Physics/Global Studies 280: Session 8

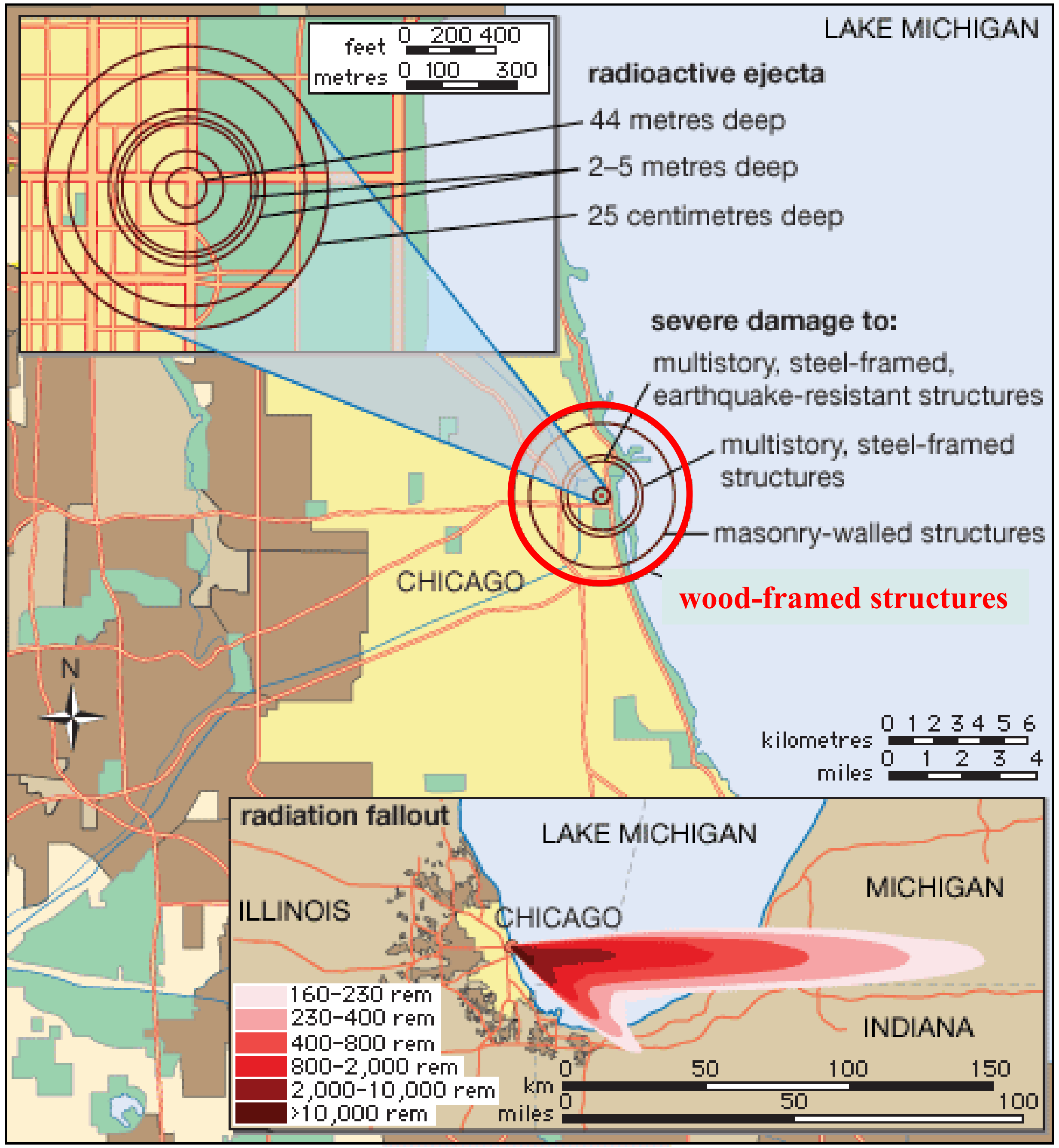
Plan for This Session

RE2v2 due today

Complete NEM

Module 3:
Effects of nuclear explosions

Impact of a 500 kiloton device detonated in Chicago



Newsweek

WORLD

U.S., RUSSIA AND FRANCE ALL LAUNCH NUCLEAR-CAPABLE MISSILES WITHIN HOURS OF ONE ANOTHER AS TREATY FALLS APART

BY TOM O'CONNOR ON 2/6/19 AT 2:03 PM

An unarmed Minuteman III intercontinental ballistic missile launches during a developmental test at Vandenberg Air Force Base, in California, on February 5. President Donald Trump has vowed to "detect and destroy any missile launched against the United States anywhere, anytime" as part of his 2019 Missile Defense Review.

SENIOR AIRMAN CLAYTON WEAR/U.S. AIR FORCE/DEPARTMENT OF DEFENSE

Newsweek

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The United States, Russia and France have all test-launched nuclear-capable missiles within hours of one another as international fears of a global arms control collapse heightened.

The U.S. and Russia have, in recent days, suspended their 1987 Intermediate-range Nuclear Forces (INF) treaty banning land-based missiles with ranges from 310 to 3,420 miles following Washington's accusations that Moscow violated the deal with its new Novator 9M729 missile. As the two sides continued to swap threats of escalation, the three countries believed to have the most nuclear weapons in the world demonstrated their strategic capabilities.

First, the French military said Tuesday that its air force conducted a rare test Monday of the nuclear-capable medium-range air-to-surface missile (ASMP). The U.S. then fired a nuclear-capable Minuteman III intercontinental ballistic missile (ICBM) later Tuesday night in local time and, about an hour and a half later, the Russian armed forces fired a nuclear-capable RS-24 Yars ICBM.

Though none of the tests were said to have been equipped with nuclear warheads and all were likely scheduled far ahead of time, they came at a period of major uncertainty as key nonproliferation agreements were dismantled.

In a press release, the French Ministry of Defense hailed a "successful demonstration" of the ASMP. Aircraft from Fighter Squadron 2/4 La Fayette departing from Saint-Dizier – Robinson Air Base in northwestern France were supported by the 31st Strategic Supply and Transport Aerial Escadre and fired the unarmed weapon at a testing center of the DGA Essais de missiles, near Biscarrosse, in southwestern France. The ministry said that the 11-hour mission had been "planned for a long time" and was a "demonstration of the reliability of the airborne weapons system over time."

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The U.S. Air Force's 30th Space Wing conducted what was described as a "developmental test" of the Minuteman III at around 11:01 p.m. PST, or 2:01 a.m. EST. In a statement sent to local NBC affiliate KSBY, Global Strike Command said its representatives "assert that missile tests are scheduled months or years in advance, this test comes just four short days after the Trump administration suspended...the U.S. from the Intermediate-Range Nuclear Forces (INF) Treaty, a crucial landmark Treaty between the U.S. and Russia that eliminated entire categories of nuclear weapons."

Just 90 minutes later, at 11:31 a.m. in Moscow and 12:31 a.m. in California, Russia's RS-24 Yars flew from the Plesetsk Cosmodrome in the northwestern Mirny, Arkhangelsk Oblast toward a target positioned more than 3,000 miles away at the Kura Missile Test Range on the far eastern Kamatchka Peninsula. The Russian Defense Ministry said that the weapon was "equipped with multiple warheads" and that "the purpose of the launch was to confirm the tactical, technical and flight characteristics of the advanced missile system."

The New York Times https://nyti.ms/39n16hg

News:

A Plea to Save the Last Nuclear Arms Treaty

Two former diplomats, from Russia and America, call for extending the nuclear arms limitation pact called New START, to make the world more secure.

By Madeleine Albright and Igor Ivanov
Dr. Albright is a former United States secretary of state and Mr. Ivanov is a former Russian foreign minister.

Feb. 10, 2020

The relationship between Russia and the United States has been mired in crisis for much of the past decade. Communication once considered routine has been cut off, deepening mistrust and making it more difficult to reduce tensions and avoid miscalculation. The current state of affairs does not serve the strategic interests of either country, and it puts global security at risk because Russia and the United States are the only countries that possess enough nuclear weapons to destroy each other — and all of humanity.

Rebuilding mutual confidence and putting United States-Russian relations on a safer track will be a challenging long-term endeavor, given the political climates in Washington and Moscow. But the two countries have a chance to head off even more instability by extending the 2010 New Strategic Arms Reduction Treaty, which expires in one year, on Feb. 5. While 12 months may seem like a lot of time, in diplomatic terms and in the present environment, the clock is ticking fast.

The United States and Russia can avoid a senseless and dangerous return to nuclear brinksmanship if they act soon. There is no reason to wait, and extending the treaty, known as New START, is the place to begin.

News: A Plea to Save the Last Nuclear Arms Treaty

With the unfortunate dissolution of the Intermediate-Range Nuclear Forces Treaty last year, New START is the only agreement still in place that limits the size of American and Russian nuclear forces. It also provides vital verification and transparency measures, including on-site inspections, that have helped foster strategic stability. The treaty allows for a five-year extension if the leaders of both countries agree. President Vladimir Putin and President Trump should seize this opportunity.

Our countries survived the nuclear dangers of the Cold War through a combination of skilled diplomacy, political leadership and good fortune. The fall of the Berlin Wall did not eliminate those dangers, but the years that followed saw continued progress on arms control, a sharp drop in nuclear peril and a reduced reliance on military means for addressing potential conflicts.

Today, in contrast, geopolitical tensions are rising and the major powers are placing a renewed emphasis on the role of nuclear weapons in their military strategies. Experts are suddenly talking less about the means for deterring nuclear conflict than about developing weapons that could be used for offensive purposes.

Some have even embraced the folly that a nuclear war can be won.

Late last year, we met in Vienna with other former foreign ministers from more than a dozen countries, as part of the Aspen Ministers Forum, to review the global security landscape and examine these trends in depth. We emerged from these consultations deeply troubled by the possible worldwide consequences of an accelerating global arms race, the increased risk of military incidents and the degradation of arms reduction and nonproliferation agreements. We believe that the world needs to move in a new, less hazardous direction.

News: A Plea to Save the Last Nuclear Arms Treaty

As a result of that meeting, we and 24 other former foreign ministers are now issuing a statement calling upon leaders of all countries to counter the uncertainties posed by nuclear weapons more urgently. The means to address these dangers are at our disposal, but they can be carried out only through wise leadership. During the Cold War, the world proved that well constructed, balanced and faithfully implemented treaties, political commitments and norms of behavior can effectively reduce tensions and the likelihood of conflict.

This spring, 190 nations will gather in New York on the 50th anniversary of the Nuclear Nonproliferation Treaty to review current nuclear risks and proliferation challenges. Extending New START would send a signal to the rest of the world as other countries consider their responsibilities to help halt the spread of nuclear weapons. It could also lay the foundation for increased international cooperation in the next decade.

The recent escalation of attacks between the United States and Iran demonstrated how quickly the lack of guardrails can move us to the brink of war. Amid the erosion of multilateral agreements and diplomatic channels, we came close to calamity. The dangers of miscalculation are too grave for leaders to resort to ambiguous communication, threats and military action.

In the years ahead, the security landscape will be made only more challenging by emerging technologies and their interplay with conventional and nuclear capabilities. So it will be crucial to create a revitalized spirit of diplomacy based on a shared understanding of the dangers, and ways to mitigate potential sources of harm. As former foreign ministers, we pledge to continue speaking out on this issue and do our part in this effort.

News: A Plea to Save the Last Nuclear Arms Treaty

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Right now, the most important thing to do is extend New START. Russia has indicated, at the highest levels, its willingness to do so. All that President Trump needs to do is agree. Legislative approval is not required.

Time is critical. Doing nothing while waiting for a "better" agreement is a recipe for disaster: We could lose New START and fail to replace it. The treaty's agreed limits on nuclear arsenals are too important to be put at risk in a game of nuclear chicken.

Moreover, we have an opportunity to improve security and rebuild trust between the world's two great nuclear powers. It must not be thrown away.

Madeleine Albright was the United States secretary of state from 1997 to 2001.

Igor Ivanov was the Russian foreign minister from 1998 to 2004.

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

20p280 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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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

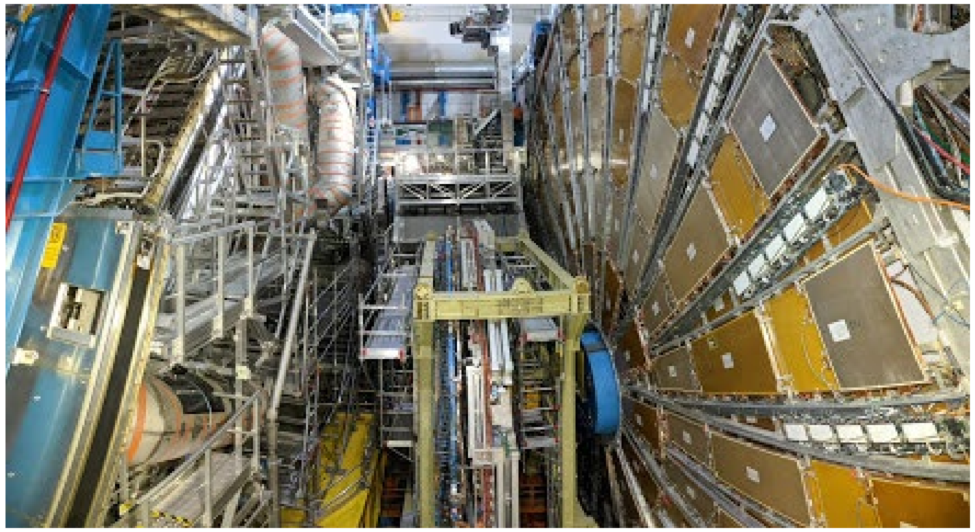
Thermo nuclear weapons: 100 kTs to few MTs of TNT

- 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!

