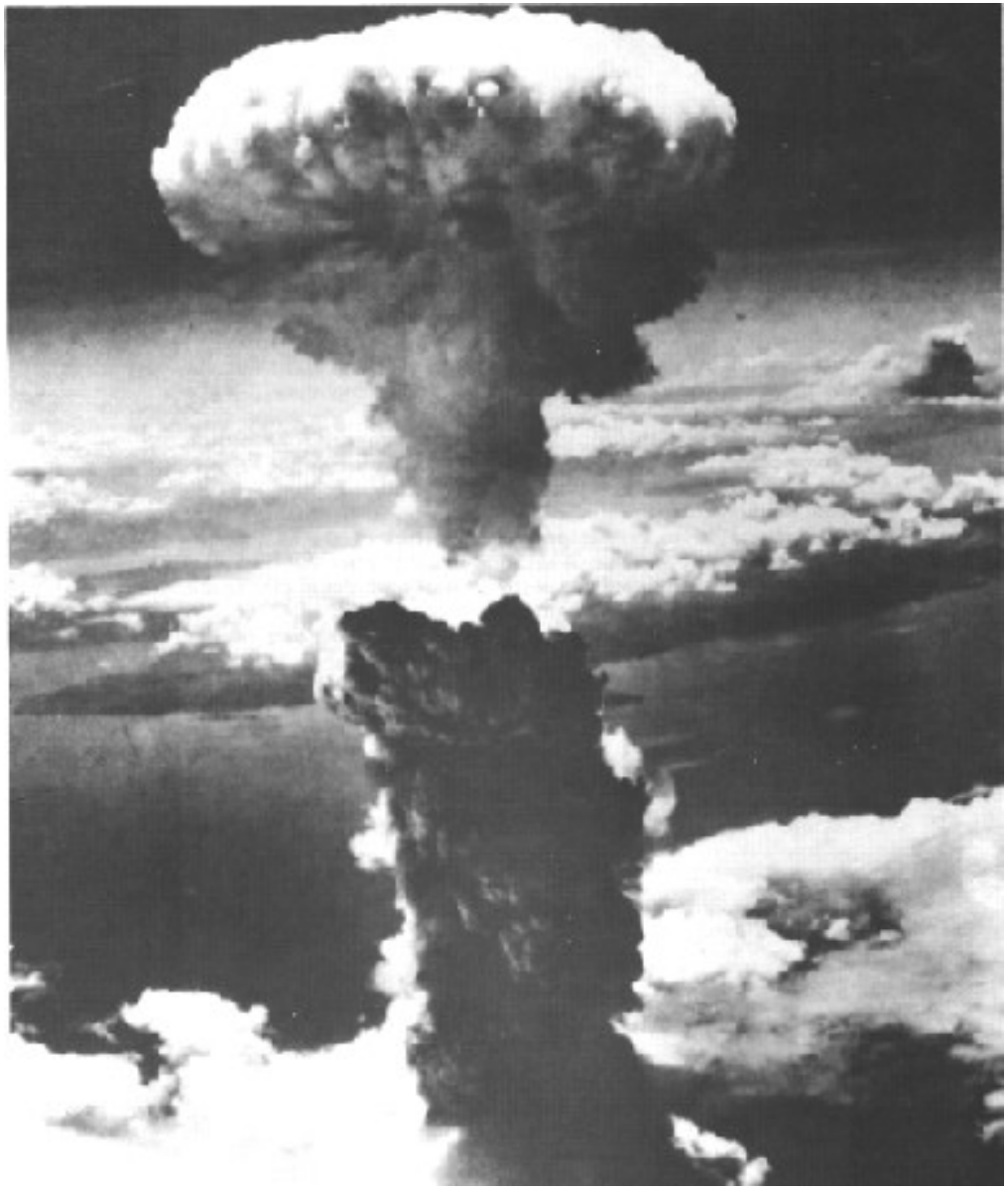
The Future of Nuclear Weapons and Nuclear Power

Richard L. Garwin
www.fas.org/RLG/

University of New Mexico, March 10, 2006

Hiroshima, October 1945

Tibbets' copy



Nagasaki mushroom cloud (20 kilotons)

Little Boy and Fat Man – Hiroshima and Nagasaki bombs
~13 and 20 kilotons

Table-- Summary of ranges for significant effects (in meters).				
Yield (kt)	(a)*	(b)*	(c)*	(d)*
1	275	610	790	5500
10	590	1800	1200	9600

a* Range for 50% mortality from air blast (m)
b* Range for 50% mortality from thermal burns (m)
c* Range for 4 Gy initial nuclear radiation (m)
d* Range to center of fallout pattern for 4 Gy fallout in first hour after blast (m)

Keep this in mind—1.2 km radius for death from prompt radiation; 1.8 km for thermal burns from a 10-kt explosion—regarding terrorist weapons in a city.

