Department of Energy
Nuclear Energy Advisory Committee
6 December 2012 – Washington, D.C.

NCRP and the Million Worker Study

John D Boice Jr
National Council on Radiation Protection and Measurements (NCRP)
Vanderbilt University, Dept of Medicine

John.Boice@ncrponline.org
http://NCRPonline.org

NCRP
Scientific Authority Since 1929

Outline

NCRP

Million U.S. Radiation Worker and Veteran Study

- DOE Manhattan Project Workers
- NRC Nuclear Utility Workers
- DOD Atomic Veteran
- Medical Workers

NCRP Scientific Authority Since 1929

Opportunities

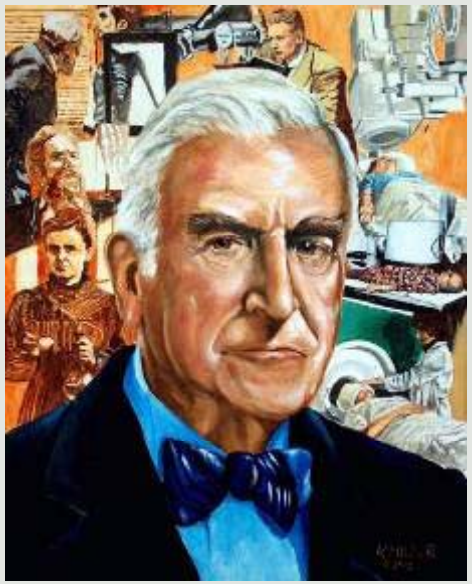
National Council on Radiation Protection & Measurements

NCRP
Scientific Authority Since 1929

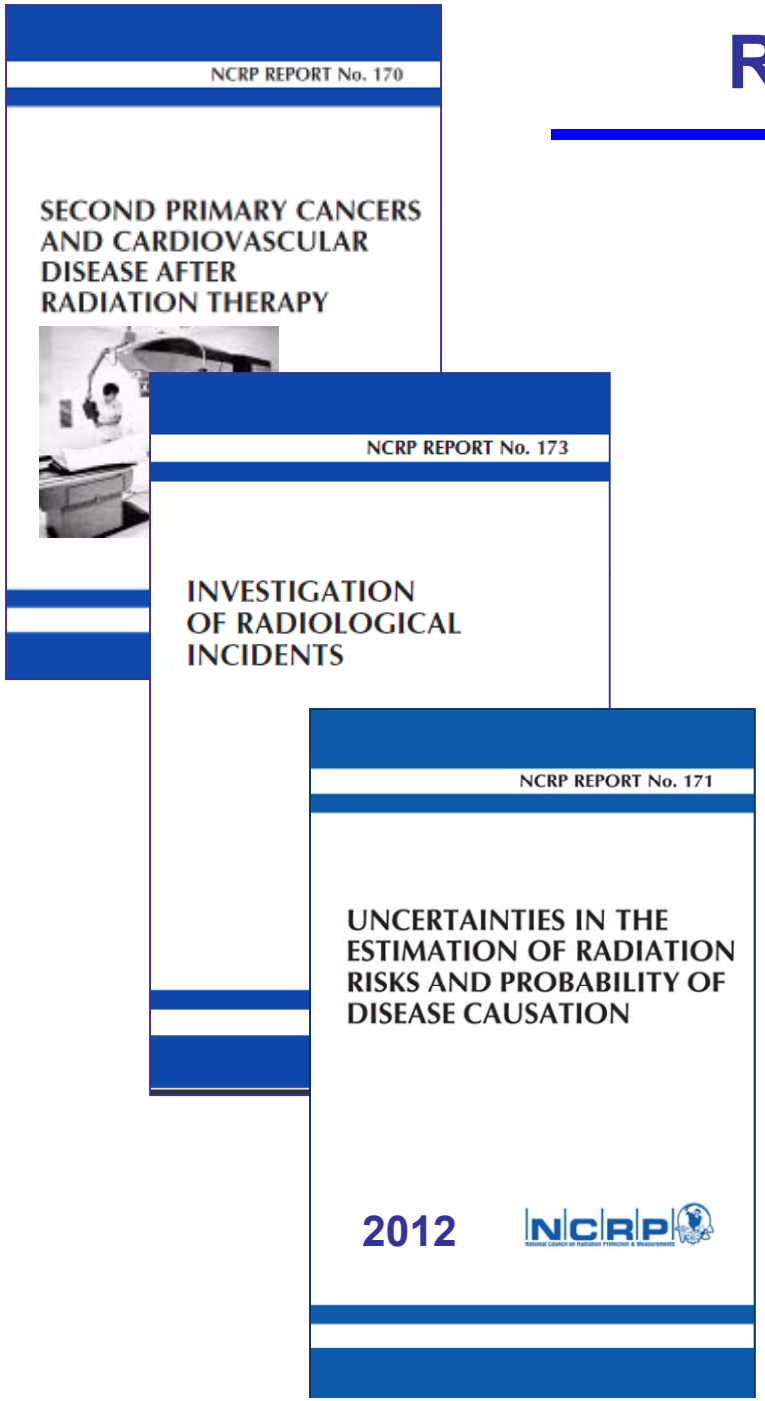
1929: U.S. Advisory Committee on X-ray and Radium Protection

1946: U.S. National Committee on Radiation Protection

1964: National Council on Radiation Protection and Measurements chartered by Congress (Public Law 88-376)



Reports, Advice, Research



National Study of One Million U.S. Radiation Workers and Veterans

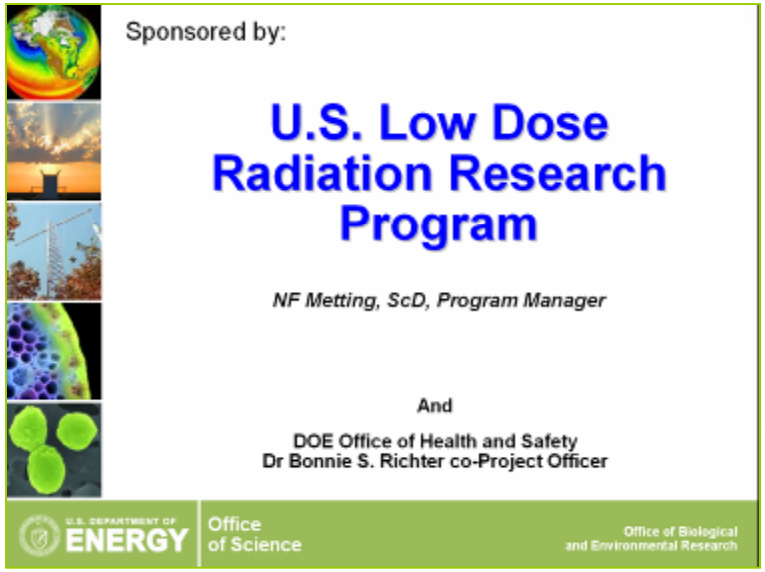
Robert Oppenheimer, General Leslie Groves, Enrico Fermi, Hans Bethe, Theodore Hall

- Manhattan Project
- Atomic veterans
- Nuclear utility workers
- Medical and other
- Other military – possibly Navy

OAK (HARDTACK I), Enewetak, 8.9 MT, 28 Jun 1958

Health Physics News October 2012

Sponsored by:



NATIONAL CANCER INSTITUTE

DEFENSE THREAT REDUCTION AGENCY
UNITED STATES OF AMERICA

U.S.NRC
United States Nuclear Regulatory Commission
Protecting People and the Environment

NASA

Vanderbilt-Ingram Cancer Center

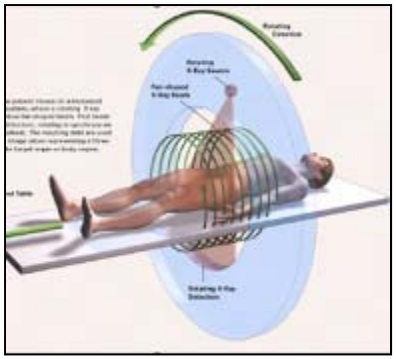
EPA

UNITED STATES
DEPARTMENT OF VETERANS AFFAIRS

The Major Issue in Radiation Epidemiology and Radiation Protection?

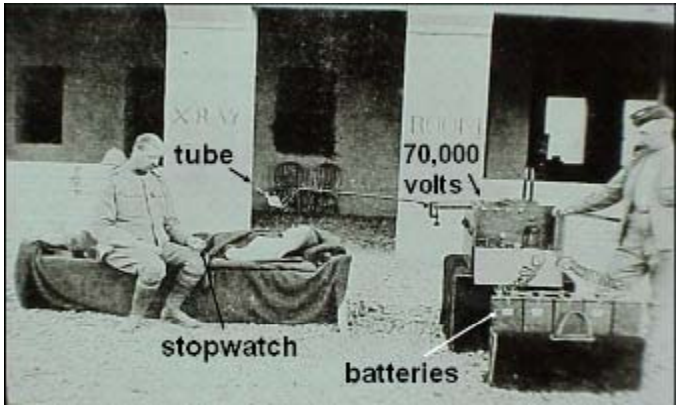
What is the level of risk when exposure received gradually over time and not briefly ?

Medicine



Accidents

Occupation



Environment

Summary of Progress

- The Pilot study demonstrated that the full-scale study is feasible.
- The study population is 10x larger than the atomic bomb survivor study and has more high-dose subjects (>100 mSv) and many more deaths (286,000 to date).
- The assembled cohort consists of 196,000 DOE uranium workers, 155,000 DOE plutonium workers, 300,000 nuclear power plant workers, over 300,000 other radiation workers, and 115,000 atomic veterans.
- The study has substantial statistical power to evaluate low-dose rate radiation effects.

WHERE THERE IS NO VISION, THE PEOPLE PERISH.

