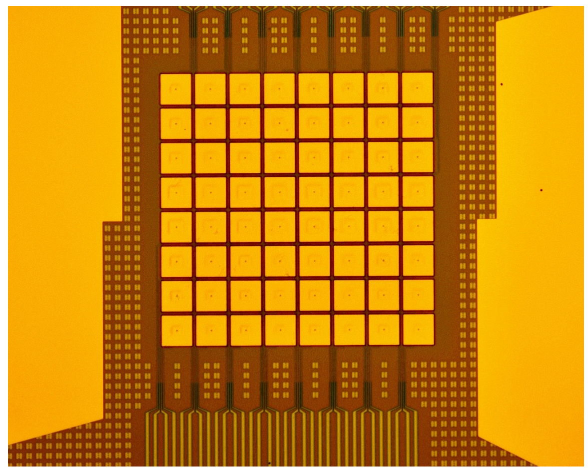

MIND THE GAP
AN ELEMENTARY SCIENTIFIC FALLACY
UNDERLIES THE THREE MILE ISLAND LOW-
LEVEL EXPOSURE PARADOX

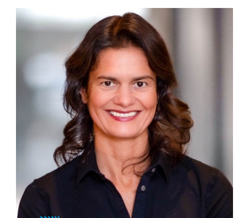
Biography & Acknowledgments

I work in quantum computing at a curious little organization known as the Laboratory for Physical Sciences in College Park, MD. I was previously at NASA GSFC, and Argonne National Laboratory before that.



My background is in superconducting detectors for astrophysics. This is a transition-edge sensor detector array for X-ray heliophysics that I designed and constructed at NASA.

COLORADO STATE UNIVERSITY



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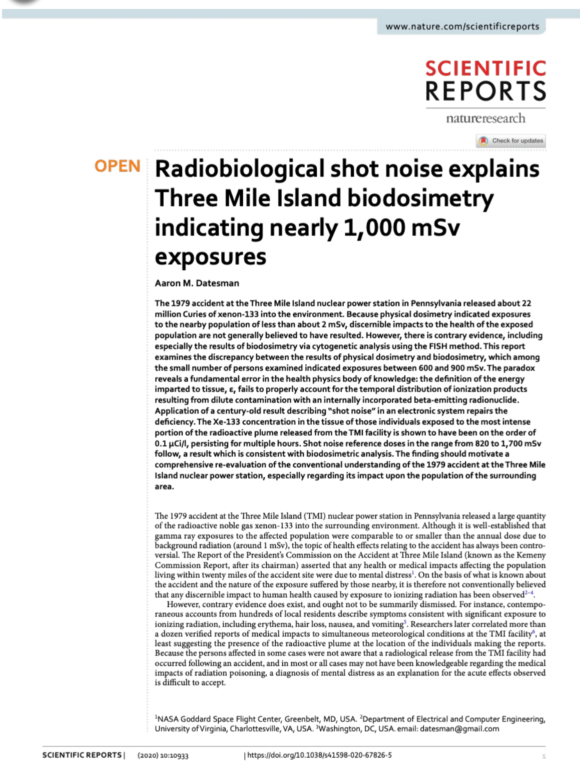
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Radiobiological shot noise explains Three Mile Island biodosimetry indicating nearly 1,000 mSv exposures

Aaron M. Datesman

The 1979 accident at the Three Mile Island nuclear power station in Pennsylvania released about 22 million Curies of xenon-133 into the environment. Because physical dosimetry indicated exposures to the nearby population of less than about 2 mSv, discernible impacts to the health of the exposed population are not generally believed to have resulted. However, there is contrary evidence, including especially the results of biodosimetry via cytogenetic analysis using the FISH method. This report examines the discrepancy between the results of physical dosimetry and biodosimetry, which among the small number of persons examined indicated exposures between 600 and 900 mSv. The paradox reveals a fundamental error in the health physics body of knowledge: the definition of the energy imparted to tissue, ε, fails to properly account for the temporal distribution of ionization products resulting from dilute contamination with an internally incorporated beta-emitting radionuclide. Application of a century-old result describing "shot noise" in an electronic system repairs the deficiency. The Xe-133 concentration in the tissue of those individuals exposed to the most intense portion of the radioactive plume released from the TMI facility is shown to have been on the order of 0.1 μCi/l, persisting for multiple hours. Shot noise reference doses in the range from 820 to 1,700 mSv follow, a result which is consistent with biodosimetric analysis. The finding should motivate a comprehensive re-evaluation of the conventional understanding of the 1979 accident at the Three Mile Island nuclear power station, especially regarding its impact upon the population of the surrounding area.

The 1979 accident at the Three Mile Island (TMI) nuclear power station in Pennsylvania released a large quantity of the radioactive noble gas xenon-133 into the surrounding environment. Although it is well-established that gamma ray exposures to the affected population were comparable to or smaller than the annual dose due to background radiation (around 1 mSv), the topic of health effects relating to the accident has always been controversial. The Report of the President's Commission on the Accident at Three Mile Island (known as the Kemeny Commission Report, after its chairman) asserted that any health or medical impacts affecting the population living within twenty miles of the accident site were due to mental distress[1]. On the basis of what is known about the accident and the nature of the exposure suffered by those nearby, it is therefore not conventionally believed that any discernible impact to human health caused by exposure to ionizing radiation has been observed[2–4].

However, contrary evidence does exist, and ought not to be summarily dismissed. For instance, contemporaneous accounts from hundreds of local residents describe symptoms consistent with significant exposure to ionizing radiation, including erythema, hair loss, nausea, and vomiting[5]. Researchers later correlated more than a dozen verified reports of medical impacts to simultaneous meteorological conditions at the TMI facility[6], at least suggesting the presence of the radioactive plume at the location of the individuals making the reports. Because the persons affected in some cases were not aware that a radiological release from the TMI facility had occurred following an accident, and in most or all cases may not have been knowledgeable regarding the medical impacts of radiation poisoning, a diagnosis of mental distress as an explanation for the acute effects observed is difficult to accept.

