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President's Special Session

Low-Level Radiation and its Implications for Fukushima Recovery

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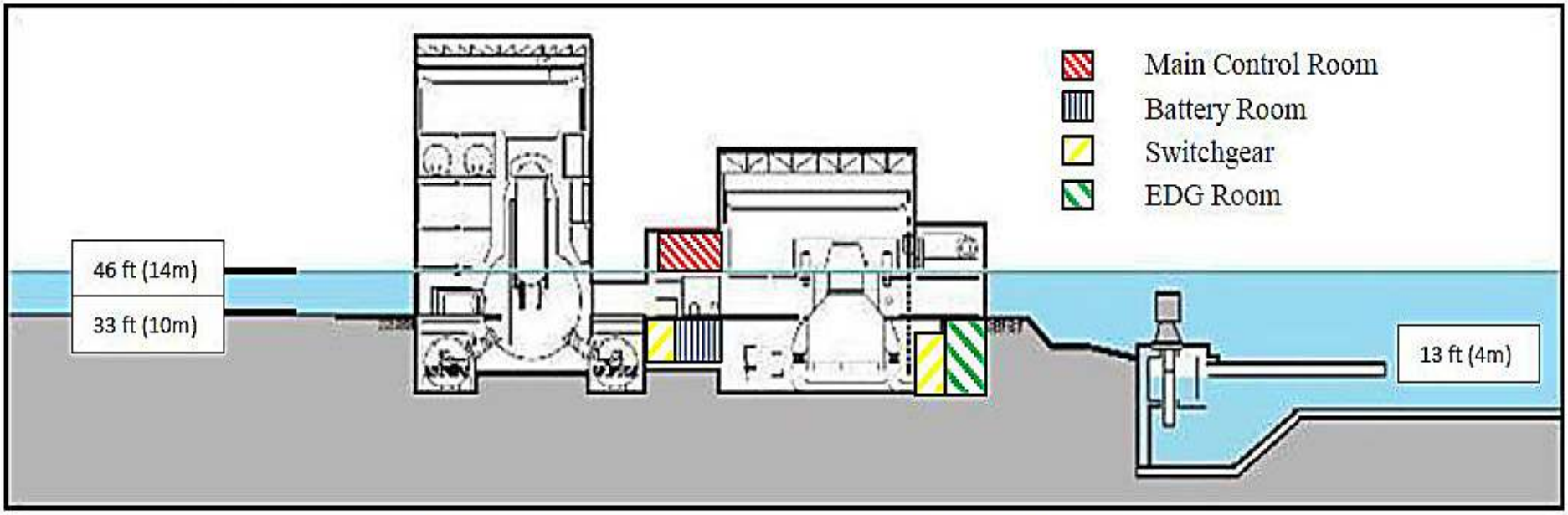
My Background

- BASc-Eng, Engineering Physics, University of Toronto, 1964
- MSc and DSc, Nuclear Sciences, Israel Institute Technology, 1971
- Technical Manager, Seforad Radiation Detectors Ltd, 1971-74
- Design & Eng Manager at AECL 1974-2000; many CANDU reactors
- Engineering Services, Cuttler & Associates Inc, 2000-2012
- **Societies:** ANS since 1971; CNS since 1979, president 1995/6; American Physical Society; Health Physics Society; Canadian Radiation Protection Association; International Dose Response Society; Professional Engineers Ontario