PROVERBS 29:18

85 mrem/y = 0.85 mSv/y

U.S. Congress

The Vision – One Million U.S. Workers

Targeted Populations Datasets Obtained

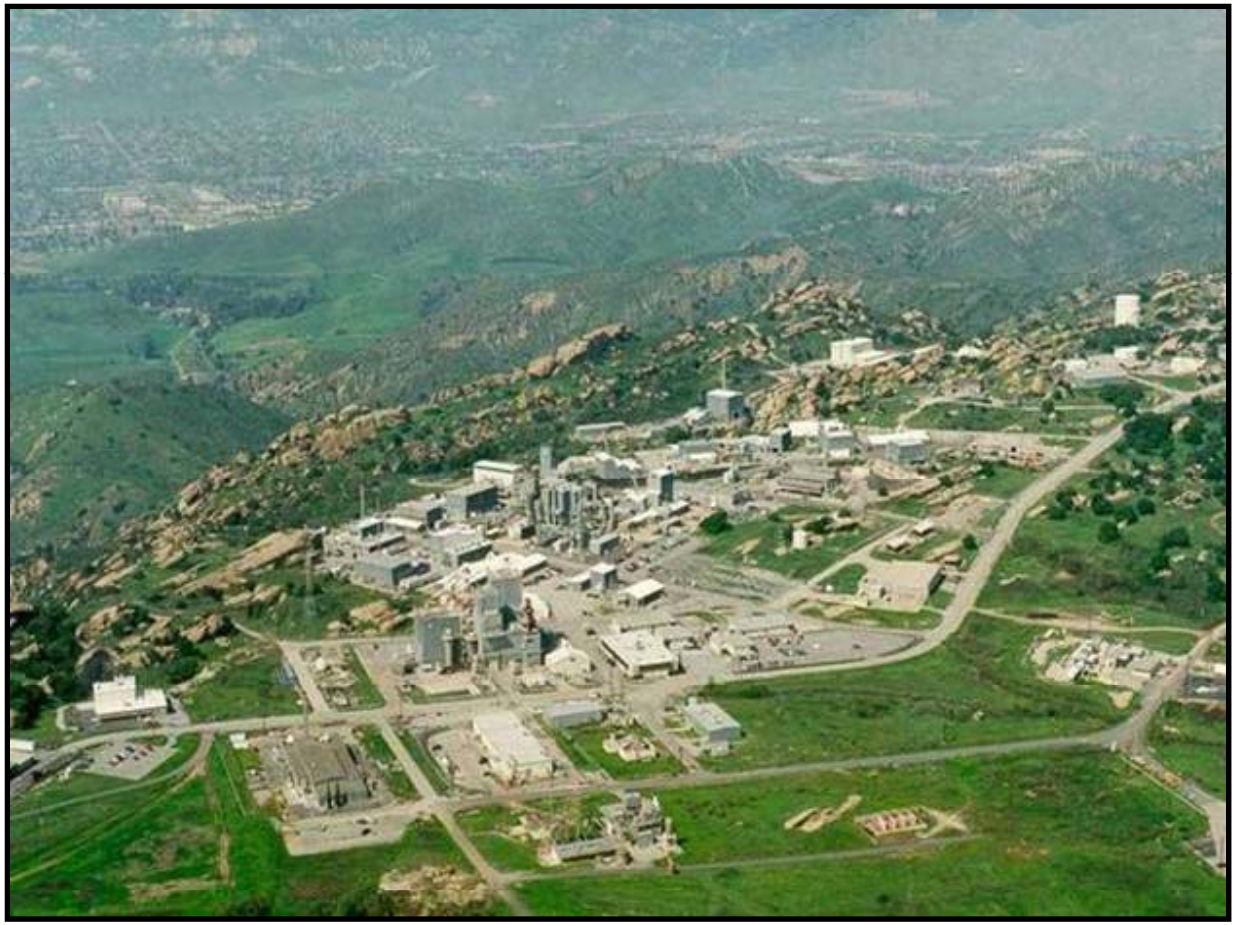
[X]	Uranium Workers DOE	196,000
[X]	Plutonium Workers DOE	155,000
[X]	Nuclear Power Plant Workers – to date	300,000
[X]	Other Radiation Workers, > 50 mSv	71,000
	other Radiologists, Industrial Radiography	~230,000
[X]	Atomic Veteran DOD	115,000
		>1,000,000

Other Possibilities

[ ]	Navy Submariners (Charpentier 1993)	76,000
[X]	Nuclear Test Participants at Underground Tests	38,000

X = Datasets obtained

The Model
Rocketdyne/Atomics International
Santa Susana Field Laboratory

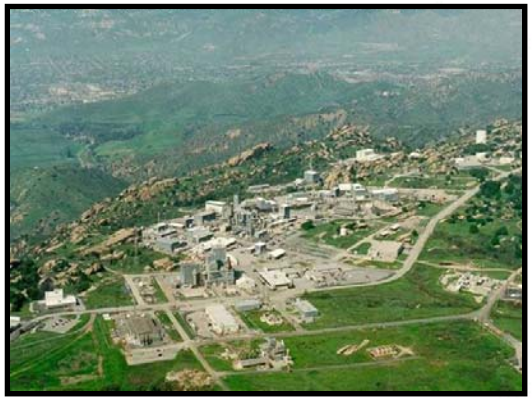


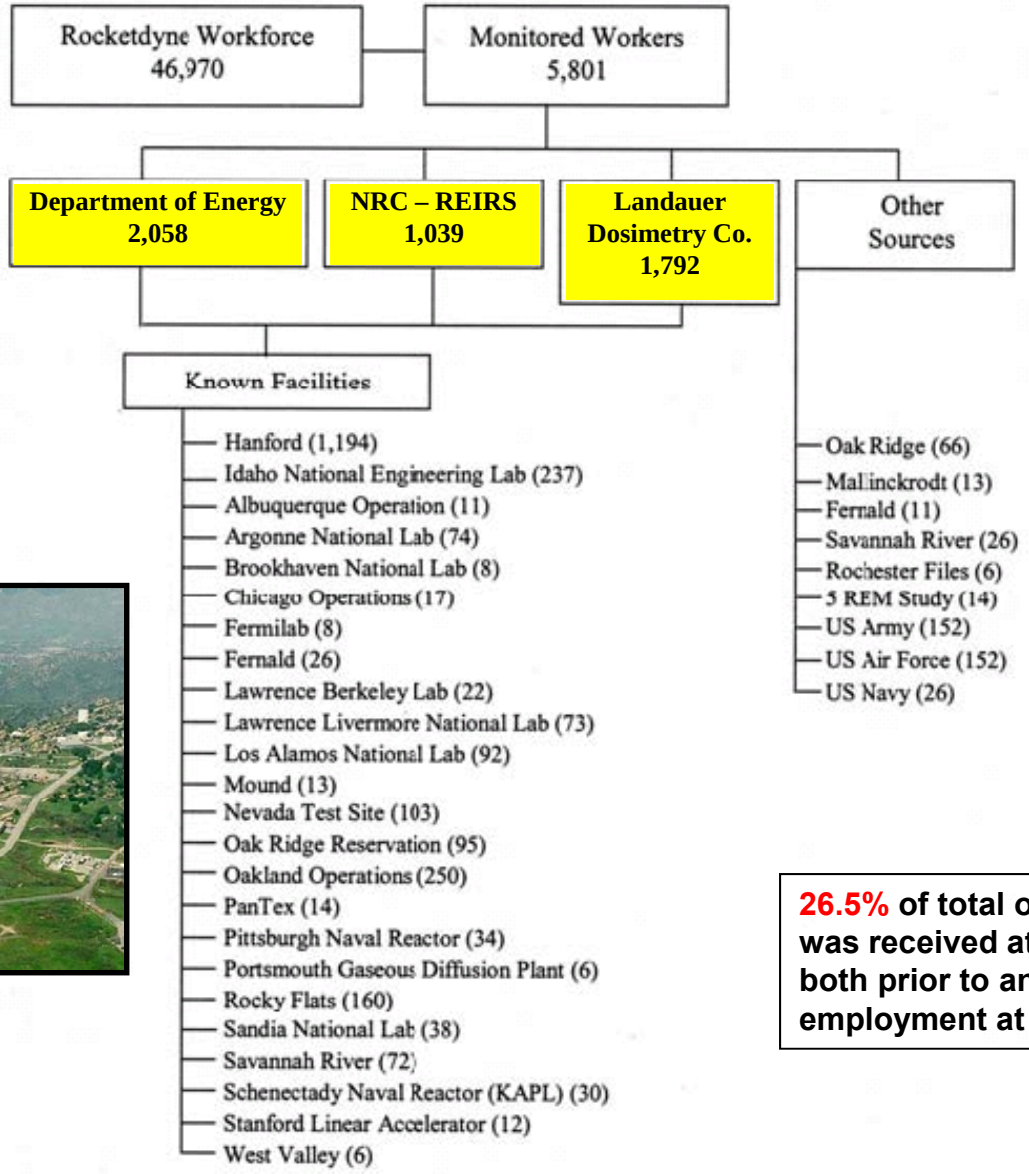
Simi Valley
Sodium reactor
Moorpark 1957
Edward R Murrow
'See it Now'
Accident 1959
Saturn Engine

Leggett et al. J Radiol Prot 2005
Boice et al. Health Physics 2006

Boice et al. Radiat Res 2006
Boice et al. Radiat Res 2011

Career Doses
Sources of Radiation Exposure Histories





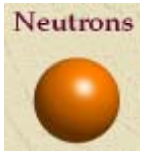
26.5% **of total occupational dose was received at other facilities both prior to and after employment at Rocketdyne.**

Types of Exposure

- Gamma
- X-ray (radiographers)
- Neutrons

- Uranium, Plutonium
- Americium, Polonium
- Thorium, Strontium
- Cesium, Tritium

External



Uniform dose

Delivered during exposure

Film (TLD) badge reading

Internal

Non uniform dose

Protracted in time

Bioassay measurements

Discussion Sessions with Former Radiation Workers

VANDERBILT UNIVERSITY

Rocketdyne (Internal Dosimetry)

ROCKETDYNE WORKER STUDY
Example of Bioassay Data (1967)

DATE	TYPE	ANALYSIS	METHOD	RESULTS	REFERENCE
18 Sept 67	Urine	UR	ID	78	U.S. Testing
25 Sept 67	Urine	UR	ID	90	U.S. Testing
2 Oct 67	Urine	UR	ID	78	"
4 Oct. 67	Urine	UR	ID	116	"
16 Oct 67	Urine	UR	ID	175	"
23 Oct 67	Urine	UR	ID	40	"
28 Oct. 67	Fecal	UR UF	ID IA	58	U.S. Testing
30 Oct. 67	Urine	UR	ID	60	U.S. Testing
6 Nov 67	Urine	UR	ID	66	U.S. Testing
17 Nov 67	TBC	U^{236} for U^{234}		0.0089 uCi U^{234}	UCLA
14 Nov 67	TBC	"		0.0087 uCi U^{234}	ORNL
20 Nov 67	Urine	UR	ID	47	US Testing
21 Nov 67	TBC	U^{238} for U^{234}		0.0086 uCi U^{234}	UCLA
27 Nov 67	Urine	UR	ID	54	US Testing

Important information to capture included specific radionuclides, urine, fecal, and whole body radionuclide count results. Information on acute versus chronic uptakes, solubility and particle size also was captured to the extent available.

