Overview

- Million U.S. Worker and Veteran Study

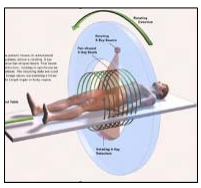
John D Boice Jr
National Council on Radiation Protection & Measurements
Vanderbilt University

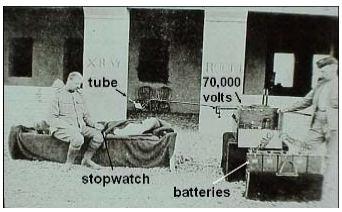
NUCLEAR & RADIATION STUDIES BOARD
Washington, DC. May 30, 2012

What is the Major Unanswered Question 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





WHERE THERE IS NO VISION, THE PEOPLE PERISH.

PROVERBS 29:18

U.S. Congress

85 mrem/y = 0.85 mSv/y

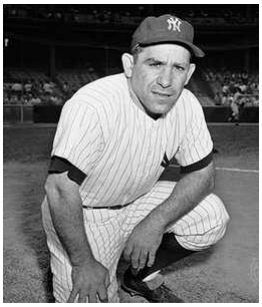
What might be done?
Optimize United States Resources

One Million U.S. Radiation Workers and Veterans

- Manhattan Project Workers
- Atomic veterans
- Nuclear utility workers
- Medical and other occupational
- Possible - Nuclear navy

https://www.orau.gov/lowdose2011/abstracts/boice_john.pdf

If you don't know where you're going, chances are you will end up somewhere else.



April 2007- A Beginning - ORAU

Dept Energy, Los Alamos Natl Lab, ORAU, Vanderbilt, Intl Epidemioloy Inst, RERF, Radiation Effects Association (Japan), ORNL, NRC, Harwell (UK), Kagoshima Univ, REACT/S, Univ Manchester (UK)

Pilot Study Results

May 1, 2010 to April 15, 2012

- The full-scale study is ***feasible***.
- The cohort has been ***assembled***.
- 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 study has substantial statistical ***power*** to evaluate low dose rate radiation effects.

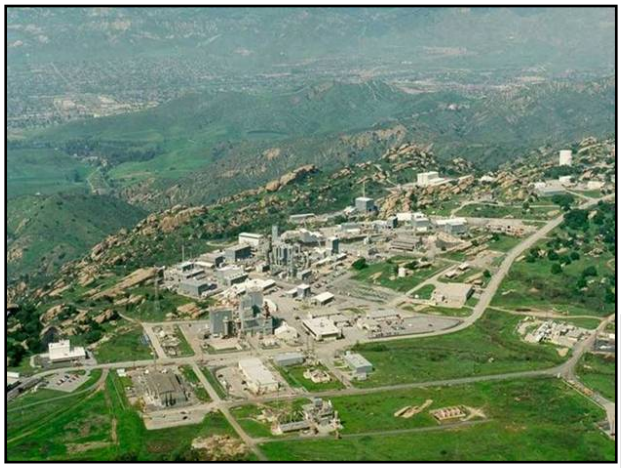
The Vision – One Million U.S. Workers

Targeted Populations Datasets Obtained

[X] DOE Uranium Workers	196,000
[X] DOE Plutonium Workers	155,000
[X] Nuclear Power Plant Workers – to date	236,000
[X] Other Radiation Workers, > 50 mSv	71,000
other Medical, Industrial Radiography	~230,000
[X] DOD Atomic Veterans	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

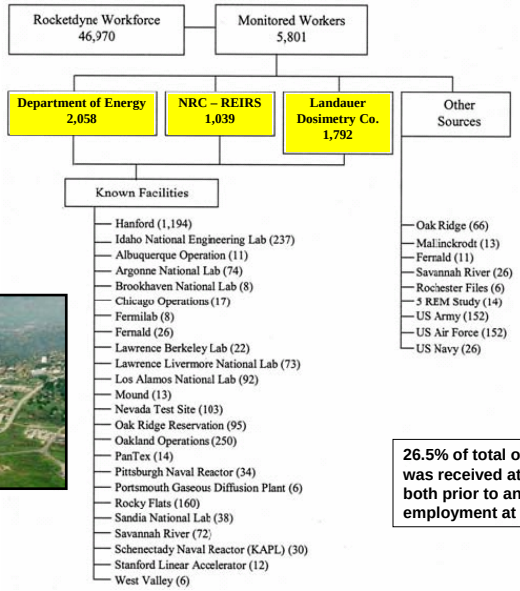


Simi Valley
Sodium reactor
Moorpark 1957
Edward R Murrow
'See it Now'
Accident 1959
Saturn Engine

