The risk of nuclear war and how Physicists, acting as citizen-scientists, can help reduce it

Frank von Hippel, Program on Science and Global Security, Princeton U.

Physics Colloquium, Fermilab, 1 Sept. 2021, 4PM (Chicago Time)

Robert R. Wilson, an out-of-the-box thinker *

Appointed at age 30, head of the Los Alamos experimental physics division while continuing to lead the cyclotron group. (His price was a weekly tutorial with Fermi.)

- ***Early on, he suggested that Soviet as well as British physicists should be invited to participate in the project so as to mitigate Soviet paranoia.***
- ***After Germany's surrender (8 May 1945), he organized discussions of "The Impact of the Gadget on Civilization."***
- ***He proposed that the Japanese government be invited to send a delegation to witness the first nuclear test in New Mexico*** (July 16, 1945), weeks before Hiroshima (August 6) and Nagasaki (August 9).
- ***He wanted nuclear weapons to be discussed during the April-June 1945 meeting at which the charter of the UN was written.***

Trapped in the bubble of wartime secrecy, his ideas obtained little traction, but, in 1946, he led the young physicists' lobbying and public outreach effort that succeeded in taking control over nuclear R&D away from the Pentagon and established the Atomic Energy Commission (now DOE).

*Based on Kai Bird and Martin J. Sherwin, *American Prometheus: The Triumph and Tragedy of J. Robert Oppenheimer* (Knopf, 2005).

Brought to you by the American Physical Society-supported Physicists Coalition for Nuclear Threat Reduction

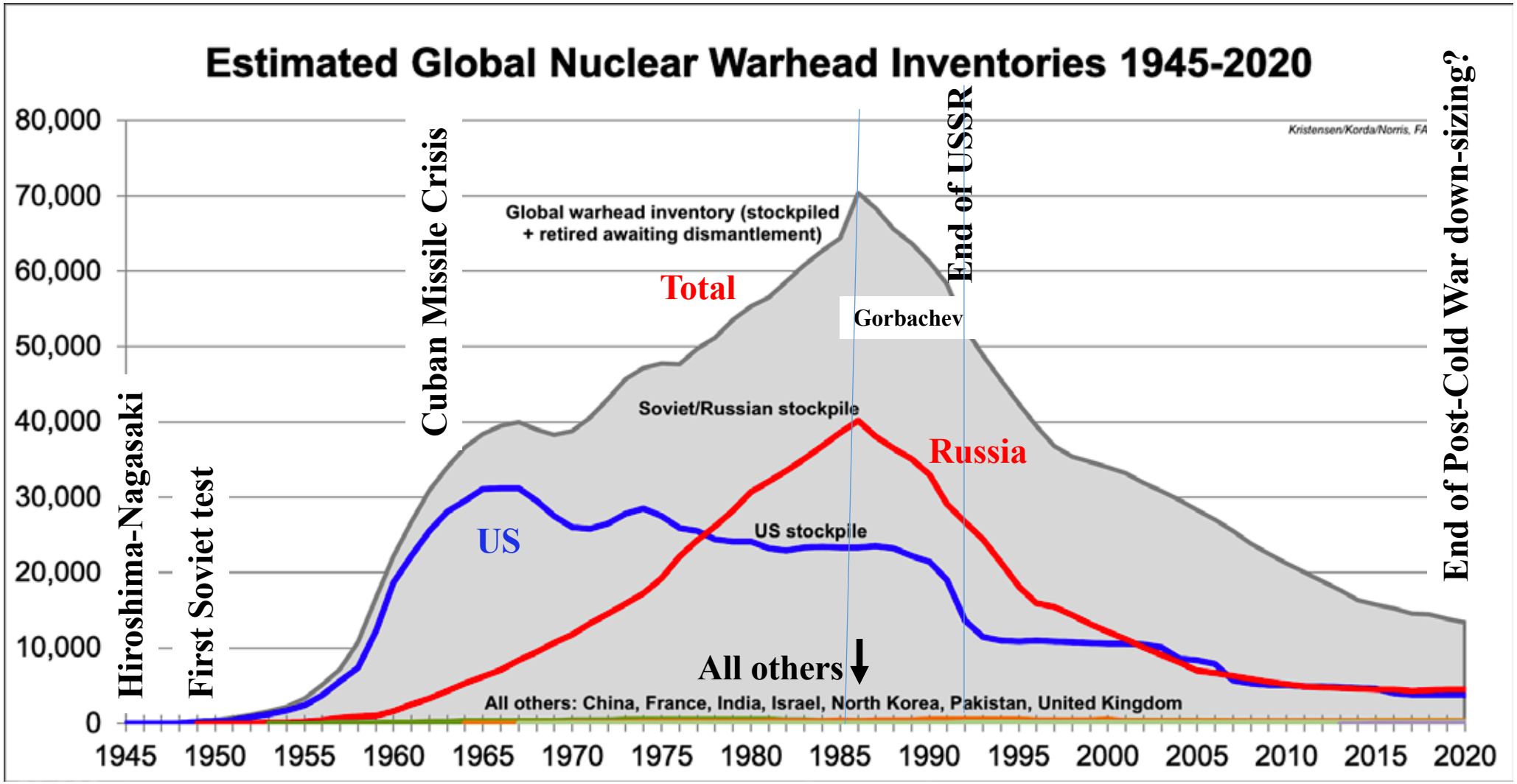
- **Our Mission**: to help concerned physicists educate their Senators and Representatives and their staffs on possible initiatives to reduce the risk of nuclear war.
- ***For those interested, more information will be provided about the Physicists Coalition in a meeting right after the Colloquium.***
- Charlotte Selton of APS Office of Government Affairs will participate.

Except where noted, the policy views expressed in this talk are my own and not endorsed by the Coalition.

Outline

- Decline in public ***and physicists***' concern about nuclear weapons after the Cold War
- But the danger of accidental nuclear war is still high
- How modern nuclear weapons work
- Nuclear explosives are weapons of mass destruction
- In the 1970 Nonproliferation Treaty, we promised nuclear disarmament in exchange for the non-weapon states not acquiring nuclear weapons, but we are now engaged in building a new generation of replacement nuclear weapons for another 70 years
- Historically physicists have made great contributions to nuclear arms control
- Physicists Coalition for Nuclear Threat Reduction

US, Russia have fewer warheads today, but still ~4000 ea. Most aimed at each other & associated support facilities ("counterforce" + "collateral damage").

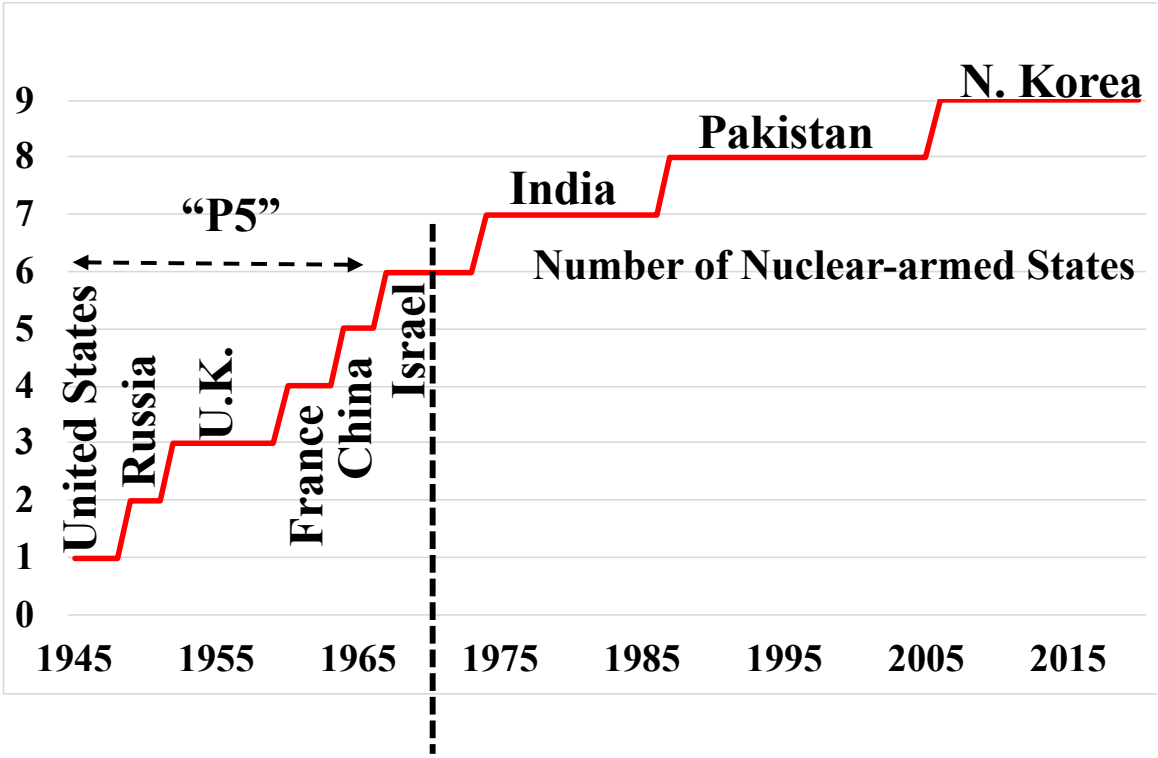


Operational nuclear warheads today
(plus a few thousand awaiting dismantlement)

Countries	Est. warheads
US (1945)	4000
Russia (1949)	4000
UK (1952)	200
France (1960)	300
China (1964)	300
Israel (~1967)	100
India (1974)	150
Pakistan (~1987)	150
N. Korea (2006)	10-40
Total	**~9,000**

"Nuclear Notebook," *Bulletin of the Atomic Scientists*

Nuclear proliferation



1970 Nuclear Nonproliferation Treaty
All other countries have committed not to acquire nuclear weapons, ***but Iran might go over the edge***.

