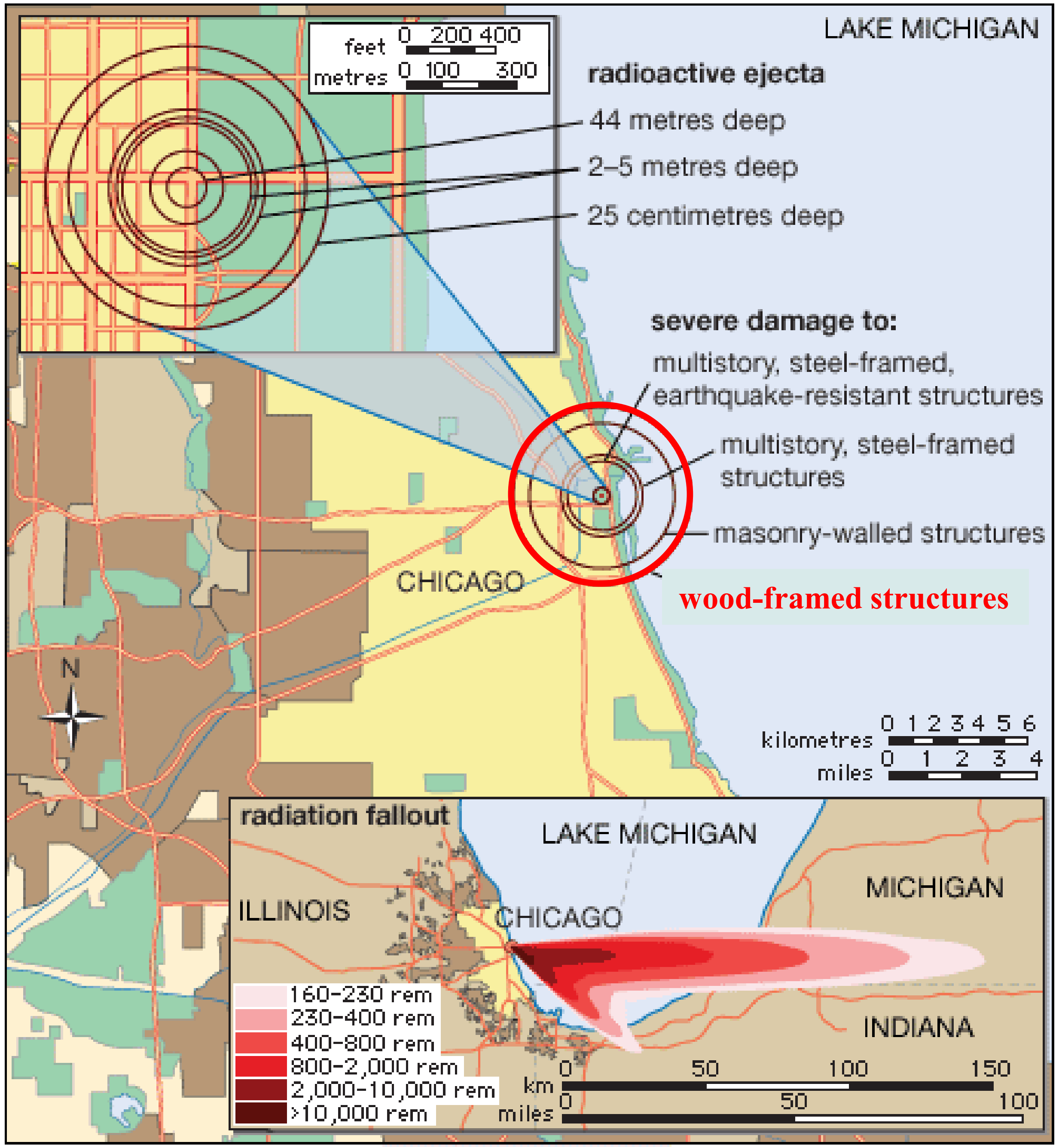
Physics 280: Effects of Nuclear Explosions

Impact of a 500 kiloton device detonated in Chicago



Plan for This Session

Module 3:
Effects of nuclear explosions

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

23p280 Nuclear Explosions, 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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Physics/Global Studies 280: Session 8

Plan for This Session

Announcements & Questions:

RPPv1 will be due Wednesday 2-15 at 10pm
and 2pm in class on Thursday (paper copy)

Office hours: today from 3:00-5:30 pm (401 Grainger Library)

Module 3 continued: Effects of nuclear explosions

News

The New York Times

North Korea Urges ‘Preparedness for War’ and Displays New Missile

Analysts said the new weapon was probably a solid-fuel ICBM, which the North’s leader, Kim Jong-un, has wanted to add to his country’s growing nuclear arsenal.

A photograph provided by North Korean state media showed an intercontinental ballistic missile during a military parade celebrating the 75th anniversary of the North Korean army in Pyongyang on Wednesday. Korean Central News Agency, via Agence France-Presse — Getty Images

By Choe Sang-Hun

Feb. 9, 2023, 4:38 a.m. ET

3 MIN READ

SEOUL — North Korea has unveiled what analysts said was a new, solid-fuel intercontinental ballistic missile during a nighttime military parade in Pyongyang on Wednesday, the latest example of the country’s effort to fill its arsenal with increasingly advanced nuclear technology.

The parade, celebrating the 75th anniversary of North Korea’s military, featured ICBMs and short-range “tactical nuclear” missiles that demonstrated the North’s “tremendous nuclear strike capability,” North Korean state media said on Thursday.

North Korea has frequently boasted about its weapons technology. But experts, saying the isolated country has often exaggerated its abilities, have expressed doubt that it has acquired the technology needed to hit targets across an ocean with ICBMs.

News

The New York Times

North Korea Urges 'Preparedness for War' and Displays New Missile

A photograph provided by North Korean state media showed an intercontinental ballistic missile during a military parade celebrating the 75th anniversary of the North Korean army in Pyongyang on Wednesday. Korean Central News Agency, via Agence France-Presse — Getty Images

The state media did not specify the capabilities of individual weapons at the parade, but the photos it carried showed the Hwasong-17 — the North's largest ICBM — which was tested in November. The photos also showed a new ICBM-sized canister, a tube from which a missile is launched.

Although it was unclear if the canister was a mock-up or contained a real missile, it was mounted on a nine-axle vehicle, indicating that it was roughly the size of the North's Hwasong-15 ICBM, first test-launched in 2017.

The new canister looked like a slightly upgraded version of a weapon that North Korea unveiled during a military parade in 2017, suspected to be a solid-fuel ICBM but never tested, said Yang Uk, an expert on North Korean weapons at the Asan Institute for Policy Studies in Seoul.
, Mr. Yang saWednesday's parade featured at least 15 ICBMs or ICBM mock-ups, more than in any previous military parade, basing his analysis on photos in North Korean state media. "They appear to have brought out all their ICBMs, including their solid-fuel ICBM launch vehicles," he said.
Solid-fuel missiles are easier to launch and harder to spot. In recent years, North Korea has tested a series of short-range, solid-fuel ballistic missiles that it said were capable of delivering nuclear warheads to South Korea.

News

The New York Times

North Korea Urges 'Preparedness for War' and Displays New Missile

But all three ICBMs that North Korea has tested so far have relied on liquid propellants. In December, the country tested a powerful new rocket engine that it said could be used to propel a solid-fuel ICBM. After that test, Kim Jong-un, the North's leader, urged his engineers to build a new, solid-fuel ICBM "in the shortest span of time."

Since taking power in 2011, Mr. Kim has staged more than a dozen military parades, using them to display his nuclear arsenal and to boost the morale of his people, who have suffered under international sanctions and food shortages.

The new missile disclosed on Wednesday was likely "a mock-up of a solid-fuel ICBM," said Kim Dong-yub, a North Korean weapons expert at the University of North Korean Studies in Seoul. "The canister may have been empty, but we cannot dismiss it as blustering. North Korea has often shown mock-ups in parades before testing the actual missiles."

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 … ?

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%

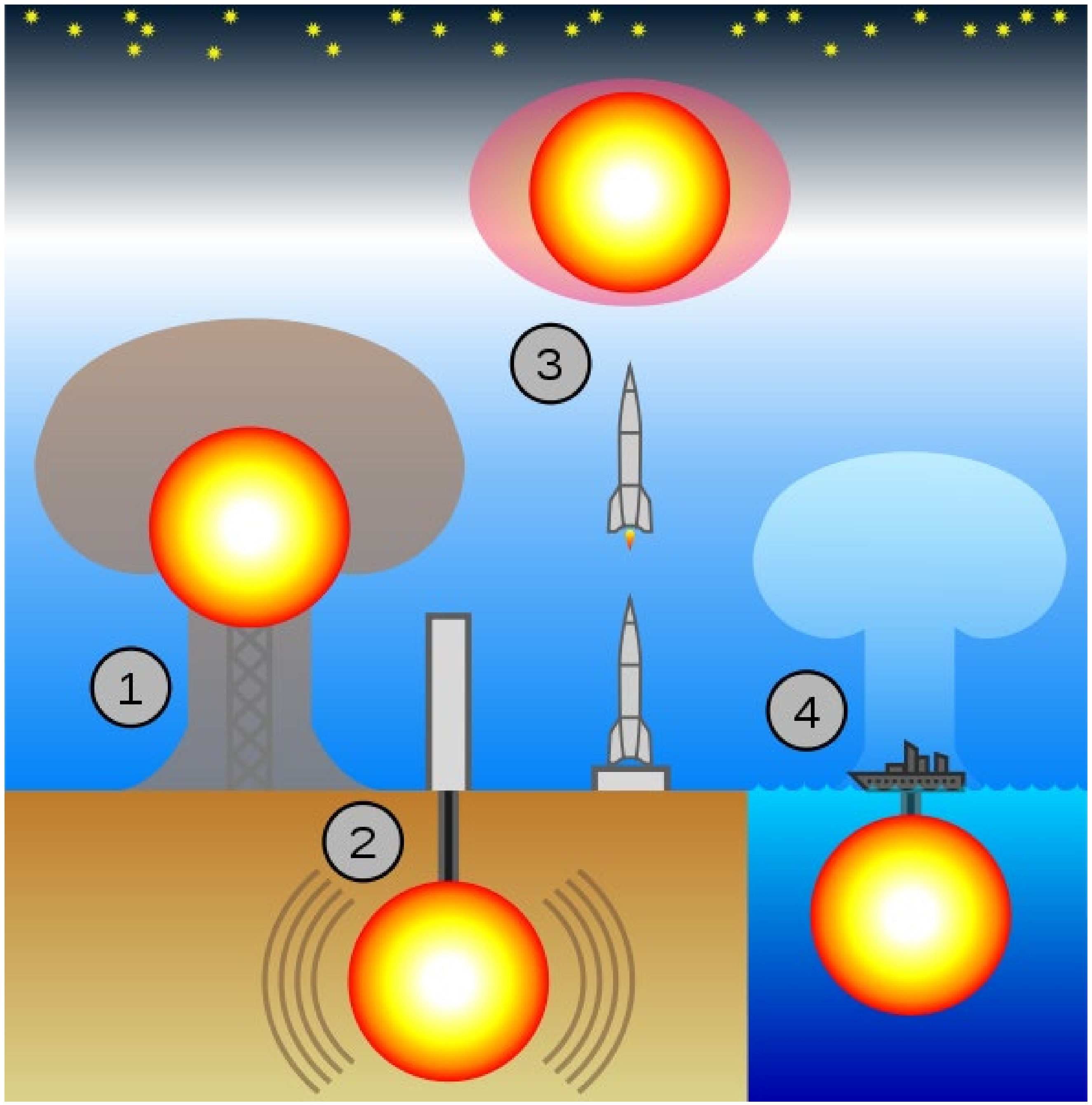
Subsequent Evolution of Nuclear Explosions

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.