Atomic Energy for Military Purposes (The Smyth Report)

The Official Report on the Development of the Atomic Bomb Under the Auspices of the United States Government (1 July 1945)

By Henry De Wolf Smyth (Now at http://www.atomicarchive.com/Docs/SmythReport/)

(August 1945)

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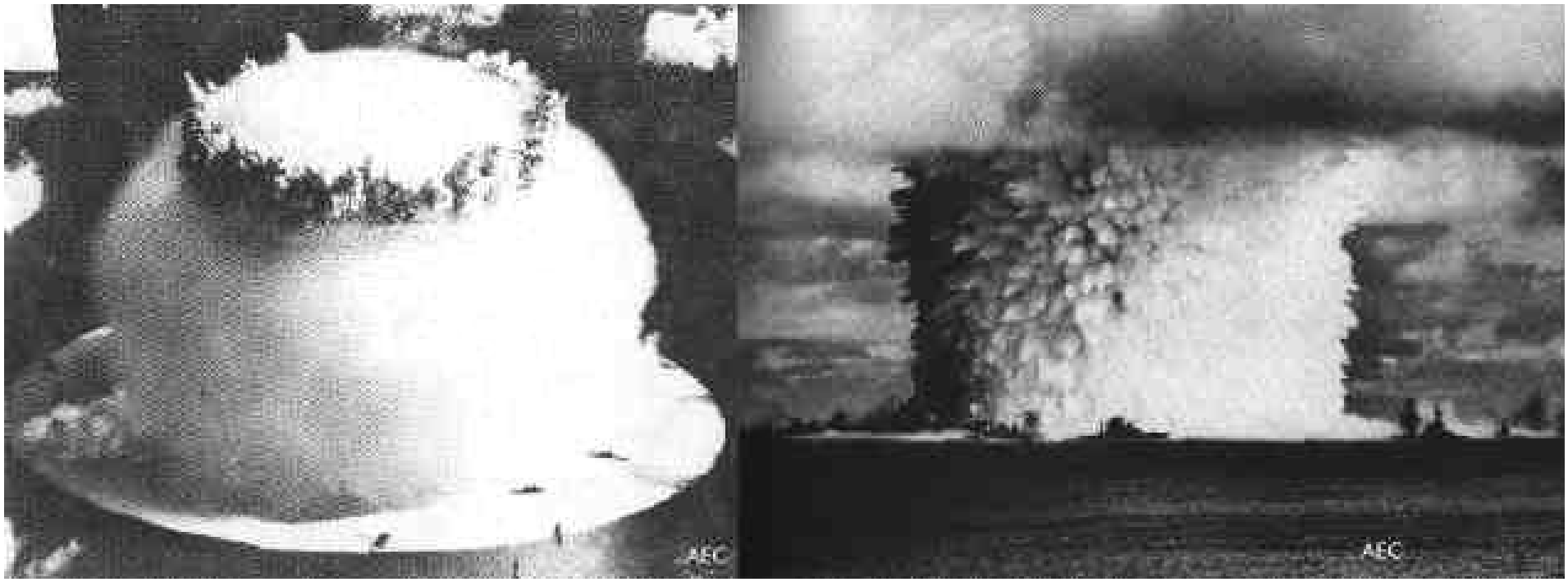
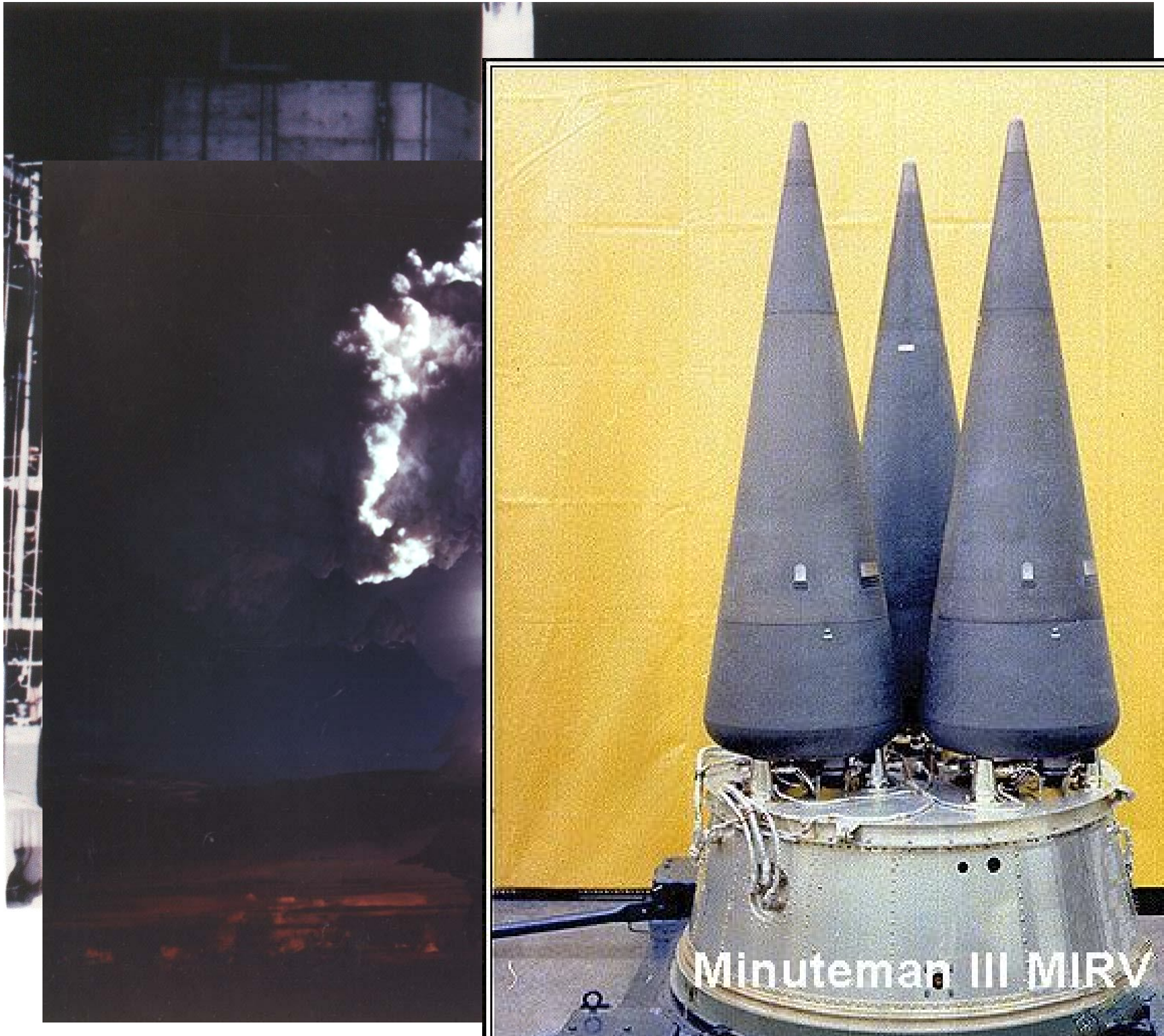