WE'RE LUCKY TO BE HERE! 1962 Cuban Missile Crisis

President Kennedy estimated probability of all-out nuclear war as high as 50%. US nuclear war plan alone would have killed 600+ million.

Kennedy said: ***"We will not prematurely or unnecessarily risk the costs of worldwide nuclear war…but neither will we shirk from that risk at any time it must be faced."***

Also, over West Berlin.

But situation was more dangerous than Kennedy thought:

- US aircraft and destroyers blockading Cuba dropped practice depth charges to force three Soviet submarines to the surface. US did not know they had nuclear torpedoes. Submariners did not know depth charges weren't real.
- US military leadership proposed to invade Cuba but did not know Soviet army units in Cuba had about 100 battlefield nuclear weapons.

Cuban Missile Crisis was peak of the first half of the Cold War. The fright ended the US buildup (at 30,000+) and galvanized serious nuclear arms control, starting with a ban on testing of nuclear weapons above ground.

20 years later, November 2-11,1983, another near miss

Accurate, short-flight-time US Pershing II nuclear missiles were deployed to W. Europe (within range of Moscow, Soviets thought).

1981. Reagan was told Soviet leaders thought they could fight and win a nuclear war. He was persuaded to order 10,000 more missile warheads accurate enough to destroy hardened Soviet missile silos and command centers. Soviets became very nervous

1983. NATO held an unusually realistic military exercise that ended in preparations for a nuclear attack on Soviet forces in East Europe.

Soviet leaders thought the preparations were for real and began to load nuclear warheads to preempt it. A US general's recommendation to not respond prevented things from spinning out of control.

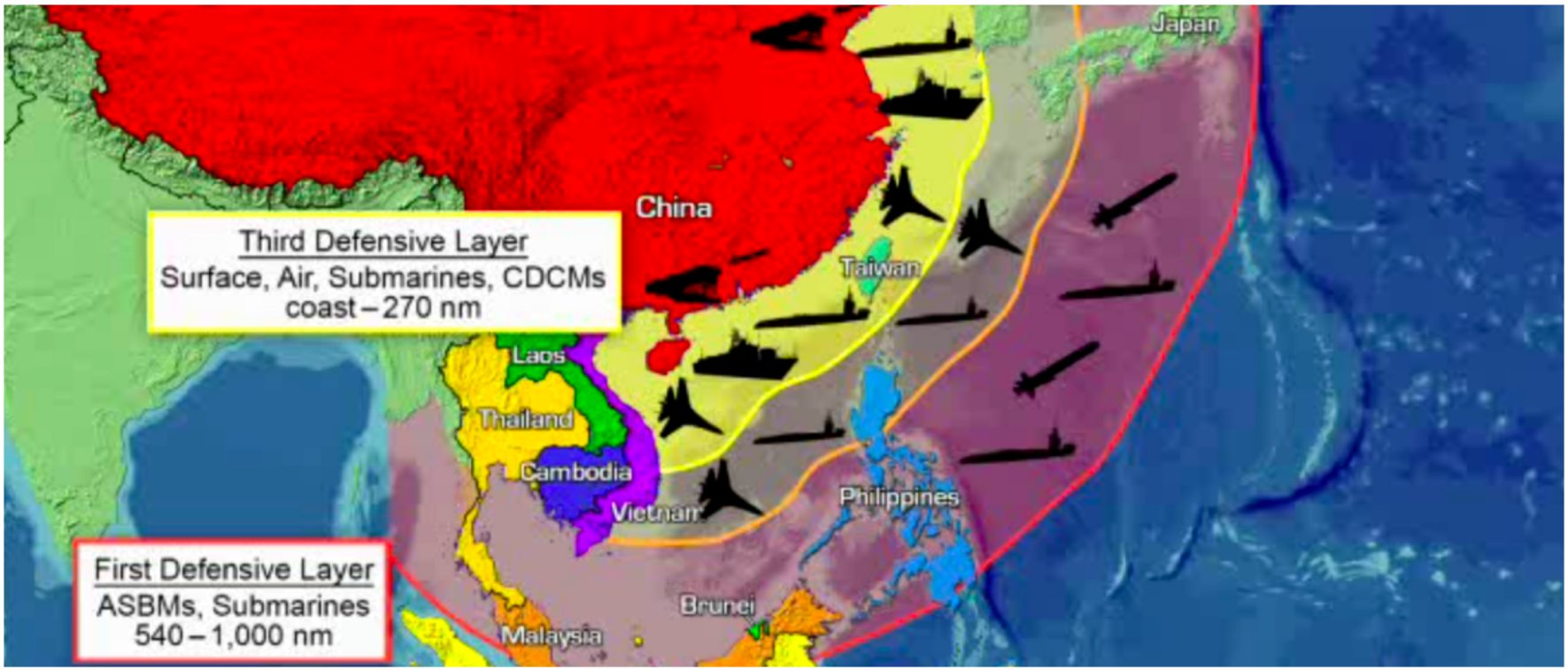
Afterwards, Reagan asked,

"Do you think Soviet leaders really fear us, or is all the huffing and puffing just part of their propaganda?"

That same month, 100 million in US, including Reagan, and a similar number in USSR watched *The Day After*.

Under public pressure, Reagan dropped buildup.

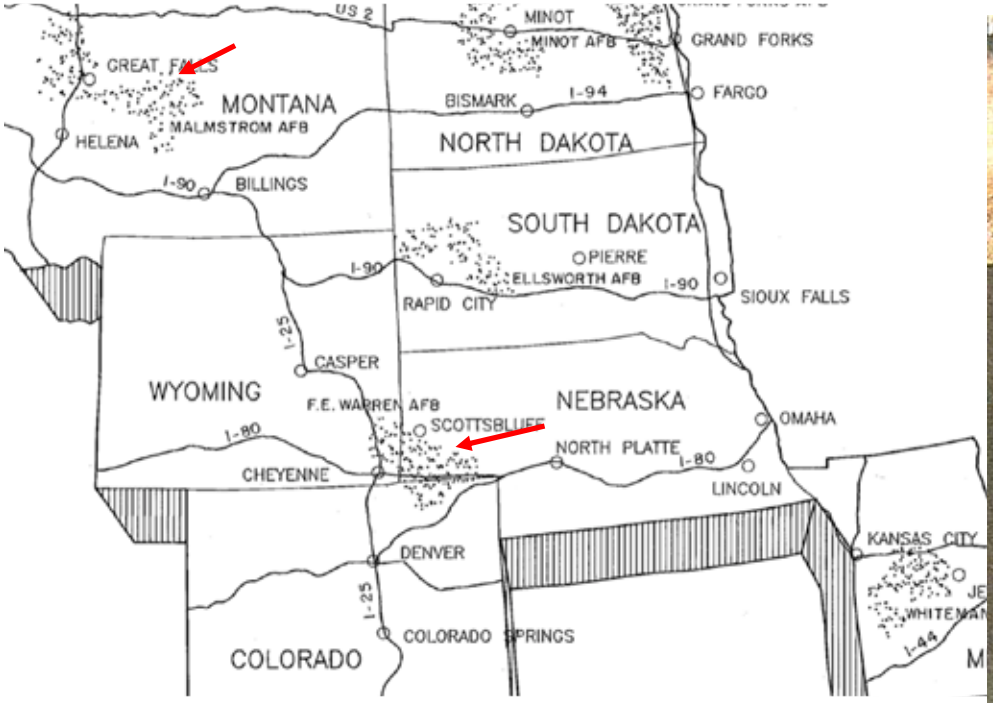
Today. Potential for war with China over Taiwan and/or South China Sea?

