

# **The Future of Nuclear Weapons and Nuclear Power**

**Richard L. Garwin**

**[www.fas.org/RLG/](http://www.fas.org/RLG/)**

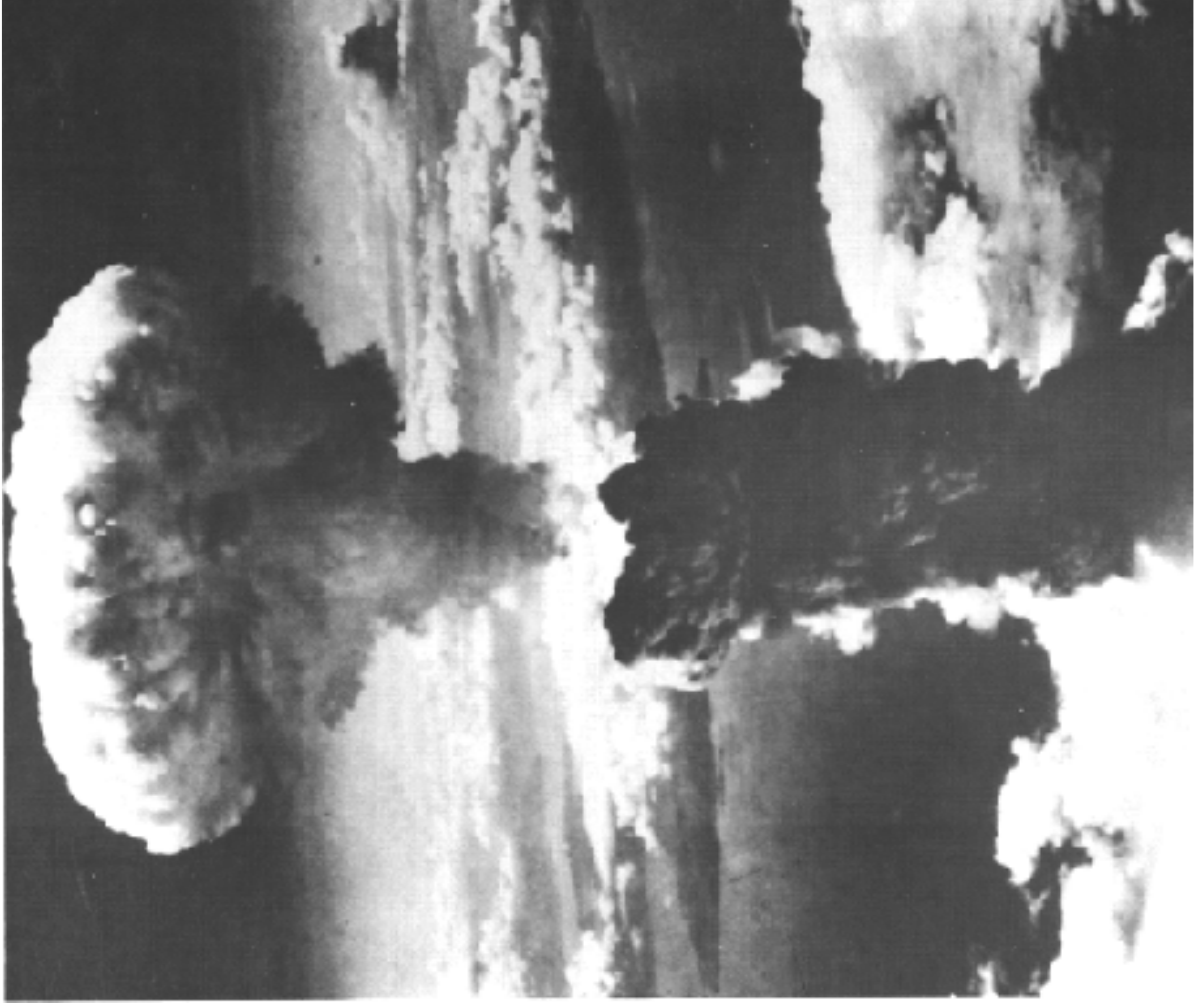
**Argonne National Laboratory, October 6, 2005**



