Physics/Global Studies 280: Session 8

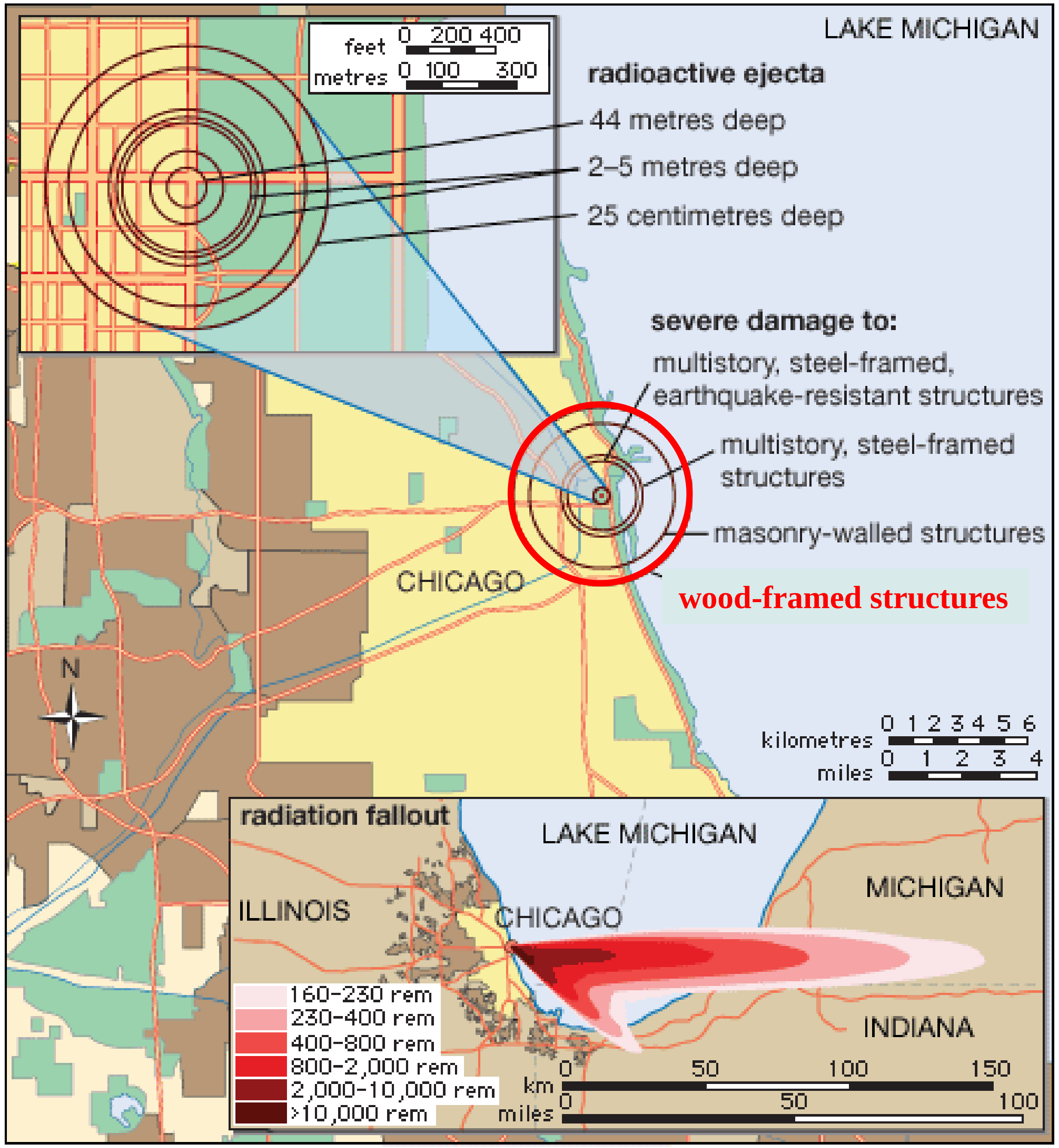
Plan for This Session

RE2v2 due today

NEM summary

Module 3:
Effects of nuclear explosions

Impact of a 500 kiloton device detonated in Chicago



Extra Credit Opportunity A

The Role of Women in Stopping the Threat of Nuclear War
Saturday, February 10th
Urbana Champaign Independent Media Center
202 S. Broadway Ave, Urbana

Attend and write 1.5 – 2 page essay

Newsweek

RUSSIA SAYS IT'S DEPORTING NORTH KOREAN WORKERS TO STOP KIM JONG UN'S NUCLEAR PROGRAM

BY **CRISTINA MAZA** ON 2/7/18 AT 1:18 PM

Russia has started the process of expelling North Korean migrant workers from its Far East region in order to comply with a United Nations Security Council resolution passed in December, officials said Tuesday.

The resolution, passed in response to North Korea's test of a ballistic missile in late November, stated that all countries must send North Korean migrant workers home within 24 months. It aims to cut off funding to the isolationist regime so Pyongyang won't have the resources to continue the development of its nuclear weapons program. It has been reported that up to 90 percent of North Korean workers' wages is forcibly sent back to Pyongyang. North Korea has denied the claim.

North Korea earns between $200 million and $500 million dollars a year from overseas laborers, Collins added.

Russia's ambassador to North Korea, Alexander Matsegora, told reporters Tuesday that there are at least 12,000 North Korean migrant workers in the country's eastern Primorsky Krai region alone. Russia relies on North Korean labor to fill low-paid, dangerous construction jobs. A State Department report from 2017 said that North Koreans work like slaves in Russia and that some workers are subjected to forced labor.

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Categories of Nuclear Explosive Materials

- 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

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
- Global effects of nuclear war

Definition: “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

While the use of chemical and biological weapons can have grave consequences:

Only nuclear weapons are “weapons of mass destruction” and can threaten the survival of the U.S. and other nations.

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

18p280 NuclearExplosions, p.

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.

Technically challenging to synthesize and effectively deliver chemical agents.

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.

Historic Example: Chemical Weapons in WW I

Gas attack during World War I.

In World War I, 190,000 tons of gas caused less than 1% of all combat deaths, still ~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.

Advanced technology would be needed to effectively deliver such an agent to large population.

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.

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.

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Nuclear Weapons

In contrast to chemical or biological agents, a “small” (10 kiloton) nuclear weapon detonated in a major city would kill more than 100,000 people and completely destroy tens of square kilometers of buildings and infrastructure.

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.

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.

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.

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 radioactive material
- seriously disrupt city life and economics

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.

Use of the Term “Weapons of Mass Destruction”

Avoid lumping together as “WMD”—

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

Broadening the definition of “WMD” can have the following consequence:

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

This language 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 PHYS/GLBL 280, we will avoid the term “WMD”. Instead, we will say what we mean: “nuclear weapons”, “chemical weapons”, or “biological weapons”.

Theft of Nuclear Material in November 2013

Stolen cobalt-60 found in Mexico; thieves may be doomed

By Gabriela Martinez and Joshua Partlow, Published: December 4

MEXICO CITY — Mexico's public-health scare turned into a logistical hurdle Thursday as authorities sought to safely put a stolen load of radioactive material back into its container.

As officials worked on the material, federal police and soldiers formed a cordon of several hundred yards around the field in Hueypoxtla where a container of highly radioactive cobalt-60 was abandoned after it was stolen from truck drivers transporting it to a storage facility in central Mexico.

The International Atomic Energy Agency (IAEA) said the "extremely dangerous" cargo of pellets used in hospital radiotherapy machines had been removed from its protective casing, but "there is no indication that it has been damaged or broken up" and there is "no sign of contamination to the area."

The theft of the material sparked international concern because of the possibility that the cobalt-60 could be used … ?

Lecture Question

The theft of Co-60 in Mexico caused international concern as

(A) Co-60 is a fertile material and can be used to breed fissile nuclides.

(B) Co-60 is a NEM and can be used in nuclear weapons.

(C) Co-60 could be used in a radiological weapon.

(D) Co-60 is radioactive, highly toxic and can be dispersed easily as a chemical weapon.

Lecture Question Answer

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Lecture Question

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

(A) No

(B) Yes, but with difficulty

(C) Yes, easily

Lecture Question Answer

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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 explosive TNT

Fission weapons: kTs to 100s of kTs of TNT

Thermo nuclear weapons: 100 kTs to few MTs of TNT

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

Energy from a nuclear explosion 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 —

- Low energy 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.

Lecture Question

A nuclear weapon test is carried out in space. A satellite 20 miles away is used to measure the energy released from the explosion. What does it find?

(A) The low energy gamma rays have been absorbed by the weapon debris and almost all energy is in the kinetic energy of the debris.

(B) 80% of the energy is carried by low energy gamma rays.

(C) At the distance of the satellite the debris has slowed and all energy is carried by low energy gamma rays.

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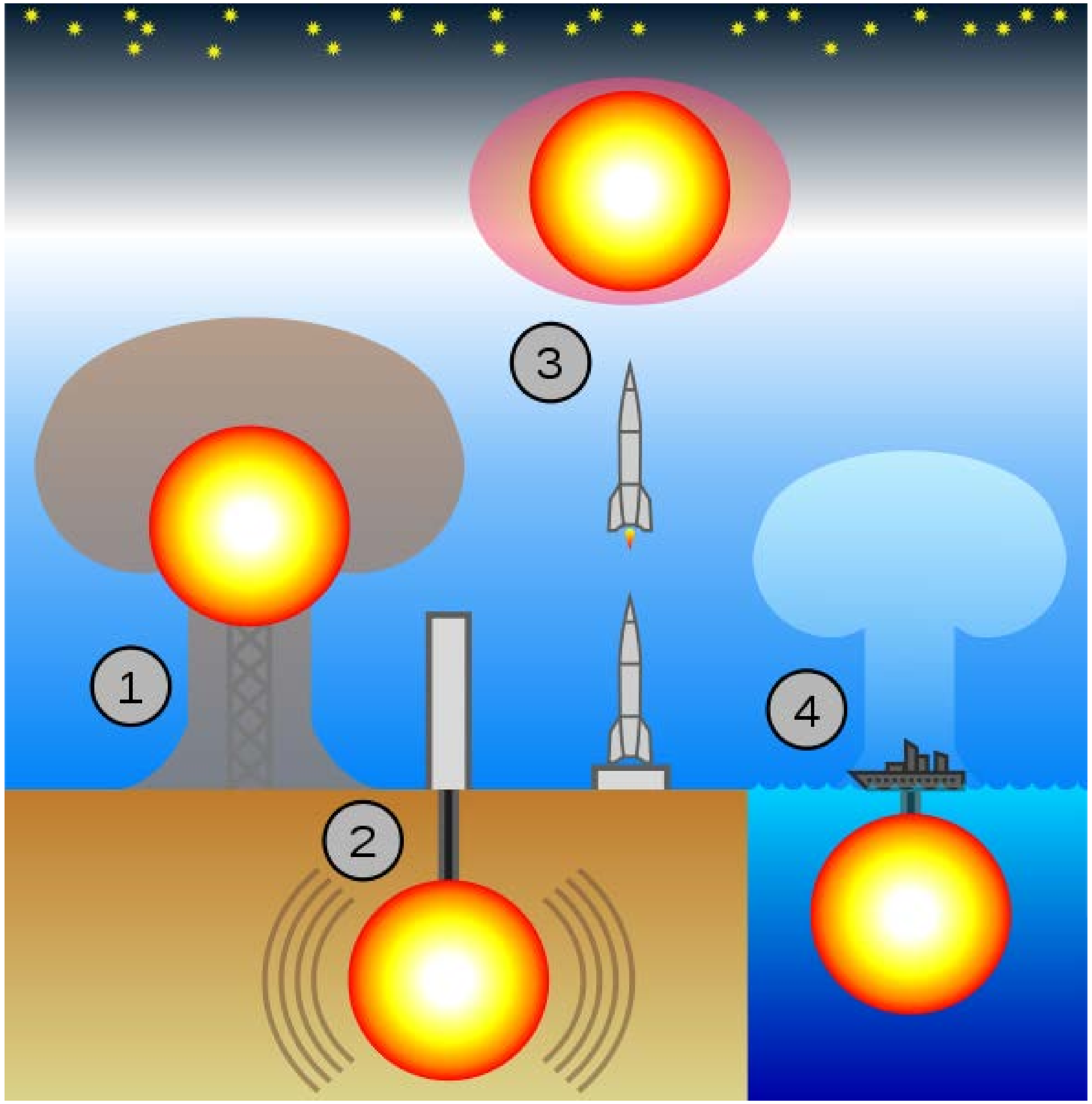
Nuclear Explosions