Nuclear Explosions



Credit: Wikipedia (nuclear weapons testing)

Possible environments —

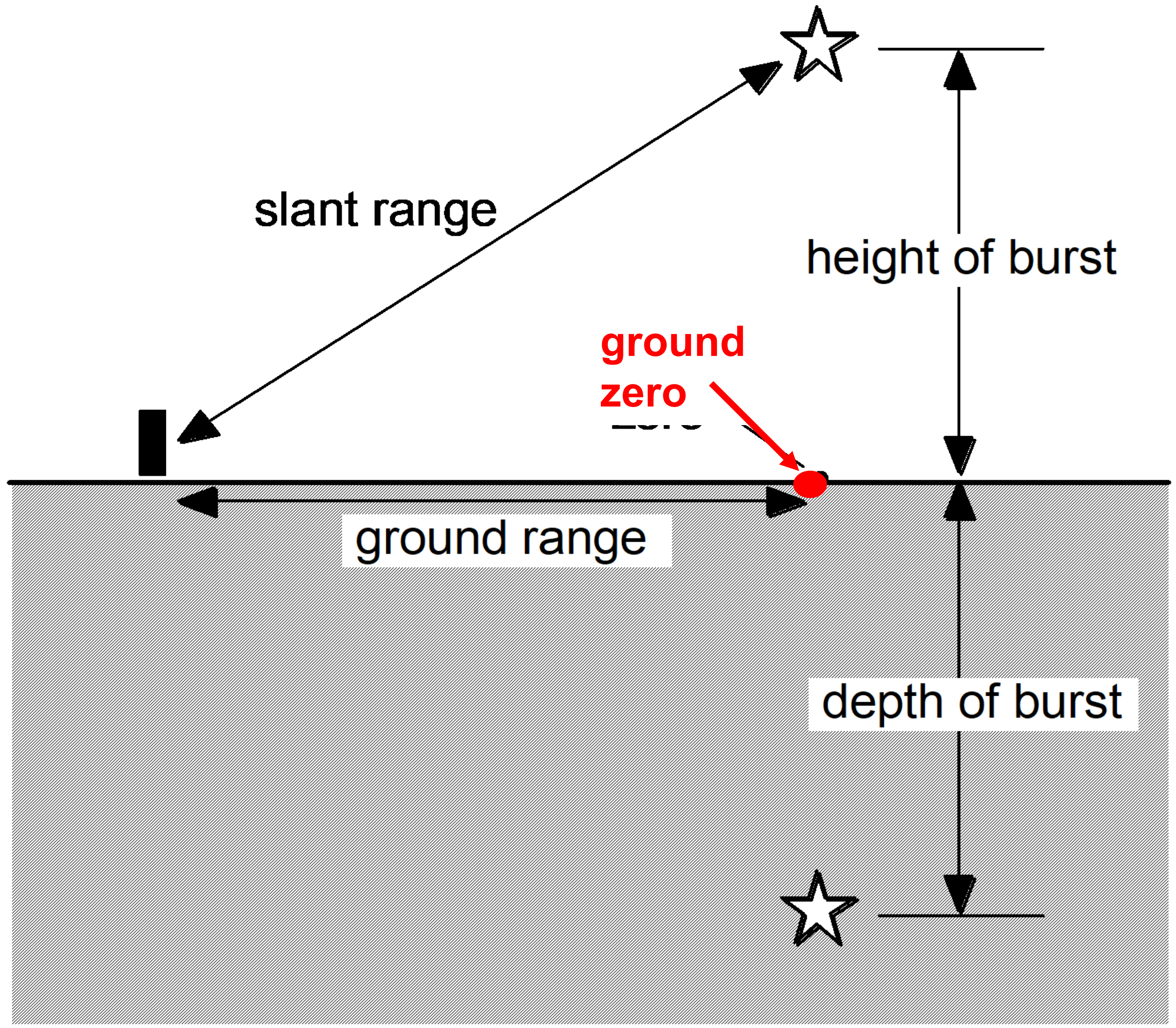
1. Air and surface bursts
2. Underground bursts

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

3b. Explosions in space

4. Underwater bursts

Nuclear Explosion Geometries

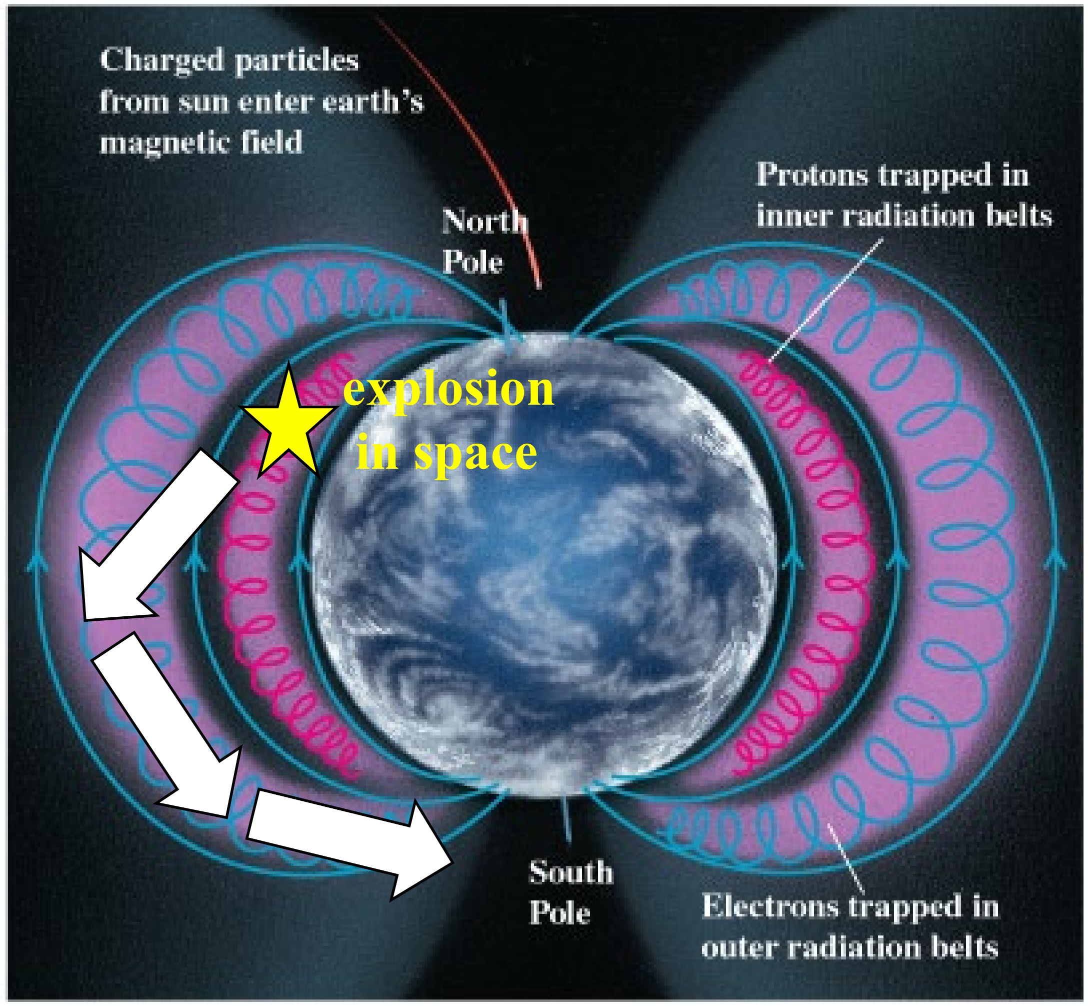


Nuclear Explosions in Space

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)

Underground Nuclear Explosions- Nevada Test Site

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

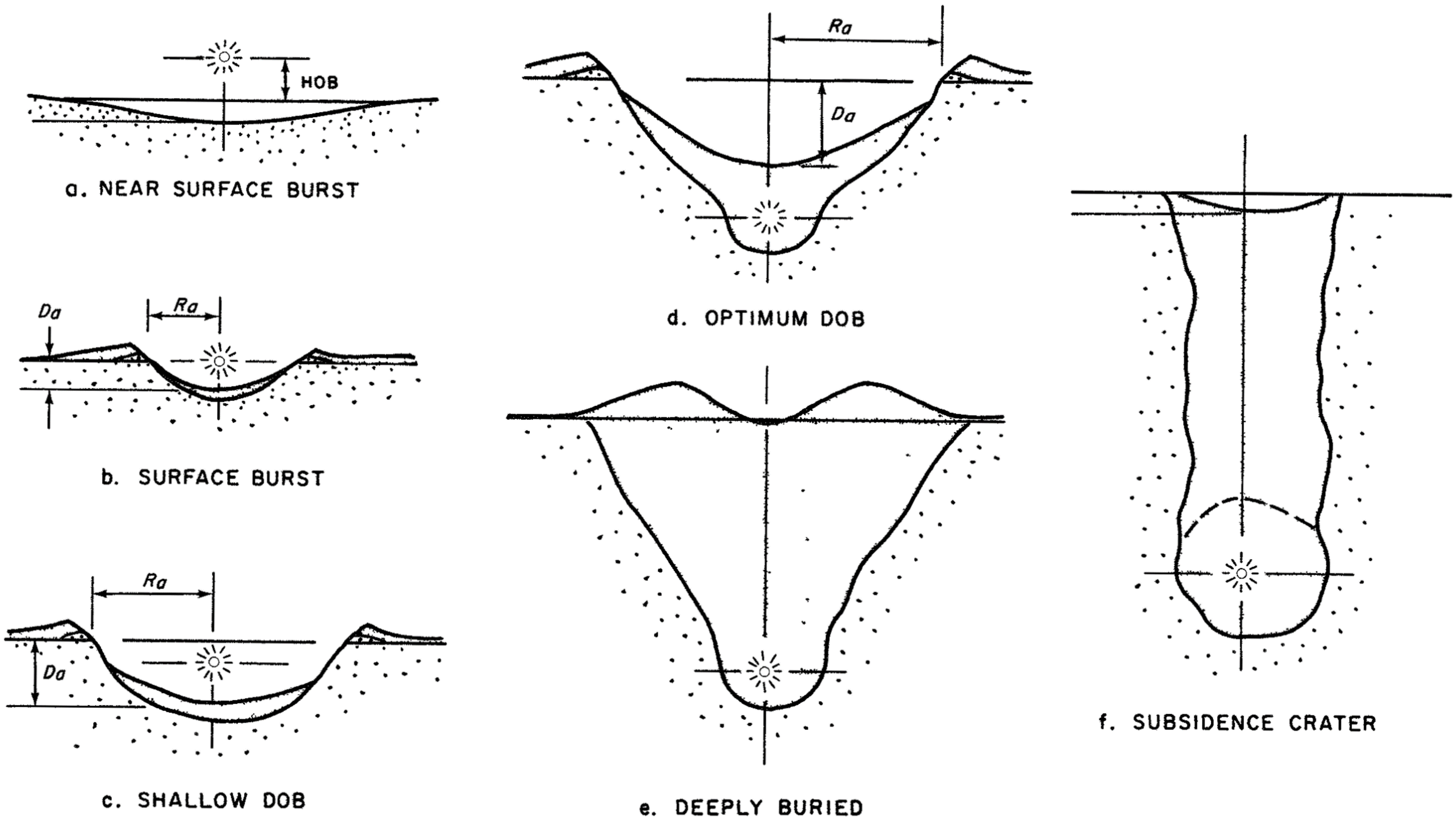
Underground Nuclear Explosions: Test Deployment & Assembly

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)