Bikini Baker, 1946 21 kilotons.
Note the ships in the stem of the mushroom cloud


Minuteman III MIRV

Now on the web at http://www.princeton.edu/~globsec/publications/effects/effects.shtml

The Effects of Nuclear Weapons

Compiled and edited by
Samuel Glasstone *and* Philip J. Dolan

Third Edition

Prepared and published by the
UNITED STATES DEPARTMENT OF DEFENSE
and the
ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION

1977

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Washington, D.C. 20402

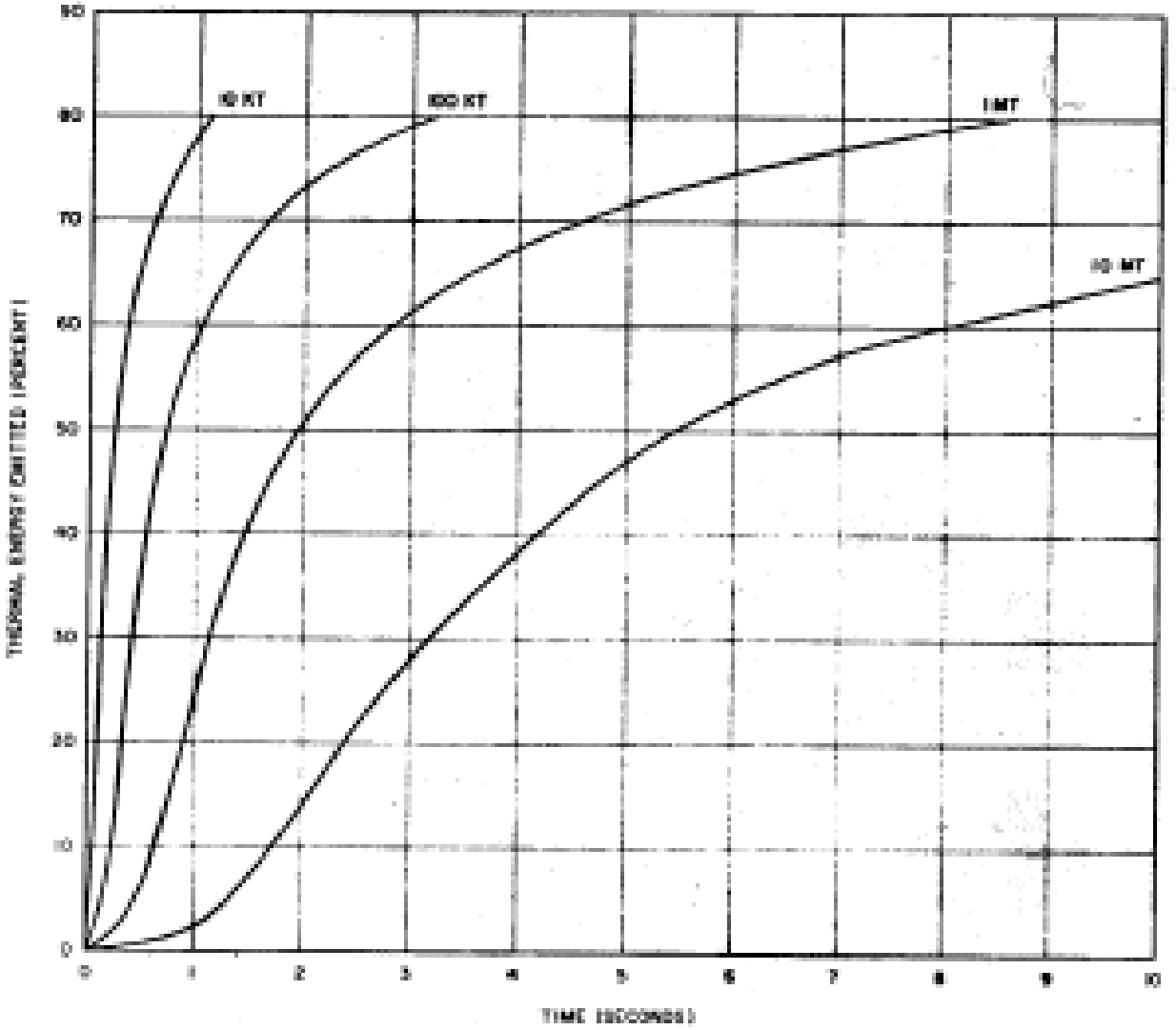
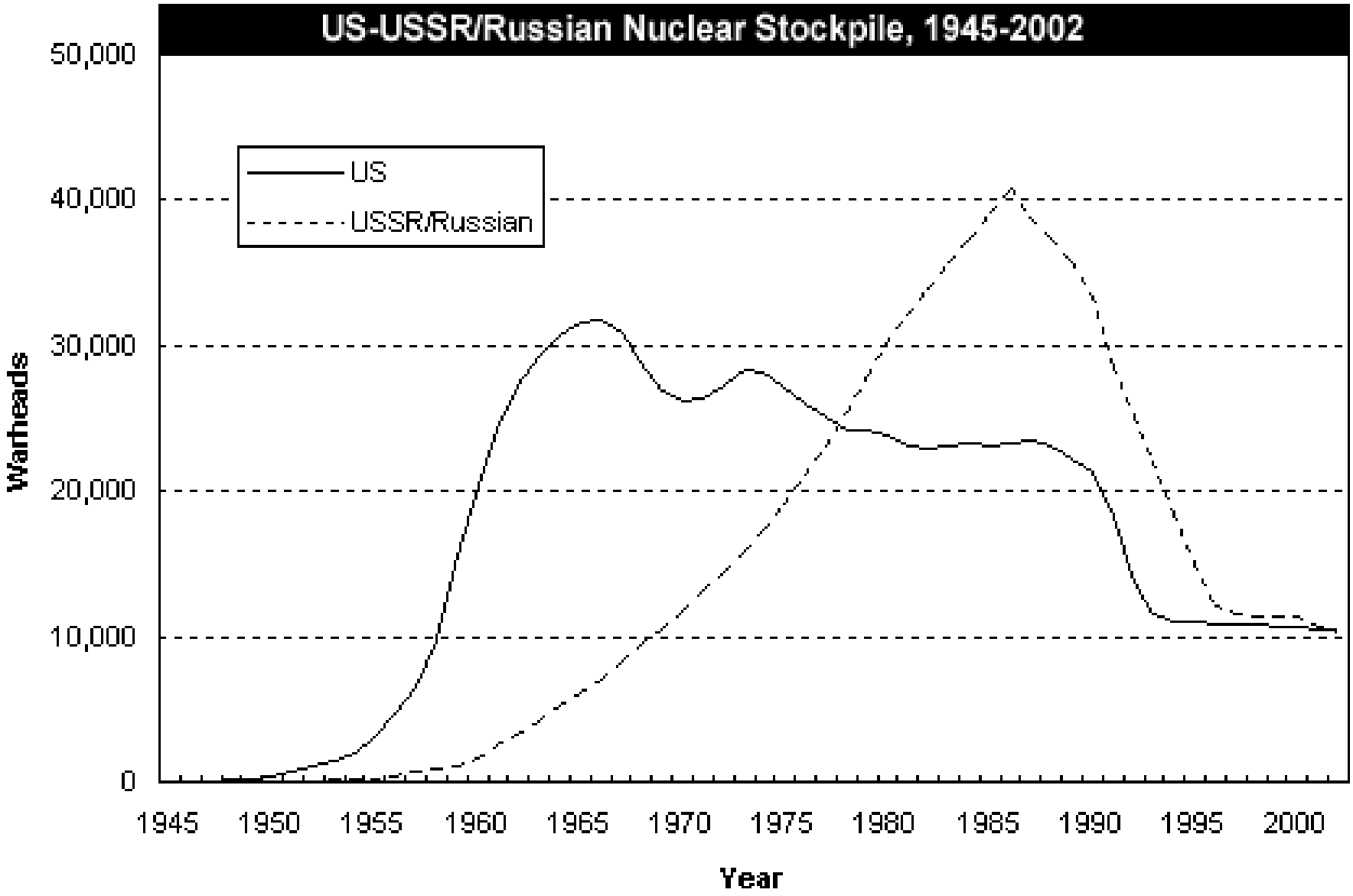