**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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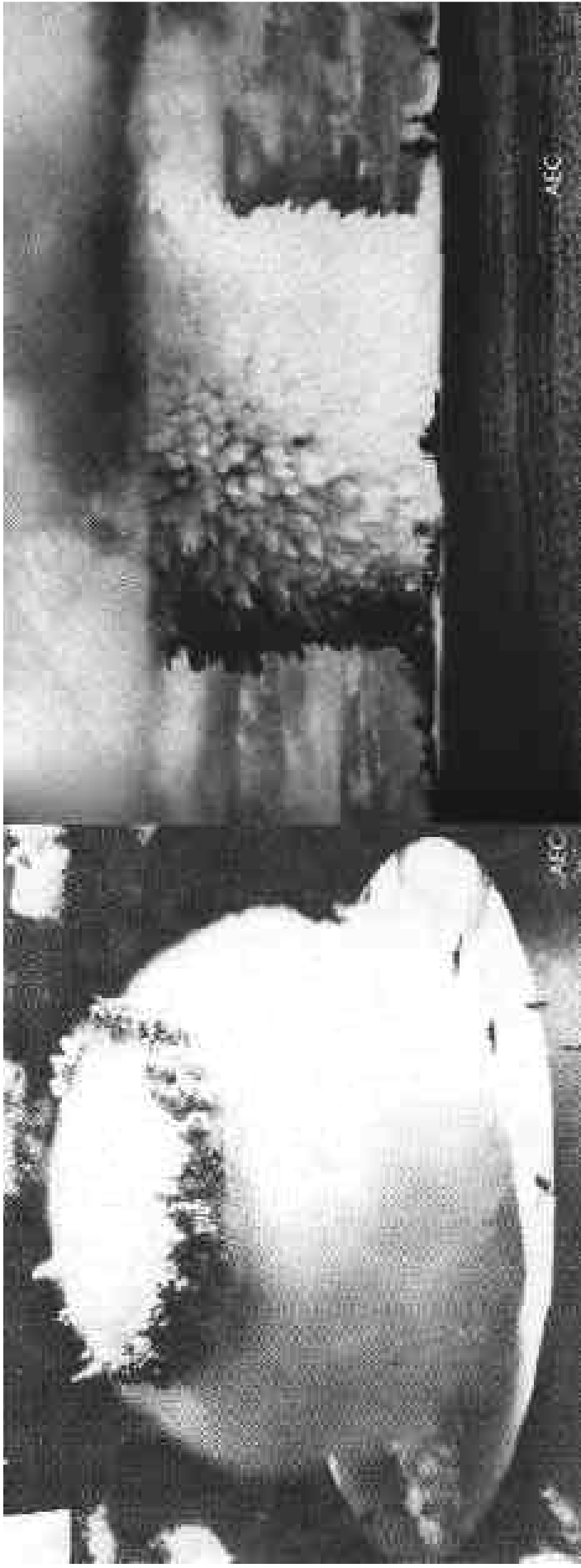