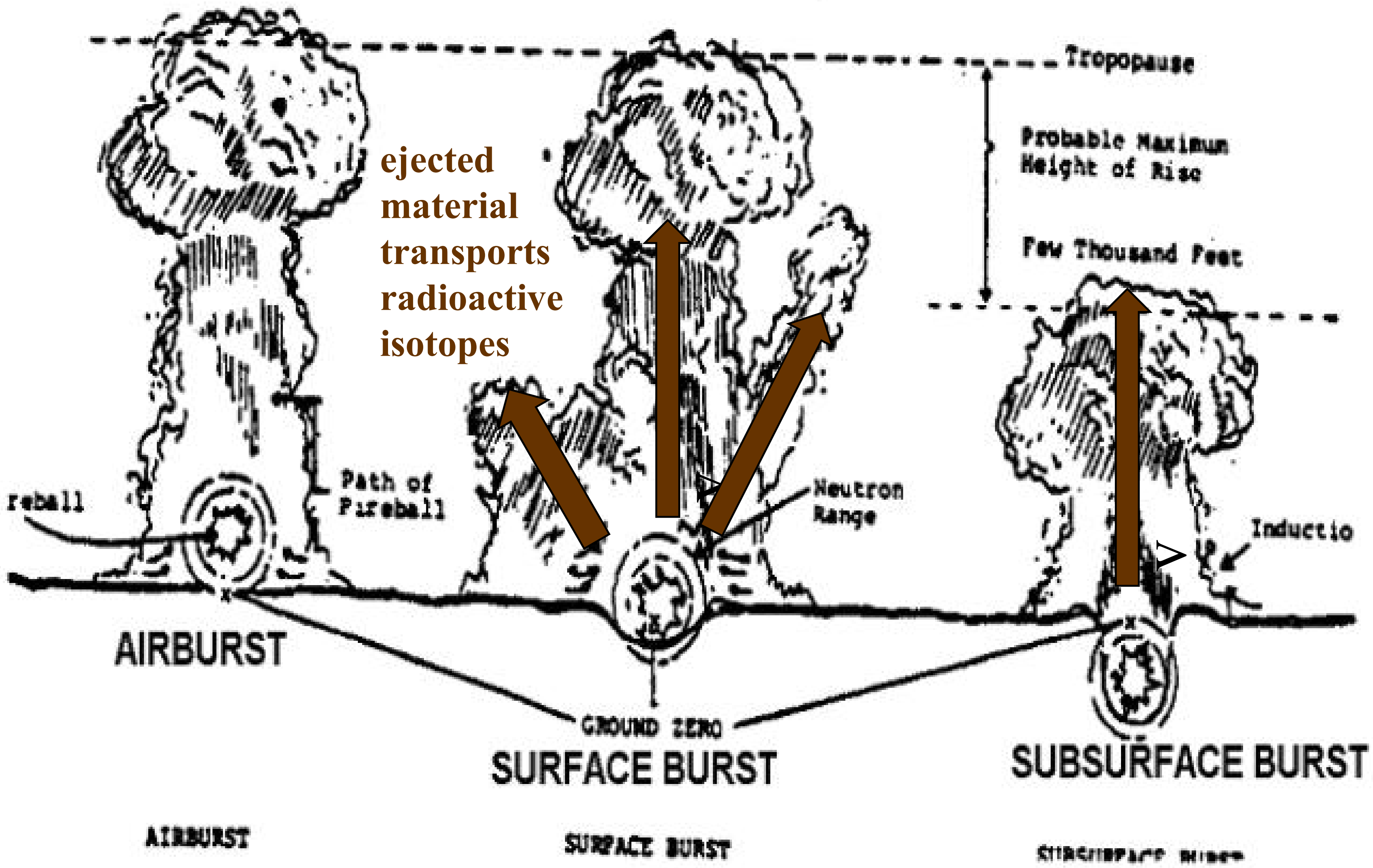


Underground Nuclear Explosions- Nevada Test Site

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

Total of 904 tests
at the Nevada test site

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

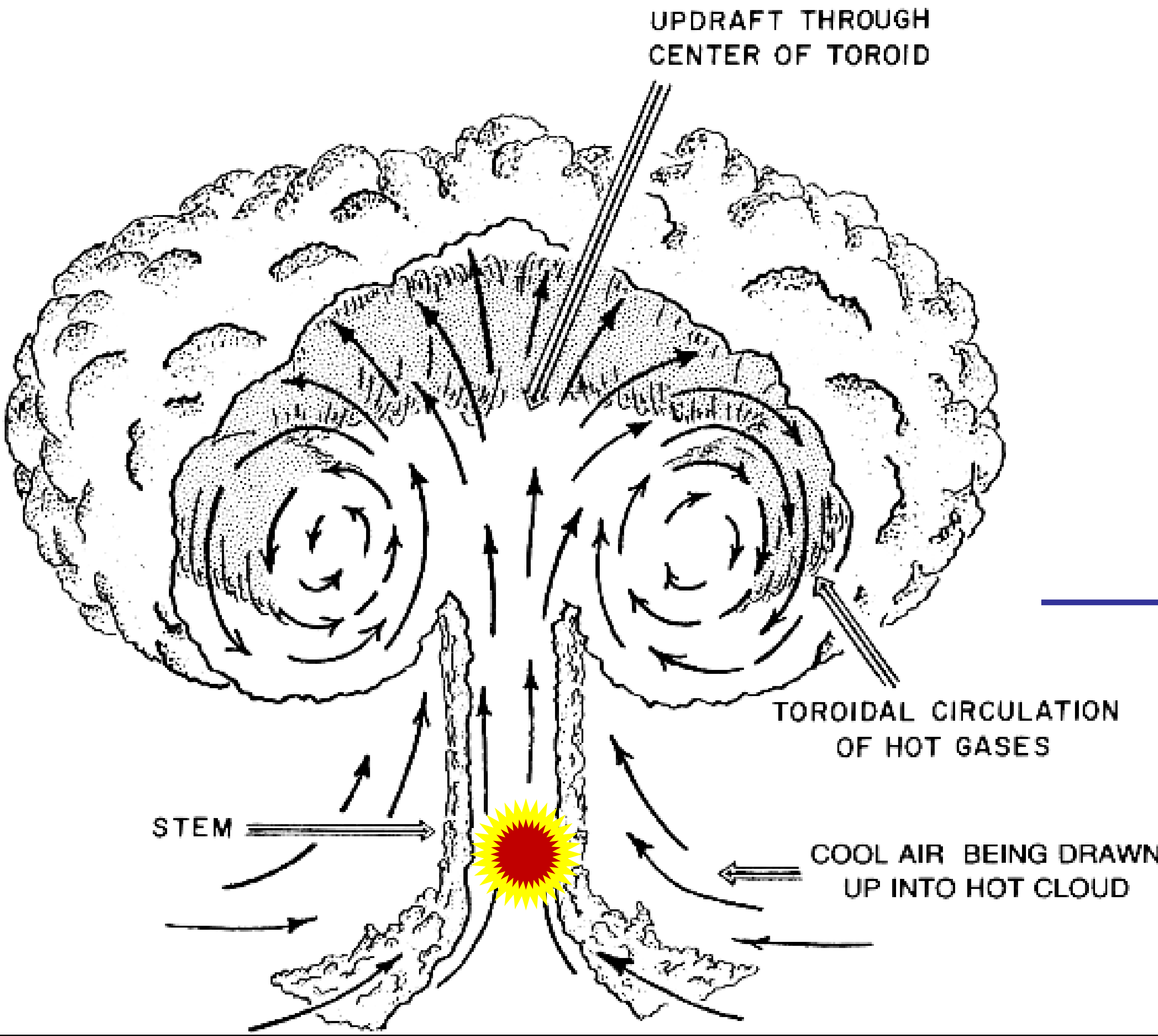
Time	Diameter	Temperature
1 ms (= 10^{-3} s)	440 ft	—
10 s	5,700 ft	6,000 C

- 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



Fireball

Stratosphere

Troposphere

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%

Physics/Global Studies 280: Session 9

Plan for This Session

Announcements & Questions:

RPPv1 will be due tomorrow Wednesday 2-16 at 10pm and 2pm in class on Thursday (paper copy)

Office hours: today 3:30-6pm online (not in person in 428)

https://illinois.zoom.us/j/3036810865?pwd=MTF3a0d0UkhnakdvVElyQit2RjAvdz09

Meeting ID: 303 681 0865
Password: 557135

Module 3 continued: Effects of nuclear explosions

News

Forbes

No Sunny Days For A Decade, Extreme Cold And Starvation: ‘Nuclear Winter’ And The Urgent Need For Public Education

Jamie Carter Senior Contributor

What would a “nuclear winter” be like? While there is no immediate sign of nuclear warheads being used in the Russia-Ukraine war, the risks of a nuclear exchange are surely at their highest for 40 years.

So why is there so little awareness of the potential consequences of the use of nuclear warheads? That’s the question at the core of new research published today by the University of Cambridge’s Centre for the Study of Existential Risk (CSER). It’s based on a survey last month of 3,000 people in the US and UK that was designed to discover how much is known about “nuclear winter.”

It reveals a lack of awareness among US and UK populations of what a “nuclear winter” would entail. Just 3.2% in the UK and 7.5% in the US said they had heard of “nuclear winter” in contemporary media or culture.

In short, we need another Carl Sagan, the late popular scientist who in the early 1980s famously warned the world about the effects of nuclear war.

“There is an urgent need for public education within all nuclear-armed states that is informed by the latest research,” said Paul Ingram, CSER senior research associate. “We need to collectively reduce the temptation that leaders of nuclear-armed states might have to threaten or even use such weapons in support of military operations.”

News

Forbes

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Jamie Carter Senior Contributor

A “nuclear winter” would be the result of a chain reaction that would go something like this:

- Nuclear warheads striking cities would cause firestorms and send huge amounts of soot into the stratosphere.
- That soot would block out much of the Sun for up to a decade.
- Temperatures would drop around the world, leaving many places sub-zero.
- Mass crop failure. International trade in food suspended.
- Mass starvation of hundreds of millions of people in countries remote from the conflict.
- Soil and water close to where nuclear weapons were used would be contaminated.

A paper published in August 2022 in *Nature Food* modeling the amount of soot injected into Earth’s atmosphere after the detonation of nuclear weapons predicted that more than five billion people could die from a war between the U.S. and Russia. The authors suggested that while the use of relatively few nuclear weapons may have a small global impact, “once a nuclear war starts, it may be very difficult to limit escalation.”

