Hiroshima and Nagasaki

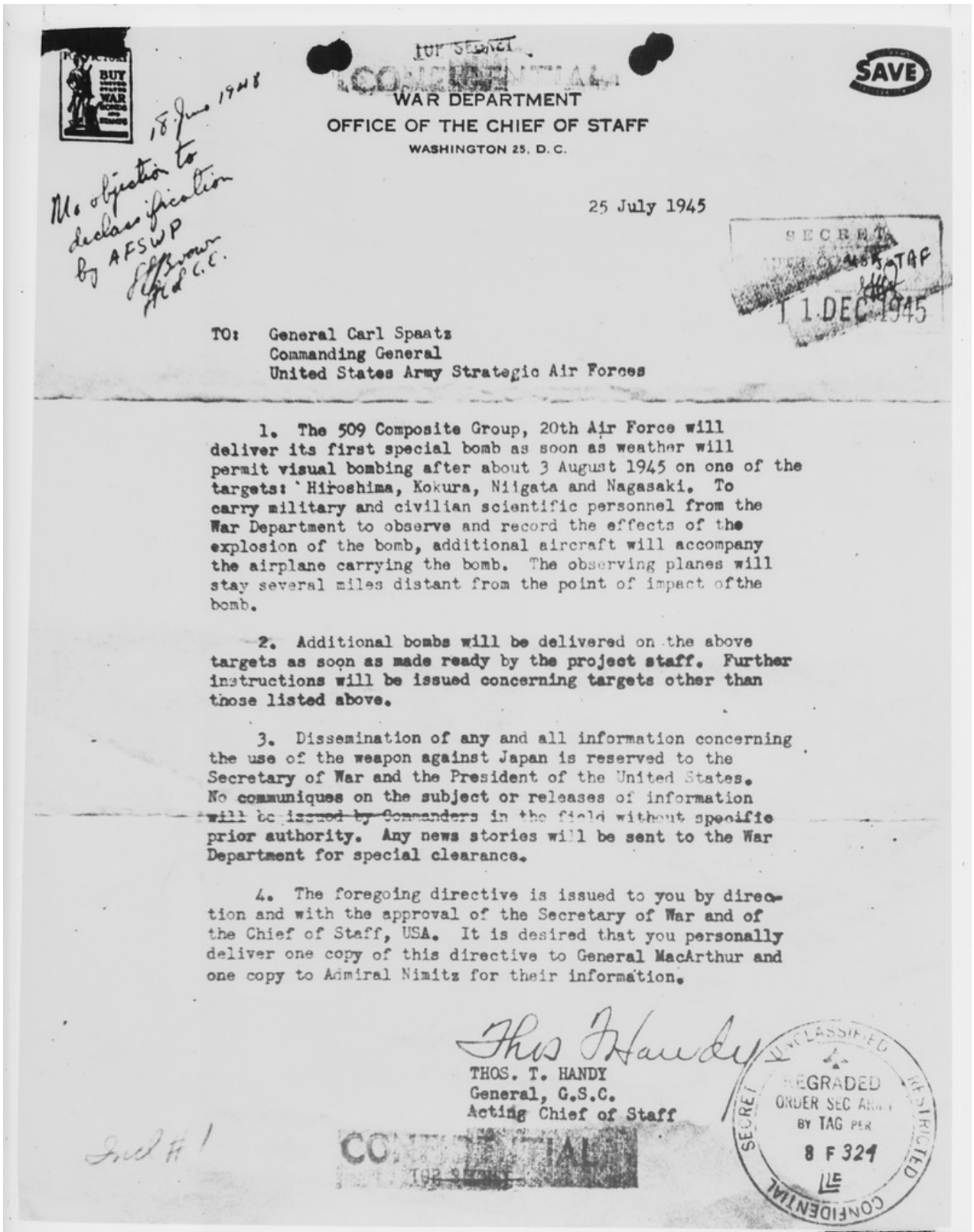
- The nuclear attack and its immediate impact
- Radiation sickness
- Long-term medical effects

Matthias Grosse Perdekamp
Physics & ACDIS at UIUC

Hiroshima August, 1945

Prior to August 1945: Extensive Conventional Bombing Raids on Japanese Metropolitan Areas

The Attacks: August 6th and August 9th, 1945



BUY UNITED STATES WAR BONDS AND STAMPS

18 June 1948
No objection to declassification
By AFSWP
[illegible] A.C.C.

TOP SECRET
CONFIDENTIAL

SAVE

WAR DEPARTMENT
OFFICE OF THE CHIEF OF STAFF
WASHINGTON 25, D. C.

25 July 1945

SECRET
[illegible] TAF
11 DEC 1945

TO: General Carl Spaatz
Commanding General
United States Army Strategic Air Forces

1. The 509 Composite Group, 20th Air Force will deliver its first special bomb as soon as weather will permit visual bombing after about 3 August 1945 on one of the targets: Hiroshima, Kokura, Niigata and Nagasaki. To carry military and civilian scientific personnel from the War Department to observe and record the effects of the explosion of the bomb, additional aircraft will accompany the airplane carrying the bomb. The observing planes will stay several miles distant from the point of impact of the bomb.

2. Additional bombs will be delivered on the above targets as soon as made ready by the project staff. Further instructions will be issued concerning targets other than those listed above.

3. Dissemination of any and all information concerning the use of the weapon against Japan is reserved to the Secretary of War and the President of the United States. No communiques on the subject or releases of information will be issued by Commanders in the field without specific prior authority. Any news stories will be sent to the War Department for special clearance.

4. The foregoing directive is issued to you by direction and with the approval of the Secretary of War and of the Chief of Staff, USA. It is desired that you personally deliver one copy of this directive to General MacArthur and one copy to Admiral Nimitz for their information.

Thos Handy
THOS. T. HANDY
General, G.S.C.
Acting Chief of Staff

2nd H!

CONFIDENTIAL

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BY TAG PER
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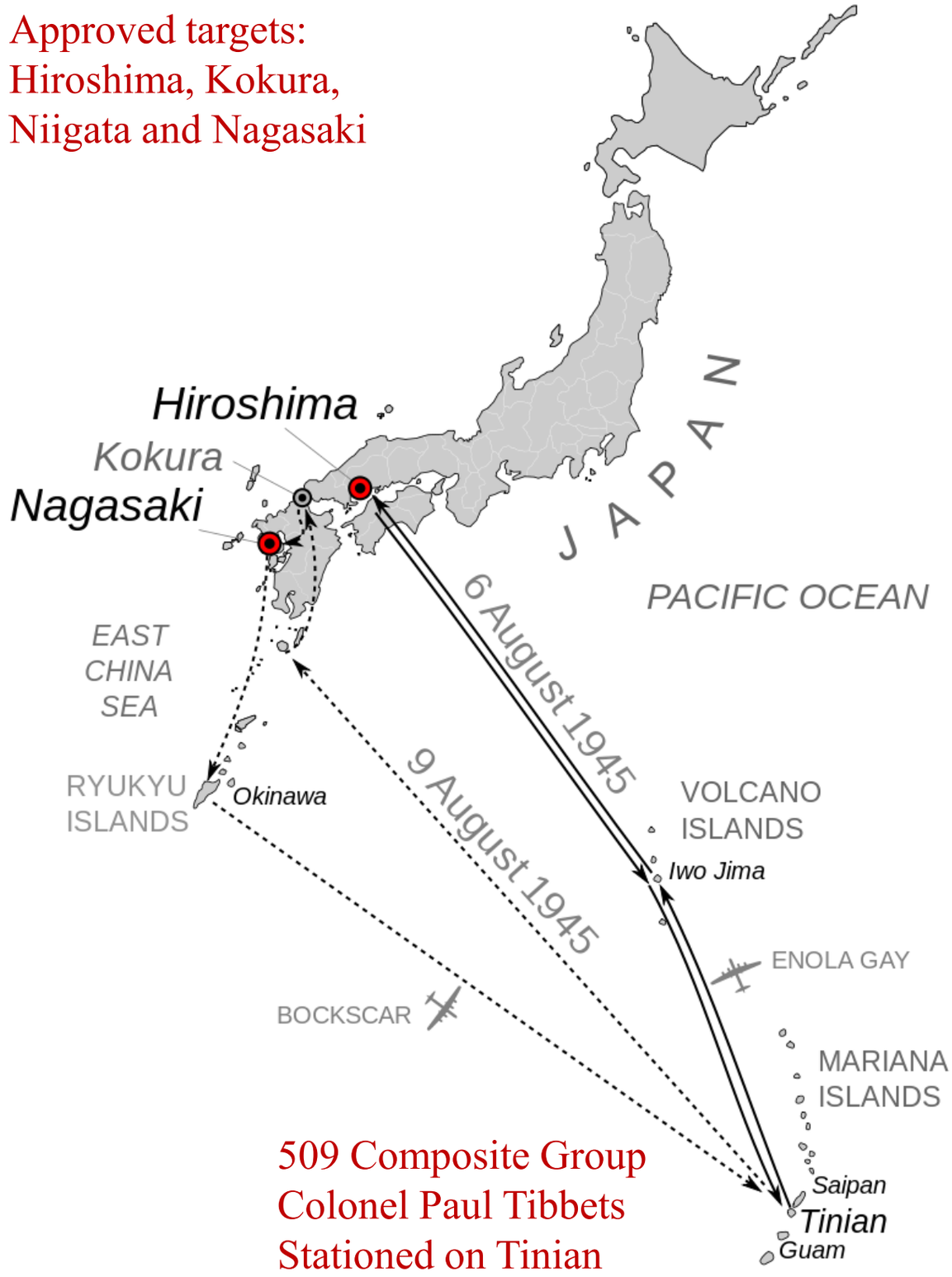
Approved targets:
Hiroshima, Kokura,
Niigata and Nagasaki



