THE LNT CONTROVERSY:
Is Low Level Radiation Really Harmful?

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Canadian Radiation Protection Association Annual Conference

Saskatoon, Saskatchewan

June 5, 2017

Outline

1)Introduction
2)High Level Radiation
3)Brief History of the LNT
4)Current International Standards
5)The “Big Three” Reactor Accidents
6)Beneficial Effects of Low Level Radiation
7)Radiation in Everyday Life
8)How Can We Resolve the LNT Issue?
9) Conclusions

1) Introduction

- **Traditional Respect for Radiation Dangers:**
  - **Time, Distance, Shielding**

- **Is Radiation that unnatural?**
  - **Take a tour of the universe**
  - **But can’t see, touch, or smell**
    - **Experience in recruiting new nuclear engineering students**
    - **Destroy everything made of atoms?**

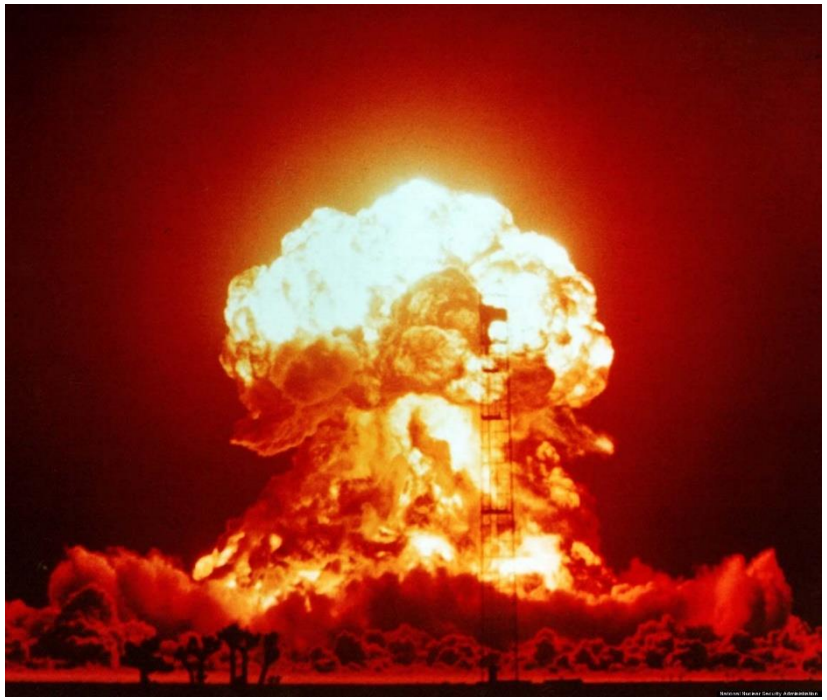
2) High Level Radiation

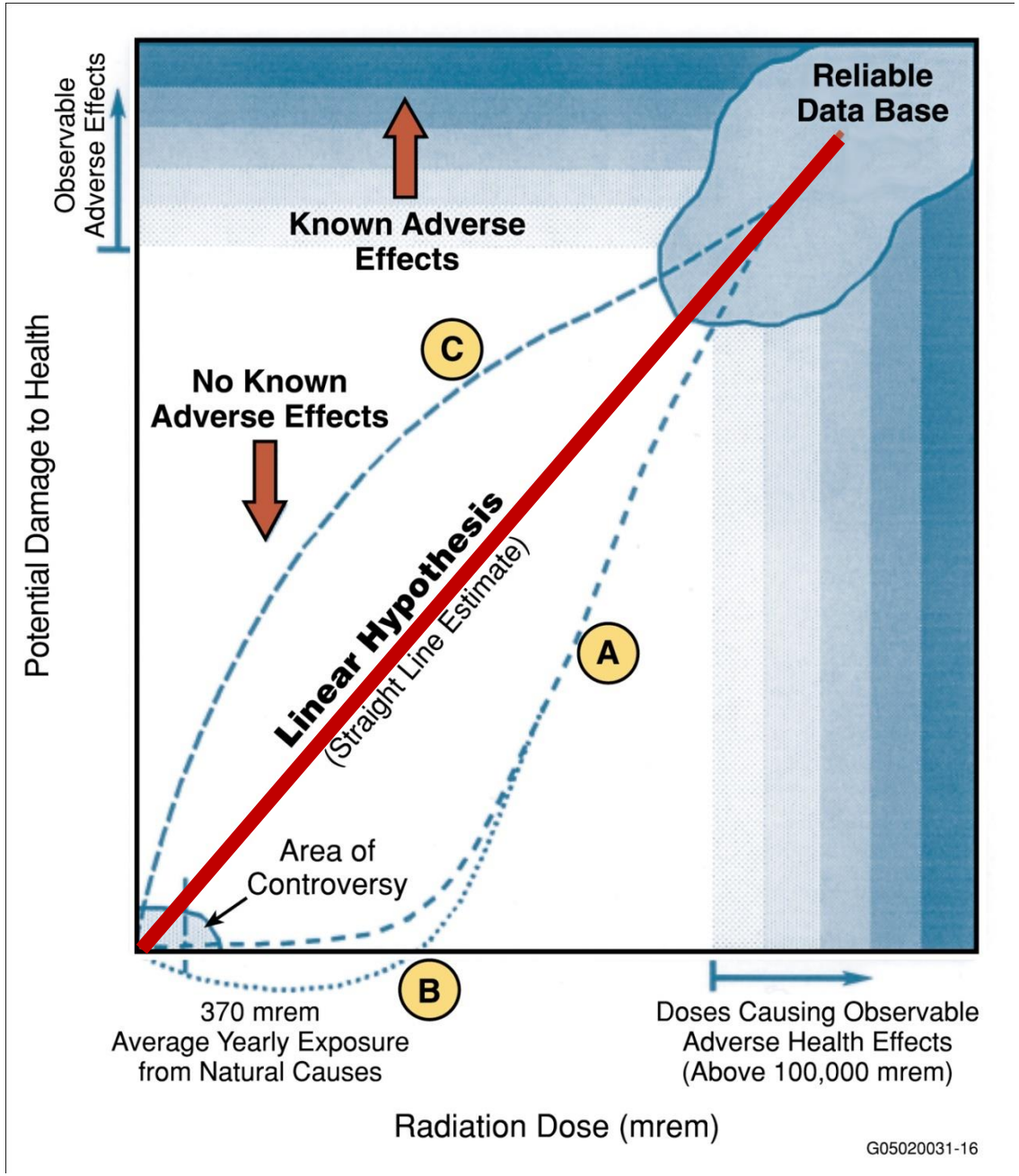
- The Atomic Bombs
- Early lab experiments
  -- SL-1
- Non-Power accidents

The Atomic Bombs

August 6 (Hiroshima) and August 9 (Nagaski), 1945

~80,000 killed ~40,000 killed




Observable Adverse Effects
Reliable Data Base
Known Adverse Effects
C
No Known Adverse Effects
Potential Damage to Health
Linear Hypothesis
(Straight Line Estimate)
A
Area of Controversy
B
370 mrem
Average Yearly Exposure
from Natural Causes
Doses Causing Observable
Adverse Health Effects
(Above 100,000 mrem)
Radiation Dose (mrem)
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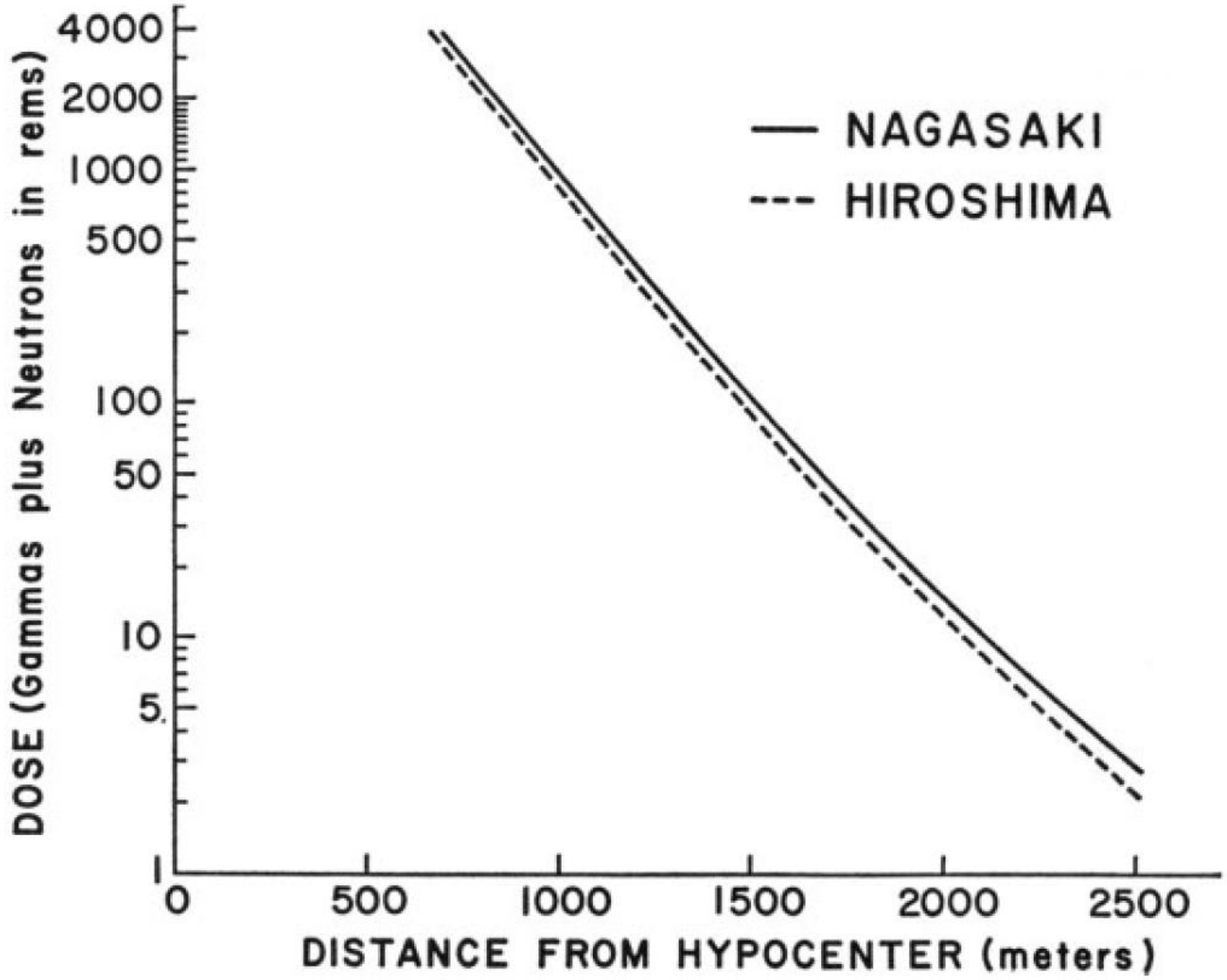
Radiation dose vs. distance from ground zero



Compliments: Jerry Cuttler

Early Lab Experiments

- **SL-1**
  - Small US Army experimental reactor at Idaho Falls
  - Accident on January 3, 1961
  - Central control rod stuck
  - Worker pulled it out too fast
  - Reactor went supercritical (reaching 20 GW in four milliseconds)
    - Over 6000 times normal safe limit
  - Steam Explosion ➡ Three Workers Died
  - Radiation release was approximately 80 Curies of Iodine-131
    - Radiation level at 500 R/hr on one body when pulled from the site of the accident
    - Radiation exposure limit prior to accident for saving a life was 100 R
    - 22 people responding to accident received doses of 3 to 27 R full body exposure
    - NOTE: 1 R ~ 1 Rem or 10 mSv

Global Deaths Due to High Level Non-Power Radiation*

Category	#	Date	Place	Incident
LIFETIME	1	1934	Poland	Marie Curie from lifetime of unprotected sources
OVER EXPOSURE	1	1932	USA	Eben Byers, Ingested 1400 bottles of Radithor
MACHINE MALUNCTION	5	1981-1987	Canada	Therac-25 radiation therapy machines (6 accidents) (some persons exposed to hundreds of Grays)
	1	2006	Scotland	Lisa Norris received 55 Gy to central nervous system in treatment for brain cancer (58% overdose)
FOUL PLAY	4	1987	Brazil	Scavengers broke open abandoned radiation therapy machine and sold kilocuries of Cs-137
	3	2000	Thailand	Thieves stole teletherapy unit from parking lot, removed Co-60 shielding, and sold for scrap metal

* Wikipedia, Civilian Radiation Accidents, 6-28-2009

Global Deaths Due to High Level Non-Power Radiation*

(CONTINUED)

Category	#	Date	Place	Incident
ACCIDENTAL	1	1989	El Salvador	Worker entered Co-60 radiation zone of medical sterilizer machine
OVER-EXPOSURE	1	1990	Israel	Worker bypassed safety system on commercial irradiation facility; received 10 Gy
	1	1991	Belarus	Same error as above: received 11 to 20 Gy
	3	1996	Costa Rica	Co-60 machine improperly calibrated (60% overdose) (IAEA Report – Module XIX)
TOTAL =	31			

NOTE #1: In April of 2010, a New Delhi scrap dealer suffered very serious exposure to radiation after handling a cobalt-60 source. Six pieces of this dangerous material were recovered from the scrap pile. One person died and six others were sickened.

NOTE #2: Abel Gonzales has noted additional incidents in Brazil, Belarus, Turkey, Iran, Peru, Bolivia, Chile, Thailand, Poland, Panama, Russia, Estonia, and Georgia where some 200 citizens were overexposed in radiation accidents.