Rocketdyne - 2011

Updated Mortality Analysis

VANDERBILT UNIVERSITY

RADIATION RESEARCH 176, 244–258 (2011)
0033-7587/11 $15.00

DOI: 10.1667/RR2487.1

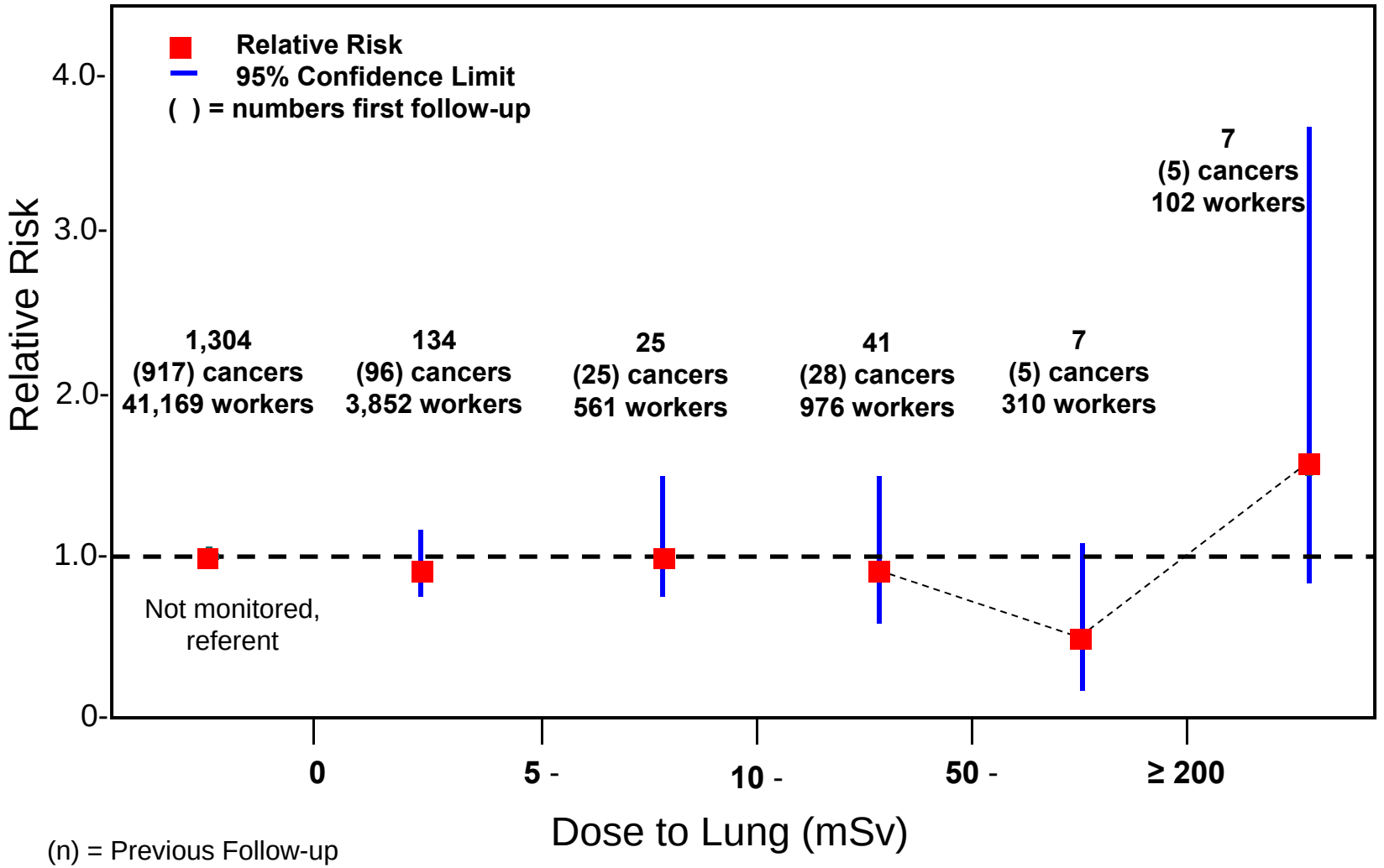
Updated Mortality Analysis of Radiation Workers at Rocketdyne (Atomics International), 1948–2008

John D. Boice, Jr.,[a,b,1] Sarah S. Cohen,[a] Michael T. Mumma,[a] Elizabeth Dupree Ellis,[c] Keith F. Eckerman,[d] Richard W. Leggett,[d] Bruce B. Boecker,[e] A. Bertrand Brill[b] and Brian E. Henderson[f]

[a] *International Epidemiology Institute, Rockville, Maryland 20850;* [b] *Vanderbilt University Medical School and Vanderbilt-Ingram Cancer Center, Nashville, Tennessee;* [c] *Oak Ridge Associated Universities, Oak Ridge, Tennessee;* [d] *Oak Ridge National Laboratory, Oak Ridge, Tennessee;* [e] *Lovelace Respiratory Research Institute, Albuquerque, New Mexico; and* [f] *University of Southern California, Los Angeles, California*

"Larger combined studies of early workers in the United States using similar methodologies are warranted to refine and clarify radiation risks after protracted exposures."

Incorporation of Internal Doses (UAI_x) + EXT Lung Cancer - Rocketdyne



(n) = Previous Follow-up

10 year lag

10 mSv = 1 rem

Mound Plant, Dayton, Ohio
Innovations & Polonium

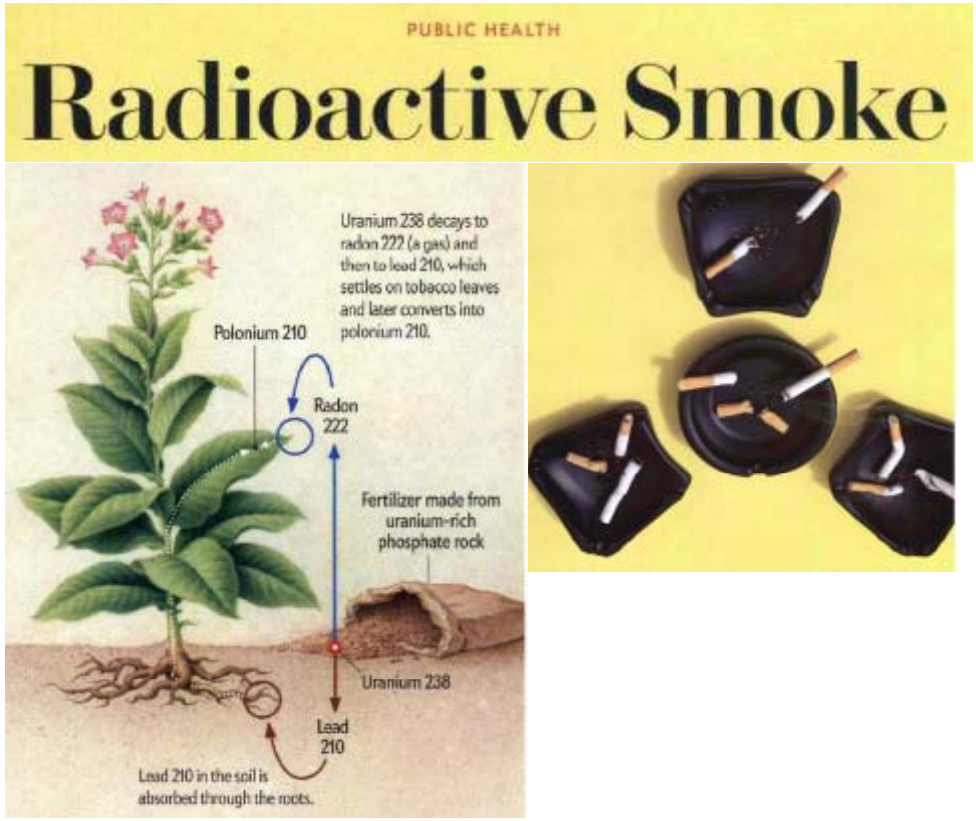
- **Dosimetry**: Polonium, Plutonium, Tritium, External
- **Tracing**: 98% of 7,291 workers (1944+)
- **Cancer incidence** - linkage with Ohio Cancer Registry (1996+)
- **Renal Disease Registry** linkage (1976+)
- **Historical note**: produced triggers for Trinity site and Nagasaki "Fat Man" plutonium bombs

Mound, Dayton, Ohio
Polonium 210 (7,291 Workers)

Alexander V. Litvinenko in his hospital bed in London on Nov. 20, 2006

George Koval
December 25, 1913 to January 31, 2006

Current Interest
Radioactive Smoke / Arafat



Rego, Sci Am 2011

People visit the grave of Palestinian leader Yasser Arafat the day after he was buried in Ramallah, West Bank, in 2004.