Credit: Wikipedia (nuclear weapons testing)

Possible environments —

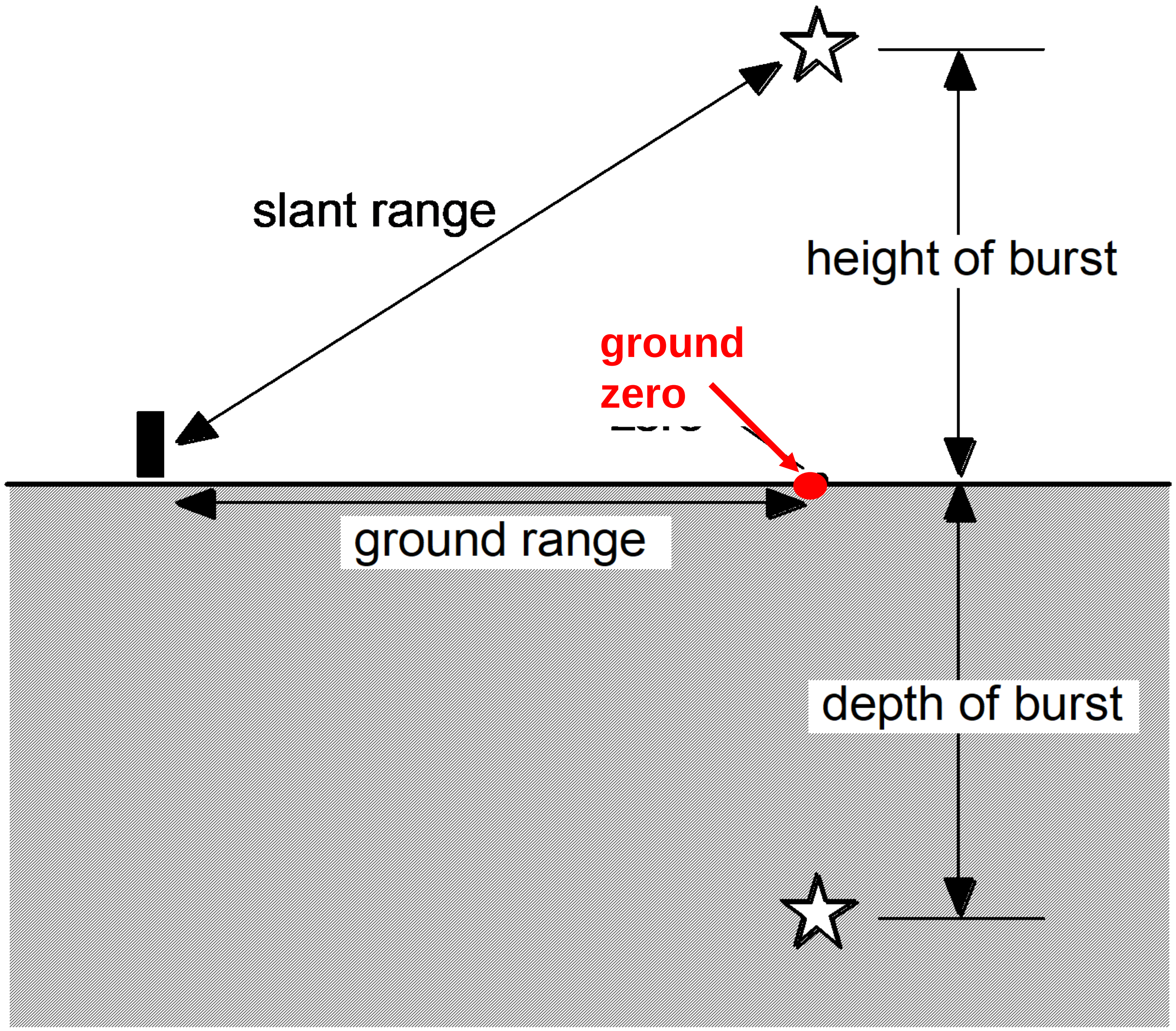
1. Air and surface bursts
2. Underground bursts

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

3b. Explosions in space

4. Underwater bursts

Nuclear Explosion Geometries

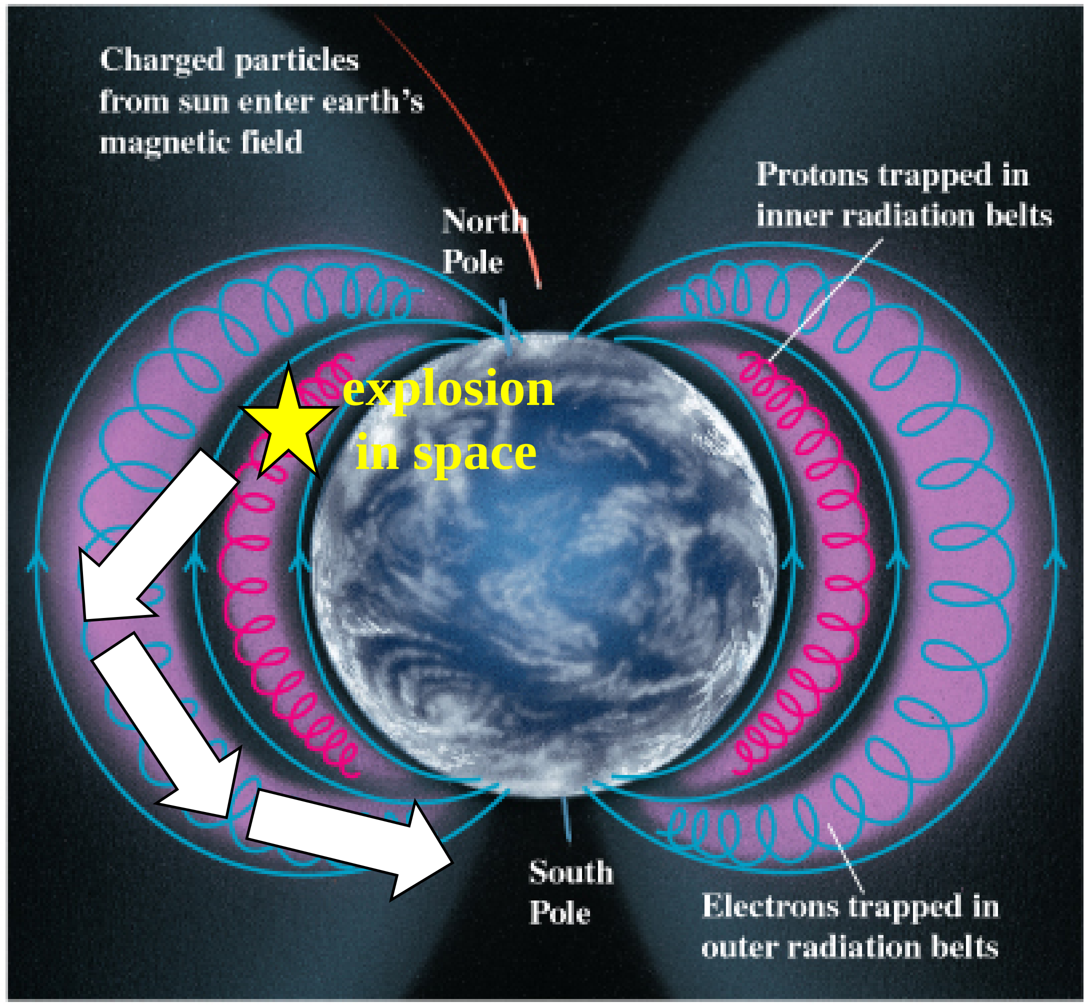


Nuclear Explosions in Space

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 the Electromagnetic Pulse (EMP) and damage to satellites by particles trapped in the geomagnetic field

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/Global Studies 280: Session 9

Plan for This Session

Announcements & Questions:

RE3v1 will be due Thursday 2-15 at 1pm (.doc/.docx) and 2pm in class (paper copy)

➔ make sure to print from pdf in case you are editing a google document!

News

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

News: Sandia's detectors key Russian nuke inspections

Albuquerque Journal, February 12th

Sandia National Laboratories designed new radiation detection equipment for New START monitoring that was first used in Russia in July. (Randy Montoya/Sandia National Laboratories)

New radiation detectors designed, tested and built at Sandia National Laboratories were recently used by inspectors with the federal Defense Threat Reduction Agency to inspect Russia's nuclear weapons as part of a treaty between that country and the United States.

The New Strategic Arms Reduction Treaty, known as New START, was entered in 2011 and required both countries to meet set limits on nuclear weapons by Feb. 5, 2018.

Each country was allowed to make 18 inspections of nuclear weapons storage facilities per year to verify reported weapon numbers.

The neutron-detecting equipment, which replaced devices originally developed by Sandia in the late 1980s, is used by inspectors to guarantee objects that are declared non-nuclear are indeed non-nuclear.

Stoddard said the equipment was in need of an update after it became increasingly difficult to find replacement components for the aging systems.

The new units are also 60 pounds lighter, weighing in at 120 pounds.

The Russians approved the equipment for use in May 2017, and the equipment was used in a July 2017 inspection.

"The Russian Federation has repeatedly stated its commitment to the New START Treaty, including meeting the central limits, and we expect our upcoming data exchange under the Treaty to reaffirm that commitment," the news release read.

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News: Football Italia: North Korean player could violate UN and EU sanctions on North Korea

Juventus to meet for Han

reported by Andi Mankolli

January 19th 2018

Juventus will meet Cagliari today to discuss North Korean striker Han Kwang-song, according to reports. The 19-year-old is on loan at Perugia in Serie B, and has been impressing this season after becoming the first ever North Korean player to play and score in Serie A in 2016-17.

That has attracted the interest of the Bianconeri, and La Stampa reports they'll meet Cagliari in Milan today to discuss a potential deal. The newspaper is owned by the Agnelli family, and it reports that Juve not only admire Han's talent, but feel he could boost their profile in Asia.

Any transfer could well prove problematic though, as North Korean players plying their trade in Italy has proven controversial. It's suspected that the wages paid to players such as Han go back to their homeland to help fund Kim Jong-Un's totalitarian regime. Fiorentina terminated Choe Song Hyok's contract in July 2016 after rumours up to 70 per cent of his salary was going to the government in Pyongyang, which would therefore be a breach of UN and EU sanctions on North Korea.

