Exposure to Radioactive Fallout to Residents of Southern Utah

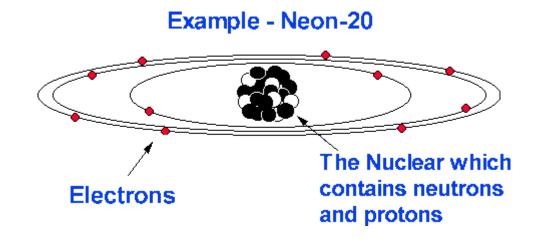
An Overview by Bruce W. Church and Antone L. Brooks

BASIC PREMISE

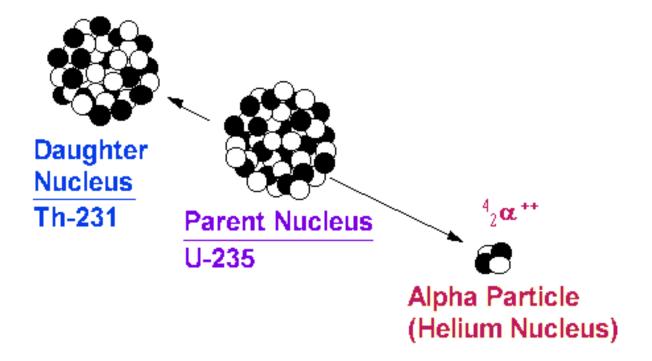
"THE POISON IS IN THE SIZE OF THE DOSE"

Radiation and Radioactivity

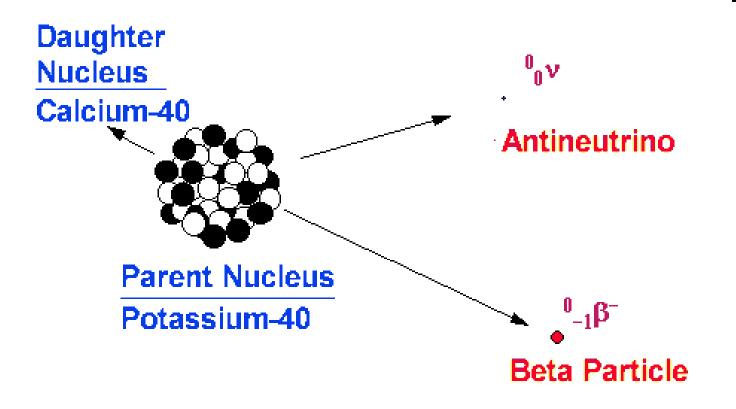
- Radiation: Energy in transit, either as particles or electromagnetic waves.
- Radioactivity: The characteristic of various material to emit ionizing radiation.
- Ionization: The removal of electrons from an atom. The essential characteristic of high energy radiations when interacting with matter.