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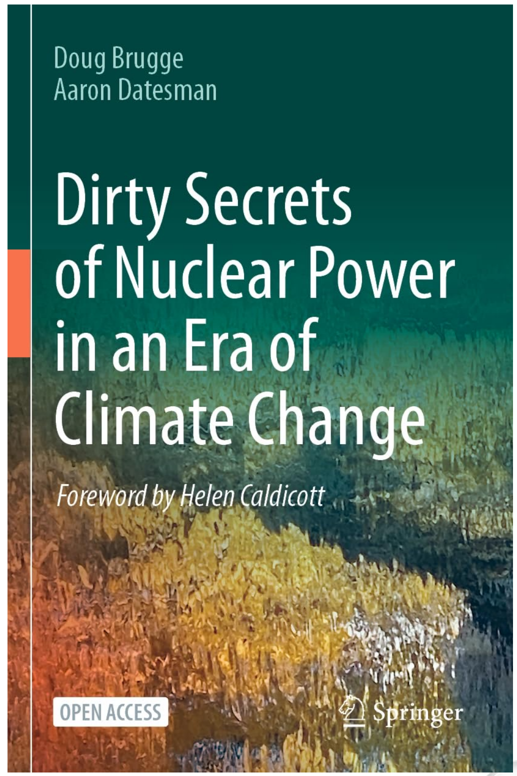
https://www.nature.com/articles/s41598-020-67826-5



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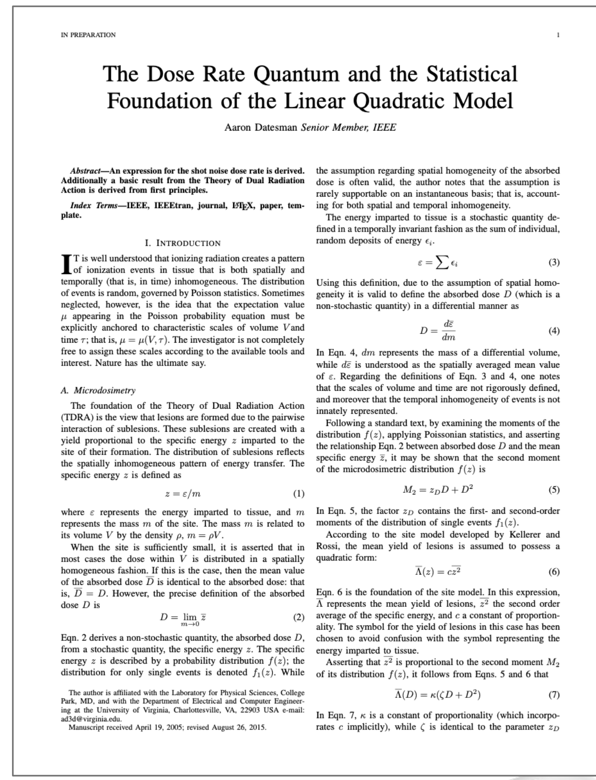
IN PREPARATION 1

The Dose Rate Quantum and the Statistical Foundation of the Linear Quadratic Model

Aaron Datesman *Senior Member, IEEE*

***Abstract*—An expression for the shot noise dose rate is derived. Additionally a basic result from the Theory of Dual Radiation Action is derived from first principles.**

***Index Terms*—IEEE, IEEEtran, journal, LaTeX, paper, template.**

I. Introduction

It is well understood that ionizing radiation creates a pattern of ionization events in tissue that is both spatially and temporally (that is, in time) inhomogeneous. The distribution of events is random, governed by Poisson statistics. Sometimes neglected, however, is the idea that the expectation value μ appearing in the Poisson probability equation must be explicitly anchored to characteristic scales of volume V and time τ; that is, $\mu = \mu(V, \tau)$. The investigator is not completely free to assign these scales according to the available tools and interest. Nature has the ultimate say.

A. Microdosimetry

The foundation of the Theory of Dual Radiation Action (TDRA) is the view that lesions are formed due to the pairwise interaction of sublesions. These sublesions are created with a yield proportional to the specific energy z imparted to the site of their formation. The distribution of sublesions reflects the spatially inhomogeneous pattern of energy transfer. The specific energy z is defined as

$$z = \varepsilon / m \quad (1)$$

where ε represents the energy imparted to tissue, and m represents the mass m of the site. The mass m is related to its volume V by the density ρ, $m = \rho V$.

When the site is sufficiently small, it is asserted that in most cases the dose within V is distributed in a spatially homogeneous fashion. If this is the case, then the mean value of the absorbed dose $\overline{D}$ is identical to the absorbed dose: that is, $\overline{D} = D$. However, the precise definition of the absorbed dose D is

$$D = \lim_{m \to 0} \overline{z} \quad (2)$$

Eqn. 2 derives a non-stochastic quantity, the absorbed dose D, from a stochastic quantity, the specific energy z. The specific energy z is described by a probability distribution $f(z)$; the distribution for only single events is denoted $f_1(z)$. While the assumption regarding spatial homogeneity of the absorbed dose is often valid, the author notes that the assumption is rarely supportable on an instantaneous basis; that is, accounting for both spatial and temporal inhomogeneity.

The energy imparted to tissue is a stochastic quantity defined in a temporally invariant fashion as the sum of individual, random deposits of energy ϵ_i.

$$\varepsilon = \sum \epsilon_i \quad (3)$$

Using this definition, due to the assumption of spatial homogeneity it is valid to define the absorbed dose D (which is a non-stochastic quantity) in a differential manner as

$$D = \frac{d\overline{\varepsilon}}{dm} \quad (4)$$

In Eqn. 4, dm represents the mass of a differential volume, while $d\overline{\varepsilon}$ is understood as the spatially averaged mean value of ε. Regarding the definitions of Eqn. 3 and 4, one notes that the scales of volume and time are not rigorously defined, and moreover that the temporal inhomogeneity of events is not innately represented.

