Detonation of a Single 10-kiloton Terrorist Explosive in a City

by

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At the session of the
Permanent Monitoring Panel on Mitigation of Catastrophic Risks
PMP-MCR during the Planetary Emergencies week

August 18, 2022 at 16:00 CET
Via Zoom rather than in Erice


Summer 2010
NUCLEAR DANGERS
The BRIDGE
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Siegfried S. Hecker, Sean C. Lee, and Chaim Braun
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Brian Radzinsky and George Perkovich
A Nuclear Explosion in a City or an Attack on a Nuclear Reactor
Richard L. Garwin
Reducing the Consequences of a Nuclear Detonation: Recent Research
Brooke Buddemeier
Medical Preparedness and Response to Nuclear Terrorism
Georges C. Benjamin
Radiological Terrorism: First Responders and Communicating Risk
John F. Ahearne
Health Aspects of a Nuclear or Radiological Attack
Thomas S. Tenforde, David A. Schauer, Ronald E. Goans, Fred A. Mettler Jr., Terry C. Pellmar, John W. Poston Sr., and Tammy P. Taylor
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Should begin with this issue of the U.S. National Academy of Engineering quarterly,

NUCLEAR DANGER, for the National Academy of Engineering in *The Bridge*,Vol. 40, No. 2, Summer 2010. https://www.nae.edu/File.aspx?id=19815 From that site one can download a 1.93 MB PDF of the entire issue. Unfortunately, color has not been included in these versions of Vol. 40, except for the cover page.

In particular, in that 2010 publication;

[1] A Nuclear Explosion in a City or an Attack on a Nuclear Reactor, by Richard L. Garwin

[2] Reducing the Consequences of a Nuclear Detonation: Recent Research, by Brooke Buddemeier

I summarize my 2010 article, adding what is now ubiquitous and would be helpful under the terrible circumstances in the minutes and hours following even a single terrrorist nuclear explosion in one modern city. Much of this was included in my August 20, 2011 Erice talk,

[3] "Learning More from Fukushima Dai-ichi," by R.L. Garwin. Presented at Erice, Sicily, International Seminars on Planetary Emergencies and Associated Meetings - 44th Session, *The Role of Science in the Third Millenium*, August 20, 2011.

FIGURE 1 Hiroshima in October 1945. Iconic photo taken by U.S. Navy personnel and signed by the captain of the B-29 bomber that released the bomb.

Everyone prefers to avoid a terrorist nuclear explosion rather than to partially mitigate the consequences, but as with autombile accidents, every society has created emergency medical facilities to prevent some deaths and to repair damages to the victims.

A terrorist nuclear explosion is not a "lesser included case" of nuclear war; because the rest of the country and the state or prefecture would be untouched, there are resources available, in prinicple, to increase substantially the number of survivors, if the fallout pattern can be mapped in some detail, and advisories tailored to the observations generated and communicate directly to the populace.

[From 1]: A more modern description appeared in a 2006 RAND paper for the U.S. Department of Homeland Security (DHS), which posited a 10-kiloton nuclear explosion in a cargo container in Long Beach harbor. Because the harbor region has relatively low population density, only about 60,000 deaths were predicted. Nevertheless, about 6 million people would be evacuated, and losses would amount to $1 trillion. The paper included graphics showing the range-to-effect for blast effects, burns, and prompt radiation, as well as the contours of the lethal fallout area (Meade and Molander, 2006). The area exposed to near-lethal fallout levels of 300 rem would be about 30 km^2, with the orientation of the fallout pattern dependent on the winds aloft.

[From 1]: ... though there are some unknowns and variations, the broad outlines are clear. The downtown area, about one mile in radius, would be obliterated. Just outside the area leveled by blast, people wounded by flying debris, fires, and intense radiation would stand little chance of survival. Emergency workers would not get to them because of the intense radiation, and in any event, their burns and acute radiation exposure would require sophisticated and intensive medical care to offer any chance of survival. Further downwind from the detonation point, a plume of

radioactive debris would spread. Its shape and size would depend on wind and rain conditions, but within one day, people within five to 10 square miles who did not find shelter or flee within hours would receive lethal radiation doses.