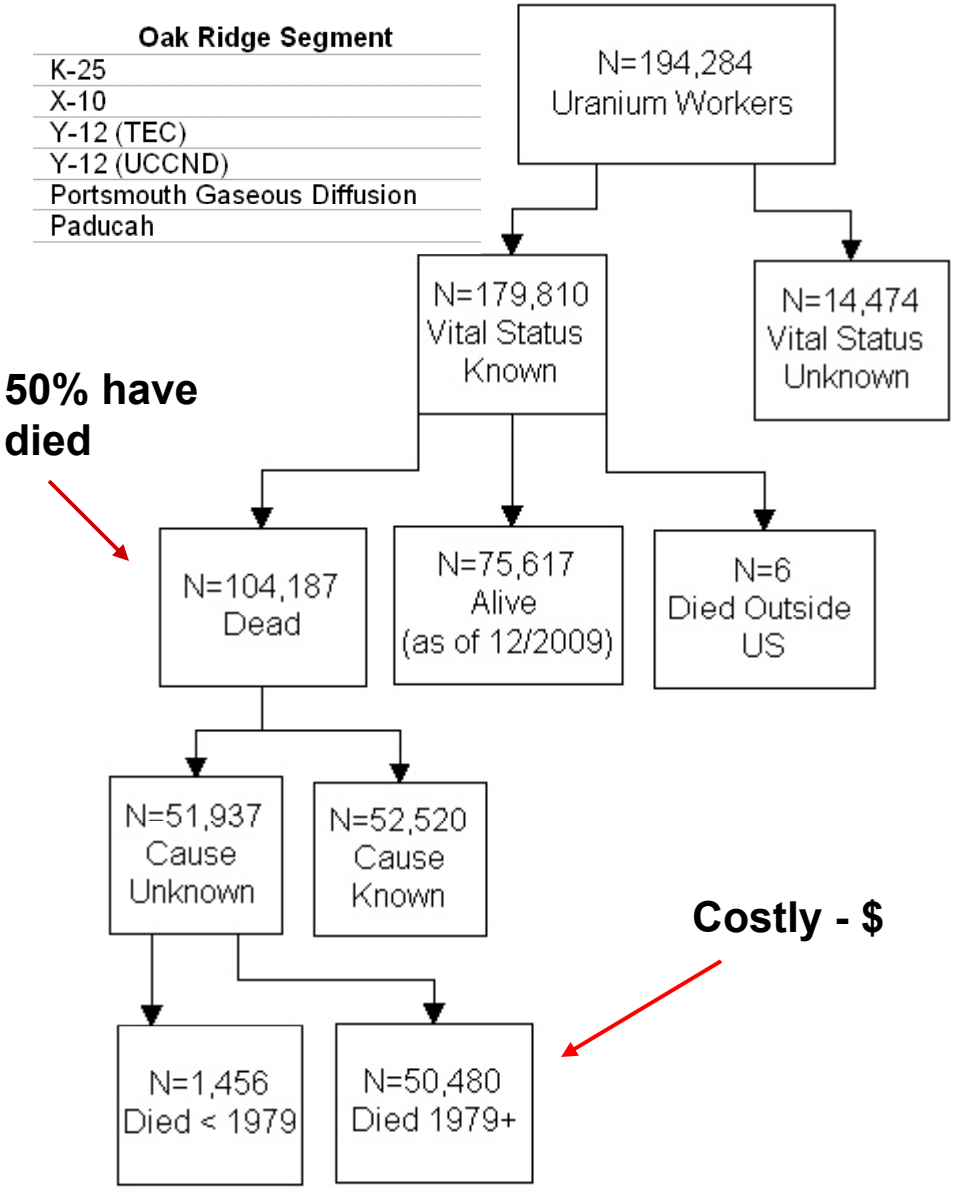
Polonium: A little goes a long way

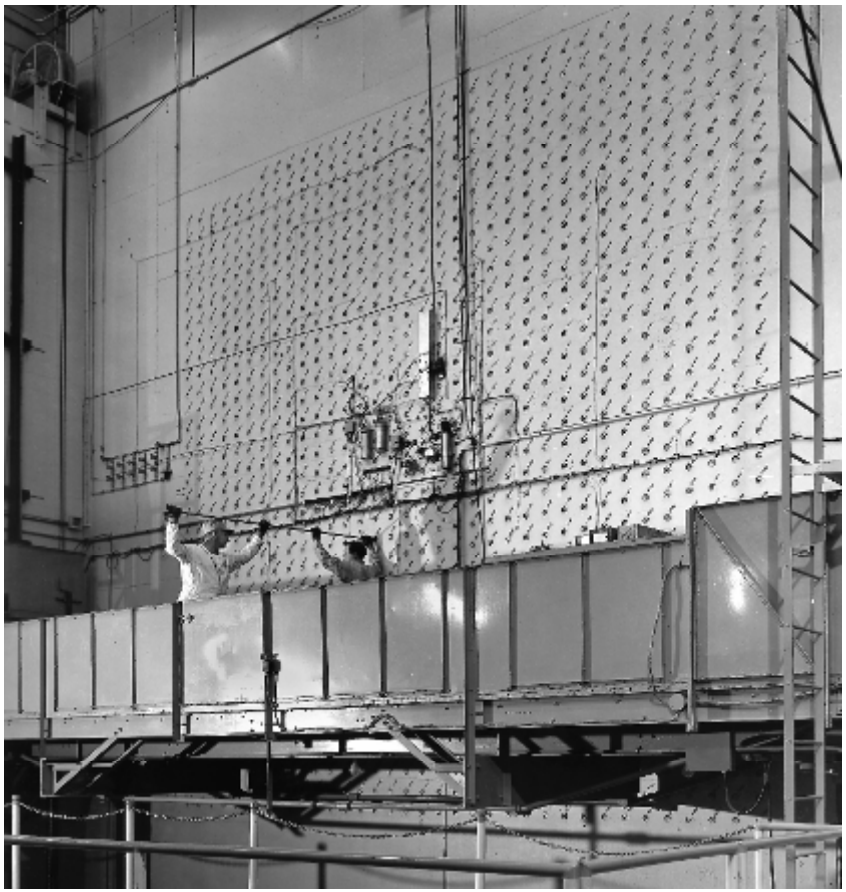
By **Elizabeth Landau**, CNN
updated 3:21 PM EST, Tue November 27, 2012

CNN Health

Uranium Workers – Vital Status

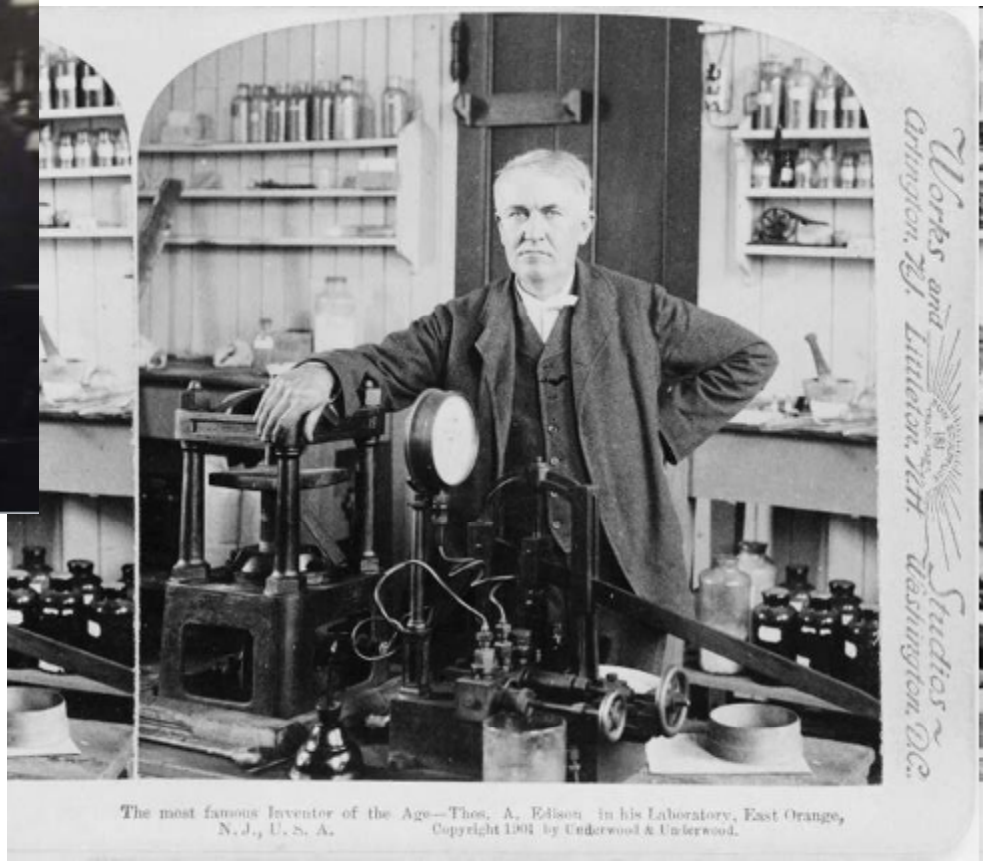
Oak Ridge Segment
K-25
X-10
Y-12 (TEC)
Y-12 (UCCND)
Portsmouth Gaseous Diffusion
Paducah





Workers load uranium slugs into the X10 Graphite Reactor face in Oak Ridge, TN. Built as part of the Manhattan Project, X10 was the first-ever production reactor. Circa 1943

Genius is one percent inspiration and ninety-nine percent perspiration – Thomas Edison



Scanning 30 Boxes of Death Certificates (29,300)

The Scanners --- Employing America's Youth

Wake Forest (2), Milligan, Towson State, Gettysburg, U of Virginia, Ohio U

Plutonium Workers

Table 5-1. Cohorts of plutonium workers

Worker cohort	No. in database
Los Alamos	23,288
Rocky Flats	9,586
Hanford	56,688
Mound	7,293
Sandia	24,685
Sum of workers	121,540
Other	**33,388**
	Total 154,928

13th International Congress of the International Radiation Protection Association, Glasgow, Scotland

Dose Assessment Due to Inhalation of Plutonium Nanoparticles

Leigh Cash, Guthrie Miller, and Luiz Bertelli

Los Alamos National Laboratory • PO Box 1663, MS G761 • Los Alamos, NM 87545, USA • lcash@lanl.gov