Following a standard text, by examining the moments of the distribution $f(z)$, applying Poissonian statistics, and asserting the relationship Eqn. 2 between absorbed dose D and the mean specific energy $\overline{z}$, it may be shown that the second moment of the microdosimetric distribution $f(z)$ is

$$M_2 = z_D D + D^2 \quad (5)$$

In Eqn. 5, the factor z_D contains the first- and second-order moments of the distribution of single events $f_1(z)$.

According to the site model developed by Kellerer and Rossi, the mean yield of lesions is assumed to possess a quadratic form:

$$\overline{\Lambda}(z) = c\overline{z^2} \quad (6)$$

Eqn. 6 is the foundation of the site model. In this expression, $\overline{\Lambda}$ represents the mean yield of lesions, $\overline{z^2}$ the second order average of the specific energy, and c a constant of proportionality. The symbol for the yield of lesions in this case has been chosen to avoid confusion with the symbol representing the energy imparted to tissue.

Asserting that $\overline{z^2}$ is proportional to the second moment M_2 of its distribution $f(z)$, it follows from Eqns. 5 and 6 that

$$\overline{\Lambda}(D) = \kappa(\zeta D + D^2) \quad (7)$$

In Eqn. 7, κ is a constant of proportionality (which incorporates c implicitly), while ζ is identical to the parameter z_D

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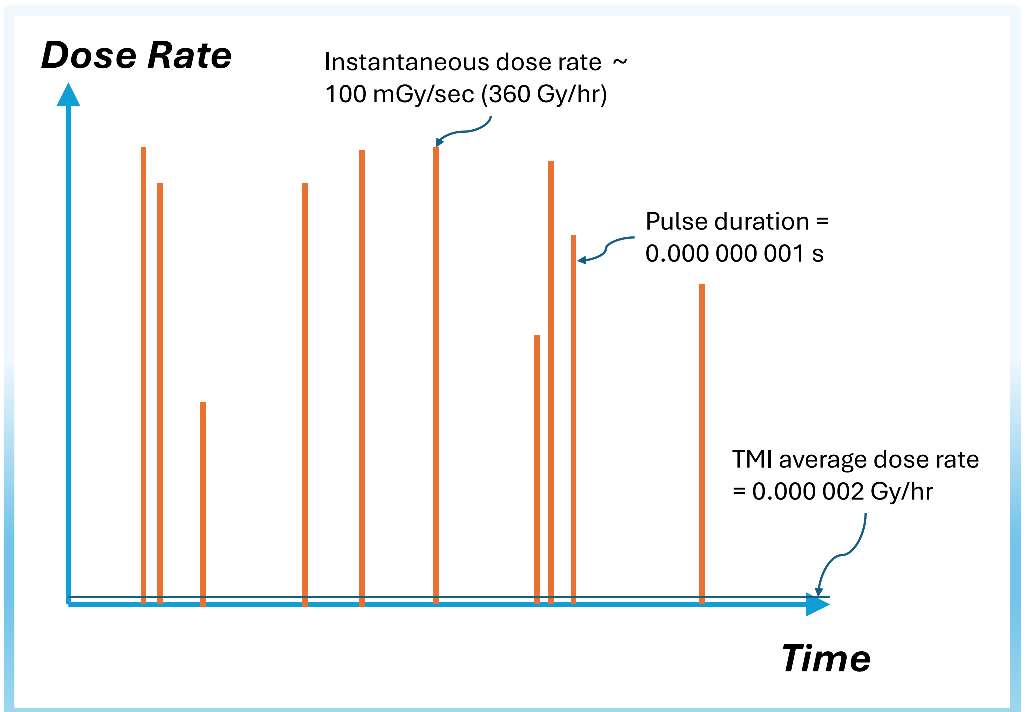
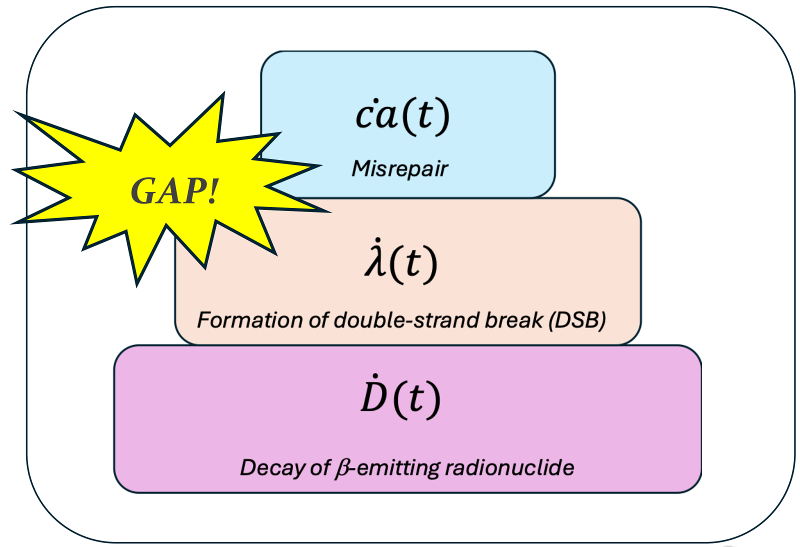
Available by request.

What am I going to tell you?