509 Composite Group
Colonel Paul Tibbets
Stationed on Tinian

The Attacks: August 6th and August 9th, 1945

Hiroshima
Weather Reconnaissance:
3 B-29: Hiroshima, Kokura, Nagasaki
1 B-29 for weapon delivery (“Enola Gay”)
2 B-29 for strike observation & measurements
(Luis Alvarez on “The Great Artiste”)

Nagasaki
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(including two British Observers)

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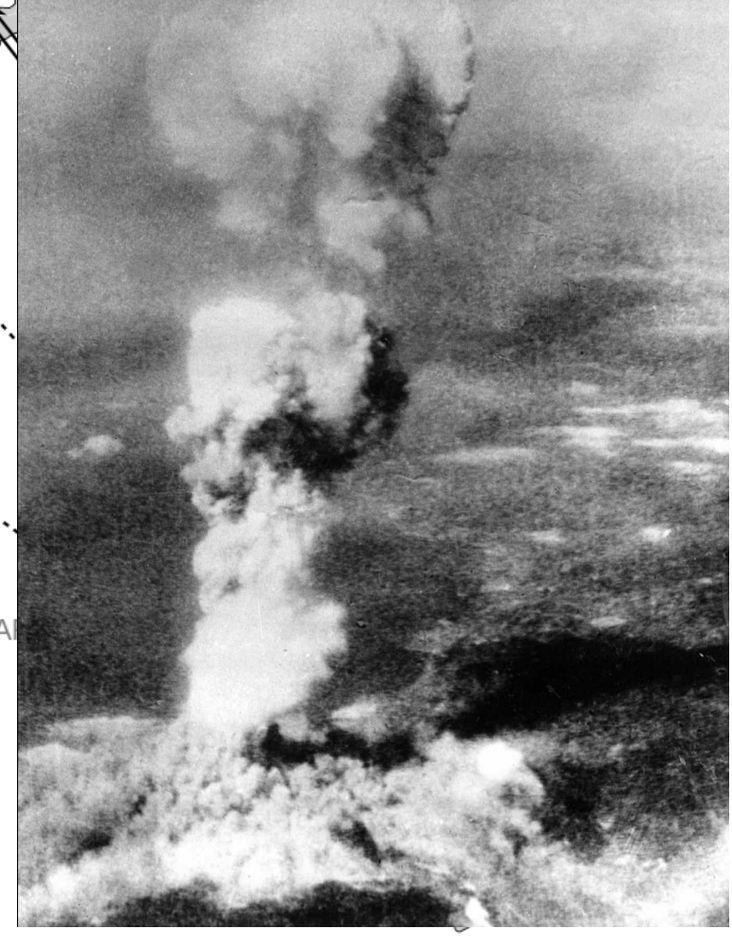
Photograph taken by Bob Caron From the Enola Gay



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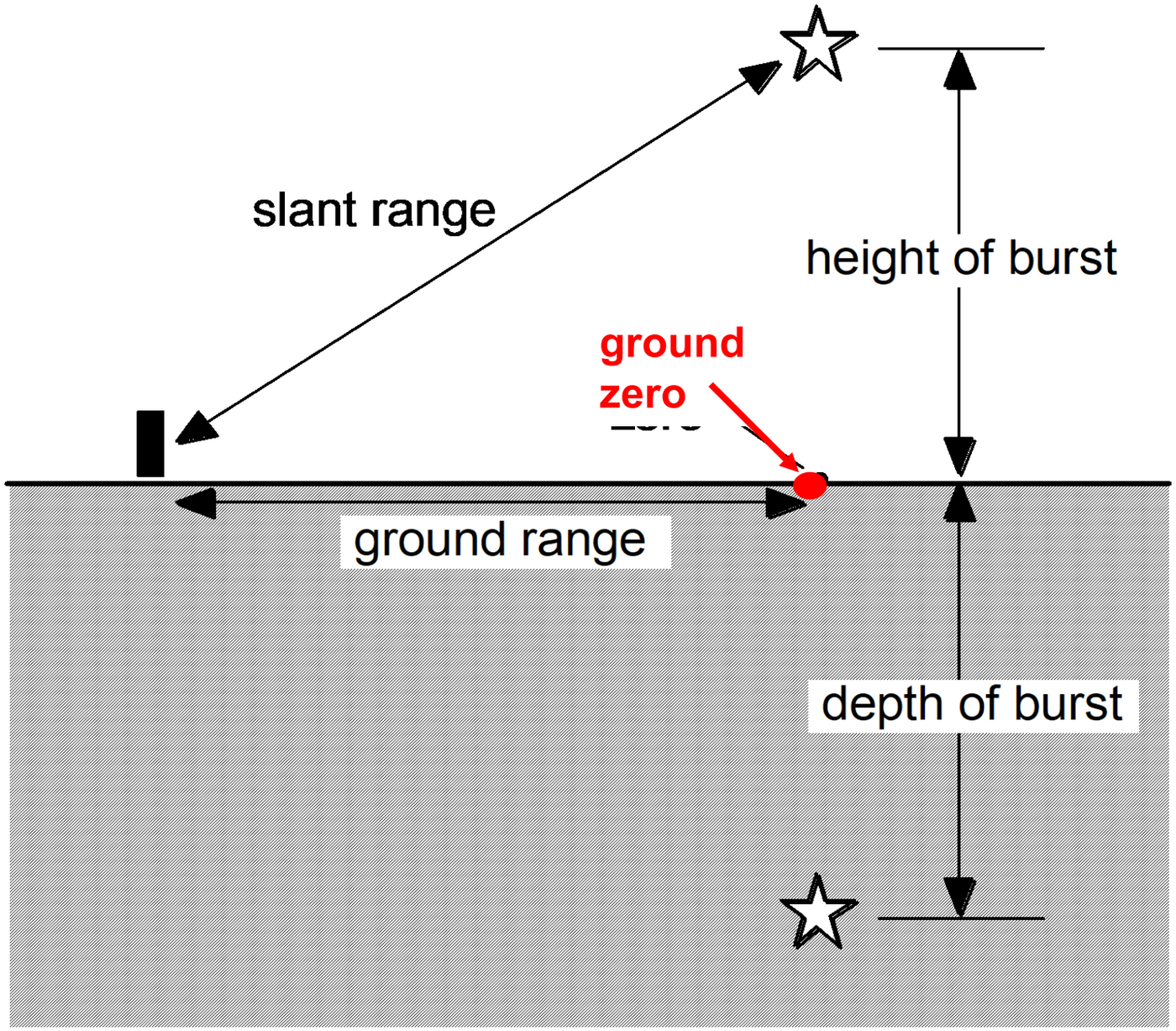
Nuclear Explosion Terms to be Used



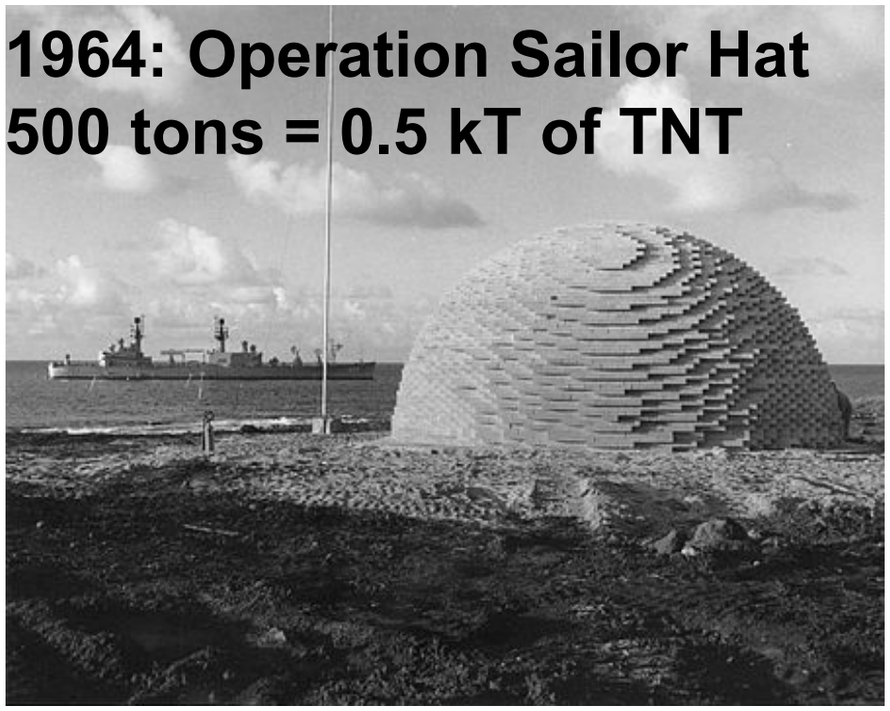
Energy Released in a Nuclear Explosion

The total energy released is the “yield” Y and is measured by comparison with explosive yields of TNT explosions.