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

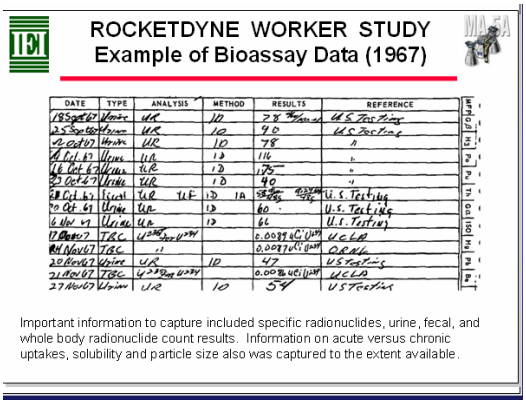
Internal

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	111	28	U.S. Testing
25 Sept 67	Urine	UR	10	90	U.S. Testing
2 Oct 67	Urine	UR	10	78	"
4 Oct 67	Urine	UR	13	116	"
16 Oct 67	Urine	UR	13	175	"
23 Oct 67	Urine	UR	13	90	"
28 Oct 67	Fecal	UR UF	13 13		U.S. Testing
30 Oct 67	Urine	UR	13	80	U.S. Testing
6 Nov 67	Urine	UR	13	66	U.S. Testing
17 Nov 67	TBC			0.0089	UCLA
14 Nov 67	TBC	"		0.0087	UCLA
20 Nov 67	Urine	UR	10	47	U.S. Testing
21 Nov 67	TBC			0.008	UCLA
27 Nov 67	Urine	UR	10	54	U.S. 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.

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."

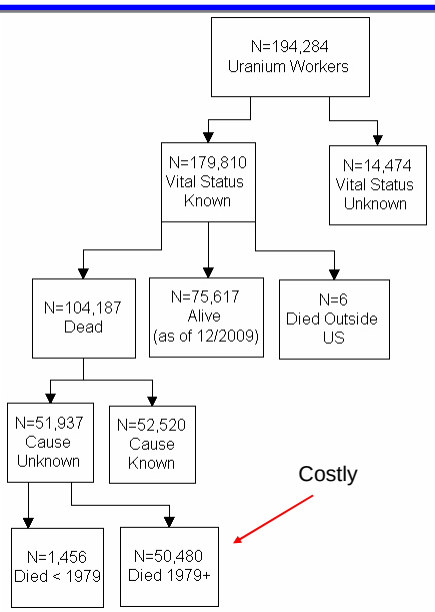
Uranium Workers

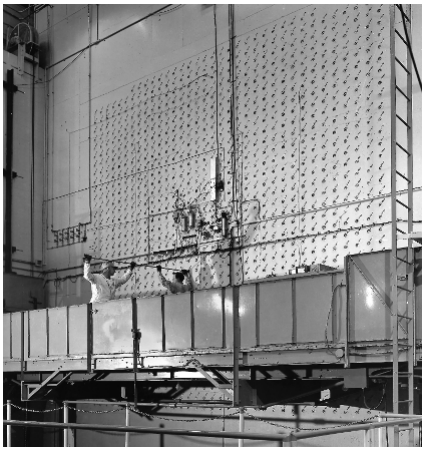
Table 1-1. Studies of uranium workers

Worker cohort	No. in database
Oak Ridge Segment	
K-25	49,794
X-10	28,528
Y-12 (TEC)	41,107
Y-12 (UCCND)	26,059
Portsmouth Gaseous Diffusion	9,308
Paducah	5,731
Manhattan Engineering District	
Niagara Frontier	
Harshaw. Electromet, Bethlehem	1,144
Linde	1,551
Middlesex	387
FMPC (Fernald)	7,337
MCW (Mallinckrodt)	3,272
SRS (uranium processing)	21,509
Pantex (Weapons assembly)	12,670
Rocketdyne (Atomics International)	5,801
Sum of workers	**202,990**

Alpha Track Calutron at the Y-12 Plant at Oak Ridge, Tennessee from the Manhattan Project, used for uranium enrichment by electromagnetic separation process. Circa 1944-1945.