* Wikipedia, Civilian Radiation Accidents, 6-28-2009

Dangers of Inappropriate Use of Non-Power Radiation

A) Global Deaths (Google) ~ 31

(Gonzalez) ~ 100

- **Over Exposure**
- **Machine Malfunction**
- **Foul Play**

B) HOWEVER: Some cases reveal positive health effects from Low Level Radiation:

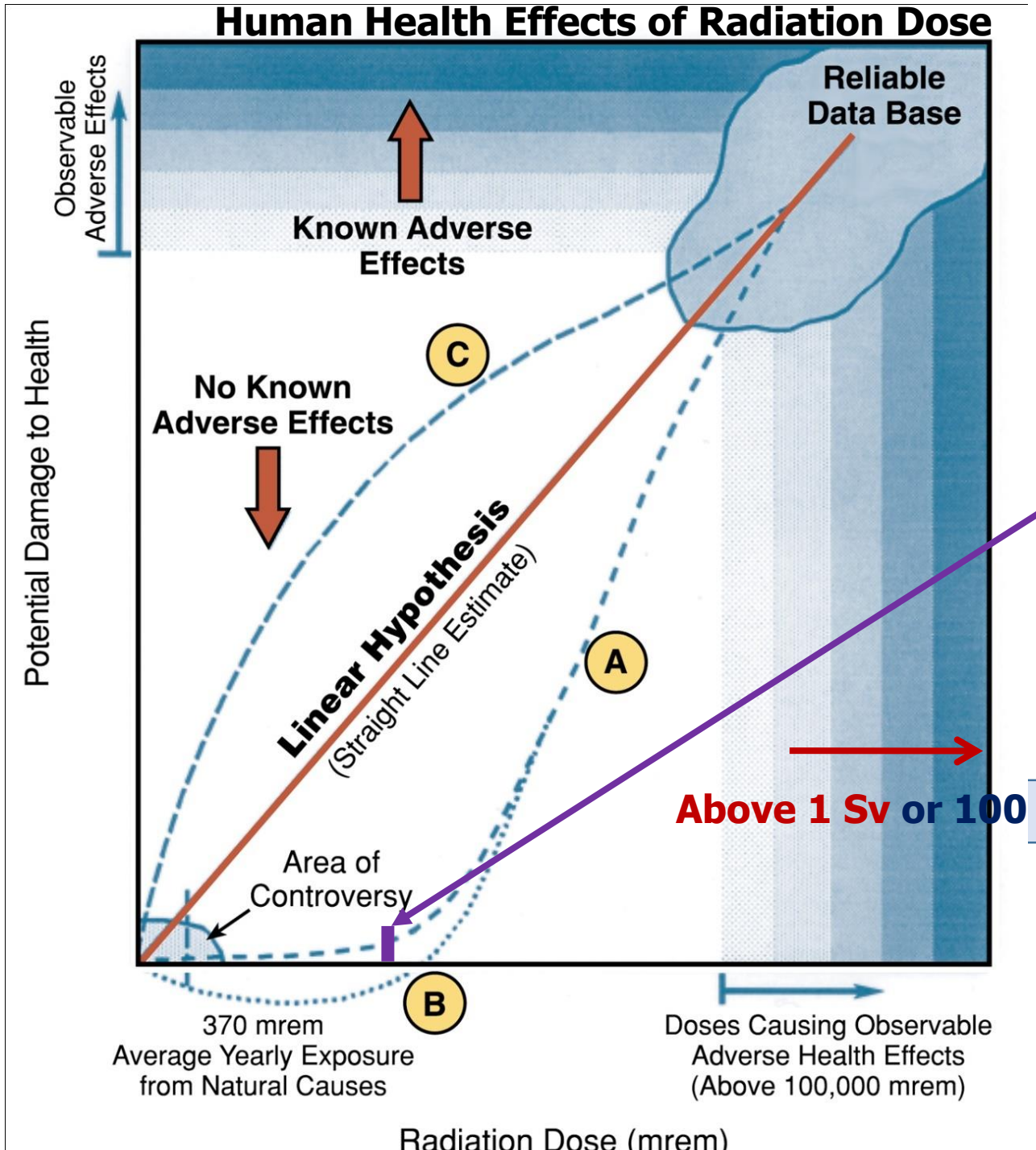
-- Shipping Yard Study

-- Taiwan Apartment Study

NOTE: More deaths from Non-Power Radiation Applications than from Nuclear Power Accidents!

3) Brief History of the LNT

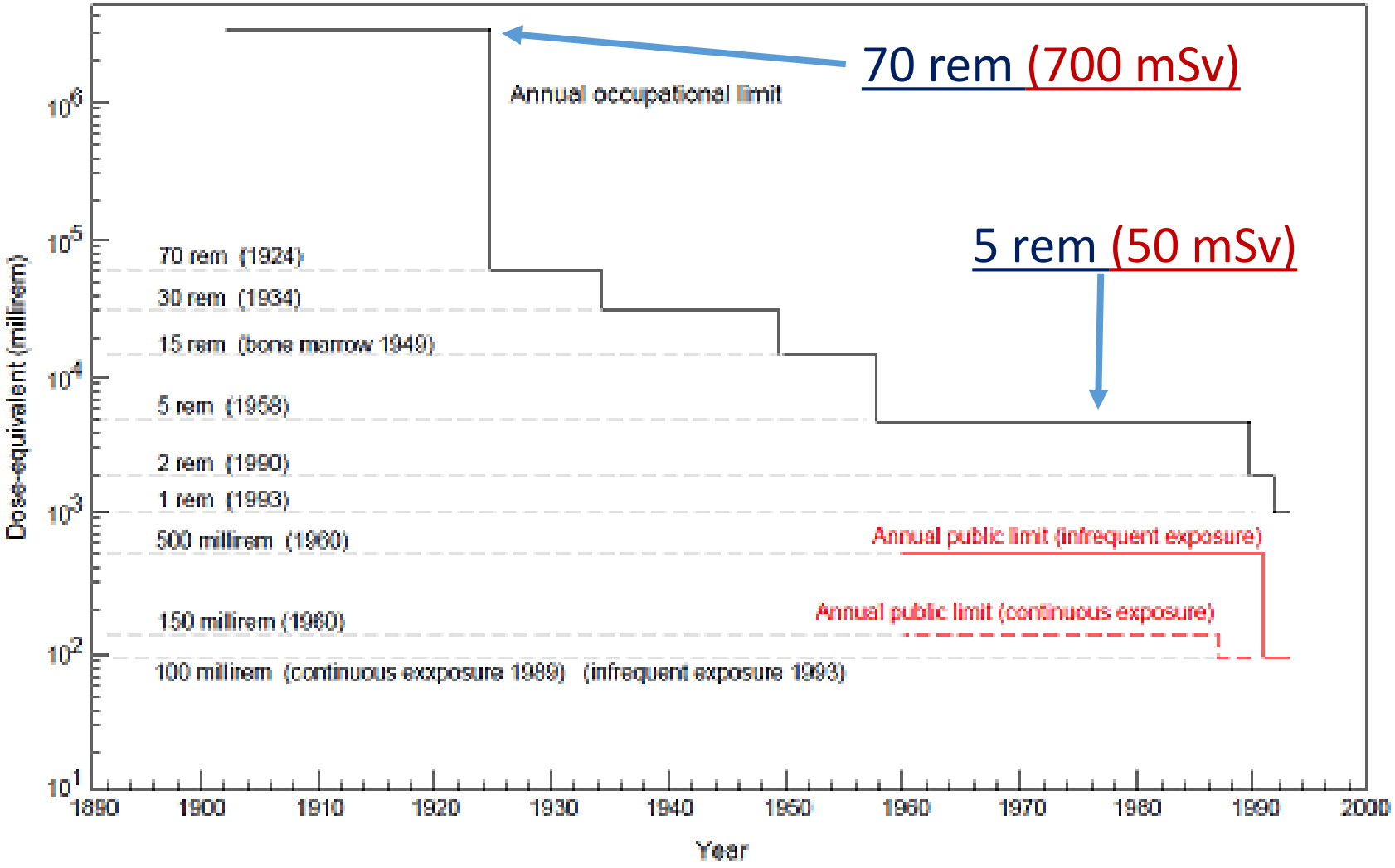
- **Herman Muller's 1946 Nobel Prize**
- **1956 National Academy of Sciences Decision**
  - → **Go from Threshold to LNT**



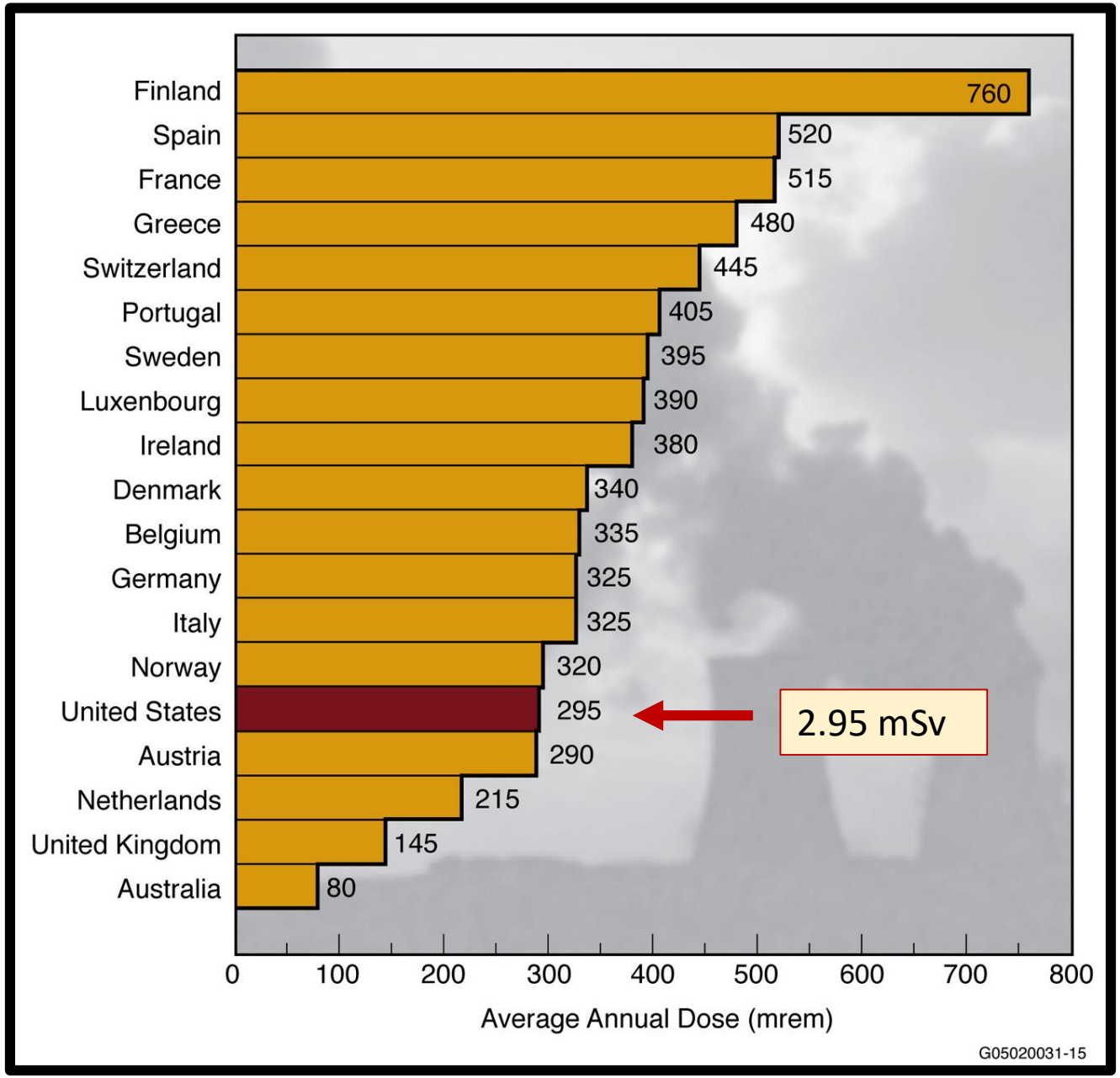
~ 70 mSv (7 rem)
Threshold Original Limit

Above 1 Sv or 100 Rem

The Ratcheting Down on Allowable Public Exposure Limits



Paper from Los Alamos: Inkret, et al. 1995 (provided by Jerry Cuttler)

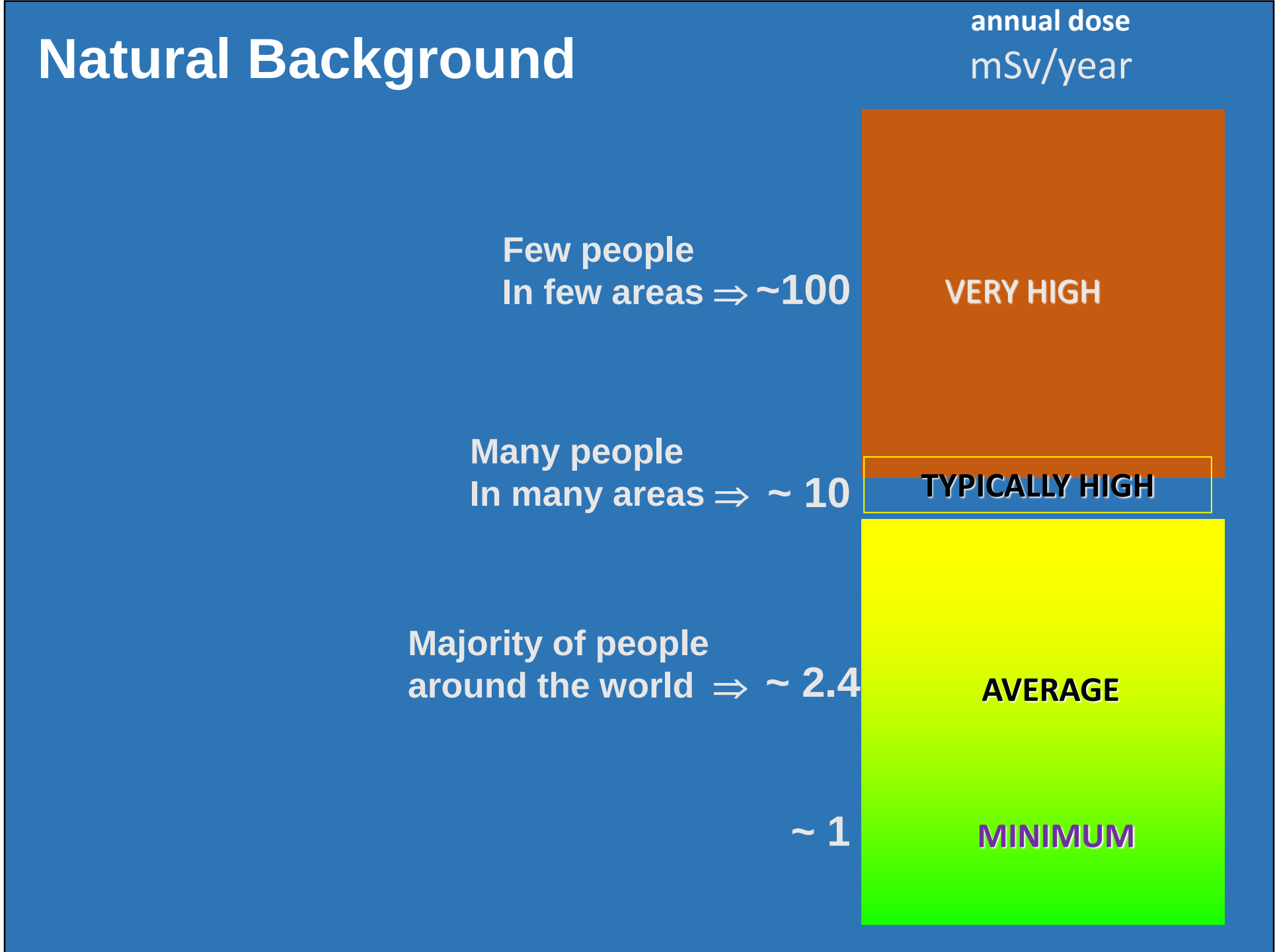


NOTE: Ramsar, Iran
Up to 26 rem (260 mSv/y)