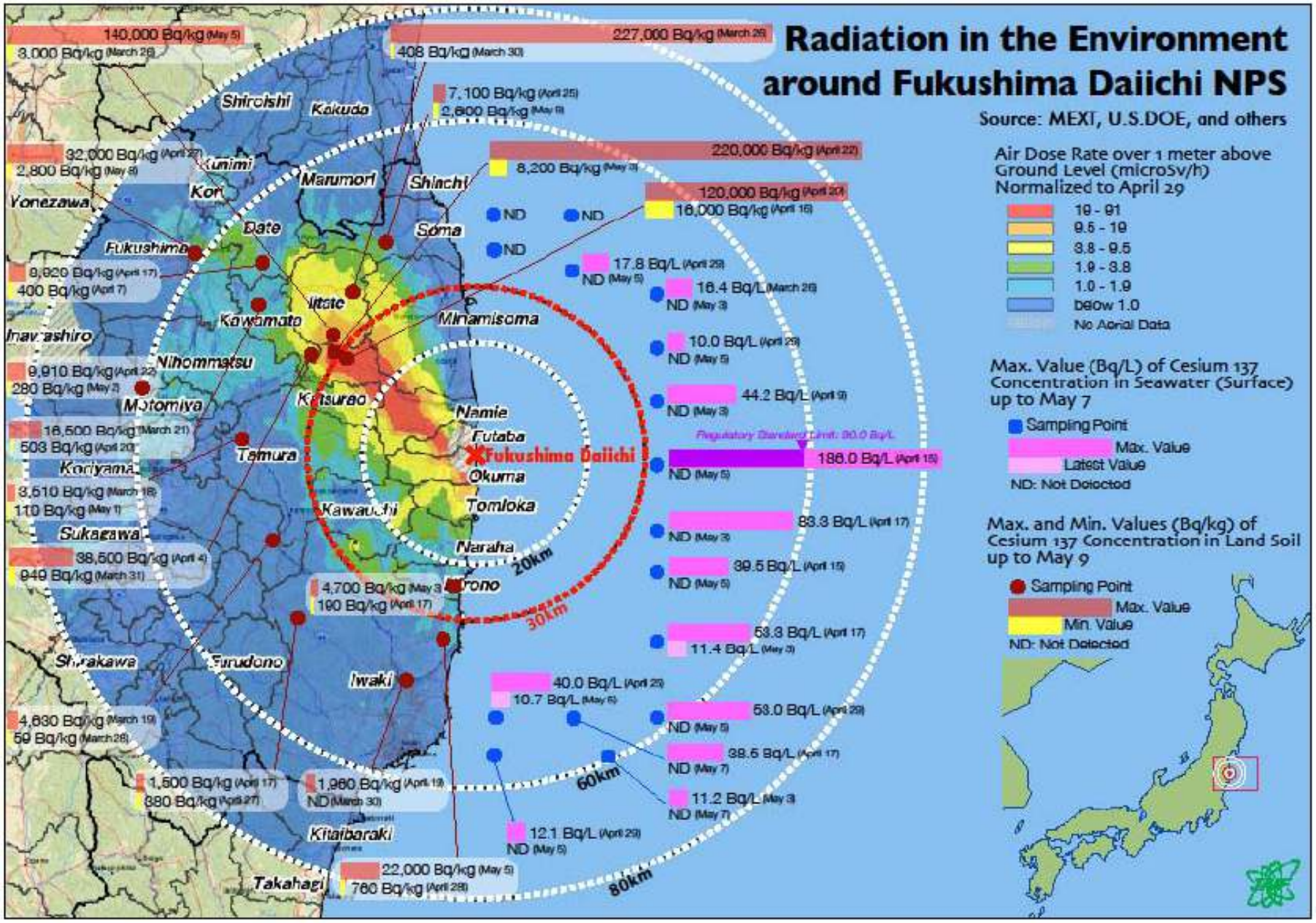
Main Points

- Fukushima radiation level is comparable to high natural background areas; UNSCEAR
- Radiation protection standard in 1920s was a safe tolerance dose: 680 mSv/year
- Radiation-induced DNA damage rate due to 1 mSv/year is more than 6 million times <u>lower</u> than spontaneous DNA damage rate, -- negligible in comparison with natural rate