Uranium Workers – Vital Status





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

Mound Plant, Dayton, Ohio
Innovations & Polonium

- 7,291 workers (1944+)
- 98% located
- External, tritium, polonium, plutonium **dosimetry**
- **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 (7,300 Workers)

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

George Koval
December 25, 1913 to January 31, 2006

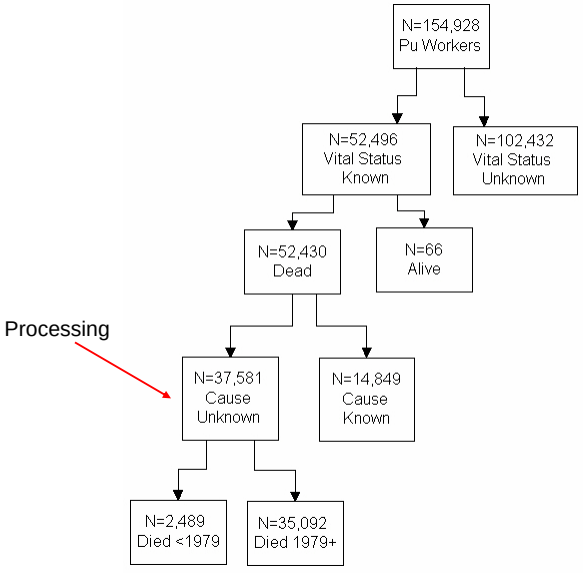
Plutonium Workers

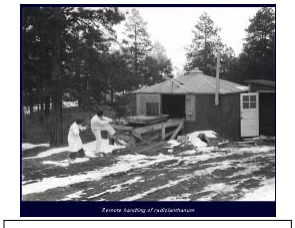
Table 5-1. Cohorts of plutonium workers

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

Hanford N

Plutonium Workers – Vital Status





Los Alamos National Laboratory, Remote handling of radiolanthanum

Scanning 30 Boxes of Death Certificates (29,300)

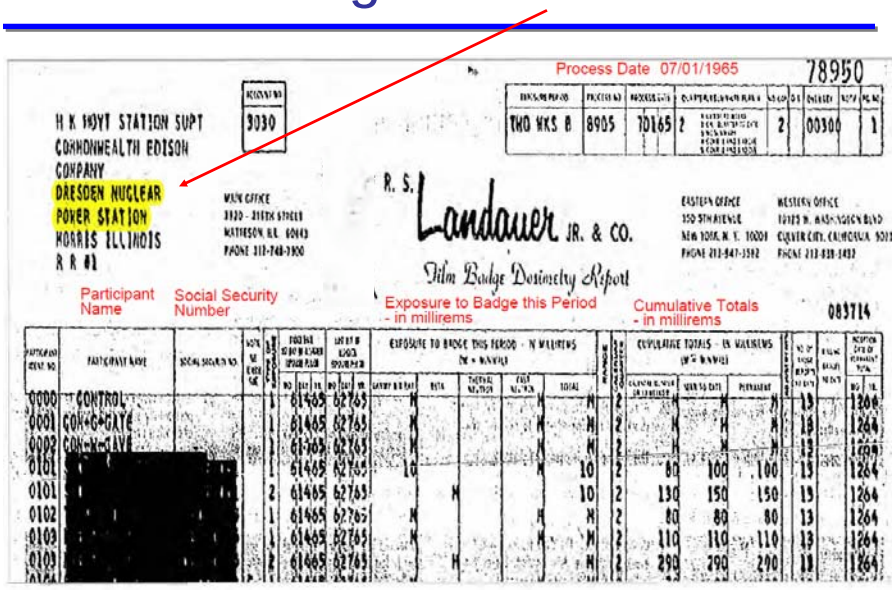
The Scanners --- Employing America's Youth

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

Nuclear Power Plant Workers

- ***U.S. Early Nuclear Utility Workers***
  - " The study of U.S. utility workers who were exposed occupationally could prove to be fruitful. 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.)
  - **235,000** early workers identified in Landauer/NRC-REIRS databases