- Our scientific understanding of how low-level exposure to ionizing radiation causes injury is contrary to physical law. THERE IS NO SUCH THING AS A LOW DOSE. Any exposure is properly understood as a collection of high-dose rate exposures of very limited duration. The distinction is not semantic.
- There is a gap in our knowledge relating to DNA double strand breaks. The gap has existed for nearly fifty years (at least).
- Cytogenetics (counting chromosome aberrations) is a more reliable/less contested indicator of injury than epidemiology. We have shown that a definitive molecular cytogenetic investigation is still possible in the present day.
- The topic of Three Mile Island health effects is controversial because there is a tension between the magnitude of exposure (low level) and assessments of increased cancer incidence (and other impacts). There is no tension if the scientific fallacy and the knowledge gap are addressed.

The Fallacy: Improper Averaging





On YouTube: [“There is No Such Thing as a Low-Level Radiation Exposure”]

Chronology and Context

- In September 1979, shortly after the accident, the PA Department of Health TMI Advisory Panel for Health Research Studies recommended that a cytogenetic study of the exposed population be undertaken.

> emergency (unanimous vote). In addition to the TMI-5pc, several other studies were ongoing, including the POS and a cytogenetics study. The Panel officially voted to expand the current planned cytogenetics study of TMI-exposed individuals from 10K cells to 30–40K cells per data point (unanimous). Other informal recommendations

GAP!

- In 1982, citing an insufficient scientific understanding of DNA double strand breaks, the panel reversed its recommendation. The cytogenetic investigation was not conducted, and the knowledge gap was not addressed [1].

> "long-term childhood follow-up study" protocol should be developed. APHRS also revisited its earlier consideration of the cytogenetics study and in light of the uncertainty surrounding causes of DNA strand breakage, unanimously recommended that the cytogenetics study be conducted as a "reassurance" study, but not a scientific

- Nevertheless, a cytogenetic investigation was performed in 1994-95 by expert witnesses on behalf of the plaintiffs in the large *TMI Consolidated* lawsuit. Stable (unstable) chromosome aberrations were reported at 6x (10x) background levels, consistent with significant exposure to ionizing radiation.

- The cytogenetic results did not appear in the peer-reviewed literature until 2021 [2]. The authors of that work did not support the judgment of the original investigators that the observed frequencies of chromosome aberrations could be due to releases from the 1979 accident.

The 3MILER RUN Investigation

The TMI story embodies a legitimate scientific paradox that has been submerged for several decades.

The paradox can be resolved by a modern investigation. To that end, we describe the two contributions we have made:

- We (well, I) resolved the knowledge gap by developing a comprehensive first-principles description of how the misrepair of double strand breaks creates chromosome aberrations [1]. Contrary to the conventional understanding, the low-level TMI exposures were entirely consistent with detectable injury.
- We undertook a pathfinding cytogenetic investigation, with 26 enrolled participants, demonstrating that a comprehensive effort toward retrospective biological dosimetry of the TMI-exposed population is still possible in the present day.

[1] A. Datesman, "The Dose Rate Quantum and the Statistical Basis of the Linear Quadratic Model". Coming soon to a newsstand near you!

How to Understand an Unprecedented Industrial Disaster

SOURCE TERM
How much radioactivity was released?

~3 – 44 MCi Xe-133.
BDC report 22 MCi.

ATMOSPHERIC TRANSPORT

DOSE
What was the exposure to the population?

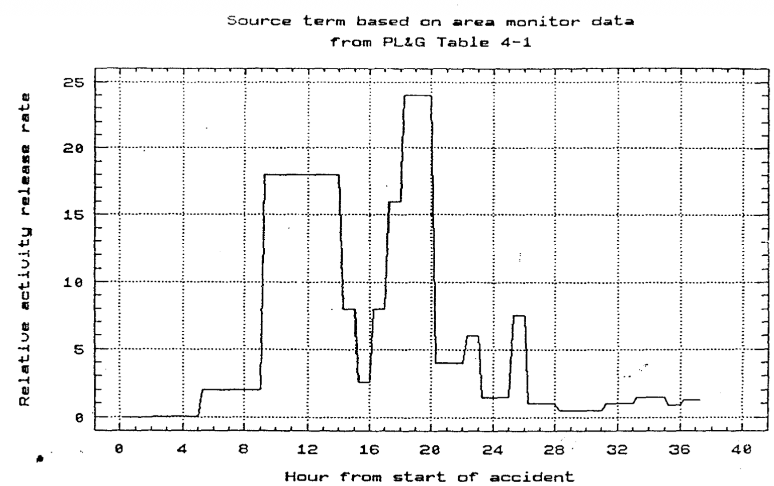
Largest ~2 mSv.
Less than or about equal to annual background.

LOW DOSE EXPOSURE

(Radiation Science)

EPIDEMIOLOGY
Was there an excess of cancer?

CONTROVERSIAL
Around 100 excess cases of lung cancer in a population of 130,000.



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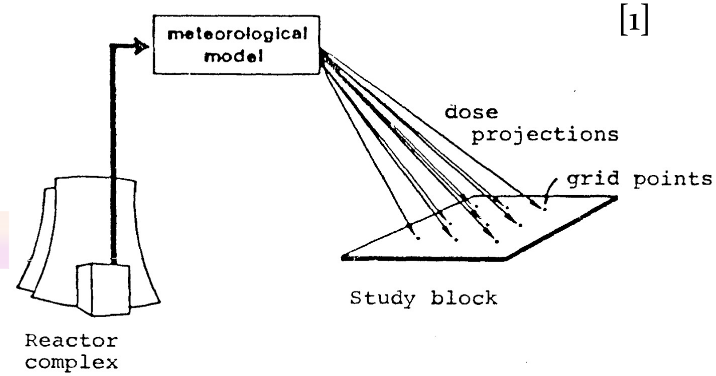

Questioning the Unspoken Assumption

SOURCE TERM
How much radioactivity was released?