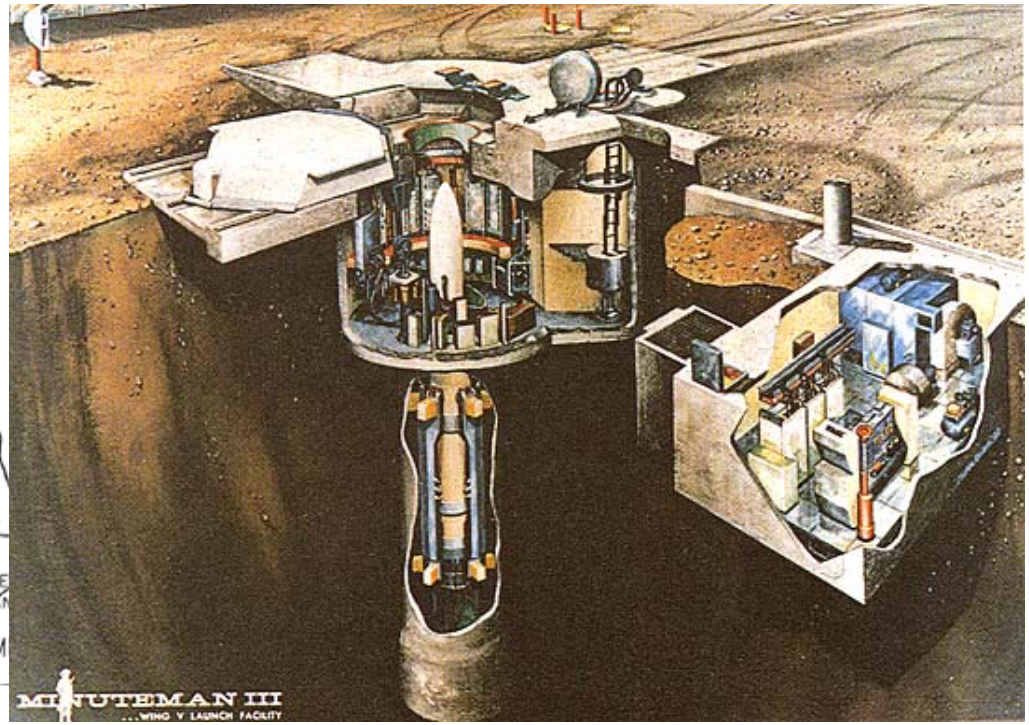


(Office of Naval Intelligence, https://www.oni.navy.mil/News/Naval-Capabilities/China/)

Nuclear war with Russia because of false warning?
US & Russian silo-based ICBMs poised for launch-on-warning

1000 silos (450 active today)





Russia's ballistic missiles can destroy US ICBMs with ≤ 30 min. flight time.
President's decision time less than 10 minutes.

Anticipated "window of vulnerability" as Soviet missiles became more accurate led to a "temporary," launch-on-warning posture for US ICBMs since 1978. Now, proposal is to put a new generation of ICBMs in those same silos in that same posture for another 60 years.

President has sole authority to order launch on warning and about eight minutes to decide. Presidents have found this situation unacceptable but were unable to change it

President Reagan proposed getting rid of ballistic missiles altogether and going back to bombers, because they can be recalled.

George W. Bush complained the time available wasn't enough for him to "get off the crapper."

President Obama tried to go to a "de-alerted" posture but the pushback from Strategic Command was too strong for him.

Four best-known false warnings

US

1979. ***Computer simulation of Soviet missile attack loaded into warning system without notification***. National Airborne Command Post took off.

1980. ***Failed computer chip reported 2, 220, 2200 Soviet missile launches***. Nuclear bombers, their tankers and the National Airborne Command Post taxied into takeoff positions, Pacific airborne command post took off.

In both cases, the falseness of the warnings was only confirmed because the crews monitoring the early-warning systems took more than the mandated three minutes of study time. They were fired for their trouble.

Soviet/Russia

1983. ***New Soviet early warning satellites misinterpreted as missile launches sunlight reflected off clouds over US***. ("*The Man Who Saved the World*")

1995. ***Russian early-warning radars misidentified a US scientific rocket launched from an island off Norway as a submarine-launched ballistic missile***.

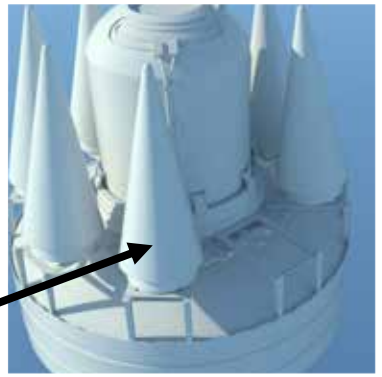
And now… computer hacking.

How modern high yield/weight nuclear warheads work

Nagasaki bomb: 20 kt, ~0.004 kt/kg

Trident II missile "bus" (2 m diameter)