Tsunami Inundation



91 µSv/h x 8766 h/y = 798 mSv/y



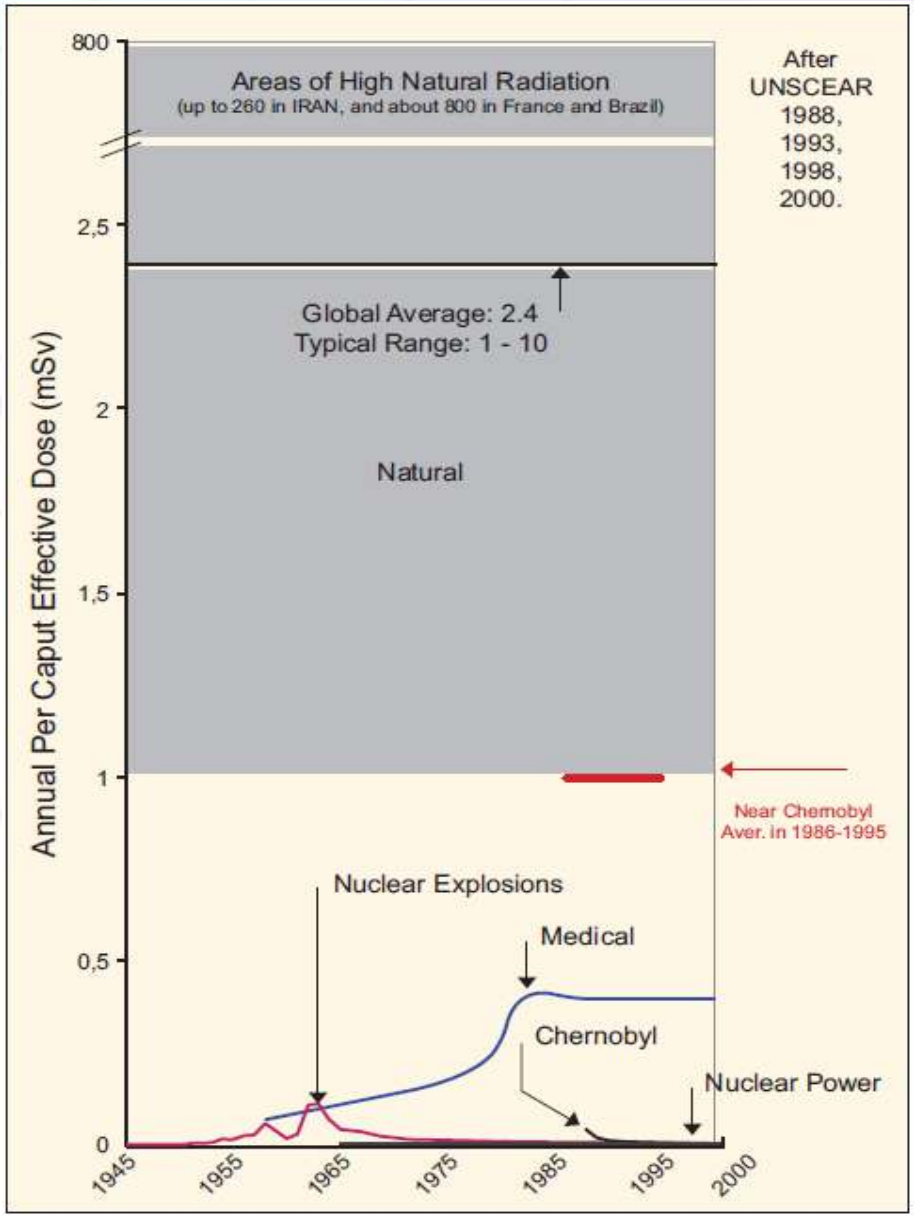


Figure 1. Worldwide and local (near Chernobyl and in areas of high natural radiation) average annual radiation doses from natural and man-made sources. Based on UNSCEAR (1988, 1993, 1998, 2000b).

Radiologists used safe tolerance dose rate
from 1920 to 1955

The level was **0.2 roentgen (R) per day** in 1931, based on applying a factor of 1/100 to the commonly accepted average erythema dose of 600 R, to be spread over one month (30 days).

In September 1924, at a meeting of the American Roentgen Ray Society, Arthur Mutscheller was the first person to recommend this “tolerance” dose rate for radiation workers, a dose rate that could be tolerated indefinitely.

This level is equivalent to **680 mSv/year**.

Mortality of 1338 British Radiologists 1897-1976

Cause of death	Observed (O) and expected (E) numbers of deaths					
	Entry prior to 1921			Entry after 1920		
	O	E	O/E	O	E	O/E
All causes	319	(1) 334.42	0.95	411	541.77	0.76***
		(2) 308.03	1.04		461.14	0.89*
		(3) 327.97	0.97		469.97	0.87**
All neoplasms	62	(1) 49.11	1.26*	72	114.93	0.63***
		(2) 43.07	1.44**		91.07	0.79*
		(3) 35.39	1.75***		68.65	1.05
Other causes	257†	(1) 285.31	0.90*	339†	426.84	0.79***
		(2) 264.96	0.97		370.07	0.92
		(3) 292.58	0.88*		401.32	0.84**

(1) Based on rates for all men in England and Wales.
(2) Based on rates for social class 1.
(3) Based on rates for medical practitioners.
† includes one death with unknown cause.

*P < 0.05
**P < 0.01
***P < 0.001
One sided in direction of difference.

Smith and Doll Study published 1981

1981 British Radiologists Study

- After radiation exposures of the British radiologists were limited below the safe “tolerance dose” level in 1921, the cancer mortality of the British radiologists decreased.
- Their cancer mortality decreased from about 44% above the cancer mortality of Social Class 1 to about 21% below the Social Class 1 cancer mortality.
- Their mortality from “other causes” also decreased.

Calabrese 2009, ICRP Road to Linearity

Three drivers for change from 'safe level' to low-dose linearity

- Theory of eugenics (pseudoscience) postulated a crisis of the gene pool leading to the deterioration of the human race (geneticists very keen to protect population gene pool)
- Muller's 1927 paper in *Science* radiation-induced mutations (fruit flies; dose > 2.7 Gy!)
- Fallout radiation scare, promoted by renowned scientists to stop the nuclear arms race

By 1955 ICRP policy changed due to Muller Nobel Prize, political activities

- Rejected permissible dose concept (no safe radiation level)
- Radiation-induced DNA damage is linear with dose, cumulative (no repair) and harmful
- Adopted concept of cancer and genetic risks, kept small compared to other risks in life
- "Since no radiation level higher than natural background can be regarded as absolutely 'safe,' the problem is to choose a practical level that, in the light of present knowledge, involves negligible risk."

As Low As Reasonably Achievable (ALARA)

Lauriston Taylor in 1980

- The founder and former president of the NCRPM denounced using the LNT model to calculate annual deaths from x-ray diagnoses:
- “These are deeply immoral uses of our scientific heritage.”
- “No one has been identifiably injured by radiation while working within the first numerical standards set by the ICRP in 1934.”

RADIATION RESEARCH **124**, 242–245 (1990)

COMMENTARY

Spontaneous DNA Damage and Its Significance for the "Negligible Dose" Controversy in Radiation Protection

DANIEL BILLEN[1]

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BILLEN, D. Spontaneous DNA Damage and Its Significance for the "Negligible Dose" Controversy in Radiation Protection. *Radiat. Res.* **124**, 242–245 (1990).