Figure 7.87. Percentage of thermal energy emitted as a function of time for air bursts of various yields.


US-USSR/Russian Nuclear Stockpile, 1945-2002
US
USSR/Russian
Warheads
50,000
40,000
30,000
20,000
10,000
0
1945
1950
1955
1960
1965
1970
1975
1980
1985
1990
1995
2000
Year

NRDC graph

Nonproliferation Treaty (1970 entry into force)

Article I

Each nuclear-weapon State Party to the Treaty undertakes not to transfer to any recipient whatsoever nuclear weapons or other nuclear explosive devices or control over such weapons or explosive devices directly, or indirectly; and not in any way to assist, encourage, or induce any non-nuclear weapon State to manufacture or otherwise acquire nuclear weapons or other nuclear explosive devices, or control over such weapons or explosive devices.

Article II

Each non-nuclear-weapon State Party to the Treaty undertakes not to receive the transfer from any transferor whatsoever of nuclear weapons or other nuclear explosive devices or of control over such weapons or explosive devices directly, or indirectly; not to manufacture or otherwise acquire nuclear weapons

Article IV

1. Nothing in this Treaty shall be interpreted as affecting the inalienable right of all the Parties to the Treaty to develop research, production and use of nuclear energy for peaceful purposes without discrimination and in conformity with articles I and II of this Treaty.

2. All the Parties to the Treaty undertake to facilitate, and have the right to participate in, the fullest possible exchange of equipment, materials and scientific and technological information for the peaceful uses of nuclear energy. Parties to the Treaty in a position to do so shall also cooperate in contributing alone or together with other States or international organizations to the further development of the applications of nuclear energy for peaceful purposes, especially in the territories of non-nuclear-weapon States Party to the Treaty, with due consideration for the needs of the developing areas of the world.

Article VI

Each of the Parties to the Treaty undertakes to pursue negotiations in good faith on effective measures relating to cessation of the nuclear arms race at an early date and to nuclear disarmament, and on a Treaty on general and complete disarmament under strict and effective international control.

NUCLEAR AND BIOLOGICAL MEGATERRORISM

August 21, 2002

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The loss of 3000 Americans to Al Qaeda terrorism September 11, 2001 brought to many the sudden recognition that America was no longer leading a charmed life. Since then, a great deal of hand wringing and discussion has ensued, but the problem is a serious one and won't go away. Not that it was unrecognized and unpublicized. For instance, in 1999 the Commission chaired by former U.S. senators Gary Hart and Warren Rudman reported:

"There will...be a greater probability of (catastrophic terrorism) in the next millennium...Future terrorists will probably be even more hierarchically organized, and yet better networked than they are today. This diffuse nature will make them more anonymous, yet their ability to coordinate mass effects on a global basis will increase...Terrorism will appeal to many weak states as an attractive option to blunt the influence of major powers...(but) there will be a greater incidence of ad hoc cells and individuals, often moved by religious zeal, seemingly irrational cultist beliefs, or seething resentment...The growing resentment against Western culture and values...is breeding a backlash...Therefore, the United States should assume that it will be a target of terrorist attacks against its homeland using weapons of mass destruction. The United States will be vulnerable to such strikes."

--U.S. Commission on National Security/21st Century, *New World Coming: American Security in the 21st Century*, September 1999, p. 48

The concept of megaterrorism was well known; the warning was there; only the date, place, and nature of the deed were in question to those who had looked at the prospects.

How have we survived 60 years of potential annihilation?

- Nuclear monopoly. Defense? Deterrence by assured destruction.
- Enormous stocks of nuclear weapons in part irrational, but rationalized by needs of assured destruction in face of potential air defense, missile defense and destruction before launch
- Joint U.S. and USSR interest in survival and nonproliferation.
- Barriers to proliferation- political, intellectual, material.

- Highly enriched uranium (gaseous diffusion, centrifuge, “electromagnetic separation”...) 25 kg “Significant Quantity”-- SQ
- Plutonium from production reactors or power reactors.