Units used: kT of TNT = kilo Tons of TNT = 1000 Tons of TNT

For example, Little Boy had a yield of 16 kT TNT equivalent

Modern thermo nuclear bombs can have 100s to 1000s of kT TNT equivalent explosive yield
1000 kT = 1 Mega Ton = 1MT

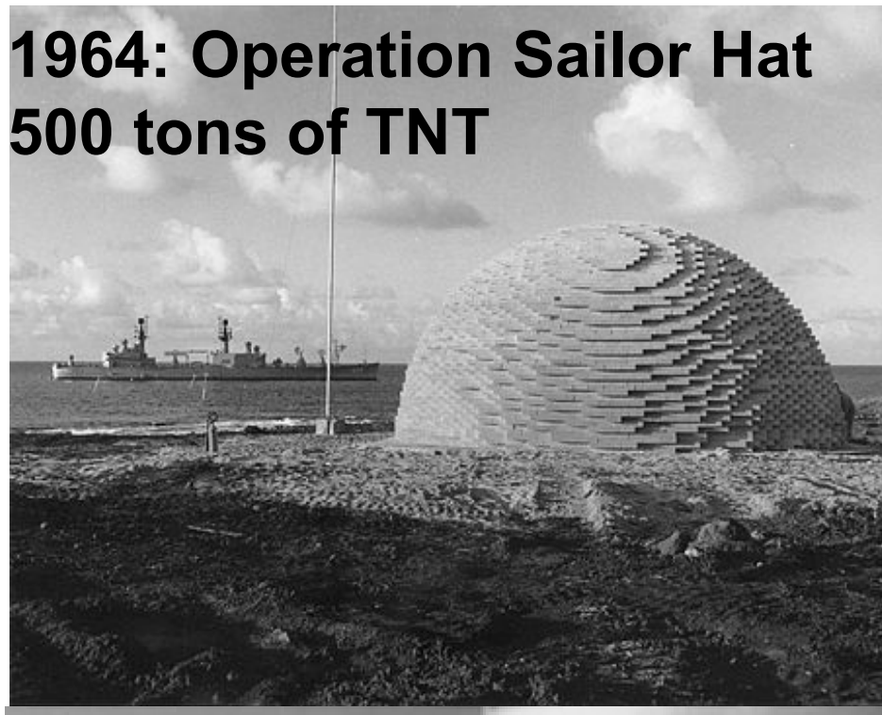


Comparison with TNT

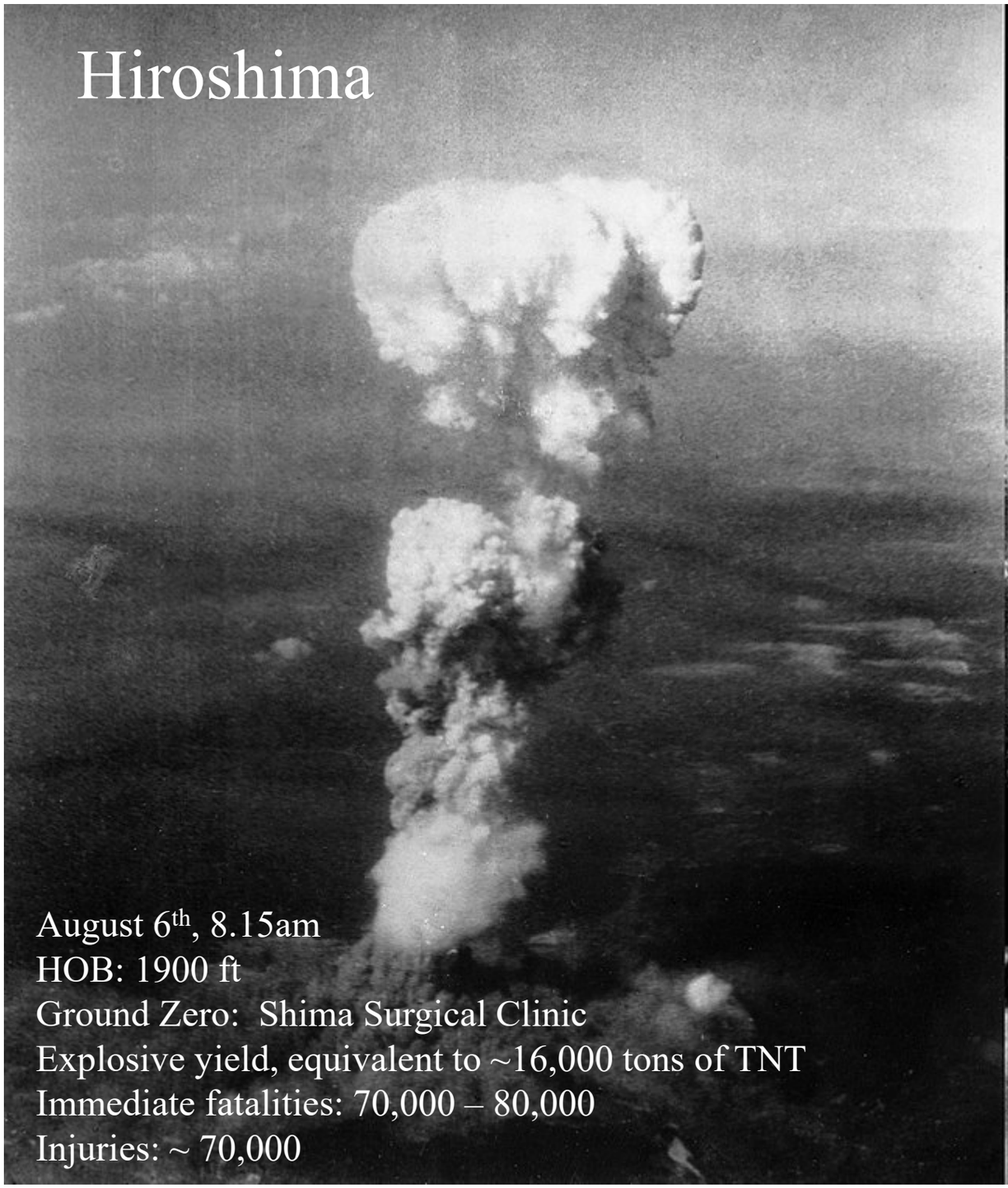
How much energy doe nuclear weapons release (per weight of explosive) compared to conventional explosives?

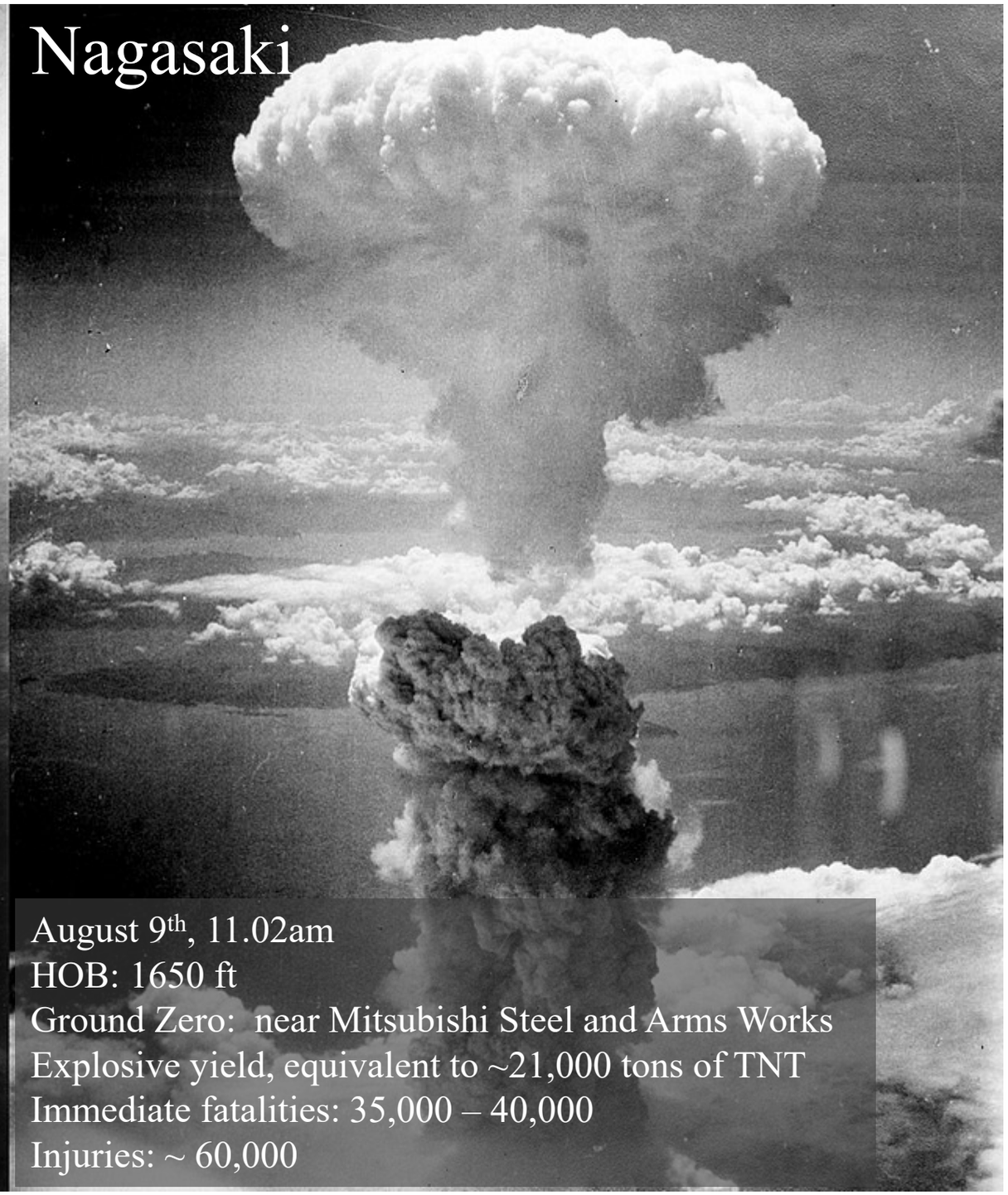
about 1,000,000 times more!

