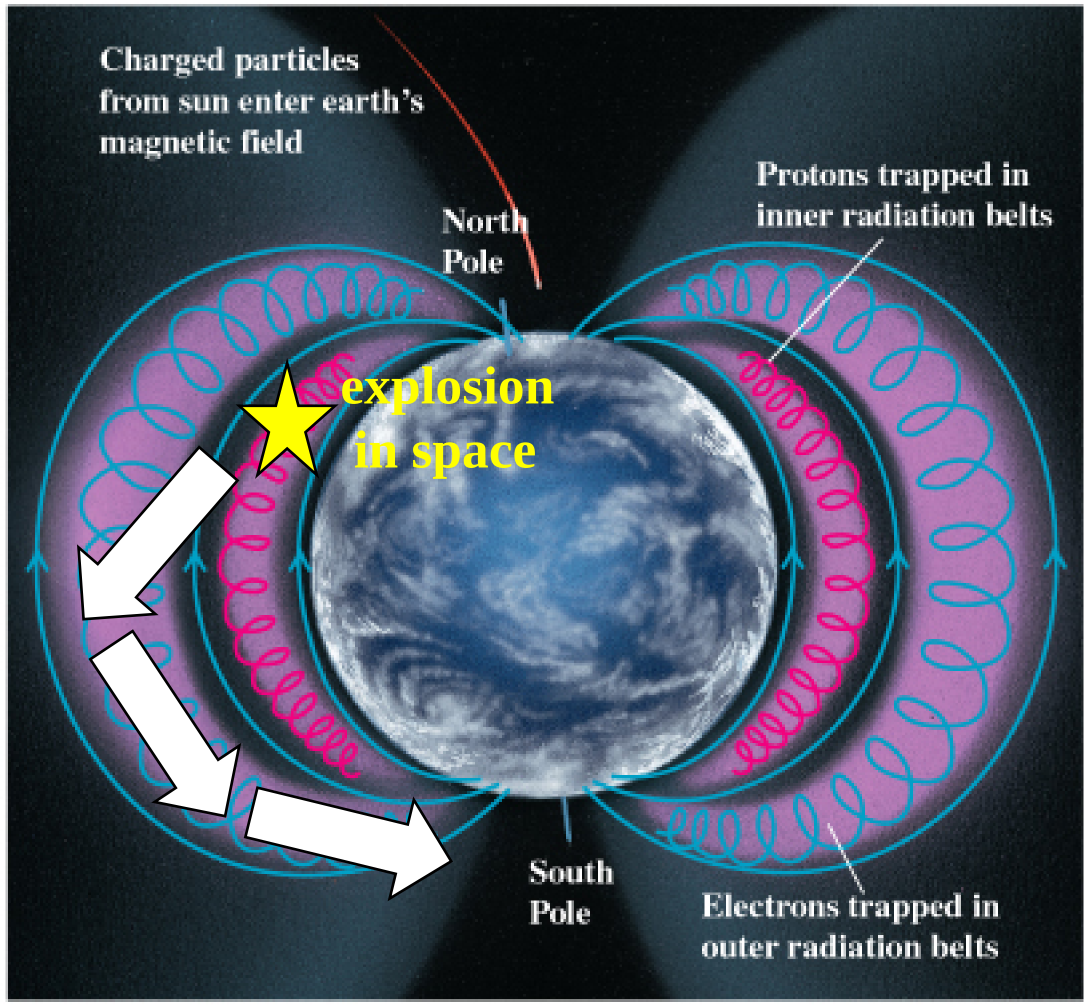


Nuclear Explosions in Space

The U.S. exploded nuclear weapons in space in the late in 1950s and early 1960s –

- Hardtack Series (Johnston Island, 1958)
  - Teak (1 Mt at 52 miles)
  - Orange (1 Mt at 27 miles)
- Fishbowl Series (1962)
  - Starfish (1.4 Mt at 248 miles)
  - Checkmate (sub-Mt at tens of miles)
  - Bluegill (sub-Mt at tens of miles)
  - Kingfish (sub-Mt at tens of miles)

Charged particles trapped in the earch magnetic field
Van Allen Radiation Belt



(a)

Led to discovery of EMP and damage to satellites by particles trapped in the geomagnetic field

Underground Nuclear Explosions

http://www.nv.doe.gov/library/photos/testprep.aspx

Underground Nuclear Explosions

http://www.nv.doe.gov/library/photos/testprep.aspx

http://www.nv.doe.gov/library/photos/craters.aspx

Underground Nuclear Explosions

Fully contained (no venting) —

- No debris from the weapon escapes to atmosphere
- No ejecta (solid ground material thrown up)
- Subsidence crater may form in hours to days
- No radioactivity released (except noble gasses)
- Characteristic seismic signals released

Partially contained (some venting) —

- Throw-out crater formed promptly (ejecta)
- Radiation released (mostly delayed)
- Characteristic seismic signals released
- Venting is forbidden for US and Soviet/Russian explosions by the LTBT (1974) and PNET (1974)

Physics 280: Session 9

Plan for This Session

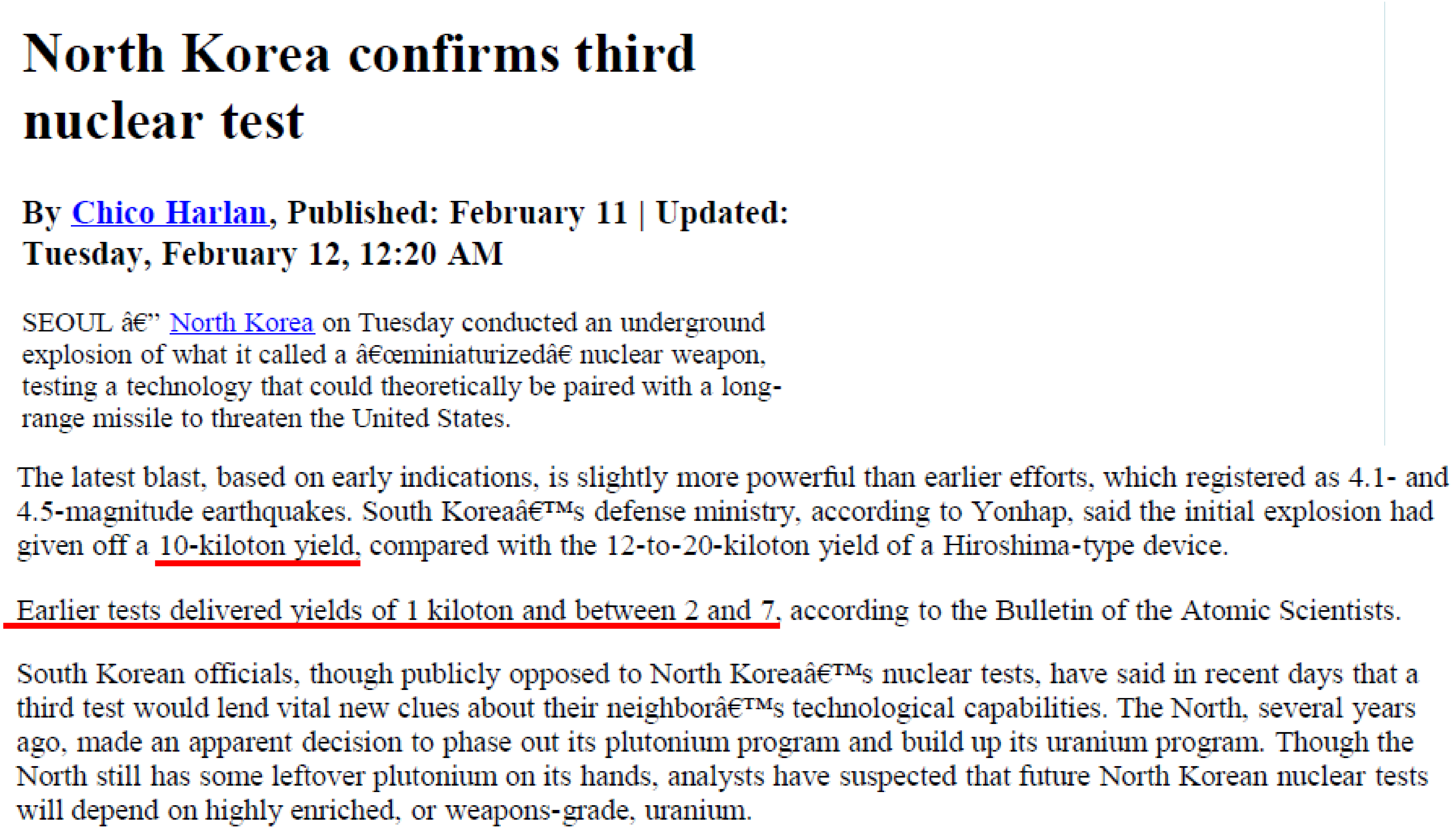
Questions and discussion

News

Module 3: Effects of nuclear explosions (cont’d)