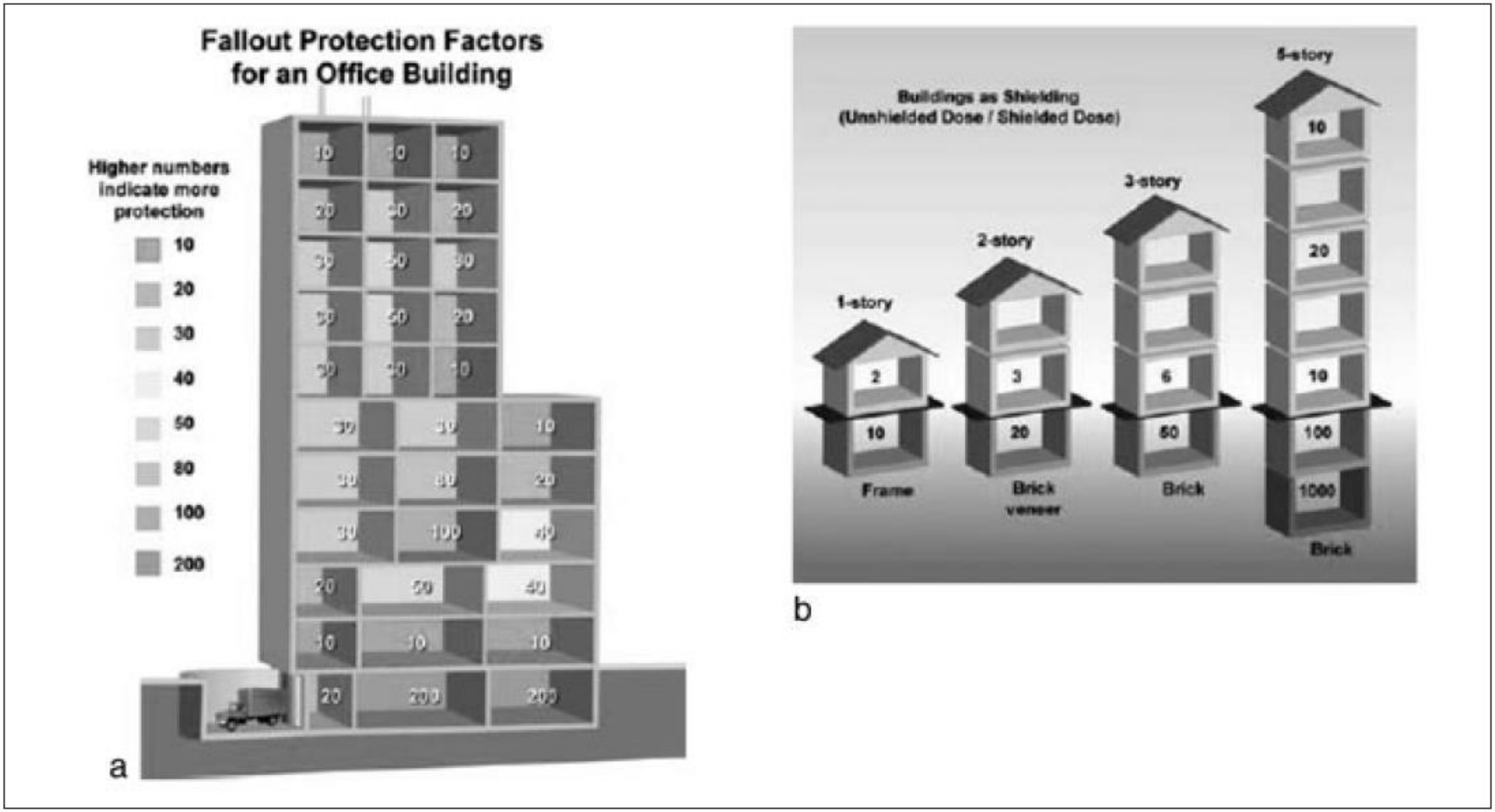