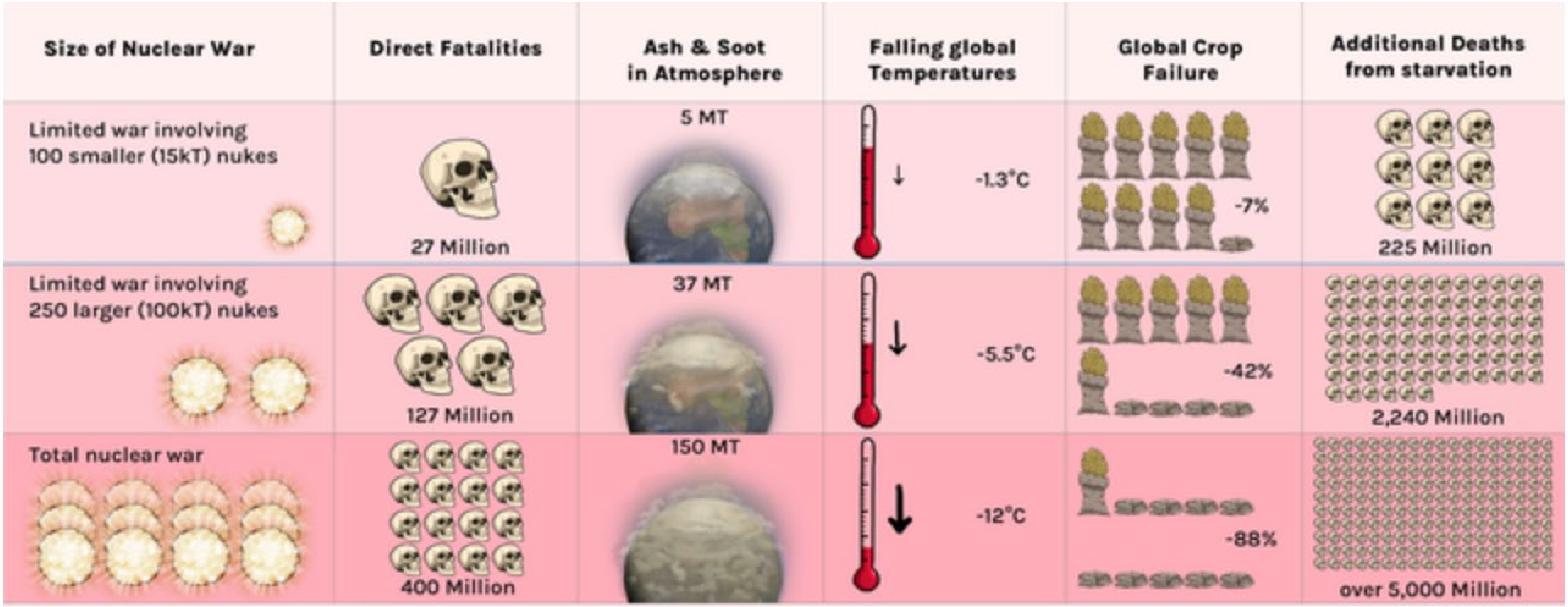
News

Forbes

No Sunny Days For A Decade, Extreme Cold And Starvation: 'Nuclear Winter' And The Urgent Need For Public Education

Jamie Carter Senior Contributor

[Opinion Poll Survey: Public awareness of 'nuclear winter' is too low given current risks (cser.ac.uk)]



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

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 ^{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 —

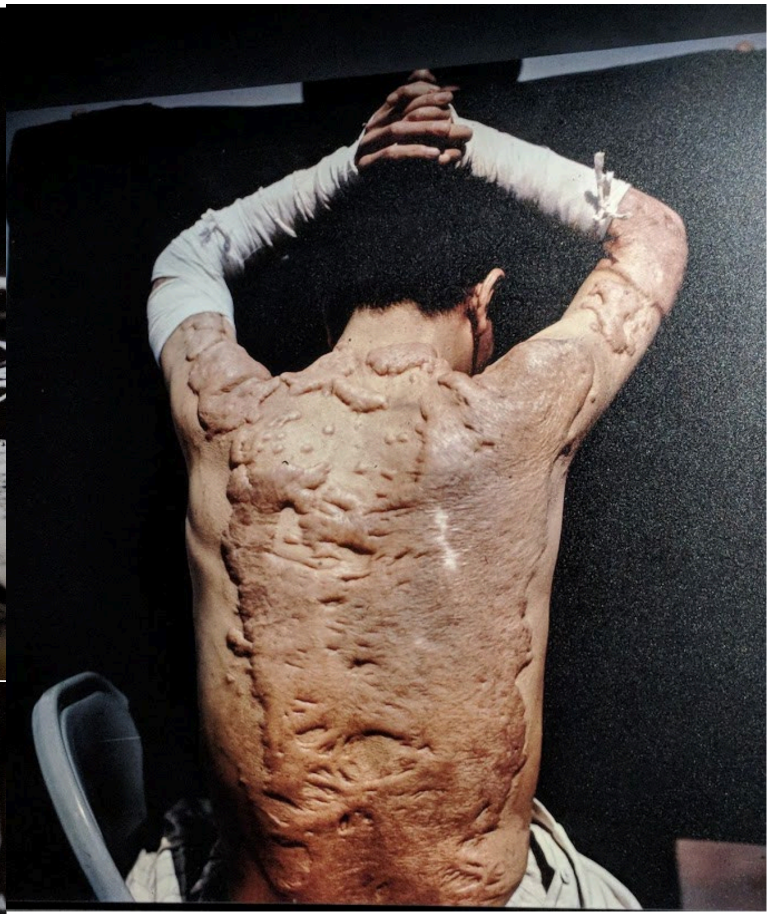
- Flash blindness (temporary)
- Retinal burns (permanent)
  - —Approximately 13 mi on a clear day
  - —Approximately 53 mi on a clear night
- Skin burns
- Ignition of clothing, structures, surroundings