How have we survived (2)

- Common interest in survival—NATO, "Atoms for Peace," limits on nuclear testing, Nonproliferation Treaty and IAEA, US-Soviet pacts such as 1972 ABM Treaty and Limited Offensive Agreement. SALT, START.

- Undeterrable states? Which? Why?

- Bar access to weapon-usable material—HEU and Pu. Problem of "civil plutonium" produced about 250 kg/yr by typical power reactor. 250/"8" = 30 bombs/yr each

- Terrorists, nihilists—the unsolved problem. According to General George C. Marshall, solving a problem depends on the shape of the table.

The key is to have all the participants on one side of the table and the problem on the other.

- Problem is enormous stocks and flows of weapon-usable material—HEU and Pu
  - In Russia and U.S., but also in many other states and facilities

- Some tools and progress
  - Nunn-Lugar program—consolidate and secure.
  - Megatons-to-Megawatts 20-year purchase of 500 tons of Russian HEU (20,000 nuclear weapon equivalents), but at least 700 tons more exist.

- But problem is not the first 99%-- not the problem of securing gold.

Terrorist nuclear explosion

- Knowledge barrier eroded or vanished
- Political barrier assumed absent
- Only remaining barrier is acquisition and transport of material

- Stolen nuclear weapon, improvised nuclear device—IND.

Urgent remedies

- Nunn-Lugar program—spend money with the people who will do the work in Russia and other countries—consolidate and secure weapons and weapon-usable materials
  - Spend money for national security—not votes. This is truly a matter of life and death.

- Accelerated blend-down of HEU for future world reactor fuel. Instead of 95% U-235 to 4.4% LEU, 95% to 19.9%-- not immediately weapon usable. Five times the rate, less cost, needs loan subsidy to be repaid on ultimate blend-down.

- Nuclear explosion simulator—free for world leaders; hoi polloi pay for thrills

- Universal accounting and security for HEU, Pu, reprocessing of reactor fuel, and enrichment capability.

Urgent remedies (2)

- Iran's nuclear power program. Safeguard Iran's commitment not to acquire nuclear weapons or weapon-usable material.

- North Korea certainly has several weapons-worth of Pu and probably at least two more-compact Nagasaki-type nuclear weapons. Need direct negotiations.

- Muscular extension of NPT with universal enforcement of a new provision that states not later use for nuclear weapons facilities or materials acquired as non-nuclear- weapon-states under the NPT.

- Serious barriers to smuggling of NW, uranium, plutonium

U.S. Nuclear Weapons without Nuclear Explosion Testing?

- 1992 Moratorium... No explosion testing since
- 1996 Comprehensive nuclear test ban treaty—CTBT—still not ratified by U.S., would not enter into force anyhow...
- Science-based stockpile stewardship progam—SSP—including the Accelerated scientific computing initiative—ASCI.
- How many of the 1000 US nuclear explosions were "stockpile verification" tests? ~ 0.
- Is a NW like an automobile that must run after not being started for 20 years? No; entirely testable except for the fissile material implosion. Atoms do not change...
- Even with actual stockile verification tests (e.g. missile launch) the item tested is not one that will then be used.
- Major facilities for NW labs—DARHT, μ-electronic center, NIF.

Recent problems/options

- Nuclear earth penetrating warhead to destroy deep underground facilities? B61-Mod 11 designed for penetrating frozen earth—not rock or concrete. Penetration increases ground shock from nuclear explosion; but effect saturates at ~ 20:1 for DOB of 0.5 m/kt$^{1/3}$—i.e. 0.5m for 1 kiloton, 3-m DOB for 200 kt.
- NAS-NRC Committee Report of 04/2005 funded by DOD makes it clear that DOB does not in the least reduce fallout—except by the ratio of yields required to produce similar ground shock—20:1. Fallout deaths will range from hundreds to a million or more, depending on location and wind.
- Widespread confusion (apology by Linton Brooks) so that many in Congress believed that NEPW would actually penetrate to the undrground facility.

What to do with NEPW?

- No nuclear development program; instead carry an erectable shaped charge to provide a 60-cm clear hole to allow free penetration of B61-11 to a depth of 3 m, and detonate in flight.

The more you want this capability, the less you want the nuclear development program.

- Other contentious program is the Reliable Replacement Warhead —RRW. But what is it? A 5-kt gun-type weapon? A variable-yield implosion weapon with dial-a-yield from 0.1 to 300 kilotons? We have been producing RRWs under the stockpile stewardship program for 20 years, and our confidence can only increase with the additional insight from ASCI and the science base. See NAS-NRC CISAC report, "Technical Issues Under a CTBT" at www.nap.edu.
- What is the vision for the RRW? (Linton Brooks 03/03/2006:)

Let me offer one example. If, as most of us assume, the Reliable Replacement Warhead requires pit manufacture, and if everything works as we hope, we might be able to produce 40 pits a year starting early in the next decade. Greater production must await a restored pit production capability, which may not be available for at least 15 years. So, fully implementing the Reliable Replacement Warhead and the Responsive Infrastructure portion of the New Triad will take a while. But, it is worth working toward and is well worth waiting for.