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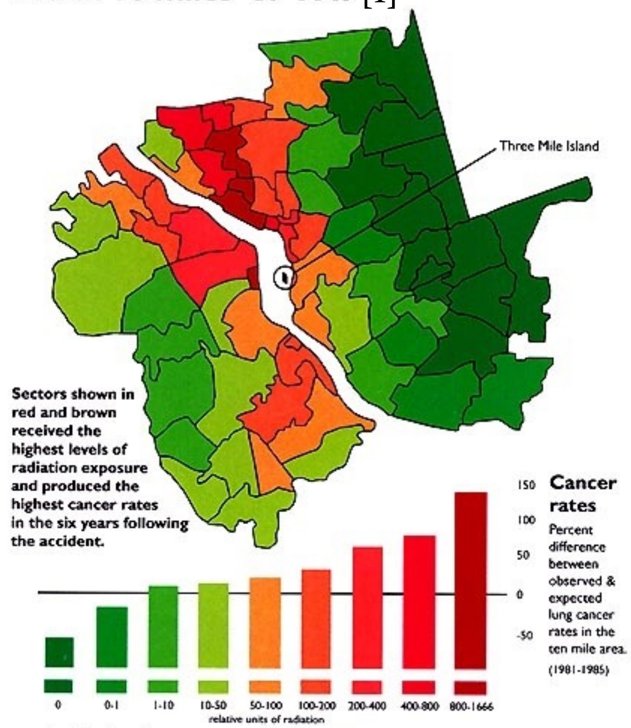
LOW DOSE EXPOSURE

(Radiation Science)

EPIDEMIOLOGY
Was there an excess of cancer?

CONTROVERSIAL
Around 100 excess cases of lung cancer in a population of 130,000.

Radiation Emissions and Cancer Incidence within 10 miles of TMI [1]



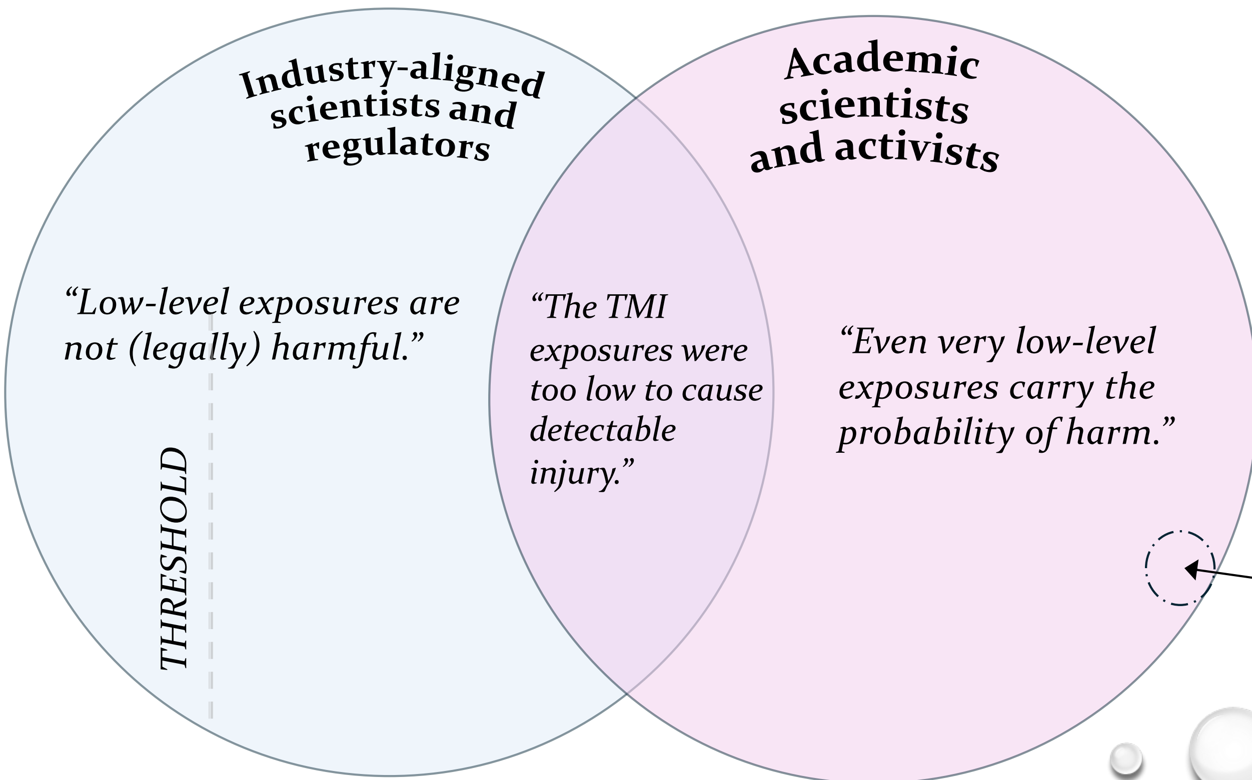
Radiation doses resulting from the 1979 nuclear accident.

Data Source: *Environmental Health Perspectives*, Volume 5, Number 1, January 1997
Graphic: Julia R. Bryan, *Endeavors*, Volume XIV, No. 1, Fall 1997

Video of Karl Z. Morgan speaking about low level exposure to ionizing radiation has been removed in order to reduce the size of the file. The 30-second video may be watched on a public YouTube channel here:

https://youtu.be/qAwm31TkR1o

The Controversy as Karl Z. Morgan Might Have Seen It. Updated.