Physics/Global Studies 280: Session 9

ATLAS Experiment at the Large Hadron Collider at CERN

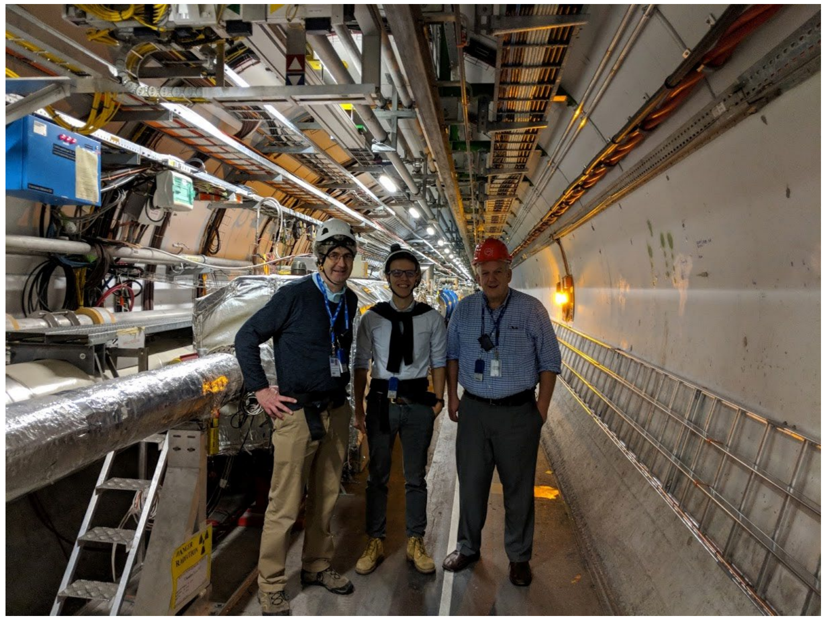


Plan for This Session (from CERN)

Announcements & Questions:

RPPv1 will be due Wednesday 2-19 at 10pm
and 2pm in class on Thursday (paper copy)

Office hours: today from 5-6 pm (basement level of Communications Library - Gregory)
Tomorrow from 4-7pm (402 Grainger Library)



Module 3: Effects of nuclear explosions

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%

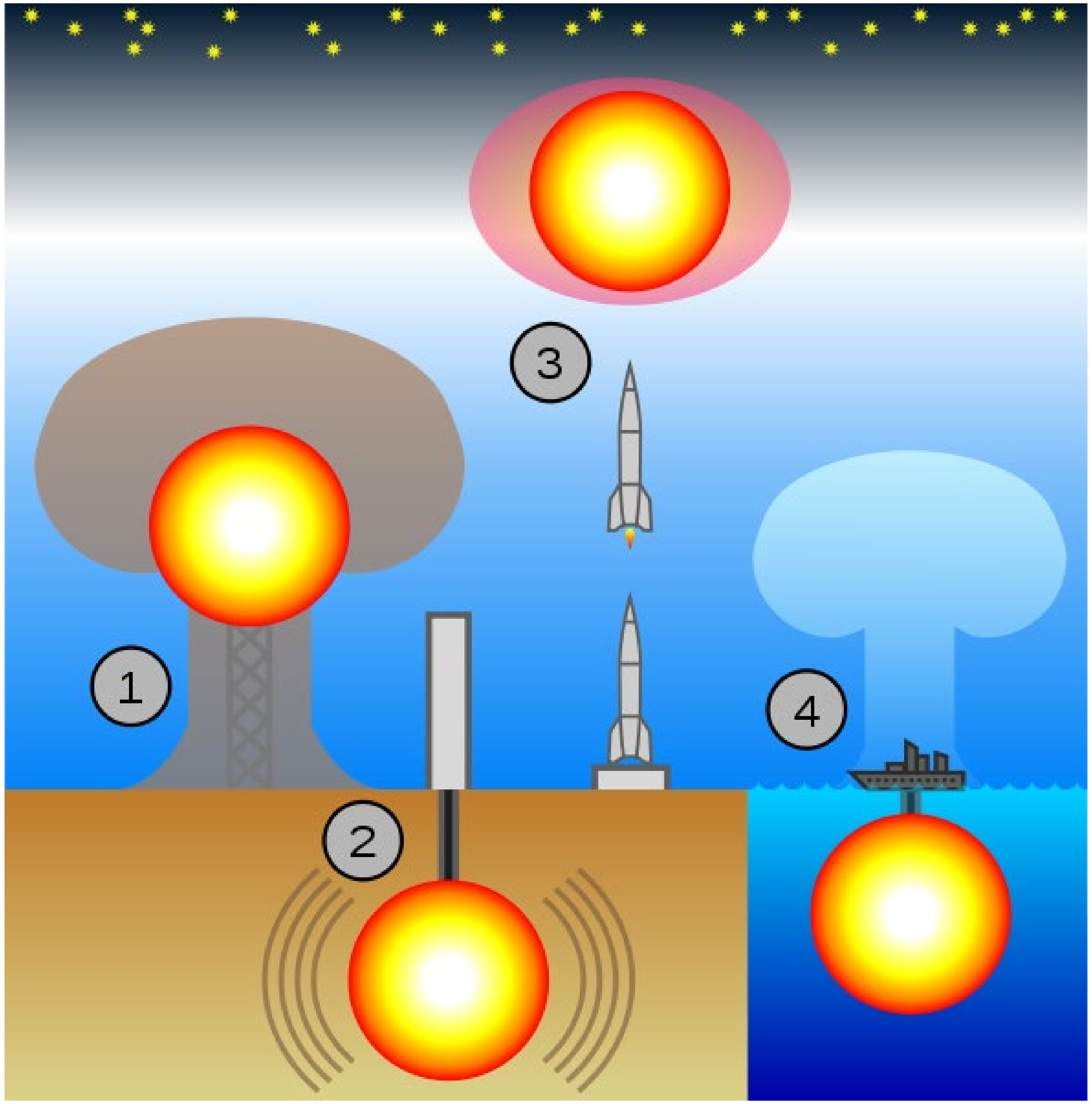
Subsequent Evolution of Nuclear Explosions

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

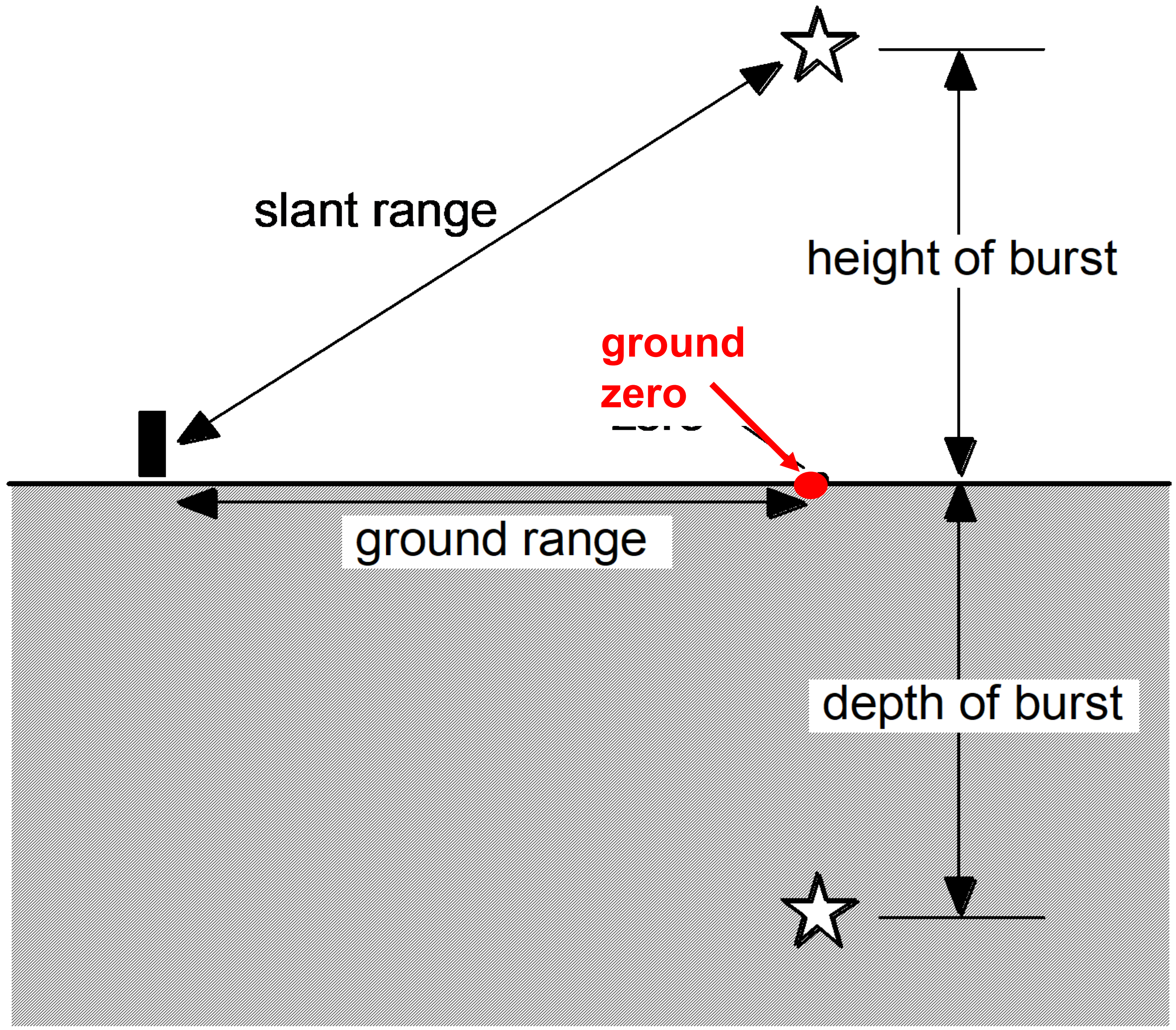


Credit: Wikipedia (nuclear weapons testing)