One of the crucial problems in radiation protection is the reality of the negligible dose or *de minimus* concept (*1–4*). This issue of a "practical zero" and its resolution is central to our understanding of the controversy concerning the existence of a "safe" dose in radiological health. However, for very low levels of environmental mutagens and carcinogens including low doses of low-LET radiations (less than 1 cGy or 1 rad), spontaneous or endogenous DNA damage may have an increasing impact on the biological consequences of the induced cellular response. It is this issue that is addressed in this communication.

The following discussion is intentionally limited to a comparison of low-LET radiation since its effects are due primarily to indirect damage in cellular DNA brought about modification events occur per hour in each mammalian cell due to intrinsic causes.

The current radiation literature will be interpreted to show that ~100 (or fewer) measurable DNA alterations occur per centigray of low-LET radiation per mammalian cell. Therefore every *hour* human and other mammalian cells undergo at least 50–100 times as much spontaneous or natural DNA damage as would result from exposure to 1 cGy of ionizing radiation. Since background radiation is usually less than 100–200 mrem (1–2 mSv)/y, it can be concluded, as discussed by Muller and Mott-Smith (*15*), that spontaneous DNA damage is due primarily to causes other than background radiation.

"INTRINSIC" OR "SPONTANEOUS" DNA DAMAGE

DNA is not as structurally stable as once thought. On the contrary, there appears to be a natural background of chemical and physical lesions introduced into cellular DNA by thermal as well as oxidative insult. In addition, in the

Daniel Billen in Radiation Research 1990

DNA is not as structurally stable as once thought

Natural background of lesions: thermal and oxidative insult

Cells have mechanisms to bypass or repair these lesions

- **Spontaneous rate = 2 x 10^5 DNA alterations/cell/day**

- Radiation-induced: 10-100 DNA alterations per cell/**cGy**

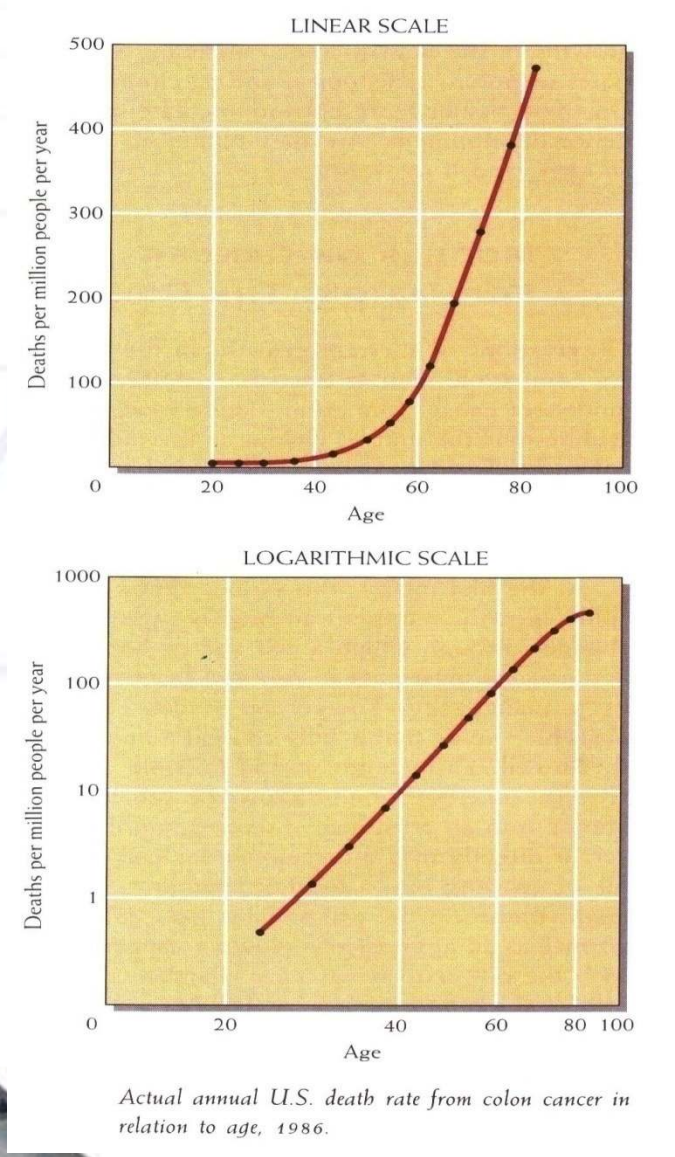
1 mGy/year radiation < 3 x 10^{-2} DNA alteration/cell/day

This is > **6 million times** lower than spontaneous rate!!!

So radiation is not a significant cause of cancer.

We've known this for more than 20 years!