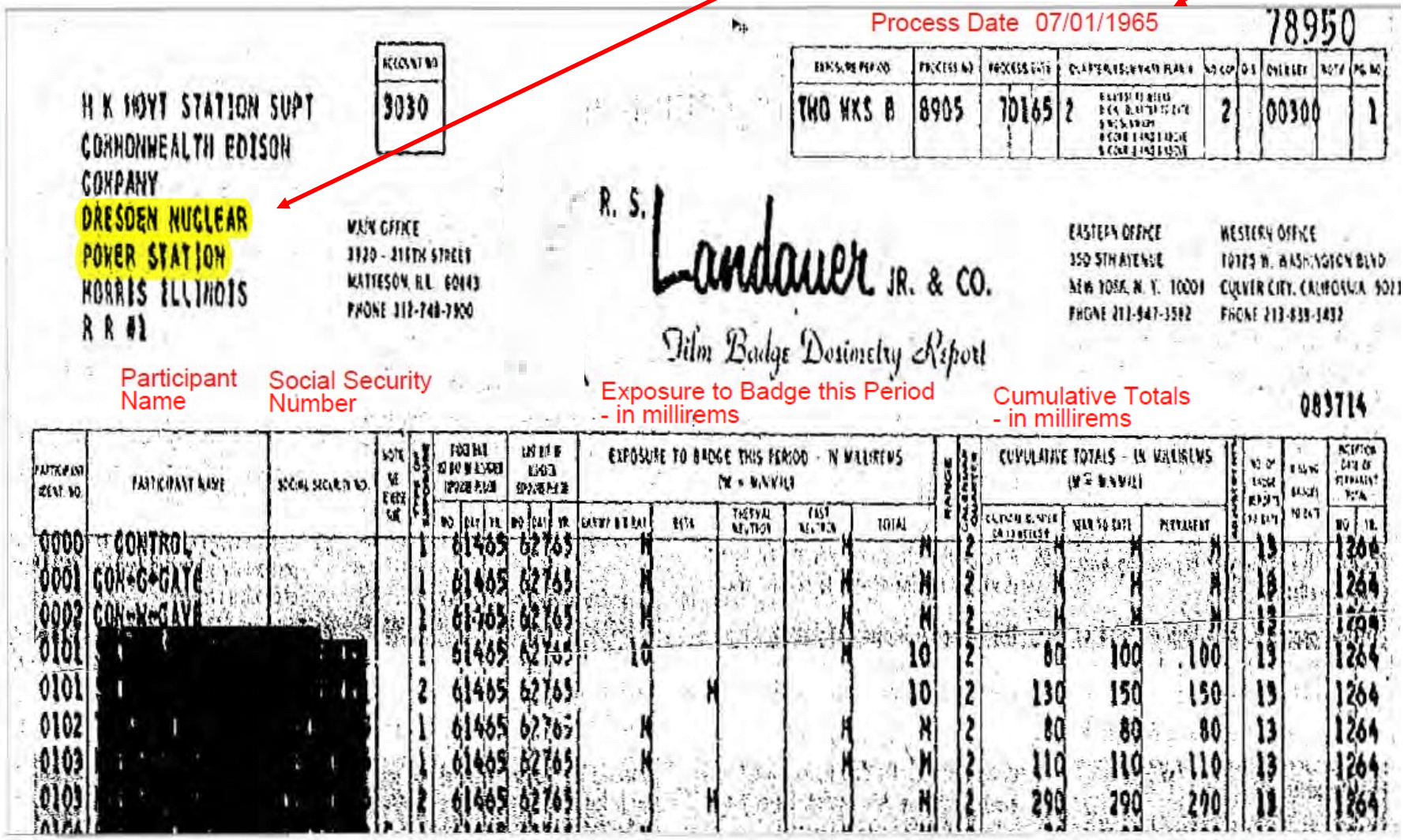
INTRODUCTION

Experience has shown that nanoparticles behave differently in terms of deposition and clearance from the respiratory tract as compared to micron-sized particles. However, currently used HRTM models have not addressed the very particular aspects of inhalation, deposition and further distribution of radioactive nanoparticles in the human body. Plutonium is one of the most important radionuclides in the nuclear industry and production of it in nanoparticle form is not negligible. Therefore, this study was done to investigate deposition to the respiratory tract, clearance, and subsequent distribution to systemic organs based on animal data and human studies.

Nuclear Power Plant Workers

- ***U.S. Early Nuclear Utility Workers***
  - "There is a large number of the order of 600,000 workers; there is good dosimetry and a range of doses. Early workers received quite high doses because at the time the maximum permissible dose was defined to be 5 (N – 18) rem.
  - As a consequence some workers recorded doses as high as 1000 mSv. " (Hall EJ et al. DOE Workshop. Rad Res 2009.)
  - **300,000** early workers identified in Landauer/NRC-REIRS databases

Microfilm Image – Dresden NPP



Director, NCI to Chairman, NRC re: annual reporting of doses for medical studies

DEPARTMENT OF HEALTH & HUMAN SERVICES

Public Health Service

National Institutes of Health
National Cancer Institute
Bethesda, Maryland 20892

SEP 17 1986

Vincent T. DeVita, Jr., M.D.

Mr. Landow W. Zech, Jr.
Chairman
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Zech:

The present risk estimates for low-dose exposure to ionizing radiation, as you know, derive from unvalidated interpolations between zero and relatively high-dose, and high dose-rate, exposure. There are few exposure situations that can be studied in the expectation that risk estimates directly applicable to the low-dose region might be obtainable. One of these is employment in the nuclear power industry, but there is at present no practical way of studying the experience of nuclear power plant workers in the U.S.

In revising 10 CFR 20 I hope you will not miss the opportunity to lay the groundwork for a Registry of Radiation Workers containing the annual doses received by individual workers. The need for such a Registry has been

103-005

Kenneth M. Carr

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

March 5, 1991

Dr. Samuel Broder, Director
National Cancer Institute
Department of Health and Human
Services
9000 Rockville Pike
Building 31, Room 11A48
Bethesda, Maryland 20892

Wheels of government turn slowly
1986→1991→2012

Dear Dr. Broder:

I am writing to inform you of the Nuclear Regulatory Commission's (NRC's) decision to establish new reporting requirements for radiation exposure information and to request the views of the National Cancer Institute (NCI) on the relative merits of conducting additional radioepidemiological studies on radiation workers. As you know, the NCI in 1986 requested that the Commission consider incorporating provisions for a Registry of Radiation Workers into the final revision of 10 CFR Part 20. I am pleased to inform you that the Commission has approved the final revision of 10 CFR Part 20 and that the final rule contains reporting requirements that will allow the collection of information necessary to establish such a registry. A total of seven categories of licensees, including nuclear power reactors, fuel cycle facilities, radiographers, major byproduct materials facilities, high- and low-level waste repositories, and independent spent fuel storage facilities, will be required to provide dose records for each monitored employee for each year. The Commission will retain this information in its currently existing Radiation Exposure Information Reporting System (REIRS) for potential use in epidemiologic studies.

REIRS – Designed with health studies in mind (2012)

103-005

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

CHAIRMAN

March 5, 1991

Chairman Kenneth M. Carr

Dr. Samuel Broder, Director
National Cancer Institute
Department of Health and Human Services
9000 Rockville Pike
Building 31, Room 11A48
Bethesda, Maryland 20892

Dear Dr. Broder:

I am writing to inform you of the Nuclear Regulatory Commission's (NRC's) decision to establish new reporting requirements for radiation exposure information and to request the views of the National Cancer Institute (NCI) on the relative merits of conducting additional radioepidemiological studies on radiation workers. As you know, the NCI in 1986 requested that the Commission consider incorporating provisions for a Registry of Radiation Workers into the final revision of 10 CFR Part 20. I am pleased to inform you that the Commission has approved the final revision of 10 CFR Part 20 and that the final rule contains reporting requirements that will allow the collection of information necessary to establish such a registry. A total of seven categories of licensees, including nuclear power reactors, fuel cycle facilities, radiographers, major byproduct materials facilities, high- and low-level waste repositories, and independent spent fuel storage facilities, will be required to provide dose records for each monitored employee for each year. The Commission will retain this information in its currently existing Radiation Exposure Information Reporting System (REIRS) for potential use in epidemiologic studies.

Cancer Causes and Control, 4, 427 - 430 **1993**

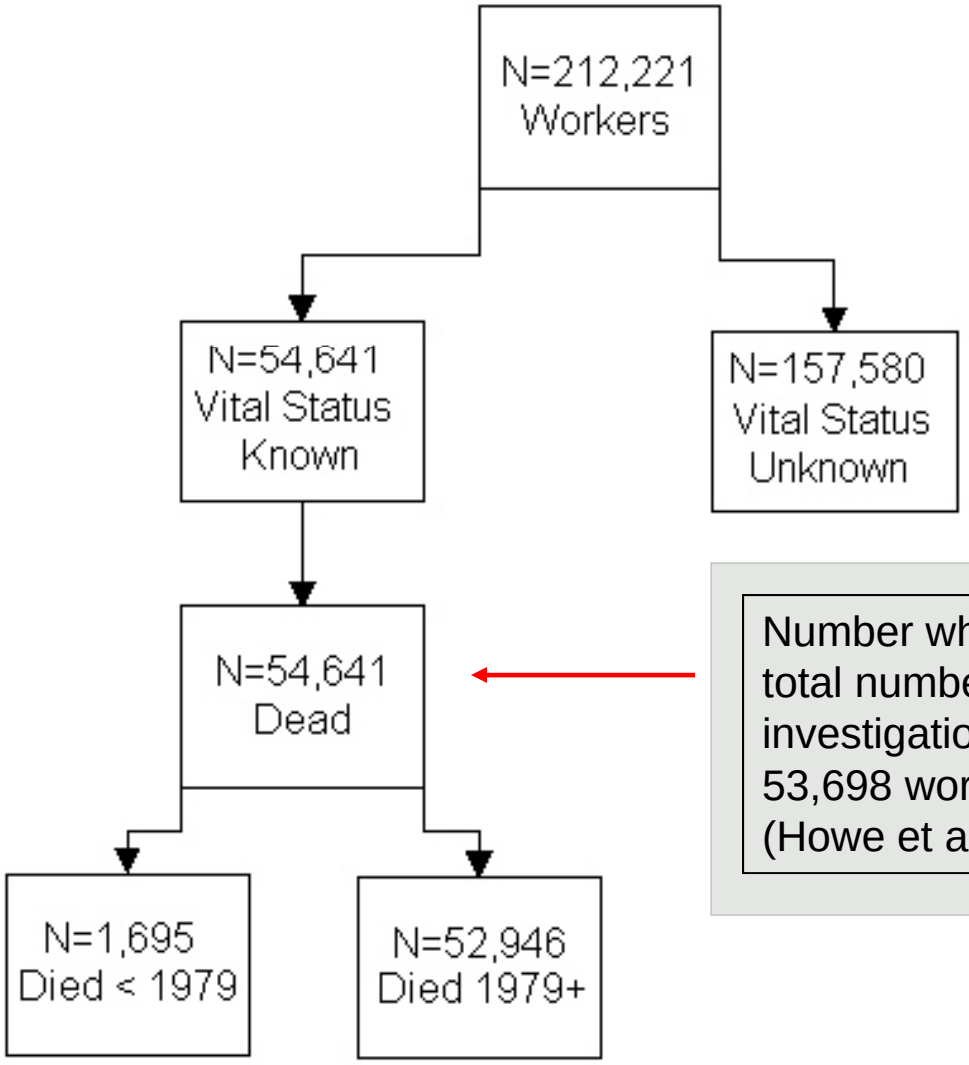
Mortality among workers at a nuclear power plant in the United States

Seymour Jablon and John D. Boice, Jr.

(Received 10 March 1993; accepted in revised form 5 May 1993)

A second follow-up of 9,000 workers at the Calvert Cliffs Nuclear Power Plant (MD, USA) identified 346 deaths in the years 1969-88, 101 of which were attributed to malignant neoplasms. The original study had the primary purpose of assessing the feasibility of studies of workers based upon individual plant and Nuclear Regulatory Commission records. The average, cumulative, occupational dose through 1984 was low, only 21 mSv, but ranged up to 470 mSv, with 12 percent of the workers receiving more than 50 mSv. Mortality from most causes of death was low and there was a deficit of deaths from diseases of the circulatory system. Ionizing radiation exposures were not related to the probability of death from neoplasms generally or from any specific form of cancer. There were only two deaths from leukemia, whereas four were expected at population death rates. Larger numbers of workers, followed for longer periods of time, are needed to determine the mortality risk to workers in the nuclear power industry. The difficulties in obtaining dose information for transient

Nuclear Power Plant Workers



Dresden Generating Station

Number who have died is greater than total number studied in large 15-utility investigation with 1190 deaths among 53,698 workers
(Howe et al Rad Res 2004)

Nuclear Utility Worker Dose Distribution
Preliminary

Lifetime dose (mSv)	Frequency	Percent	Frequency	Percent
<10	81,930	76.13	81,936	76.13
10 - 49	18,714	17.39	100,650	93.52
50 - 499	6,846	6.36	107,496	99.88
500 - 999	90	0.08	107,586	99.96
1,000+	38	0.04	107,624	100.00

Paracelsus: The Poison is in the Dose.