Next session: “Ground Zero” Video presentation

News: North Korea 3^{rd} Nuclear Weapons Test



North Korea confirms third nuclear test

By Chico Harlan, Published: February 11 | Updated: Tuesday, February 12, 12:20 AM

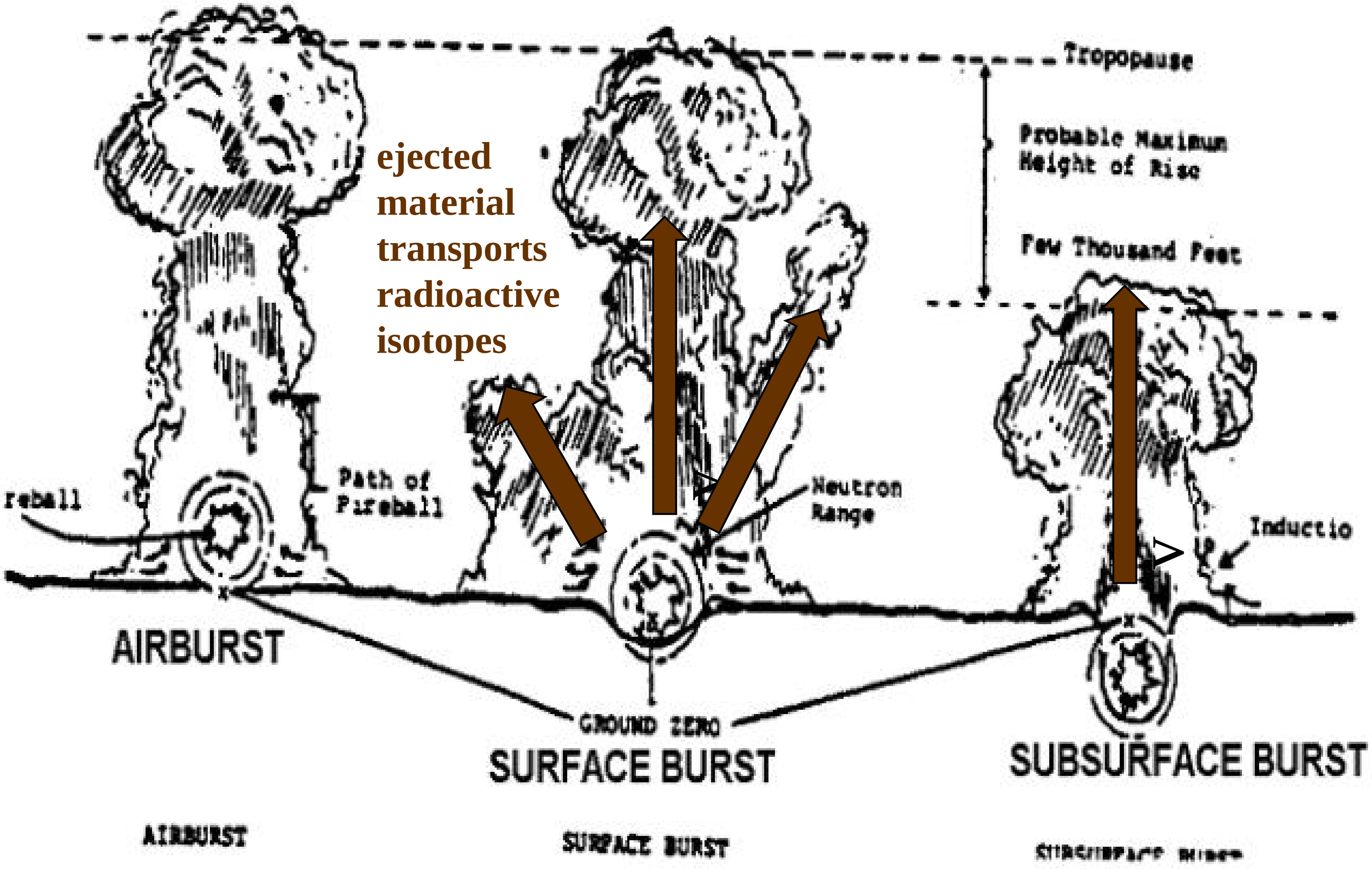
SEOUL â€” North Korea on Tuesday conducted an underground explosion of what it called a â€œminiaturizedâ€ nuclear weapon, testing a technology that could theoretically be paired with a long-range missile to threaten the United States.

The latest blast, based on early indications, is slightly more powerful than earlier efforts, which registered as 4.1- and 4.5-magnitude earthquakes. South Koreaâ€™s defense ministry, according to Yonhap, said the initial explosion had given off a 10-kiloton yield, compared with the 12-to-20-kiloton yield of a Hiroshima-type device.

Earlier tests delivered yields of 1 kiloton and between 2 and 7, according to the Bulletin of the Atomic Scientists.

South Korean officials, though publicly opposed to North Koreaâ€™s nuclear tests, have said in recent days that a third test would lend vital new clues about their neighborâ€™s technological capabilities. The North, several years ago, made an apparent decision to phase out its plutonium program and build up its uranium program. Though the North still has some leftover plutonium on its hands, analysts have suspected that future North Korean nuclear tests will depend on highly enriched, or weapons-grade, uranium.

Nuclear Explosions in the Atmosphere or a Small Distance Underground



ejected material transports radioactive isotopes

The amount of radioactive fallout is increased greatly if the fireball ever touches the ground.

Will the Fireball Touch the Ground?

The HOB needed to prevent the fireball from touching the ground increases much more slowly than the yield—a 6x increase in HOB compensates for a 100x increase in Y.

Examples —

- Y = 10 kt
  Fireball touches ground unless HOB > 500 ft
- Y = 100 kt
  Fireball touches ground unless HOB > 1200 ft
- Y = 1 Mt
  Fireball touches ground unless HOB > 3000 ft

Air and Surface Bursts

Sequence of events —

- Fireball forms and rapidly expands

Example: 1 Mt explosion

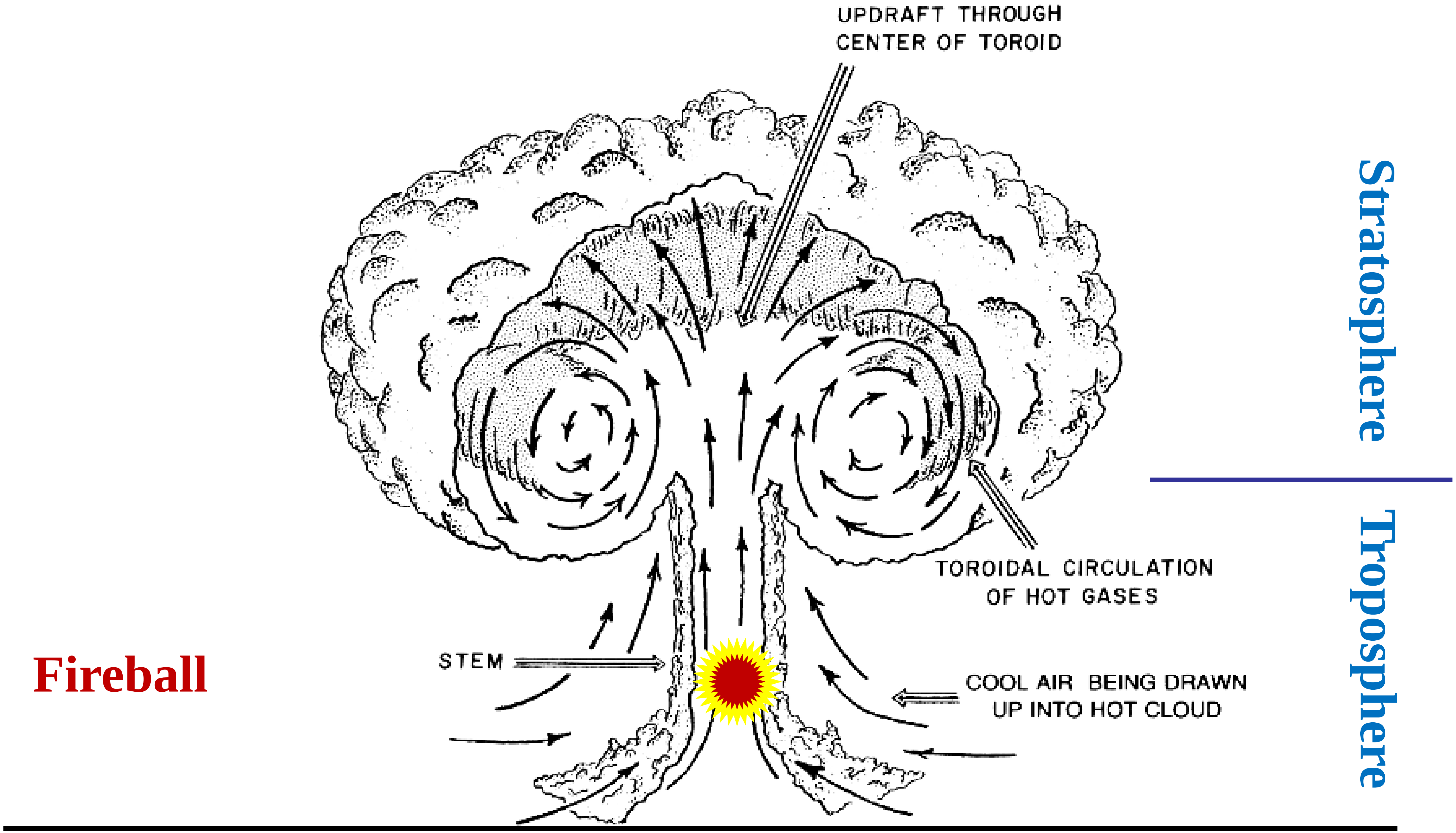
Time	Diameter	Temperature
1 ms (= 10^{-3} s)	440 ft	—
10 s	5,700 ft	6,000 C