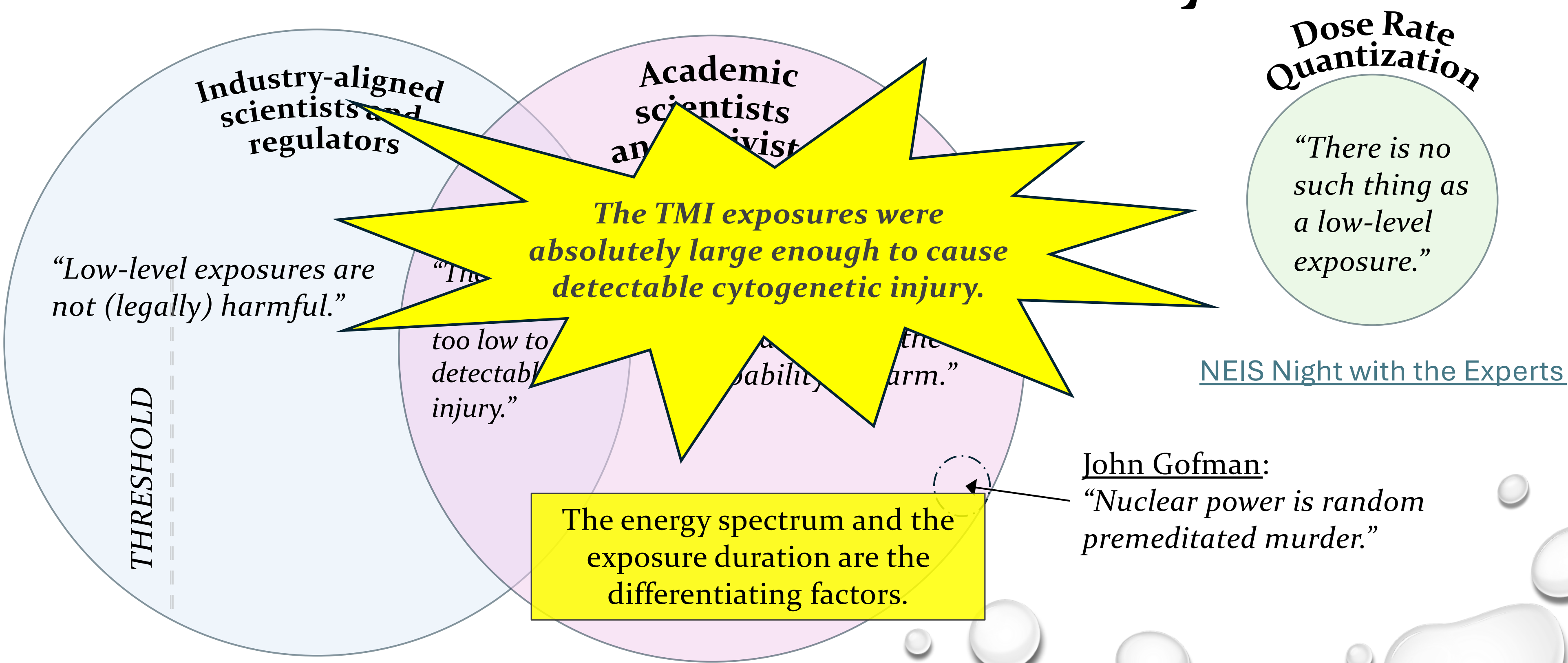
Dose Rate Quantization

“There is no such thing as a low-level exposure.”

NEIS Night with the Experts

John Gofman:
“Nuclear power is random premeditated murder.”

The Experts are Not Playing in the Same Sandbox as Reality



So: How dangerous is low-level exposure to ionizing radiation, REALLY?

The authorities assert a "Linear-Quadratic" form. But it's charitable, honestly, to describe this idea as a guess. The experts have a bad case of what my beloved high-school mathematics teacher described as the "It Looks Like It Theorem" [1].

$$\overline{CA} = \alpha D + \beta D^2$$

I have worked out the actual answer using established concepts from statistical physics. **The experts left out a few pieces.**

$$\overline{S_Z(\omega)} = \mathscr{F}^2 \cdot \lim_{T\to\infty} \frac{2}{T} \cdot \frac{sin^4(\frac{\omega s}{2})}{(\frac{\omega s}{2})^4} \cdot \overline{\sum_{k,l,m,n}^{K} \lambda_k \lambda_l \lambda_m \lambda_n e^{-\omega(t_k+t_l-t_m-t_n)}}$$

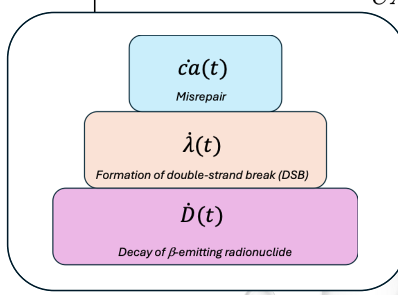
$$\overline{S_Z^{(1)}(\omega)} = 2\mathscr{F}^2 \cdot \left[\nu_Y \overline{\lambda^4} + 4\left[\overline{\lambda^2}\right]^2 \nu_Y^2 T\right] \cdot \frac{sin^4(\frac{\omega s}{2})}{(\frac{\omega s}{2})^4}$$

$$\overline{S_Z^{(2)}(\omega)} = 4\pi[\overline{\lambda}]^4 \mathscr{F}^2 \cdot \left[7\nu_Y^2 + 6\nu_Y^3 T + \nu_Y^4 T^2\right] \cdot \delta(\omega)$$

$$\overline{CA^2} - \overline{CA_o^2} = \mathscr{F}^2 \cdot \left[\mathcal{I} \cdot \left[\nu_Y T \overline{\lambda^4} + 4\left[\overline{\lambda^2}\right]^2 (\nu_Y T)^2\right] + [\overline{\lambda^2}]^2 \cdot \left[7(\nu_Y T)^2 + 6(\nu_Y T)^3 + (\nu_Y T)^4\right]\right]$$

$$\mathcal{I} = \frac{T}{\pi} \cdot \int_0^\infty \frac{sin^4(\frac{\omega s}{2})}{(\frac{\omega s}{2})^4} \cdot \frac{sin^2(\frac{\omega T}{2})}{(\frac{\omega T}{2})^2} \cdot d\omega$$

$$\overline{CA} - \overline{CA_o} = \mathscr{F}\overline{\lambda}^2 \cdot \left[3(\nu_Y T) + (\nu_Y T)^2\right]$$