A Study of Mortality and Morbidity Among Persons Occupationally Exposed to ≥50 mSv in a Year: Phase I, Mortality Through 1984

Shirley A. Fry, E.A. Dupree, A.H. Sipe, D.L. Seiler, and P.W. Wallace

Center for Epidemiological Research, Medical Science Division,
Oak Ridge Associated Universities, Oak Ridge, Tennessee

1996

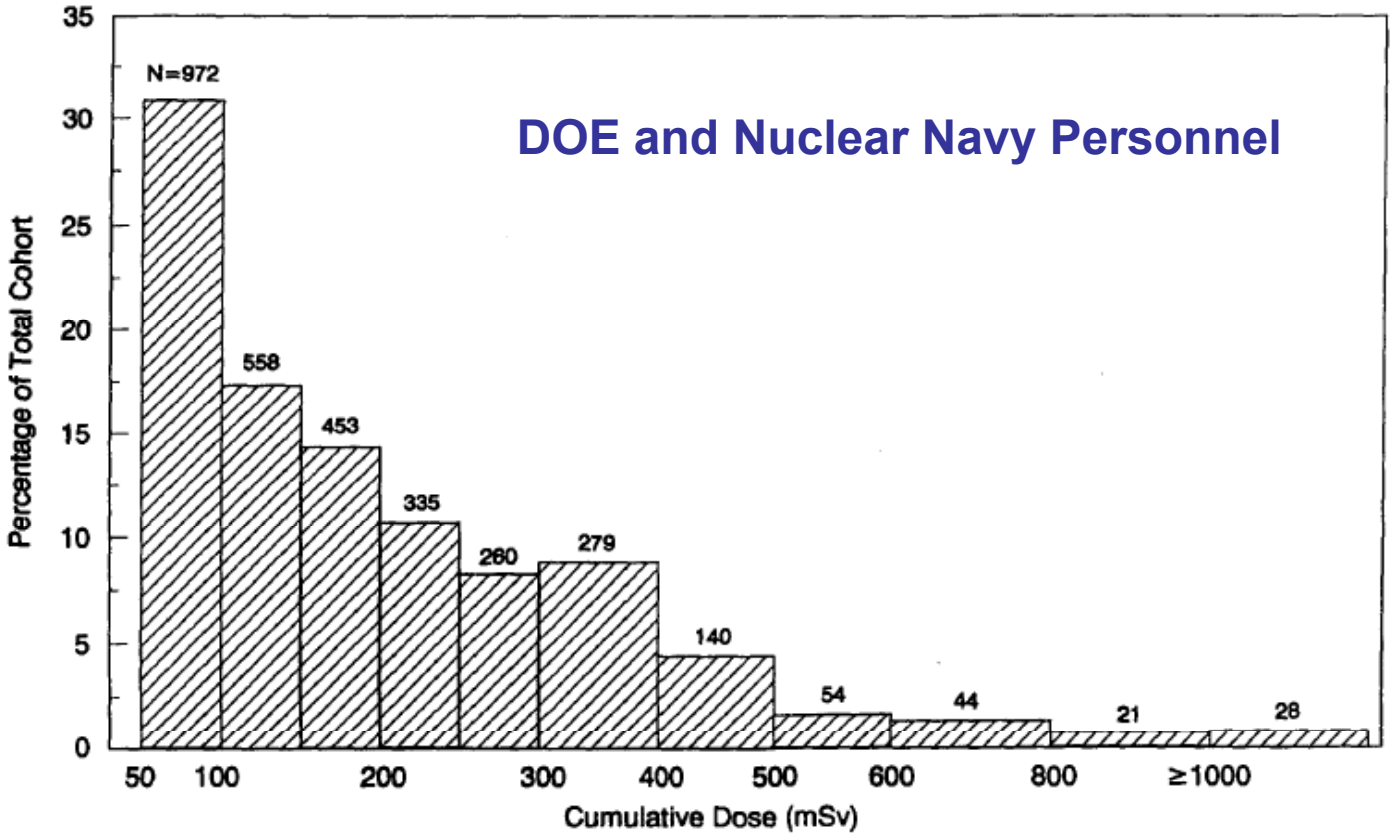
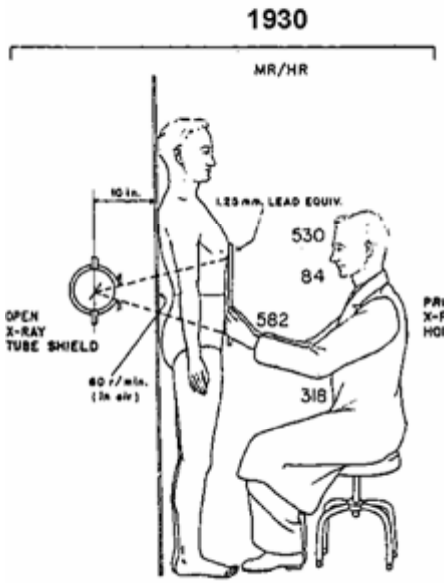


FIGURE 2. Distribution of cumulative dose groups among the ≥50-mSv cohort (N = 3145).

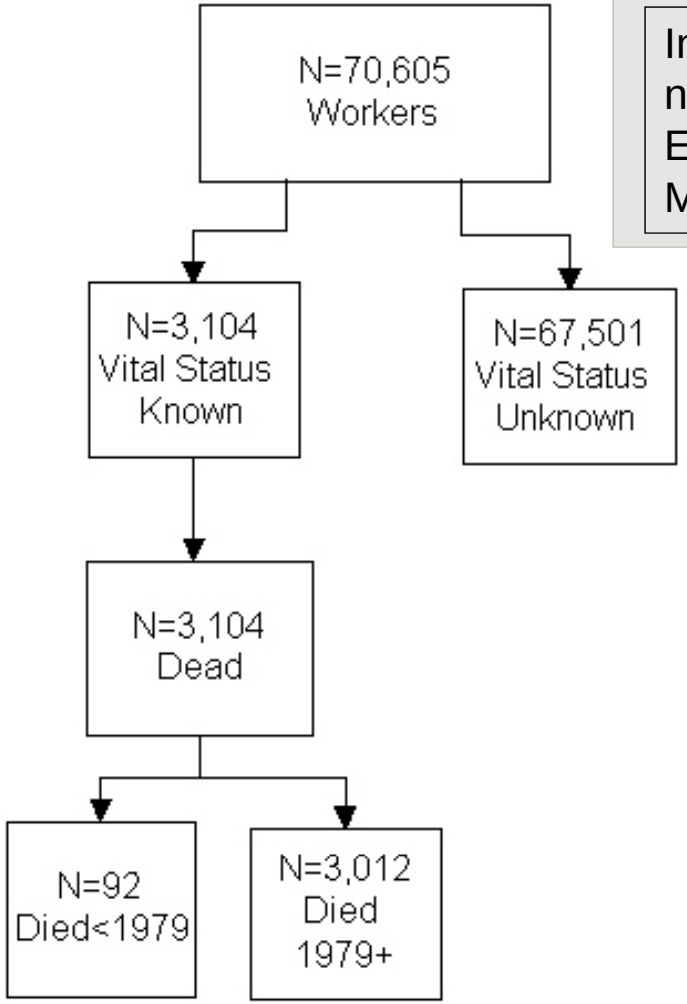
Other Radiation Workers

- Radiologists, nuclear medicine, radiotherapists, other medical, industrial radiographers
- **2700 roles of microfilm** from the 1950s through 1976 available from Landauer (**5 million dosimetry reports**)
- Microfilm being imaged/digitized
- Electronic records after 1976 records (**1.5 million dosimetry reports** for the: Over 70,000 non-nuclear utility workers identified with cumulative dose > 50 mSv.



Other Radiation Workers

Landauer (> 50 mSv)



Includes industrial radiographers, radiologists, nuclear medicine, radiotherapy & other medical
Electronic database 1977+
Microfilm 1953+ (being processed)

Other Workers - Landauer > 50 mSv Dose Distribution

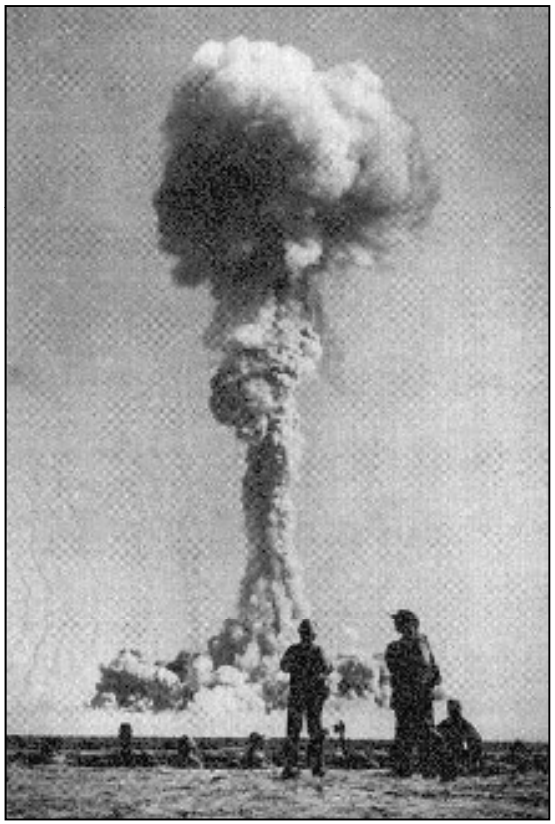
Dose category (mSv)	Frequency	Percent
< 50	1,639	2.3
50 -	42,393	60.0
100 -	24,049	34.1
500 -	1,307	1.9
> 1000	1,180 *	1.7
Problematic	37	0.1
Total	70,605	100

- Japanese atomic bomb survivors > 1000 mSv = 2,389 (Preston Rad Res 2004)

  Japanese atomic bomb survivors > 100 mSv = 18,444 compared with 26,536 above

Nuclear Weapons Test Participants
The Eight Series Study

VANDERBILT UNIVERSITY



Desert Rock VI exercise (TEAPOT), NTS, 1955

National Cancer Institute

UNITED STATES
DEPARTMENT OF VETERANS AFFAIRS

The 8th Series - Trinity

- First weapons test, Alamogordo, NM, 16 July 1945

- Historical figures:

  J. Robert Oppenheimer
  General Leslie Groves
  Enrico Fermi, Hans Bethe
  Theodore Hall

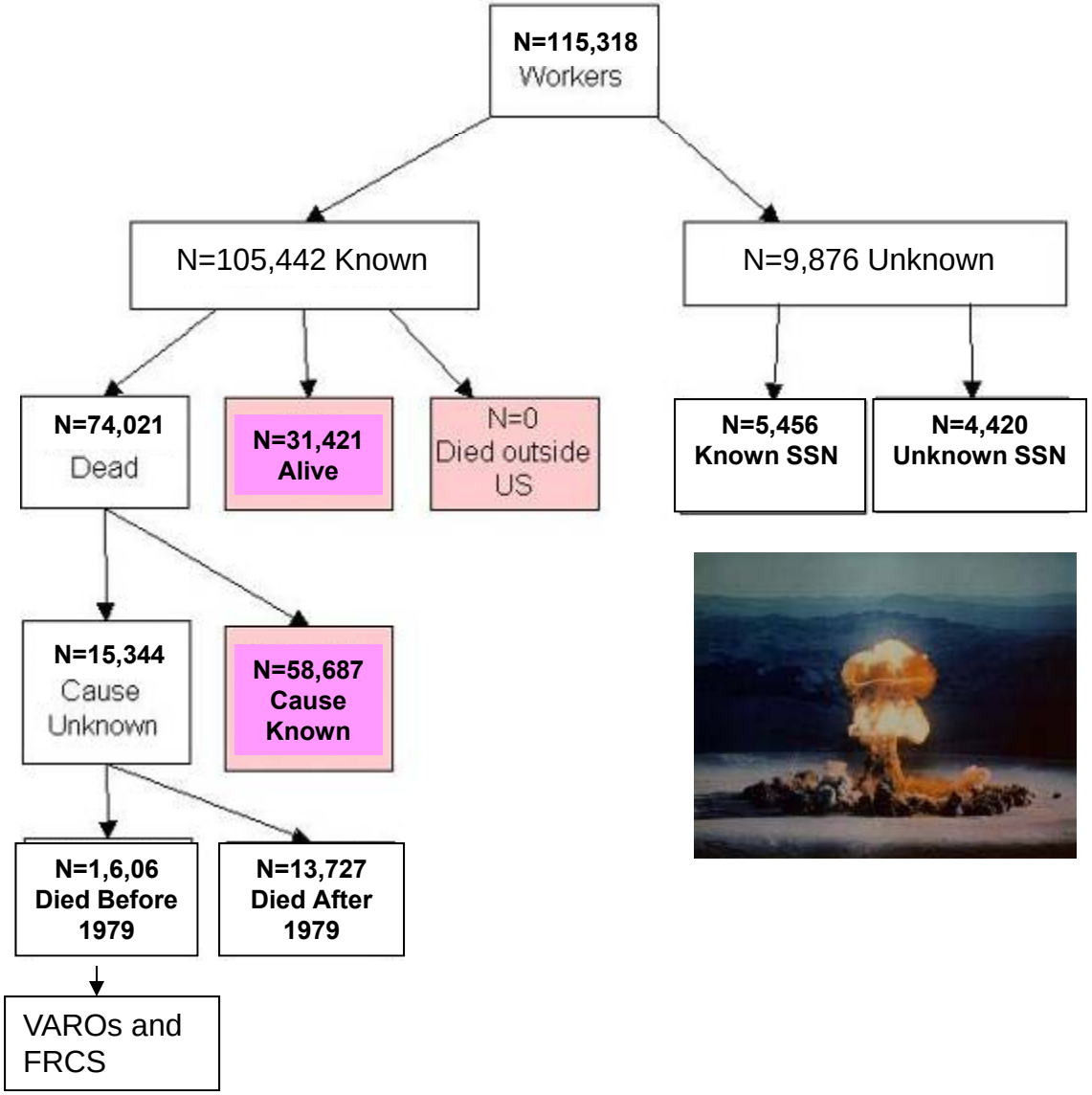
- Note the film badges

Atomic Veterans – Cancers to Date

- **Aim**. Estimate the lifetime risk of radiation-induced **leukemia**

CauseOfDeath	UCOD_ Only	UCODor CCOD
CLL	126	156
nonCLL	518	557
MyelodysplasticSyndrome	62	104
Thyroid	47	54
Salivary	15	15
MaleBreast	24	27
BiliaryLiver	403	428
Bone	35	40

Atomic Veterans Tracing Efforts



VA – BIRLS

FaceBook

Credit Bureaus

Oct 2012

Atomic Veterans Study Group

Nashville, TN –
10-11 October 2012

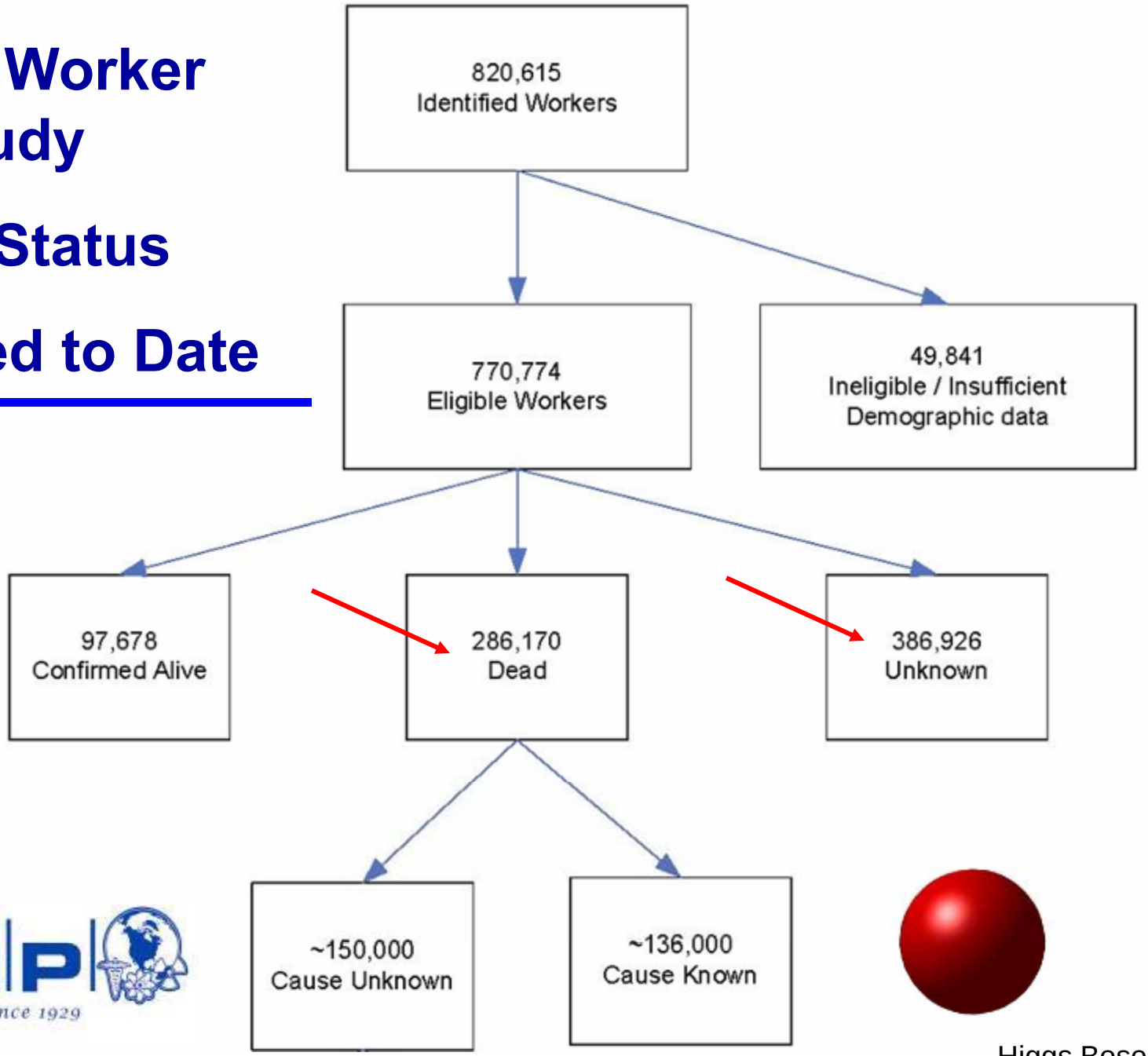
Nashville, TN –
19-20 January 2011

Health Physics News December 2012

Million Worker Study

Vital Status

Processed to Date



NCRP
Scientific Authority Since 1929

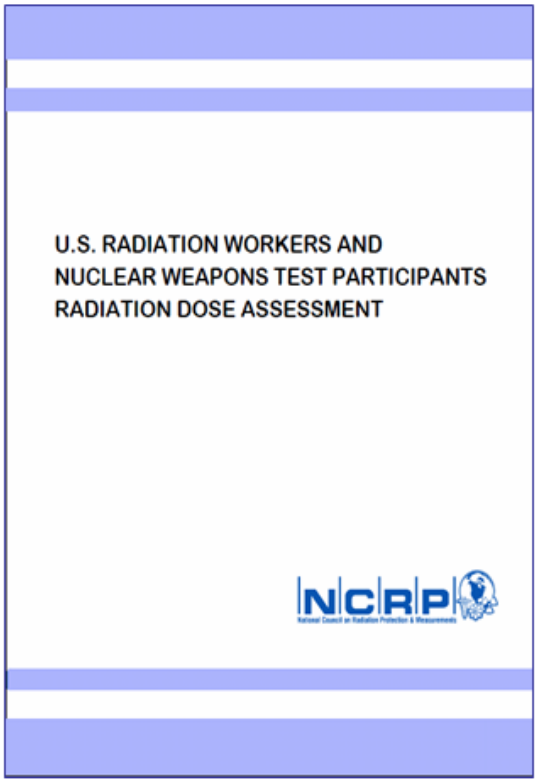
Higgs Boson

OPPORTUNITIES

- Dose Reconstruction Report.
- Integrating Biology with Epidemiology.
- Studying Cancer Risk Around DOE Nuclear Facilities