Underground Nuclear Explosions- Nevada Test Site

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

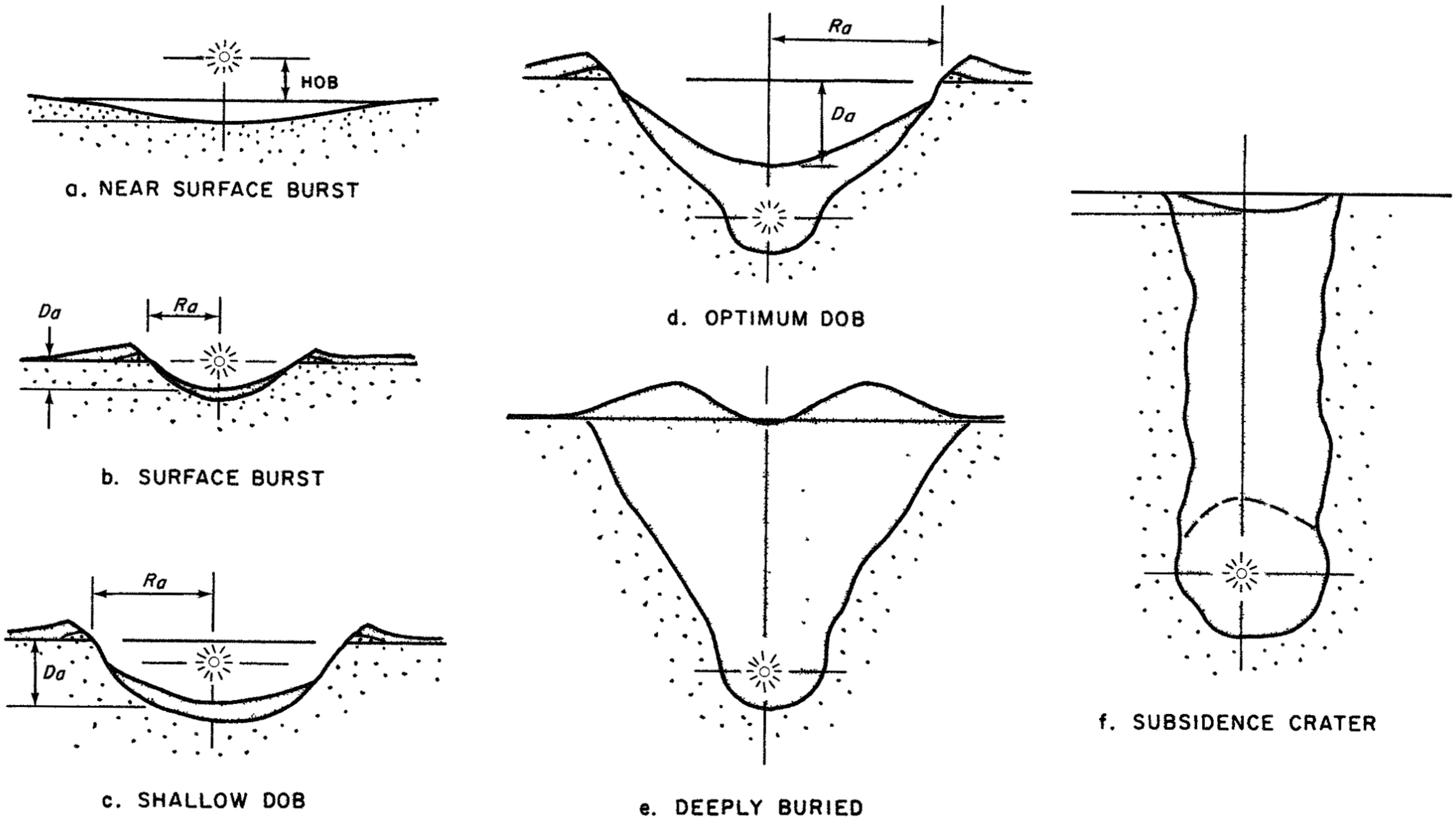
Underground Nuclear Explosions: Test Deployment & Assembly

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

Nuclear weapon tests serve the acquisition of information/data concerning explosions of different warheads.

A large number of measurement probes were installed prior and readout during the explosion.

Crater Formation vs DOB (depth of burst)



Underground Nuclear Explosions- Nevada Test Site

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

Total of 904 tests
at the Nevada test site

Lecture Question

In you opinion, can underground nuclear weapon test be carried out undetected?

(A) Yes, if tested at sufficient depth.

(B) No, radioactive noble gases escape and can be detected.

(C) No, seismic waves caused by the explosion can be detected.

(D) No, sound waves from the explosion travel long distances through earth’s crust and can be detected.

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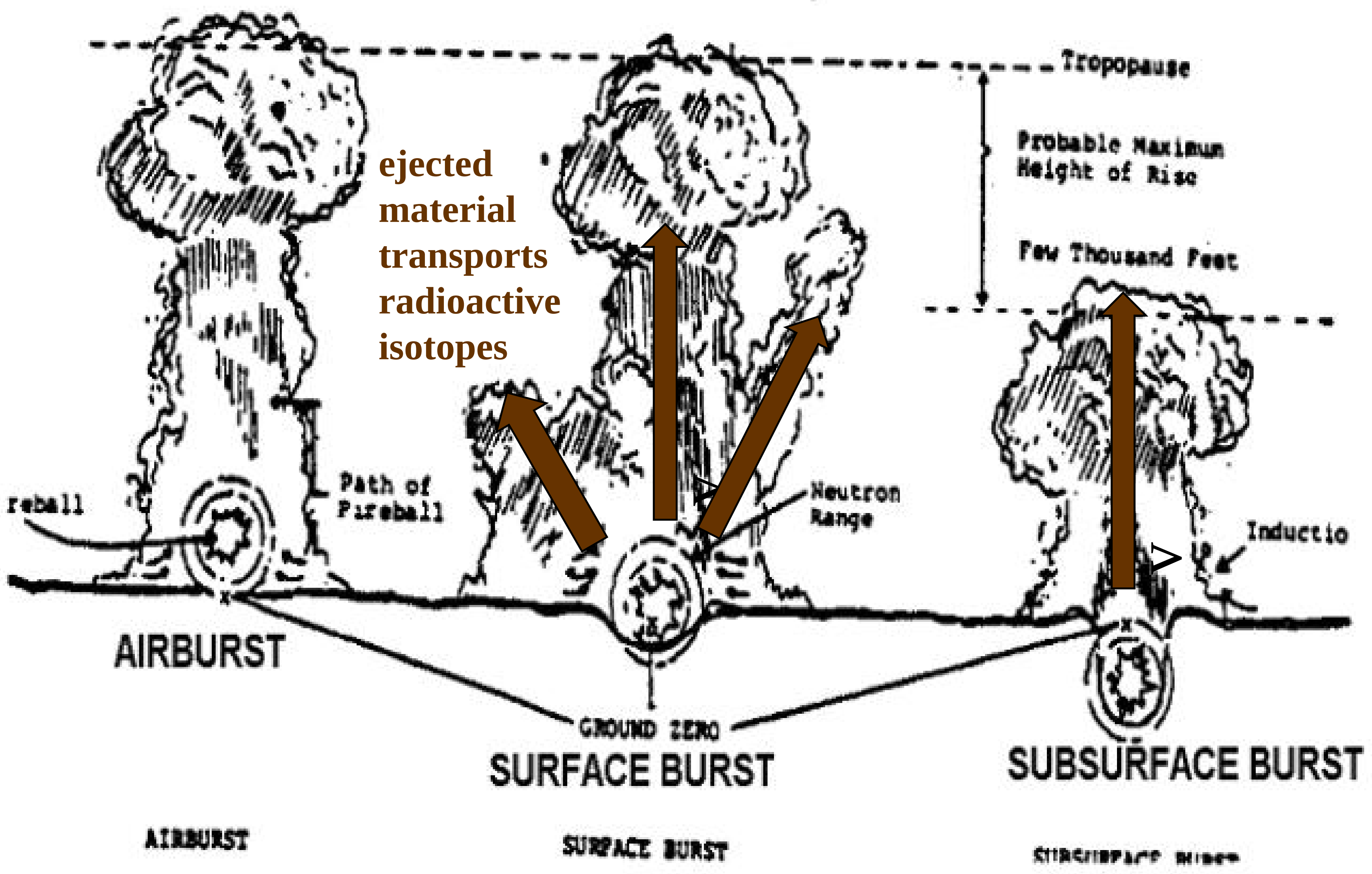
Nuclear Explosions in the Atmosphere or a Small Distance Underground



The amount of radioactive fallout is increased greatly if the fireball 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

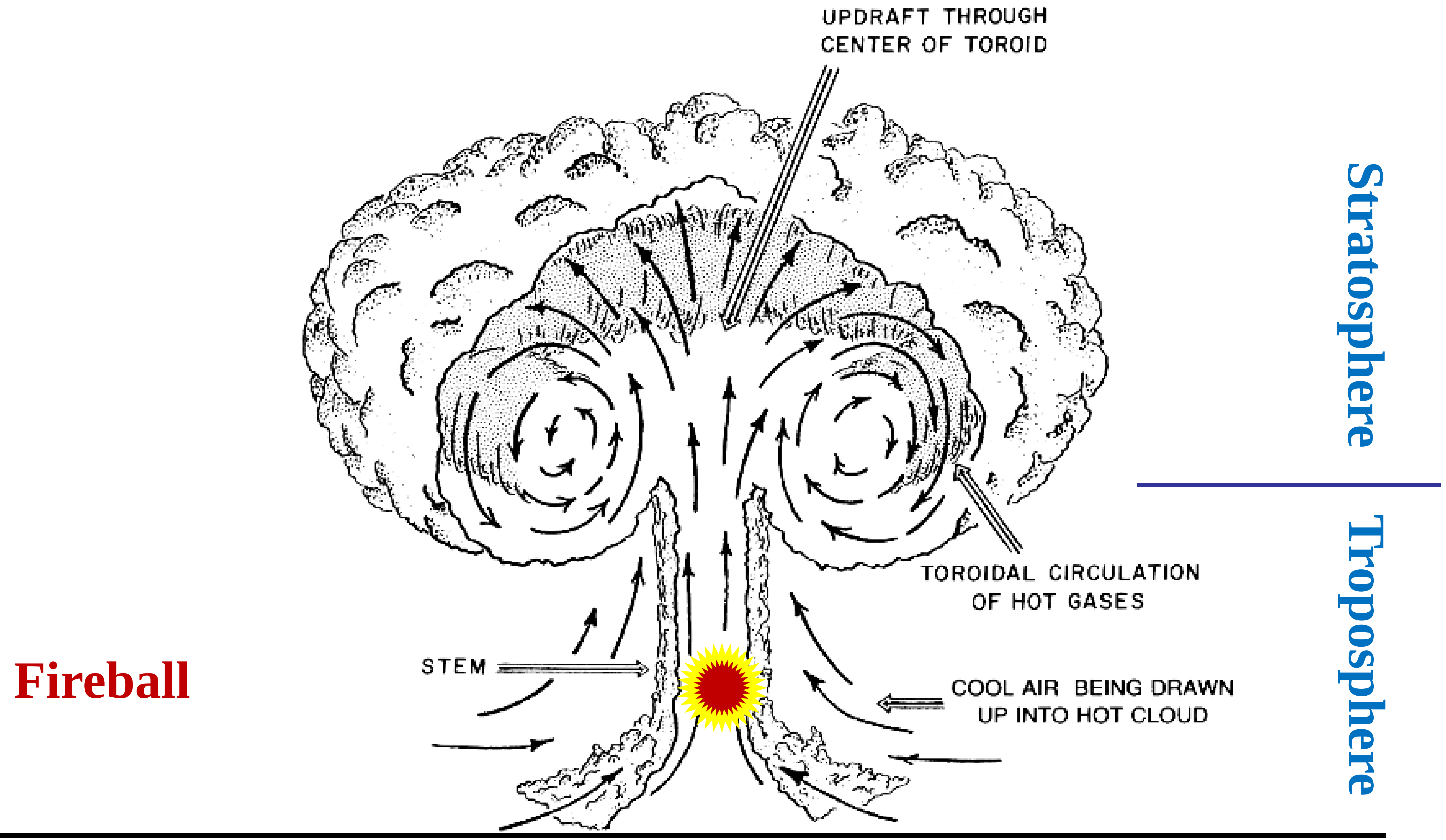
Time	Diameter	Temperature
1 ms (= 10^{-3} s)	440 ft	—
10 s	5,700 ft	6,000 C

- 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



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

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%

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 < 10^{-6} s)
- Thermal radiation (lasts ~ 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, ash and soot into atmosphere

Lecture Question

Is there historic precedence for an explosion ejecting dust, ash and soot into the stratosphere cooling earth ?

(A) Yes, following the nuclear attacks on Hiroshima and Nagasaki

(B) Yes, following the nuclear weapon tests in the 60s

(C) No, at any given time the yield of historic explosions was insufficient to transport very large amounts of dust and soot into the stratosphere.

(D) Yes, following the eruption of the Laki fissure system on Iceland in 1783.

(E) No, Vulcano eruptions cannot propel ash into the stratosphere.