Cancer death rate rises exponentially with age

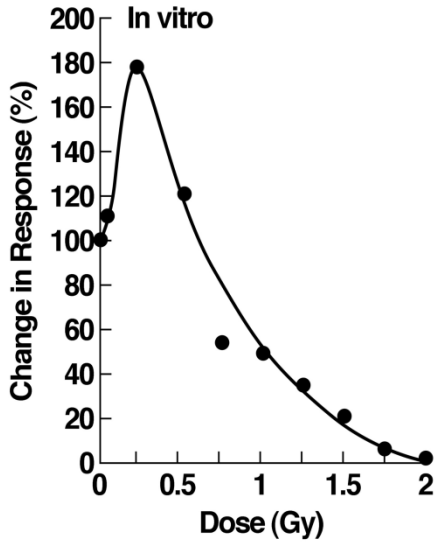


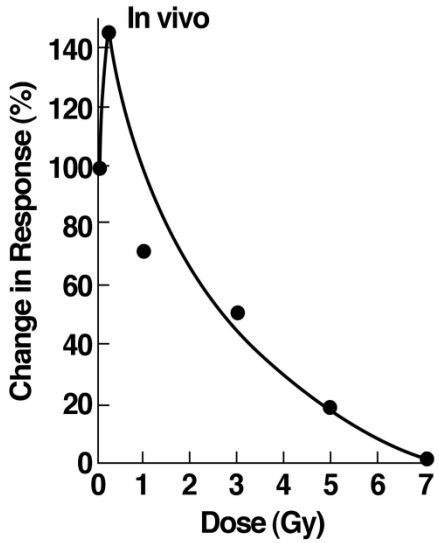
Actual annual U.S. death rate from colon cancer in relation to age, 1986.

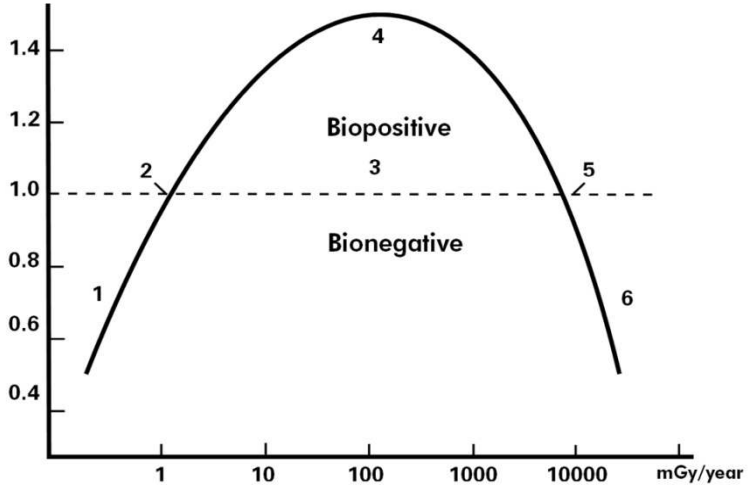
Main cancer cause is <u>spontaneous</u> DNA damage due to free radicals, reactive oxygen species (ROS), thermal effects