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

Effects of Thermal Radiation – 5

Examples of Flash Burns Suffered at Hiroshima



Keloids resulting from burns

Burns depend on distance and protection available

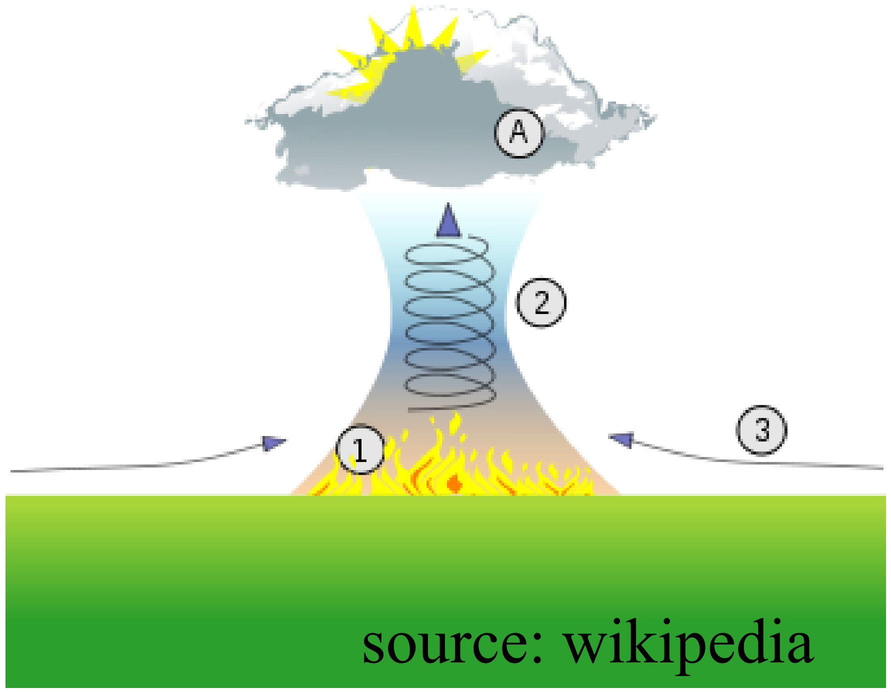
Conflagrations Versus Firestorms

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

Conflagrations Versus Firestorms

Tokyo after fire bombing in March 1945

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

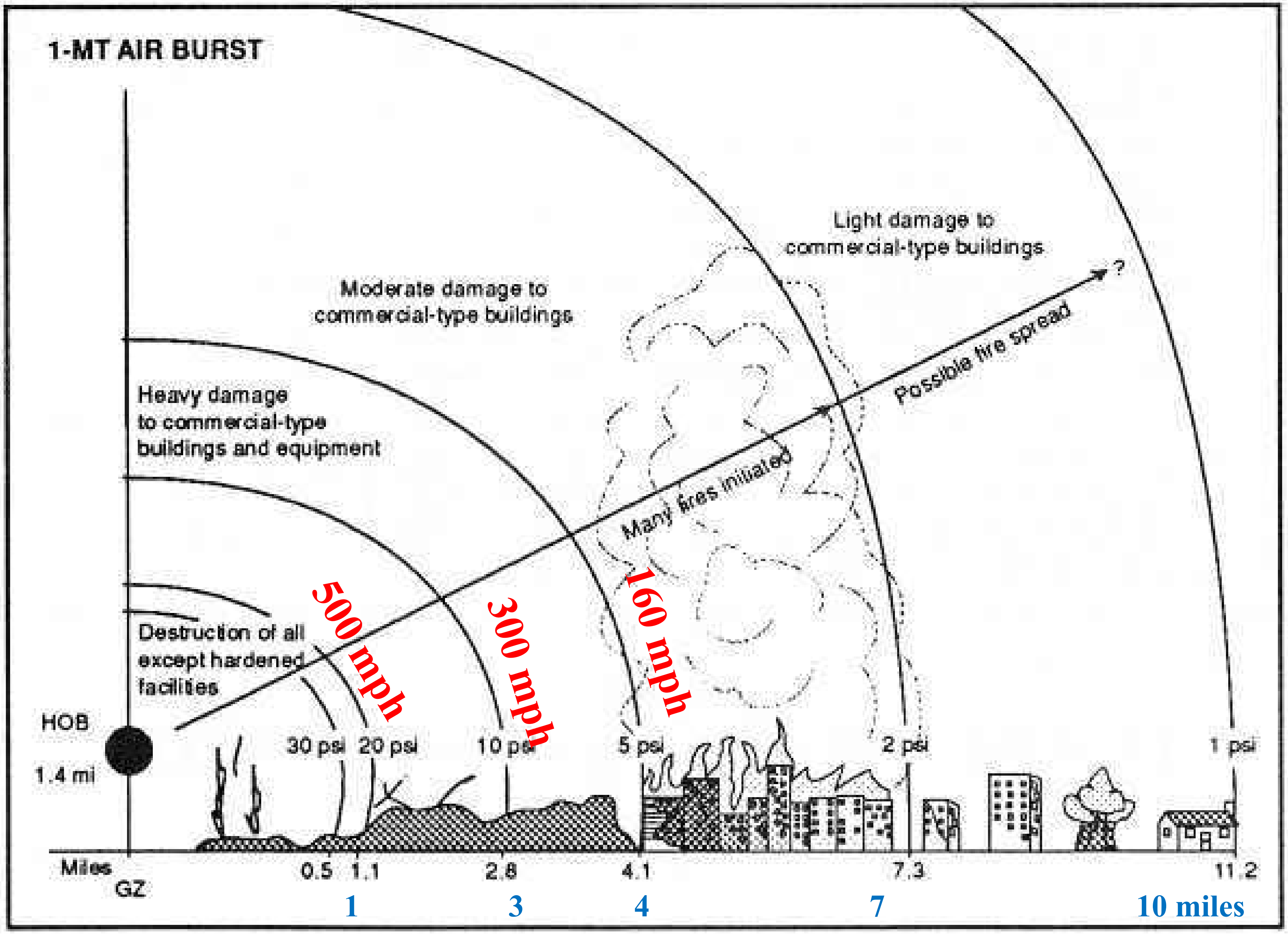
This is followed by

  - 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

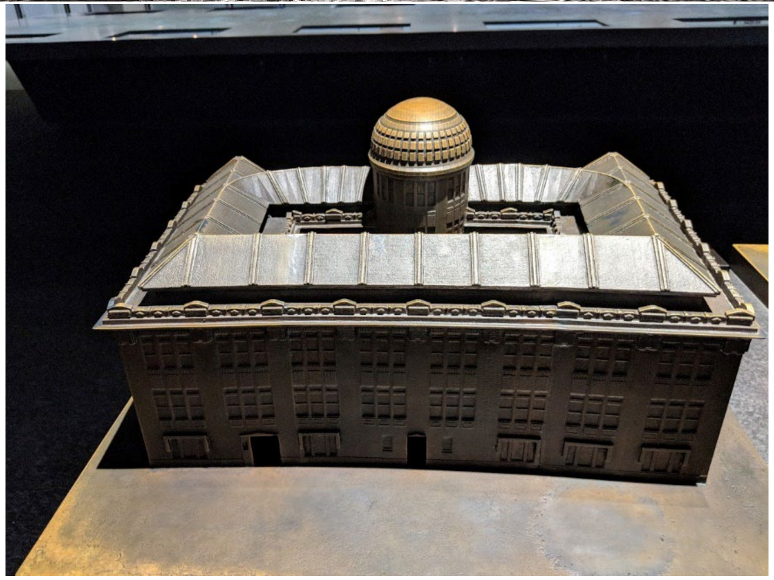


Damage in Hiroshima

Atomic Dome
near
Ground Zero

T-shaped bridge was used for targeting

Damage in Hiroshima:
HOB ~ 2000 ft above Atomic Dome



Hiroshima Prefectural Industrial Promotion Hall

Hiroshima Peace Memorial

Effects of Shallow Underground Nuclear Explosions

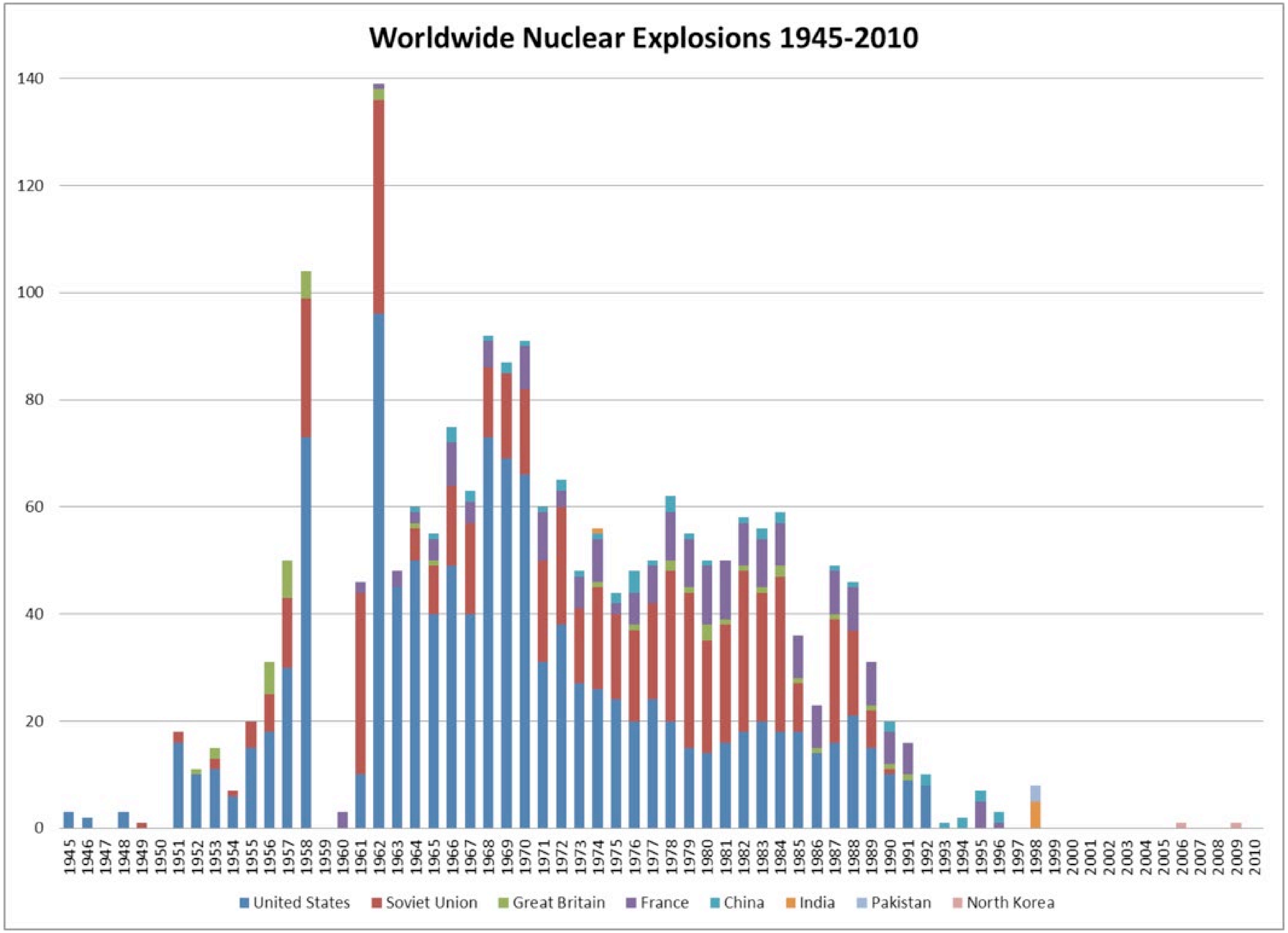
Effects of the Sedan Event (1962)

- 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

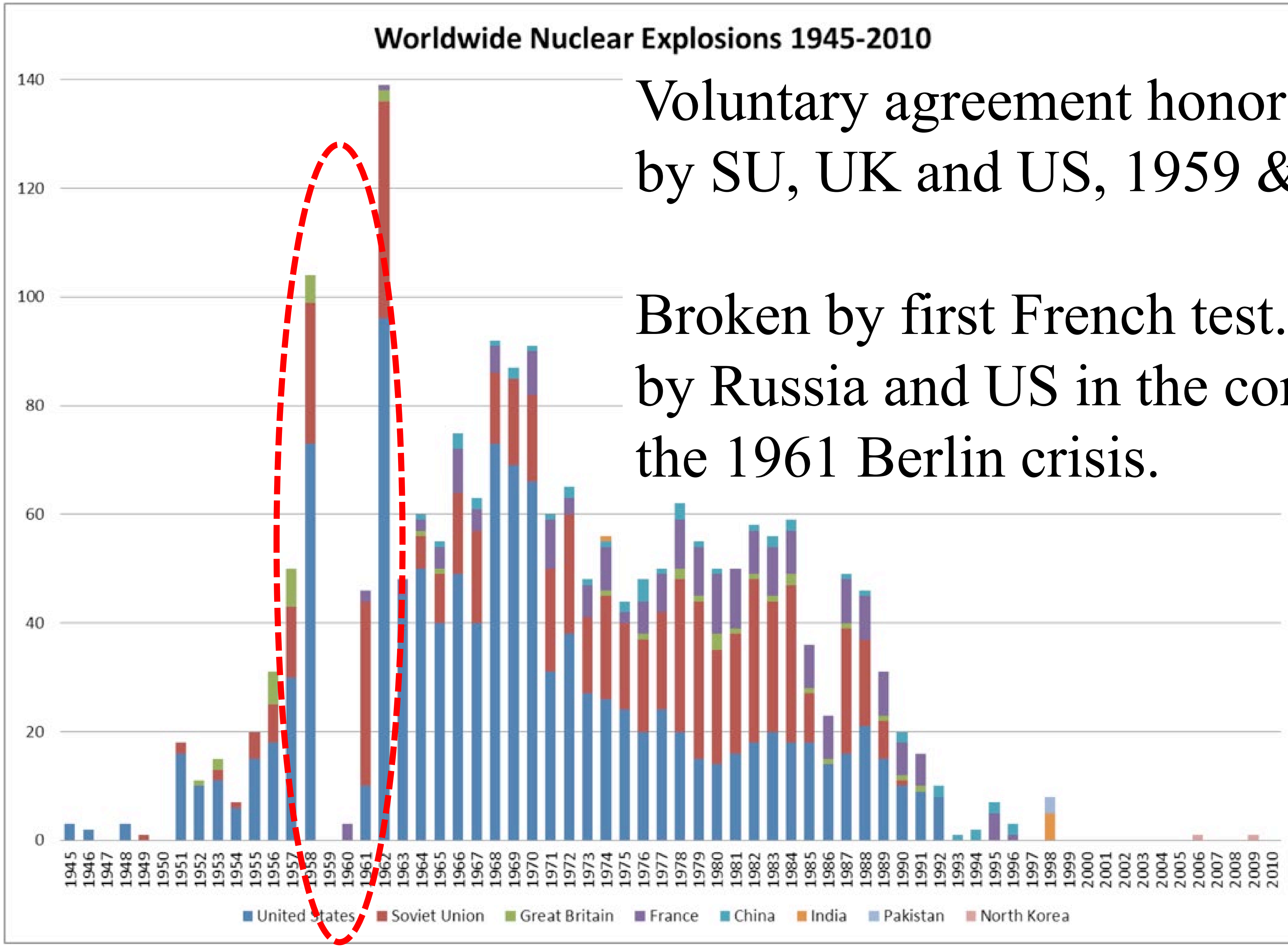
Example: The Sedan Test (100 kt, 1962)

Effects of Nuclear Explosions



Credit: Wikipedia Commons

Test Moratorium 1959-1960



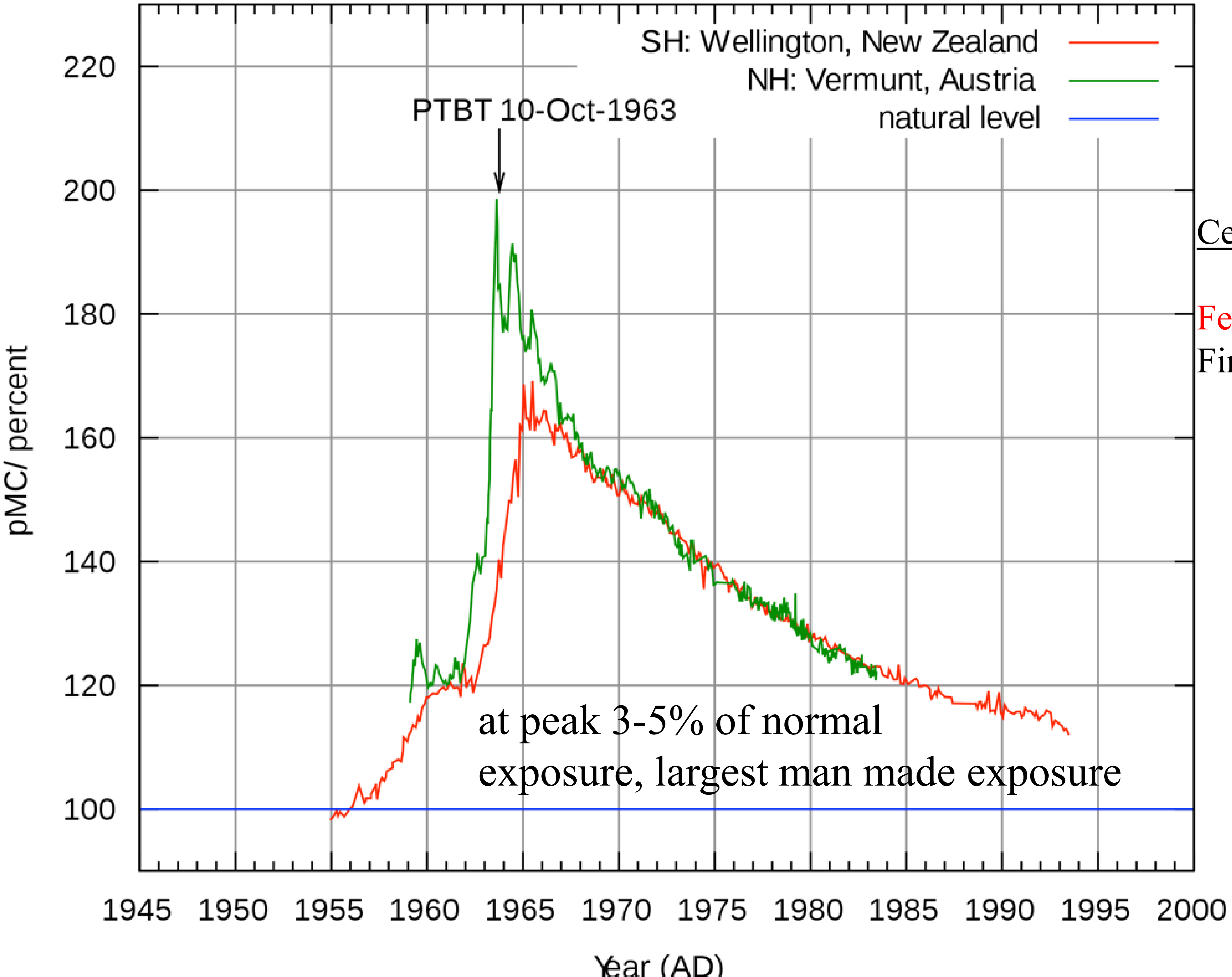
Voluntary agreement honored by SU, UK and US, 1959 & 1960