NCRP
Scientific Authority Since 1929

Dosimetry Committee



Andre Bouville

Harold Beck

Larry Dauer

Keith Eckerman

Ethel Gilbert

Kathy Pryor

Marvin Rosenstein

Steve Simon

Dan Stram

John Till

Dick Toohey

Craig Yoder

NCRP COMMENTARY No. 23

INTEGRATING BASIC SCIENCE WITH EPIDEMIOLOGICAL STUDIES ON LOW-DOSE RADIATION EFFECTS

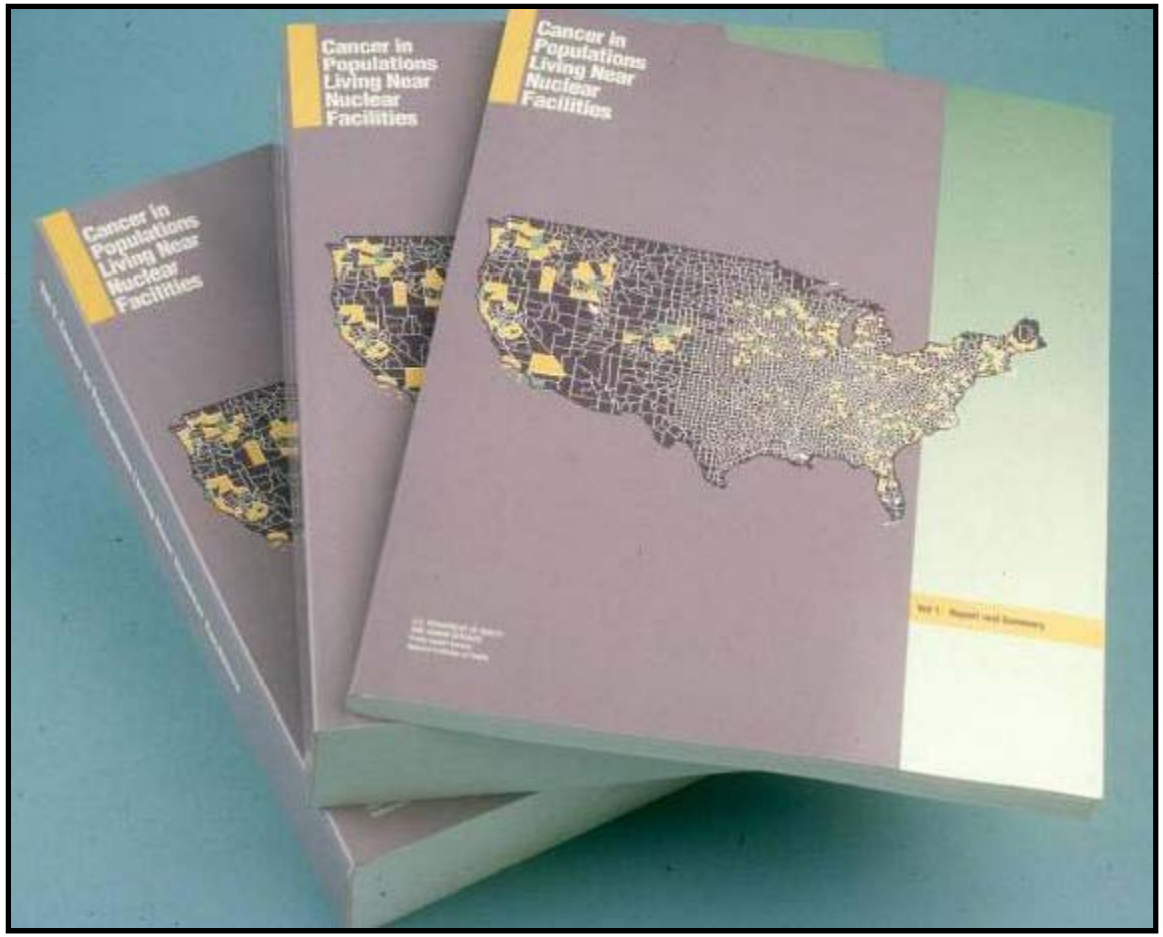
2013-2014

NCRP

National Council on Radiation Protection & Measurements

NCRP is grateful to CDC for financial support.

Cancer in Populations Living Near Nuclear Facilities *JAMA* 256: 1991



"NO MATTER
WHAT ACCOMPLISHMENTS
YOU MAKE,
SOMEBODY HELPS YOU."

ALTHEA GIBSON

Workshop – Study of One Million US Workers and Veterans Bethesda, Maryland 15-16 February 2012

National Cancer Institute, Department of Energy, Nuclear Regulatory Commission, Department of Defense, Oak Ridge National Laboratory, Oak Ridge Associated Universities, Harvard University, Vanderbilt University, National Institute of Occupational Health and Safety, University of Southern California, Landauer Inc., Environmental Protection Agency, Radiation Effects Research Foundation (Japan), International Epidemiology Institute, National Council on Radiation Protection & Measurements

National Council on Radiation Protection and Measurements (NCRP)

NCRP
Scientific Authority Since 1929

- March 11- 12, 2013 Annual Meeting, Bethesda

RADIATION DOSE AND IMPACTS ON EXPOSED POPULATIONS

Including presentation on:

Two Year Results from the Fukushima Health Surveys
Shunichi Yamashita, *Vice Pres, Fukushima Medical University*

Members Dinner: Science, Media and the Public

Miles O'Brien, *Science Correspondent, PBS NEWSHOUR*

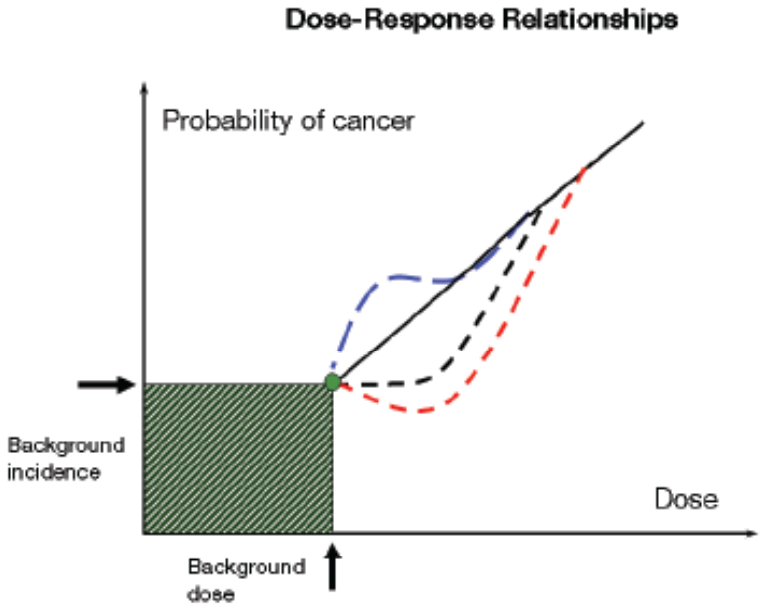
Domo - Arigato

Thank you

Risk Below 100 mSv (10 rem) - Judgment

(27) … The Recommendations are based on scientific knowledge and on expert judgement (ICRP Publ 103, 2007).

(62) In the case of cancer, epidemiological and experimental studies provide evidence of radiation risk albeit with uncertainties at doses about 100 mSv or less.



“All models are wrong,
some models are useful.”

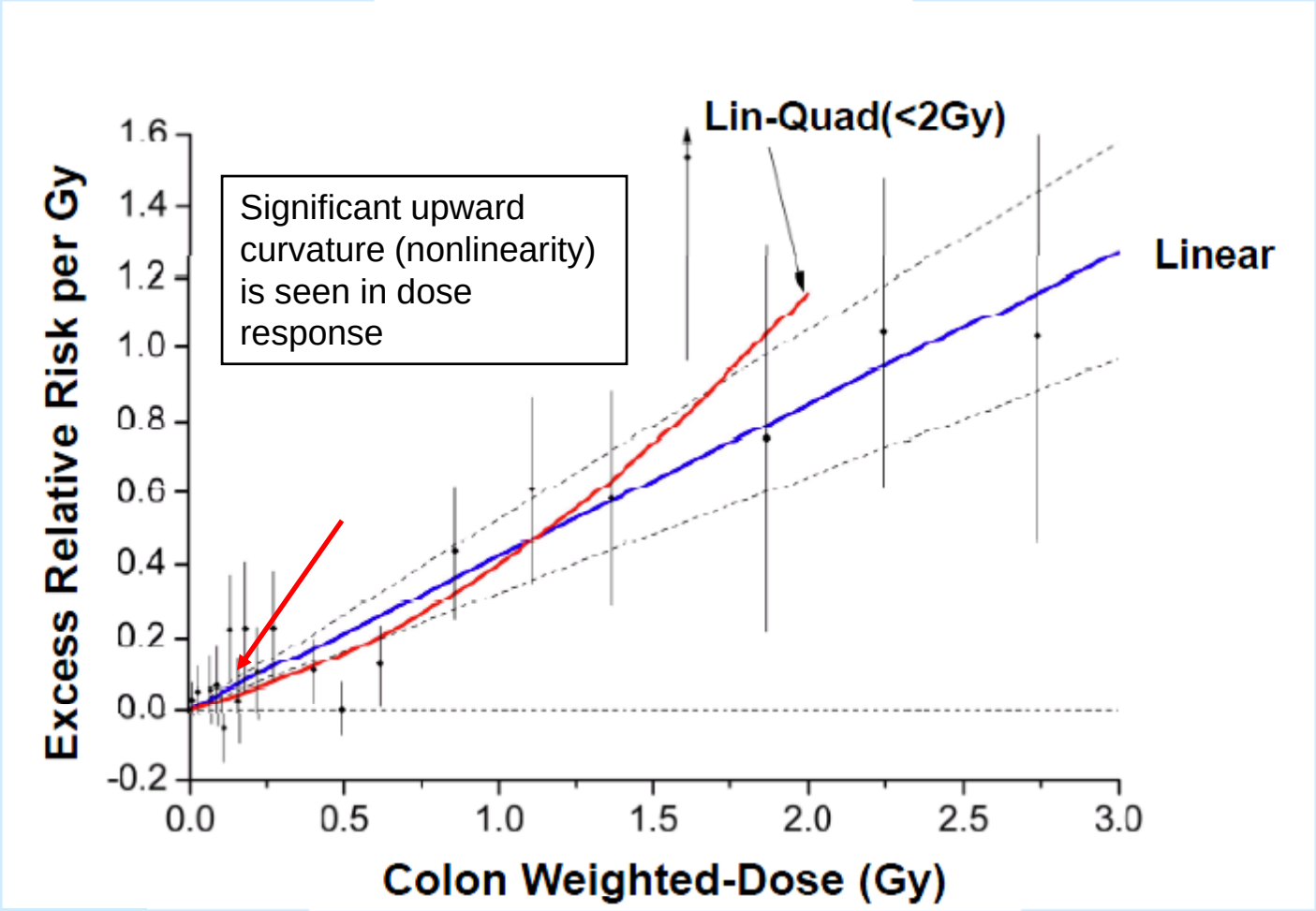
--- George Box, industrial statistician, 1979

Not everyone agrees -- Preview of upcoming LNT Debate

Forty-Fourth
Annual Meeting Program

Low Dose and
Low Dose-Rate Radiation
Effects and Models 2008

LSS Dose Response - Solid Cancer Mortality, 1950-2003



Ozasa et al, *Rad Res* 177; 2012