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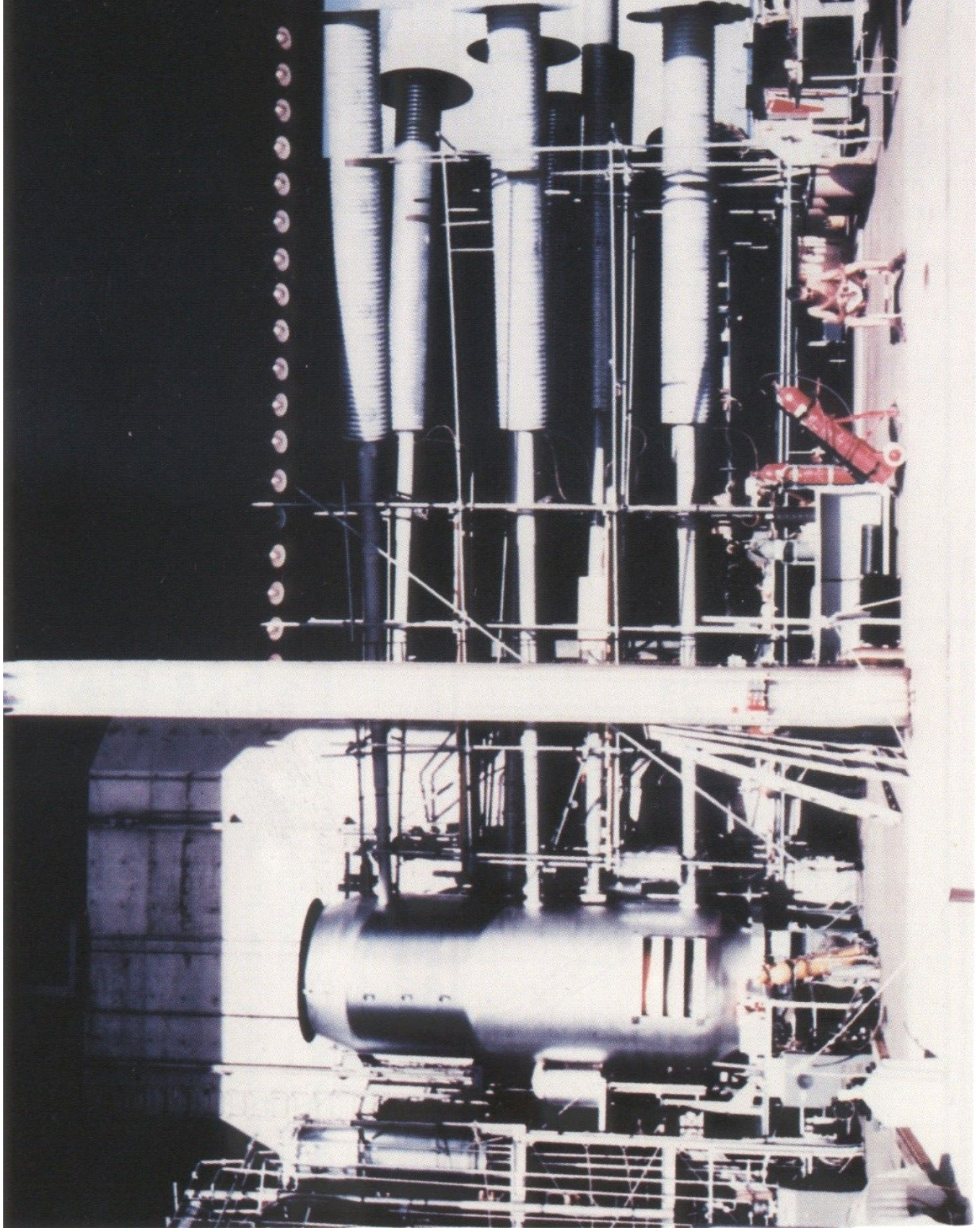
Appendix 6. War Department Release on New Mexico Test,  
July 16, 1945