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)



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

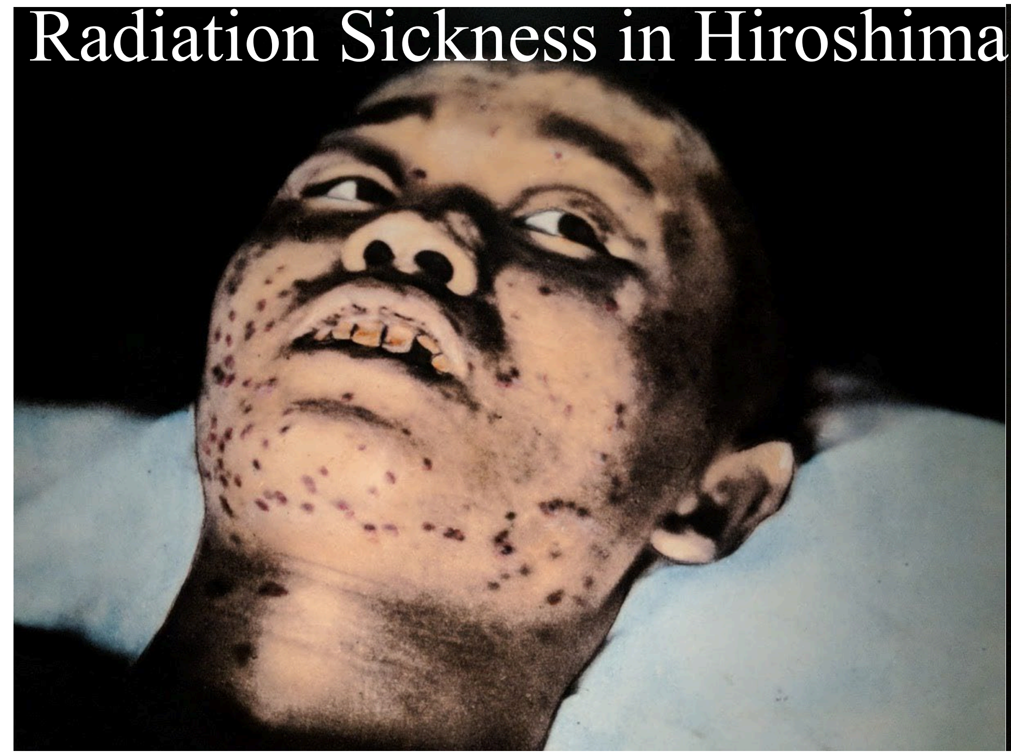
<u>Centers for Disease Control and Prevention:</u>

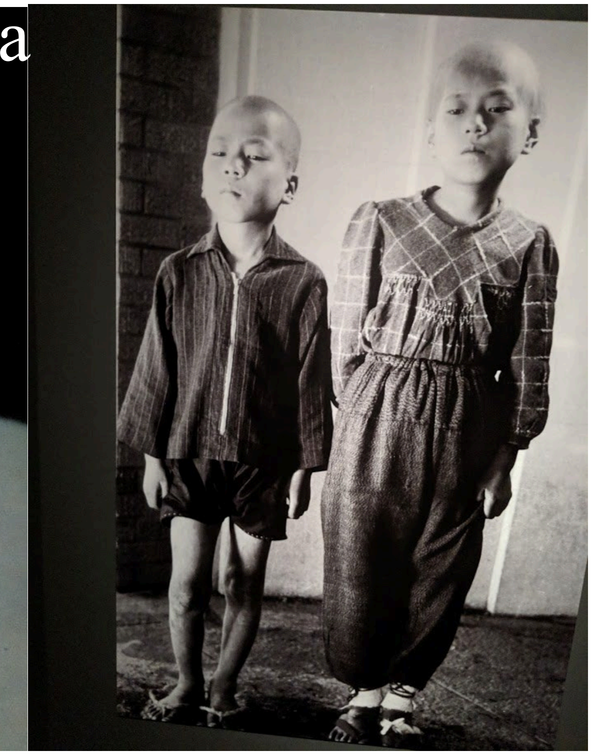
Feasibility Study of Weapons Test Fall Out
Final report from April 2005

~ 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

Fallout Radiation from a 1 Mt Burst





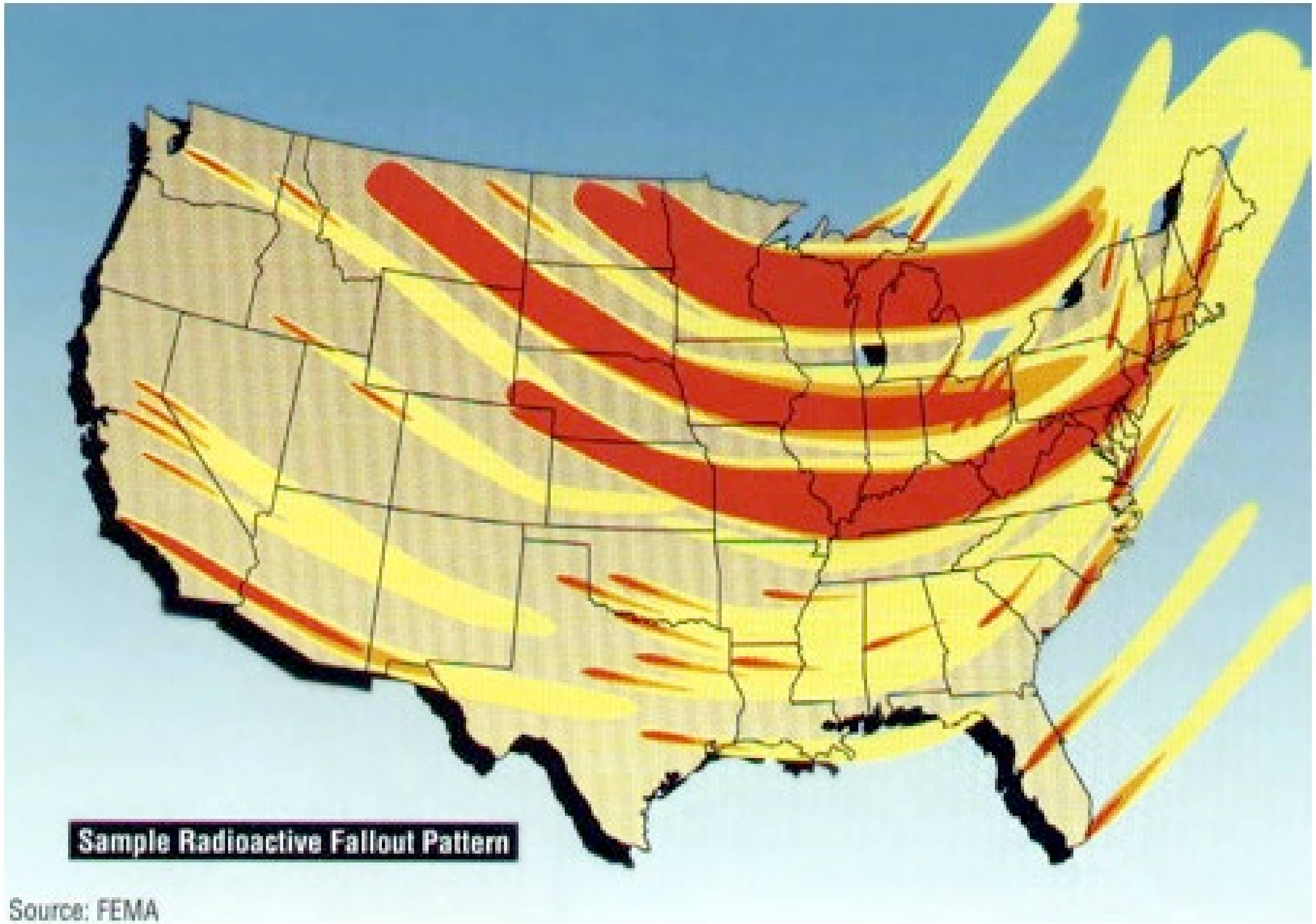
Assume —

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

Distances and doses —

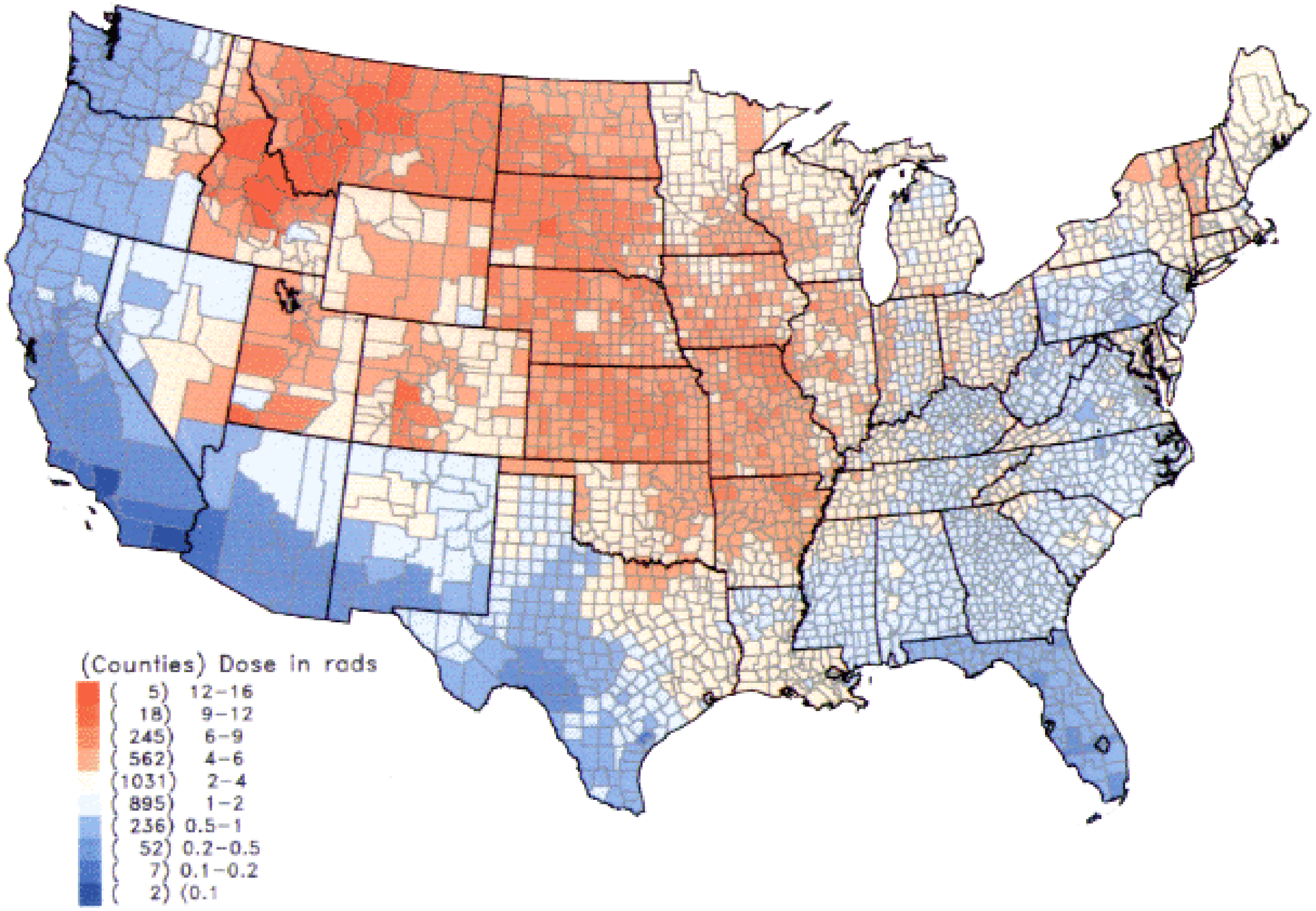
- 30 miles: 3,000 rem (death within hours; more than 10 years before habitable)
- 90 miles 900 rem (death in 2 to 14 days)
- 160 miles: 300 rem (severe radiation sickness)
- 250 miles: 90 rem (significantly increased cancer risk; 2 to 3 years before habitable)

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."