Microfilm Image – Dresden NPP



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

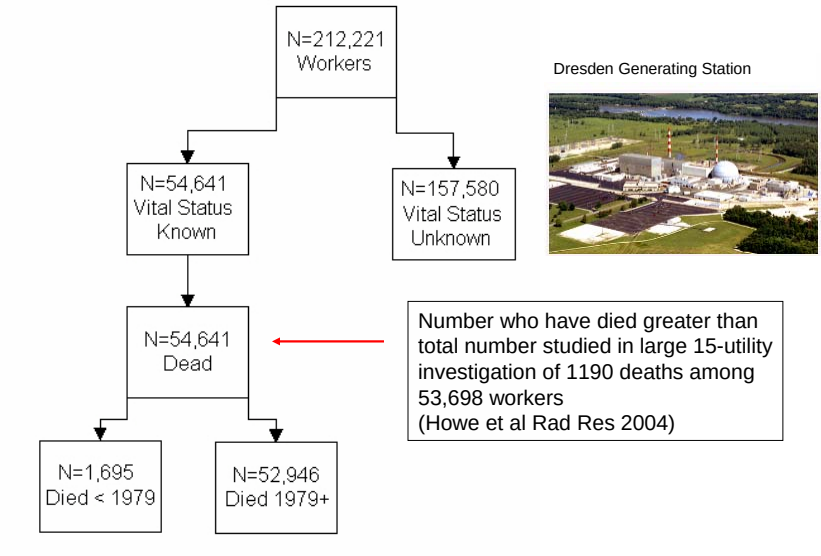
Mortality among workers at a nuclear power plant in the United States

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 greater than total number studied in large 15-utility investigation of 1190 deaths among 53,698 workers
(Howe et al Rad Res 2004)

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

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

CHAIRMAN

103-005

Kenneth M. Carr

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

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.

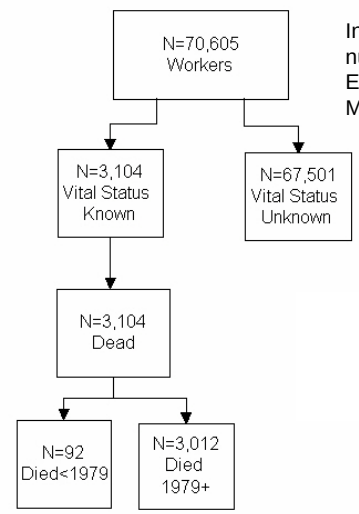
Nuclear Utility Worker Dose Distribution - Preliminary

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

Other Radiation Workers

- Radiologists, nuclear medicine, radiotherapist, 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)

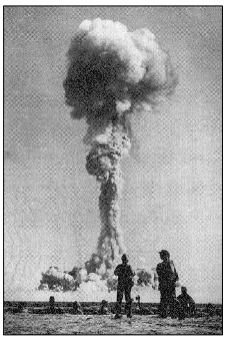
  Japanese atomic bomb survivors > 100 mSv = 18,444 compared with 26,536 above

Nuclear Weapons Test Participants
The Eight Series Study

Atomic Veterans - Vanderbilt
NIH Grant (2010-2015)

- 230 aboveground detonations, Large numbers (115K) previously studied, complex dosimetry, $300 million DOD
- 557 leukemia deaths at present, 1,000 estimated

Troops leaving a trench shortly after a detonation at the Nevada Test Site



Desert Rock VI exercise (TEAPOT), NTS, 1955

The 8th Series - Trinity

- First weapons test, Alamogordo, NM, 16 July 1945
- Historical figures:
  Robert Oppenheimer
  General Leslie Groves
  Enrico Fermi, Hans Bethe
  Theodore Hall

Atomic Veterans – Cancers to Date

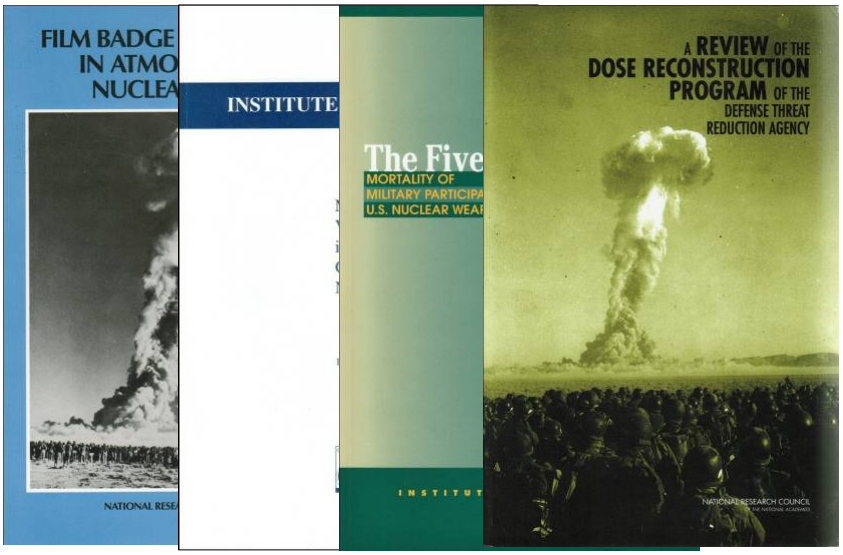
- **Aim**. Estimate the lifetime risk of radiation-induced **leukemia**