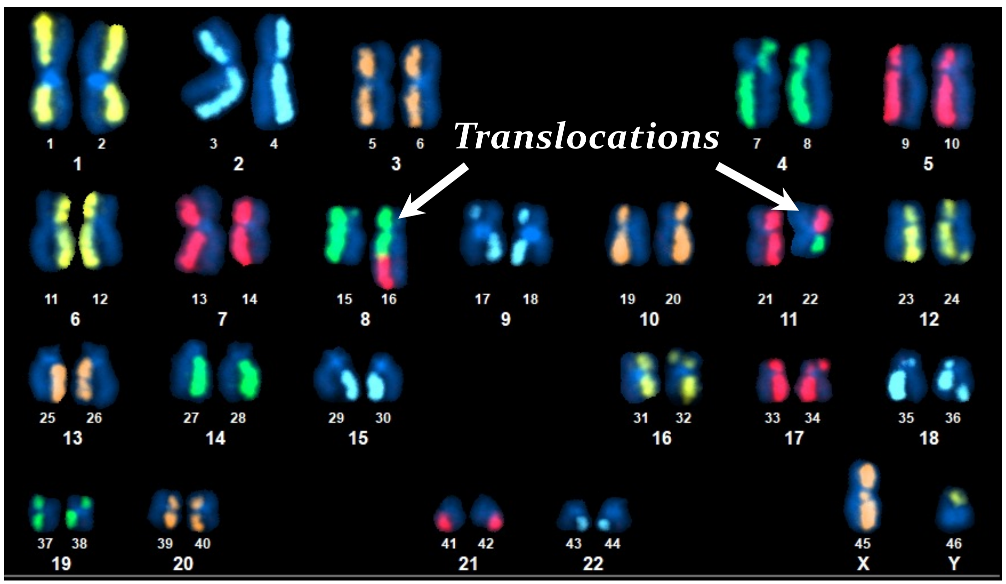


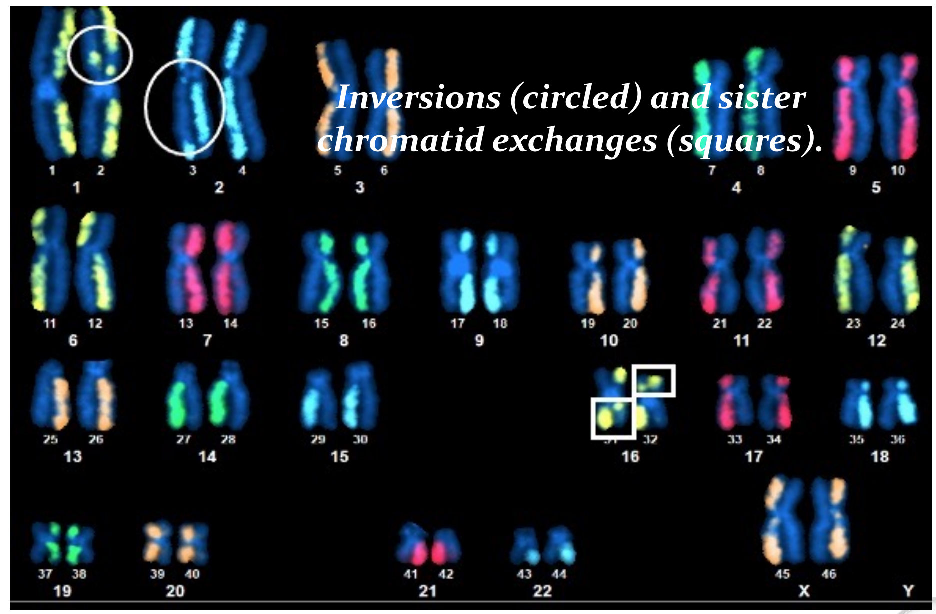
$$\mathscr{F} = \frac{3}{\mathcal{I}} \frac{\overline{\lambda}^2}{\overline{\lambda^4}} \frac{\overline{ca^2}}{\overline{ca}} h(B_Z T)$$

$$\mathcal{I} = \frac{\overline{\lambda}^4}{2\overline{\lambda^4}} \cdot \left[\frac{[\overline{\lambda^2}]^2}{\overline{\lambda^4}} - \frac{1}{12}\right]^{-1}$$

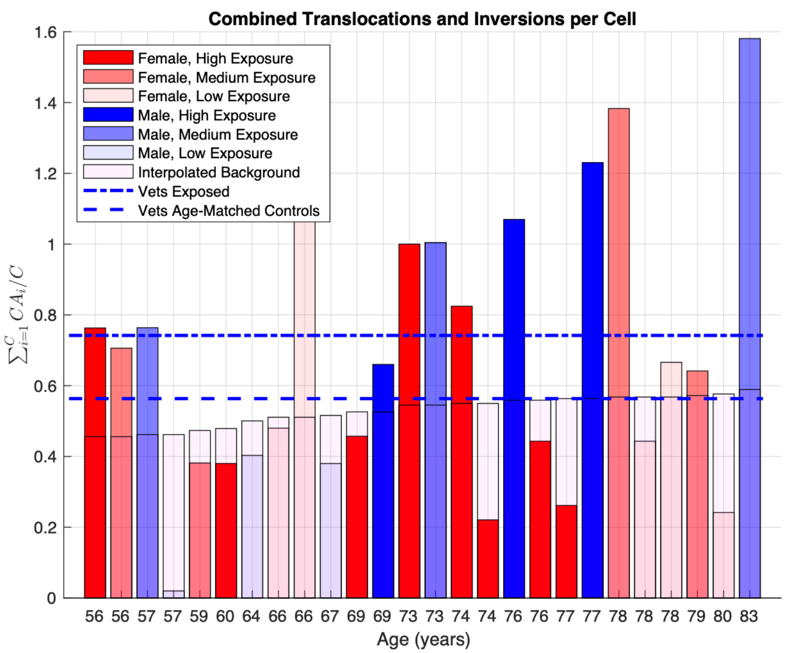
[1] Greetings to Liz Hoelter of New Jersey and California! I am grateful to you for a great many things.