Physics/Global Studies 280: Session 10

Plan for This Session

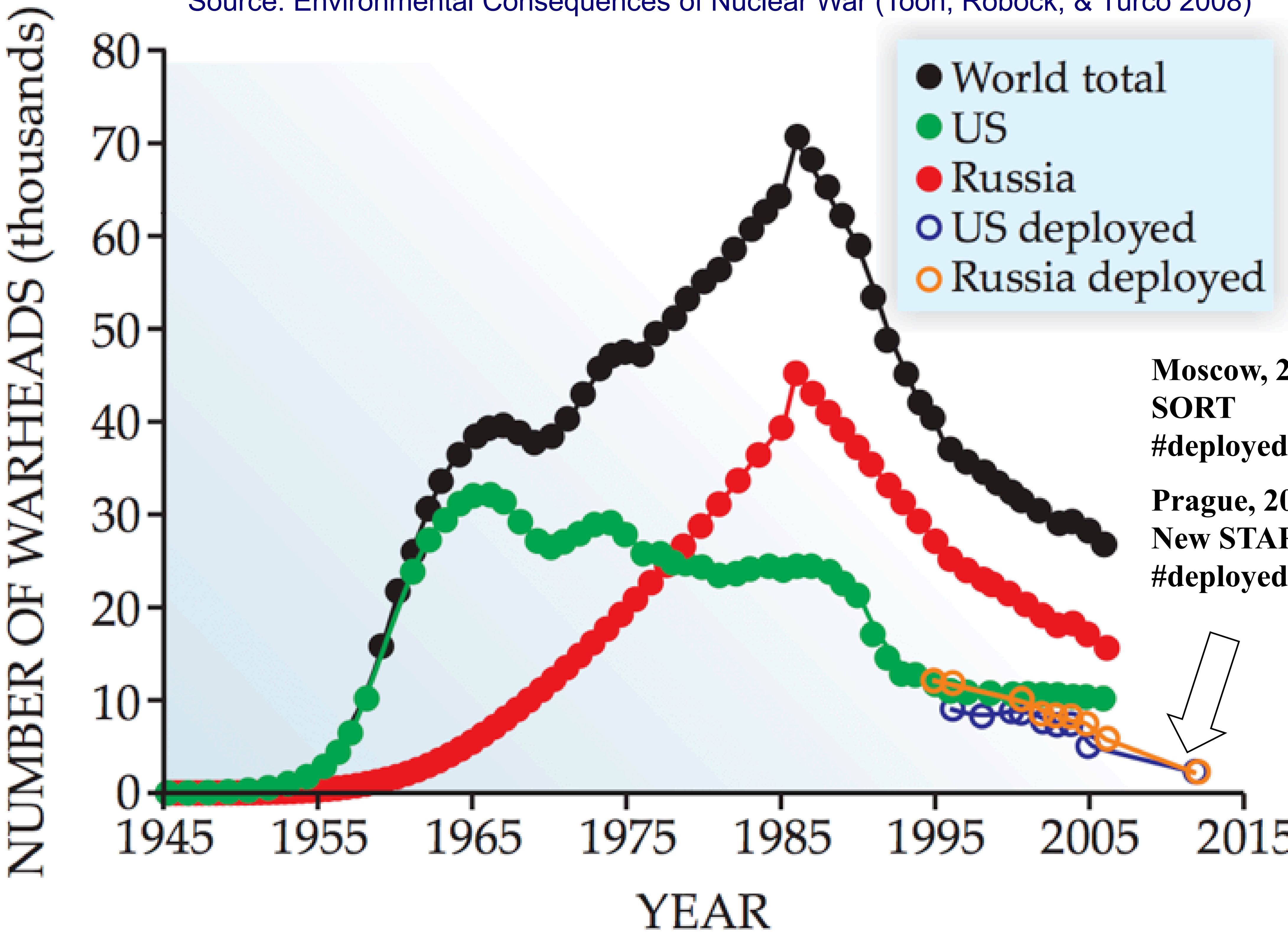
Announcements & Questions:

Research Paper: the two members of an expert team can choose different topics!

Module 3 continued: Effects of nuclear explosions

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)

Physics/Global Studies 280: Session 10

Plan for This Session

RPPv1 is due today

News

Nuclear Explosions Conclusion: “Nuclear Winter”

“Ground Zero” Video presentation

News

FOREIGN AFFAIRS

America Needs to Reassure Japan and South Korea

How to Shore Up Washington's Eroding Credibility in Asia

BY KATRIN FRASER KATZ, CHRISTOPHER JOHNSTONE, AND VICTOR CHA
February 9, 2023

KATRIN FRASER KATZ is a Fellow at the Center for Strategic and International Studies and a Scholar in Residence at the University of Miami. From 2007 to 2008, she served as Director for Japan, Korea, and Oceanic Affairs at the National Security Council.

CHRISTOPHER JOHNSTONE is Senior Adviser and Japan Chair at the Center for Strategic and International Studies. At the National Security Council, he served as Director for East Asia from 2021 to 2022 and Director for Japan and Oceanian Affairs from 2014 to 2016.

VICTOR CHA is Senior Vice President and Korea Chair at the Center for Strategic and International Studies and a Professor at Georgetown University. From 2004 to 2007, he was Director for Asian Affairs at the National Security Council.

News

Last month, South Korean President Yoon Suk-yeol warned that in the face of mounting North Korean provocations, South Korea might consider building its own nuclear weapons or asking the United States to deploy tactical nuclear weapons to the South, as it did during the Cold War.

…

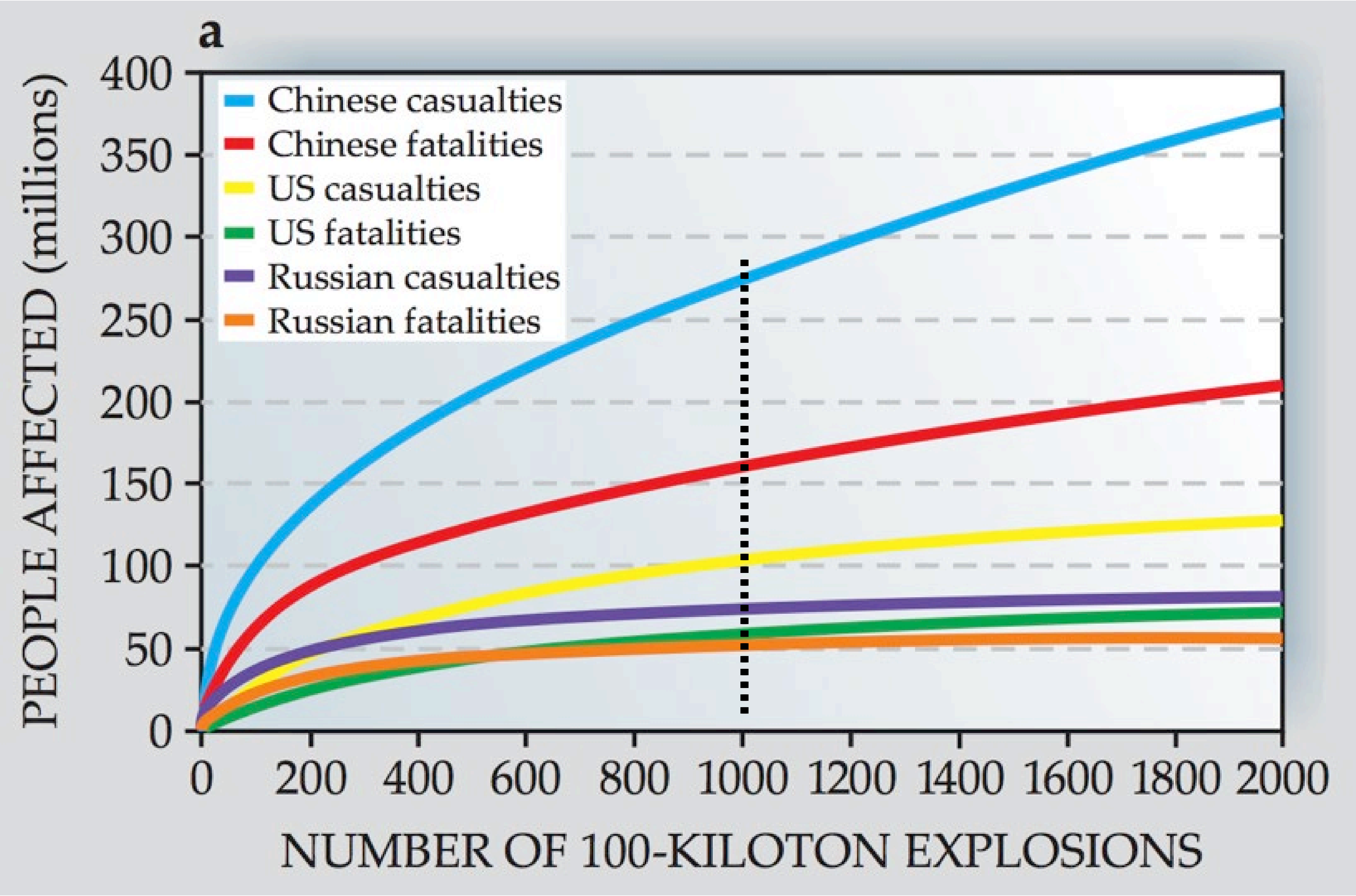
Allied apprehension about U.S. security commitments may seem puzzling in light of the Biden administration's emphasis on shoring up U.S. alliances and the broad alignment of the Biden, Yoon, and Kishida administrations on North Korea and regional policies. But even at the best of times, maintaining the credibility of external deterrence commitments is a challenge. Doing so requires convincing allies not just that the United States has the capabilities to deter and defend against potential attacks against them but that it also has the will to use those capabilities—even if that means putting U.S. cities at risk.

In recent years, however, the level of doubt among Japanese and South Korean officials has exceeded that normal baseline level. Rapidly intensifying threats—particularly from North Korea, China, and Russia—have created unique and urgent security challenges that Tokyo and Seoul worry the United States is either unwilling or unable to address. In 2022, for instance, North Korea embarked on an unprecedented campaign of weapons development, testing over 90 cruise and ballistic missiles of various ranges(one of which flew over Japan) and preparing for a nuclear test, which would be the seventh it has carried out since 2006.