Enola Gay → 1,600 bombers each carrying 20 bombs of 1000 pounds of TNT



Nuclear Explosions over Hiroshima and Nagasaki





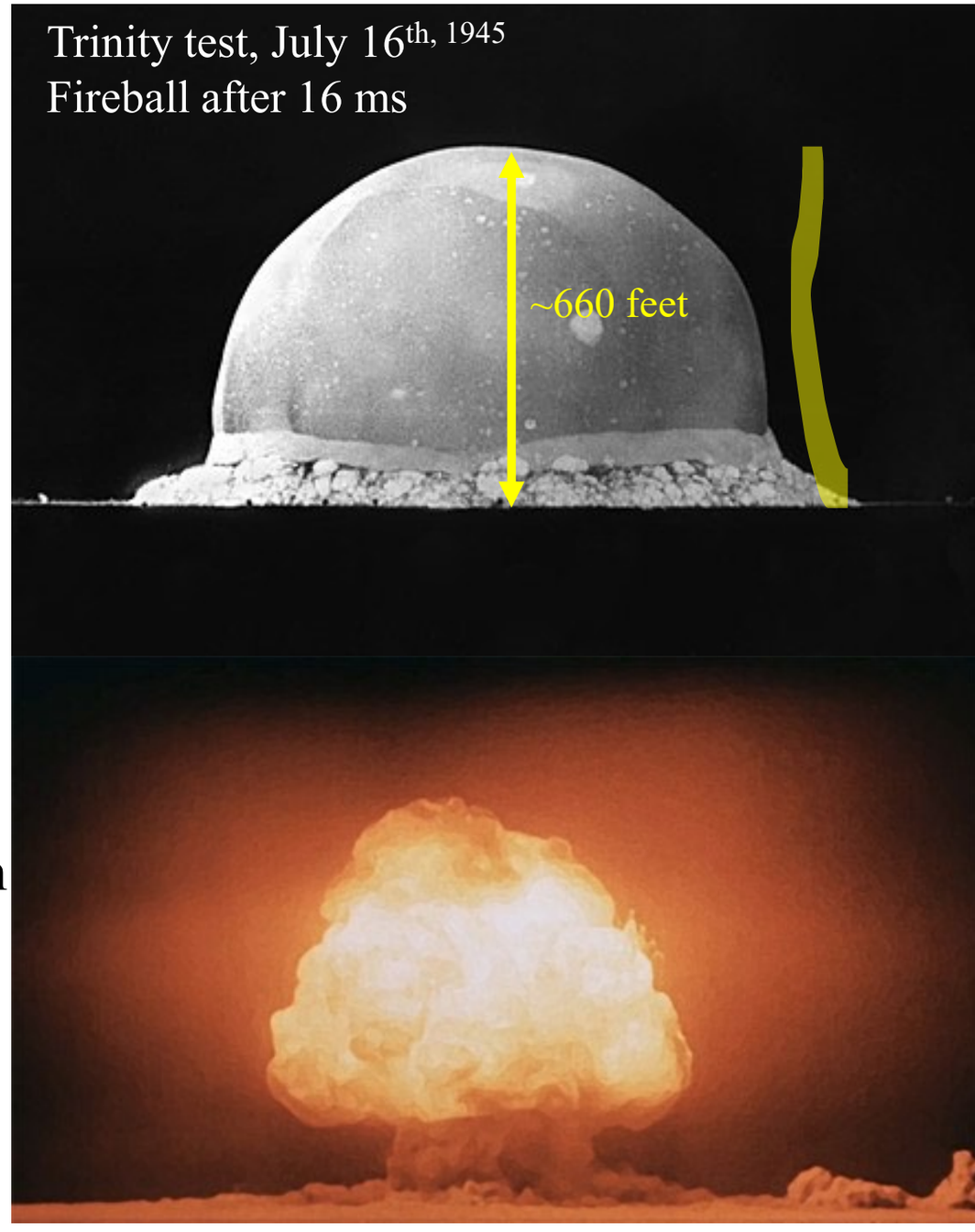
Ground Zero: Shima Surgical Clinic – HOB 1900 ft
Explosive yield, equivalent to ~16,000 tons of TNT
Immediate fatalities: 70,000 – 80,000 (including ~20,000 soldiers related to 2nd General Army HQ)
Injuries: ~ 70,000

Radius of destruction ~ 1.2 miles (blast and firestorm)
~70% of all buildings destroyed, 6-7% damaged
Hospitals severely damaged or destroyed
~90% of doctors and nurses injured or killed

Hiroshima on the ground

Effects of Nuclear Explosions

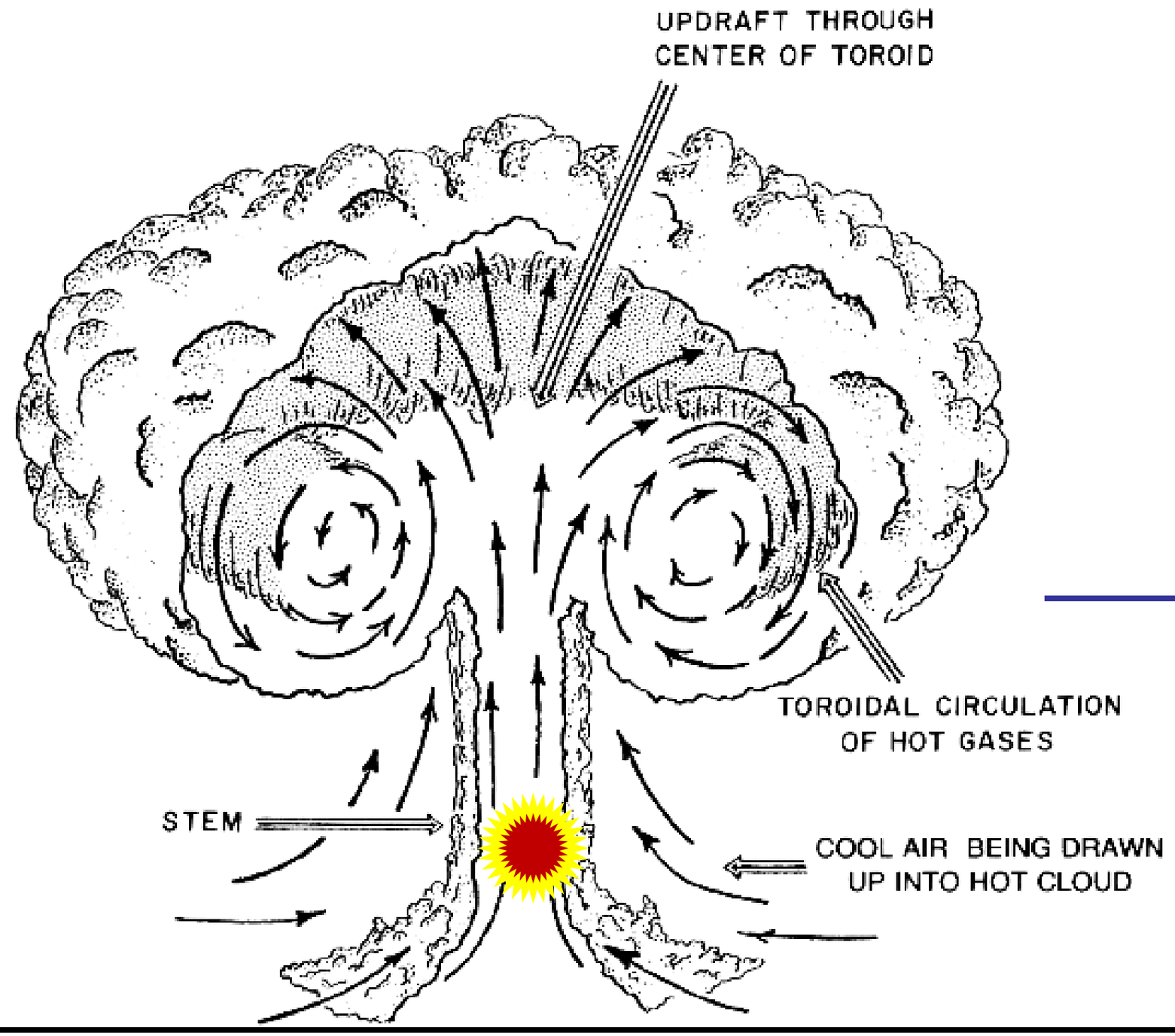
- Effects of a single nuclear explosion
  - Prompt nuclear radiation
  - Electromagnetic Pulse (EMP)
  - Thermal radiation
  - Blast wave
  - Residual nuclear radiation (“fallout”)
  - Secondary effects (fires, explosions, etc.)