Average Annual Dose from Natural Radiation Sources

Natural Background

annual dose
mSv/year



Herman Muller and the Nobel Prize*

- 1927: Muller's first publication on X-ray mutations on fruit flies (high dose)
  -- Presented at Fifth International Genetics Conference in Berlin (Curt Stern co-organizer)

  --Linear relationship with high dose
- Stern initiated Manhattan Project in 1943

  -- Invited Muller to participate as consultant

  -- Ernst Caspari performed definitive work on fruit fly irradiations at very low levels

  -- Found threshold
- Was Muller aware of Caspari's work?

  --Not clear, but likely so just before his departure to Stockholm to accept Nobel Prize

  -- Nobel lecture firmly states NO THRESHOLD (just linear with dose).

  -- Just months later stated in writing "There is absolutely no threshold dose; Even the most modest dose carries a definite chance of providing a change exactly proportional to the size of the dose.

National Academy of Sciences Decision*

- 1956--NAS BEAR-I Committee
  - Genetics Panel Input—June 1956
    - 13 geneticist on panel (Warren Weaver, Chair)
    - Challenged to estimate genomicic risk from radiation to gonads
    - 9 took up the challenge
    - James Crow assigned to review the input (huge scatter in the responses)
      - He threw out 3 inputs (reporting only six)
      - Calabrese call this deception the “LNTgate”
- June 12, 1956, NAS recommended LNT (no threshold)
  - From a threshold of 50 mSv (5 rem) to no threshold at all
  - Immediate media coverage!
  - Calabese suspicious of political influence (stop atmospheric testing?)

*Edward Calabrese, U. Massachusetts, Amherst

4) Current International Standards

• Members of Public	<1 mSv/y = 100 mrem/y
• Radiation Workers	< 20 mSv/y = 2 rem/y
• Following Accident	Several tens of mSv (tens of rem) with special interventi

EPA for Nuclear Repository	<0.15 mS/y after 10,000 years <15 mrem/y after 10,000 years

5) The “Big Three” Reactor Accidents

- **Three Mile Island---1979**
- **Chernobyl –1986**
- **Fukushima ---2011**

Three Mile Island

March 28, 1979

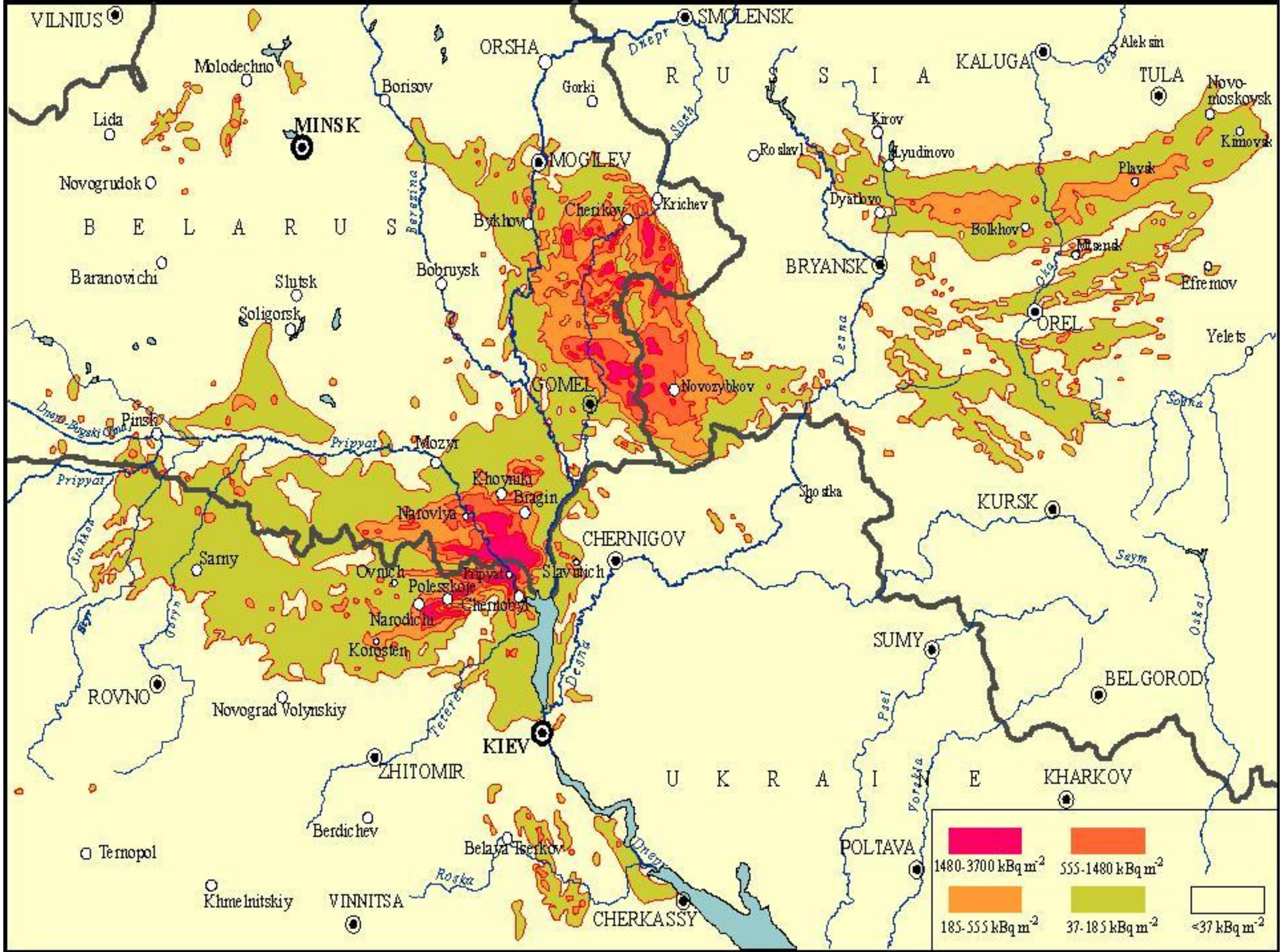
- Minute amount of radiation dumped into river
- No radiation injuries
- Top Level News for weeks!

Chernobyl

April 26, 1986

- **Running test prior to accident**
- **Took reactor into completely unknown territory**
- **Suffered massive reactivity insertion and subsequent steam explosion**
- **Blew tin roof cover apart and scattered radiation over wide world swath**
- **Global Scare**
  - ~10,000 abortions in Europe
  - Food consumption severely restricted in Europe
  - No precautions in either Pripyat or downwind

CHERNOBYL


VILNIUS
Molodechno
SMOLENSK
ORSHA
Borisov
Gorki
KALUGA
Aleksin
TULA
Novo-moskovsk
Kimovsk
R U S S I A
Lida
MINSK
Kirov
Roslavl
Lyudinovo
MOGILEV
Novogrudok
Plavsk
Krichev
Cherikov
Dyatkovo
Bykhov
B E L A R U S
Bolkhov
Mtsensk
Baranovichi
Slutsk
Bobruysk
BRYANSK
Efremov
Soligorsk
OREL
Yelets
GOMEL
Novozybkov
Pinsk
Mozyr
Pripyat
Khoyniki
Bragin
Narovlya
Shostka
KURSK
CHERNIGOV
Sarny
Ovruch
Pripyat
Slavutich
Polesskoje
Chernobyl
Narodichi
Korosten
SUMY
BELGOROD
ROVNO
Novograd Volynskiy
KIEV
ZHITOMIR
U K R A I N E
KHARKOV
Berdichev
Belaya Tserkov
Ternopol
POLTAVA
Khmelnitskiy
VINNITSA
CHERKASSY
Dnepr
Sozh
Oka
Berezina
Desna
Sosna
Seym
Oskol
Psel
Vorskla
Teterev
Roska
1480-3700 kBq m^{-2}
555-1480 kBq m^{-2}
185-555 kBq m^{-2}
37-185 kBq m^{-2}
<37 kBq m^{-2}

Casualties from Chernobyl

- **Liquidators (heavily irradiated) = 134 persons**

  28 died soon after the accident from acute radiation disease

  106 persons remained alive

  Of these, 22 died within 10 years → 1.09% mortality

  Non-exposed mortality in nearby areas is as follows:

  Russia = 1.38%

  Belarus = 1.4 %

  Ukraine = 1.65%

- **Children in Belarus (Thyroid Cancer)**
  - **No remediation**
  - **~ Two dozen died**

Radiation Doses Following Chernobyl

- **Lifetime dose for 5 million inhabitants ~ 70 mSv (7 rem)***
  - **NOTE: Natural lifetime dose ~ 170 mSv (17 rem)**

- **DNA double strand breaks from daily living = 1 in 10 cells/day ****
  - **This corresponds to damage of 30 mSv/y of low-level ionizing radiation**
  - **Hence, 30 mSv/y x 70y = 2100 mSv for lifetime dose to equal natural damage**
  - **Stated differently, Chernobyl dose ~ 3.3% of natural spontaneous metabolism**

* Jaworowski (Poland)

** Feinedegen (Germany)

Fukushima

March 11, 2011

- Enormous Damage
- Thousands of Citizens Evacuated
- Global Panic Over Radiation Releases

Recall some Headlines…

Reactor Adds to Horror

Threat of Meltdown Rocks Japan

Japan's Misery Mounts

Americans Leaving Japan

New Fears in Tokyo as Radiation Level Spiked Tap Water

Setbacks Mount at Leaking Nuclear Plant

High Radiation Outside Japan's Exclusion Zone

Fukushima Radiation Reaches West Coast of USA

About Fukushima…

I believe we will *eventually* be able to say…

THIS WAS NUCLEAR POWER'S FINEST HOUR!

Review of Accident

- Reactors survived the massive earthquake!

- Tsunami hit an hour later and wiped out the diesel generators' heat sink
- No cooling capability for a considerable time

- Increasing pressure from released hydrogen gas inside containment caused some venting to outer building

- A hydrogen explosion took the roof and sides off the outer building

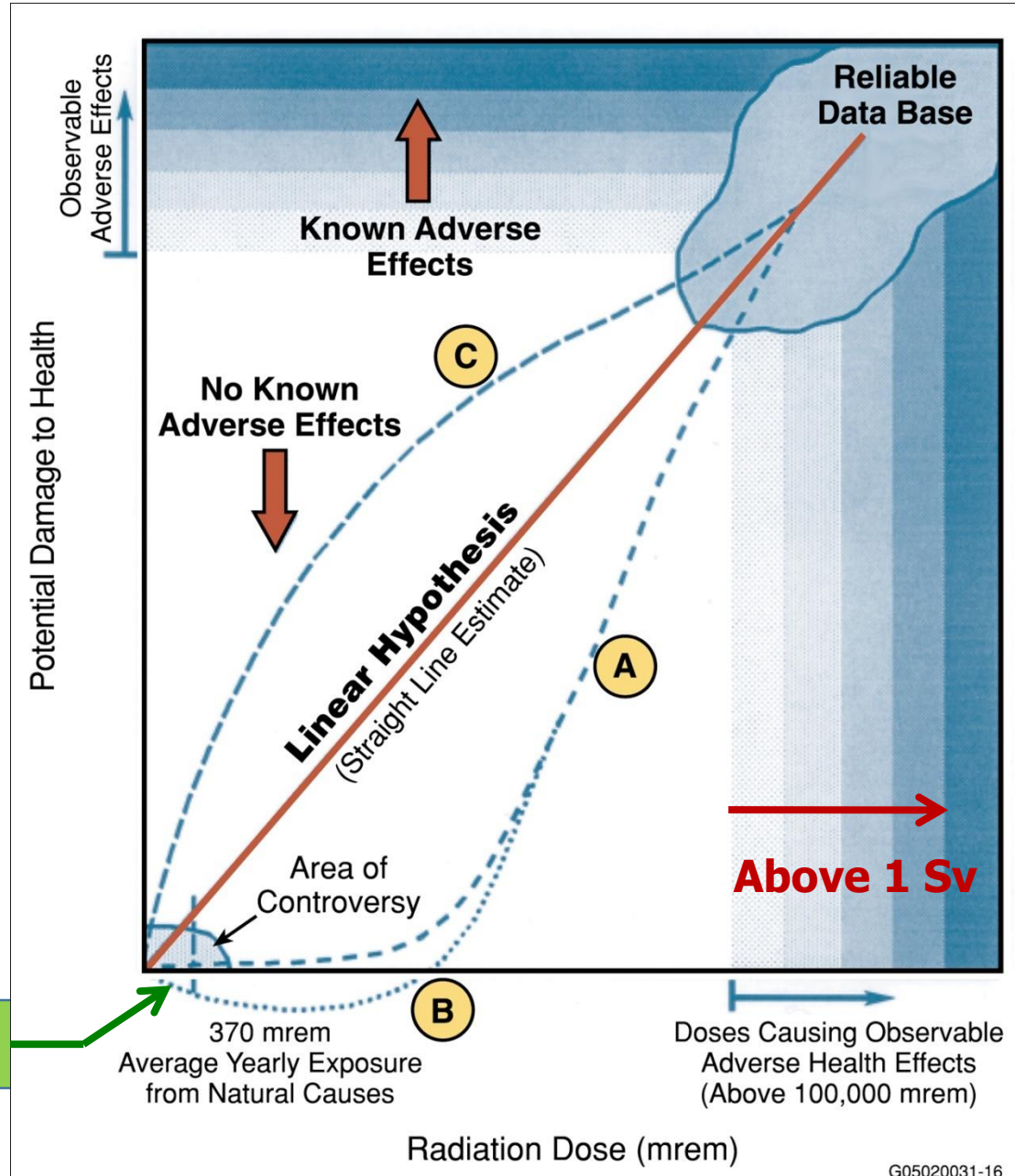
- Containment stayed in-tact.