China's sweeping military modernization is also fueling Japanese and South Korean security concerns. After more than two decades of near double-digit growth in defense spending, including efforts to improve its missile capabilities and dramatically expand its nuclear arsenal, China is increasing its maritime and air activity near Japan, including making regular incursions into the territorial waters around the Senkaku Islands

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: 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

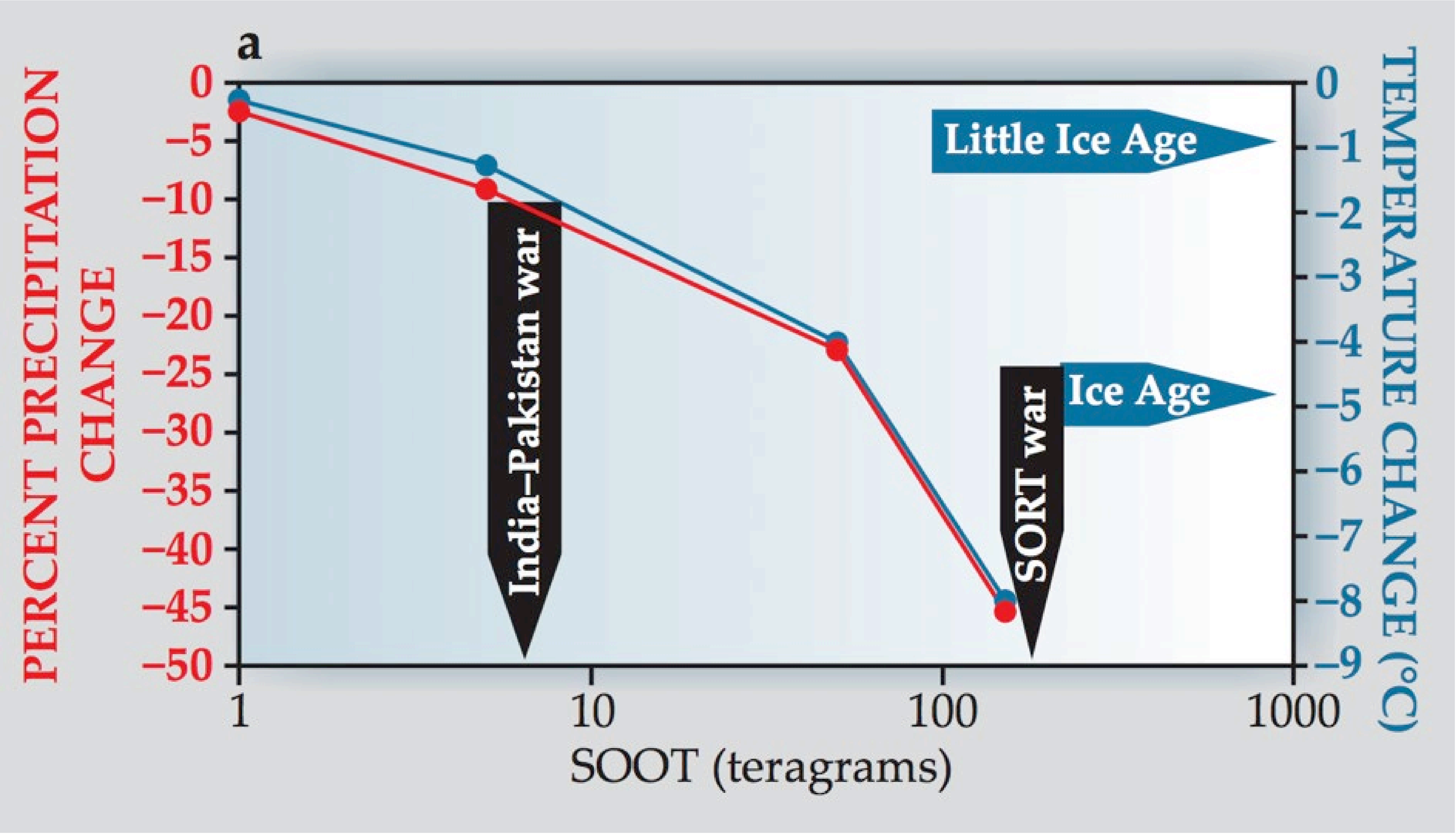
A regional war between India and Pakistan could generate 5 Tg of soot (5 million tons), sufficient to —

- 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)

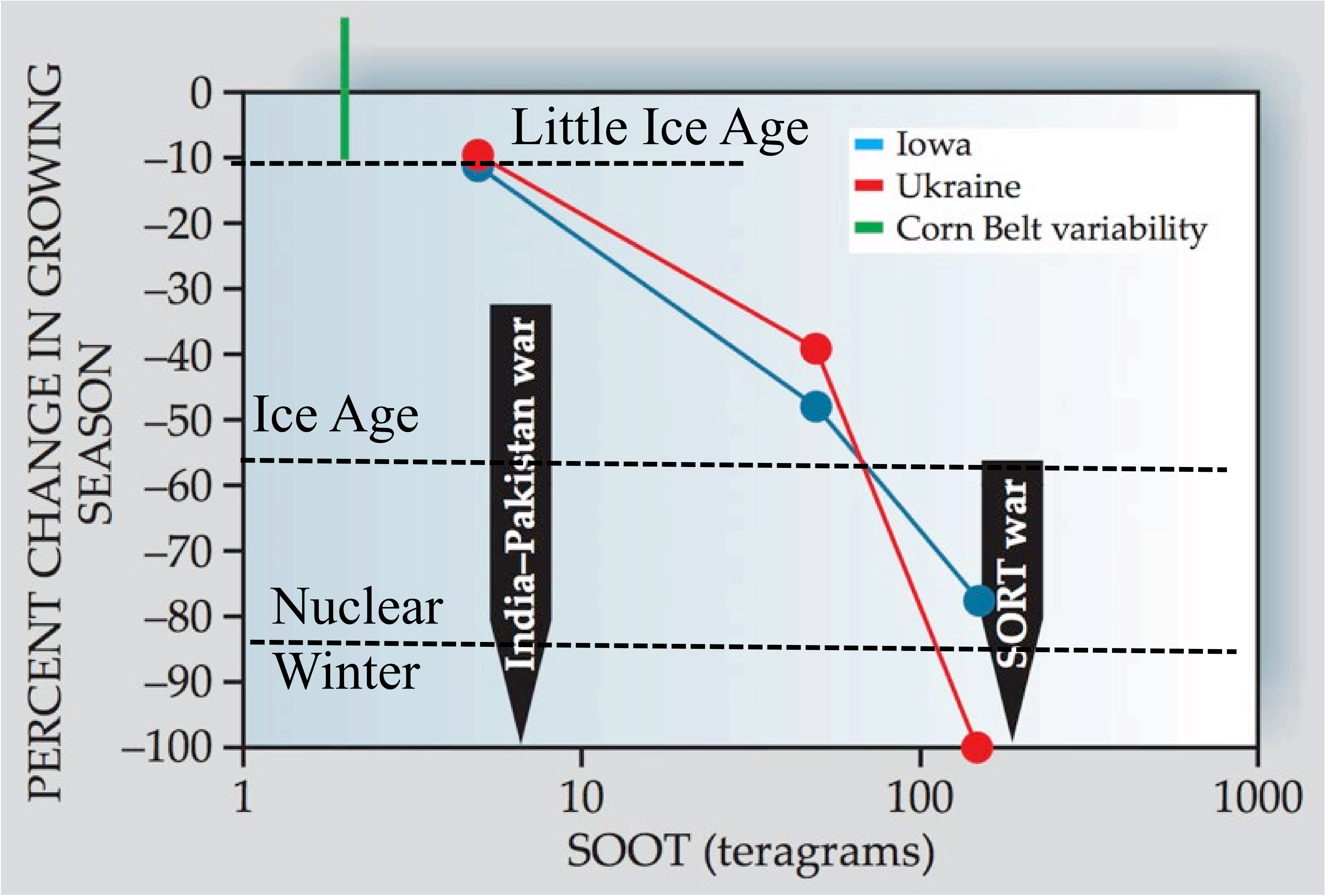
Effects of Nuclear War: Change in Precipitation and Temperature

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



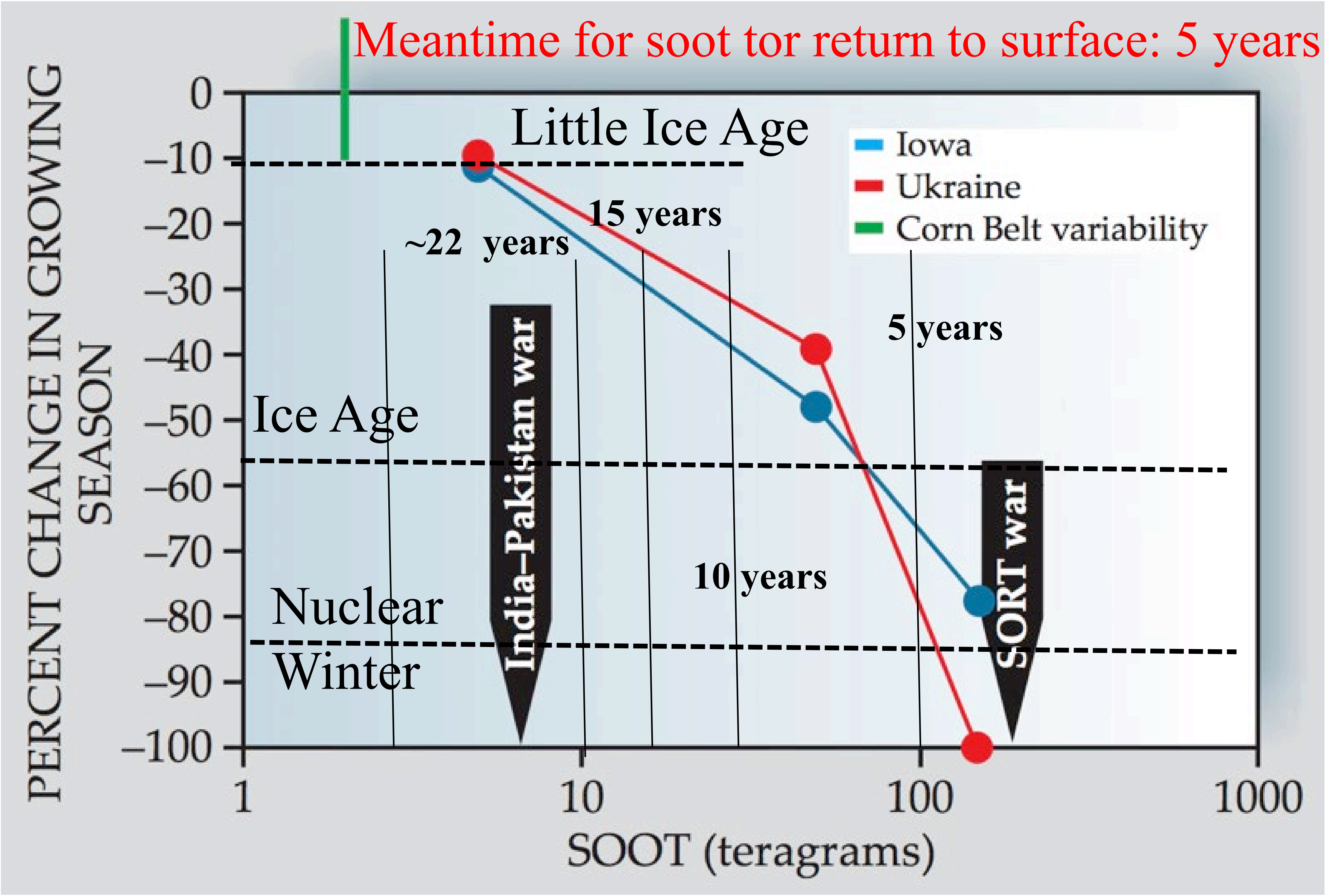
Effects of Nuclear War: Percent Change in Growing Season

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)