Trinitite is a glass formed within a radius of ~ 1000 ft from ground zero of the trinity test

➔ serves as thermometer …

Formation of the Mushroom Cloud



Fireball

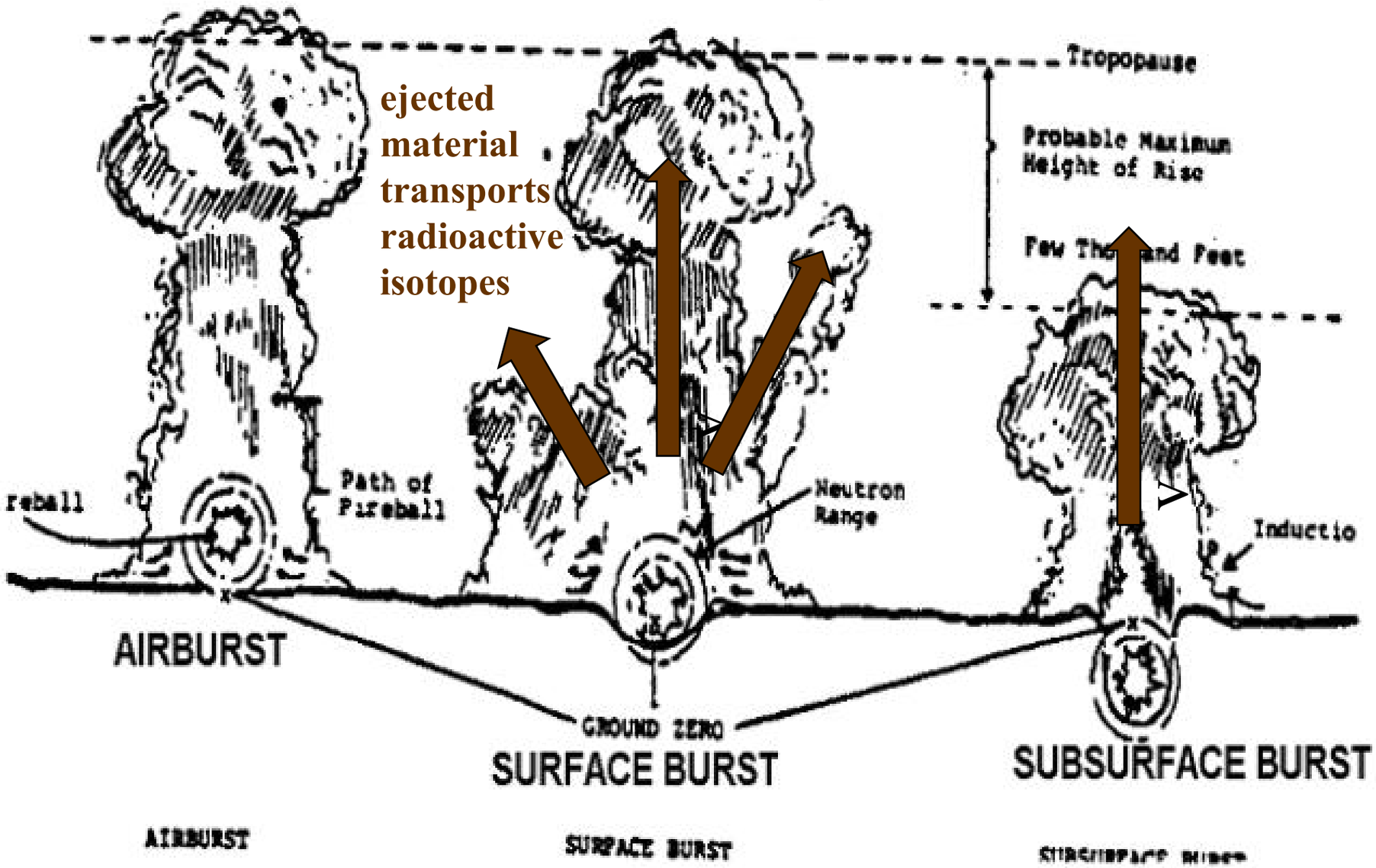
Stratosphere

Troposphere

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

Radioactive Fallout



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

Did the Fireball Touch the Ground at Hiroshima?

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.

For Example:

- Hiroshima Y = 16 kT
  Fireball touches ground if HOB < 600 ft
  However, HOB was ~ 2000 ft

- Thermo Nuclear Weapon with Y = 1000 kT = 1 MT
  Fireball touches ground unless HOB > 3000 ft

Effects of Thermal Radiation from Fire Ball

Effects of Thermal Radiation

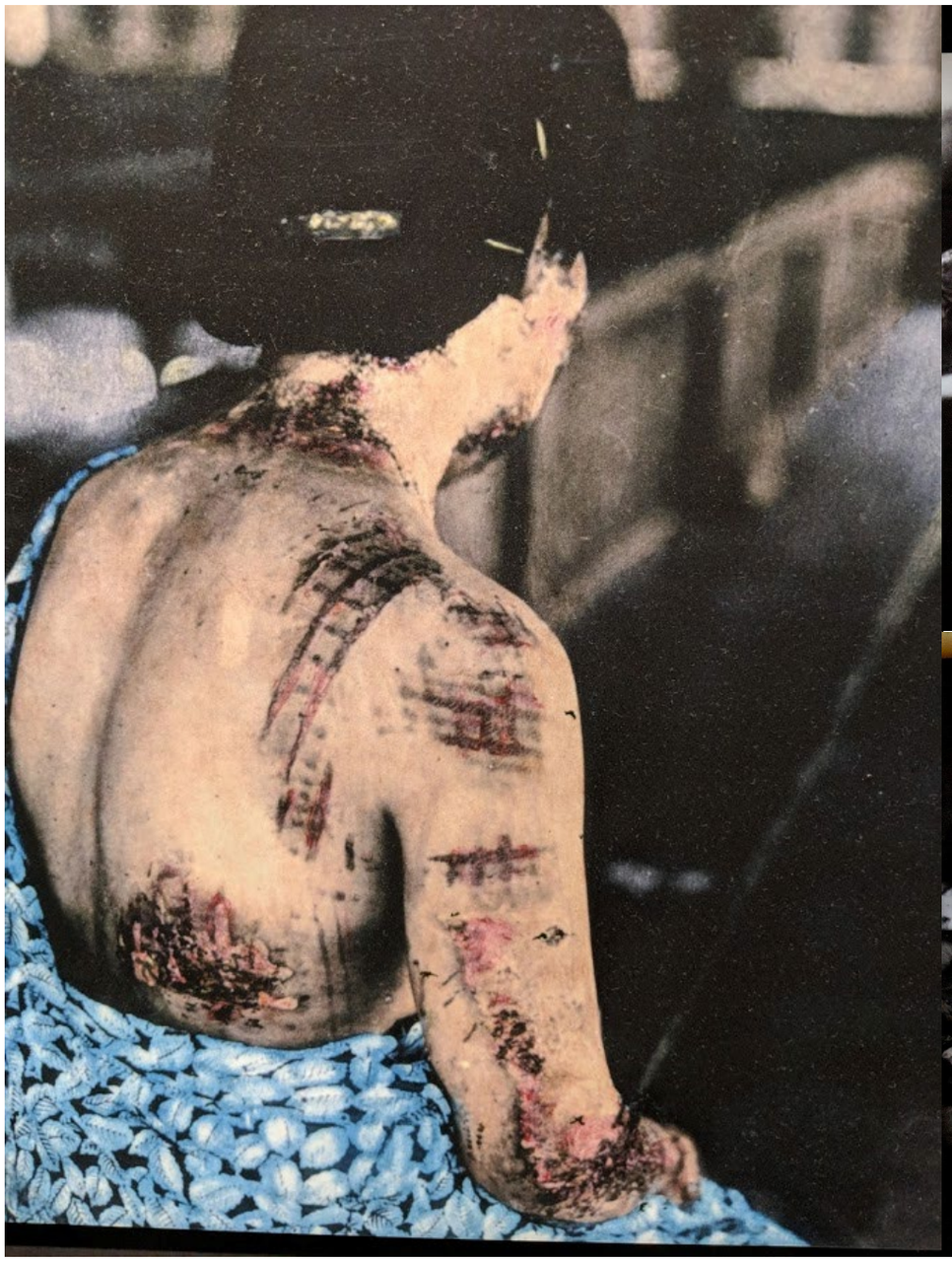
Harmful direct effects on humans

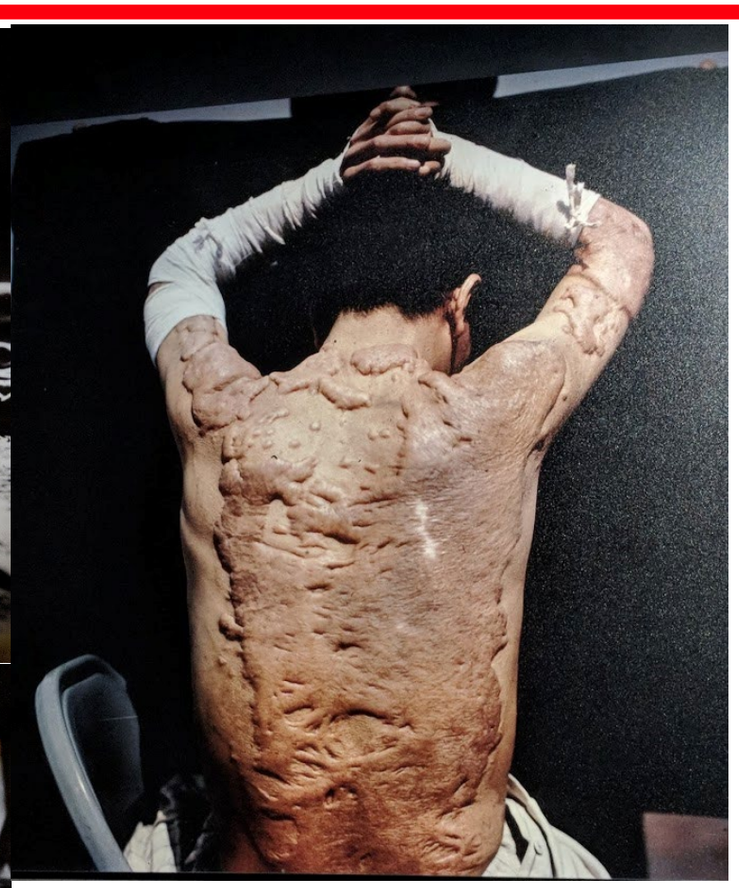
- Skin burns
- Ignition of clothing, structures, surroundings
- Flash blindness
- Permanent retinal burns (with larger yields)