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

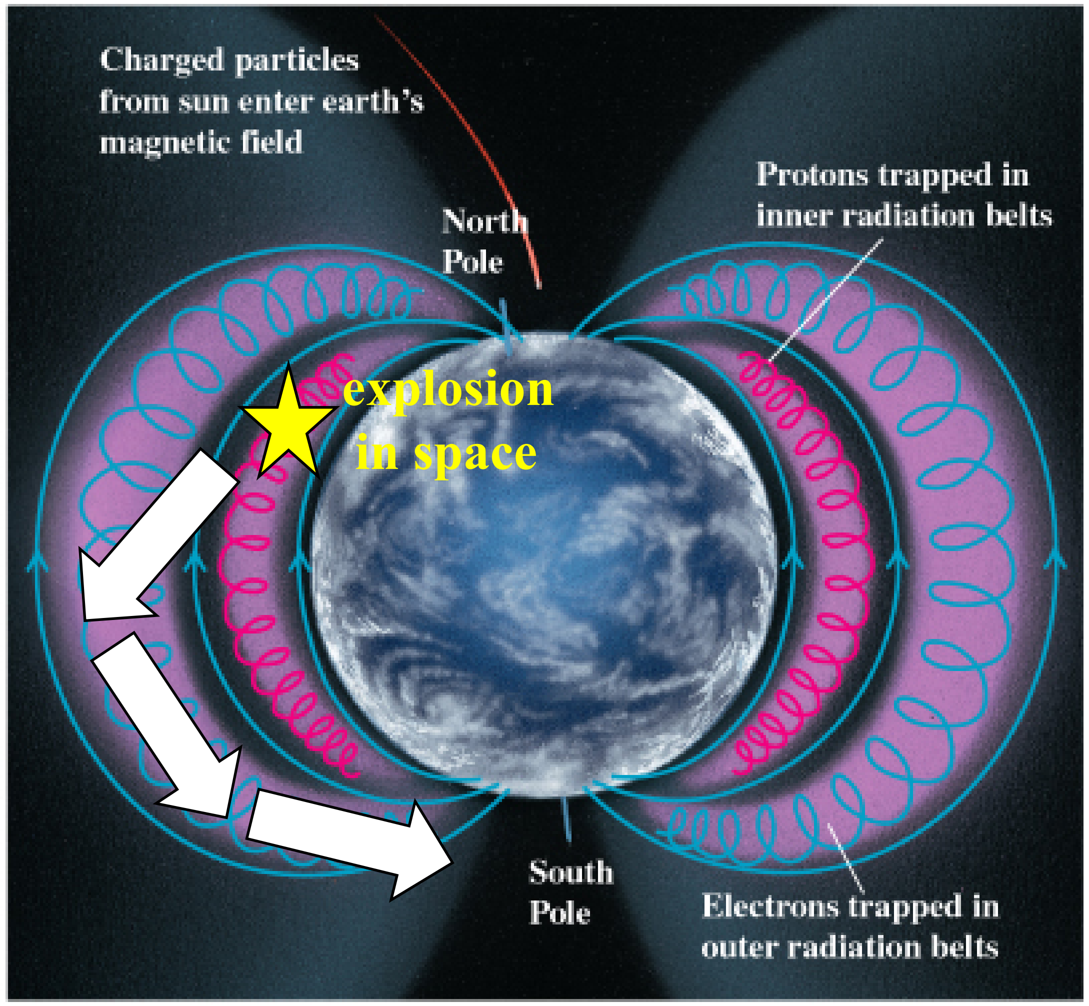


Nuclear Explosions in Space

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

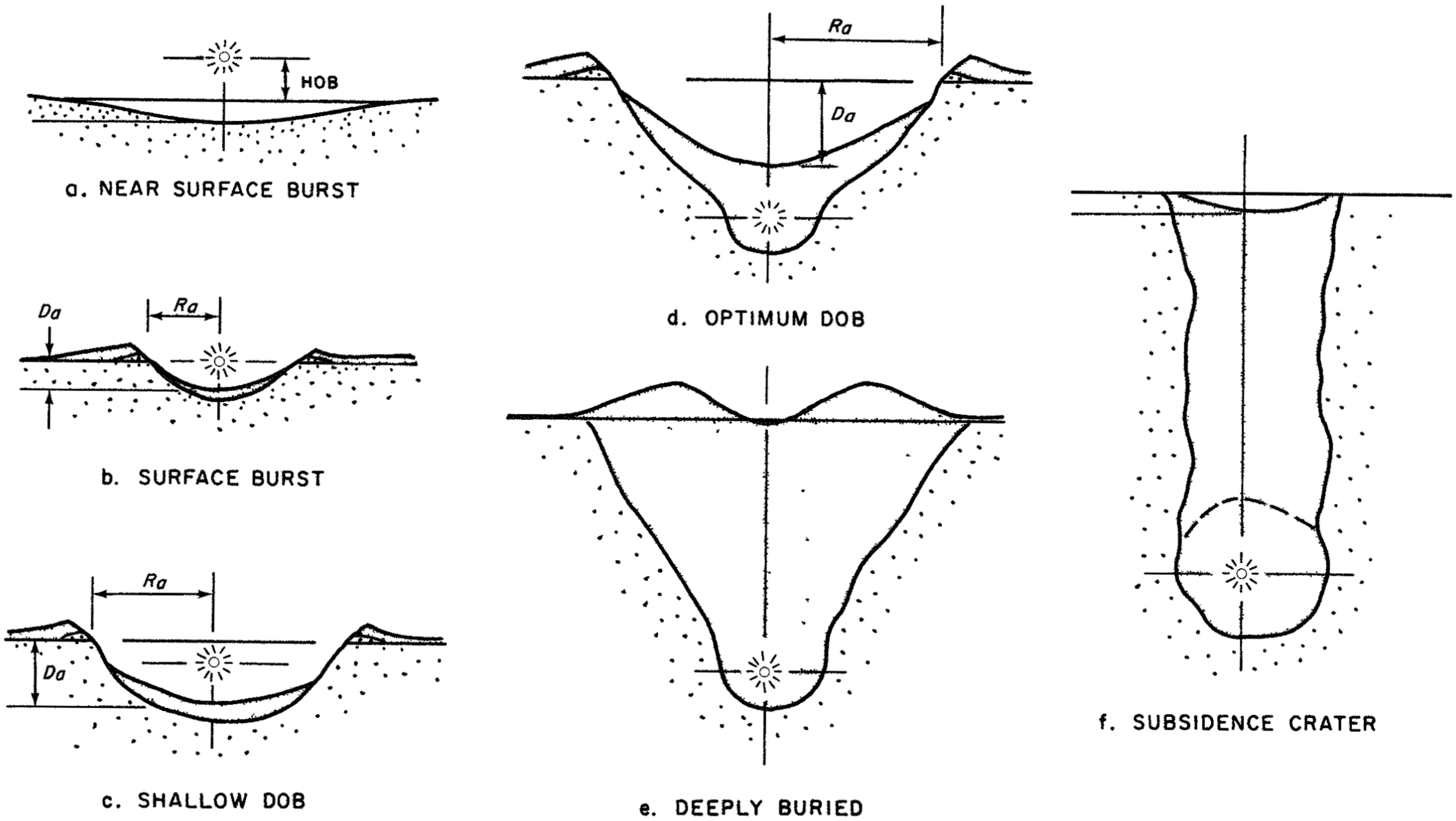
Underground Nuclear Explosions: Test Deployment & Assembly

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)

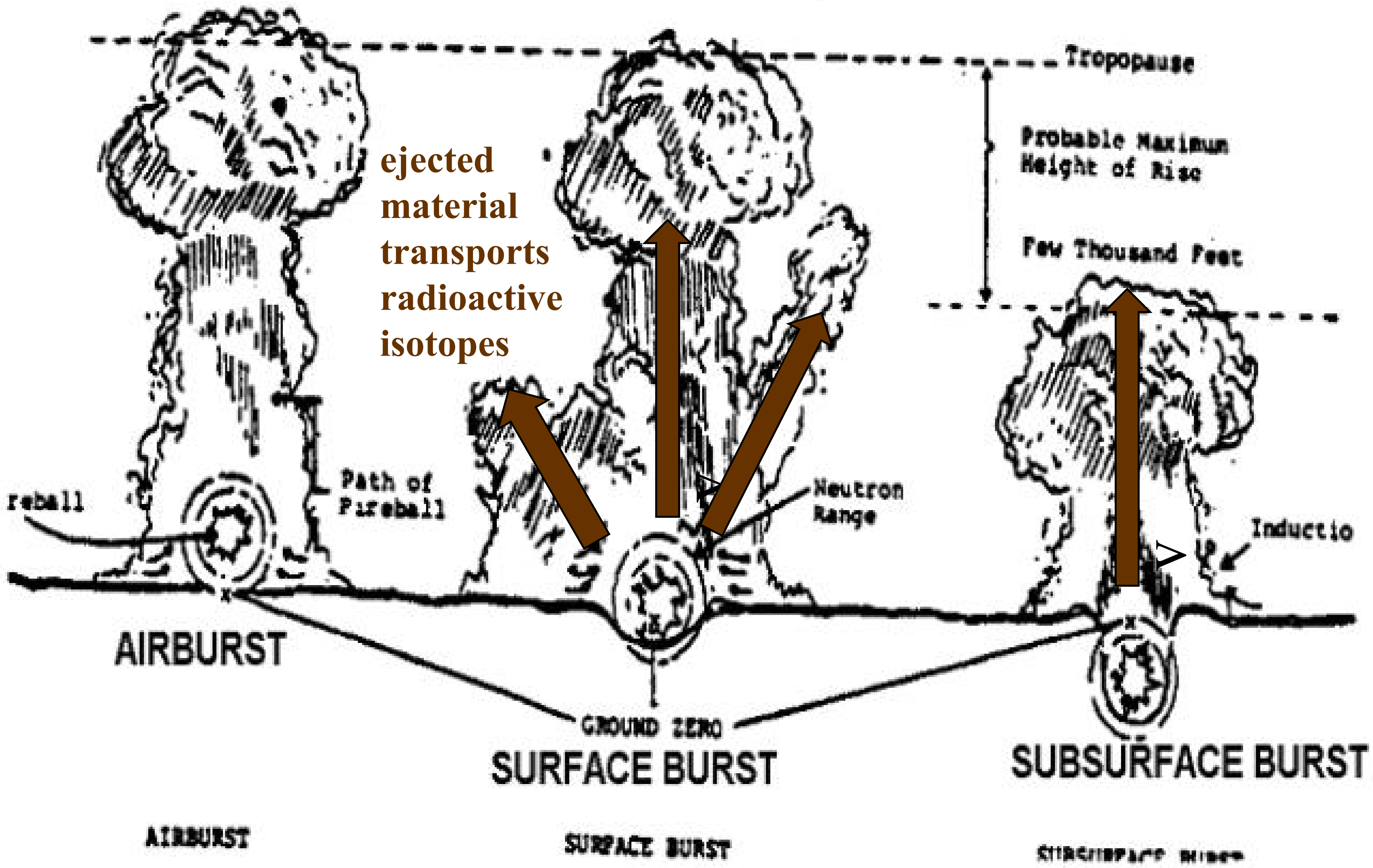


Underground Nuclear Explosions- Nevada Test Site

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

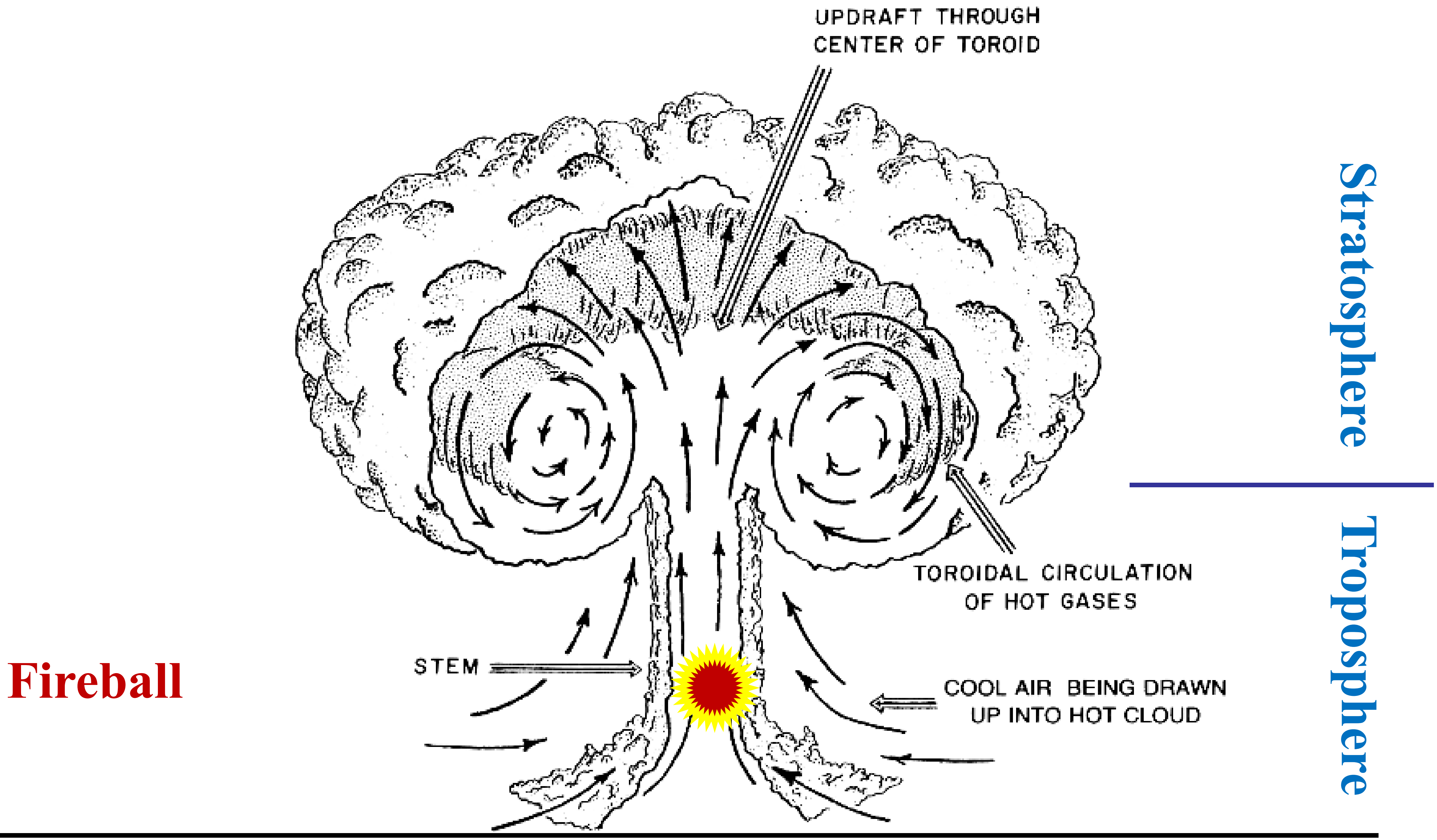
Time	Diameter	Temperature
1 ms (= 10^{-3} s)	440 ft	—
10 s	5,700 ft	6,000 C