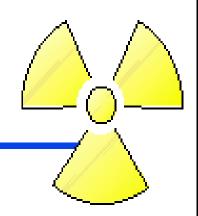


Alpha Particle Radiation

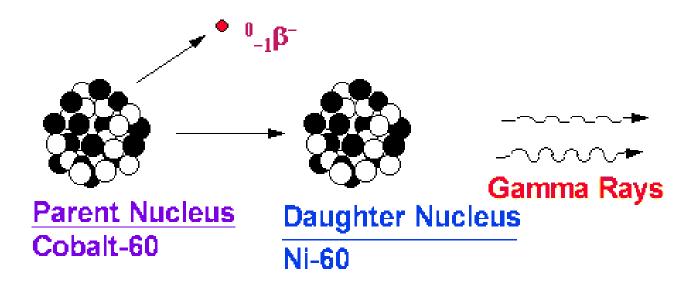


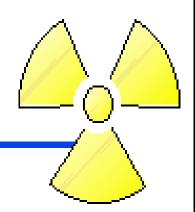
Beta Particle Radiation



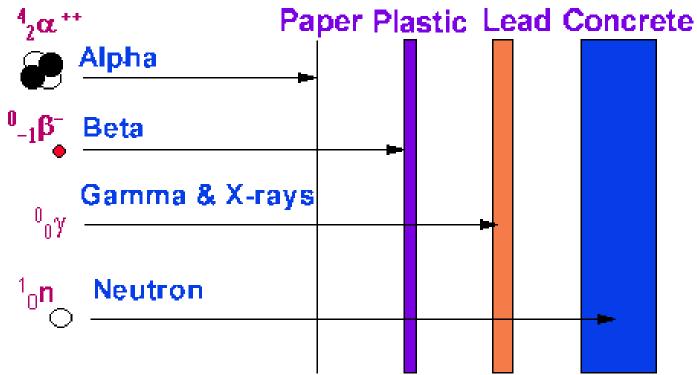


Gamma-Ray Radiation

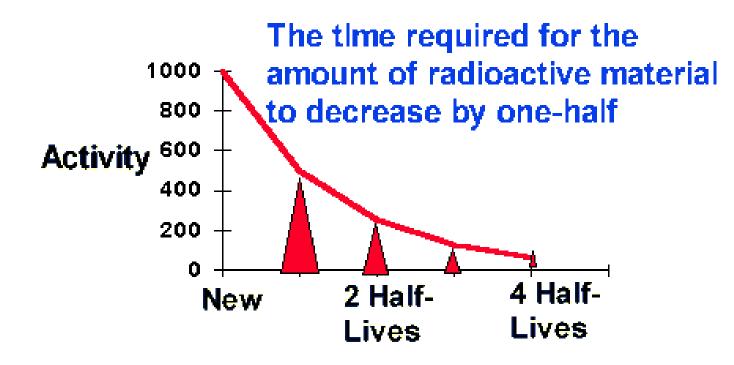




Penetrating Distances



Half-Life



Measures of Radioactivity

Activity: The quantity of radioactive material at a given time:

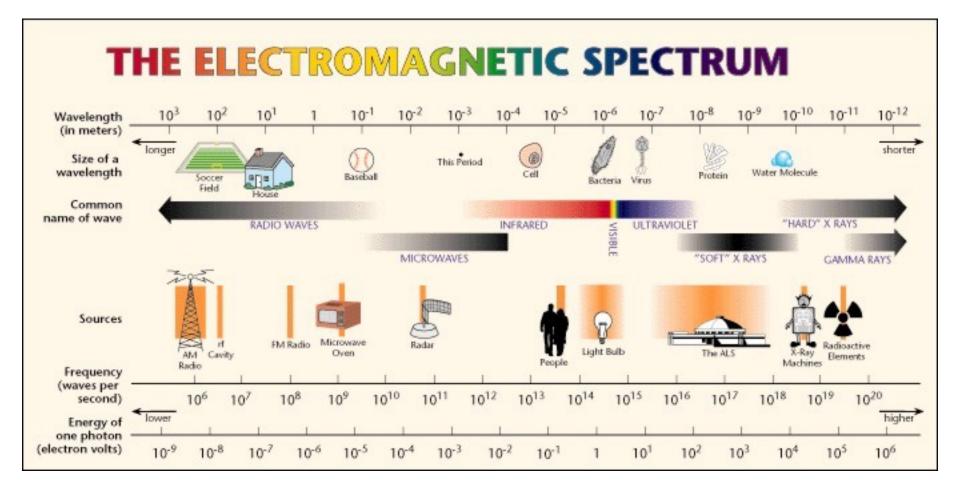
– Curie(Ci): 3.7 10¹⁰ disintegrations per second(dps)

or

- Becquerel (Bq): 1 dps

Measures of Exposure & Dose

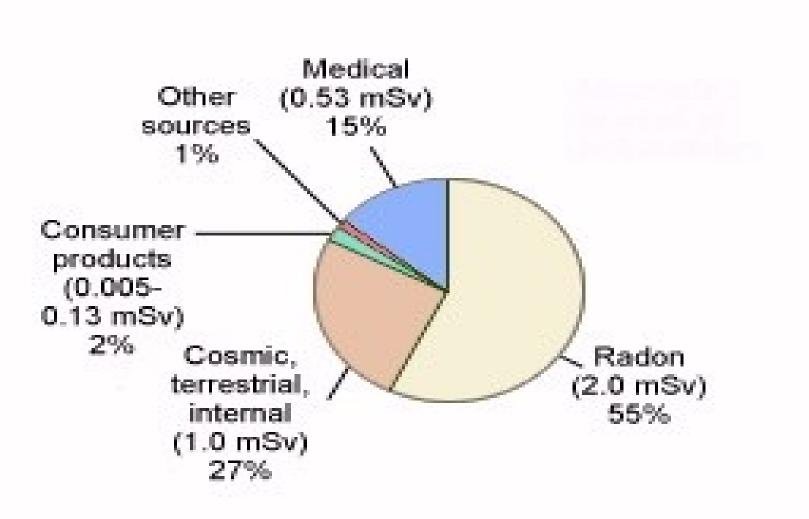
- Exposure Roentgen (R), 0.001 R = 1 mR
- Dose equivalency:
 - rem (old), 0.001 rem = 1 mrem
 - Sv (new); 1 Sv = 100 rem, 10 mSv = 1 rem
- Absorbed Dose:
 - rad (old), 0.001 rad = 1 mrad
 - Gray (new), 1 Gy = 100 rad, 10 mGy = 1 rad



Natural Background

 the average annual radiation doses received per capita in the United States from naturally occurring and manmade sources of radioactivity. The total yearly dose is approximately 0.0036 Sv (ie, 3.6 mSv).

Exposure to Natural Background



Areas of High Background Radiation

Background doses in some areas of the world are exceptionally high when compared to other regions. Specifically areas in Iran, India, Brazil and China are high because of geologic formations, deposits and/or geothermal activity. Monazite sands, high in natural thorium and radium are the large contributors to the values seen in the following table taken from UNSCEAR 2000.