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

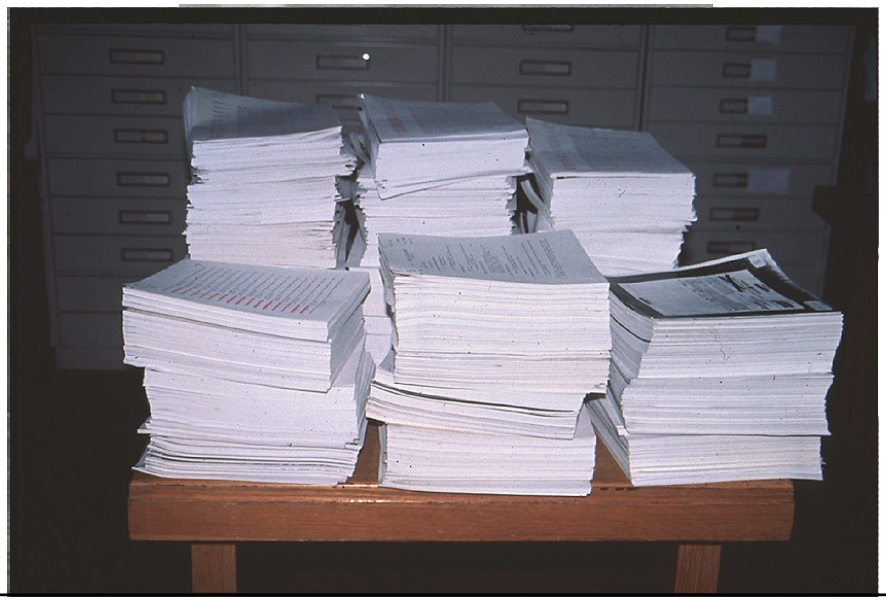
Leukemia in Military Participants at Atomic Tests

Study	Subjects	No.	RR (95% CI)
Caldwell et al. 1983 United States Smoky	3,217 participants general population	10 4.0	2.50 (1.20, 4.6)
Watanabe et al. 1995 (>1 rem) United States Navy-Hardtack I	1,094 participants 14,625 comparisons	2 15	1.73 (0.39, 7.56)
Watanabe et al. 1995 (ALL) United States Navy-Hardtack I	8,554 participants 14,625 comparisons	6 15	0.69 (0.27, 1.78)
Johnson et al. 1996 United States CROSSROADS	38,668 participants 35,036 comparisons	73 91	1.02 (0.75, 1.39)
IOM 2000 (ALL) United States (5 Series) (NTS)	66,168 participants 64,787 comparisons	156 126	1.14 (0.90, 1.44) 1.49 (1.04,2.13) NTS
Muirhead et al. 2004 United Kingdom	21,357 participants 22,333 comparisons	40 23	1.83 (1.15, 2.93)
Pearce et al. 1990, 1997 New Zealand	528 participants 1,504 comparisons	4 2	5.59 (1.04, 41.7)