- 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



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

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 —

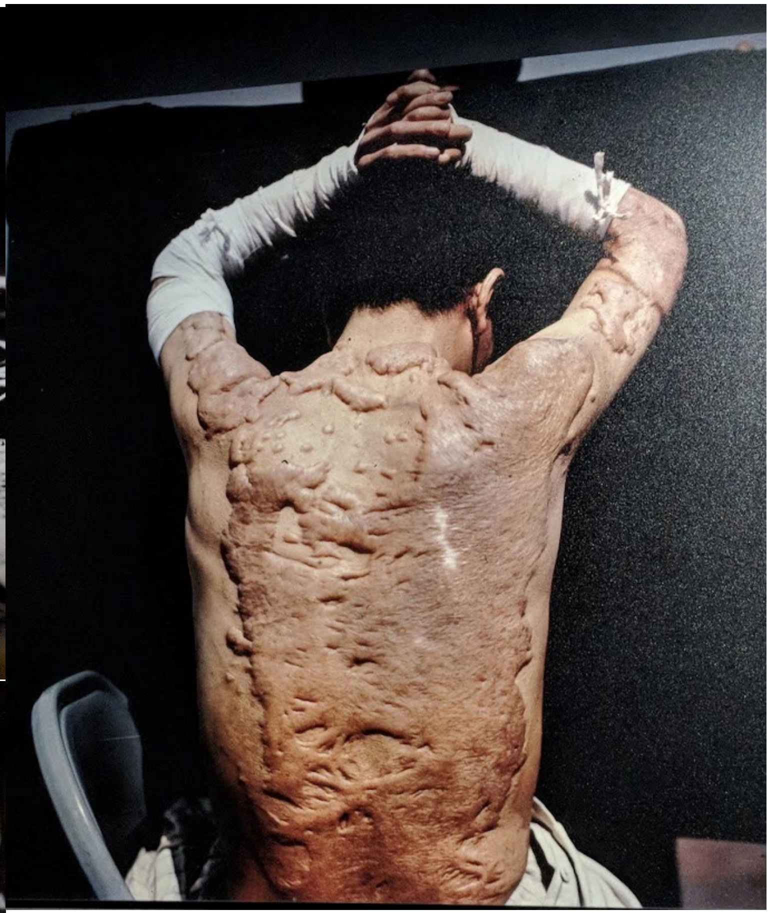
- Flash blindness (temporary)
- Retinal burns (permanent)
  - —Approximately 13 mi on a clear day
  - —Approximately 53 mi on a clear night
- Skin burns
- Ignition of clothing, structures, surroundings

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

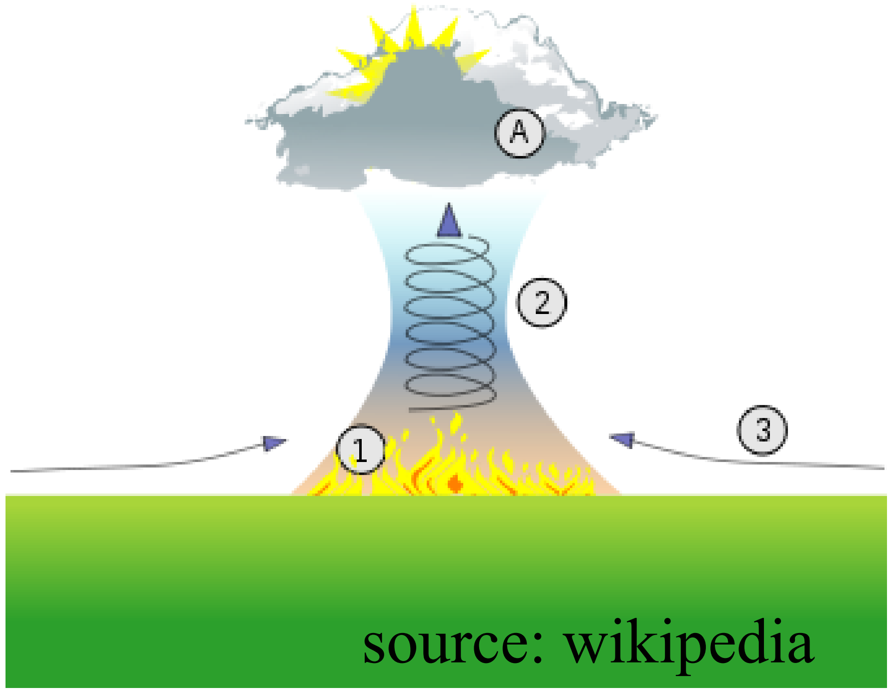
Conflagrations Versus Firestorms

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



source: wikipedia

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

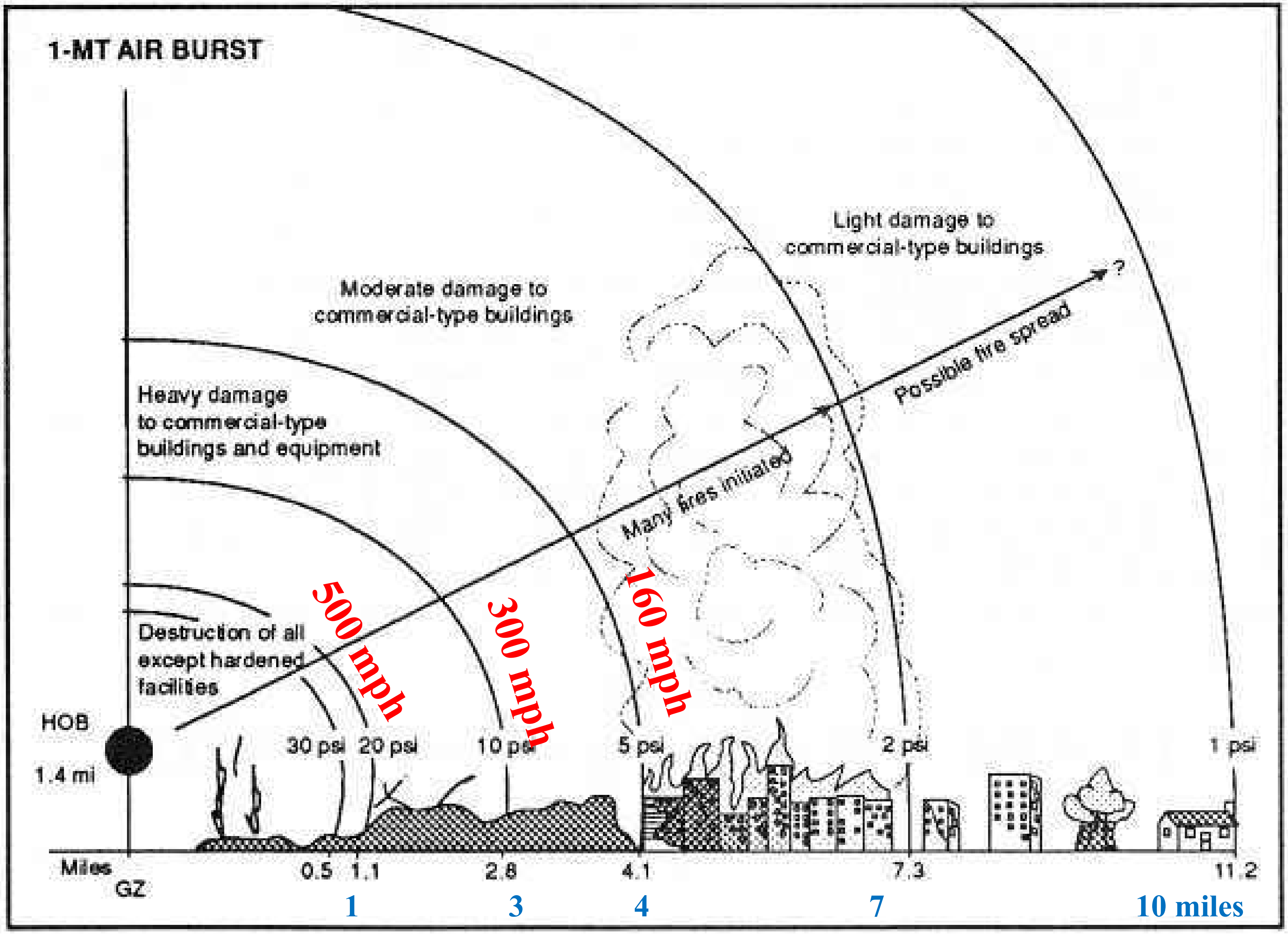
  - A strong outward wind that produces dynamic pressure that blows structures and victims outward

- 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

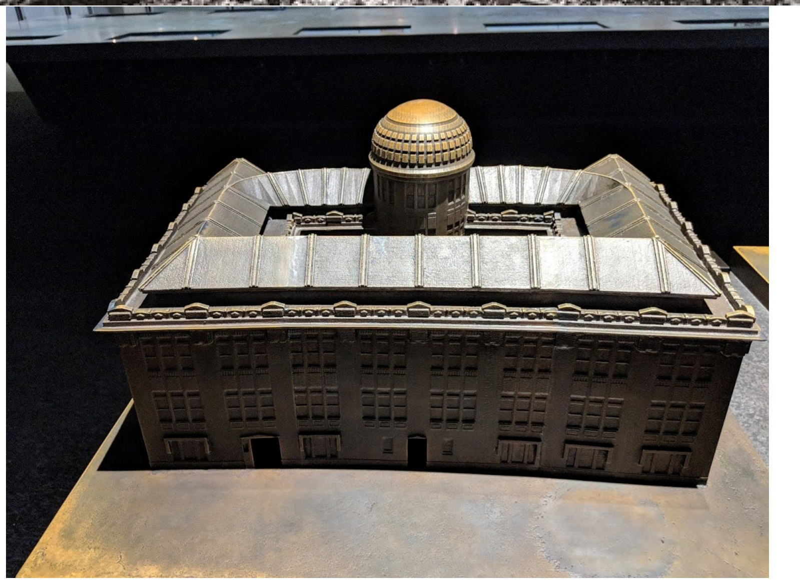


Damage in Hiroshima

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

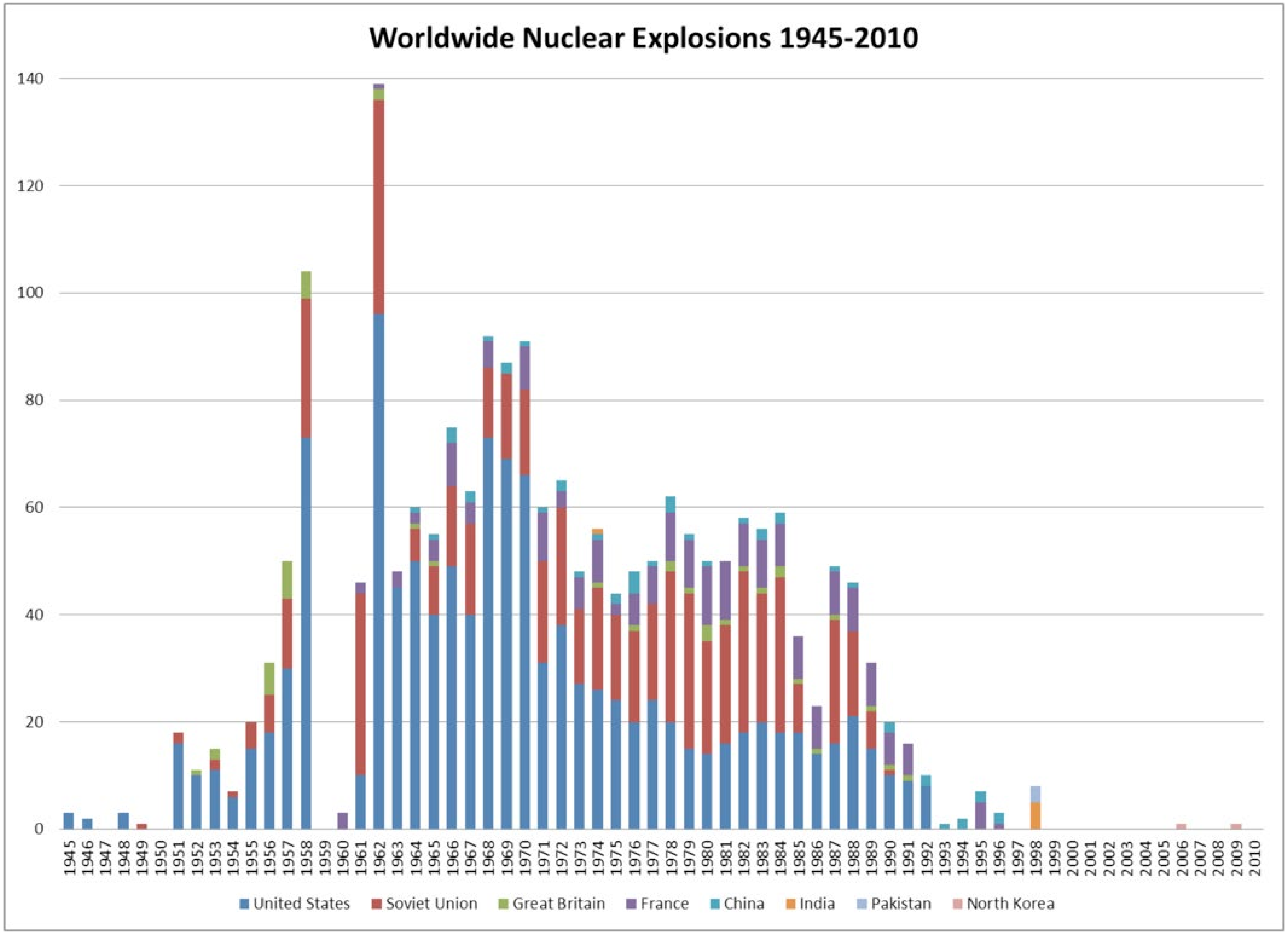
Effects of the Sedan Event (1962)