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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 ^{o}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)

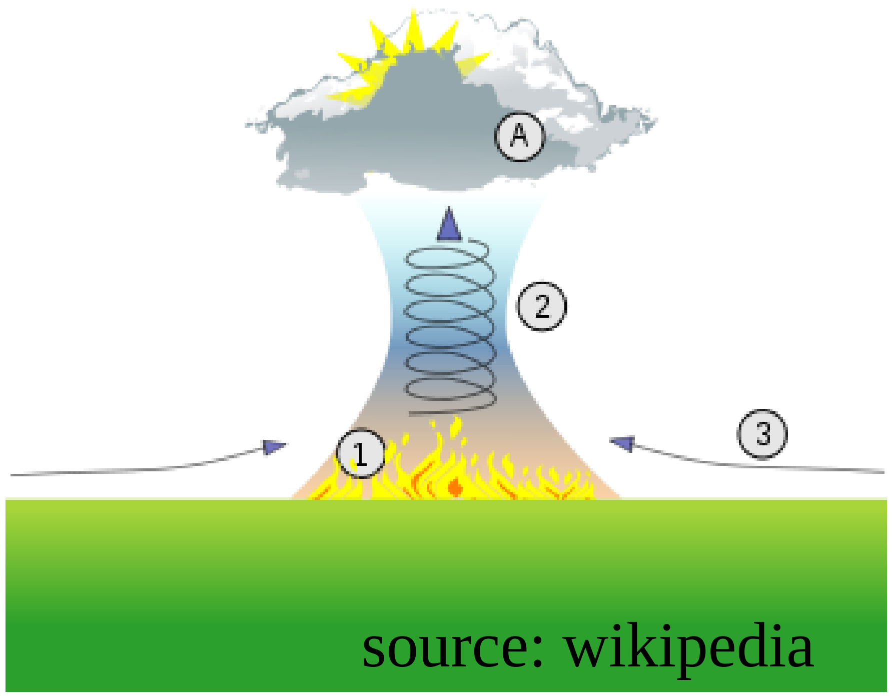
Conflagrations Versus Firestorms

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



Conflagrations Versus Firestorms

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

Effects of Blast Waves

Damaging Effects of a Blast Wave

- The blast wave is considered the militarily most 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

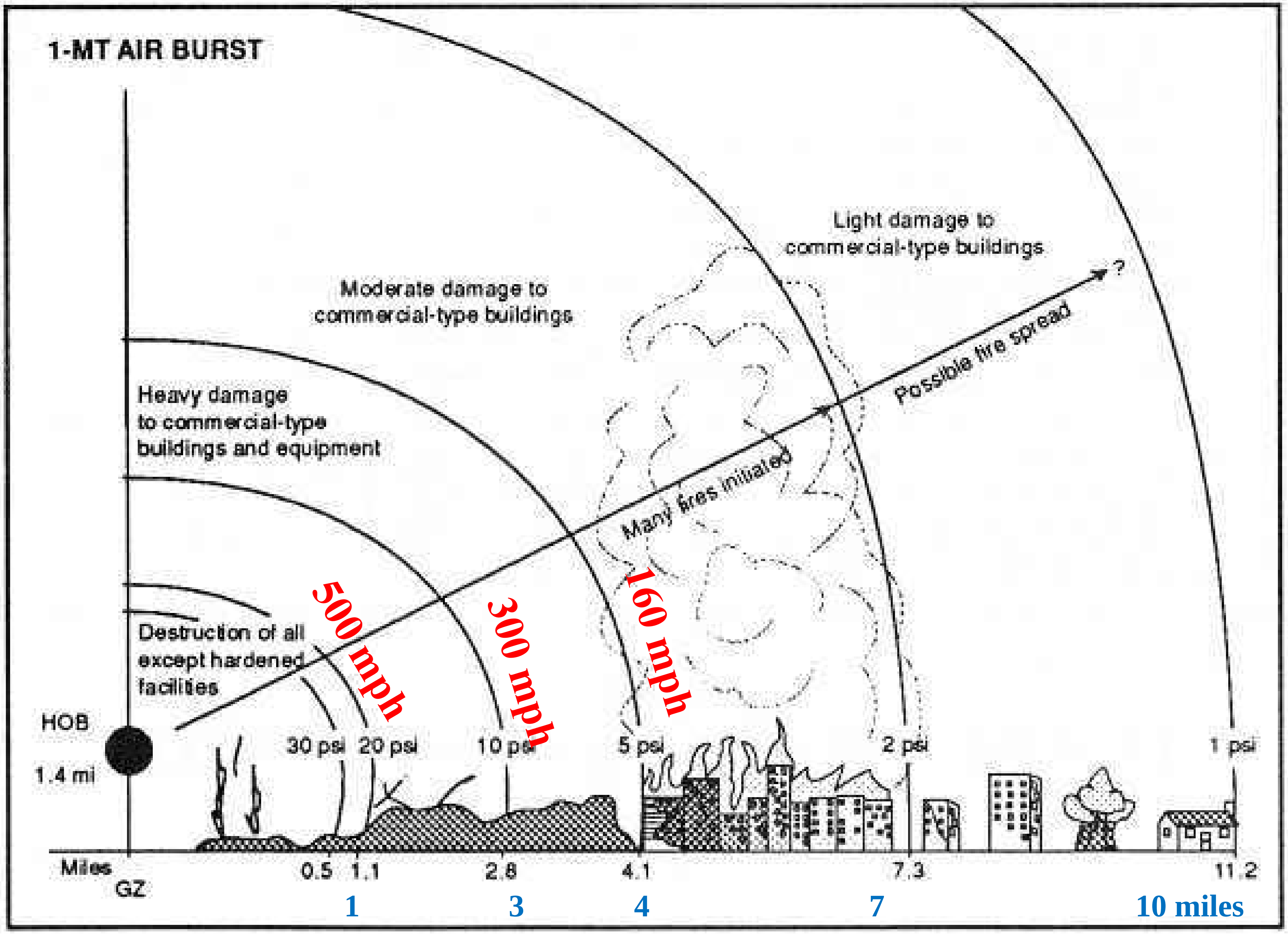
  - –A strong outward wind that produces dynamic pressure that blows structures and victims outward

- 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

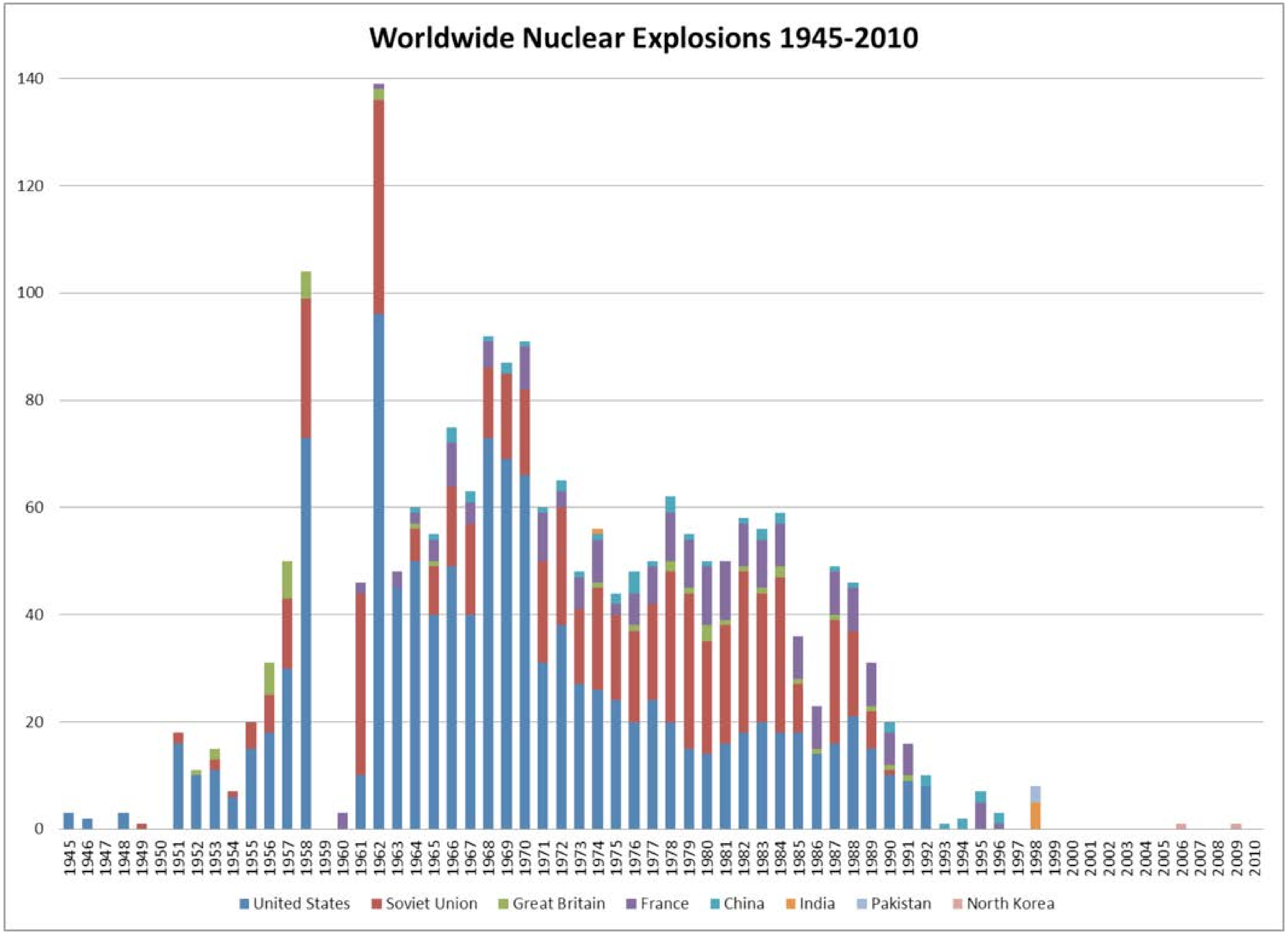
Effects of the Sedan Event (1962)

- 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

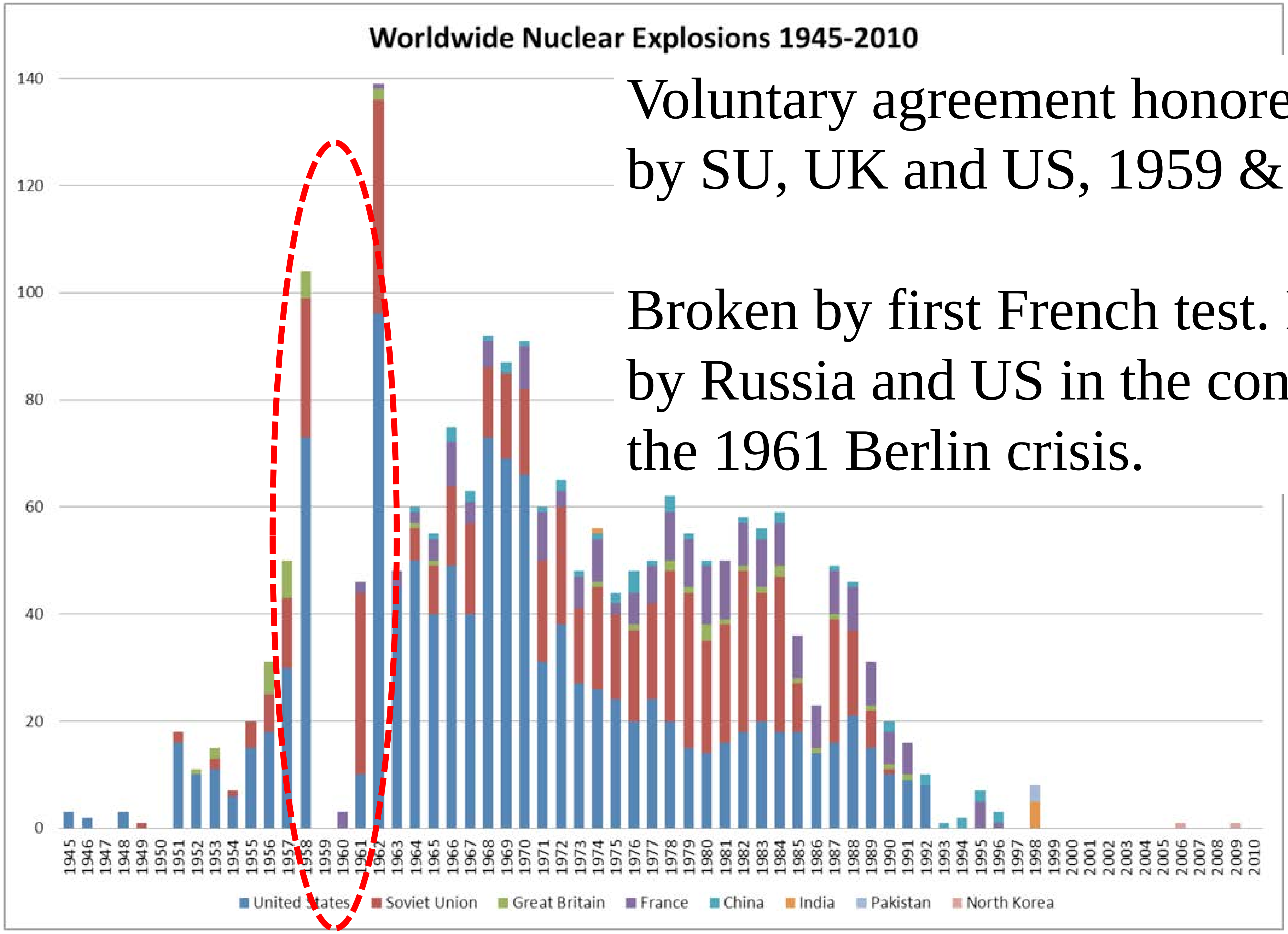
Example: The Sedan Test (100 kt, 1962)