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





Keloids resulting from burns

Burns depend on distance and protection available

Damaging Effects of the Blast Wave

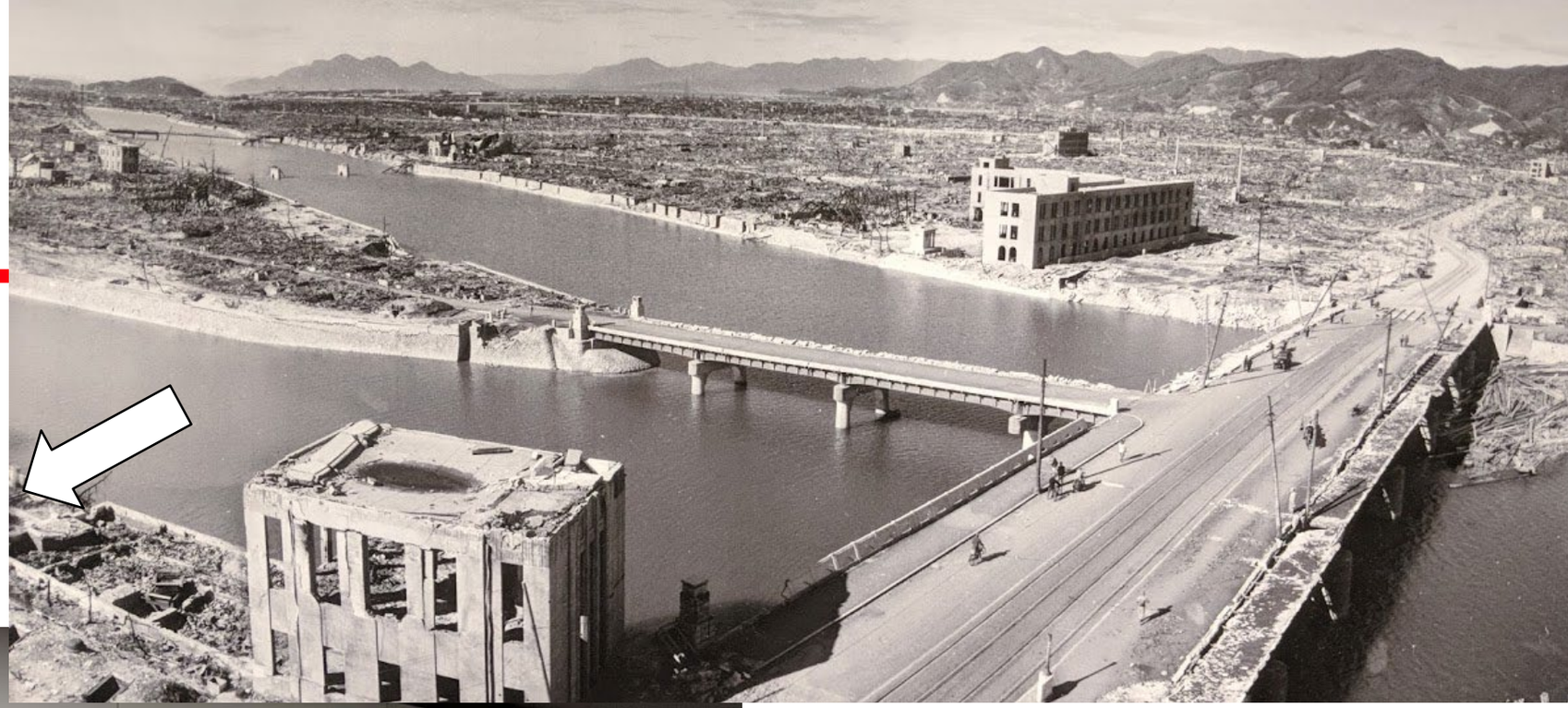
- The blast wave is considered the militarily most significant effect of a nuclear explosion in the atmosphere
- Like any shockwave, a blast wave produces —
  - A sudden isotropic (same in all directions) pressure P that compresses structures and victims

This is followed by

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

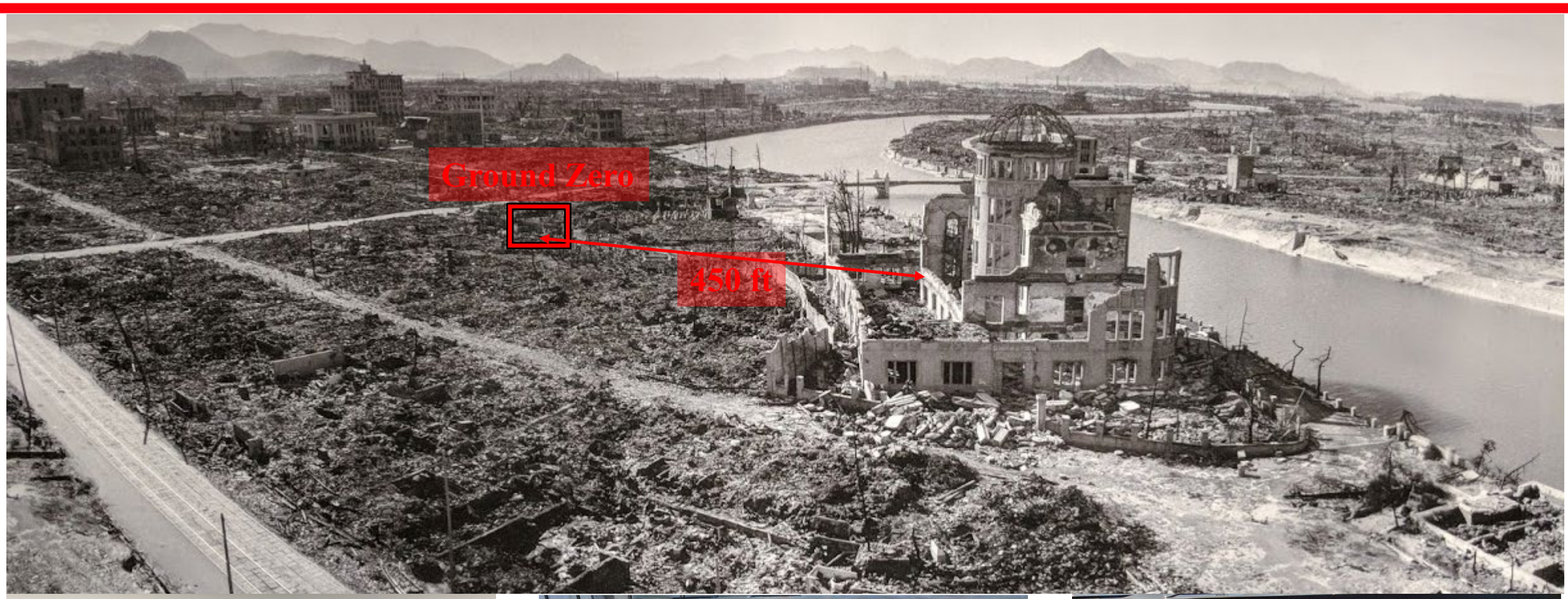
Damage in Hiroshima

Atomic Dome
near
Ground Zero

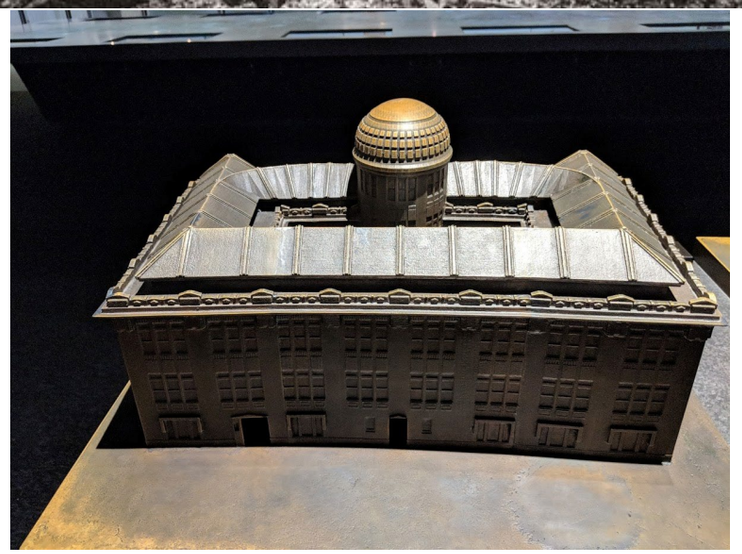


T-shaped Aioi bridge
was used for targeting

Damage in Hiroshima:
HOB ~ 1900 ft near Atomic Dome



Hiroshima Prefectural Industrial Promotion Hall

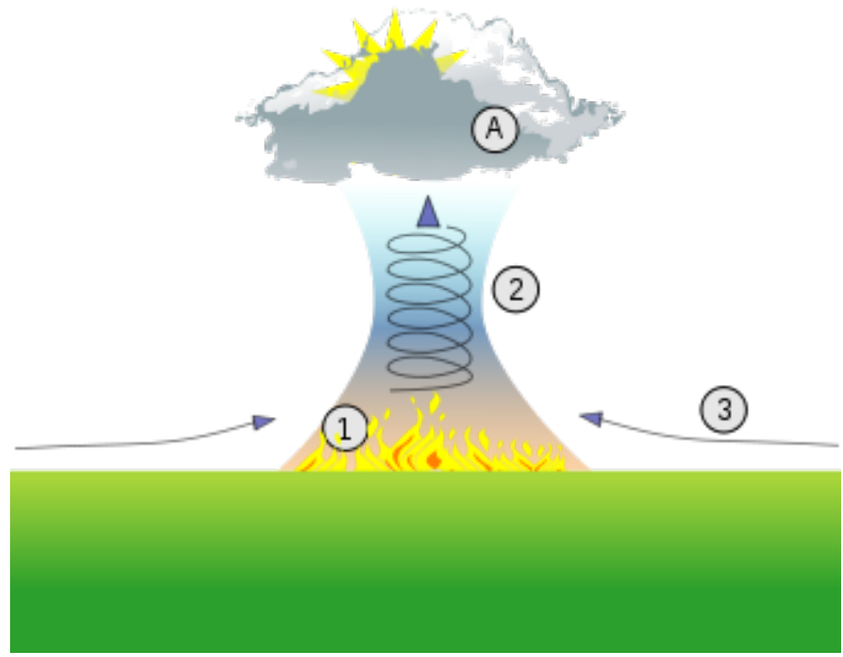


Hiroshima Peace Memorial

Firestorms in Hiroshima?