- 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

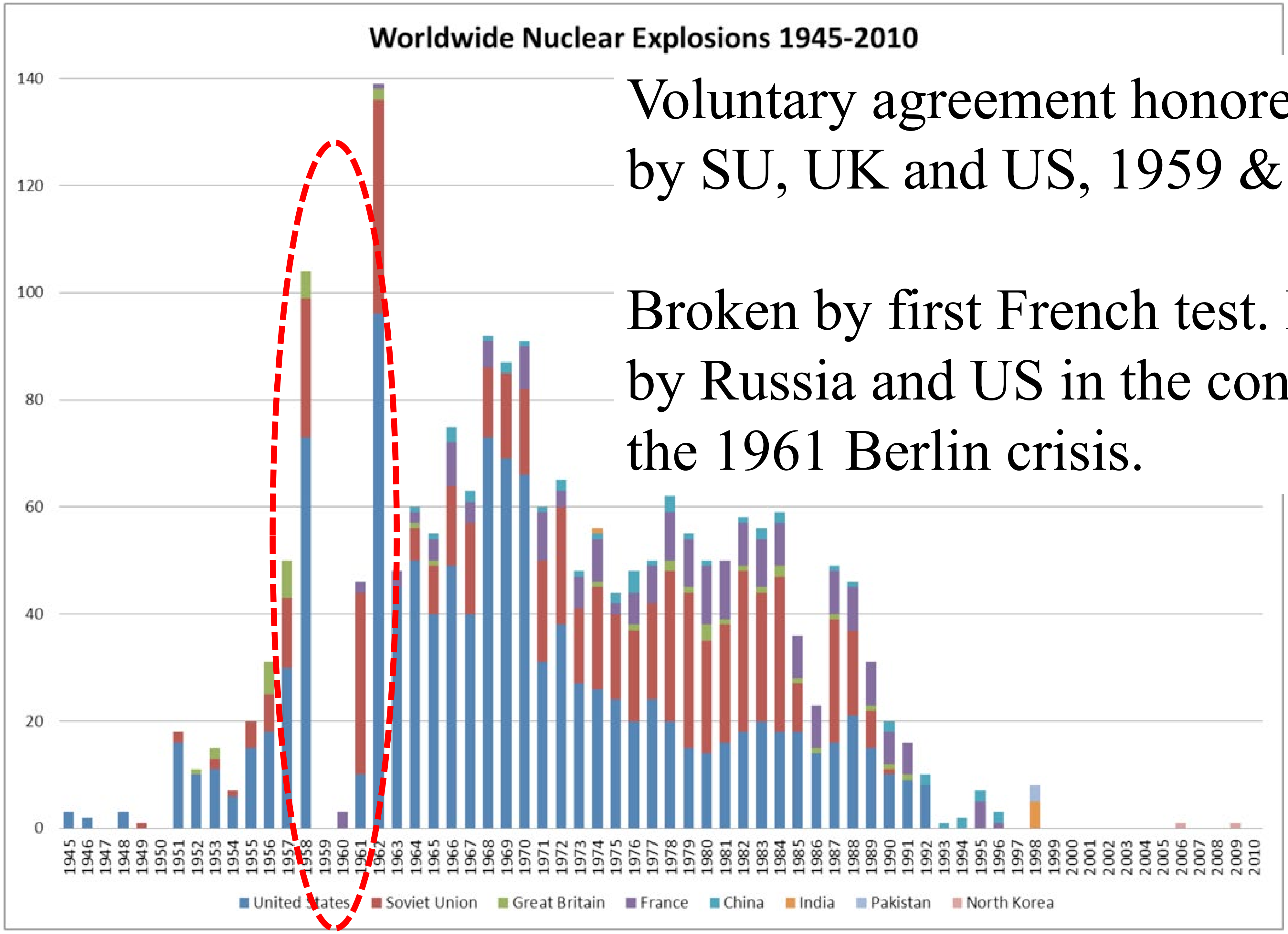
Example: The Sedan Test (100 kt, 1962)

Effects of Nuclear Explosions



Credit: Wikipedia Commons

Test Moratorium 1959-1960



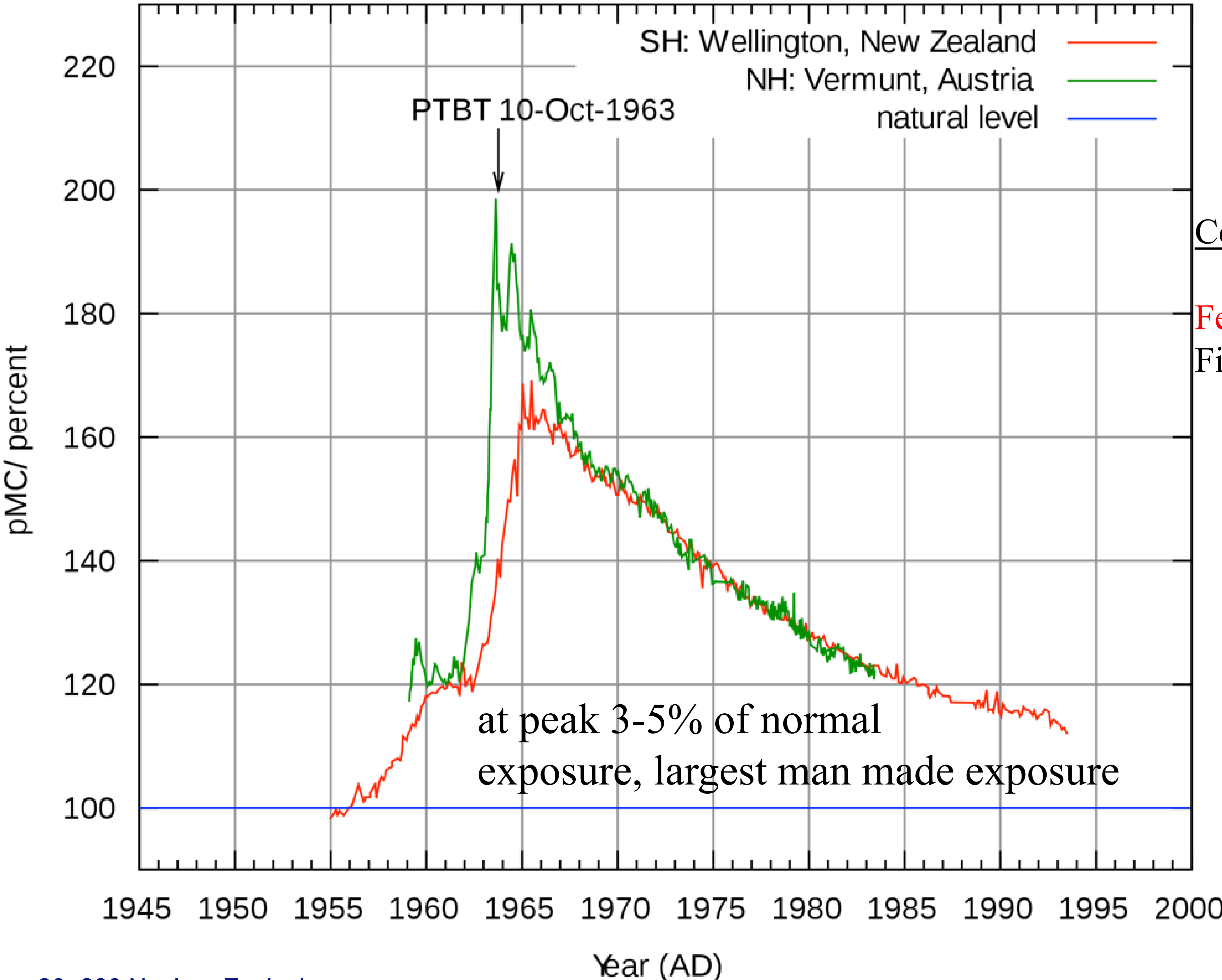
Voluntary agreement honored by SU, UK and US, 1959 & 1960

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)



Centers for Disease Control and Prevention:

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

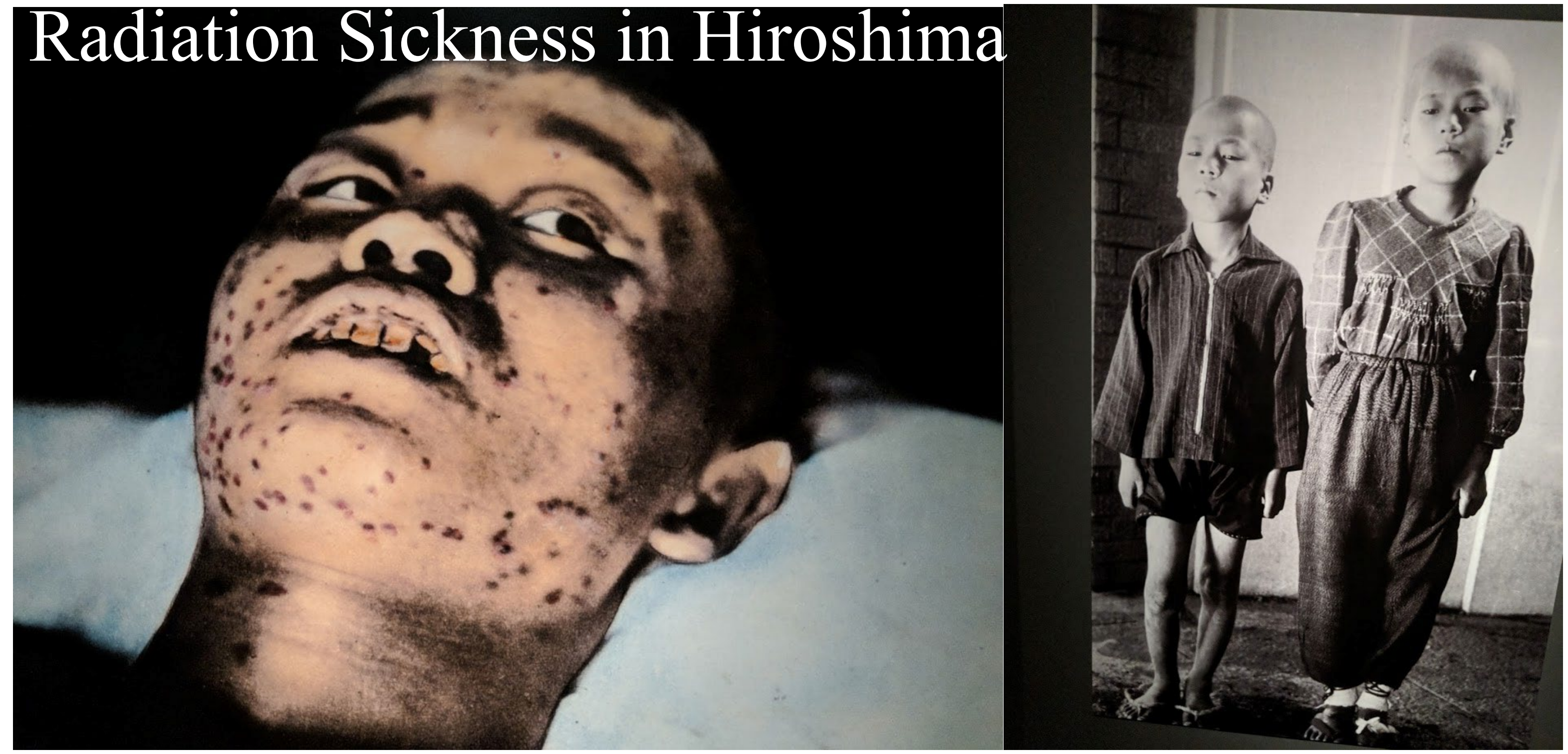
~ additional 11,000 cancer deaths among US population alive in the years from 1951 to 2000.