... The goal is to develop designs that are not resource intensive or rely on hard to make hazardous and exotic materials. In the future, as we move forward with this effort, Y-12 will have a key role in manufacturing components to support the stockpile of the future.

Let me take you forward 20 or 25 years to a point when the Administration's vision of a nuclear weapons enterprise of the future has come to fruition. The deployed stockpile - almost certainly considerably smaller than today's - has largely been transformed.

Reliable Replacement Warheads have relaxed warhead design constraints imposed on Cold War systems. They are more easily manufactured at fewer facilities with safer and more environmentally benign materials. They have the same military characteristics, are carried on the same delivery systems, and they hold at risk the same targets as the variants they replaced - but they have been redesigned for reliability, security, and ease of maintenance.

By 2030, confidence in the U.S. stockpile is high because of the RRW's large design margins and because we continue to gain a deeper understanding of nuclear phenomena from principles enabled by Stockpile Stewardship and the advanced technology tools that came with it. The deployed stockpile is backed up by a much smaller non-deployed stockpile than today. The United States has met the Responsive Infrastructure objective of being able to diagnose and correct minor warhead problems and redeploy them within one year. The elimination of dangerous and environmentally difficult materials like conventional high explosives and beryllium has made this possible and obviated the need for large numbers of spare warheads to hedge against reliability problems.

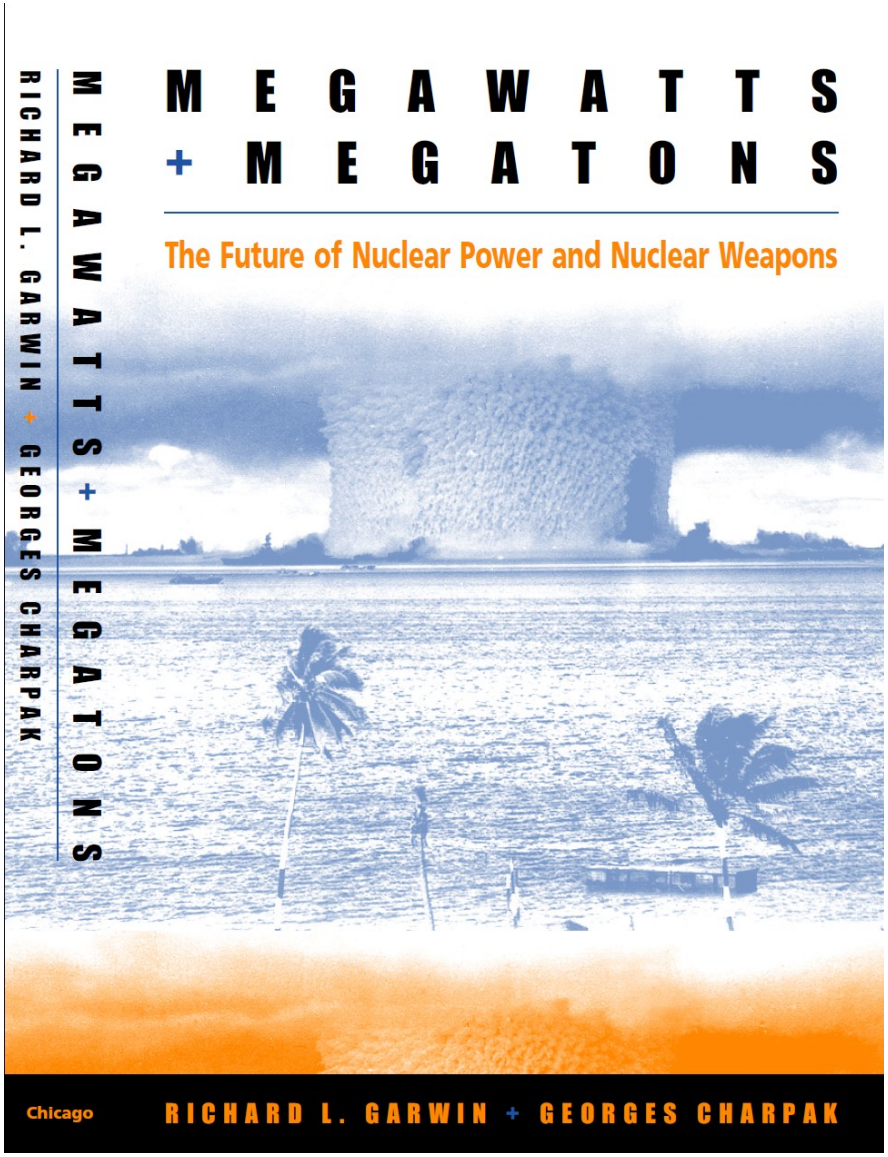
Garwin comments:

- A new-design RRW will inevitably lead to demand for nuclear explosion tests, and China and Russia will then have a robust test program that will really advance Chinese weapons to allow MIRVs on mobile missiles. And other non-NNW states under the NPT will be driven for reasons of status (e.g., Japan, South Korea) to acquire nuclear weapons.
- In Russia, China, the U.S., there are like-minded individuals chafing under the no-test constraints. The U.S. has no reason to test, and every national security interest that Russia and China not test.
- Each year the 3 US NW labs—LANL, SNL, LLNL—have certified the stockpile nuclear weapons as safe and reliable. SNL in particular is essentially unconstrained in its modernization and replacement program; nuclear explosion tests would be a distraction—not a help.
- We already have reliable replacement warheads.

Nuclear power for the U.S. and for the World?

- 400+ power reactors worldwide; ~ 104 in U.S., 58 in France.
- Each produces ~ 1000 MWe + 2000 MW of discarded heat + 1000 kg of fission products (FP) annually and 250 kg of Pu.
- Separated "civil Pu" can be used about as well as military Pu for a terrorist nuclear weapon. Barriers to proliferation essential.
- Essentials for a healthy nuclear industry:
  - Few catastrophic accidents; reasoned response
  - Economic viability, including all costs for all options—carbon capture and storage costs; pay $40K-$400K per person-Sv.
  - Adequate supply of nuclear fuel—LEU for LWRs, natural or depleted U for breeders
  - Safe and routine disposal of spent fuel or FPs and storage before disposal

Where do we stand?



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GEORGES CHARPAK
RICHARD L. GARWIN
VENANCE JOURNÉ

De Tchernobyl en tchernobyls

Published by Editions
Odile Jacob
October 6, 2005

Two remarkable reports:

"L'énergie nucléaire civile dans le cadre temporel des changements climatiques"
Rapport à l'Académie des sciences par Robert Dautray
Décembre 2001 - 65,00 €

"Les isotopes du plutonium et leurs descendants dans le nucléaire civil"
Rapport à l'Académie des sciences par Robert Dautray
Mai 2005 - 55,00 €

Strong message: Even France, with its excellent technical accomplishments is not even at the beginning of a "plutonium plan" and has not nearly begun the planning and work for industrial-scale disposal of vitrified FP and spent MOX

Where do we stand?

- Accidents: tolerable at the present rate, but 10/2003 WANO session (and 2005 BNFL Sellafield experience) a bad omen
- Economics: marginal, but would be aided by a carbon tax of $50/tC.
- Fuel supply for 300 GWe --> 9,000 GWe? At 200t/yr per GWe from a LWR would total 2 million t/yr. Ludicrous with reserves of 3-4 Mt, but Gen IV group estimates 170 Mt at cost of $260/kg. So $50 M/yr for fuel for a LWR.
- Saving uranium by recycle in LWR is an economic burden: from $700/kg to $2000/kg of natural uranium saved (max 20%).
- Ultimately, when economical, a breeder and its necessary processing and refabrication cycle— ~100-fold less fuel.
- Nonproliferation—another built-in cost. Assured fuel cycle option for many users (President Bush, Dr. ElBaradei)

- New US initiative: **G**lobal **N**uclear **E**nergy **P**artnership—GNEP:

USG presentation of Global Nuclear Energy Partnership...

http://www.gnep.energy.gov/pdfs/gnepPresentationFinal020606.pdf

Garwin comments (after showing GNEP pdf):

- Reprocessing of LWR fuel would be premature, costly, and would hurt, not help, expansion of nuclear power
- Reprocessing impairs economics, would not ease repository needs without deployment of large numbers of "sodium cooled" fast-neutron reactors—ABRs. Deserves intensive technical design effort, rather than a current commitment.
- Nuclear electric power is a commodity, not a goal in itself. Need market-driven expansion of LWRs, with economical introduction of new-type reactors—e.g., MHTGTR, small cartridge reactors.

Remedies

- Expansion of nuclear power from world's present 400+ reactors (15% of world's electricity) to 3000 or 9000 must feature nonproliferation and protection against accidents and terrorism.

- Role for government in learning cost of extraction of uranium from seawater—a store of 3+ billion tons.

- Competitive, commercial mined geologic repositories for reactor waste, under IAEA supervision and international protection.

- Assured supply (including buy-ahead) of LEU fuel, and take-back of spent fuel for 100-yr interim storage and direct disposal or eventual recycle when economically justified.

In summary:

Not "nothing to fear but fear itself," but for our country of 300 million to lose 300,000 must not be the end of our history. We must plan and invest to prevent and then to live with this loss.

Still, finite probability does not add to a certainty:

$$\text{e.g., } P + 0.9P + (0.9)^2P + (0.9)^3 \ldots$$

sums to 10P—10 years of exposure to current unknown hazard P. (This simple formula is valid only if the resulting probability is small.)