- Blast wave forms and outruns fireball
- Fireball rises and spreads, forming characteristic mushroom cloud

Formation of the Mushroom Cloud

- A fireball forms and rises through the troposphere, sucking surrounding air inward and upward
- The moving air carries dirt and debris upward, forming the stem
- The fireball slows and spreads once it reaches the stratosphere

Formation of the Mushroom Cloud



Final Distribution of the Energy of a Large Air Burst (Important)

The *final* distribution of the energy of a large (~ 1 Mt) explosion, in order of appearance —

• Prompt neutrino radiation (not counted in the yield)	~ 5%
• Prompt nuclear radiation	~ 5%
• Electromagnetic pulse	« 1%
• Thermal radiation	~ 35%
• Blast	~ 50%
• Residual nuclear radiation	~ 10%

Radioactive Fallout from a Nuclear Burst

- Vaporized weapon debris is highly radioactive
- If the fireball touches the ground, rock and earth are also vaporized and become highly radioactive
- The radioactive vapor and particles are carried aloft as the fireball rises and spreads
- Radioactive vapor condenses on the particles in the mushroom cloud
- The cloud (“plume”) is carried downwind
- Large particles “rain out” near ground zero
- Smaller particles are carried much further

Short-Term Physical Effects of a 1 Mt Burst

- Prompt nuclear radiation (lasts ~ 10^{-3} s)
  - —Principally γ, β and neutron radiation
  - —Intense, but of limited range
- Electromagnetic pulse (peak at ~ 5×10^{-9} s)
- Thermal radiation (lasts ~1–10 s)
  - —X-ray and UV pulses come first
  - —Heat pulse follows
- Blast (arrives after seconds, lasts < 1 s)
  - —Shockwave = compression followed by high winds
  - —5 psi overpressure, 160 mph winds @ 4 mi
- Residual nuclear radiation (lasts minutes–years)
  - —Principally γ and β radiation

Long-Term Physical Effects

- Fallout
  - —From material sucked into fireball, mixed with weapon debris, irradiated, and dispersed
  - —From dispersal of material from nuclear reactor fuel rods
- Ozone depletion (Mt bursts only)
  - —Caused by nitrogen oxides lofted into the stratosphere
  - —Could increase UV flux at the surface by ~ 2x to ~ 100x
- Soot injected into the atmosphere cools Earth (“nuclear winter”)
  - —Caused by injection of dust and soot into atmosphere

iClicker Question

Which of the following countries once had nuclear weapons but gave them up?

Belarus

Kazakhstan

Ukraine

South Africa

All of the above

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Nuclear Weapon Effects

Effects of Thermal Radiation

Thermal Radiation from the Fireball

- The fireball—like any hot object—emits electromagnetic radiation over a wide range of energies
  - — Initially most is at X-ray energies
  - — But the atmosphere is opaque to X-rays
  - — Absorption of the X-rays ionizes (and heats) the air
  - — The fireball expands rapidly and then cools
- Radiation of lower energy streams outward from surface of the fireball at the speed of light
  - — Atmosphere is transparent for much of this
  - — Energy cascades down to lower and lower energies
    - »Ultraviolet (UV) radiation
    - »Visible light
    - »Infrared (IR) radiation

1 Mt at 10s
Diameter ~ 1 mile
T ~ 6000 °C (sun surface)

Effects of Thermal Radiation – 1

The seriousness of burn injuries depends on —

- The total energy released (the yield Y)
- Transparency of the atmosphere (clear or fog, etc.)
- The *slant* distance to the center of the burst
- Whether a person is indoors or out, what type of clothing one is wearing, etc.

Effects of Thermal Radiation – 2

Duration and intensity of the thermal pulse —

- 1 s for 10 kt ; 10 s for 1 Mt
- In a transparent atmosphere, the heat flux at a distant point scales as $1/D^2$ where D is the slant range
- In a real atmosphere, absorption and scattering by clouds and aerosols (dust particles) cause a steeper fall-off with D; given by the "transmission factor" T :

  T = 60–70 % @ D = 5 miles on a "clear" day/night

  T = 5–10% @ D = 40 miles on a "clear" day/night
- Atmosphere transmission is as complicated and as variable as the weather

Effects of Thermal Radiation – 3

Typical characteristics —

- Thermal effects are felt before the blast wave arrives
- For Y < 10 kt, direct effects of thermal radiation are lethal only where blast is already lethal
- For Y > 10 kt, direct effects of thermal radiation are lethal well beyond where blast is lethal
- Direct effects of thermal radiation are greatly reduced by shielding
- Indirect effects of thermal radiation (fires, explosions, etc.) are difficult to predict
- Interaction of thermal radiation and blast wave effects can be important

Effects of Thermal Radiation – 4

Some harmful direct effects —

- Flash blindness (temporary)
- Retinal burns (permanent)
  - —Approximately 13 mi on a clear day
  - —Approximately 53 mi on a clear night
- Skin burns
- Ignition of clothing, structures, surroundings

Types of burns —

- Direct (flash) burns: caused by fireball radiation
- Indirect (contact, flame, or hot gas) burns: caused by fires ignited by thermal radiation and blast

Examples of Flash Burns Suffered at Hiroshima and Nagasaki


(a)


(b)

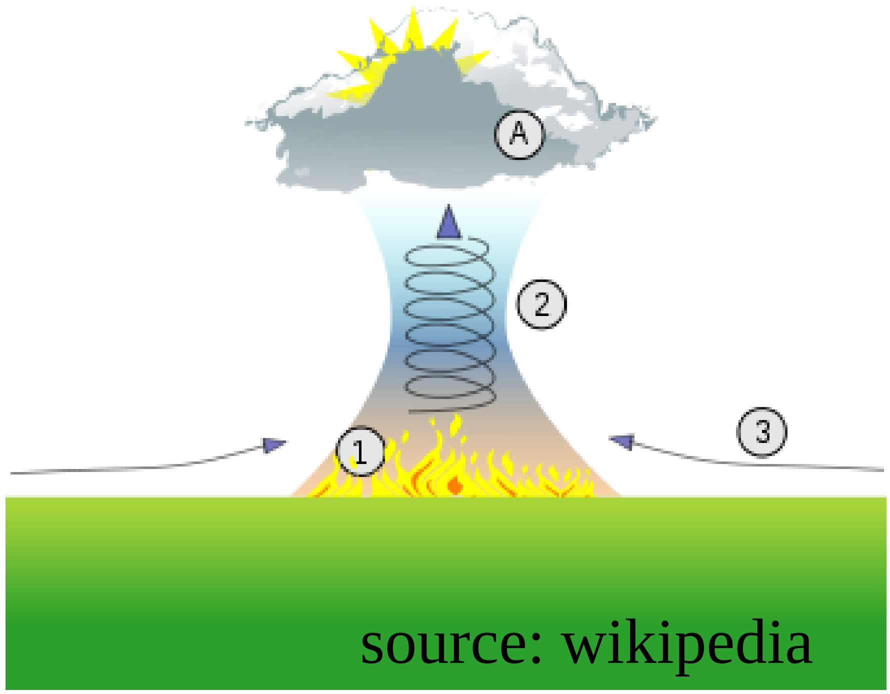
Conflagrations Versus Firestorms

Conflagration —

- Fire spreads outward from the ignition point
- Fire dies out where fuel has been consumed
- The result is an outward-moving ring of fire surrounding a burned-out region

Firestorm —

- Occurs when fires are started over a sizable area and fuel is plentiful in and surrounding the area
- The central fire becomes very intense, creating a strong updraft; air at ground level rushes inward
- The in-rushing air generates hurricane-force winds that suck fuel and people into the burning region
- Temperatures at ground level exceed the boiling point of water and the heat is fatal to biological life



source: wikipedia

Conflagrations Versus Firestorms

Hamburg after firestorm in July 1943
similar in Dresden, Tokyo and possibly in Hiroshima

67

Effects of Nuclear Explosions

Effects of Blast Waves

Damaging Effects of a Blast Wave

- The blast wave is considered the most militarily significant effect of a nuclear explosion in the atmosphere
- Like any shockwave, a blast wave produces —
  - A sudden isotropic (same in all directions) pressure P that compresses structures and victims