8 warheads x(90-455) kt ~ 2 kt/kg

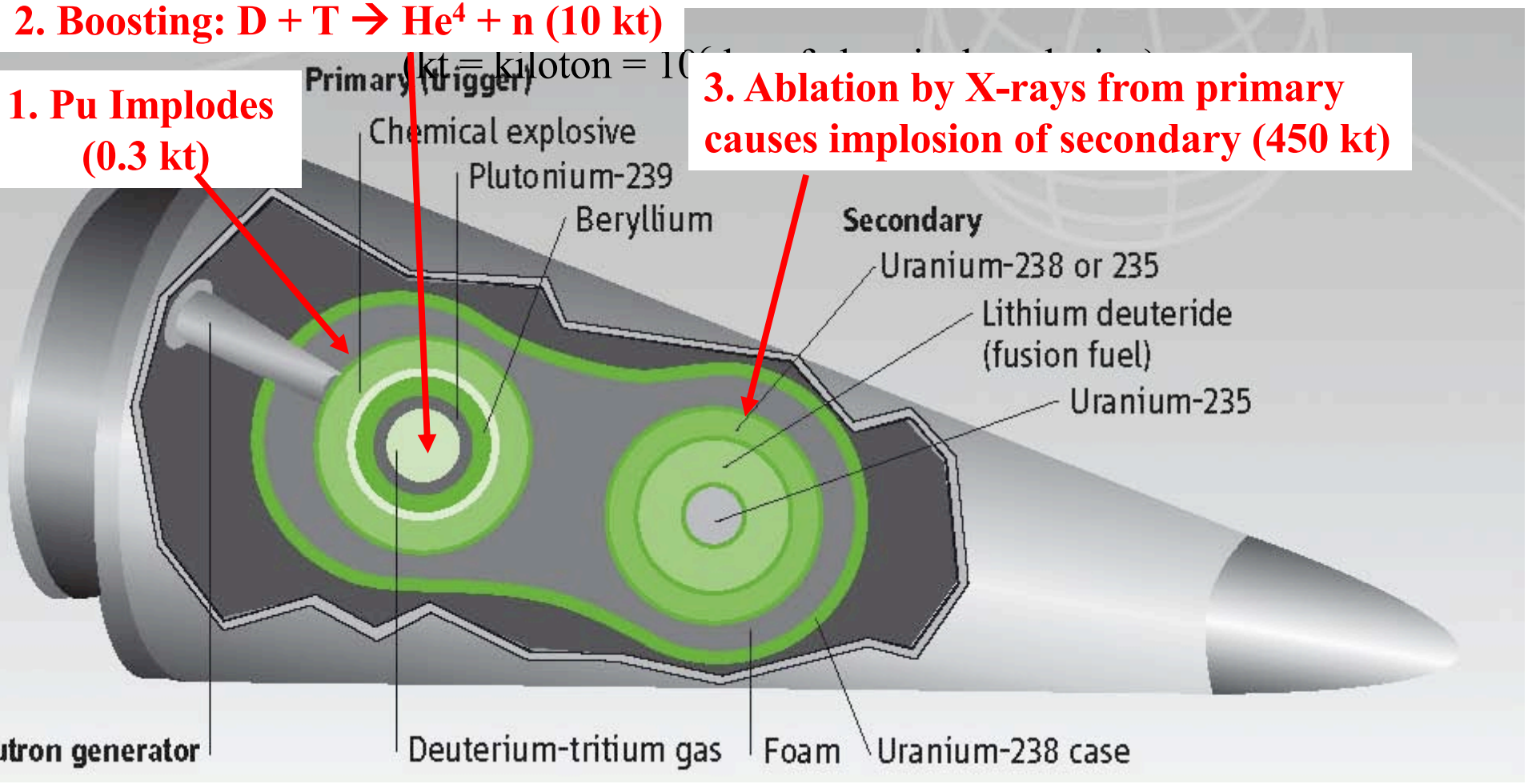


2. Boosting: D + T → He^4 + n (10 kt)

(kt = kiloton = 10

1. Pu Implodes (0.3 kt)

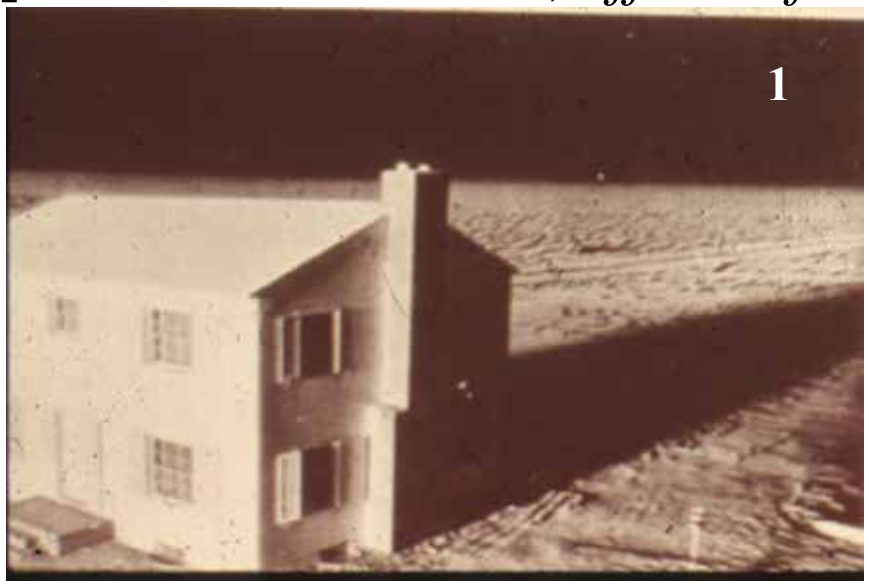
3. Ablation by X-rays from primary causes implosion of secondary (450 kt)



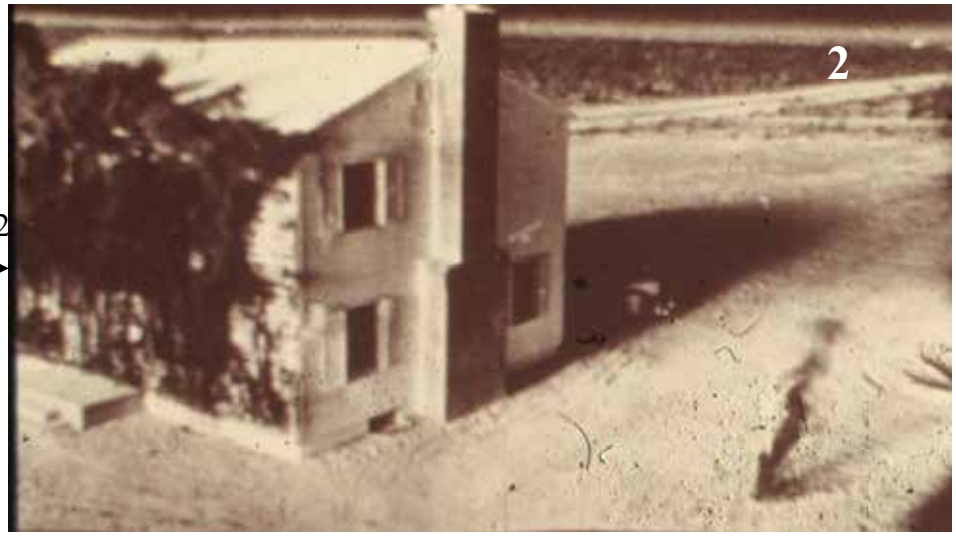
After *U.S. National Security and Military/Commercial Concerns with the People's Republic of China* [Report of a Select Committee of the U.S. House of Representatives (Cox Report) 1999] Vol. 1, p. 78.

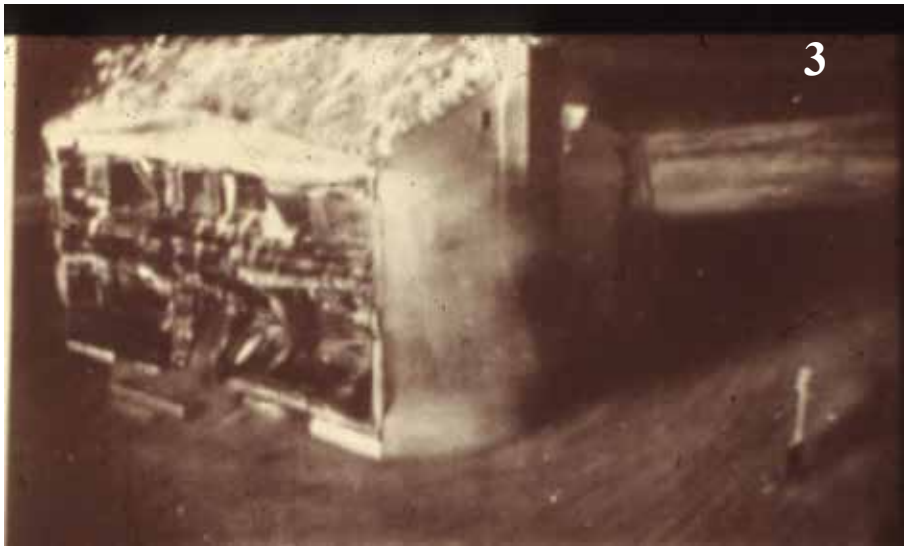
Nuclear heat and blast: Nevada Test Site: 1.1 km from 16-kt tower shot

[Glasstone and Dolan, *Effects of Nuclear Weapons, 3rd ed.* (DOD/DOE, 1977)]

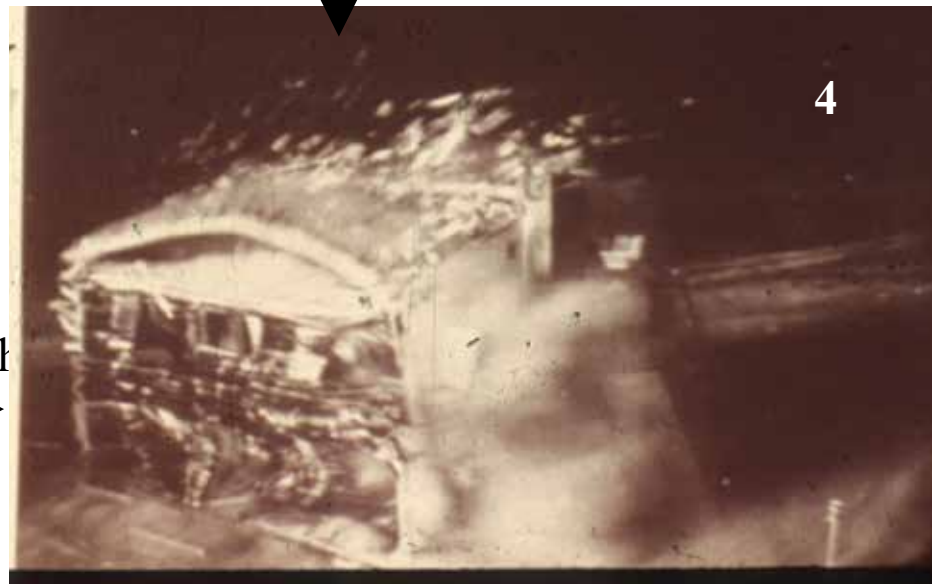


Heat
25 cal/cm^2





Then Blast
5 psi
160 mph



Upshot-Knothole Annie, 17 March 1953,

Nuclear weapons are indiscriminate

Hiroshima had population of today's New Orleans ~100,000 deaths

Yield (Y) ~15 kilotons
Blast ~ 50% of energy
Heat ~ 35%
Ionizing radiation ~ 15%

Scaling:

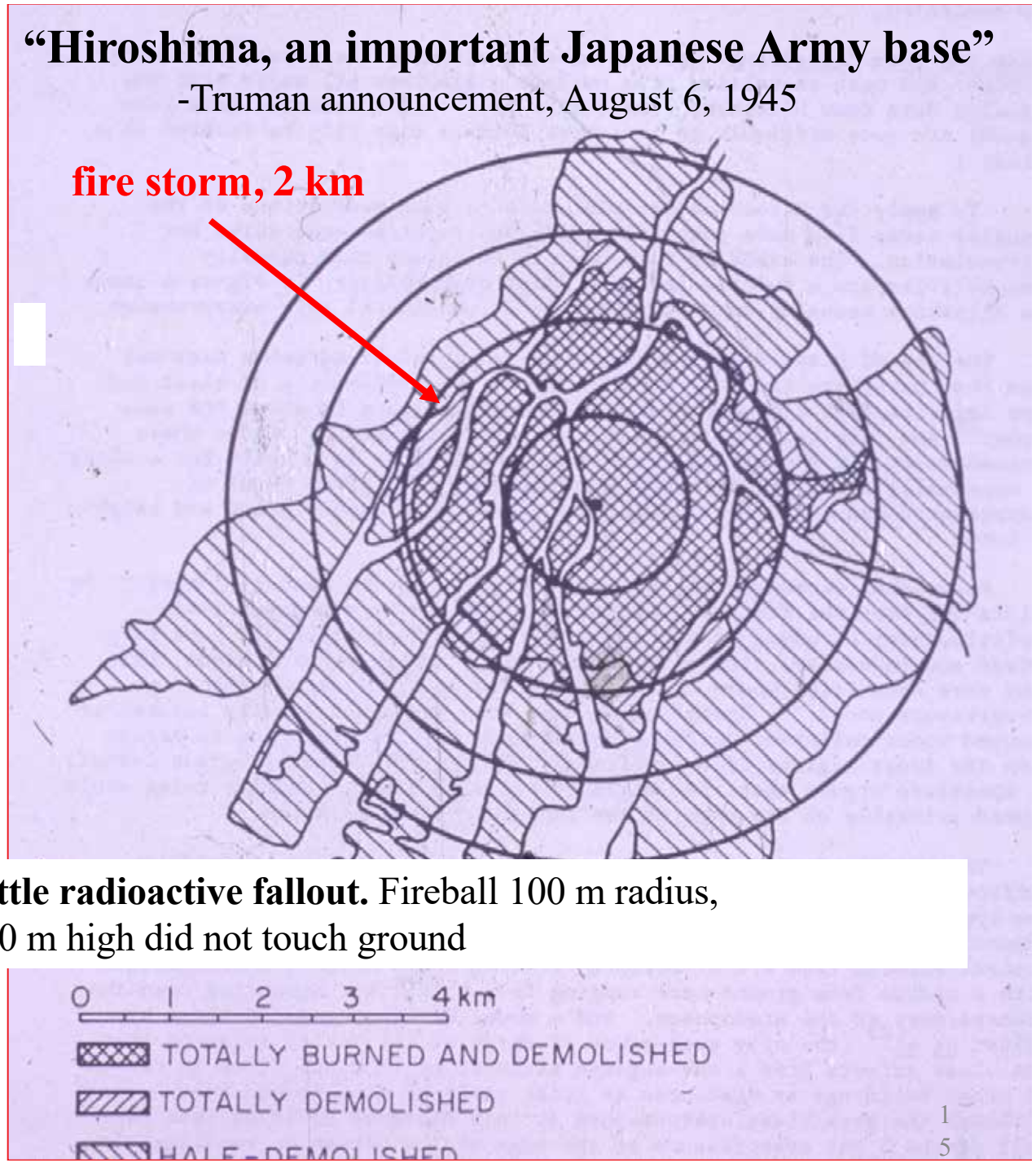
Blast radius ~$Y^{1/3}$
Heat radius ~$Y^{1/2}$

For 500 kt:

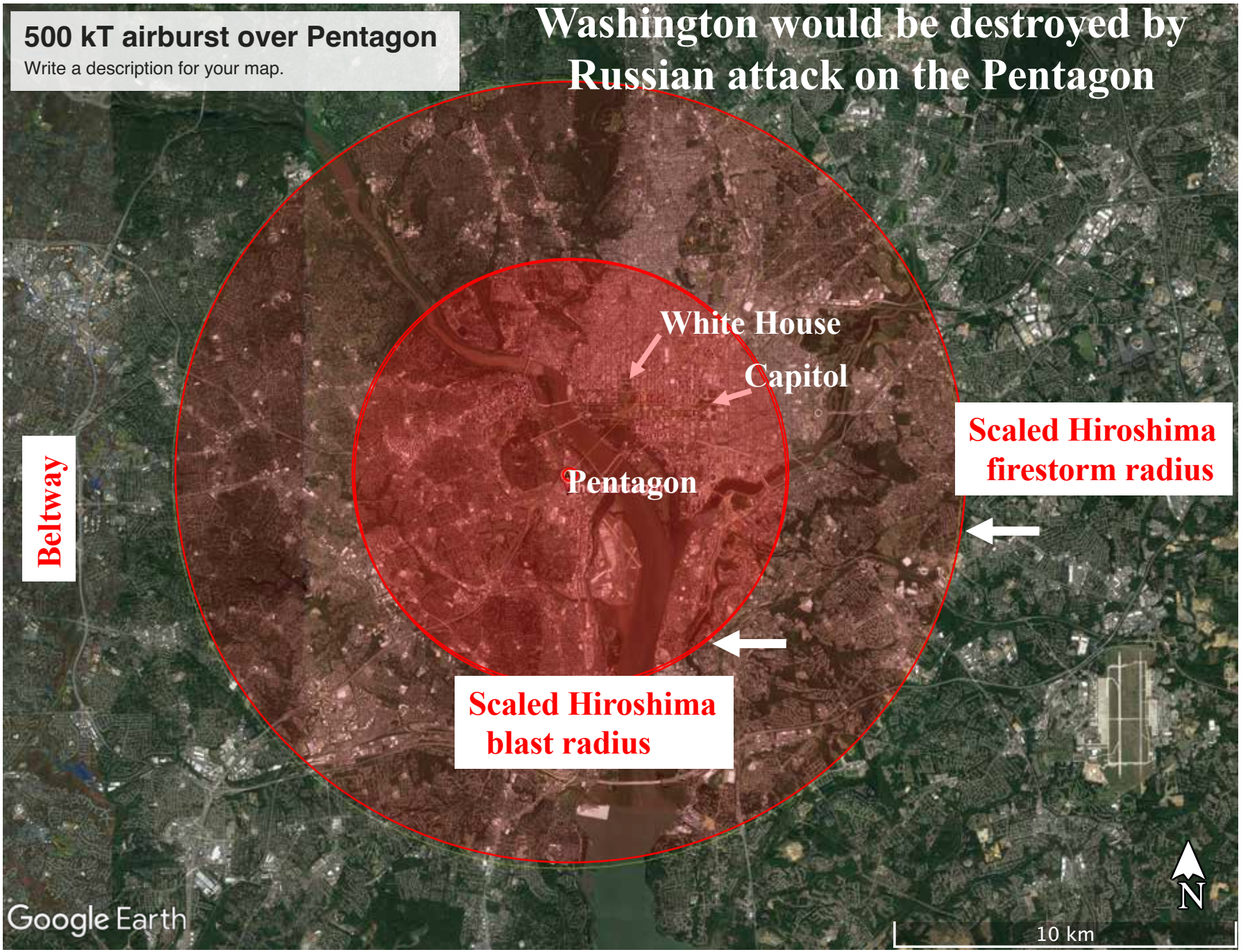
Radius 2 → 6.4-11.5 km

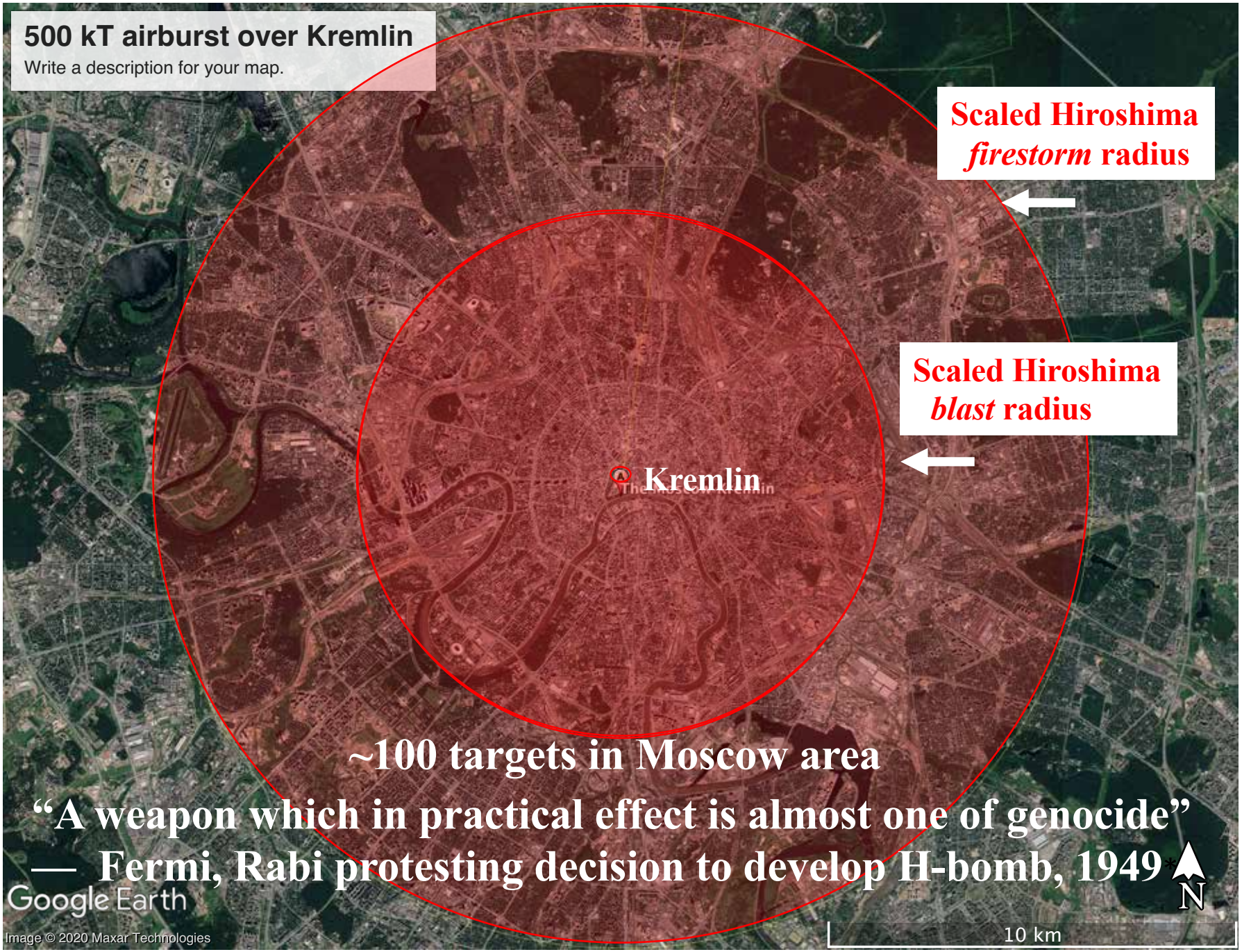
***The Effects of Nuclear Weapons, 3rd* ed.** (1977)
https://www.dtra.mil/Portals/61/Documents/NTPR/4-Rad_Exp_Rpts/36_The_Effects_of_Nuclear_Weapons.pdf

"Hiroshima, an important Japanese Army base"
-Truman announcement, August 6, 1945

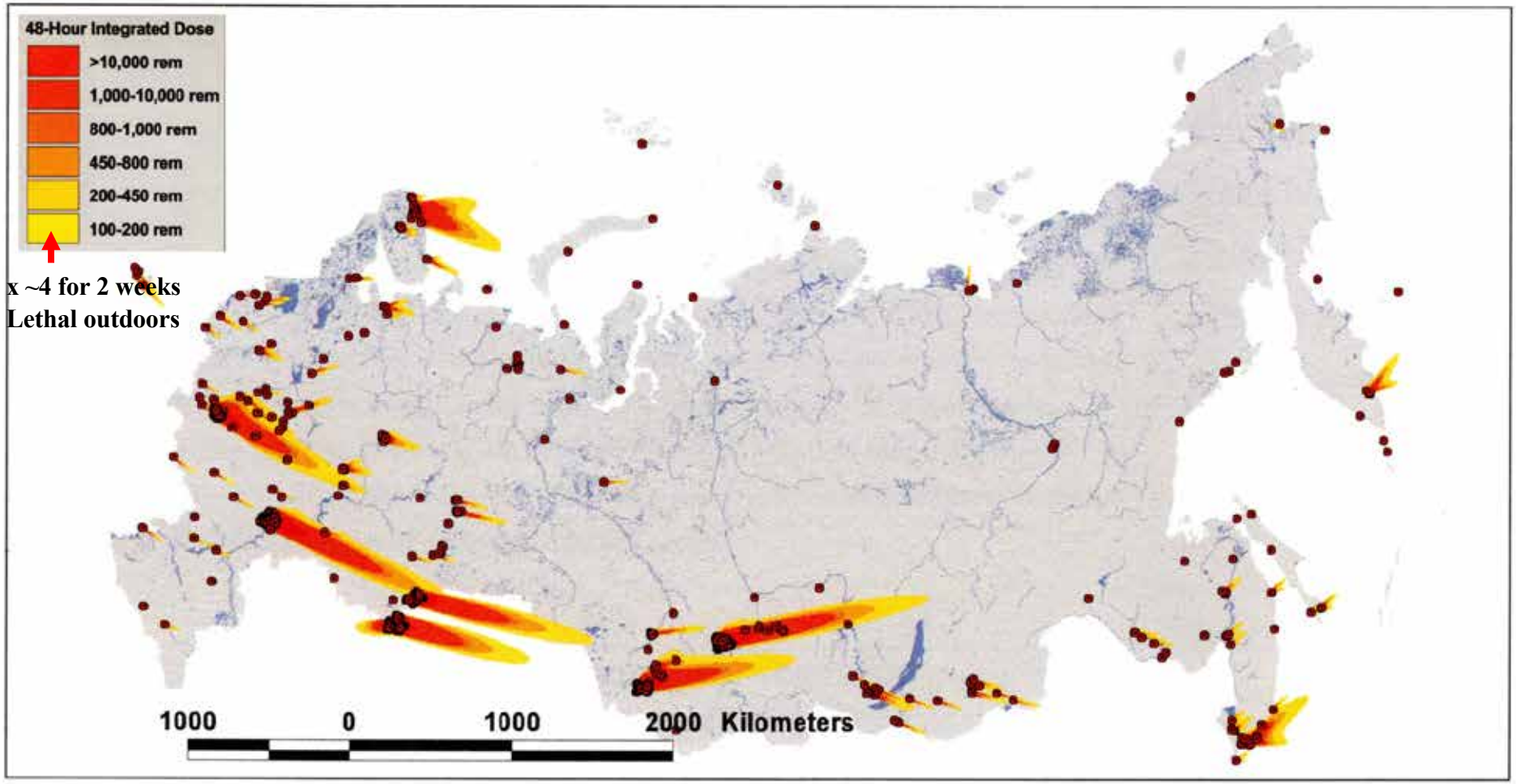


Little radioactive fallout. Fireball 100 m radius, 500 m high did not touch ground


500 kT airburst over Pentagon
Write a description for your map.
Washington would be destroyed by Russian attack on the Pentagon
White House
Capitol
Pentagon
Beltway
Scaled Hiroshima firestorm radius
Scaled Hiroshima blast radius
Google Earth
N
10 km


500 kT airburst over Kremlin
Write a description for your map.
Scaled Hiroshima *firestorm* radius
Scaled Hiroshima *blast* radius
Kremlin
~100 targets in Moscow area
"A weapon which in practical effect is almost one of genocide"
— Fermi, Rabi protesting decision to develop H-bomb, 1949
Google Earth
Image © 2020 Maxar Technologies
10 km
N

Radioactive fallout from groundbursts on some of Russia's nuclear forces: missile/bomber bases, command posts, communication links, 2001. Tens of millions of deaths.* (~ 1200 warheads, dots are airbursts.)



* Major U.S. attack on Russian nuclear forces (*The U.S. Nuclear War Plan: Time for a Change* https://www.nrdc.org/sites/default/files/us-nuclear-war-plan-report.pdf, 2001) Fig. 4.84.