No Actual Casualties from Radiation Release ….NONE!

- **UNSCEAR** - 59th Session, May 21-25, 2012
  - "To date, no health effects attributable to radiation exposure have been observed among children or any other member of the population."

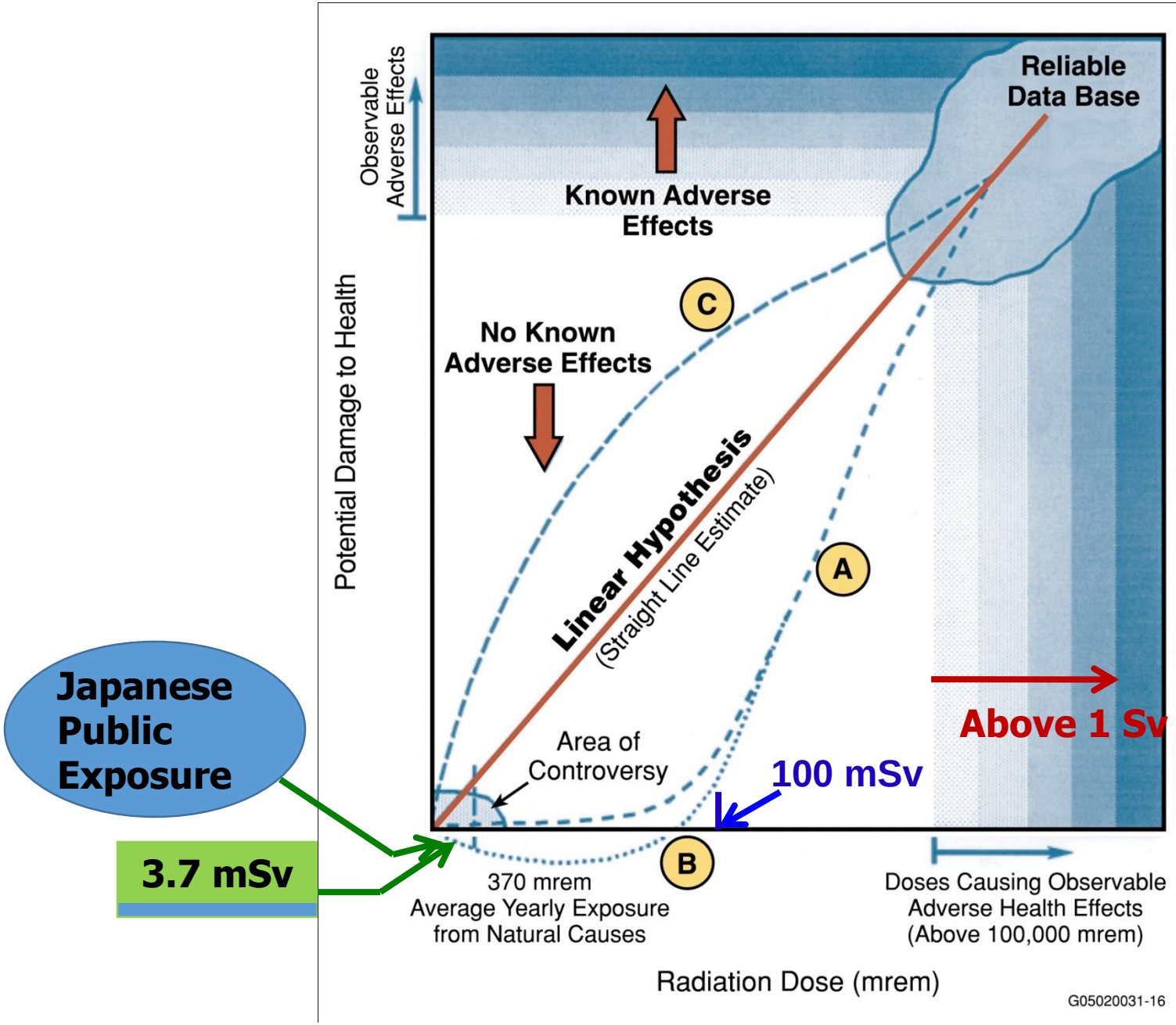
- **ICRP** – Task Group 84, November 22, 2012
  - " …no one incurred a lethal dose of radiation (or a dose sufficiently large to cause radiation sickness)"

  - However, "psychological consequences included depression, grieving, post-traumatic stress disorder, chronic anxiety, sleep disturbances, sever headaches, and increased smoking and alcohol use."



3.7 mSv

Human Health Effects of Radiation Dose


Japanese Public Exposure
3.7 mSv
Observable Adverse Effects
Potential Damage to Health
Known Adverse Effects
Reliable Data Base
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No Known Adverse Effects
Linear Hypothesis
(Straight Line Estimate)
A
Above 1 Sv
Area of Controversy
100 mSv
B
370 mrem
Average Yearly Exposure
from Natural Causes
Doses Causing Observable
Adverse Health Effects
(Above 100,000 mrem)
Radiation Dose (mrem)
G05020031-16

Perspective

- Number of fatalities caused by the earthquake/tsunami = > 15,000
- Number of fatalities caused by excess radiation = zero
- Number of injuries caused by radiation sickness = zero
- Number of latent cancers expected from excess radiation = zero
- Number of news stories hyping the "dangers" of radiation = Thousands!

Lessons to be learned:

- **The reactors survived the massive earthquake**

The tsunami is the issue—NOT radiation

Design for huge tsunamis

LNT Model is Responsible for Casualties and Economic Harm following Nuclear Reactor Accidents in Fukushima

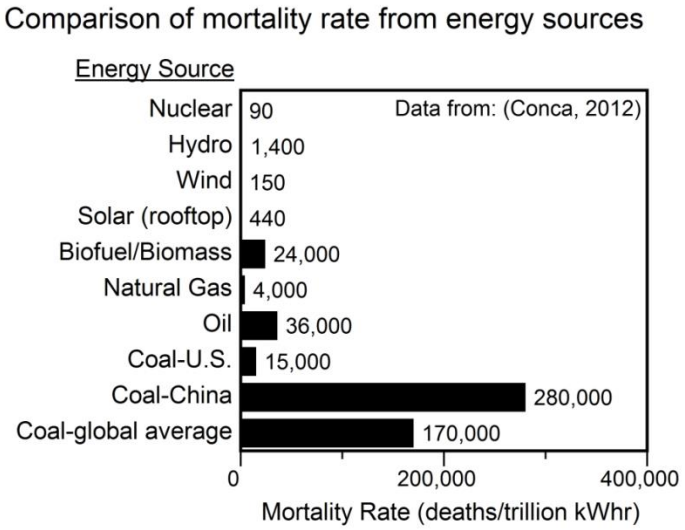
In Fukushima, evacuations based on the LNT model caused:

- More than 1000 deaths, Disruption of over 100,000 lives
- Maximum dose averted due to evacuation ~70 mSv (UNSCEAR, 2013)

  (such radiation doses would not cause cancer)

After the Fukushima Accidents:

Germany and Japan decided to shut down all their nuclear power plants, because of LNT model based cancer concerns, even though nuclear power has proven to be the safest mode of power generation.



LNT model based fears are resulting in countries making more hazardous choices for energy production.

Compliments: Mohan Doss

6) Beneficial Effects of Low Level Radiation

Radiation protection standards enacted by regulatory agencies have generally reflected ethical concerns based on two suppositions:

1. **The linear, no-threshold hypotheses derives from scientific data in radiobiology that ar virtually conclusive; and**
2. **It is "morally better" for health protection to assume that any radiation exposure, no mater how small, as some harmful effects which can and ought to be prevented.**

BUT…Are either of these true???

1) **Scientific at low dose?**
2) **Unintended consequences!**

Listening to the Medical Community

- **Dr. Myron Pollycove, MD**
  - **If low-level radiation did not have a beneficial effect, it would be an anomaly of science**
    - **We all have an incredible immune system**
    - **Each cell in our body suffers mutations from various attacks daily**
    - **Without such an immune system, we could not survive**
    - **We have lived in a radioactive environment since humanity arrived**
  - **We purposely stimulate our immune system by submitting it to low doses of toxins:**
    - **Vaccinations**
    - **Exercise**
    - **Copper, Selenium, Fluoride, …**
    - **Low doses of aspirin**

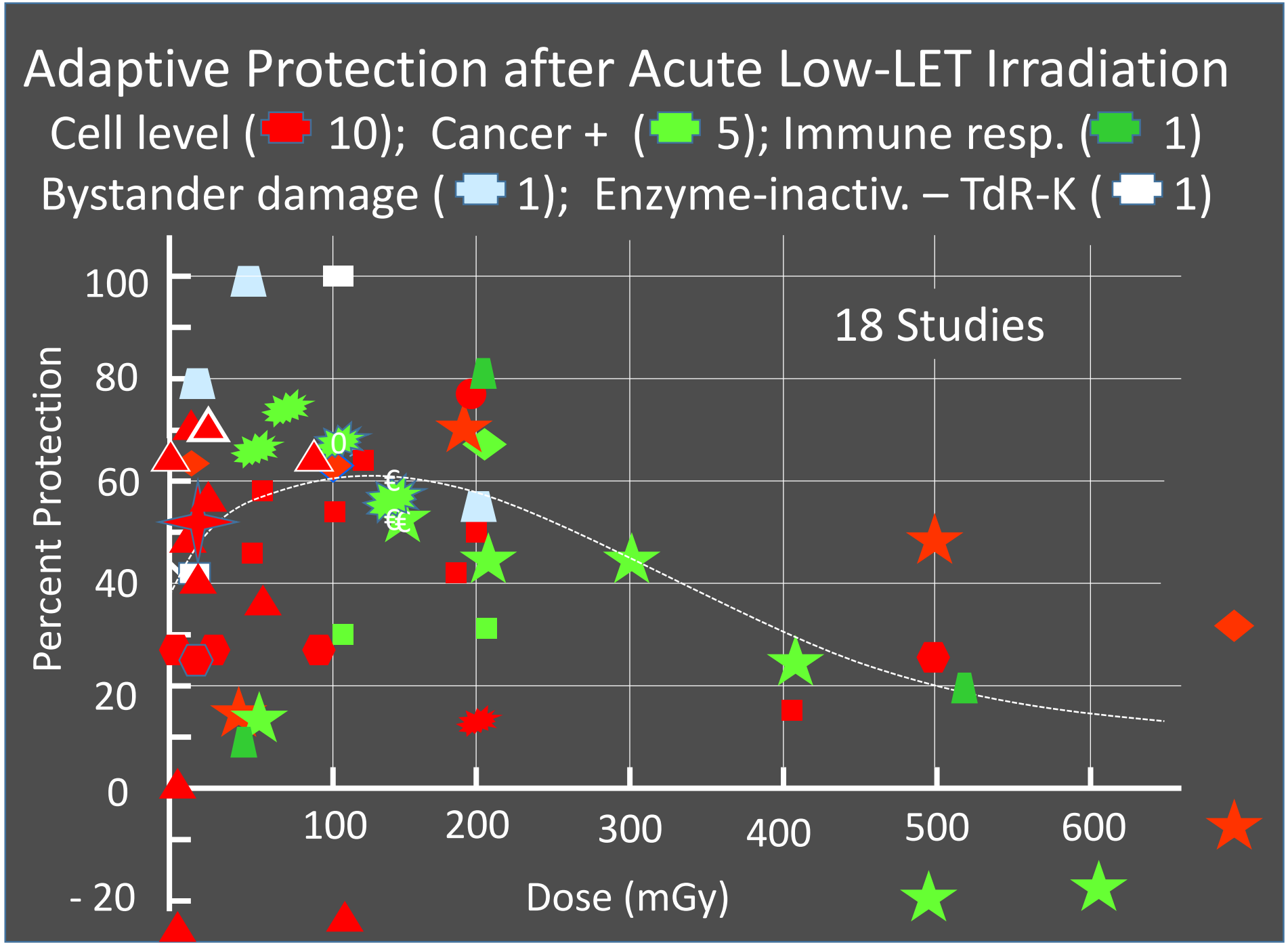
Regions of Applicability

High Dose

- Cellular damage increases linearly with dose
- Pure physics prevails; immune system is overwhelmed
- Hence, the LNT prevails for High Dose

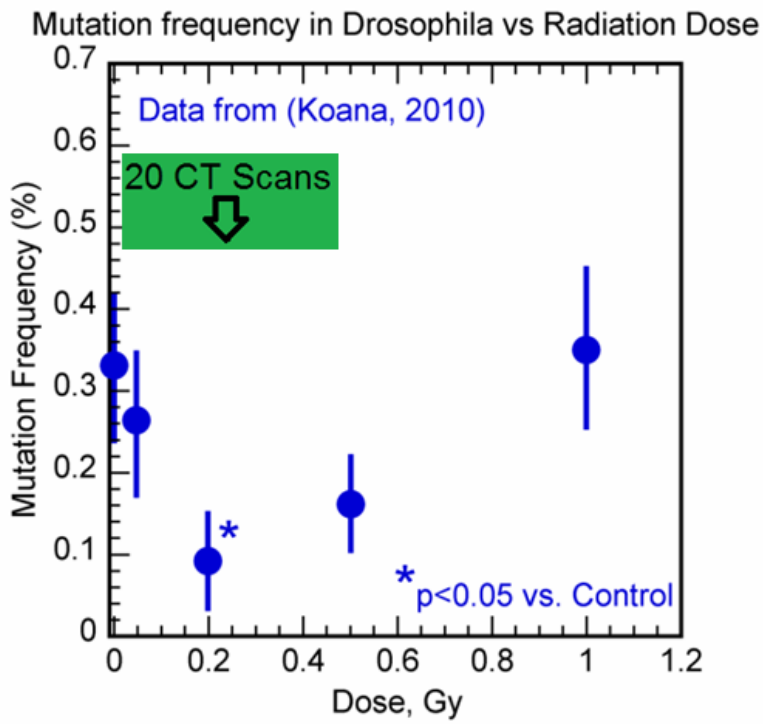
Low Dose

- Cell damage still increases linearly with dose
- But…biological response is **Non-Linear**
- Adaptive response has been clearly demonstrated experimentally



Compliments: Dr. Ludwig Feinendegen

Do mutations increase with radiation dose at low doses?