- **Mutations add up**
- **Defences get old**

Radiation Hormesis







Organisms are stressed: physical, chemical, biological, radiation

Organisms adapt to stress

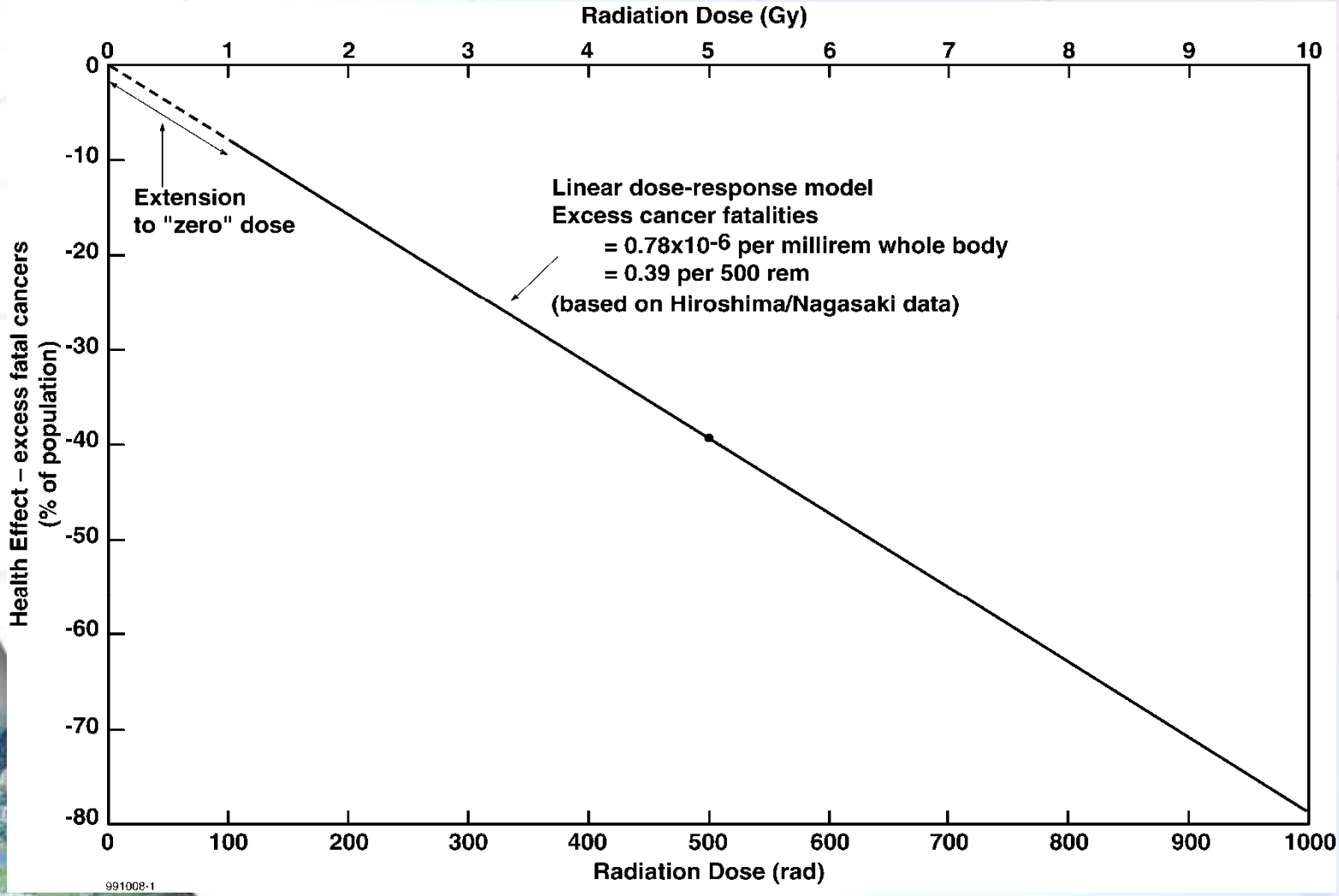
Radiation modulates organism's defenses

<u>Low</u> radiation dose/dose-rate <u>reduces</u> cancer incidence because it <u>stimulates</u>:

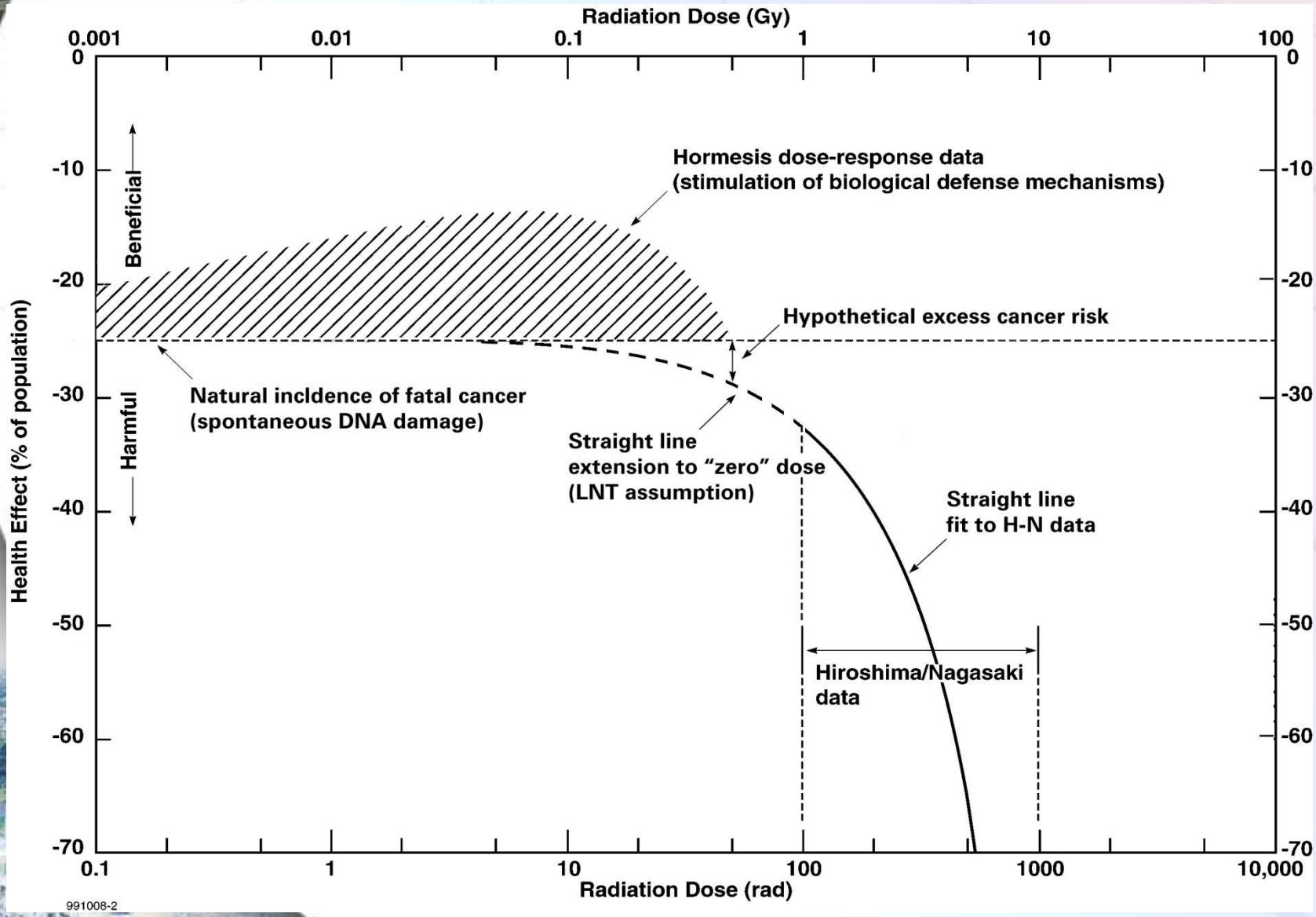
- prevention of DNA damage
- repair of DNA damage
- removal of damaged cells and <u>removal</u> of cancer cells