**Bikini Baker, 1946 21 kilotons.**

**Note the ships in the stem of the mushroom cloud**

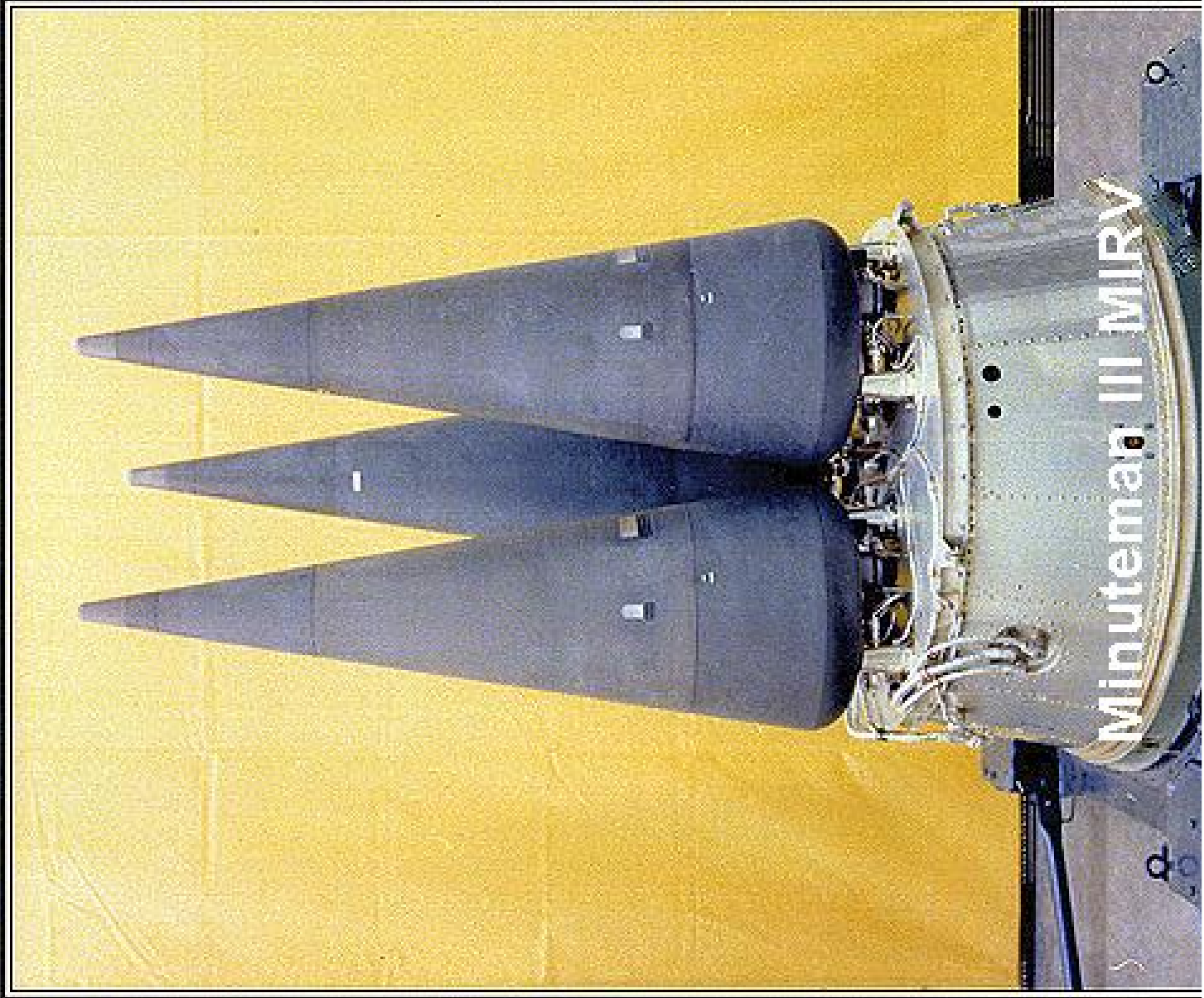




Ivy Mike in preparation



Ivy Mike mushroom cloud, 11 megatons



# 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

For sale by the Superintendent of Documents, U.S. Government Printing Office  
Washington, D.C. 20540