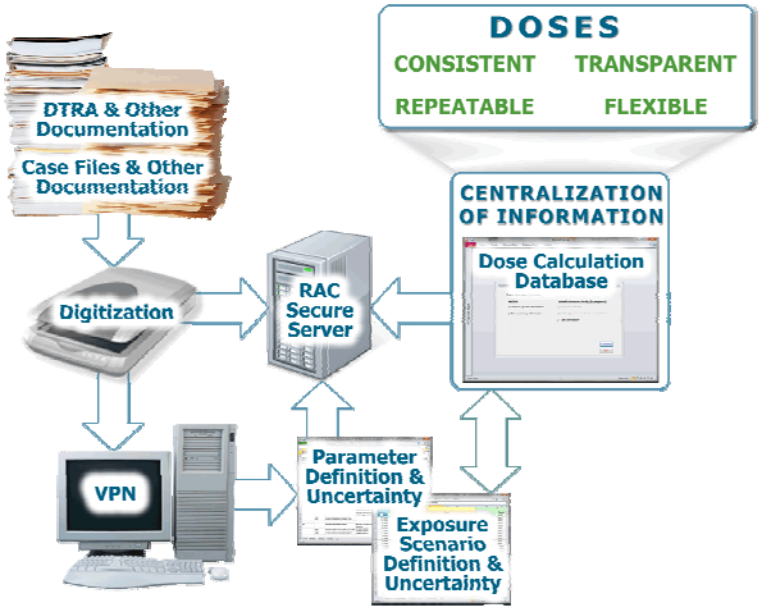
Dosimetry for Epidemiology



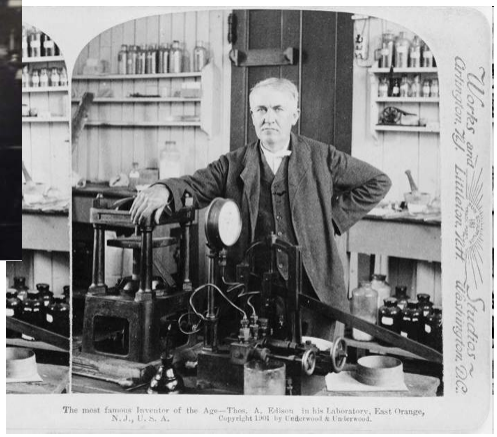
Information Available



Technically Integrated Dosimetry

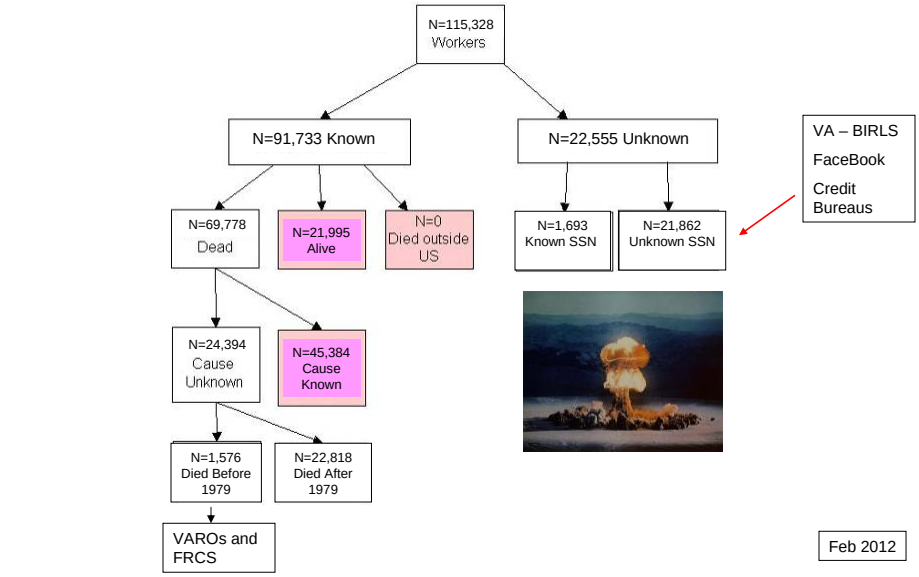


Genius is one percent inspiration and ninety-nine percent perspiration
– Thomas Edison



Dosimetry Team

Atomic Veterans Tracing Efforts



Getting off the Ground

- **VBDR** – 2005 discussions.
- **DTRA** – 2007 approval to access NTPR
- **VU IRB** – 2008 Human Subjects approval
- **SSA** – 2008 approval to access vital status

- **NCHS NDI** – 2009 approval to access mortality data
- **NIH** – 2010 grant awarded
- **VA** -- 2011 IRB approval!

Even if you're on the right track,
you'll get run over if you just sit there -- Will Rogers.