<u>High</u> radiation dose/level has <u>opposite</u> effects

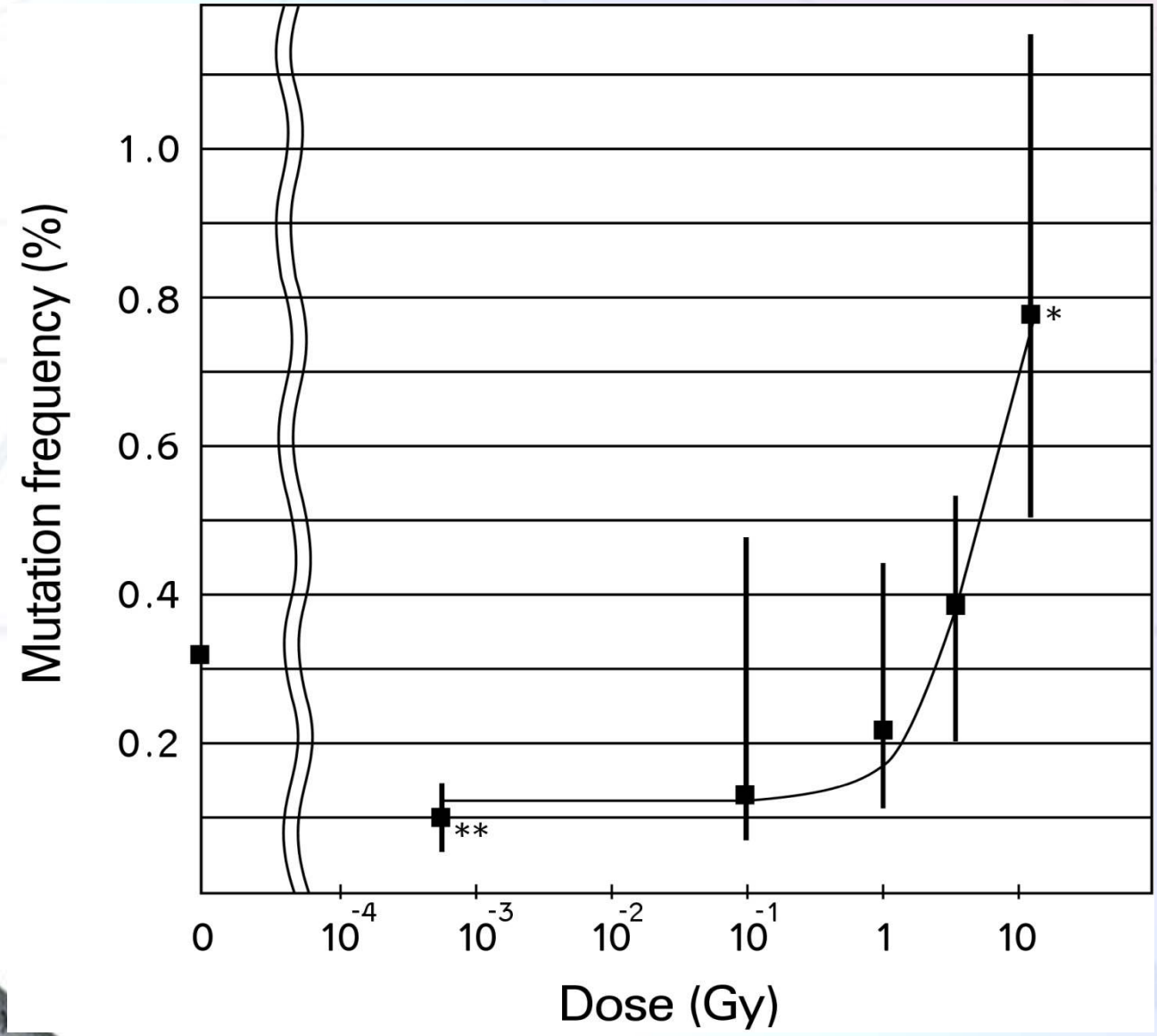
LNT Assumption



LNT Assumption (dose on log scale)



Mutation Frequency in Fruit Flies: Japanese vs. Muller



ScienceDaily

Your source for the latest research news

http://www.sciencedaily.com/releases/2011/09/110920163320.htm

No Safe Level of Radiation Exposure? Researcher Points to Suppression of Evidence On Radiation Effects by Nobel Laureate

ScienceDaily (Sep. 20, 2011) — University of Massachusetts Amherst environmental toxicologist Edward Calabrese, whose career research shows that low doses of some chemicals and radiation are benign or even helpful, says he has uncovered evidence that one of the fathers of radiation genetics, Nobel Prize winner Hermann Muller knowingly **lied** when he claimed in 1946 that there is **no** safe level of radiation exposure.