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

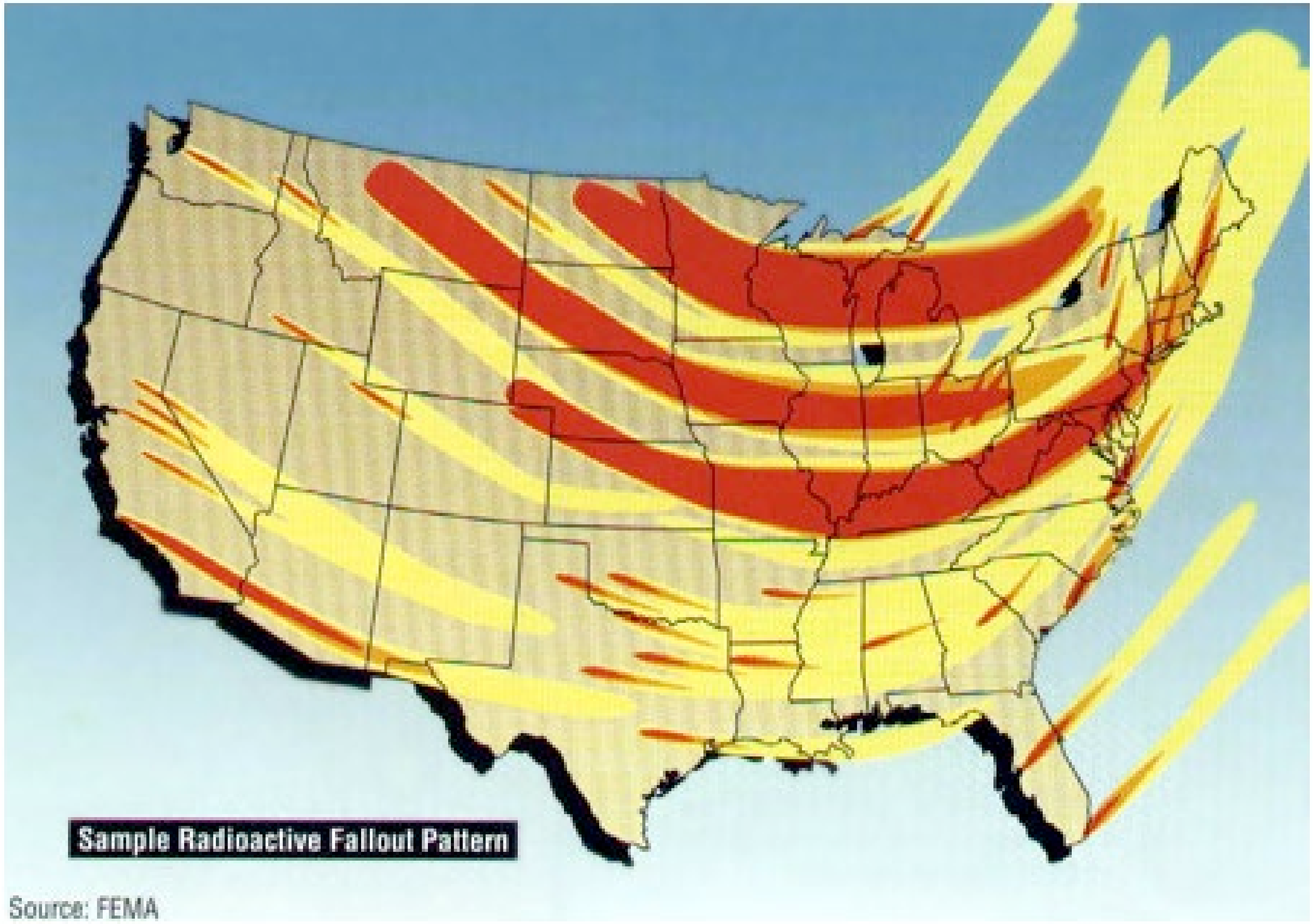


Radiation Sickness in Hiroshima

Distances and doses —

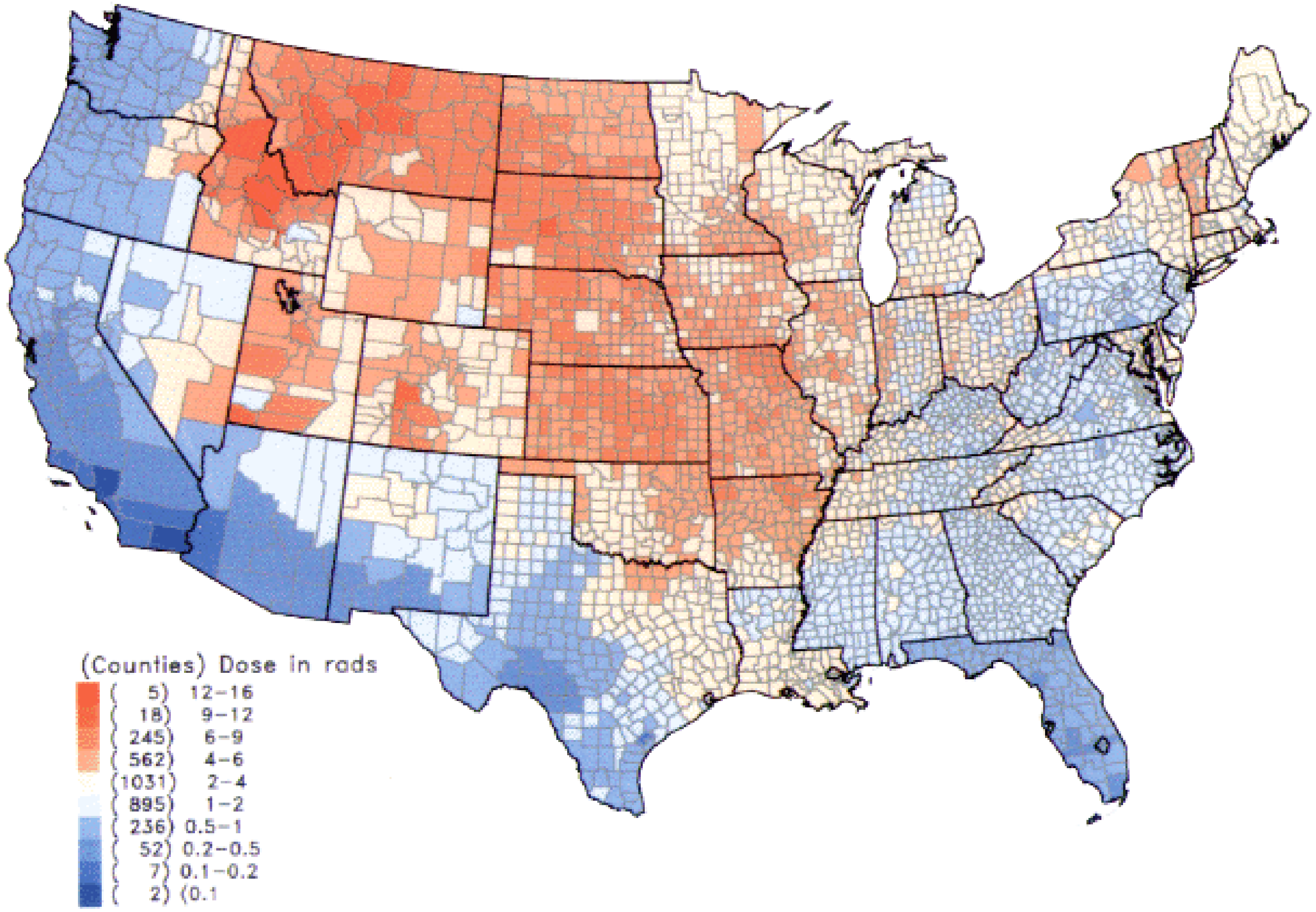
- 30 miles: 3,000 rem (death within hours; more than 10 years before habitable)
- 90 miles 900 rem (death in 2 to 14 days)
- 160 miles: 300 rem (severe radiation sickness)
- 250 miles: 90 rem (significantly increased cancer risk; 2 to 3 years before habitable)

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



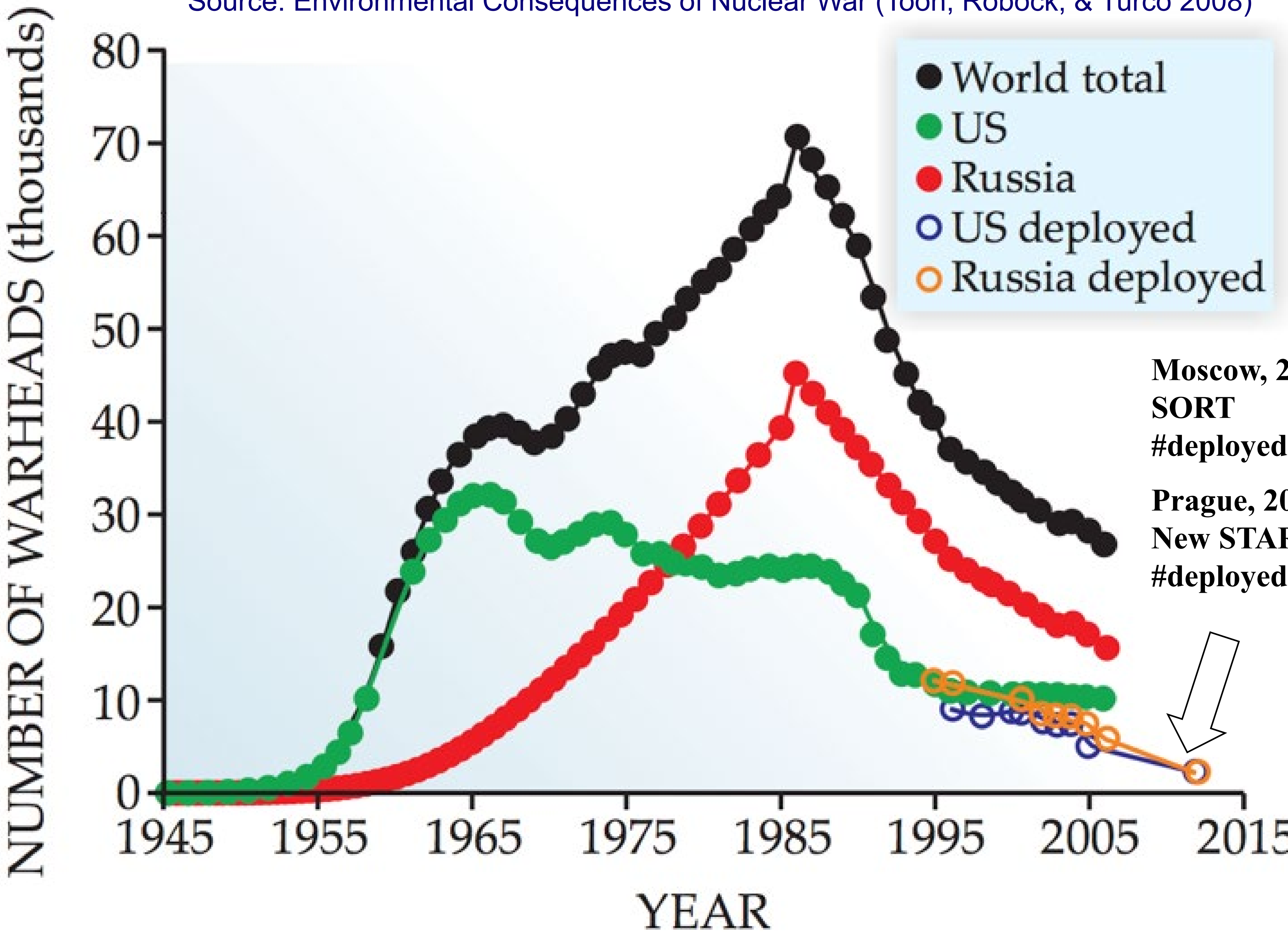
Centers for Disease Control, Feasibility Study of Weapons Test Fall Out:

"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."

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)

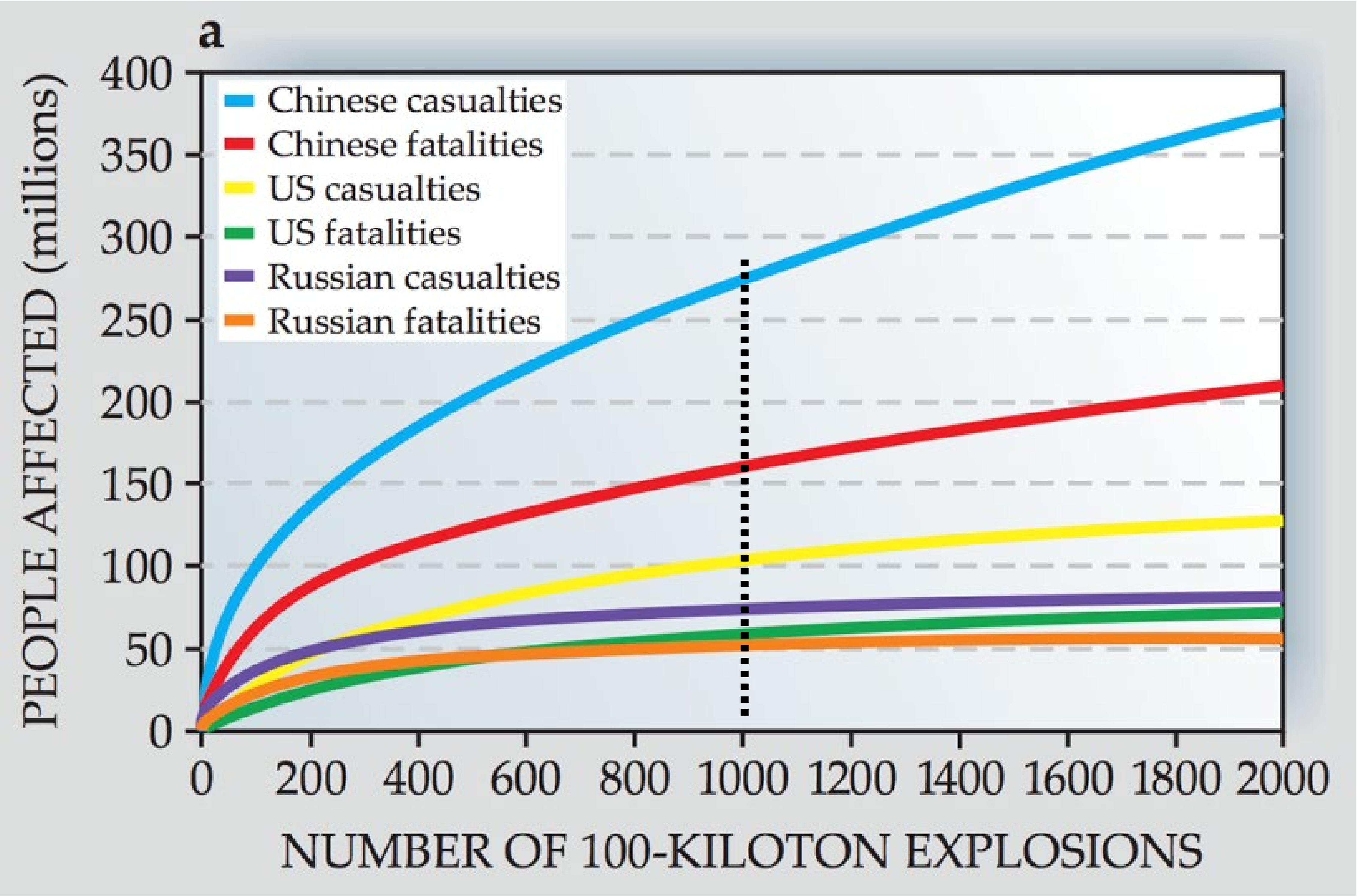
1,000 weapons detonated on Russia would *immediately* —