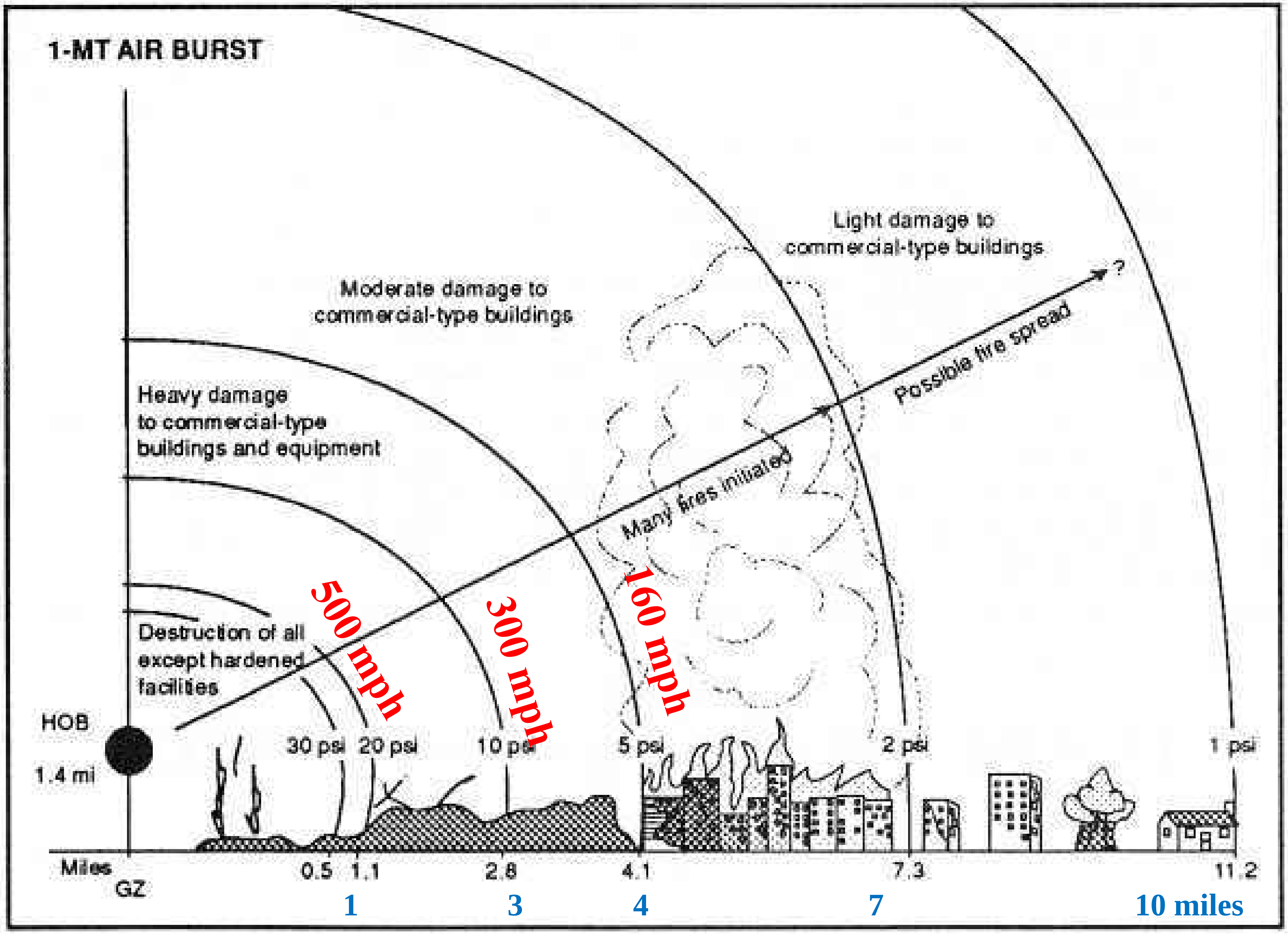
This is followed by

  - A strong outward wind that produces dynamic pressure Q that blows structures and victims outward
- The two pressures are directly related; both are usually given in psi = pounds per square inch

Blast Wave Pressures and Winds

Pressure (psi)	Dynamic Pressure (psi)	Wind (mph)
200	330	2,078
150	222	1,777
100	123	1,415
50	41	934
20	8	502
10	2	294
5	1	163

Damaging Effects of a Blast Wave



Effects of Shallow Underground Nuclear Explosions

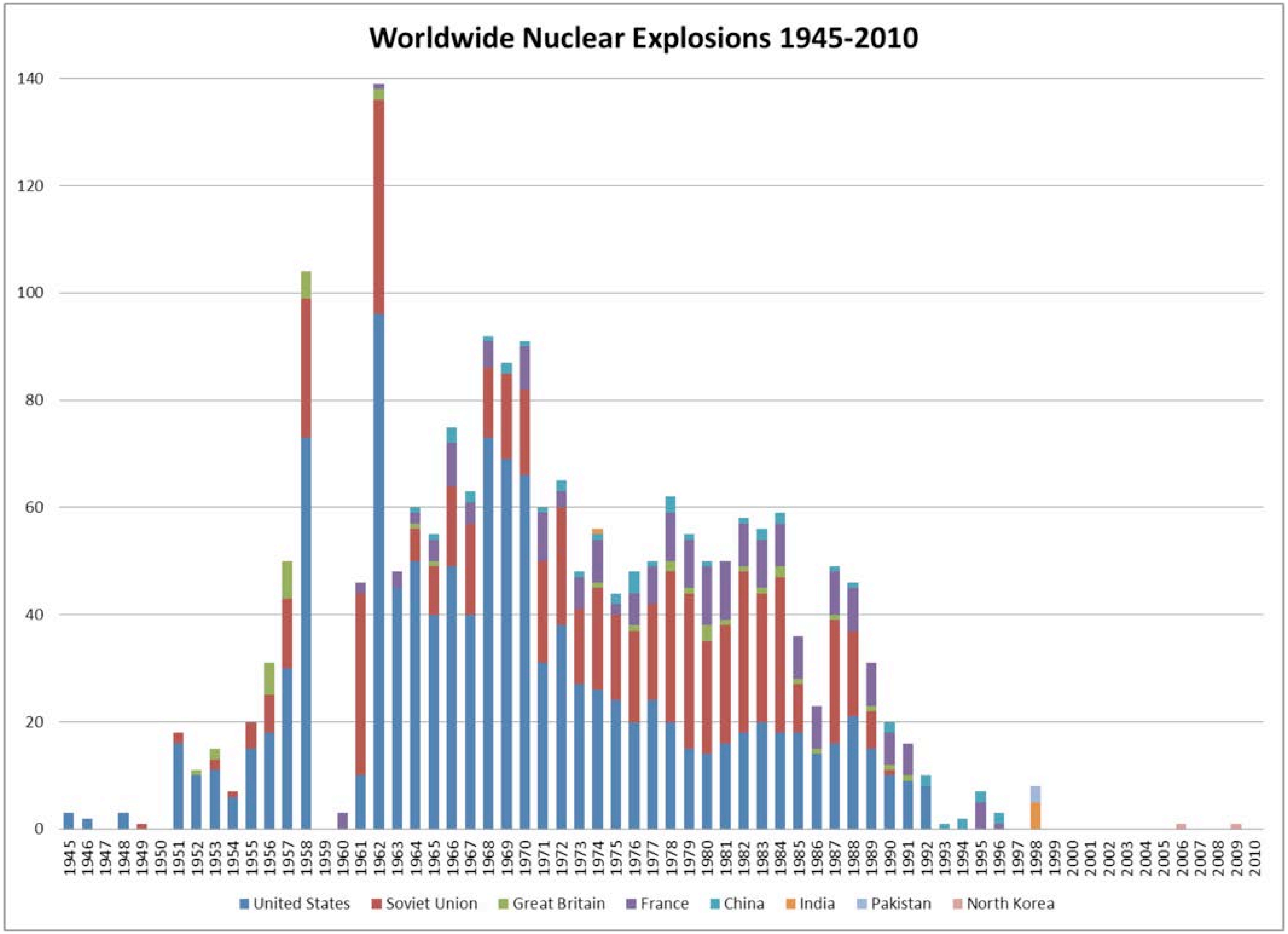
Effects of the Sedan Event (1962)

- Explosive yield: 100 kt
- Depth of burial: 635 feet
- Crater radius: 610 feet
- Crater depth: 320 feet
- Earth displaced: 12 million tons

Effects of Shallow Underground Nuclear Explosions

Example: The Sedan Test (100 kt, 1962)