Calabrese's interpretation of this history is supported by letters and other materials he has retrieved, many from formerly classified files. Published findings in three articles, in scientific journals

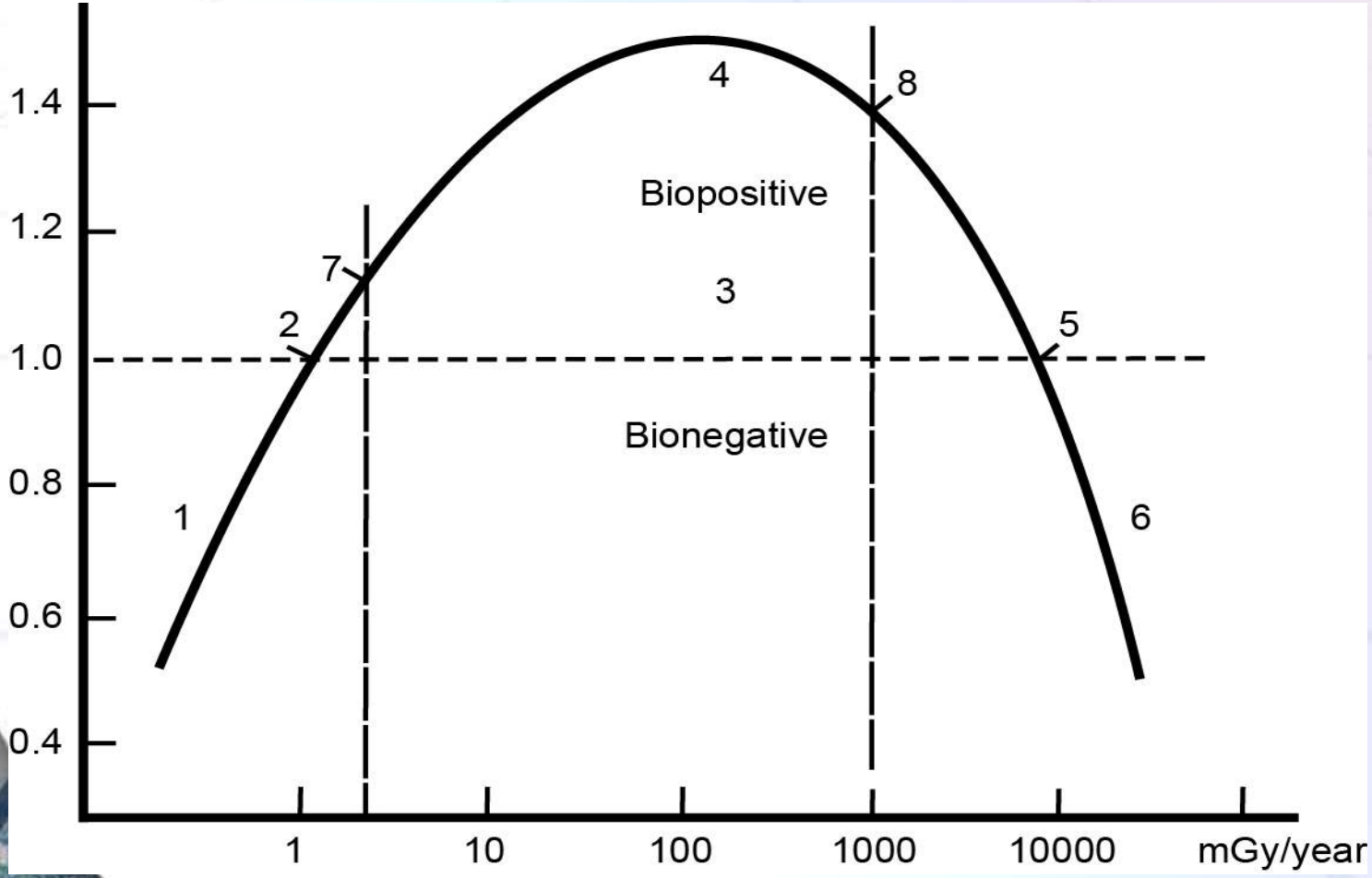
Radiation Exposures of 18,846 Plant Workers 2011 March 11 to December 31

Workers	vs Dose since Mar 11
135	100 to 150 mSv
23	150 to 200 mSv
3	200 to 250 mSv
6	309 to **678** mSv

167 total, more than 100 mSv

678 mSv vs tolerance dose 680 mSv/year

Radiation Stimulates Biological Defences



We should use As High As Reasonably Safe – AHARS instead of ALARA

Radiation Protection Activity

Recommendations

- Scientific societies should organize events to discuss radiation and health
- Regulatory bodies and health organization should examine the scientific evidence
- Stop calculating nuclear safety cancer risk
- Stop regulating harmless radiation sources
- Develop public communication programs
- **Raise radiation level for evacuation from 20 to 1000 mSv/year**

“We should never waste a serious crisis”

“And what I mean by that is an opportunity to do things you think you could not do before.”

Rahm Emanuel: Feb 9, 2009

Fukushima crisis is the opportunity to change the ICRP’s protection concept from LNT-based cancer risk back to the safe “tolerance dose” concept of 1931