Effects of Nuclear Explosions



Credit: Wikipedia Commons

Test Moratorium 1959-1960



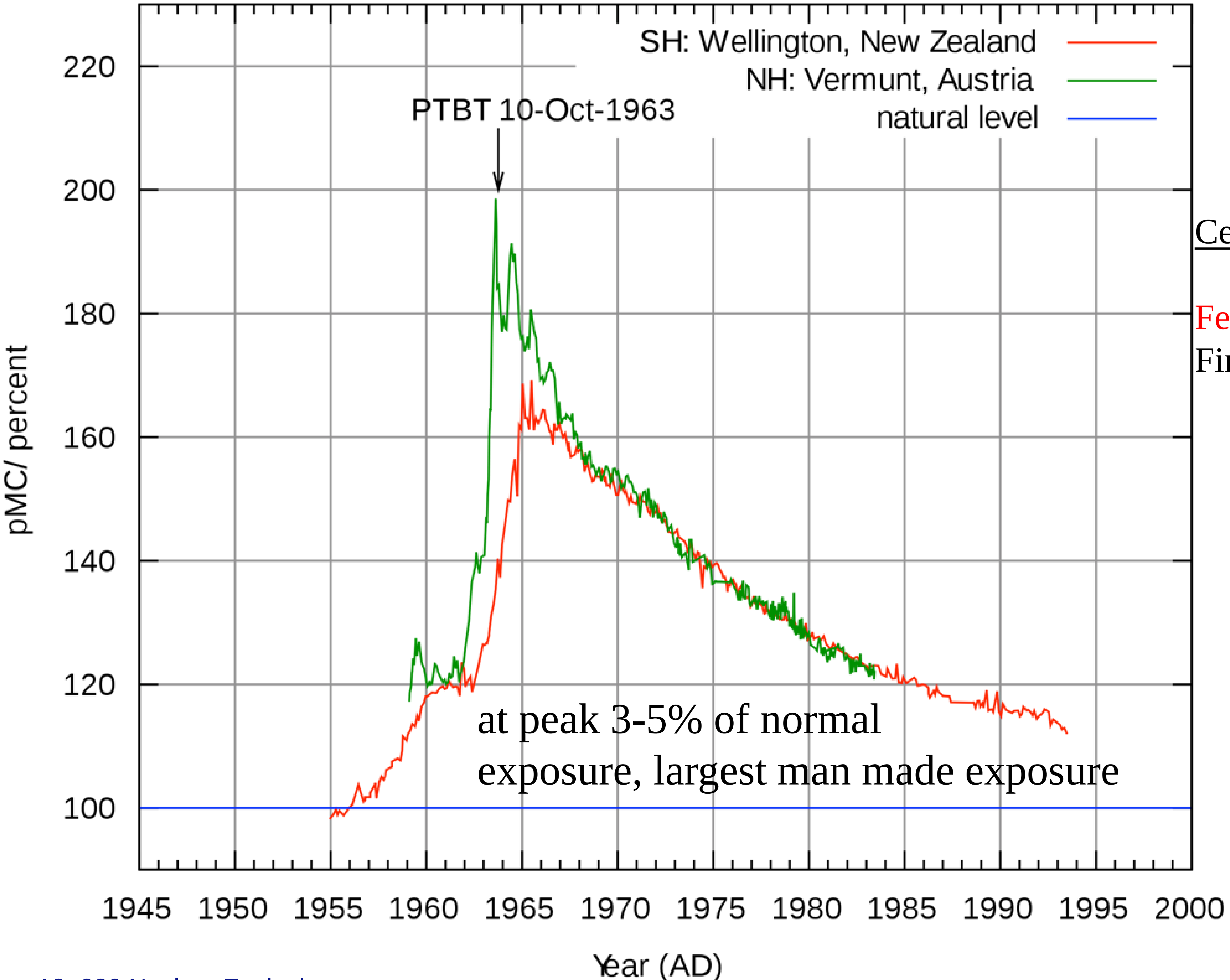
Voluntary agreement honored by SU, UK and US, 1959 & 1960

Broken by first French test. Broken by Russia and US in the context of the 1961 Berlin crisis.

Credit: Wikipedia Commons

Effects of Nuclear Explosions

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



<u>Centers for Disease Control and Prevention:</u>

Feasibility Study of Weapons Test Fall Out
Final report from April 2005

~ additional 11,000 cancer deaths among US population alive in the years from 1951 to 2000.

http://www.cdc.gov/nceh/radiation/fallout/default.htm

Plan for This Session

RE3v1 is due at 2pm (now!) – Peer review will be due by Monday 10 am (electronic upload). Peer review will be 25% of your grade of RE3v1.

Questions

Nuclear Explosions Conclusion: “Nuclear Winter”

“Ground Zero” Video presentation

News

Can Scientist Model the Impact of a Nuclear Attack on Human Behavior?

WIRED

MEGAN MOLTENI SCIENCE 02.13.18 08:00 AM

SCIENTISTS KNOW HOW YOU'LL RESPOND TO NUCLEAR WAR—AND THEY HAVE A PLAN

IT WILL START with a flash of light brighter than any words of any human language can describe. When the bomb hits, its thermal radiation, released in just 300 hundred-millionths of a second, will heat up the air over K Street to about 18 million degrees Fahrenheit. It will be so bright that it will bleach out the photo chemicals in the retinas of anyone looking at it, causing people as far away as Bethesda and Andrews Air Force Base to go instantly, if temporarily, blind. In a second, thousands of car accidents will pile up on every road and highway in a 15-mile radius around the city, making many impassable.

That 's what scientists know for sure about what would happen if Washington, DC, were hit by a nuke. But few know what the people-those who don't die in the blast or the immediate fallout-will do. Will they riot? Flee? Panic? Chris Barrett, though, he knows.

News

Can Scientist Model the Impact of a Nuclear Attack on Human Behavior?

WIRED

The science of prediction has changed a lot, too. Now, researchers like Barrett, who directs the Biocomplexity Institute of Virginia Tech, have access to an unprecedented level of data from more than 40 different sources, including smartphones, satellites, remote sensors, and census surveys. They can use it to model synthetic populations of the whole city of DC-and make these unfortunate, imaginary people experience a hypothetical blast over and over again.
That knowledge isn't simply theoretical: The Department of Defense is using Barrett's simulations-projecting the behavior of survivors in the 36 hours post-disaster-to form emergency response strategies they hope will make the best of the worst possible situation.

Fusing together the 40-plus databases to get this single snapshot requires tremendous computing power. Blowing it all up with a hypothetical nuclear bomb and watching things unfold for 36 hours takes exponentially more. When Barrett's group at Virginia Tech simulated what would happen if the populations exhibited six different kinds of behaviors-like healthcare-seeking vs. shelter-seeking-it took more than a day to run and produced 250 terabytes of data. And that was taking advantage of the institute's new 8,600-core cluster, recently donated by NASA. Last year, the US Threat Reduction Agency awarded them $27 million to speed up the pace of their analysis, so it could be run in something closer to real time.

Then Barrett's team can run experiments to see how different behaviors result in different mortality rates. The thing that leads to the worst outcomes? If people miss or disregard messages that tell them to delay their evacuation, they may be exposed to more of the fallout-the residual radioactive dust and ash that "falls out" of the atmosphere. About 25,000 more people die if everyone tries to be a hero, encountering lethal levels of radiation when they approach within a mile of ground zero.