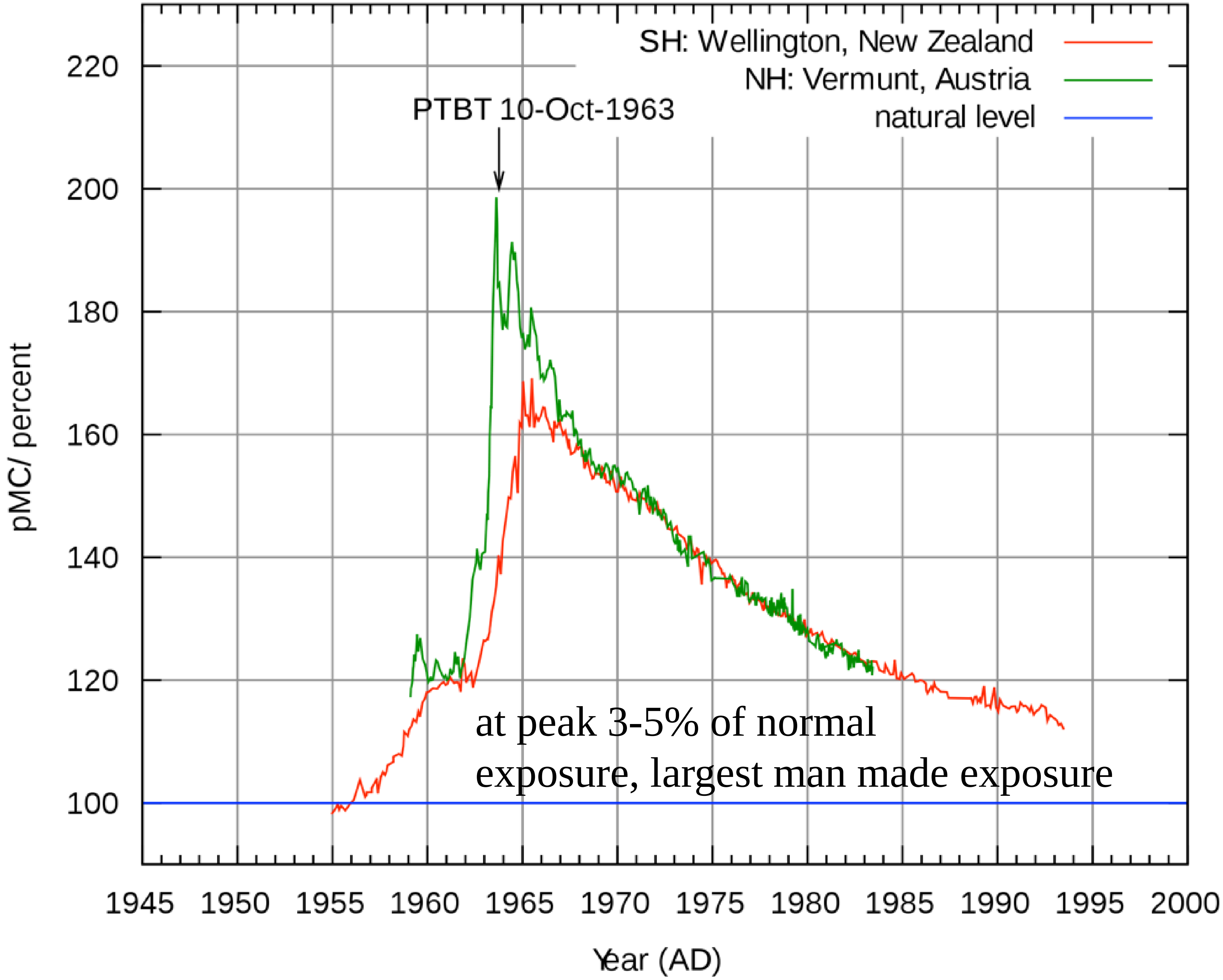
Effects of Nuclear Explosions



Credit: Wikipedia Commons

Effects of Nuclear Explosions

$^{14}C/^{12}C$ in atmospheric CO_2. Source: Hokanomono (Wikipedia)



at peak 3-5% of normal exposure, largest man made exposure

Fallout Radiation from a 1 Mt Burst

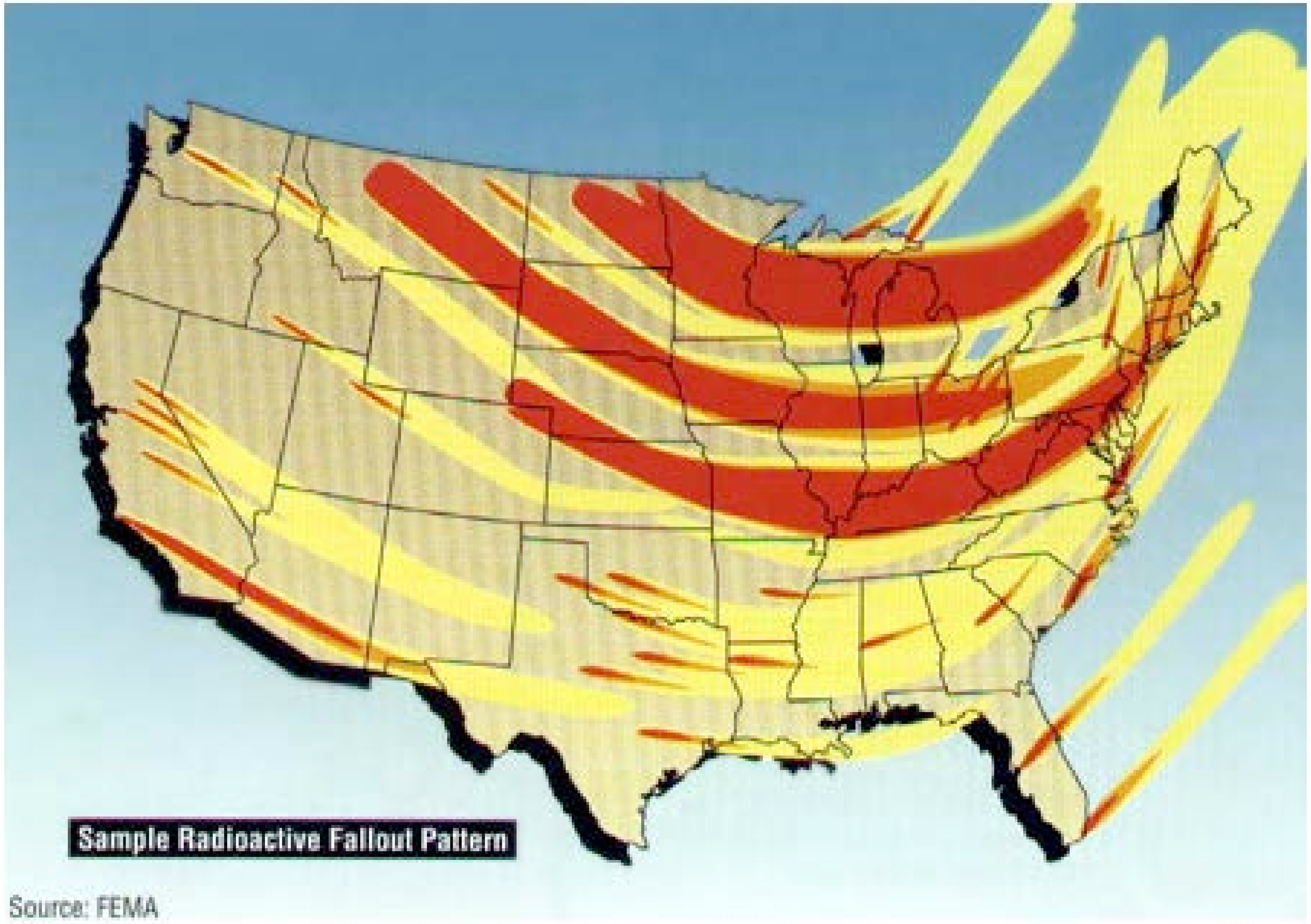
Assume —

- Surface burst
- Wind speed of 15 mph
- Time period of 7 days

Distances and doses —

- 30 miles: 3,000 rem (death within hours; more than 10 years before habitable
- 90 miles 900 rem (death in 2 to 14 days)
- 160 miles: 300 rem (severe radiation sickness)
- 250 miles: 90 rem (significantly increased cancer risk; 2 to 3 years before habitable)

Effects of Nuclear Explosions



Map of nuclear fallout distribution after a potential nuclear attack on the United States. Source: FEMA

iClicker Question

Which of the following effects of a Megaton explosion would be felt **first** 5 miles away?

Blast

Thermal radiation

Electromagnetic pulse

Residual nuclear radiation (“fallout”)

iClicker Answer

Which of the following effects of a Megaton explosion would be felt **first** 5 miles away?

Blast

Thermal radiation

Electromagnetic pulse

Residual nuclear radiation (“fallout”)

iClicker Question

Which of the following effects of a Megaton explosion would be felt **last** 5 miles away?

Blast

Thermal radiation

Electromagnetic pulse

Residual nuclear radiation (“fallout”)

iClicker Answer

Which of the following effects of a Megaton explosion would be felt **last** 5 miles away?