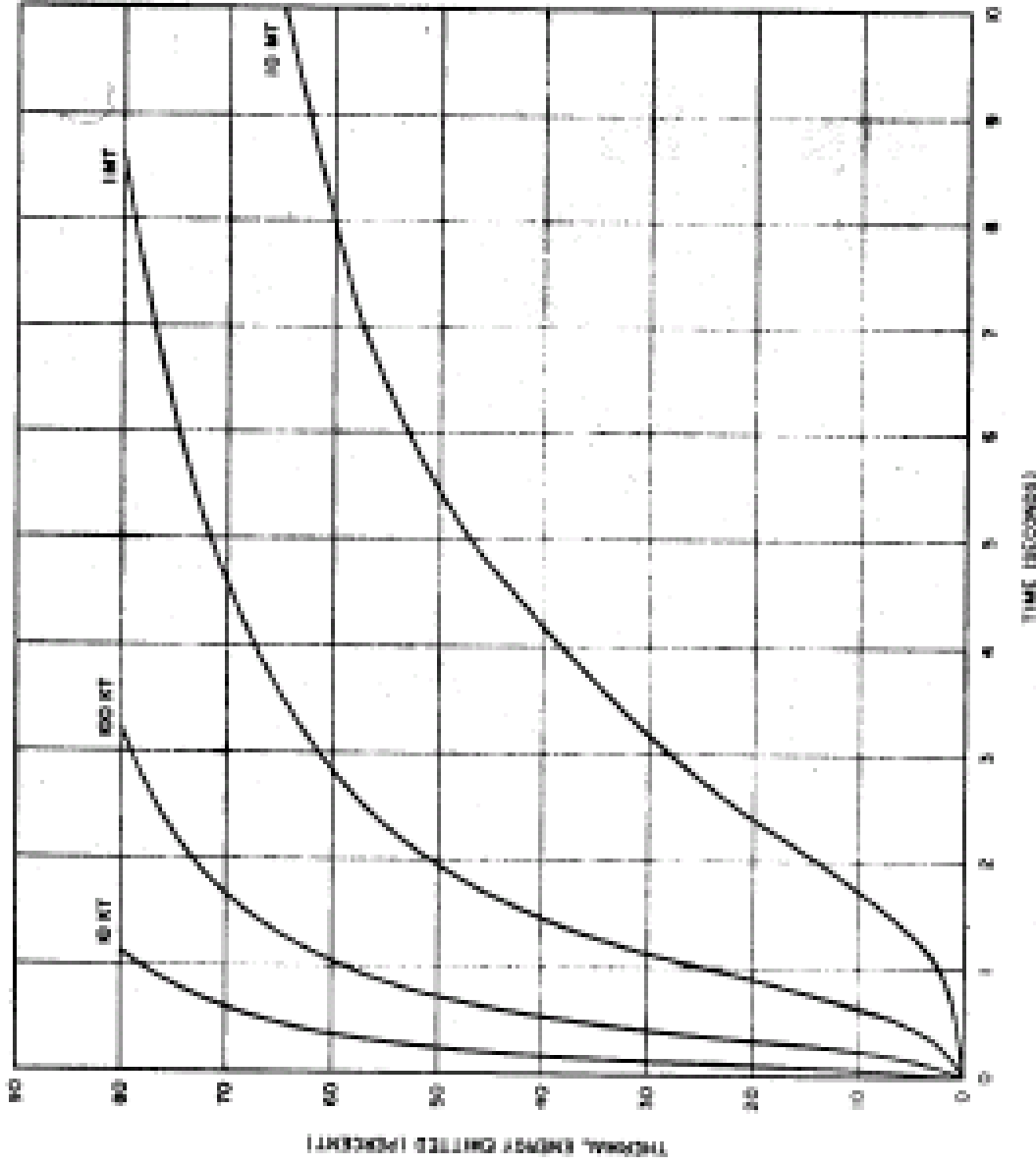