Climate impact of US-Russia nuclear war

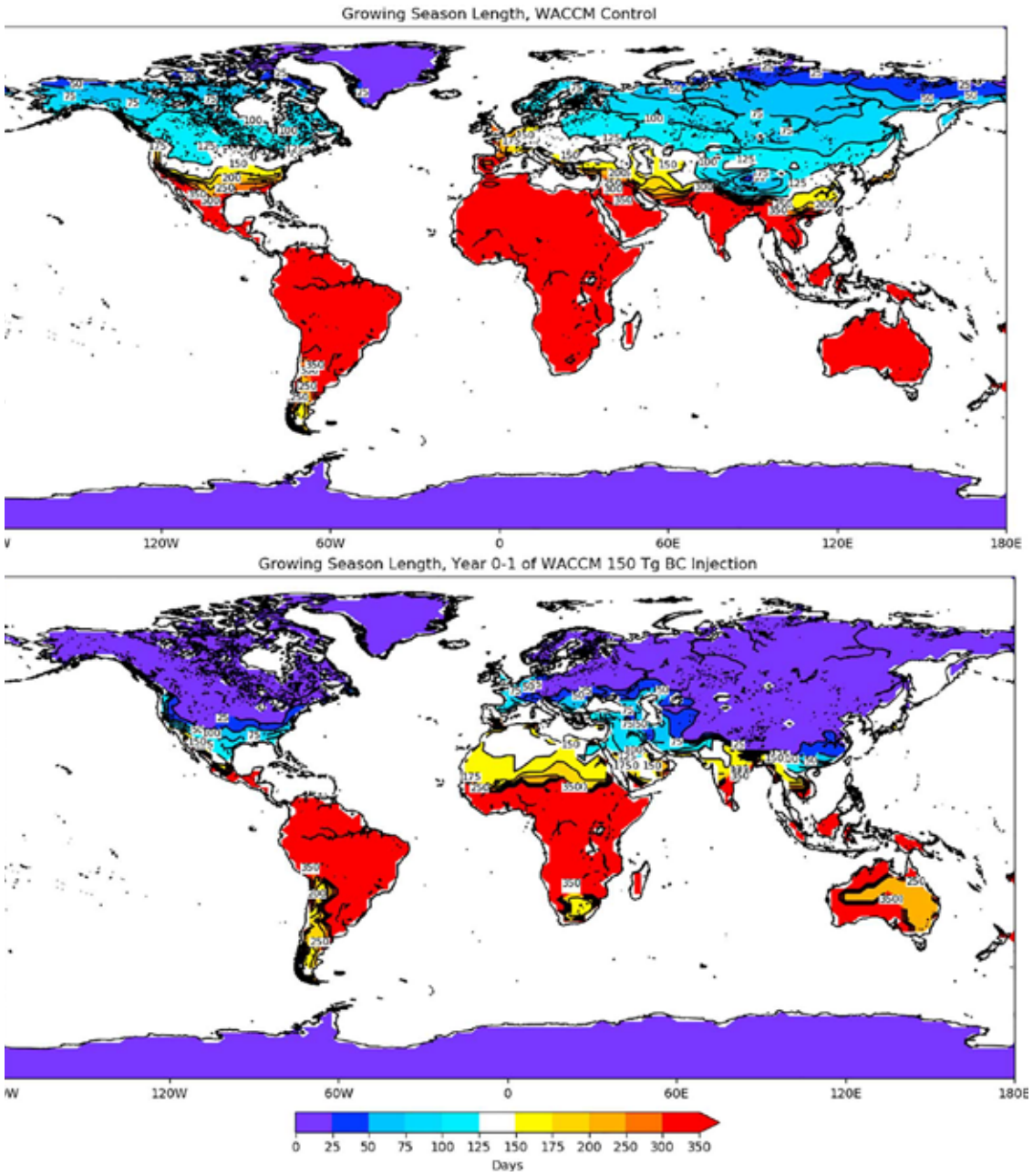
~400 Mt nuclear explosions on cities on May 15

→ 100 Mt black of sun-blocking soot in stratosphere from firestorms ***(7-yr half-life).***

First two years: Antarctic growing season in North America, Russia, Eastern/Central Europe, China, aka "nuclear winter"

Mass starvation?

After 40 years, Congress has finally asked National Academies to evaluate climate impacts.



J. Coupe, C. G. Bardeen, A. Robock, O. B. Toon, "Nuclear Winter Responses to Nuclear War Between the United States and Russia," *Journal of Geophysical Research: Atmospheres* (2019) 124, 8522–8543. https://doi.org/10.1029/2019JD030509

Defense unlikely to work but destabilizes by incentivizing first strike

1945-49. Manhattan Project physicists:

"There is no secret! There is no defense!"

1950s. But both sides built ***nuclear-armed defensives against each others' bombers***.

1960s. ***Moscow missile defense made missile defense*** **politically necessary in US.**

- US physicists went public to explain how easily could be defeated. Not-in-my-backyard uprising against nuclear-armed interceptors in US suburbs (incl. Chicago).

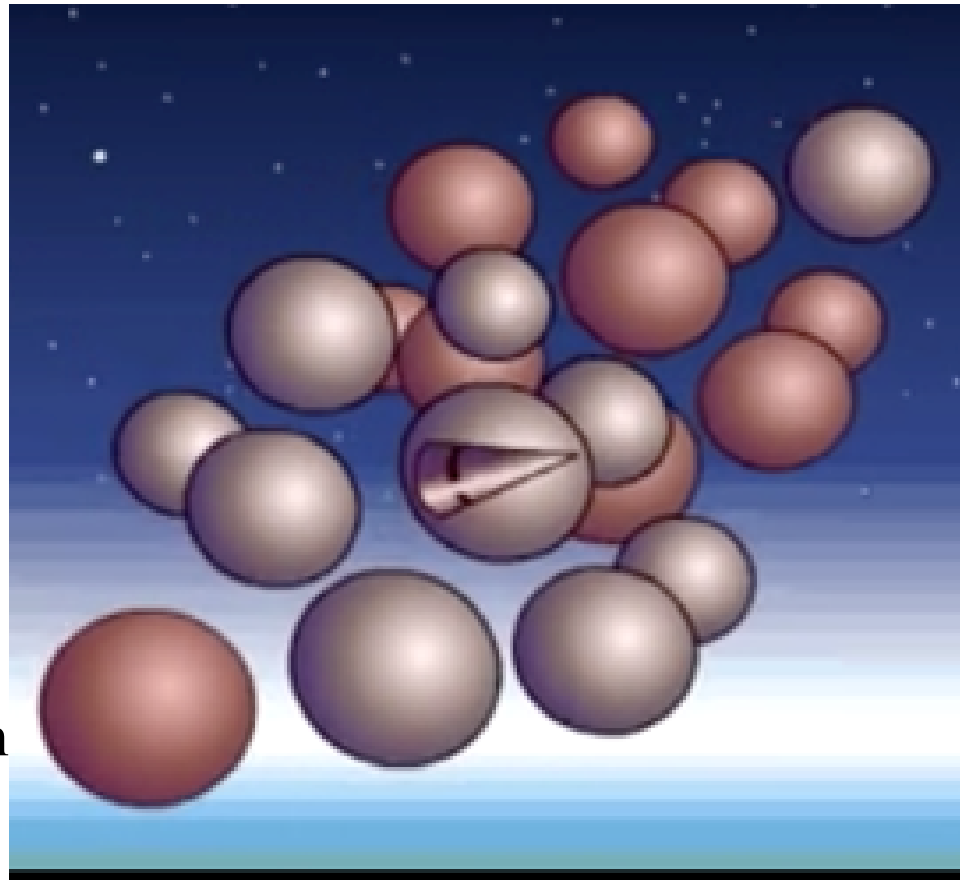
1972-2002. Anti-Ballistic Missile (ABM) Treaty limited US & Russia each to a single site with 100 interceptors.

Russia still has interceptors north of Moscow.

US installed its 100 in N. Dakota to defend an ICBM field but Soviets had 1000s of warheads. Congress ordered system shutdown after one day of operation.

One countermeasure:

Hide warhead in aluminized balloon among others with handwarmers.



Countermeasures **report** (2000) : https://www.ucsusa.org/sites/default/files/2019-09/countermeasures.pdf.