Fallout Radiation from a 1 Mt Burst

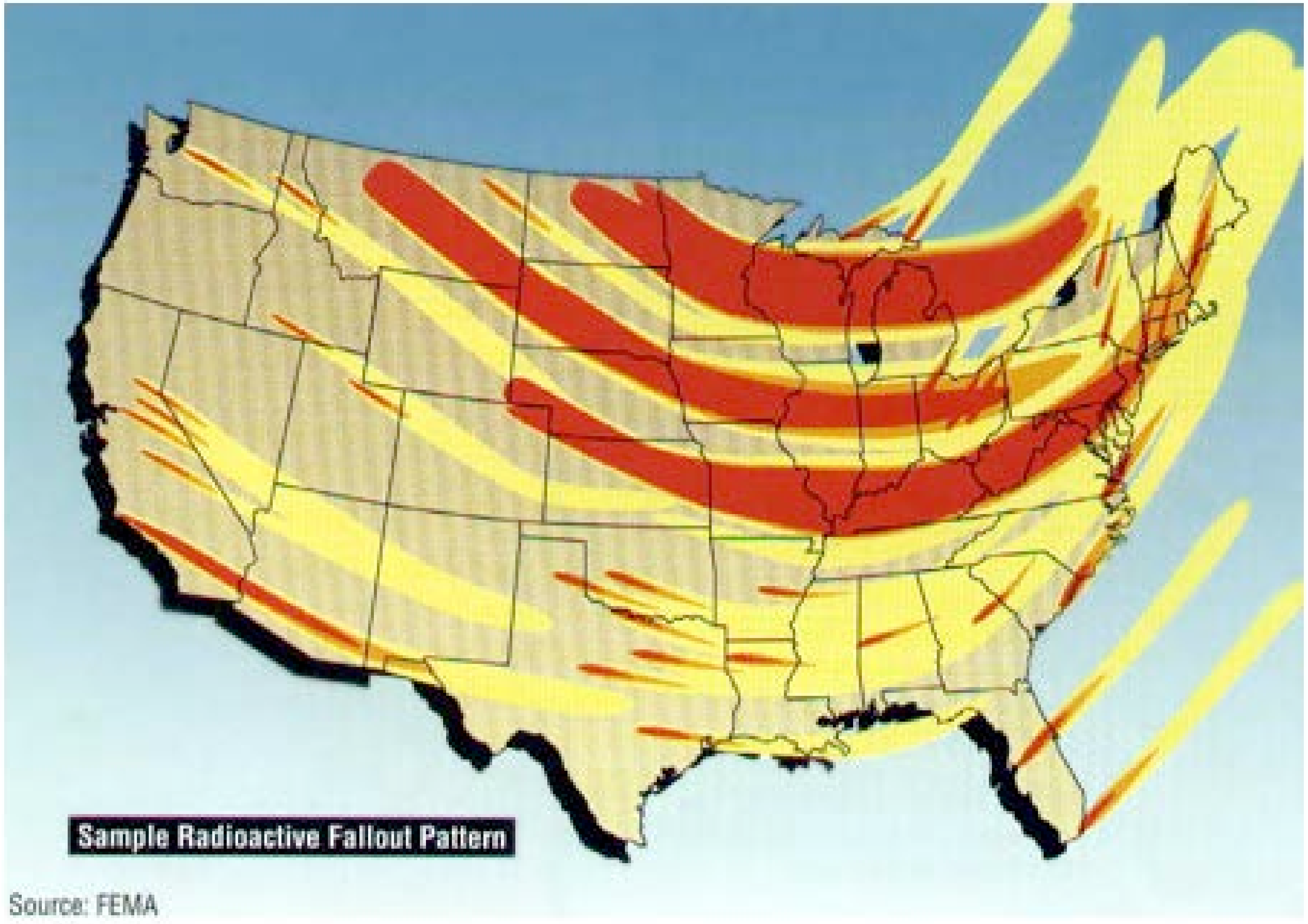
Assume —

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

Distances and doses —

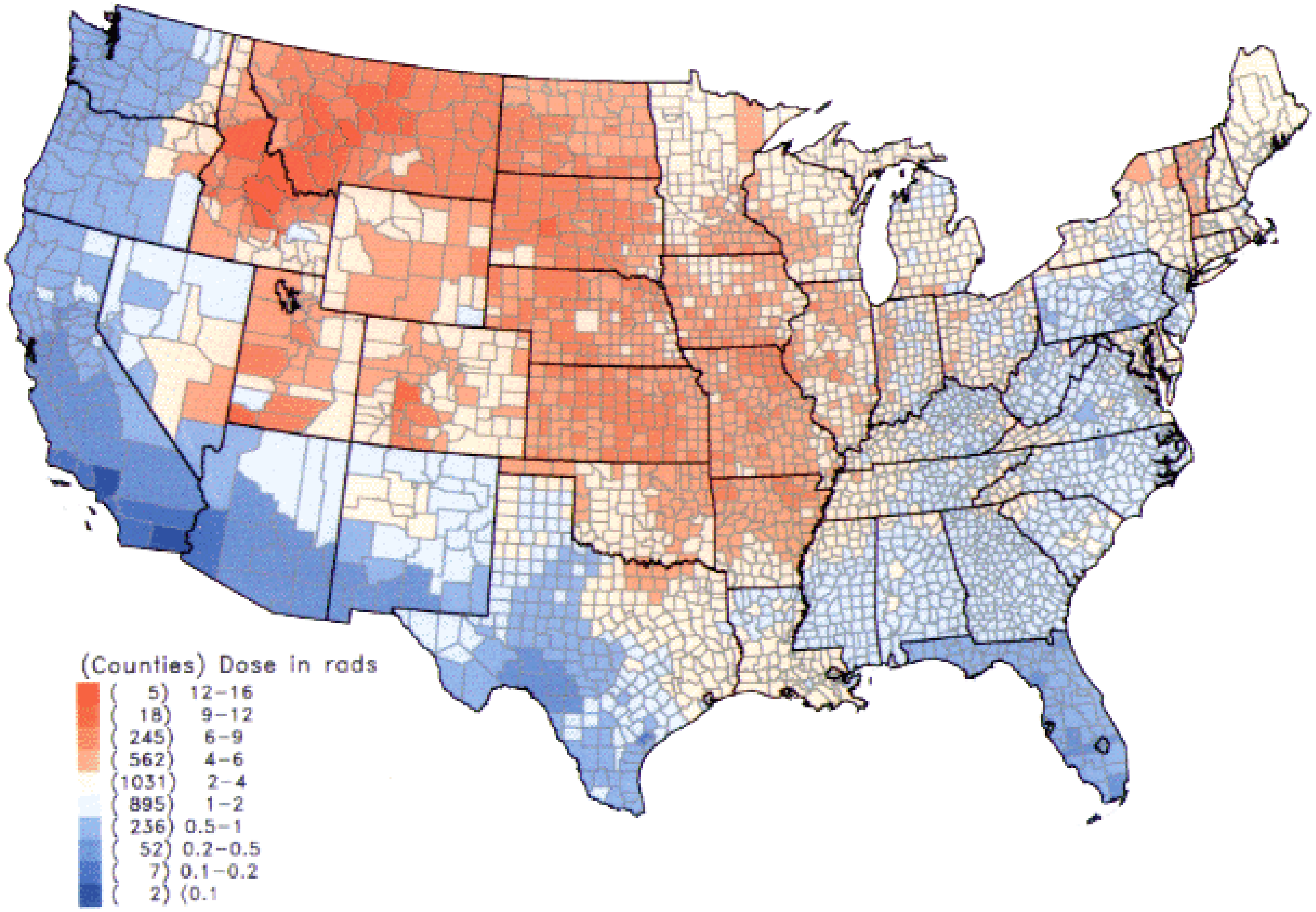
- 30 miles: 3,000 rem (death within hours; more than 10 years before habitable)
- 90 miles 900 rem (death in 2 to 14 days)
- 160 miles: 300 rem (severe radiation sickness)
- 250 miles: 90 rem (significantly increased cancer risk; 2 to 3 years before habitable)

Effects of Nuclear Explosions



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

Per Capita Thyroid Doses from 1951-1962 Nuclear Testing at the Nevada Test Side



Centers for Disease Control, Feasibility Study of Weapons Test Fall Out:

"For example, the population of 3.8 million people born in the United States in 1951 will likely experience fewer than 1,000 extra fatal cancers as a result of fallout exposures, a lifetime risk of less than 0.03% or about 1 in 3800. This number may be compared with the approximately 760,000 fatal cancers that would be predicted in the absence of fallout.

It is expected that the largest number of excess cancer deaths would occur in the group of people born in 1951, because, on average, this group received higher doses at younger ages than groups born earlier or later."

Lecture Question

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

(A) Blast

(B) Thermal radiation

(C) Electromagnetic pulse

(D) Residual nuclear radiation (“fallout”)

Lecture Question Answer

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

(A) Blast

(B) Thermal radiation

(C) Electromagnetic pulse

(D) Residual nuclear radiation (“fallout”)

Lecture Question

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

(A) Blast

(B) Thermal radiation

(C) Electromagnetic pulse

(D) Residual nuclear radiation (“fallout”)

Lecture Question Answer

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

(A) Blast

(B) Thermal radiation

(C) Electromagnetic pulse

(D) Residual nuclear radiation (“fallout”)

Lecture Question

Nuclear Weapon Effects

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

(A) Prompt nuclear radiation

(B) Electromagnetic pulse

(C) Thermal radiation

(D) Blast

(E) Residual nuclear radiation (“fallout”)

Lecture Question Answer

Nuclear Weapon Effects

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

(A) Prompt nuclear radiation

(B) Electromagnetic pulse

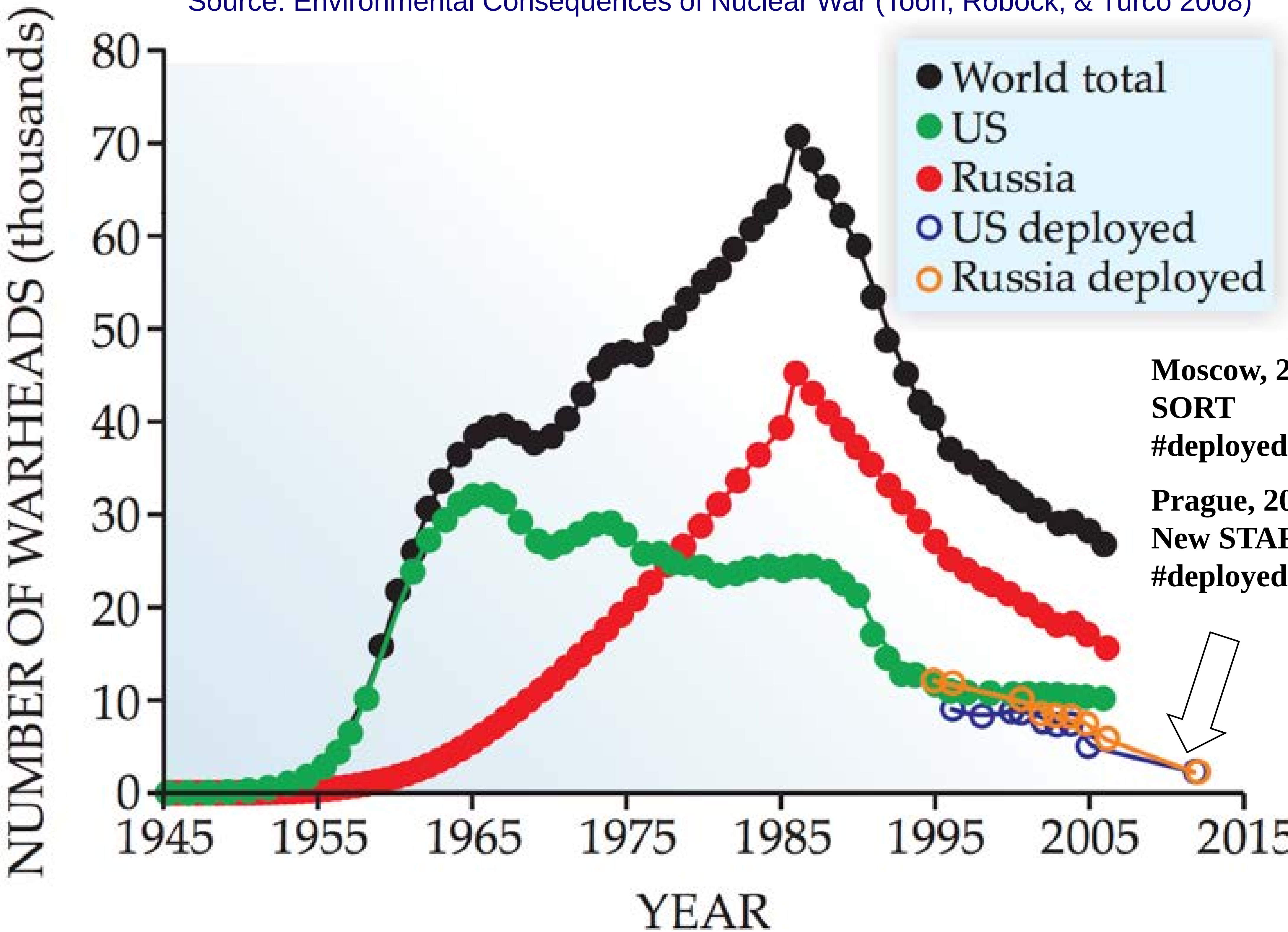
(C) Thermal radiation

(D) Blast

(E) Residual nuclear radiation (“fallout”)

Effects of Nuclear War – Input to War Scenarios for Illustration

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



Moscow, 2002
SORT
#deployed < 2200

Prague, 2010
New START
#deployed < 1550

Effects of Nuclear War: Direct Causalities

For Illustration assume

War fought with 100kT Nuclear Weapons

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)