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



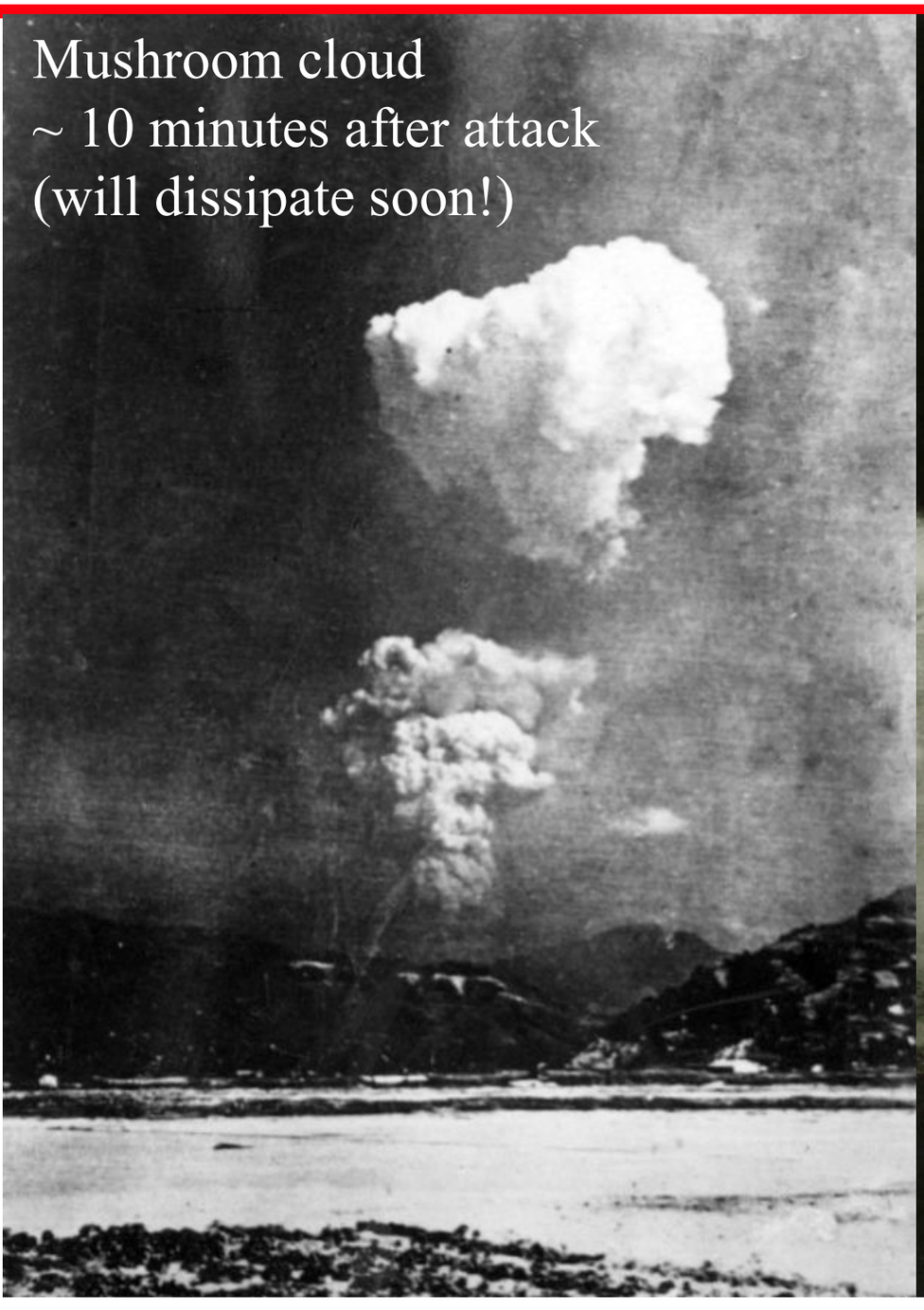
Conflagration —

- 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 in Tokyo

Tokyo after fire bombing in March 1945

Firestorm in Hiroshima ?!



Mushroom cloud
~ 10 minutes after attack
(will dissipate soon!)

Smoke plume from fires following
the nuclear attack ~ 3 hours after attack

See for example The New York Times, 5-23-2016: https://nyti.ms/25cCy3b

The Atomic Plague – Wilfried Burchett

DAILY EXPRESS

30th DAY in Hiroshima: Those who escaped begin to die, victims of—

THE ATOMIC PLAGUE

'I write this as a warning to the world'

DOCTORS FALL AS THEY WORK

Poison gas fear: All wear masks

HIROSHIMA, Tuesday

3,320,173 AMAZES AMERICA

'Most powerful in the world'

STILL THEY FALL

THE PICTURE THAT DOES NOT TELL THE WHOLE STORY

The big switch: 'Over by spring'

4.30 LATEST

MAN IS STABBED DURING DANCE

Forces may cut meat ration

MORE FOR CIVILIANS?

SPAIN TO SHARE IN TANGIER

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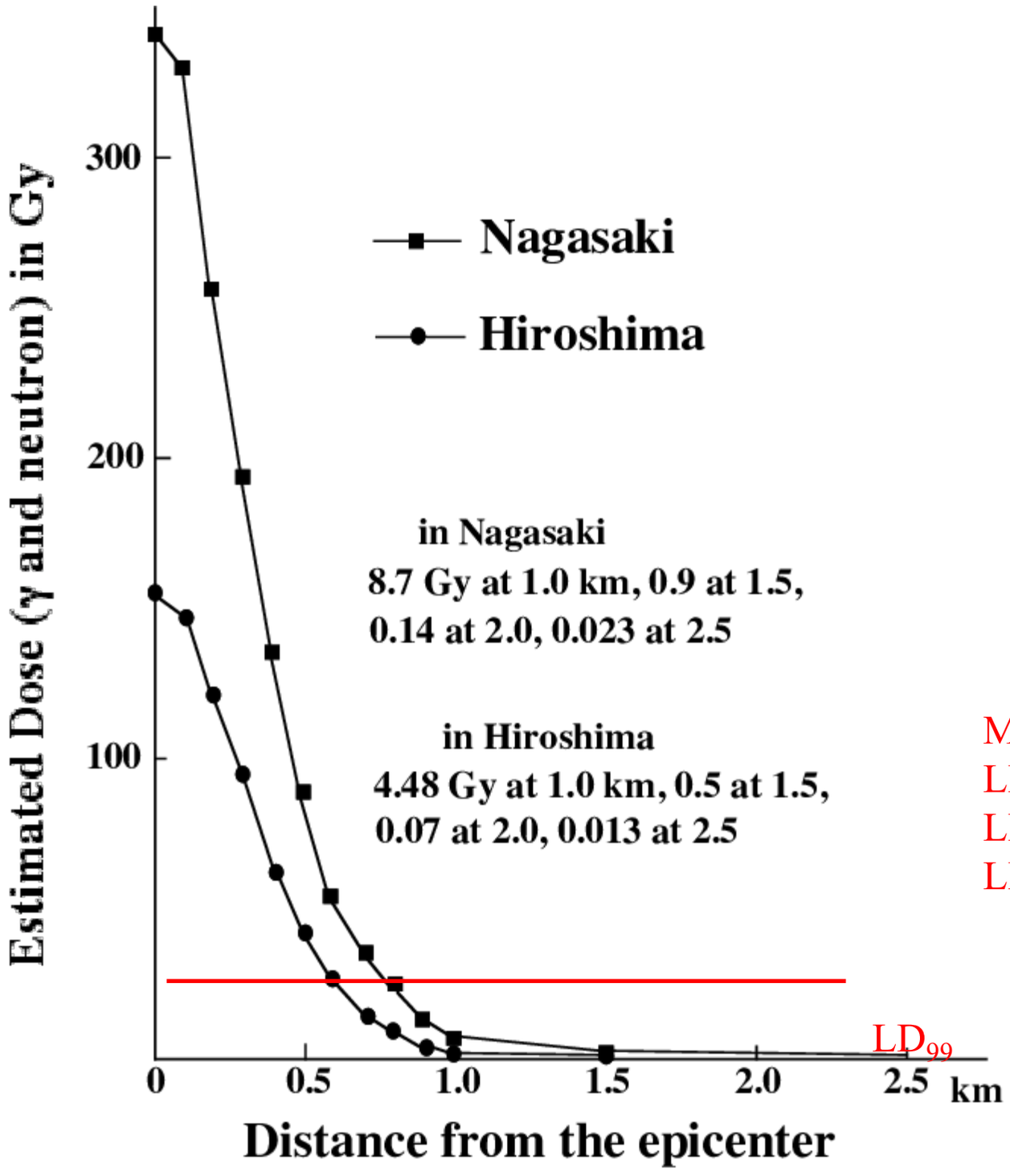
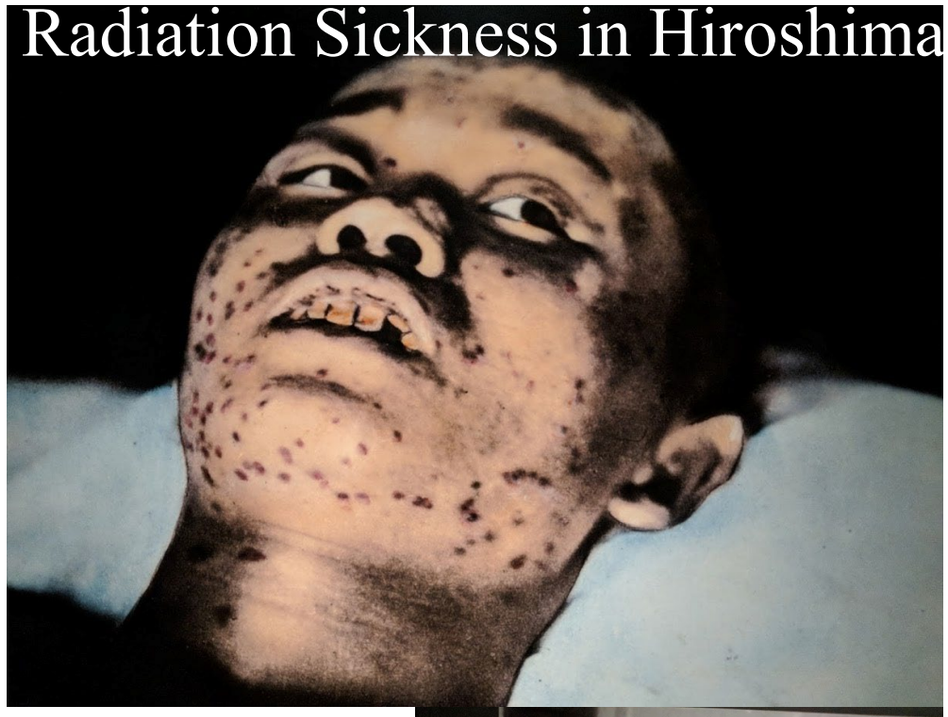
THE PICTU