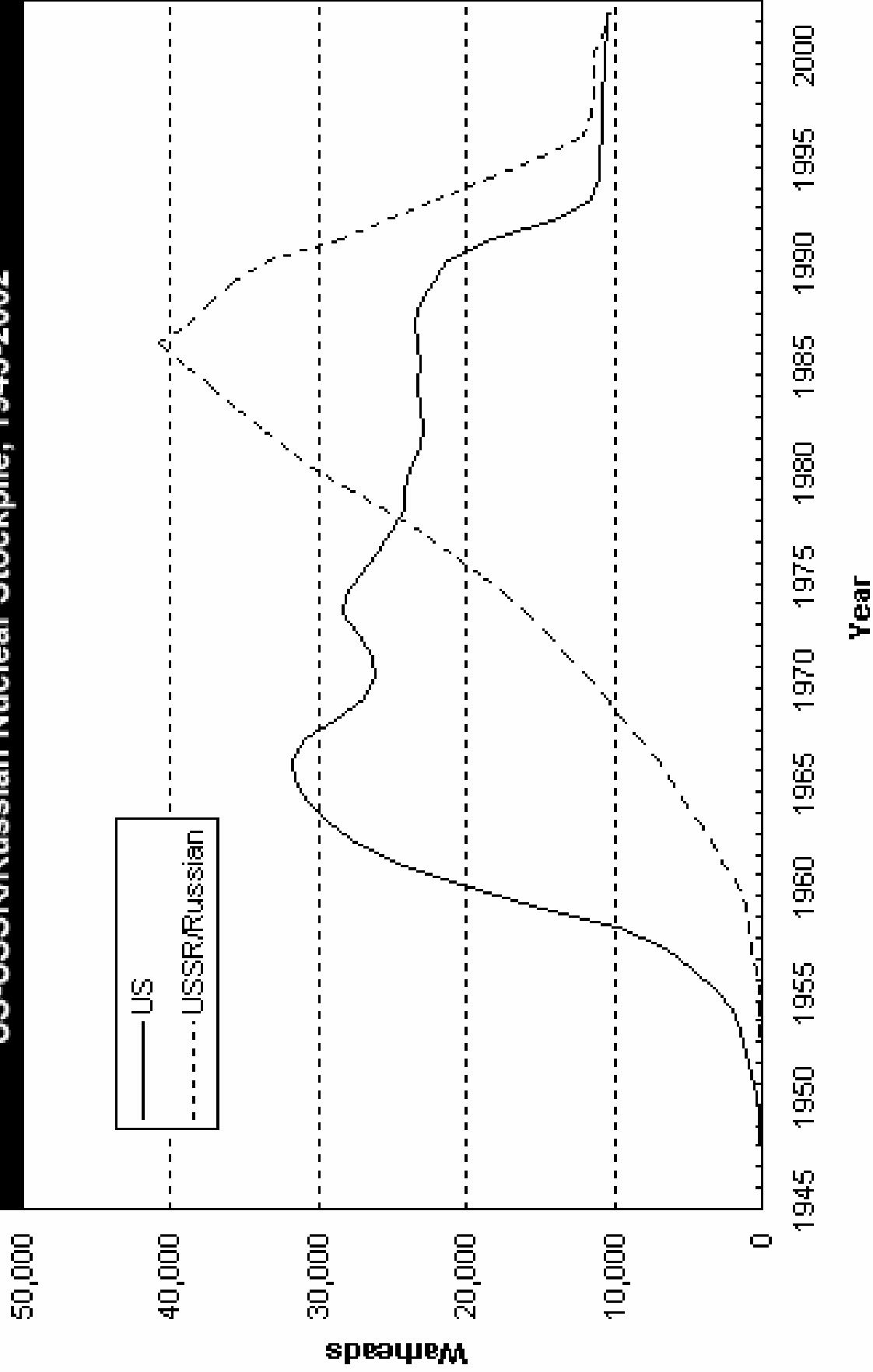