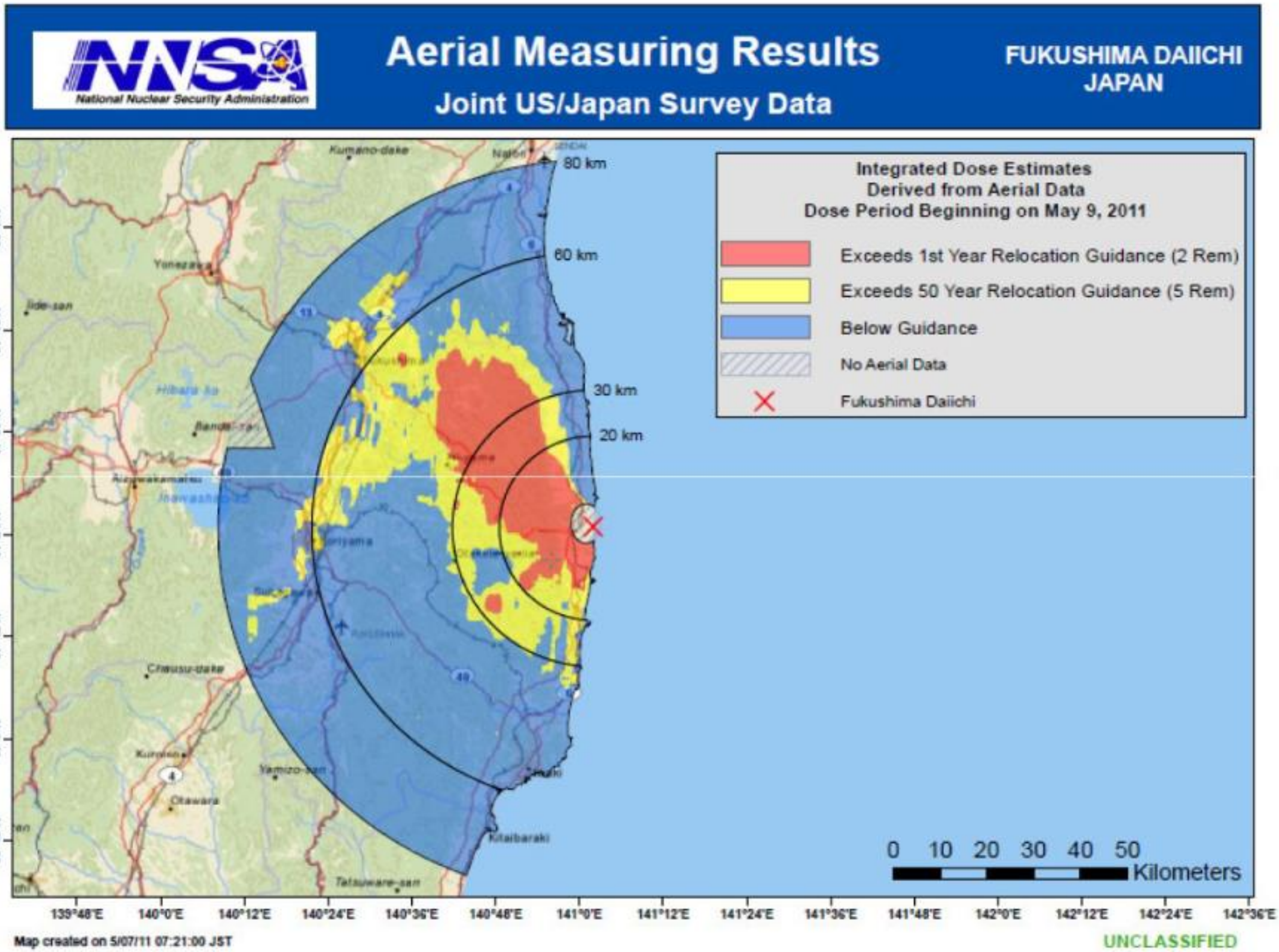