Blast

Thermal radiation

Electromagnetic pulse

Residual nuclear radiation (“fallout”)

iClicker Question

Nuclear Weapon Effects

Which effect listed below carries the largest fraction of the total energy of a Megaton nuclear explosion?

Prompt nuclear radiation

Electromagnetic pulse

Thermal radiation

Blast

Residual nuclear radiation (“fallout”)

iClicker Answer

Nuclear Weapon Effects

Which effect listed below carries the largest fraction of the total energy of a Megaton nuclear explosion?

Prompt nuclear radiation

Electromagnetic pulse

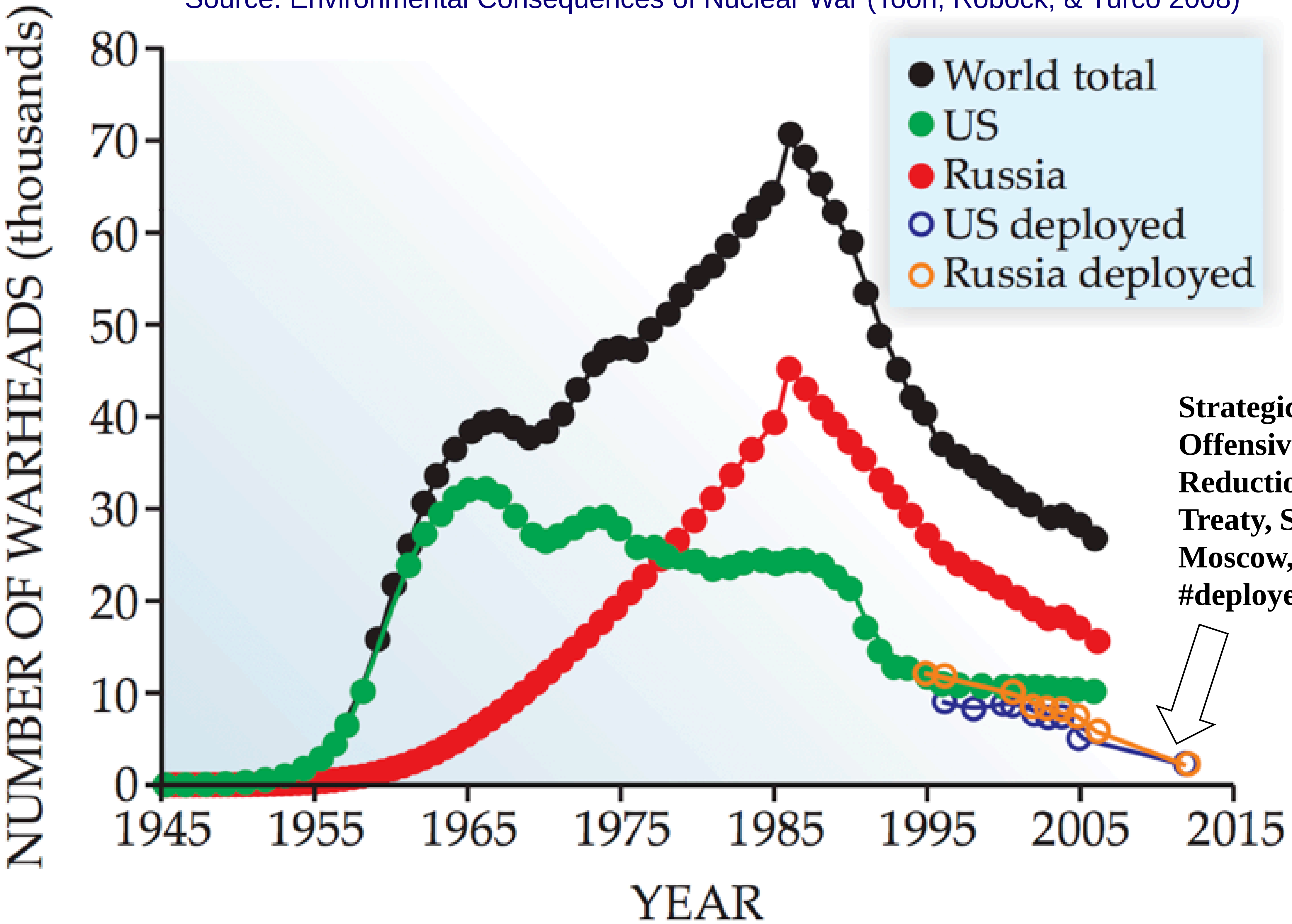
Thermal radiation

Blast

Residual nuclear radiation (“fallout”)

Effects of Nuclear War

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)



Strategic Offensive Reductions Treaty, SORT Moscow, 2002 #deployed < 2200

Effects of Nuclear War

Illustrative Effects

A regional war between India and Pakistan could generate 5 Tg of soot, sufficient to —

- produce the lowest temperatures for 1,000 years, lower than the Little Ice Age or 1816 (“the year without a summer”)
- reduce precipitation in the Asian monsoon region by 40%
- substantially reduce the length of the growing season in the U.S. midwest

Mean time for the soot to decrease is 5 years

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)

Effects of Nuclear War

Illustrative Effects

1,000 weapons detonated on the United States would *immediately* —

- kill 60 million people (20% of the total population)
- injure an additional 40 million people (16% of the total population)

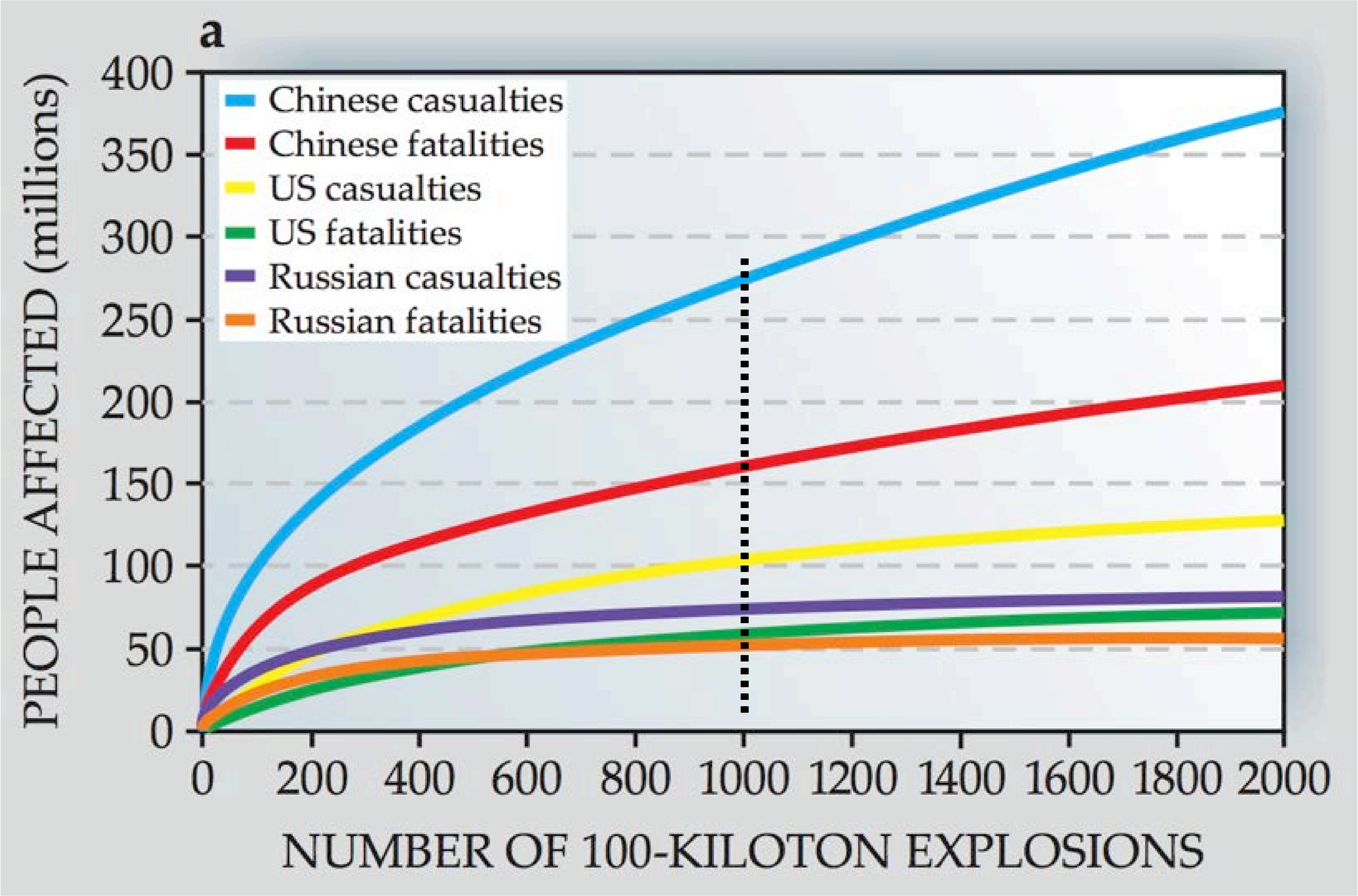
1,000 weapons detonated on Russia would *immediately* —