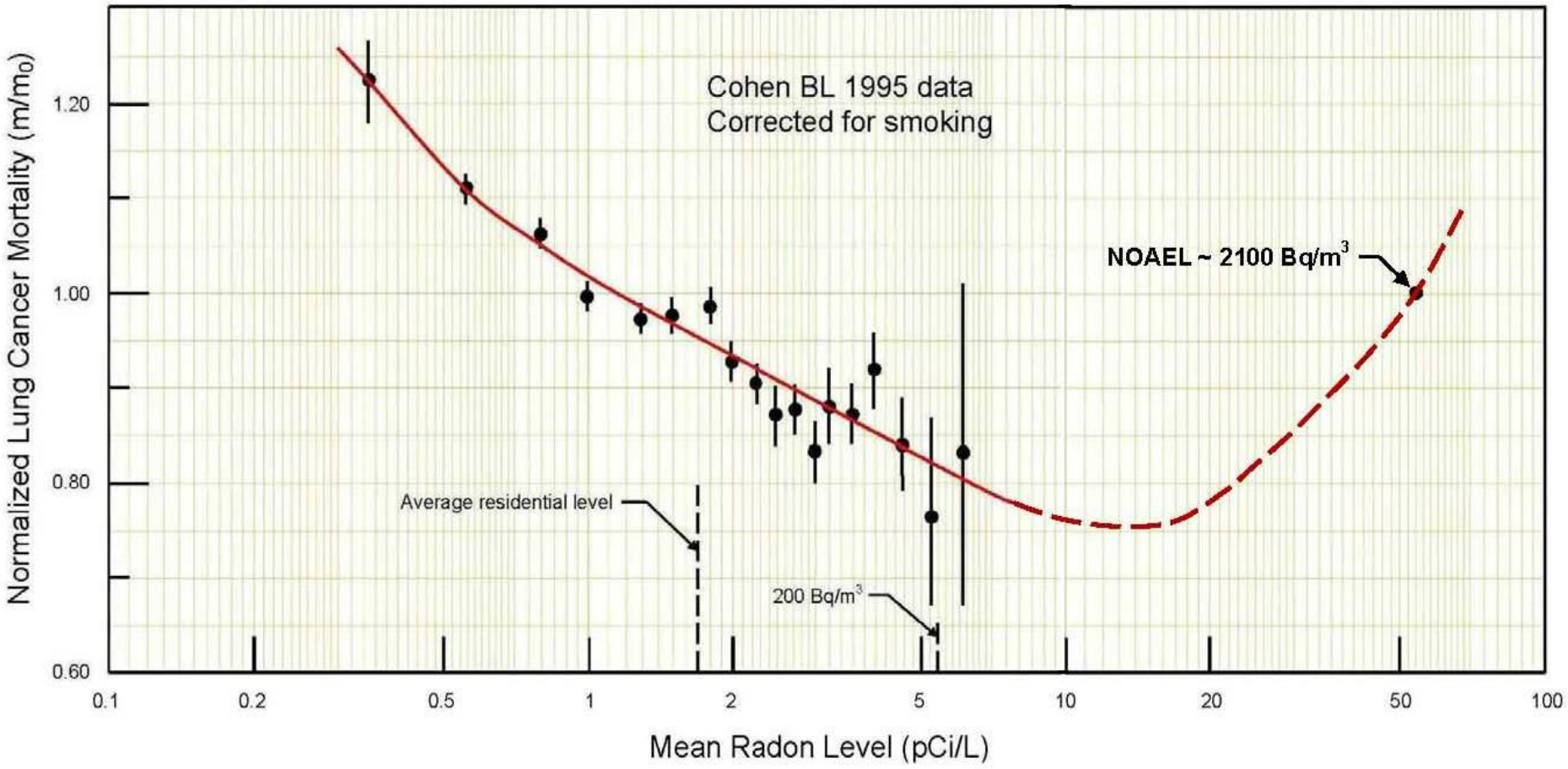


- Even in the absence of radiation, endogenous DNA damage does occur, which is much more than the damage caused by low-dose radiation **(Vilenchuk & Knudson, 2003)**.
- Low-dose radiation enhances defenses (antioxidants, DNA repair enzymes, etc. collectively known as adaptive protection) **(Feinendegen, 2013)** reducing the endogenous damage in the subsequent period.
- Net Result: Less DNA damage and mutations.

Brenner/Hall assumed that CT radiation dose would increase mutations. But when the effects of defensive responses of the body are factored in, mutations would decrease following CT scans, in a manner similar to the drosophila data above.

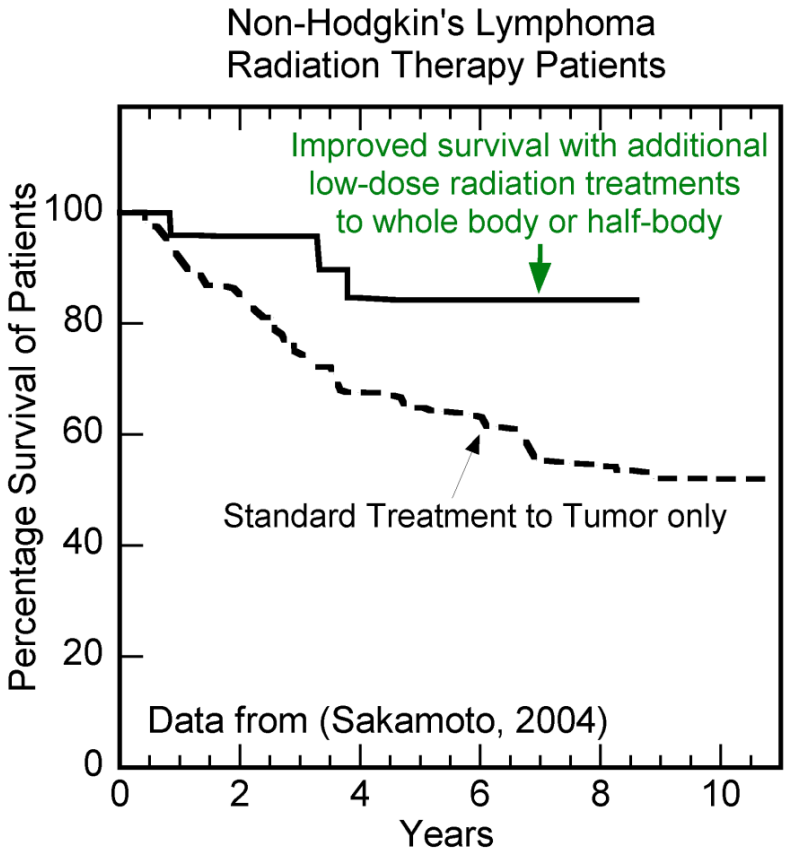
Compliments: Dr. Mohan Doss

Inhaled radon in homes



Compliments: Jerry Cuttler

Effect of Repeated Low-dose Radiation Treatments in Radiation Therapy Patients



Low-dose radiation treatments:

10 cGy X 15 over 5 weeks

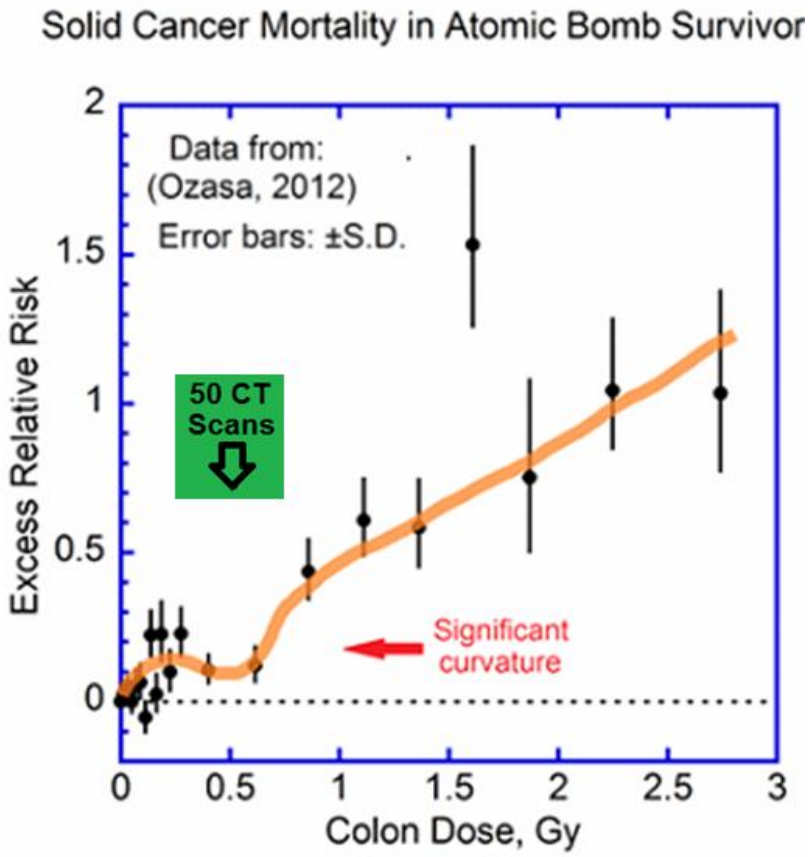
10 CT Scans

Brenner/Hall, BEIR VII Report, etc. ignored these data

Low-dose radiation treatments had a cancer therapeutic effect contradicting the LNT model.

Compliments: Dr. Mohan Doss

Atomic Bomb Survivor Data are Inconsistent with the LNT Model*



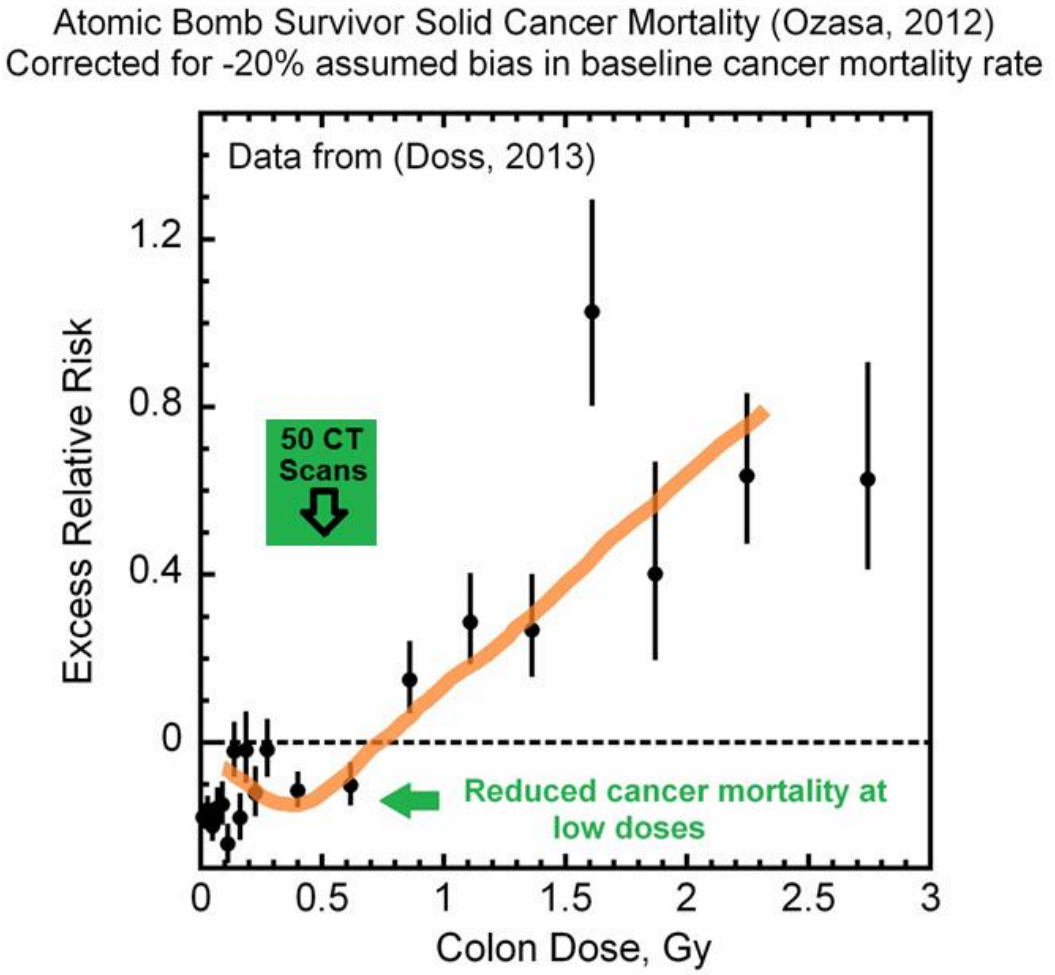
LNT model was assumed in the analysis of the data to extract the Excess Relative Risks.