3MILER RUN Preliminary Results, 1/2





3MILER RUN Preliminary Results, 2/2



- It appears that the existing data could be used to make a dosimetric estimate for men. The estimate is not presented because its statistical basis is not robust.
- The data for women are less clear. The immune systems of men and women differ and evolve differently with age. Most investigations center on young men, suggesting (yet another) important gap in our understanding.
- **A large, well-resourced investigation is clearly justified and would be productive.**

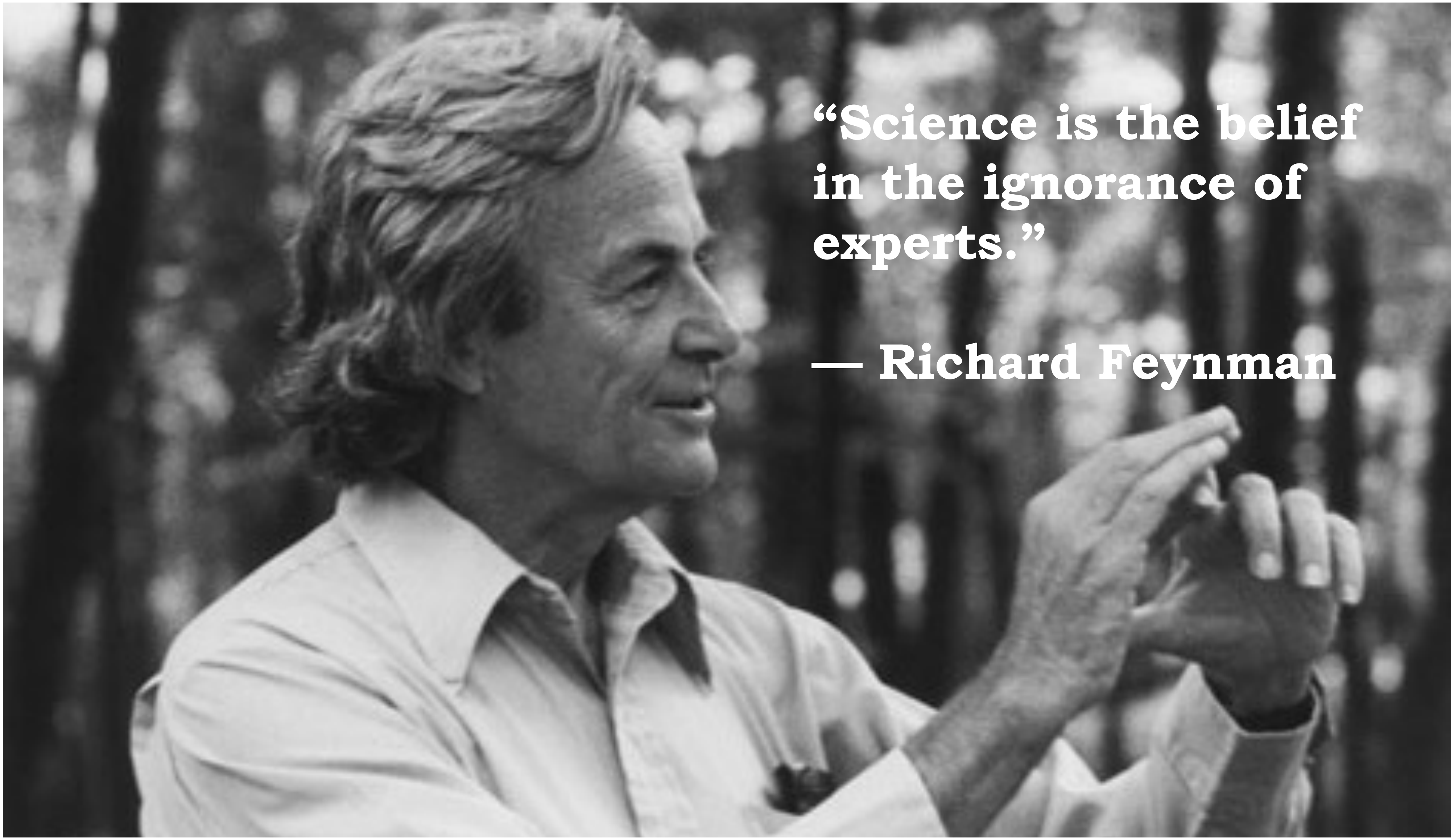
Fitting the Pieces Together

- Personally, I find the cytogenetic results from 1994-95 to be credible.
  - Further work is absolutely desirable, but also: why re-invent the wheel?
  - There is little discrepancy between claims of injury (epidemiology, cytogenetics) and estimates of exposure (source term, dose). It's the scientific link between dose and outcome that is broken.
- I have told you about Dose Rate Quantization, a revolutionary new idea that may align with your beliefs.
  - I urge you not to accept the idea uncritically. A scientific idea can be confirmed or refuted by experiment. The experiment should be conducted.
  - Low-level exposures may be far more harmful than the authorities believe. No nuclear reactor can be operated safely under any realistic body of regulation.

Recommendations

- **Dose is the wrong quantity upon which to regulate.**
  - TMI exposures were low-level (< 0.002 Gy) but nevertheless harmful.
- **If nuclear power is so safe, why not check?**
  - Routine cytogenetic monitoring of the population around nuclear power plants should be instituted.

Extra Slides


“Science is the belief in the ignorance of experts.”
— Richard Feynman