Figure 7.87. Percentage of thermal energy emitted as a function of time for air bursts of various yields.

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

# US-USSR/Russian Nuclear Stockpile, 1945-2002



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 MEGATERROISM

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 and the problem on the other.**

- Problem in 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 load 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 program—SSP—including the Accelerated scientific computing initiative—ASCI.
- How many of the 1000 US nuclear explosions were "stockpile verification" tests?  $\sim 0$ .
- 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 stockpile verification tests (e.g. missile launch) the item tested is not one that will then be used.
- Major facilities for NW labs—DARHT,  $\mu$ -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<sup>1/3</sup>—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 underground 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](http://www.nap.edu).

- 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.

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

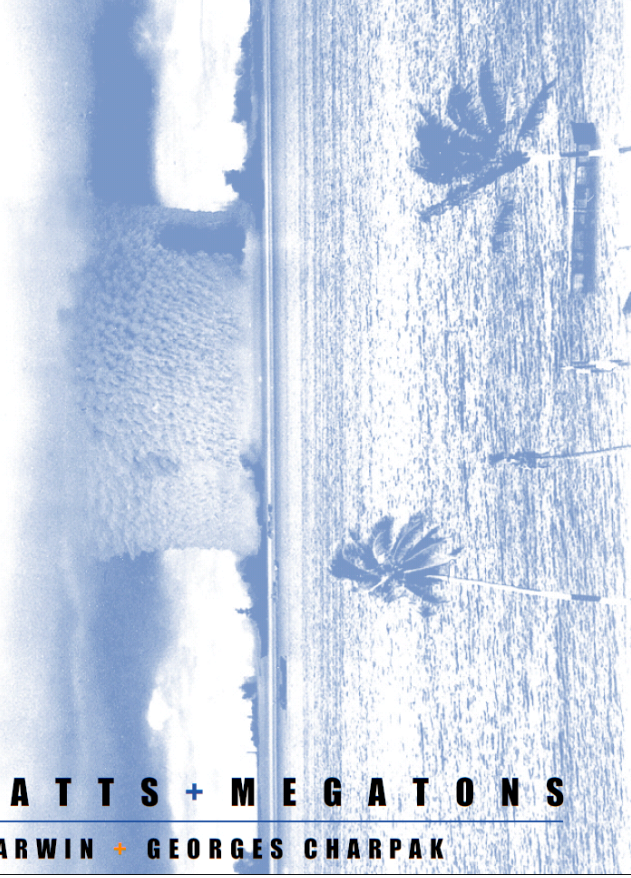
- 400+ power reactors worldwide; ~ 104 in U.S., 58 in France.
- Each produces ~ 1000 MWe + 2000 MW of discarded heat + 1000 kg of fission products (FP) annually and 250 kg of Pu.
- Separated "civil Pu" can be used about as well as military Pu for a terrorist nuclear weapon. Barriers to proliferation 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?**

**M E G A W A T T S  
+ M E G A T O N S**

**The Future of Nuclear Power and Nuclear Weapons**

**M E G A W A T T S + M E G A T O N S**  
**RICHARD L. GARWIN + GEORGES CHARPAK**



**Chicago RICHARD L. GARWIN + GEORGES CHARPAK**

Published by Alfred A. Knopf October 2001  
and by University of Chicago Press 2002

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/t.
- 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.
- Ultimately, when economical, a breeder and its necessary processing and refabrication cycle—10 to 20 times
- Nonproliferation—another built-in cost. Assured fuel cycle option for many users.

## **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.

**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:**

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

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

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October 3, 2005  
(Via Email to letters at iht.com)

Editor  
International Herald Tribune  
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FRANCE

Dear Letters Editor,

*This is a proposed Op-Ed for the Herald Tribune, in view of the September 8, 2005 article by Elizabeth S. Rosenthal and, especially, the editorial in The New York Times.*

*The problem is that the report of the Chernobyl forum was deliberately misleading, and both the New York Times and the IHT simply reported its straight reporting on this report that was intended, itself, to deceive.*

The headline of The New York Times 09/08/2005 editorial, "Chernobyl's Reduced Impact," indicated that the consequences of Chernobyl are now understood to be substantially less serious than previously estimated.

Unfortunately, although The New York Times is sometimes alert for spin and deception, the writer missed this one, long in the making. The text of the editorial in fact quotes the deceptive report accurately, in indicating that the 4000 expected deaths are among the radiation workers and those most highly exposed. But the report and the editorial (and particularly the headline) ignored the much larger impact on the less heavily exposed population, which I have long estimated as 20,000 additional deaths from cancer.

The report from the Chernobyl Forum has much interesting summary material with which I agree, as indicated by the first sentence in the following paragraph taken from my book with Georges Charpak, "Megawatts and Megatons," published in 2001 and 2002, referring to UNSCEAR (the UN Scientific

Committee on the Effects of Atomic Radiation) and "Sv" (the abbreviation for "sievert" -- a unit of human exposure to X-rays or other ionizing radiation).