- kill 50 million people (30% of the total population)
- injure an additional 20 million people (20% of the total population)

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)

Effects of Nuclear War

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)



Effects of Nuclear War

Nuclear War Models

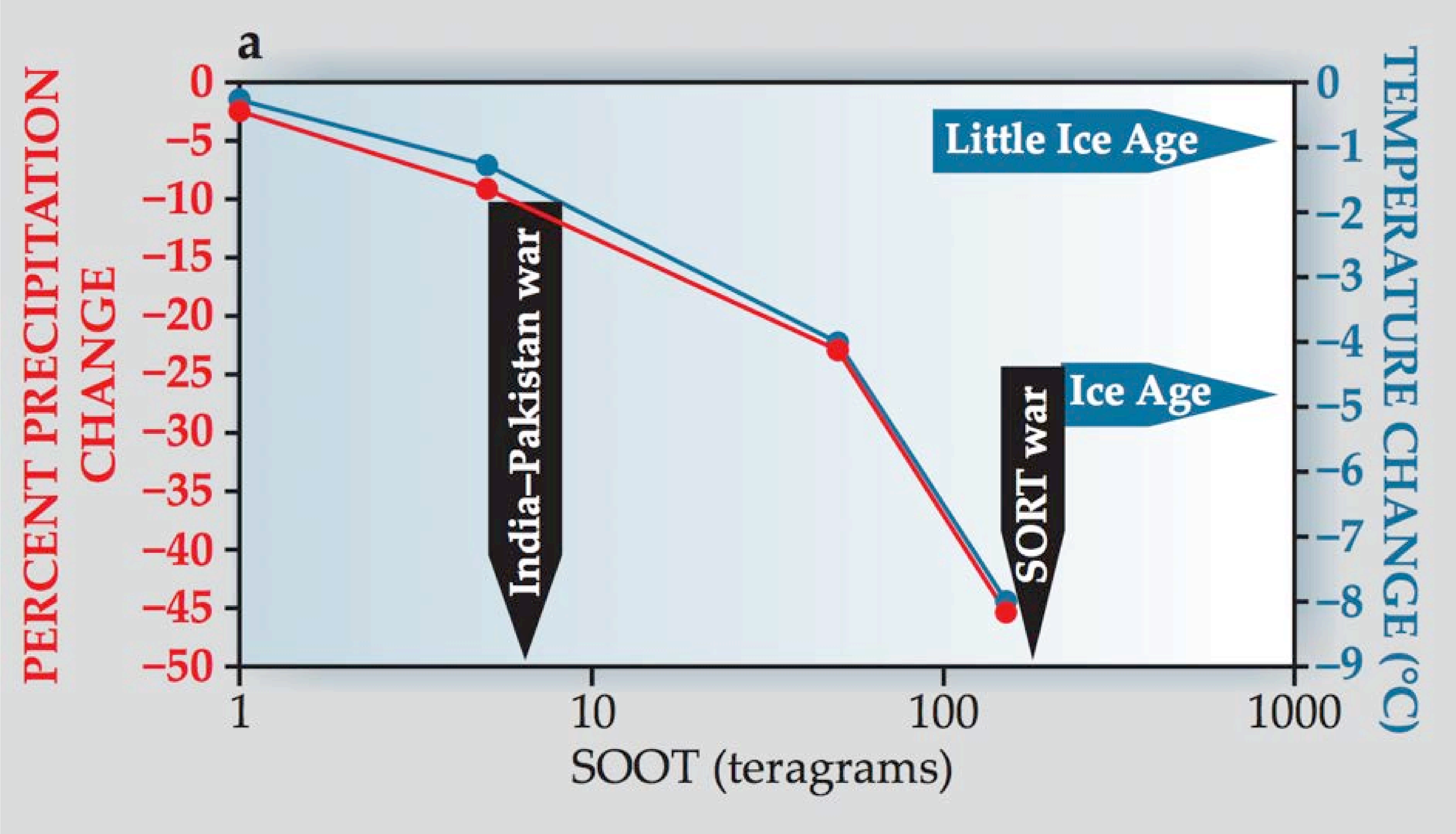
U.S.-Russian (“SORT”) war:
2200 x 2 weapons of 100-kt each = 440 Mt total

Regional nuclear war:
50 weapons of 15-kt each = 0.75 Mt total

Weapons are assumed to be targeted on industry.

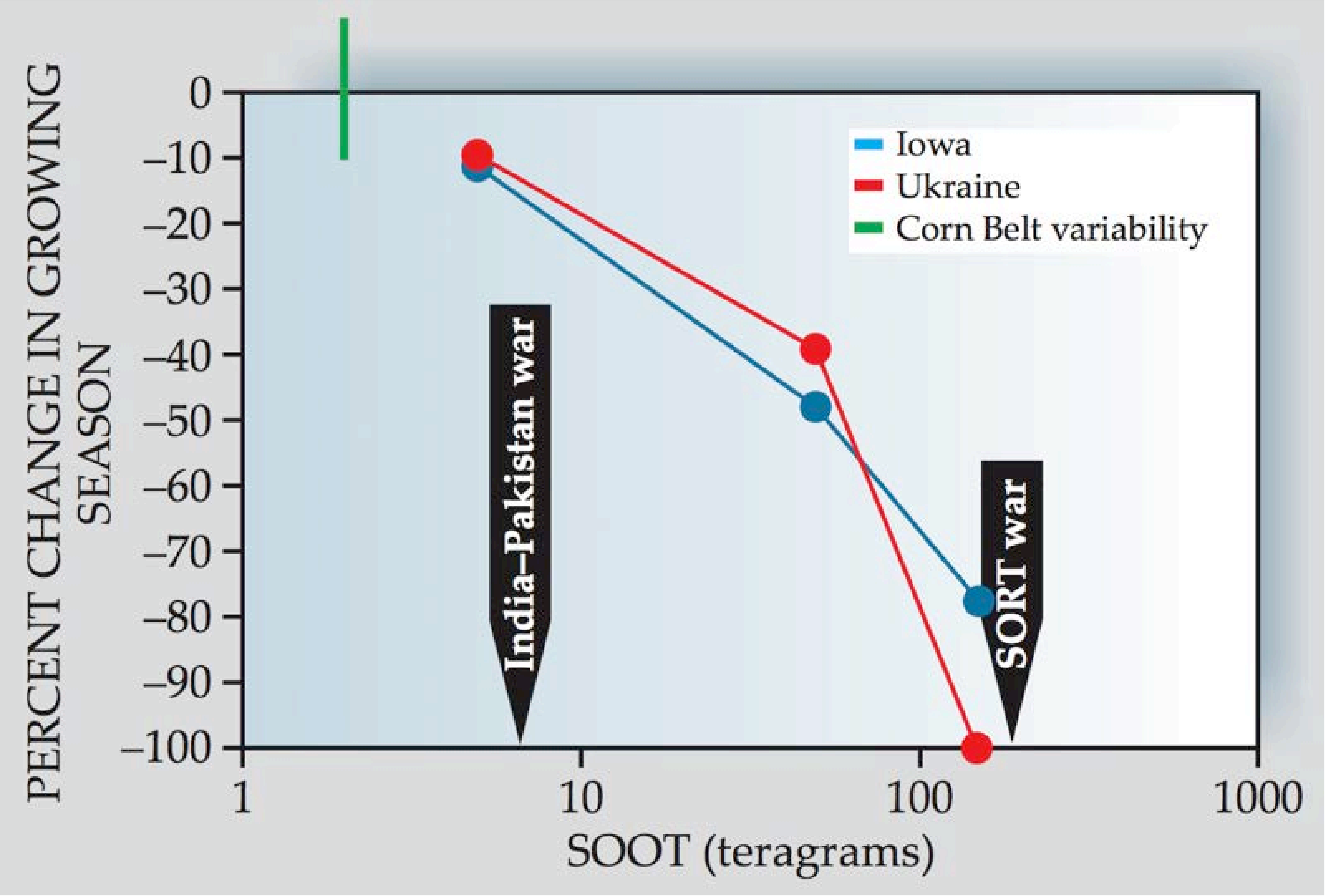
Effects of Nuclear War

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)



Effects of Nuclear War

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)



Physics 280: Session 10

Plan for This Session

Questions and discussion

Nuclear Explosions Conclusion

“Ground Zero” Video presentation

Effects of Nuclear War

Indirect Effects Would Be the Most Important

“What can be said with assurance...is that the Earth’s human population has a much greater vulnerability to the indirect effects of nuclear war, including damage to the world’s —

- agricultural
- transportation
- energy
- medical
- political
- and social

infrastructure than to the direct effects of nuclear war.”

– Environmental Consequences of Nuclear War
(Owen Toon, Alan Robock, & Richard Turco, Physics Today, December 2008)

iClicker Question

If Soot is transported to the upper atmosphere by an explosion or eruption, what is the meantime for the soot to return to earth’s surface?