As radiation dose increases from 0.25 Gy to 0.5 Gy, cancers decrease, results in significant curvature in dose-response relationship, contradicting the LNT model.

Atomic bomb survivor data, universally acknowledged to be the most important data to assess the health effects of radiation, no longer support the LNT model.

* Compliments of Dr. Mohan Doss

Evidence for Radiation Hormesis in Atomic Bomb Survivor Data*

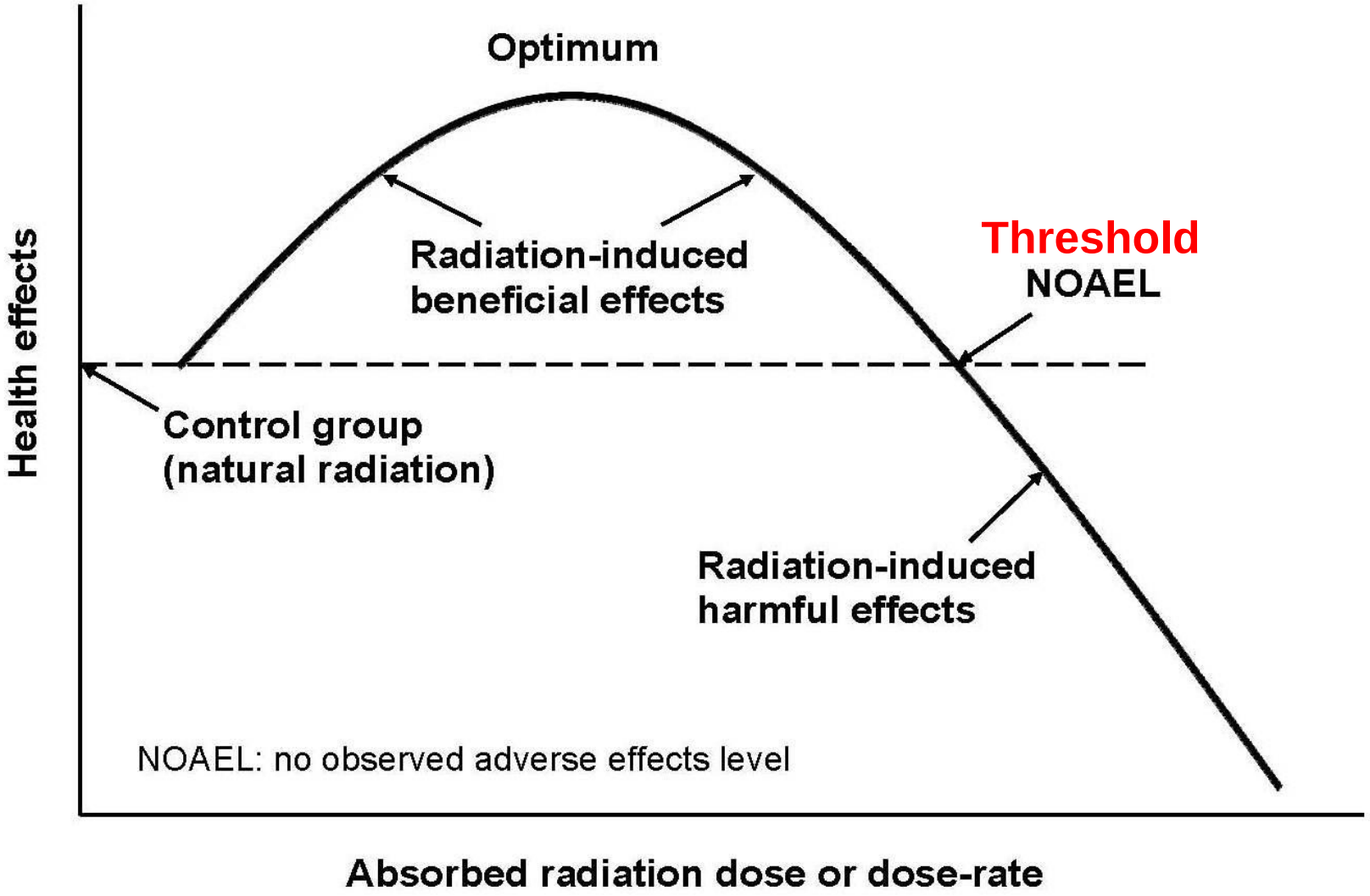


* Compliments of Dr. Mohan Doss

The shape of dose-response curve, with the correction for the likely bias in the baseline cancer rate, is consistent with the concept of radiation hormesis.

In atomic bomb survivor data, low radiation doses reduced cancers.

Radiation dose-response model



Compliments: Jerry Cuttler

Special Case of Low-Level Radiation*
Taiwan Apartment Study

- **Radioactive steel scavenged from nuclear reactor melted into rebar**
- **Used for constructing approximately 1700 apartments units/shops in Taiwan**
- **From 1982 to a 9-20 year period, ~ 10,000 people exposed to low level radiation (average accumulated dose ~ 400 mSv)**
- **Many still living in these apartments**
- **CLAIM: Over 40 deaths due to cancer**
- **BUT…In this population over this time, actual cancer deaths only 3% of cancer deaths expected from natural causes.**
- **Hence, the argument is made that this low level radiation SAVED many lives due to hormesis effect****

* Wikipedia, Civilian Radiation Accidents, 6-28-2009

** W.L. Chen, et. al, Effects of Cobalt-60 Exposure on Health of Taiwan Residents Suggest New Approach Needed in Radiation Protection, Dose Response, 2007 5(1):63-75, PM C2477708

- **NOTE: Later study by Hwang in 2006 reduced the cancer in the affected inhabitants by only 20% (Doss)**

Nuclear Shipyard Workers Study*
1980-1988

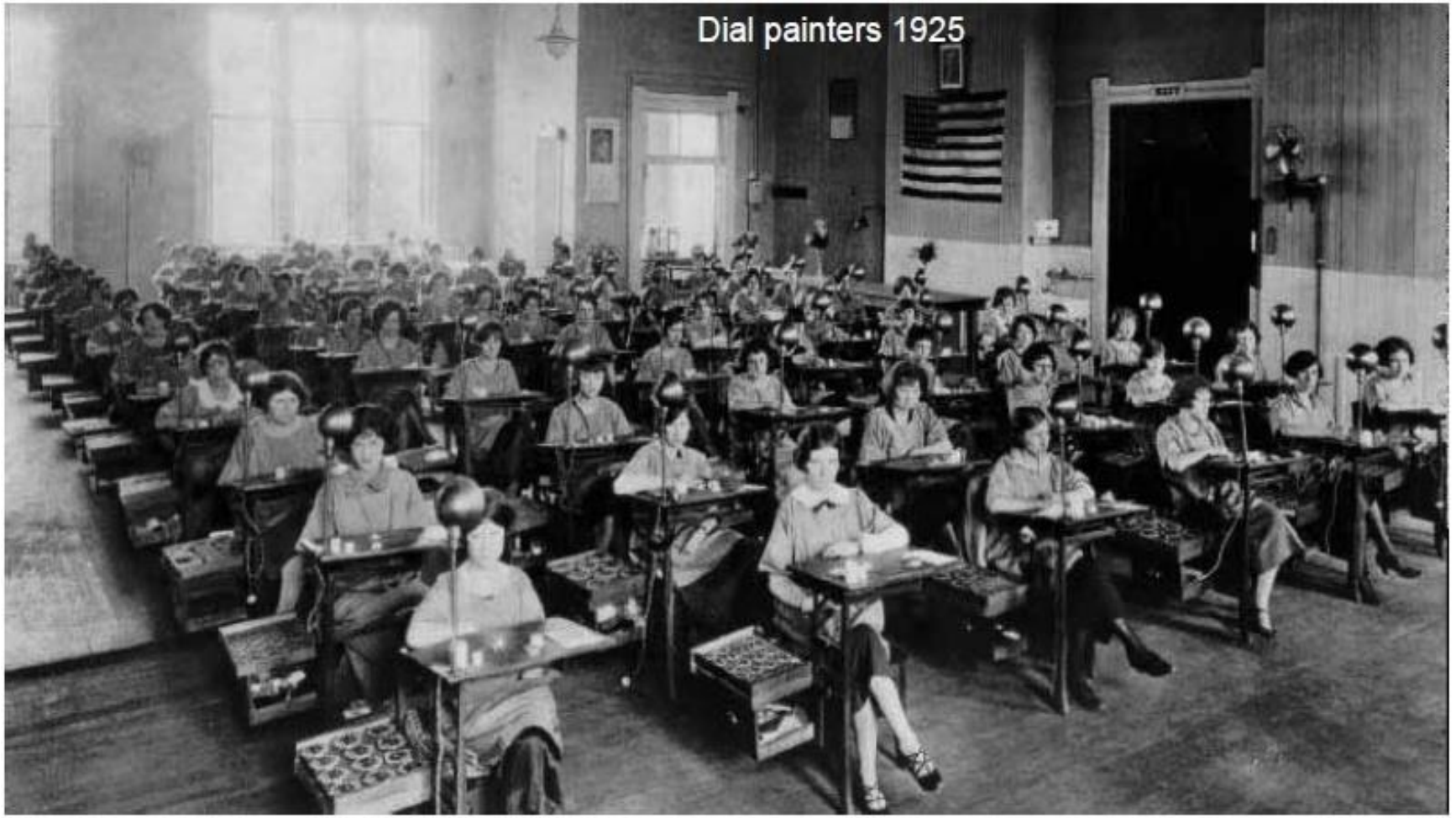
	High Dose	Low Dose	Zero Dose**
Workers	27,872	10,348	32,510
Deaths	2,215	973	3,745
Death Rate/Thousand	6.4	7.1	9.0
Death Rate	**0.76**	**0.81**	**1.00**

* Ruth Sponsler and John Cameron, *Int. J. Low Level Radiation, Vol 1, No.4, 2005*

** Beyond Background

4133 identified radium dial painters in USA

Bone cancer *threshold* at 10 Gy (1000 rad) radium alpha radiation



Compliments: Jerry Cuttler

Effect of low-dose radiation exposures on cancer

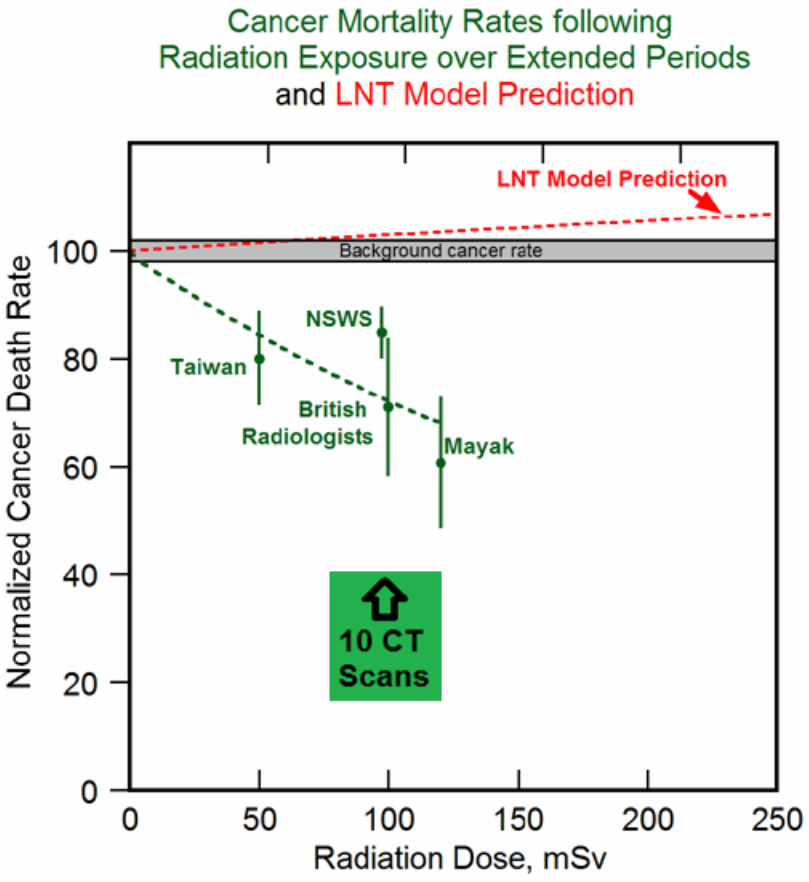


Figure legend:
LNT model Prediction – Using BEIR VII Report (NRC, 2006)
Taiwan - Residents of radio-contaminated apartments in Taiwan (Hwang, 2006)
NSWS - Radiation workers in Nuclear Shipyard Worker Study (Sponsler, 2005)
British Radiologists - British Radiologists who entered service during the period 1955-1979 (Berrington, 2001)
Mayak - Evacuated residents of villages near Mayak Nulcear Weapons Facility (Kostyuchenko, 1994)

Brenner/Hall, BEIR VII/BEIR VIII
Scoping Meeting ignored these data

Low-dose radiation exposures have resulted in reducing cancers contradicting the LNT model prediction

Compliments: Dr. Mohan Doss

Significant Quotes

- **Gunnar Walinder**, Swedish radiobiologist and author: Has Radiation Protection Become a Health Hazard?