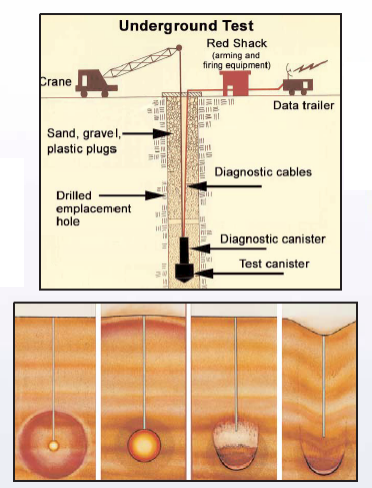
Atomic Veterans Study Group

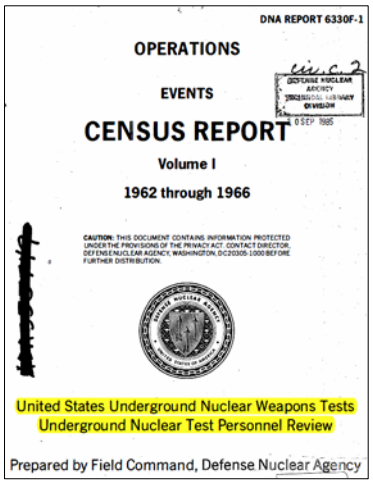
Nashville, TN –
11-13 October 2011

Nashville, TN –
19-20 January 2011

Atomic Veterans Study – Future Possibilities

- Inclusion of participants at underground NTS weapons tests – 37,568 (1962-1992)