- 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)



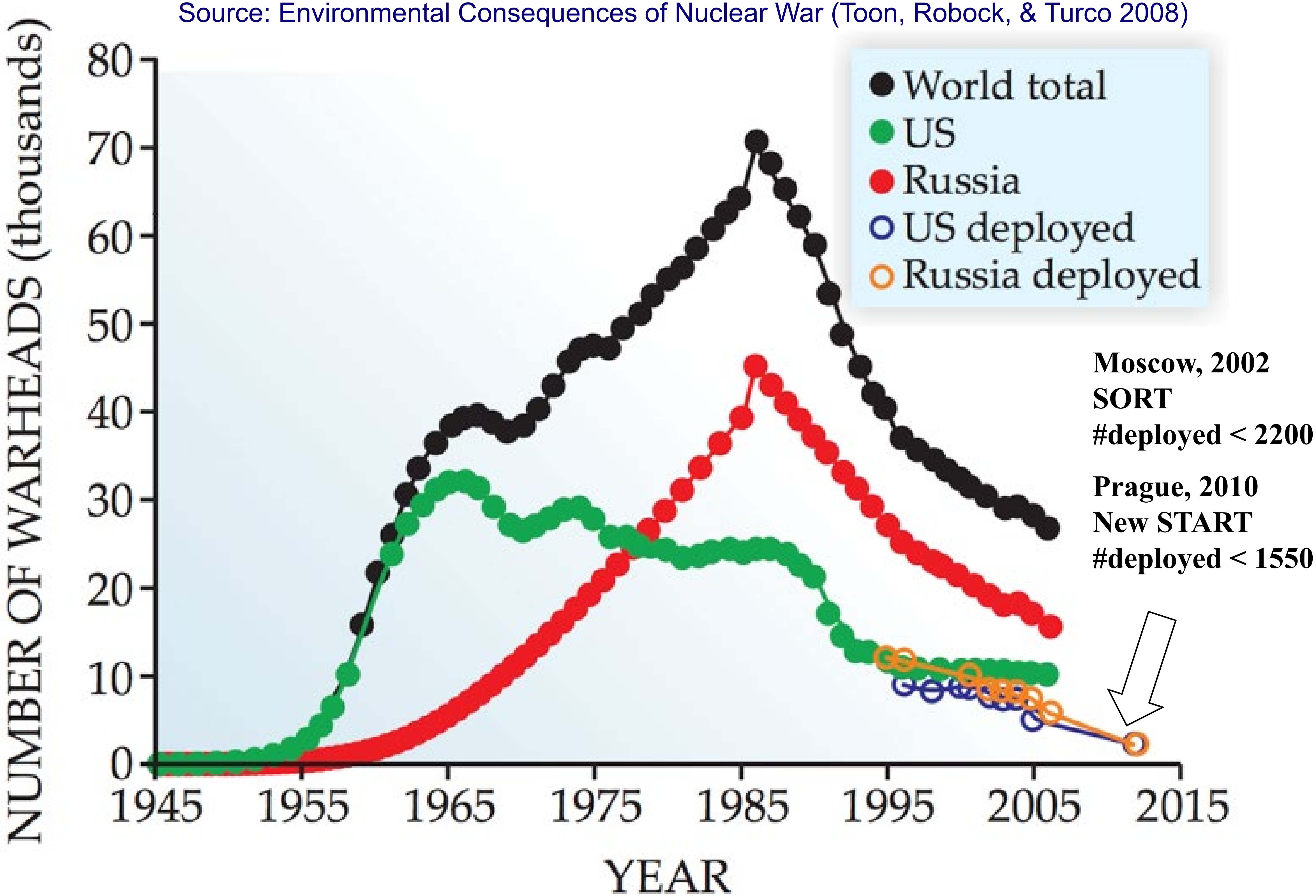
Large Cities in China, Russia and the United States

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)



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

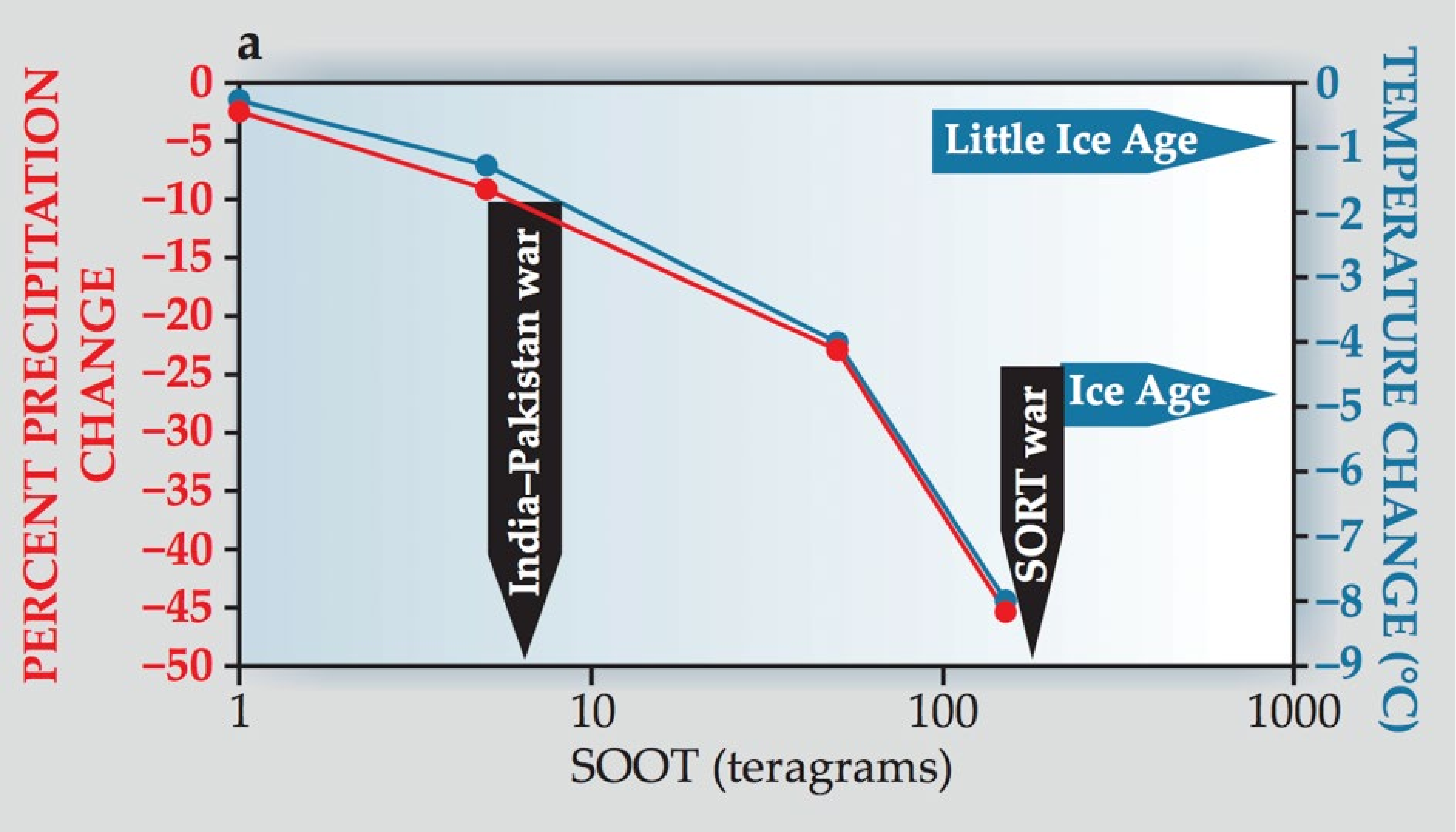
A regional war between India and Pakistan could generate 5 Tg of soot (5 million tons), sufficient to —

- 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)

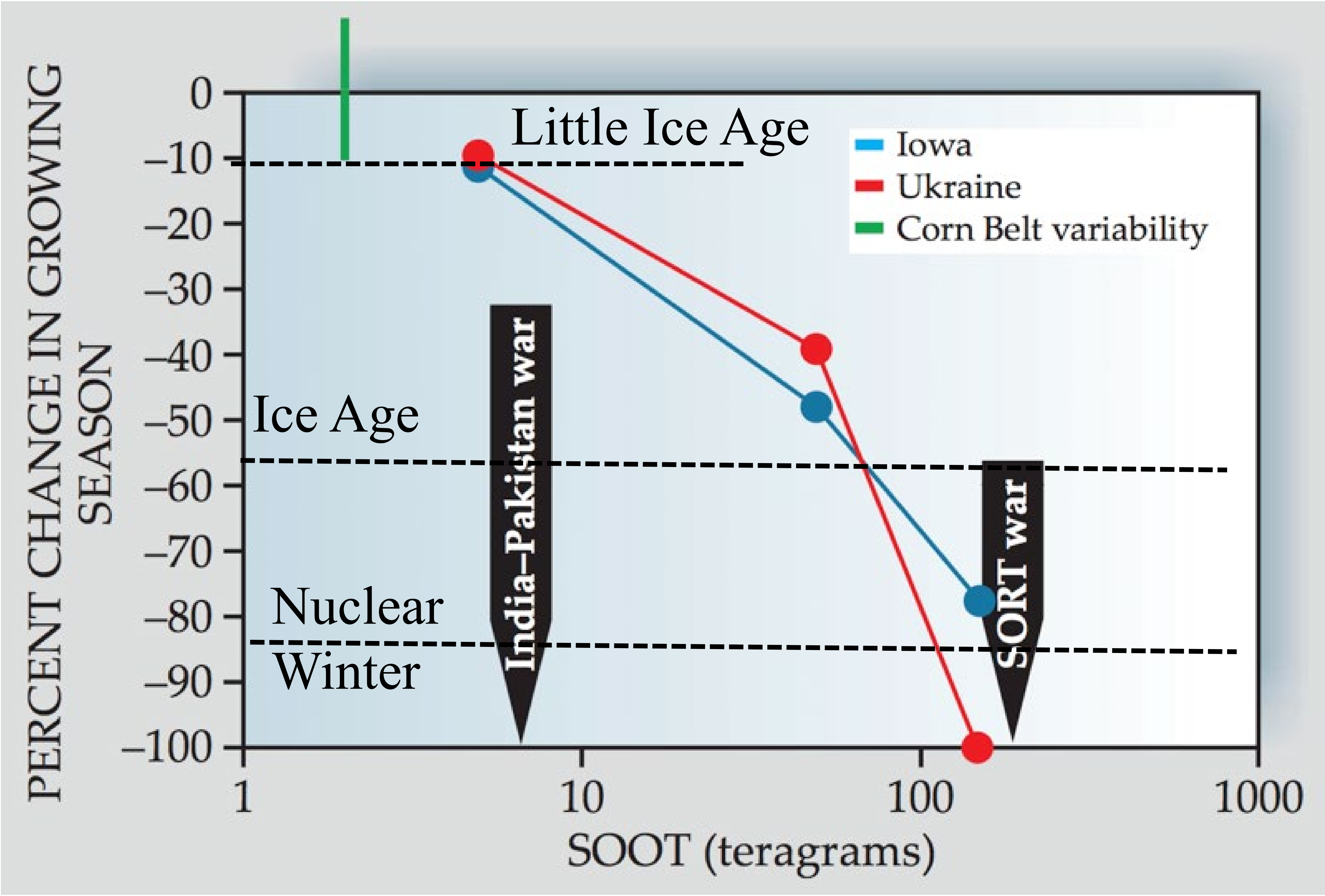
Effects of Nuclear War: Change in Precipitation and Temperature