*We have seen that widespread disease attributed to the Chernobyl disaster could not in fact have been caused by radiation. On the other hand, the nuclear industry's reluctance to take seriously the 24,000 cancer deaths that we expect as a result of Chernobyl is reminiscent of the tobacco firms in their ludicrous and deceptive charade of maintaining, until 1997, that nicotine was not addictive. The nuclear industry and official bodies would benefit from honesty in this matter. For example, in UNSCEAR 1993 (p. 23) we find this candid statement regarding Chernobyl: "The collective effective dose committed by this accident is estimated to have been about 600,000 man-Sv." But in*

*UNSCEAR 2000 there is no overall collective dose estimated--only (vol. II, p. 486) that the "estimated lifetime effective dose" for Belarus, the Russian Federation, and Ukraine totals about 60,000 man-Sv. Ignoring the dose to the rest of the world is not progress.*

Similar analysis is contained in our book just published October 6, 2005, in French, "De Tchernobyl en Tchernobyls," (p. 251).

A long-awaited report from the National Academy of Sciences' Board on the Effects of Ionizing Radiation, BEIR VII has been available at [www.nap.edu](http://www.nap.edu) since July, 2005. The BEIR VII report judges that each dose of whole-body radiation causes a lethal cancer at the rate of 0.04 cancer deaths per Sv of exposure.



Specifically (p. 15 of BEIR VII at [www.nap.edu/books/030909156X/html/15.html](http://www.nap.edu/books/030909156X/html/15.html)) reads "... we predict that approximately one individual in 1000 would develop cancer from an exposure to 0.01 Sv. As another example, approximately one individual in 100 persons would be expected to develop cancer from a lifetime (70 years) exposure to low-LET natural 'background' radiation (that) excludes radon and other high LET radiation. Because of limitations in the data used to develop risk models, risk estimates are uncertain, and estimates that are a factor of two or three larger or smaller cannot be excluded."

Some argue that such small doses, if not strictly zero, are de minimus and should not be taken into account. I can give an example. If I take one cent from each of the 300 million Americans, it can hardly be imagined that this would affect the

standard of living, but I would as a result gain \$3 million. I would be highly motivated to do that. And if I could do it, so would many others, and how much would be left of our incomes?

A radiation dose of 600,000 person sieverts, corresponding to 24,000 expected deaths might be figured to cause damage to the overall population at the rate of one million dollars per premature death, or perhaps \$24 billion. And although it is impossible to identify these 24,000 among the many tens of millions of people who would die from similar cancers from natural causes over the same period, those deaths are nevertheless a consequence of the radiation release. In order to minimize such accidents, the principle of "polluter pays" is quite reasonable.

In any case, the current Chernobyl Forum report totally ignores this dose without even making the argument that its consequences are zero or should be neglected.

As a physicist long involved with nuclear weapons and nuclear power, I can only speculate why the organizations of the Chernobyl Forum found common cause in putting the 600,000 person-Sv radiation dose into the memory hole. With the United States about to assume much of the burden of the consequences of Katrina, some of these influences are particularly poignant. Russia, Belarus, and Ukraine may well feel that they are suffering an undue burden in supporting the Chernobyl "victims", when there are many other individuals and causes equally deserving of public support in their countries. The nuclear power industry would be much

encouraged if a \$24 B liability were somehow written down to \$4 B, not only for this event but for future accidents.

My own view is that the industry should face honestly and objectively these potential costs associated with their technology, and make the argument, which I support, that the overall benefits to society and to the environment of nuclear power outweigh even the consequences of Chernobyl.

Sincerely yours,

Richard L. Garwin

The writer is a physicist, a recipient of the National Medal of Science and the Enrico Fermi Award, and a member of the U.S. National Academy of Sciences, National Academy of Engineering, and Institute of Medicine. See biography at [www.fas.org/RLG/](http://www.fas.org/RLG/)  
RLG:jah:5276EIHT:100305EIHT