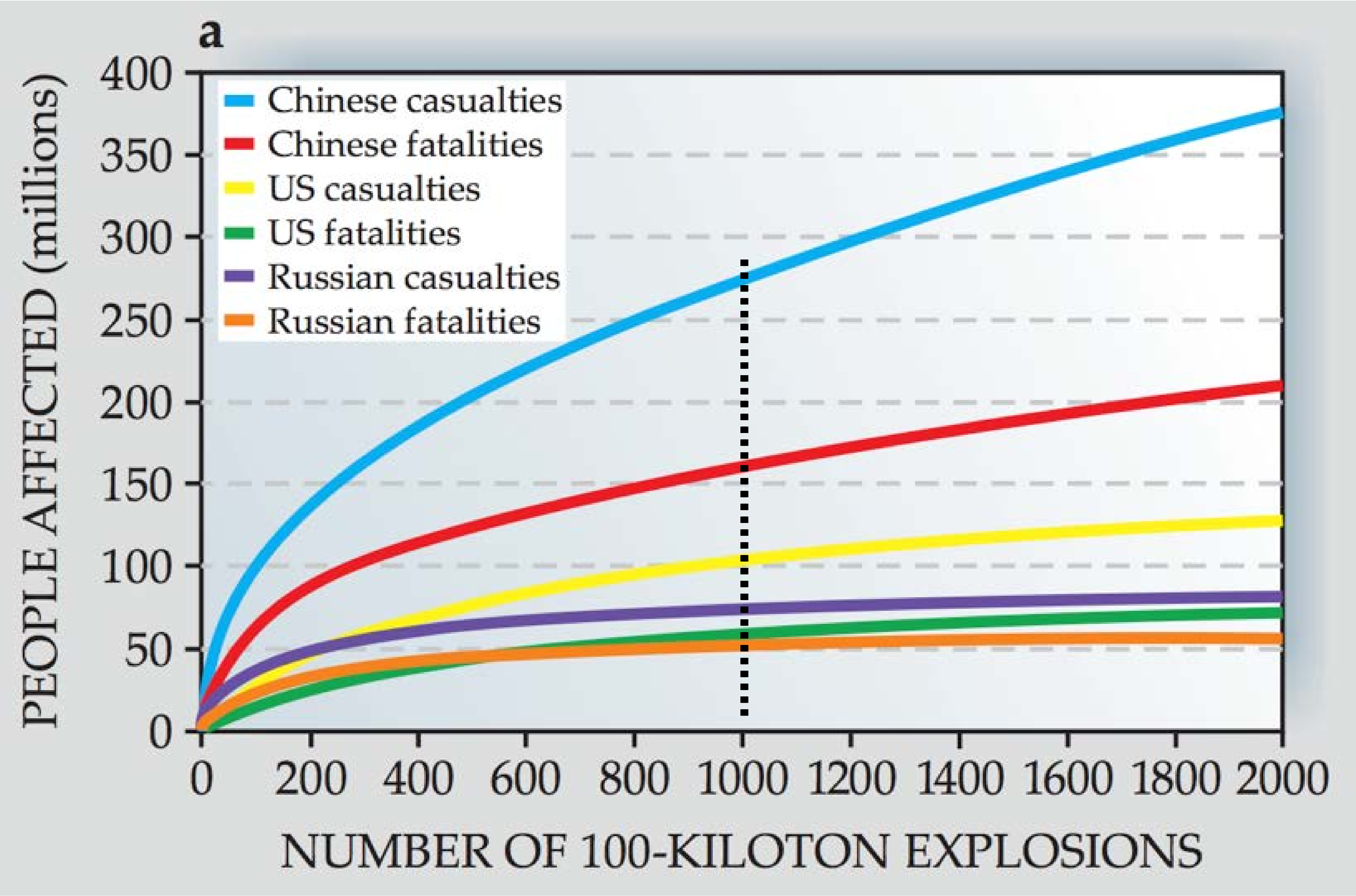
1,000 weapons detonated on Russia would *immediately* —

- 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: Direct Causalities

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



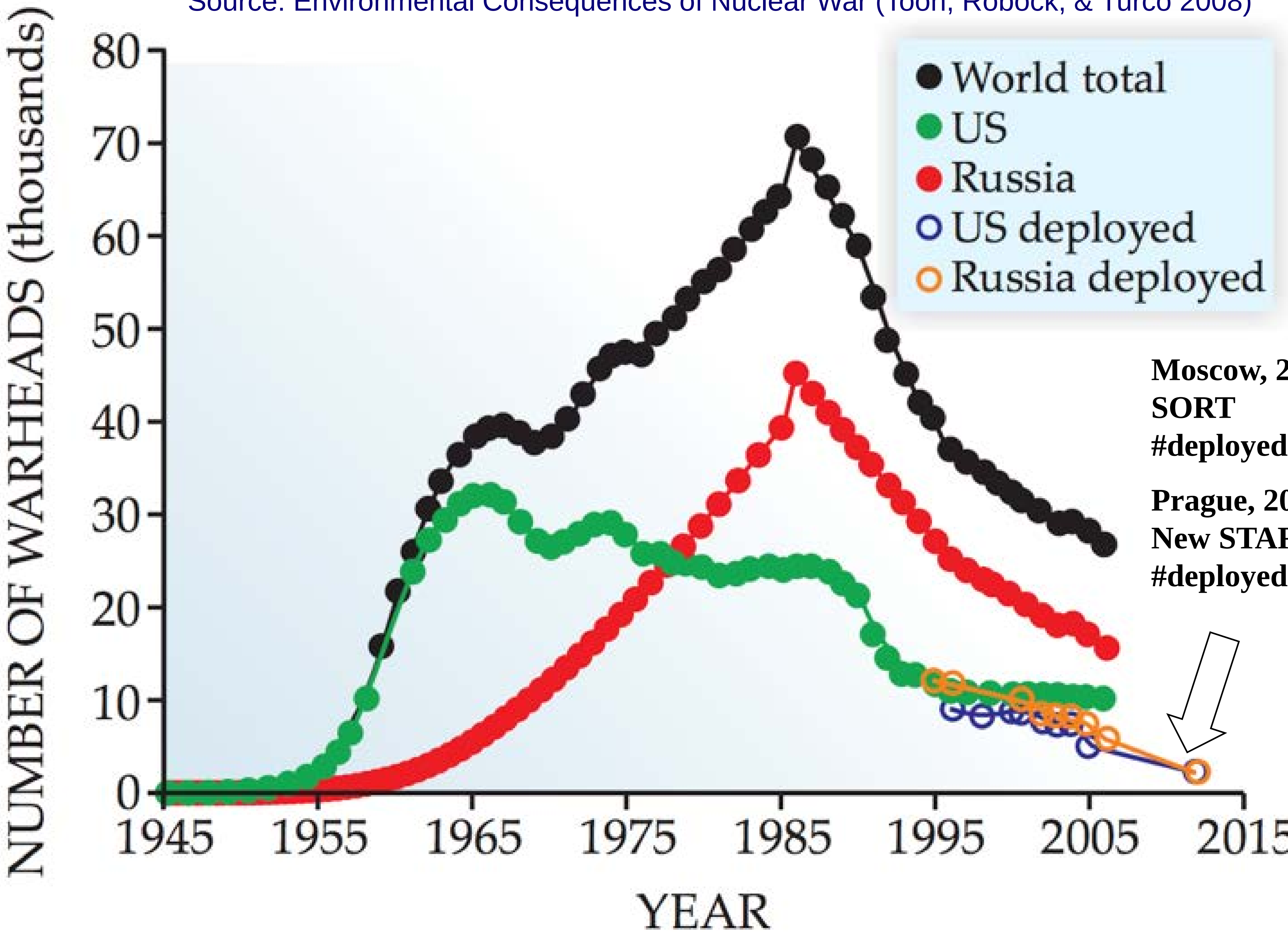
Large Cities in China, Russia and the United States

Country	above 1 Million	100,000 - 1 Millions	10,000 to 100,000
China	59	354	385
Russia	12	203	1291
U.S.	10	285	3376

However, distribution of industrial capabilities is wider in the U.S.

Effects of Nuclear War – Input to War Scenarios for Illustration

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



Moscow, 2002
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Effects of Nuclear War: Two Scenarios for the Study of Longterm Environmental Effects

Nuclear War Models:

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

(II) Regional nuclear war (eg. Pakistan – India):
50 weapons of 15-kt each = 0.75 Mt total

Weapons are assumed to be targeted on industry.

Effects of Nuclear War: Longterm Environmental Effects

SORT War ~ 4400 100 kT Warheads

A nuclear war between Russia and the USA could generate 200 Tg (200 million tons) of soot, sufficient to —

- Reduce average temperatures by ~14 Fahrenheit.
- Reduce precipitation by ~ 45%.
- Eliminate the growing season in large parts of Russia and nearby countries (eg. Ukraine).
- reduce the length of the growing season in the U.S. Midwest by ~75%.

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

Effects of Nuclear War: Longterm Environmental Effects

Regional Conflict, India and Pakistan with ~ 100 15 kT Warheads

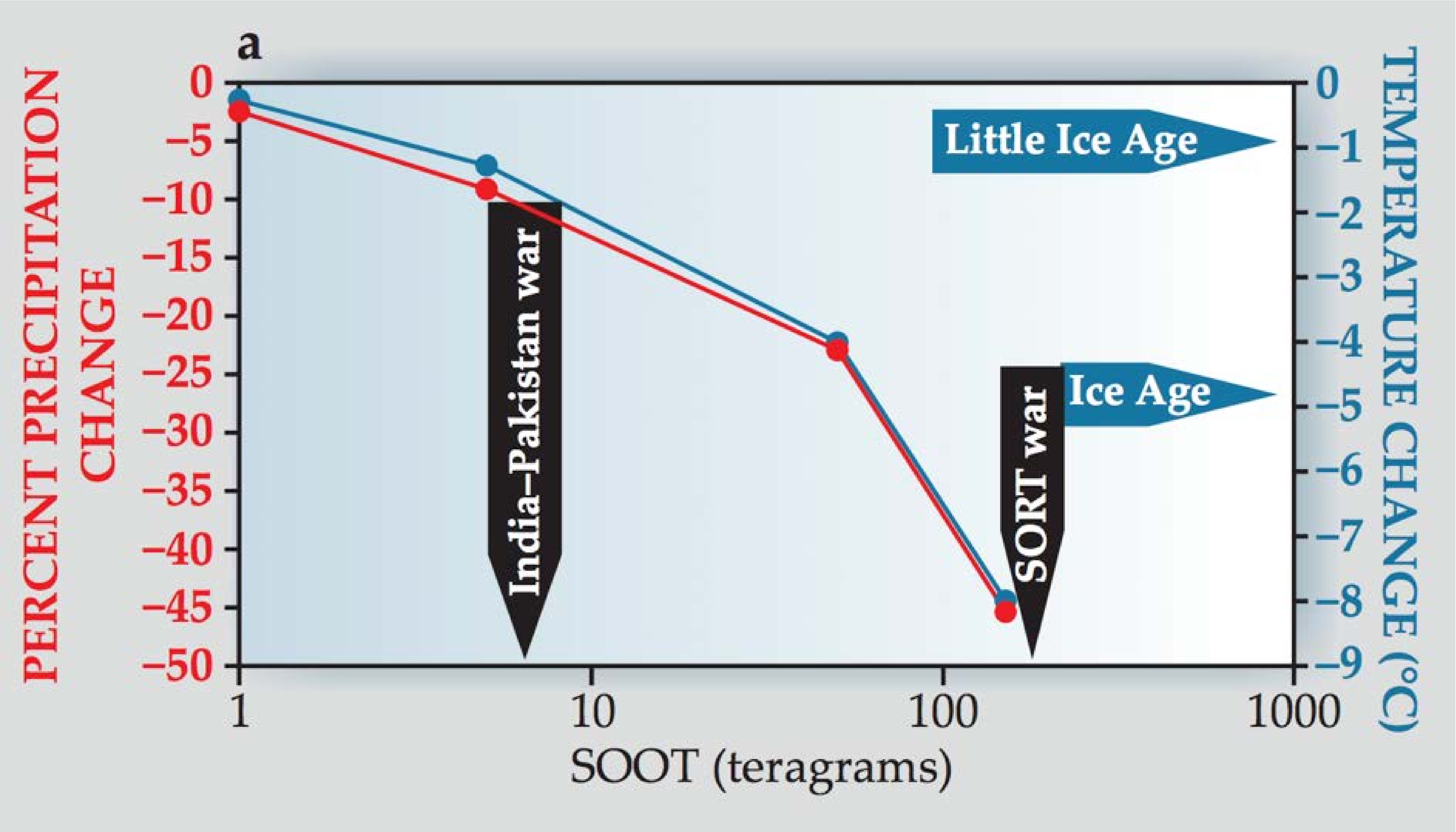
A regional war between India and Pakistan could generate 5 Tg of soot (5 million tons), sufficient to —

- produce the lowest temperatures for 1,000 years on the northern hemisphere, lower than the Little Ice Age or 1816 ("the year without a summer")
- reduce precipitation in the Asian monsoon region by 40%
- reduce the length of the growing season in the U.S. Midwest by 10%.