  "The linear, no-threshold hypotheses is one of the greatest scientific scandals of modern times"

- **Abel Gonzalez**, Author of Radiological Effects of Fukushima

  "It is not possible for a competent pathologist to *attribute* human health damage due to radiation below background levels"

  NOTE: Global background levels range from 2mSv/y to 700 mSv/y

- **Lauriston Taylor**, Long-time chair of NCRP

  "No one has been identifiably injured by radiation while working within the first numerical standards set by the NCRP and then the ICRP in 1934 (namely 50 rem)"

The Main Problem:
Unnecessary fear of low-level radiation

- **~100,000 European women chose unnecessary abortions after Chernobyl**
- **Thousands avoid life-saving medical procedures because they involve radiation**
- **Harmless low-level wastes prohibited—causing many hospitals to shut down radiomedical treatment centers**
- **Thousands of deaths from pathogens infecting seafood, eggs, beef and poultry—all preventable by irradiating food.**
- **Huge costs borne in essentially all phases of the nuclear fuel cycle (mining, milling, enriching, reactor design and operations, recycled or reprocessed used fuel, final disposal) due to overly restrictive regulations**
- **~1600 actual deaths in Japan from Fukushima evacuation (stress, heart attacks, alcohol, etc.) though NONE from radiation!**

7) Radiation in Everyday Life*

- Agriculture
- Medicine
- Energy
- Industry
- Transportation
- Space Travel
- Public Safety
- Arts and Sciences
- Environment

* RADIATION AND MODERN LIFE: Fulfilling Marie Curie's Dream

AGRICULTURE

- **Optimizing Water and Fertilizer Use**
- **Speed Breeding of Improved Crops**
  - Greater yield
  - Increased disease resistance
  - Better nutritional value

- **Improved Animal Production**
  - Increase body weight
  - Vaccines to eliminate diseases
- **Insect Control**
  - Sterilization (screw worm, Mediterranean fruit flies, gypsy moths)
- **Improved Food Safety (Food Irradiation)**
  - Kill bacteria, molds, yeasts, parasites, insects
  - Extend shelf life

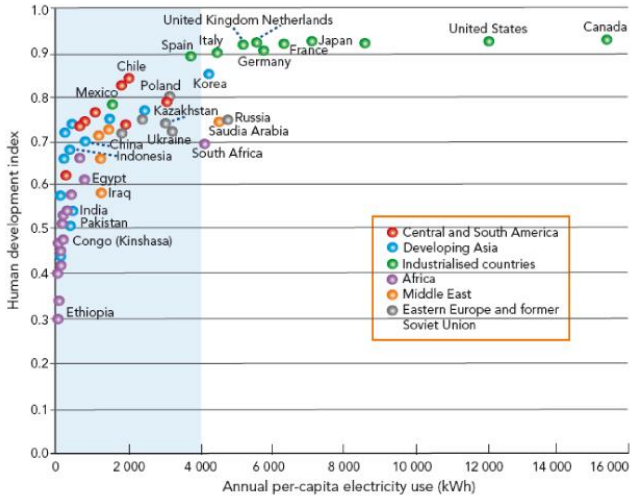
MEDICINE

- **Sterilization of Medical Products**
  - Surgical dressings, sutures, catheters, syringes
- **New Drug Testing**
  - Over 80% of all new drugs tested with radioactive tagging before approval
  - Between 200 and 300 radiopharmaceuticals in routine use
- **Medical Imaging (~90%)**
  - -- Diagnose the ailment
- **Therapy (~10%)**
  - -- Cure the ailment

NOTE: Much of the material from this talk was supplied by Professor Ilham Al-Qaradawi, Qatar University

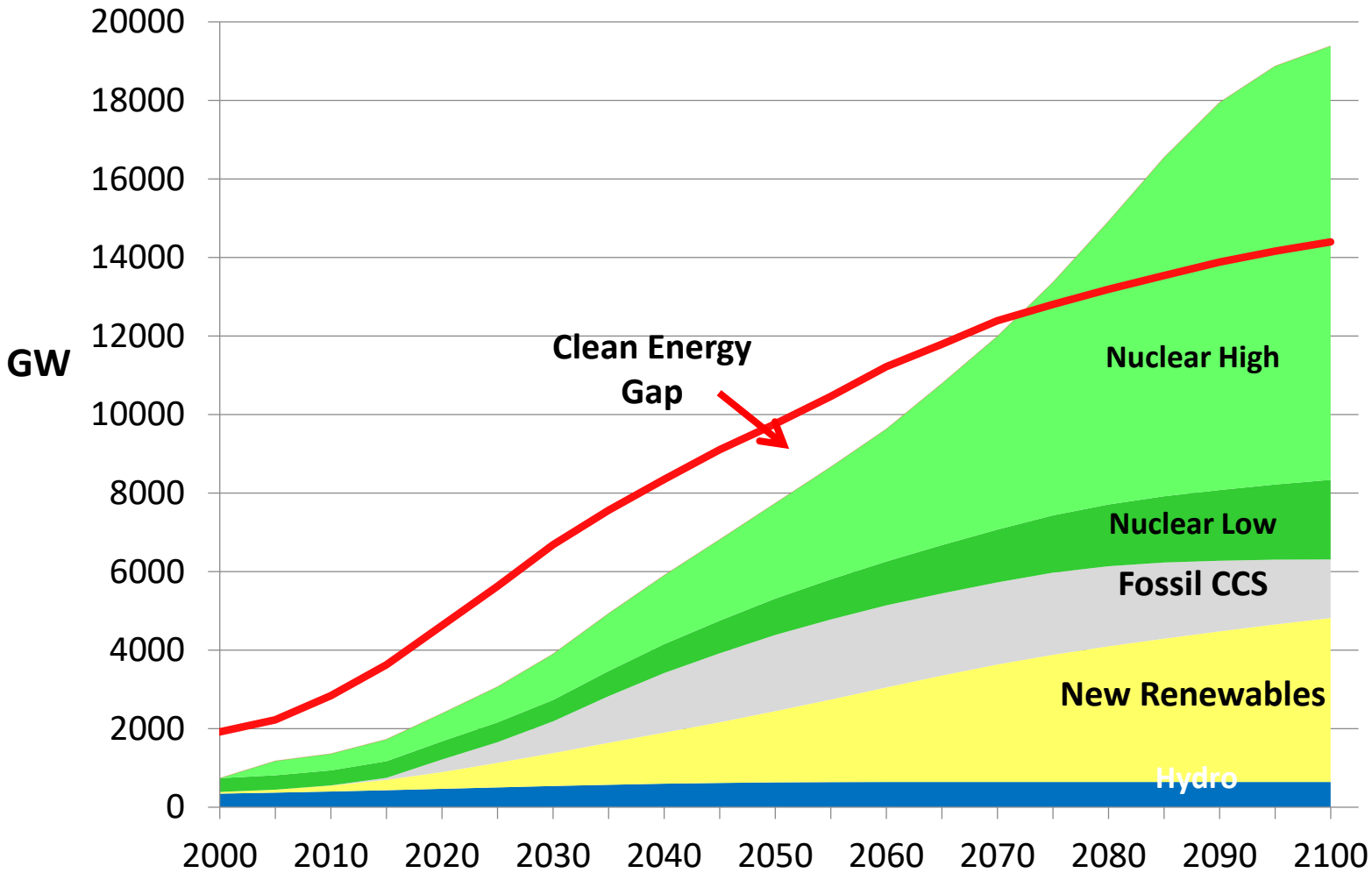
Energy

- **Electricity**
  - Strong Correlation with Quality of Life
  - Approximately 15% of Global Electrical Production
- **Desalinization**
  - ___% of Global Population Lives Near Seawater
  - Supplies of Potable Water Receding Rapidly
- **Process Heat**
  - Huge Need for Industrial Applications
- **Hydrogen Production**
  - The Road to “Hydricity”



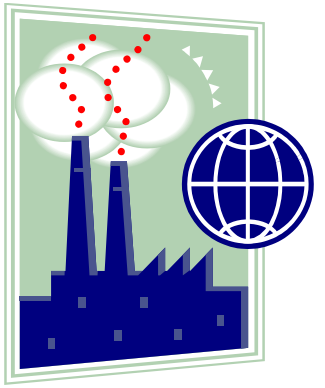
Electricity and human development

Global Clean-Energy Supply

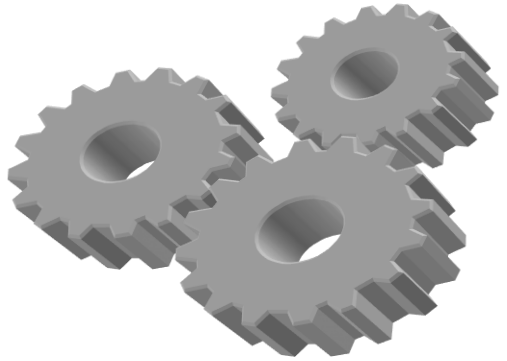


Compliments of John Ritch, WNA Nuclear Century Outlook

MODERN INDUSTRY



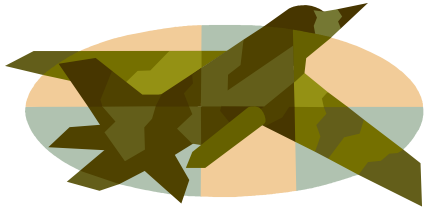
- **Process Control**
  - Thickness Gauges (sheet metal, paper, textiles)
  - Density & Level Gauges (oil and food industries)
- **Plant Diagnostics**
  - Tracers (pipeline leaks, malfunctions, wear and corrosion)
- **Materials Development**
  - Cross linking (e.g. heat shrink)
  - Gamma curing (e.g. floors)
  - Vulcanization (e.g. tires)

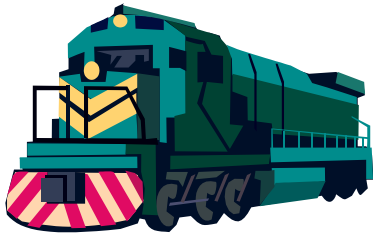


- **Materials Testing and Inspection**
  - Engine wear
  - Welds in airplanes, oil and gas pipelines
  - Corrosion in pipes

TRANSPORTATION

- **Cars and Trucks**
  - Engine Wear
  - Structure and body materials
  - Tires
  - Glass
- **Airplanes**
  - Structure and body materials
  - Weld inspections
- **Trains**
  - Rail inspections
- **Ship Power**
  - Submarines
  - Icebreakers
  - Surface Ships

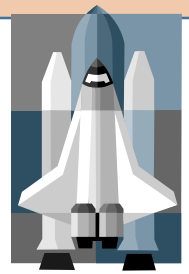




SPACE EXPLORATION

- **Heat Generation**
  - **Radioisotope Heater Unit (RHU)**
    - Pu-238 excellent heat source (87.7 yr half-life)
- **Electricity Generation**
  - Radio-Thermal Generators (RTG)
    - Direct conversion to electricity (~ 7% efficiency)
  - **Dynamic Isotope Power System (DIPS)**
    - Pu-238 still excellent heat source
    - Rankine cycle active system (~20% efficiency)

- **Nuclear Reactors**
  - For Missions > 100 KW



TERRORISM, CRIME, & PUBLIC SAFETY

- **Public Safety**
  - Smoke Detectors
  - Exit Signs
  - Airport Runway Lighting
  - Reduce Static Electricity (printing process, paper making)
- **Fighting Crime**
  - Neutron Activation of Body Samples
  - DNA Analysis
- **Fighting Terrorism**
  - Luggage Inspections (weapons, explosives, etc.)
  - Anthrax in Mail
  - Portal Monitoring
  - Detecting Mine Fields
  - Sensing Clandestine Weapons Testing
  - Sensing Contamination Releases (e.g. “Dirty Bombs”)

ARTS AND SCIENCE

- **Understanding our Origins**
  - Carbon-14 dating
- **Precious Gems**
  - “Cobalt Blue” Topaz
- **Radiation and the Arts**
  - Restoring and preserving artifacts
  - Authenticating paintings

Environmental Protection

…..ENVIRONMENTAL POLLUTION…..

Determine 1) Amounts and Locations of Pollution
2) Causes of Pollution
3) Proper Remedy

- **Managing Fresh Water Resources**
  - Preserving and Obtaining Potable Water Sources

- **Guarding the Oceans**
  - Coastal Zones and the Deep Seas

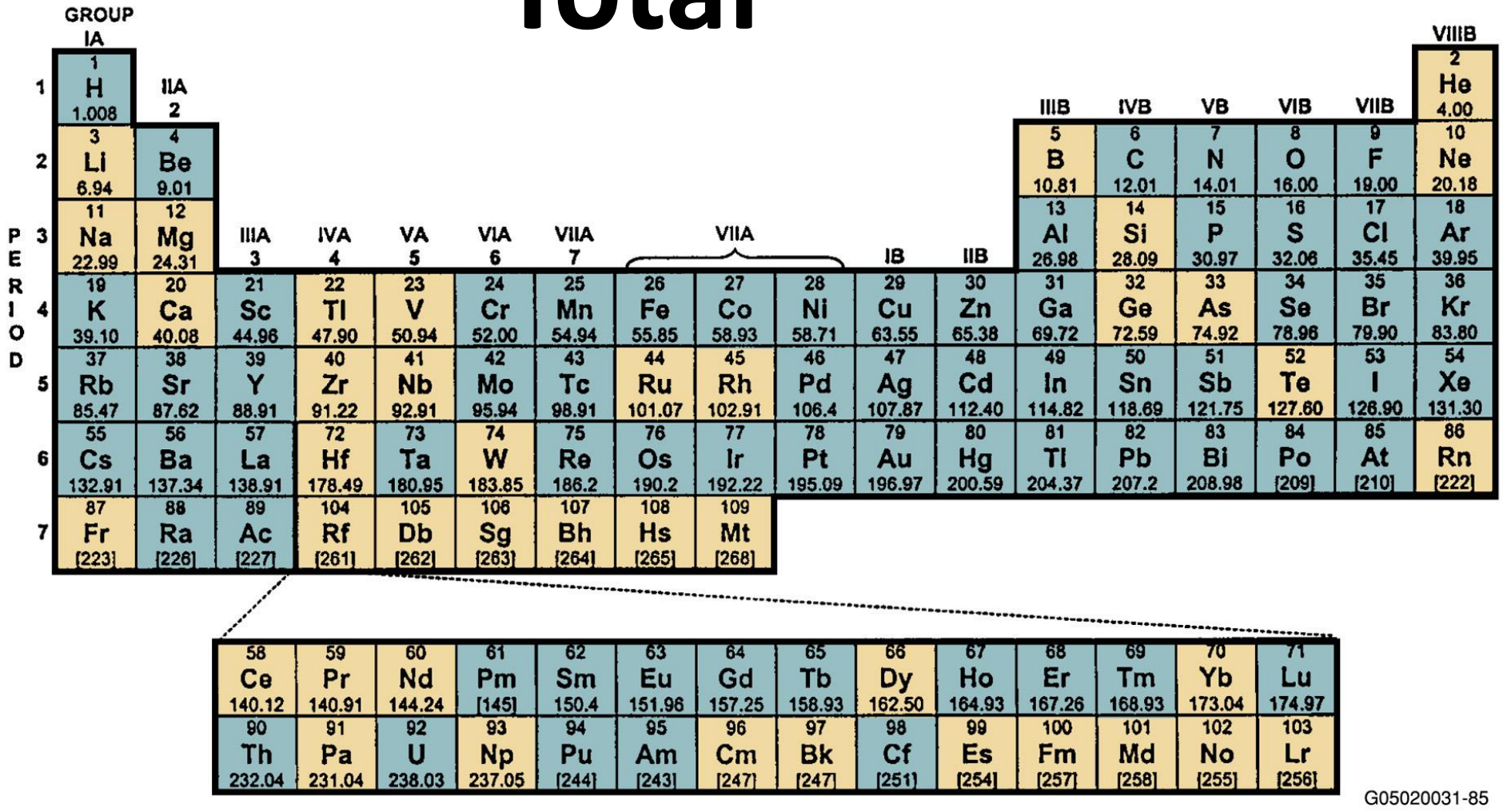
MODERN ECONOMY

Overall Impact in the U.S

(using multiplicative economic model)

	1991		1995	
	SALES $ Billions	JOBS Millions	SALES $ Billions	JOBS Millions
Radiation	257	3.7	**331**	**4.0**
Nuclear Power	73	0.4	**90**	**0.4**
TOTAL =	**330**	**4.1**	**421**	**4.4**

Total



Two-Thirds of the Elements in the Periodic Table Contain Radioisotopes Already Harnessed for Human Benefit

8) How Can We Resolve the LNT *issue*?