(A) 1 year

(B) 3 years

(C) 5 years

(D) 10 years

iClicker Question

If Soot is transported to the upper atmosphere by an explosion or eruption, what is the meantime for the soot to return to earth's surface?

(A) 1 year

(B) 3 years

(C) 5 years

(D) 10 years

iClicker Question

What would be the impact of a U.S.-Russian (“SORT”) nuclear war with 2200 x 2 weapons of 100-kt each = 440 Mt total on the length of the growing season in the mid west of the United States of America?

(A) Reduction by 5-10%   (little ice age)

(B) Reduction by 40-50%   (last ice age)

(C) Reduction by 70-80%   (no “recent” historic precedence)

iClicker Question

What would be the impact of a U.S.-Russian (“SORT”) nuclear war with 2200 x 2 weapons of 100-kt each = 440 Mt total on the length of the growing season in the mid west of the United States of Amercia

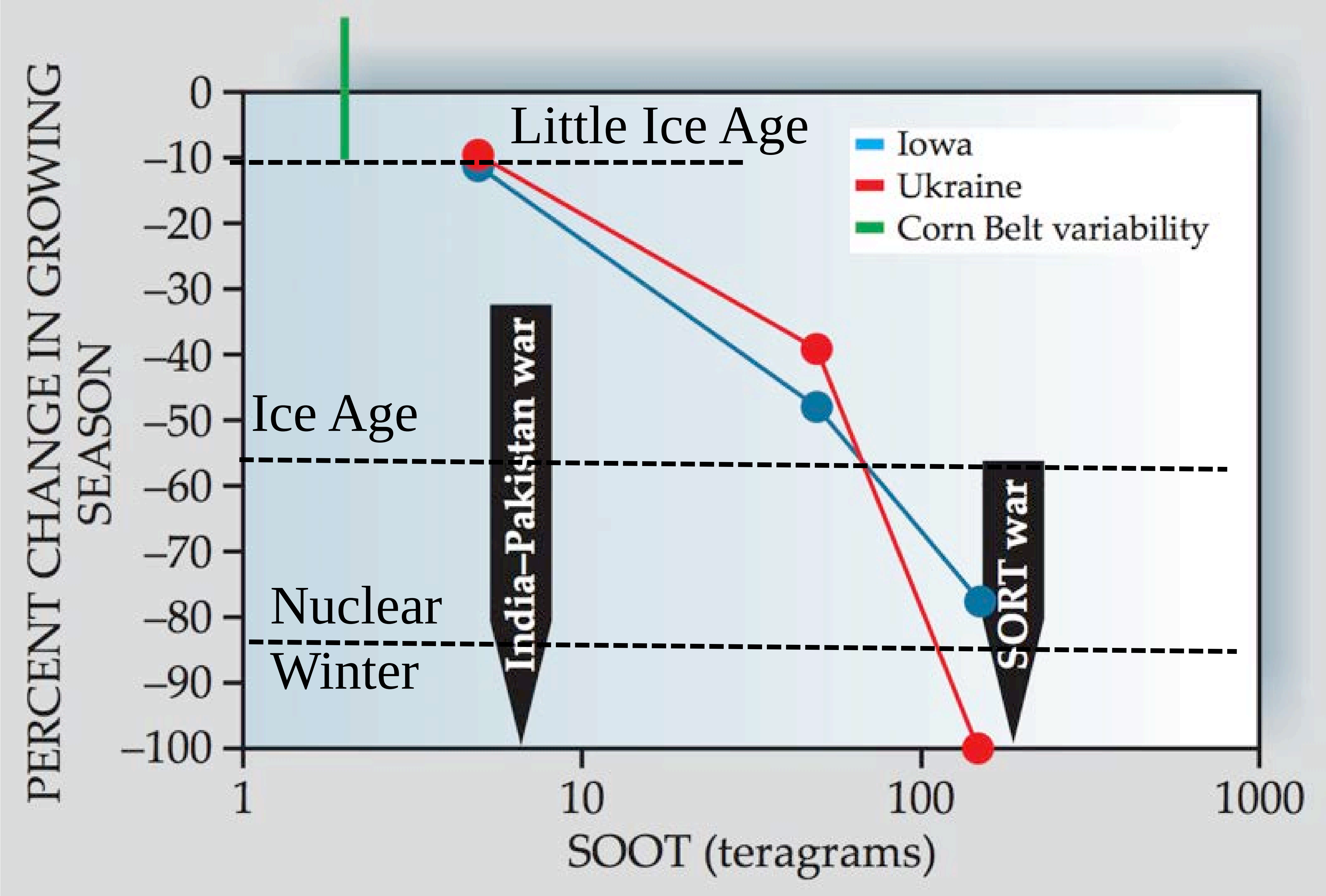
(A) Reduction by ~10% (little ice age)

(B) Reduction by 50-60% (last ice age)

(C) Reduction by 80-90% (no “recent” historic precedence)

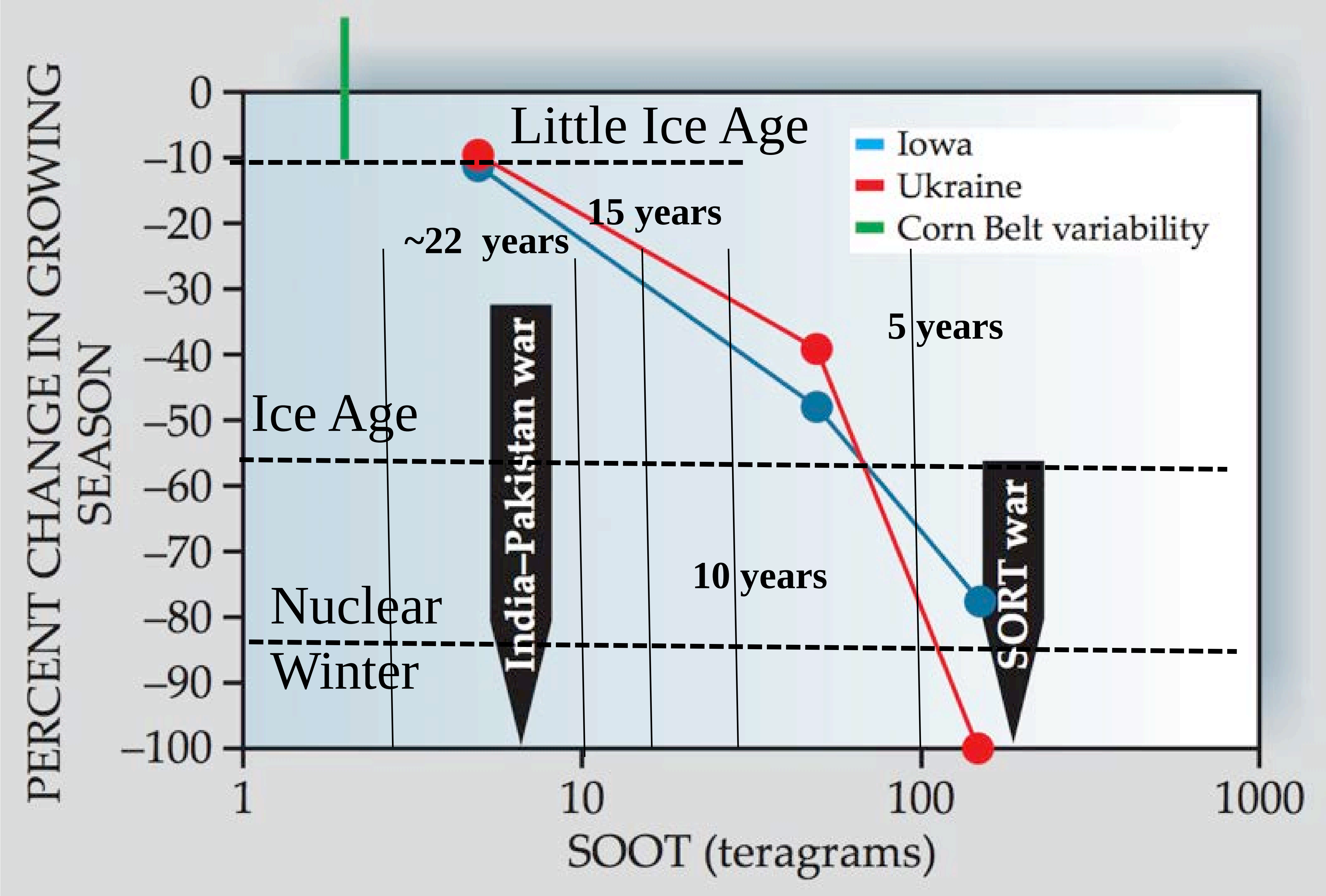
Effects of Nuclear War

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)



How Long from Nuclear Winter to Little Ice Age?

Source: Environmental Consequences of Nuclear War (Toon, Robock, & Turco 2008)



Ground Zero

Video Presentation