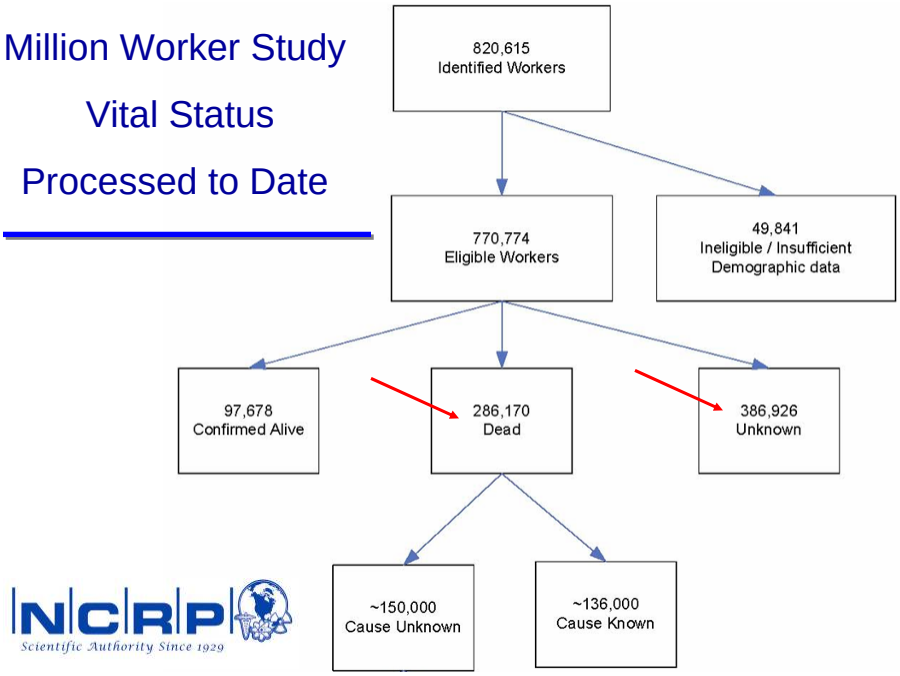




Million Worker Study

Vital Status

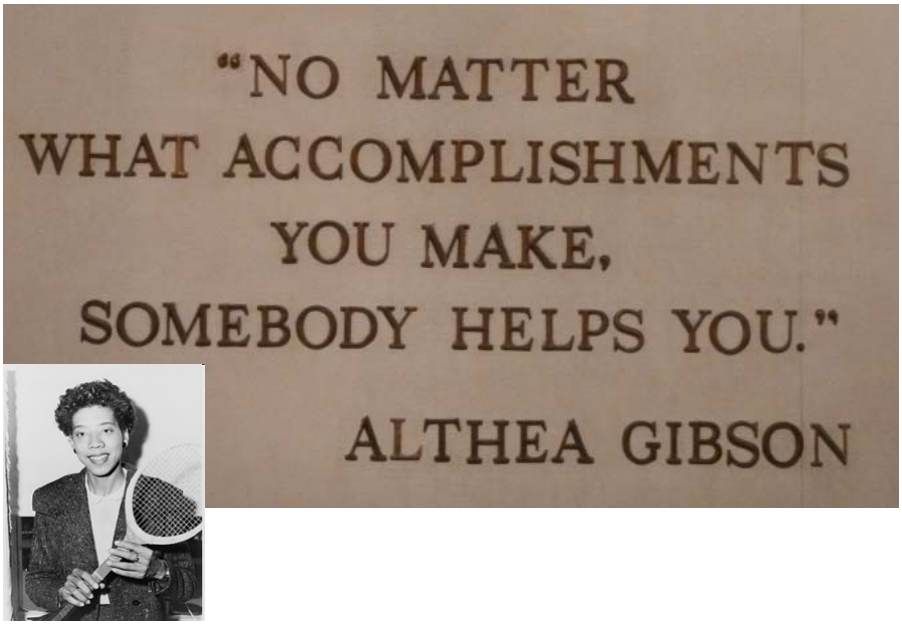
Processed to Date



NCRP
Scientific Authority Since 1929

Plans for Next Year

- **Complete Mound Study**
- **Continue Atomic Veterans, tracing, dose reconstruction**
- **Mallinckrodt Uranium Workers - Internal**
- **50 mSv Study**
- **Los Alamos Workers**
- **Nuclear Power Plant Workers**
- **Tracing**
- **Cause of Death determination**
- **Dosimetry including linkages, REMS, REIRS, Landauer, Military**
- **Renal Disease Linkage**



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

Sponsored by:

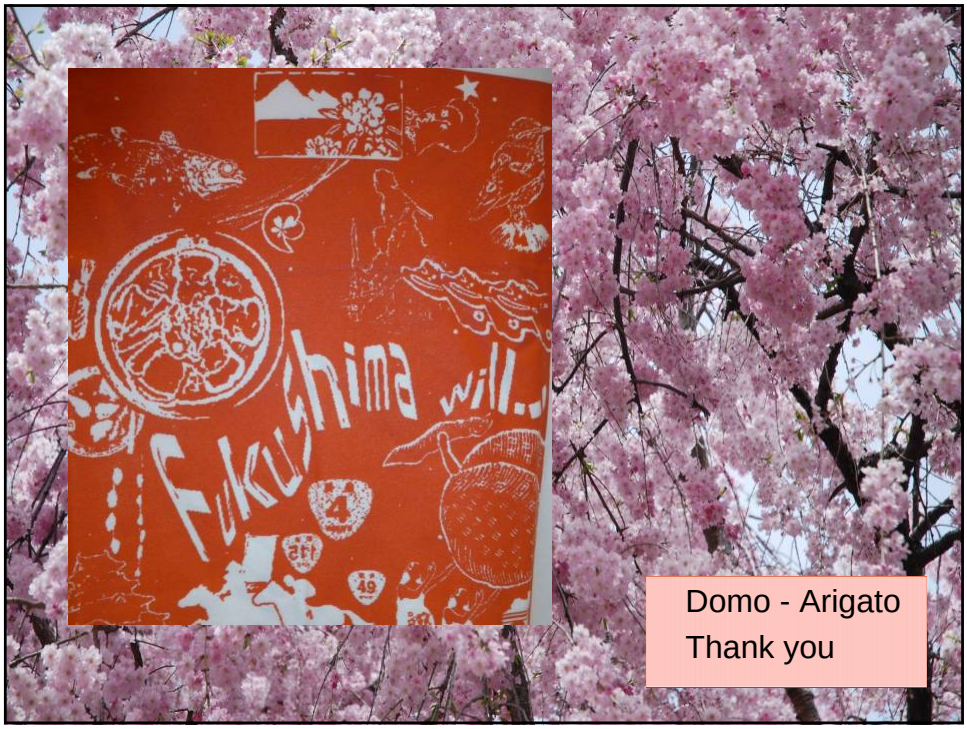
U.S. Low Dose Radiation Research Program

NF Metting, ScD, Program Manager

And

DOE Office of Health and Safety
Dr Bonnie S. Richter co-Project Officer

U.S. DEPARTMENT OF ENERGY | Office of Science | Office of Biological and Environmental Research


Fukushima will..!
Domo - Arigato
Thank you