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



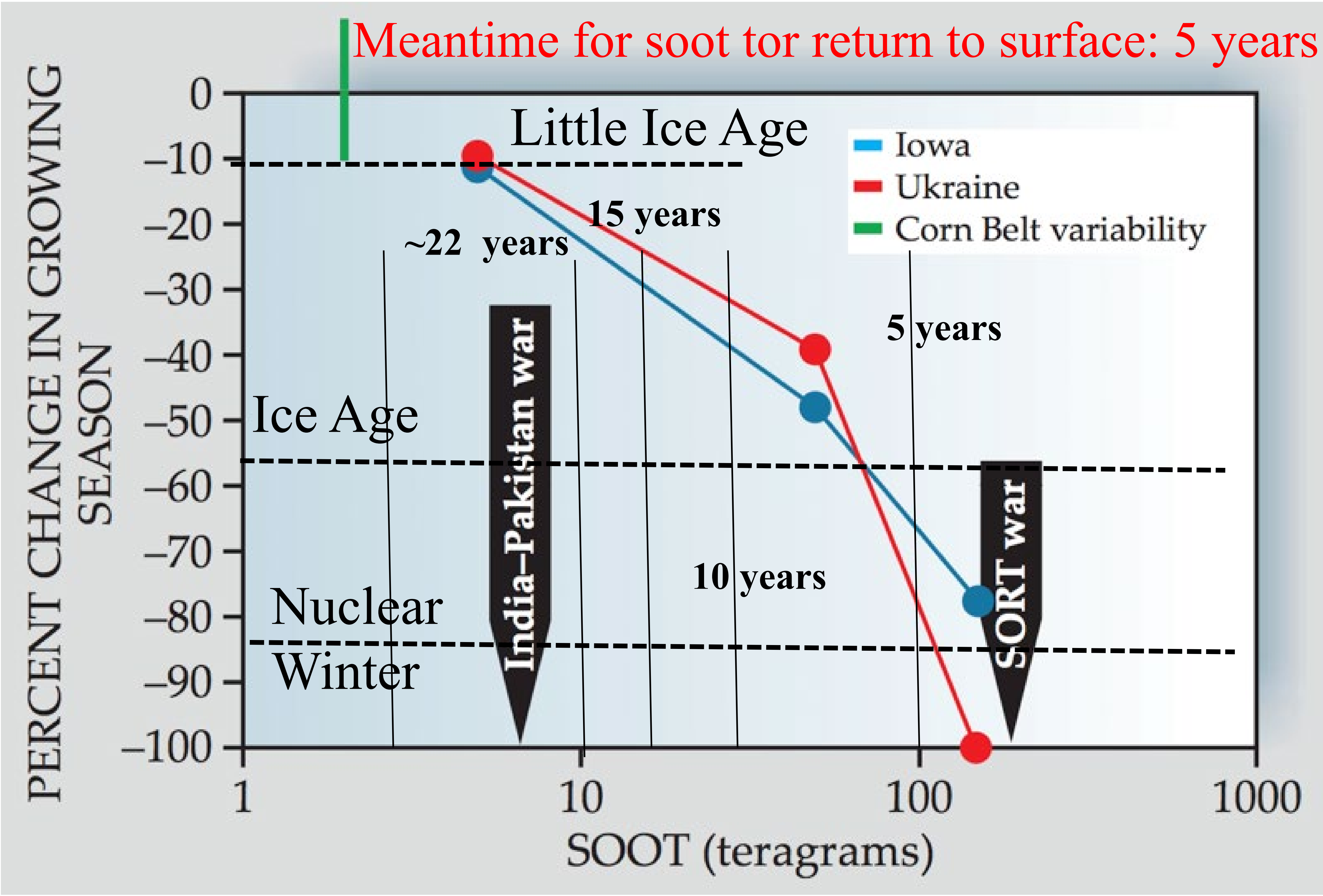
Effects of Nuclear War: Percent Change in Growing Season

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

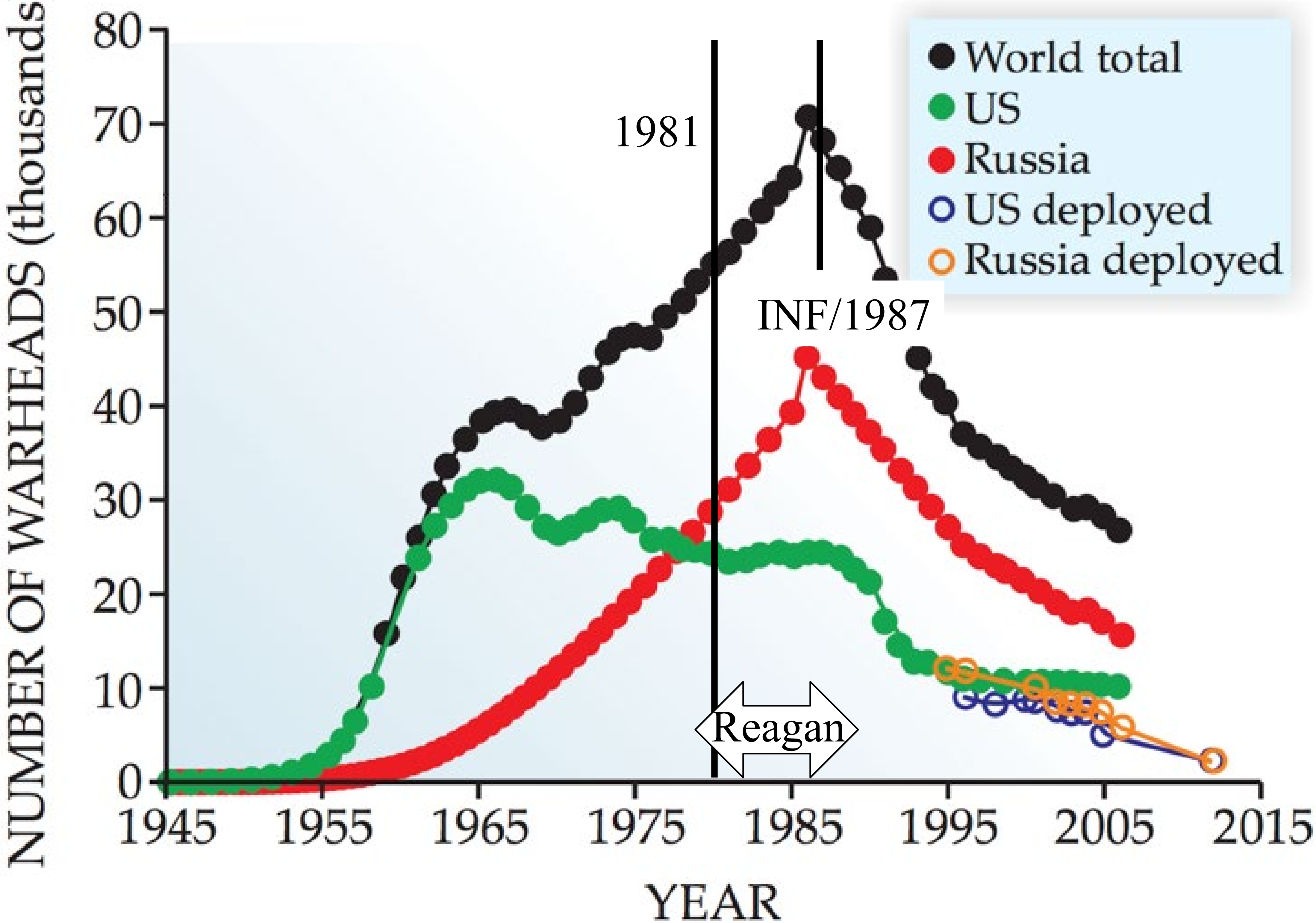
infrastructure than to the direct effects of nuclear war."

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)



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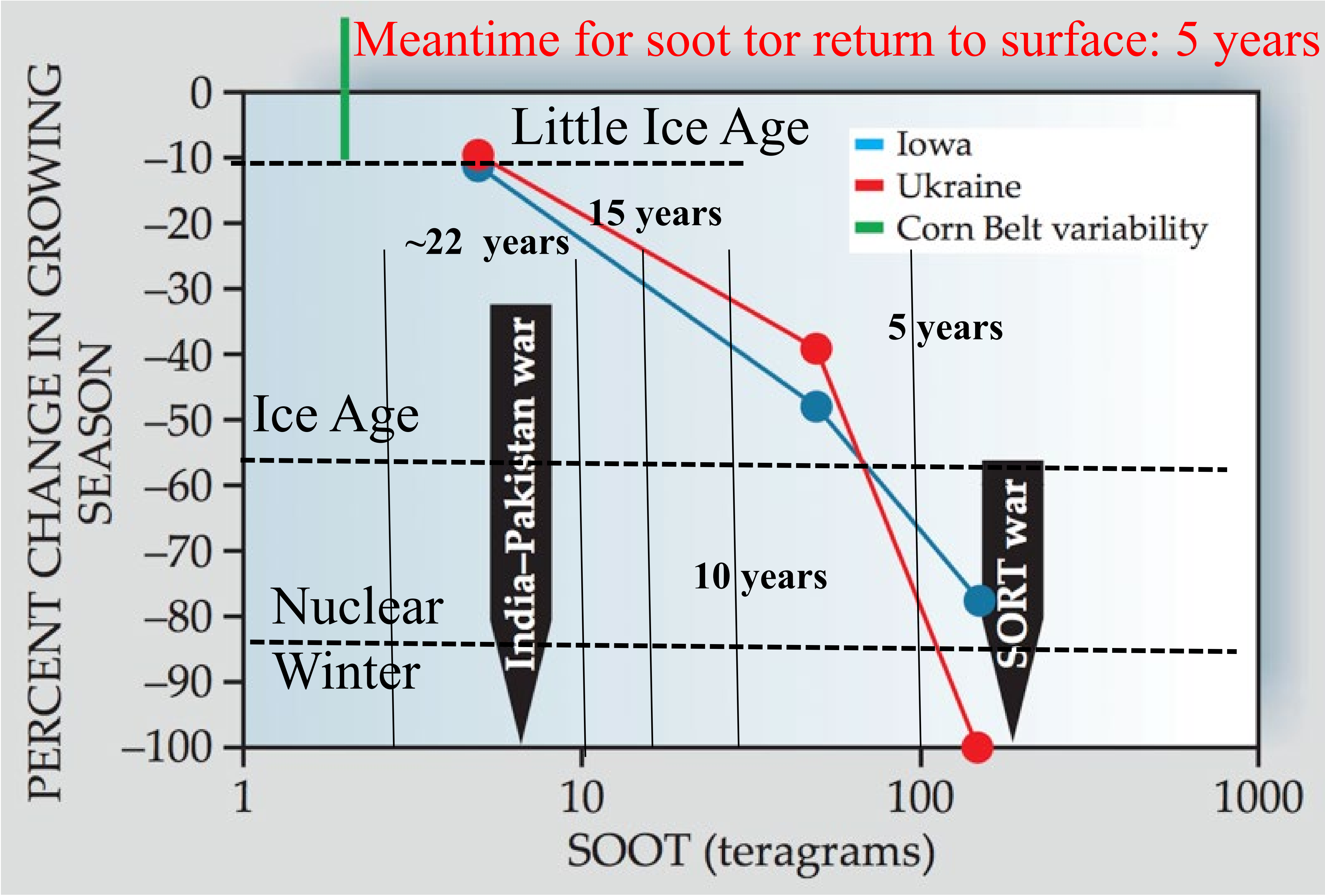

Plan for This Session

RPPv1 is due at 2pm (now!)

News

Nuclear Explosions Conclusion: “Nuclear Winter”

“Ground Zero” Video presentation

News

U.S. Revives Secret Program to Sabotage Iranian Missiles and Rockets

By David E. Sanger and William J. Broad

Feb. 13, 2019

WARSAW — The Trump White House has accelerated a secret American program to sabotage Iran's missiles and rockets, according to current and former administration officials, who described it as part of an expanding campaign by the United States to undercut Tehran's military and isolate its economy. Officials said it was impossible to measure precisely the success of the classified program, which has never been publicly acknowledged. But in the past month alone, two Iranian attempts to launch satellites have failed within minutes.

Those two rocket failures — one that Iran announced on Jan. 15 and the other, an unacknowledged attempt, on Feb. 5 — were part of a pattern over the past 11 years. In that time, 67 percent of Iranian orbital launches have failed, an astonishingly high number compared to a 5 percent failure rate worldwide for similar space launches. The setbacks have not deterred Iran. This week, President Hassan Rouhani singled out Tehran's missile fleets as he vowed to "continue our path and our military power." The Trump administration maintains that Iran's space program is merely a cover for its attempts to develop a ballistic missile powerful enough to send nuclear warheads flying between continents. Hours after the Jan. 15 attempt, Secretary of State Mike Pompeo note noted that Iran's satellite launchers have technologies "virtually identical and interchangeable with those used in ballistic missiles." Mr. Pompeo is in Warsaw this week with Vice President Mike Pence to lead a meeting of 65 nations on encouraging stability in the Middle East, including by expanding economic sanctions against Iran. It is largely an appeal to European allies who, while continuing to oppose President Trump's decision to abandon the 2015 nuclear accord with Iran, also agree that the missile tests must stop.

News

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