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

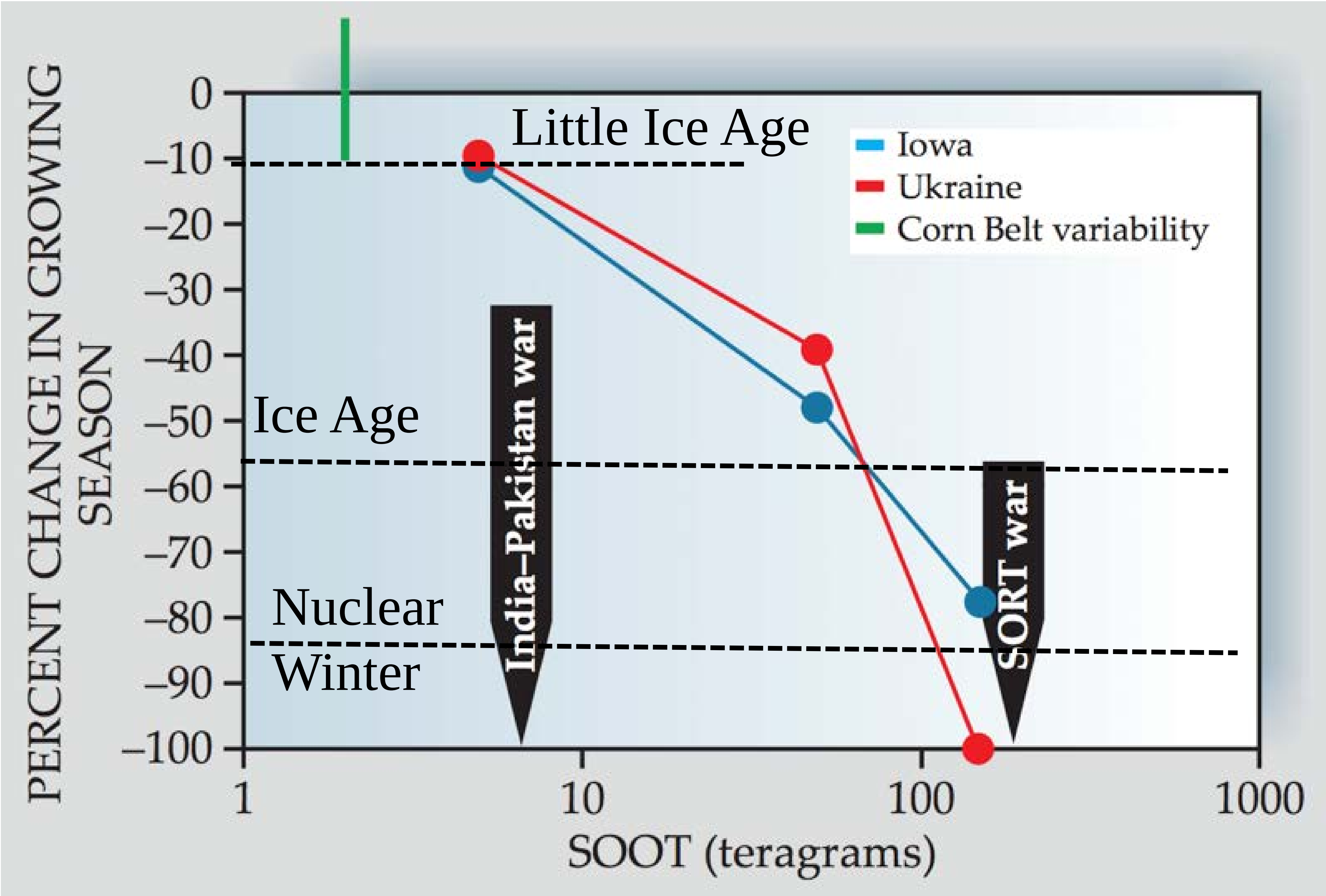
Effects of Nuclear War: Change in Precipitation and Temperature

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



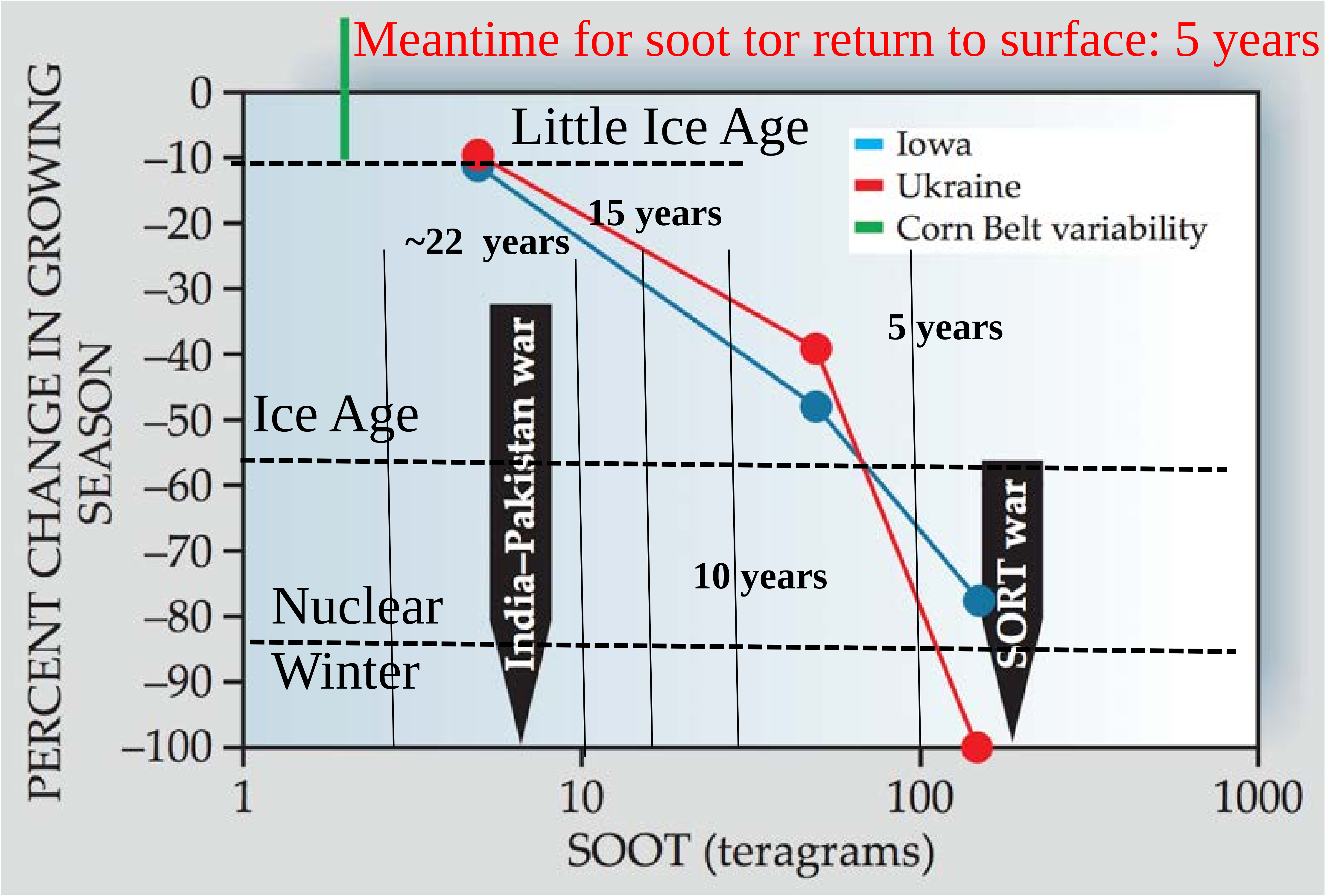
Effects of Nuclear War: Percent Change in Growing Season

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)



Effects of Nuclear War

Indirect Effects Would Be the Most Important

– ***"Environmental Consequences of Nuclear War"***

(Owen Toon, Alan Robock, & Richard Turco, Physics Today, December 2008)

"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."

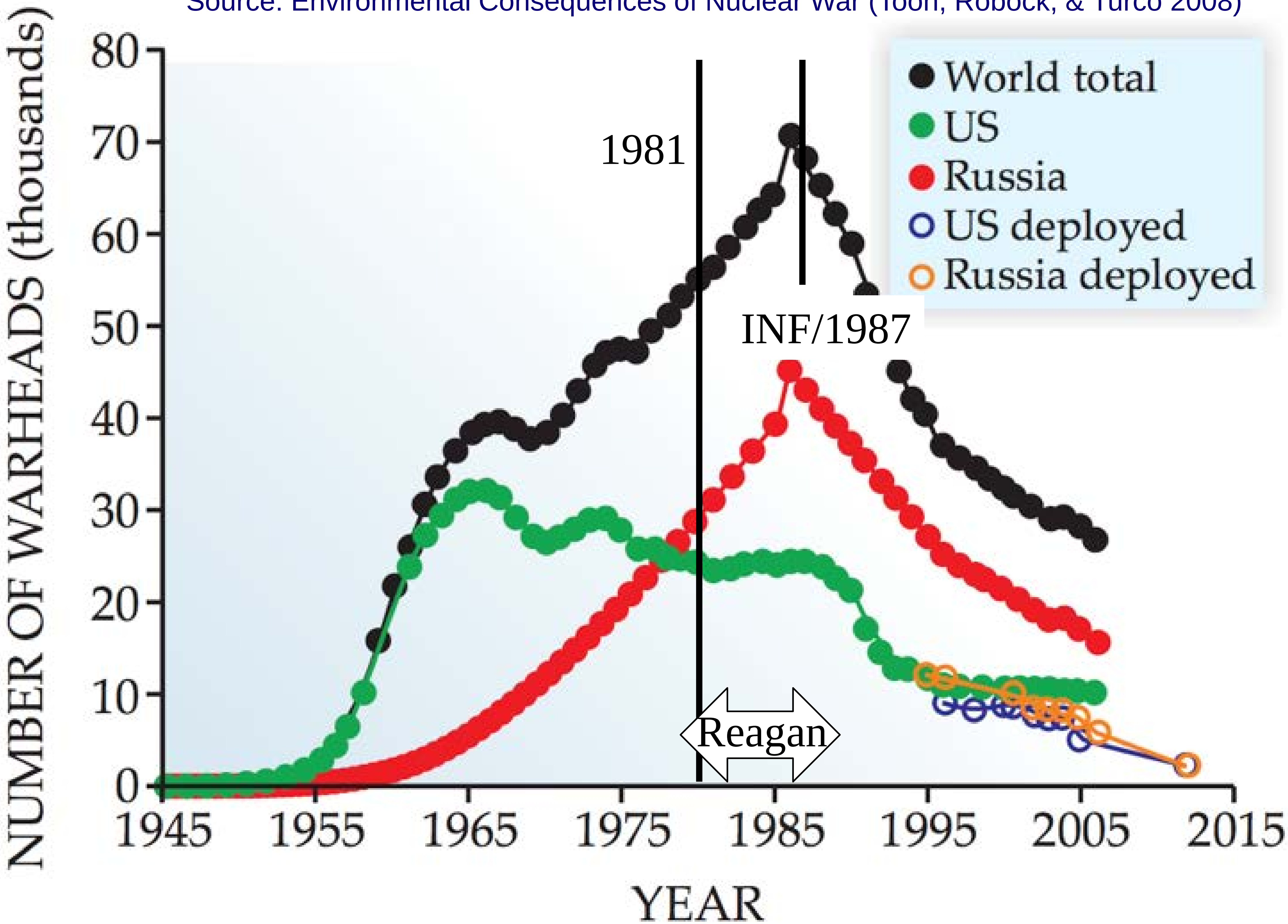
Ground Zero

Video Presentation, Ground Zero

(from CBS Reports on The Defense of the United States, aired June-14-1981)

Context: Arsenals at the Time of CBS Series

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



Questions for Discussion

(A) Which imbalance in nuclear arsenals triggered the concern of military superiority of the SU ?

(B) What is the TRIAD ?

(C) Why would there be much more fall out in a US-Russian Nuclear War than following Hiroshima and Nagasaki?

(D) Which society is more vulnerable to Nuclear War, Why?

Lecture 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

Lecture Question Answer

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

Lecture 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)

Lecture 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)

How Long from Nuclear Winter to Little Ice Age?

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