- **Articulate the Incredible Benefits of Radiation**
- **Bring the Professionals Together**
- **Professional Society Involvement**

Ingalls Creek Confluence Experiment

May 5-8, 2015 (Alan Waltar, Organizer)

LNT Proponents	Hormesis Proponents
Abel Gonzalez (Argentina)	Jerry Cuttler (Canada)
Bill Morgan (PNNL)	Ludwig Feinendegen (Germany)

Tony Brooks (WSU)

Environment Conducive to Valuing the Input of All Parties

Resulting Paper: The high price of public fear of low-dose radiation

Journal of Radiological Protection, **36**, 2016, 386

Professional Society Involvement

MEETING ANNOUNCEMENT

For more than thirty years, the scientific community has discussed and debated assumptions and models for low-dose radiation exposures.

The American Nuclear Society and Health Physics Society are joining forces to host a joint topical meeting on **Applicability of Radiation Response Models to Low Dose Protection Standards**. Topics will include:

- **Scientific foundations for radiation protection standards and emergency action guidelines**
- **Molecular basis of radiation response at low dose**
- **Applicability of linear no-threshold dose-response models**
- **Public perceptions of radiation risk**
- **Implementation of radiation protection regulations**
- **Opportunities for beneficial changes to radiation protection regulations**

Annapolis Gathering
Pre-Meeting Strategy Session
May 16-19, 2017

Participants:

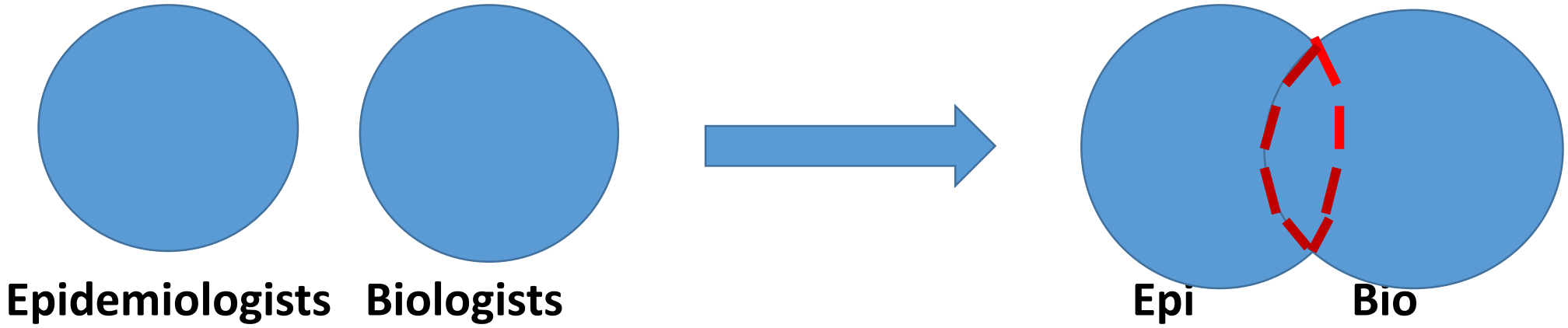
-- Ludwig Feinendegen (Germany, Radiobiology)
-- Nicholas Dainiak (ORNL, Radiation Emergency Assistance)
-- Paul Locke (John Hopkins School of Public Health, Member NCRP)
-- Randall Hyer (Center for Risk Communication)
-- Ron Neumann (Chief, Nuclear Medicine, National Institute of Health)
-- Mike Stabin (Radiobiology, Vanderbilt University)
-- James Welsh (Chairman, American College of Radiation Oncology)
-- Alan Waltar (Past President, American Nuclear Society)

Results of Annapolis Gathering

- **Help Organize the Topical Conference to Provide Welcoming Environment to All Professionals Interested in Low Dose**

  -- Radiation Epidemiologists (generally favor LNT)

  -- Radiation Biologists (generally favor low-dose benefits)



- **Produce Paper Focusing on Topical Meeting in International Journal of Radiation Protection**

Reasons for Using the LNT Model

- DNA damage increases linearly with dose
- It has withstood the test of time; Easy to administer
- Appears conservative and may protect maximum number of people
- Places regulators on the safe side
- Epidemiological data on Cancer risk at low dose scattered widely around zero
- Epidemiological data appear to support the LNT
- Radiobiology shows radio-sensitivity to vary among individuals
- Proponents do not believe upregulating mechanisms can prevent damage, repair, and removal

Reasons for Replacing the LNT for Low Doses

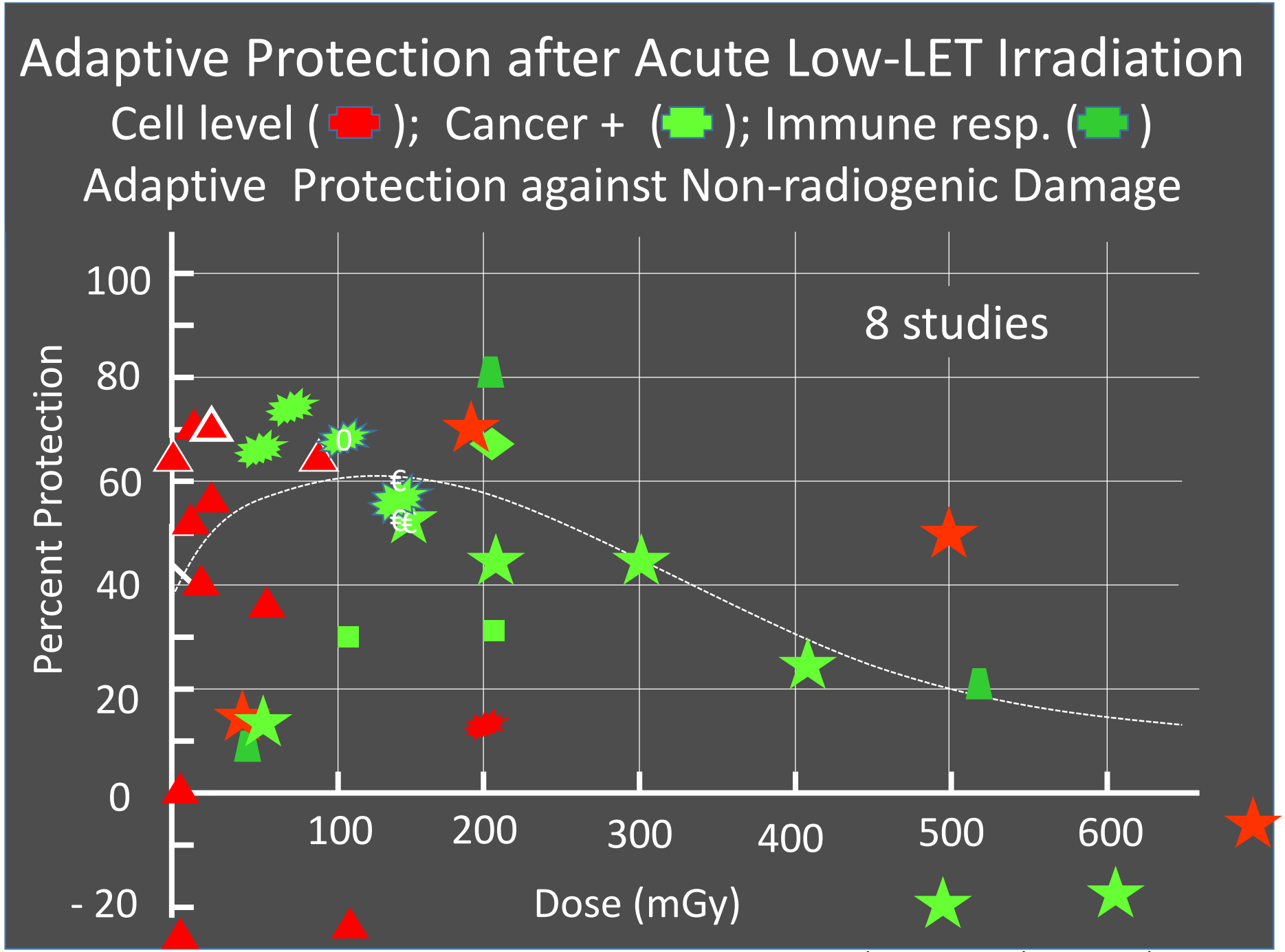
- Radiobiology challenges the LNT model as a basis of linking cancer to low-dose tissue responses
- Radiobiology demonstrates tissue responses to low dose are nonlinear
- Biological responses to high doses differ from to those at low doses
- Low doses predominately change cell signaling (such as oxidative stress) but homeostasis is maintained
- According to Bayesian statistics, the wide scatter of cancer risk at low doses close to zero argues against the LNT model
- Radiobiology has shown the potential for adaptive protection at cellular, tissue, and organism levels
- Individual radio-sensitivity is determined by observable genetic variation
- A practical threshold model simplifies recommendations for radiation protection

9) Conclusions

- **High Level Radiation is linear with dose**
  - **LNT is applicable**
- **Low Level Radiation is non-linear**
  - **LNT needs revision**
- **LNT is NOT conservative**
  - **Unintended consequences include**
    - **High cost of everything "nuclear"**
    - **Actual deaths following Fukushima**
    - **Enormous Unsubtantiated Public Fear**

- **Need to join forces to insist on modern science to improve low-dose regulations**
  - **Bring radiation epidemiologists and biologists together)—Initiate well-structured R&D program**
- **Provide international focus on resolving these issues at the 2018 ANS/HPS Topical Conference on "Applicability of Radiation Response Models to Low Dose Protection Standards"**

Backup



Compliments: Dr. Ludwig Feinendegen

In his book, *Has Radiation Protection Become a Health Hazard?* Gunnar Walinder, a Swedish radiobiologist, states unequivocally: “The linear, no-threshold hypothesis is one of the greatest scientific scandals of modern times.”

The absence of evidence of harm from low level exposures is not due to incompetence or lack of attempts to find effects. Lauriston Taylor is unambiguous: “No one has been identifiably injured by radiation while working within the first numerical standards set by the NCRP and then the ICRP in 1934. Let us stop arguing about the people who are being injured by exposure to radiation at the levels far below those where any effects can be found. The fact is, the effects are not found despite over forty years of trying to find them. The theories about people being injured have still not led to the demonstration of injury and, though considered as facts by some, must only be looked upon as figments of the imagination.” The inconclusive scientific status of the LNT hypothesis renders ethical arguments dependent upon it inherently flawed.

Hormesis: Scientific evidence now exists for a hypothesis counter to — yet equally worthy of attention given — the LNT hypothesis. Just as there are net beneficial effects from low levels of exposure to otherwise toxic substances — e.g. copper, selenium, fluoride, nickel — there is also persuasive evidence of net beneficial effects from exposure to low- level radiation. Indeed it may be essential for the continued wellbeing of living organisms which have evolved in relation to wide variations in exposure to natural radiation sources. Both LNT and ALARA guidelines unjustifiably assume that any degree of

Ethical Travesties: Fear of radiation has proved to be far more detrimental to public health than radiation itself. No actual deaths of U.S. citizens have been attributed to accidental releases of radiation from reactors. But fear of radiation has proved fatal: (1) fear of bearing a "nuclear mutant" led 100,000 European women to choose unnecessary abortions after Chernobyl; (2) thousands of people avoid life-saving medical procedures such as mammograms or radiotherapy because they involve radiation; (3) regulatory roadblocks preventing management of harmless low-level wastes are causing many hospitals to shut down radiomedical treatment centers; (4) thousands of deaths from pathogens infecting seafood, eggs, beef and poultry could be prevented by irradiating food. Moreover billions of dollars have already been spent on trivial radiation risks based on grotesque scenarios about (1) single atoms destined to migrate through miles of desert soil to contaminate a potential water source in some distant future, or (2) measurable radon producing sick buildings which require costly remediation or destruction. Fear endangers human health.

The LNT Hypothesis: Ethical Travesties

Presenter: Margaret N. Maxey, Ph.D.
Professor, Biomedical Engineering, College of Engineering
The University of Texas at Austin
Event: Wingspread Conference, Racine, WI, August 1997

Sohei Kondo at Osaka, Japan's Kinki University has conducted research into atomic bomb survivors which shows slight decreases in cancer deaths among those exposed to low doses — suggesting that radiation-induced precancerous cells undergo self-killing or apoptosis which prevents later