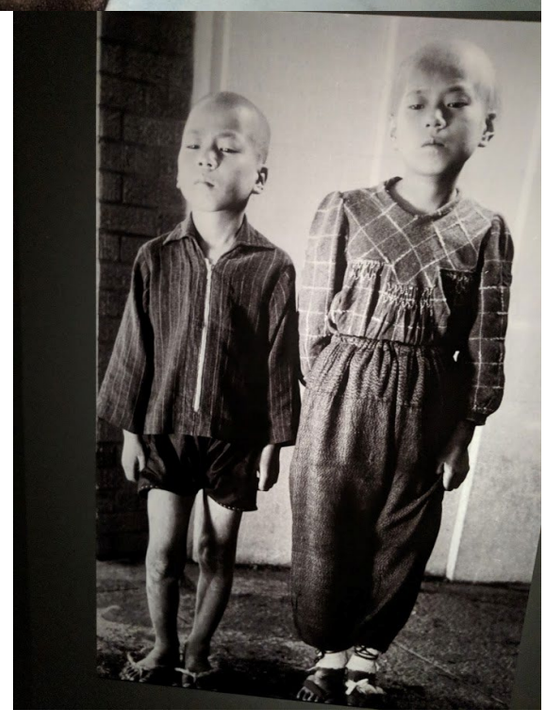
MAN STABBE DURIN DANC

In Hiroshima, 30 days after the first atomic bomb destroyed the city and shook the world, people are still dying, mysteriously and horribly – people who were uninjured by the cataclysm – from an unknown something which I can only describe as atomic plague. Hiroshima does not look like a bombed city. It looks as if a monster steamroller had passed over it and squashed it out of existence. I write these facts as dispassionately as I can in the hope that they will act as a warning to the world

Radiation Levels in Hiroshima







Median lethal dose
LD_1 – 2.5 Sv (1% fatality)
LD_{50} – 5.0 Sv (50% fatality)
LD_{99} – 8.0 Sv (99% fatality)

~25,000 fell victim to radiation sickness in the 4 months following the attack

Radiation Effects Research Foundation (RERF)
(a cooperative Japan-US Research Organization)

The RERF systematically studies the surviving population of the nuclear attacks on Hiroshima and Nagasaki to study the health impact of radiation (http://www.rerf.or.jp)

Relative risk of death due to cancer from 1 Sv of radiation exposure (1950-1997) – occupational limit for radiation workers is 0.05 Sv/year

Cancer	Relative Risk
Leukemia	5.6
All other cancers	1.5
Esophageal cancer	2.2
Stomach cancer	1.4
Colon Cancer	1.5
Lung cancer	1.8
Breast cancer	1.8
Urinary bladder cancer	2.2

Excess relative risk for solid cancers vs attained aged for different ages at Exposure (10, 30 and 50 year old)

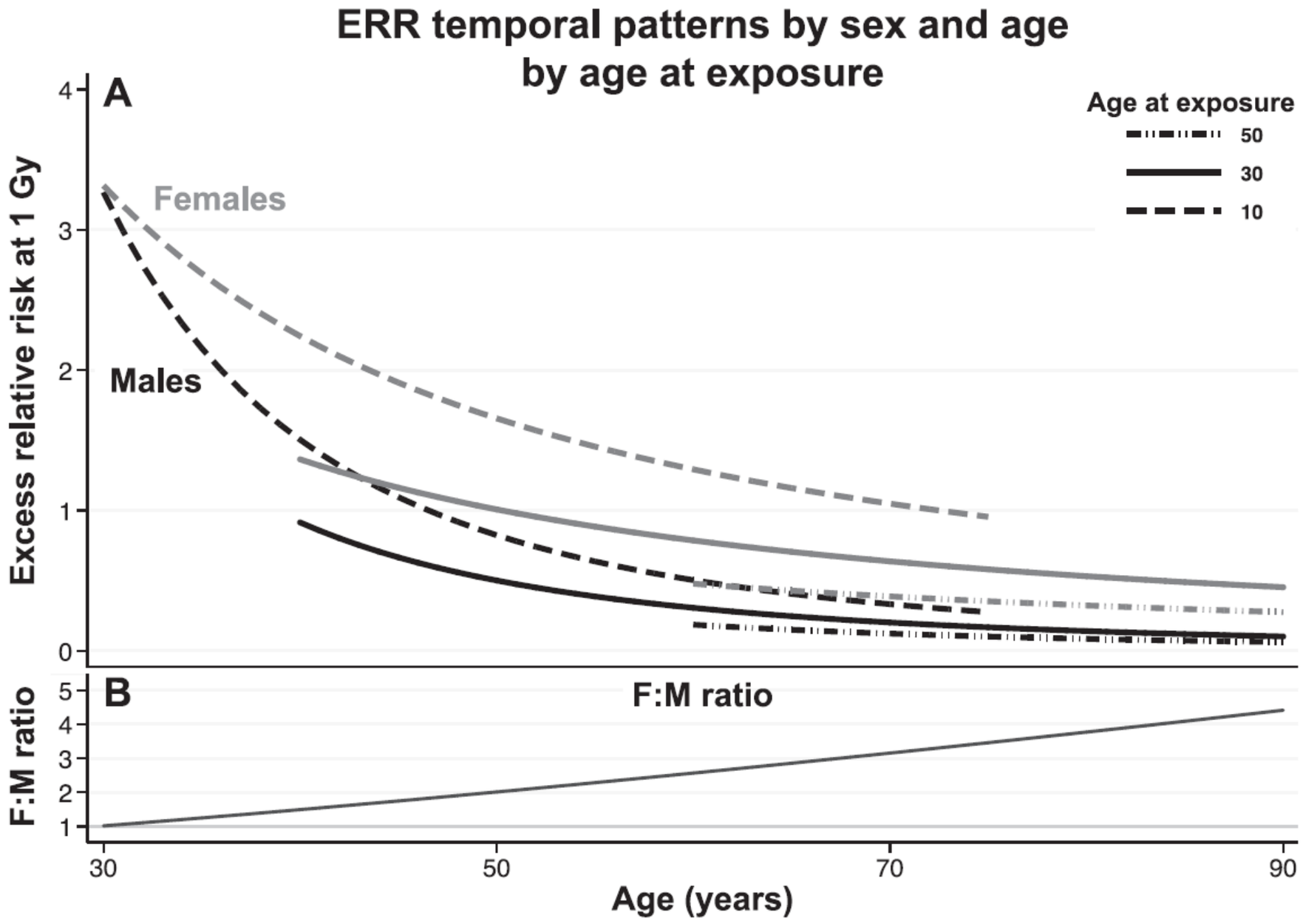


FIG. 3. Age-at-exposure and attained-age effects on solid cancer ERRs at 1 Gy by age at exposure and sex. Panel A shows how the radiation ERRs varied with attained age by sex (gray for females and black for males) and by age of exposure. This is a linear ERR model with multiplicative adjustment for smoking, sex-averaged age-at-exposure modification and sex-specific attained-age modification. Panel B shows how the female-to-male (F:M) ERR ratio varies with attained age at 1 Gy.

RERF Summary Findings

1. Cancers of specific organs have increased among nuclear bombing survivors.

2. Non-cancer diseases (cataract, benign thyroid tumor, heart disease, stroke, etc.) have also increased among survivors exposed to high doses of radiation.

3. Survivors exposed to high doses of radiation tend to show deterioration of the immune system similar to that observed with aging.

4. Many survivors exposed to high doses of radiation exhibit minor inflammatory reactions.

5. Research thus far has not indicated any genetic effects in A-bomb survivors' children.

6. Observations made to date have not confirmed increased mortality or cancer incidence among A-bomb survivors' children.

Psychological and Societal Challenges for Survivors, Hibakusha

1. Survivors severely impacted by post-traumatic stress disorder, often unable to participate in workforce. (Atomic-Bomb Numbness Syndrom)

2. No significant government assistance for hibakusha before mid 50s.

3. Hibakusha faced ostracism due to misconceptions of health impact of radiation.

4. Strong leadership for initiatives seeking to abolish nuclear weapons. For example, the International Campaign to Abolish Nuclear Weapons (ICAN)