FIGURE 3 Fallout protection factors for occupants of high-rise and low-rise buildings. (3a) Fallout protection factors: numbers represent a dose reduction factor. A dose reduction factor of 10 indicates that a person in that area would receive 1/10 the dose of a person in the open. (3b) Building as shielding: numbers represent a dose reduction factor. A dose reduction factor of 200 indicates that a person in the area would receive 1/200 the dose of a person out in the open. Source: Homeland Security Council, 2009.

Figure 3 provides the kind of information that can be life saving, if known to the individuals, that could be generated automatically, in principle, by the use of elementary AI and Geographic Information Systems – GIS -- that have been widely used in societies for more than a decade.

On 11 March 2011, following an intense offshore earthquake and with a site-wide electrical power failure induced by flooding from the resulting tsunami that took some 23,000 lives in the northeast coastal section of Japan, the fuel elements of three of the six boiling water reactors at Fukusima Daiichi melted down after the reactors properly shut down during the earthquake. After some days, to avoid growing overpressure in the containment of the individual reactors from the contnuing evolution of fission product decay heat in the recently fissioning uranium oxide fuel, and with Herculean efforts on the part of the reactor operators, they released highly radioactive water vapor and hydrogen to the atmosphere. This created an unknown distribution of life-threatening and cancer-inducing radioactivity on the ground, to more than 50 km from the reactor site.

I was one of a few non-governmental technical people asked by U.S. Secretary of Energy Steven Chu, to support him in trying to help our Japanese colleagues mitigate the result of the melt downs. My [3] benefitted from that involvment.



Learning More From Fukushima Dai-ichi

Richard L. Garwin

In resonding to the U.S. National Academy of Engineering's request for a paper about a nuclear explosion in a city, I was not informed of the context of the special issue of *The Bridge* and especially not that Buddemeier would provide an article as well. He was much better informed than was I about U.S. Government's capabilities, and I suggest in 2022 following his later publications for reliable information.

I note major differences betwee my topic here and the "real-world" massive radiation releases at Fukushima Daiichi in 2011, Cherynoby in 1986, and Three Mile Island (Pennsylvania) in 1979, on the one hand, and a nuclear explosion on the the other. At 1 kg of fission corresponding to 17 kilotons of energy release, a 10 kt explosion liberates 590 gram of fission products, most of which are short lived and, as a result, a greater contributor to hazard before or during evacuation. The gamma-ray dose from this impulse of fission falls as $(t\text{-}t_o)^{-1.2}$ whereas the dose after shutdown of a steady-power reactor falls as the **Wigner-Way formula**[1]

$$P_d(t) = 0.0622\ P_o\left[t^{-0.2} - (t_o + t)^{-0.2}\right]$$

:

- $P_d(t)$ = thermal power generation due to beta and gamma rays,
- P_0 = thermal power before the shutdown,
- t_0 = time, in seconds, of thermal power level before the shutdown,
- t = time, in seconds, elapsed since the shutdown.

[1] https://www.nuclear-power.com/nuclear-power/reactor-physics/reactor-operation/residual-heat/decay-heat-decay-energy/

Thus, sheltering in nearby buildings where one is not exposed to the fallout of most of the bomb residue that has been mixed with thousands of tons of materials because of the surface detonation of the nuclear explosive – completely different from Hiroshima and Nagasake, where the detonation was at 580 m and 500 m, respective, so that no ground material was excavated by the bomb and there was essentially no local fallout – the radiation being only prompt radiation from the nuclear explosion, and from the resulting kilogram of fission products as the cloud accelerated upward.

Post-explosion sheltering from radiation would have done no good for these 1945 wartime explosions planned to destroy structures at the maximum distance rather than for surface detonation. But for a terrorist surface detonation, with the rapid initial decay compared with a reactor release, sheltering with a protection factor of 10 in the basement of a frame house, or even a PF 2 above ground inside a one-storey house would be highly beneficial; and the PF of 10 or more anywhere (except the top floor) in an office building would allow even longer optimum shelter time and further reductioin of casualties amont those surviving intial blast.

WHAT TO DO?

From the viewpoint of the PMP-MCR, we need to encourage govenrments to define and share, in advance, country-wide programs to provide national response within minutes, hours, and days to the possibility of a surface detonation of a nuclear explosive in a city. I have suggested the few approaches that could help to halve the number of deaths from local fallout, that are likely to dominate deaths in such a case. This includes a fleet of few-kg drones with simple detectors of nuclear radiation, flying pre-generated adaptive mapping paths at an altitude of a few hundred meters, to rate "escape routes" according to lethality from the fallout deposition.

My [3] has details of a drone candidate for aerial mapping, but consumer technology such as the camera drone platform form DJI.com have evolved since 2011, with quadcopters and controls in the $1,000 range. That is only the basis for a radiation mapping system.

The creation of a number of competitive apps, downselected to a current one and a potential successor that can operate in parallel, would allow anyone with a smart phone to get actionalble guidance about the emergency – in this case the life-destroying nuclear explosion. Such an app would be of great value in other environmental and medical emergencies.

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