Offense-defense arms race again after the Cold War

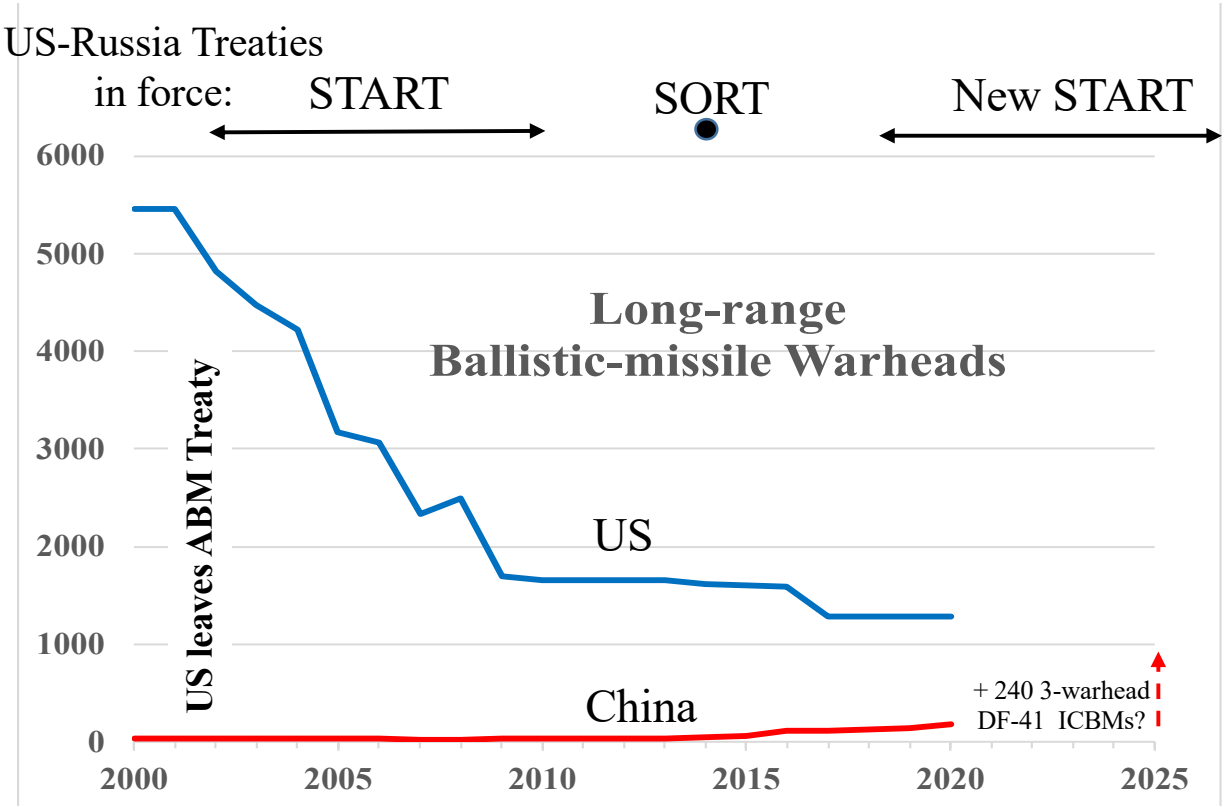
2002. G.W. Bush took US out of ABM Treaty (North Korea, Iran, Iraq threats).

Worst-case analyses drive Russian/Chinese buildups

2018. Putin announced new types of delivery vehicles to bypass US BMD:

- hypersonic maneuverable glide vehicles to underfly;
- ocean-spanning, high-speed, nuclear-powered torpedoes,
- atmospheric supersonic cruise missiles.

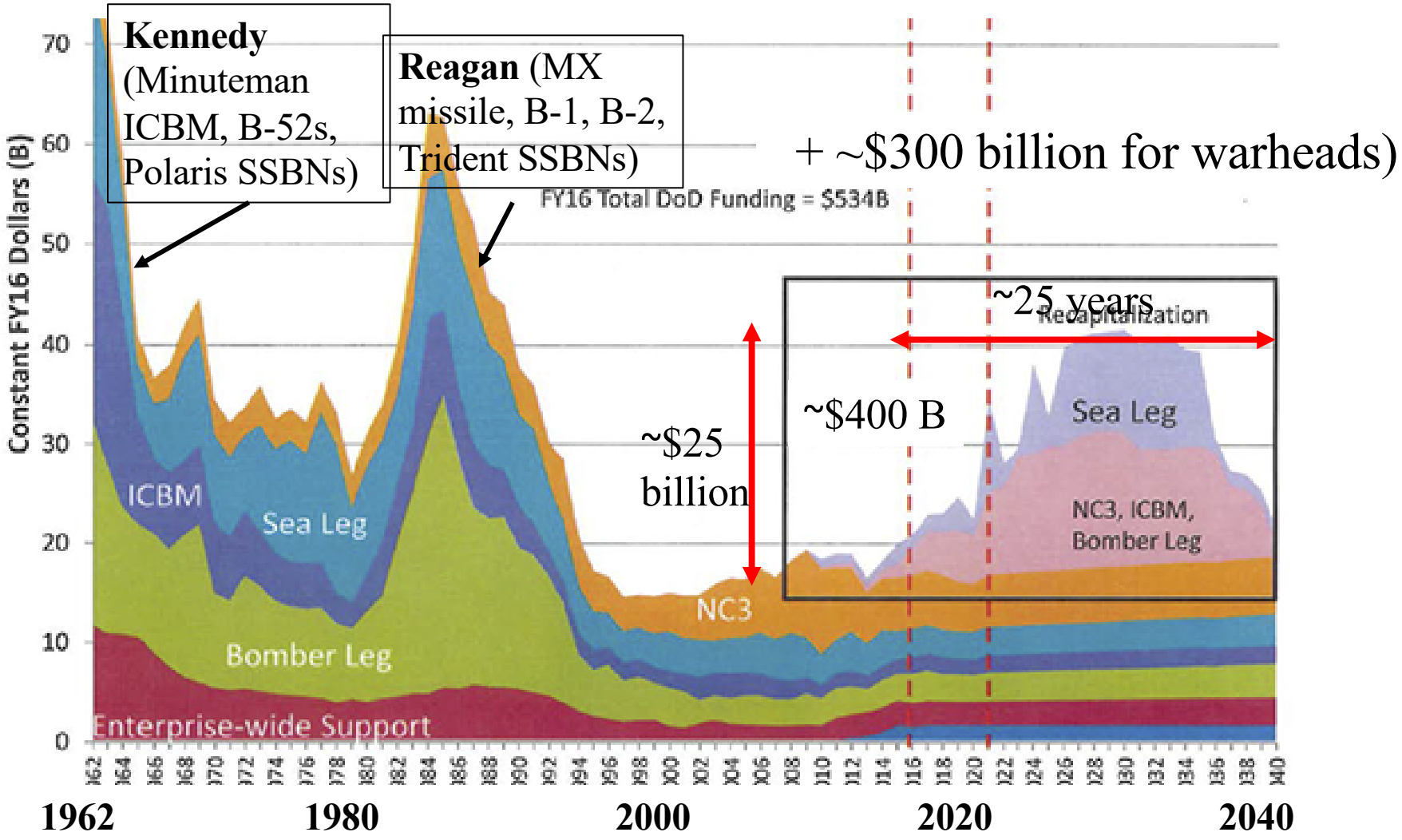
China:



Nuclear arms control and nonproliferation have been in retreat

- **2002**. ***G.W. Bush took US out of ABM Treaty.***
- **2018**. ***Trump exited JCPOA* (*Iran Nuclear Deal*)**.
- **2019**. ***Trump exited 1987 Intermediate-range Nuclear Forces treaty*** under which US and Soviet Union eliminated ~2700 nuclear-armed land-based missiles with ranges between 500 and 5500 km.
- **2018-20.** ***National Security Council discussed ending global nuclear test moratorium*** (*Physics Coalition issue*).
- ***US-Russia New START Treaty (last US-Russian arms-control deal) would have expired Feb. 5 if Biden had not agreed with Putin to extend by 5 years.*** Limits intercontinental and sea-launched ballistic missiles and their warheads verified with onsite challenge inspections. (*Physics Coalition issue*).

New replacements planned for US nuclear "Triad"
Budget stringency may create opportunity to eliminate one (ICBMs?)



Department of Defense, Cost Assessment and Program Evaluation, January 2017, https://www.armscontrol.org/files/images/TriadModernizationCosts1.png

The great history of scientists and nuclear arms control

1944. ***Niels Bohr met with both Churchill and Roosevelt*** warning of a post-war nuclear arms race with Soviet Union.

1954-63. ***Linus Pauling*** led scientists' campaign to end atmospheric tests. ***Partial Test Ban Treaty of 1963***.

1968-72. ***Hans Bethe, Richard Garwin, others*** explained ineffectiveness of ballistic missile defense to public and Congress. ***ABM Treaty of 1972.***

1980s: ***US seismologists*** demonstrated in-country seismic monitoring for nuclear tests in Soviet Union. ***Comprehensive Nuclear Test Ban of 1996.***

Sidney Drell (1926-2016). "Nuclear war – not on my watch!"

"Once more unto the breach, dear friends, once more"

- *Henry the Fifth* (Shakespeare)

If you are interested in Physicists Coalition, please stay on
(We also welcome engineers, computer scientists…)

Your Senators are Tammy Duckwort and Richard Durbin

Duckworth is on Senate Armed Services Committee.

Durbin is on Senate Defense Appropriations Subcommittee

Your local representatives include Bill Foster, the only physicist in Congress and Lauren Underwood

I suspect they and their staffs would welcome hearing from local physicists interested in reducing risks from nuclear weapons.

See also, **https://www.aps.org/policy/nuclear/**

- **Charlotte Selton**, **selton@aps.org,** of APS Office of Government Affairs
- **Frank von Hippel, fvhippel@Princeton.edu**