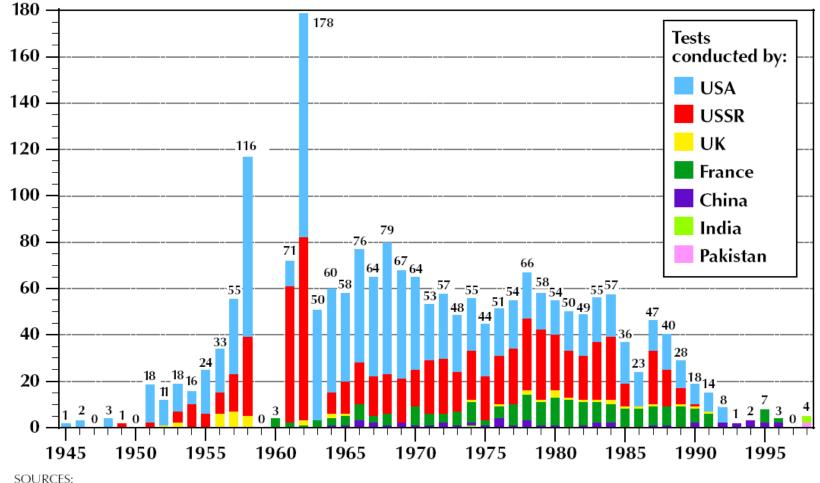
High Natural Radiation Areas fm UNSCEAR 2000 annex B, Table 11

Table 11 Areas of high natural radiation background

Country	Area	Characteristics of area	Approximate population	Absorbed dose rate in air ° (nGy h ¹)	Ref.
Brazil	Guarapari Mineas Gerais and Goias Pocos de Caldas Araxá	Monazite sands; coastal areas Volcanic intrusives	73 000 350	90-170 (streets) 90-90 000 (beaches) 110-1 300 340 average 2 800 average	[P4, V5] [A17, P4] [V5]
China	Yangjiang Quangdong	Monazite particles	80 000	370 average	[W14]
Egypt	Nile delta	Monazite sands		20-400	[E3]
France	Central region Southwest	Granitic, schistous, sandstone area Uranium minerals	7 000 000	20-400 10-10 000	[J3] [D10]
India	Kerala and Madras Ganges delta	Monazite sands, coastal areas 200 km long, 0.5 km wide	100 000	200-4 000 1 800 average 260-440	[S19, S20] [M13]
Iran (Islamic Rep. of)	Ramsar Mahallat	Spring waters	2 000	70-17 000 800-4 000	[S21] [S58]
Italy	Lazio Campania Orvieto town South Toscana	Volcanic soil	5 100 000 5 600 000 21 000 -100 000	180 average 200 average 560 average 150-200	[C12] [C12] [C20] [B21]
Niue Island	Pacific	Volcanic soil	4 500	1 100 maximum	[M14]
Switzerland	Tessin, Alps, Jura	Gneiss, verucano, 220Ra in karst soils	300 000	100-200	[851]

Includes cosmic and terrestrial radiation

Total Worldwide Nuclear Tests by Year (1945–98)



U.S. Department of Energy; Natural Resources Defense Council; Arms Control Association Coalition to Reduce Nuclear Dangers June 1999

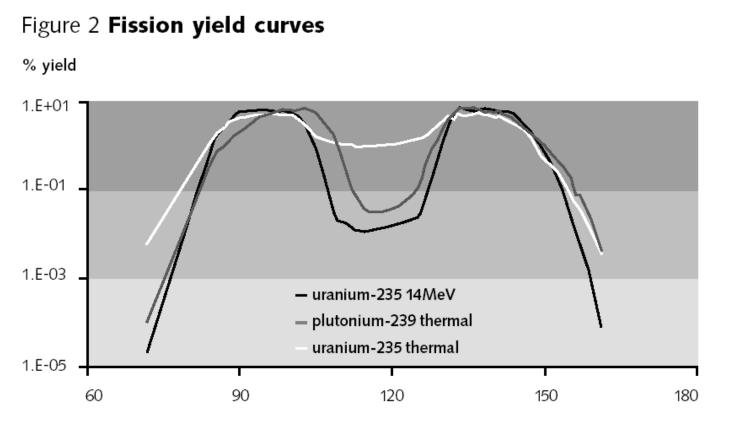
US Nuclear Tests – Total by Type

ТҮРЕ	US	US – UK
Airburst	1	0
Airdrop	52	0
Balloon	25	0
Barge	36	0
Rocket	12	0
Surface	28	0
Tower	56	0
Total Atmospheric	210	0
Crater	9	0
Shaft	739	24
Tunnel	67	0
Total Underground	815	24
Total Underwater	5	0
TOTAL TESTS	1030	24

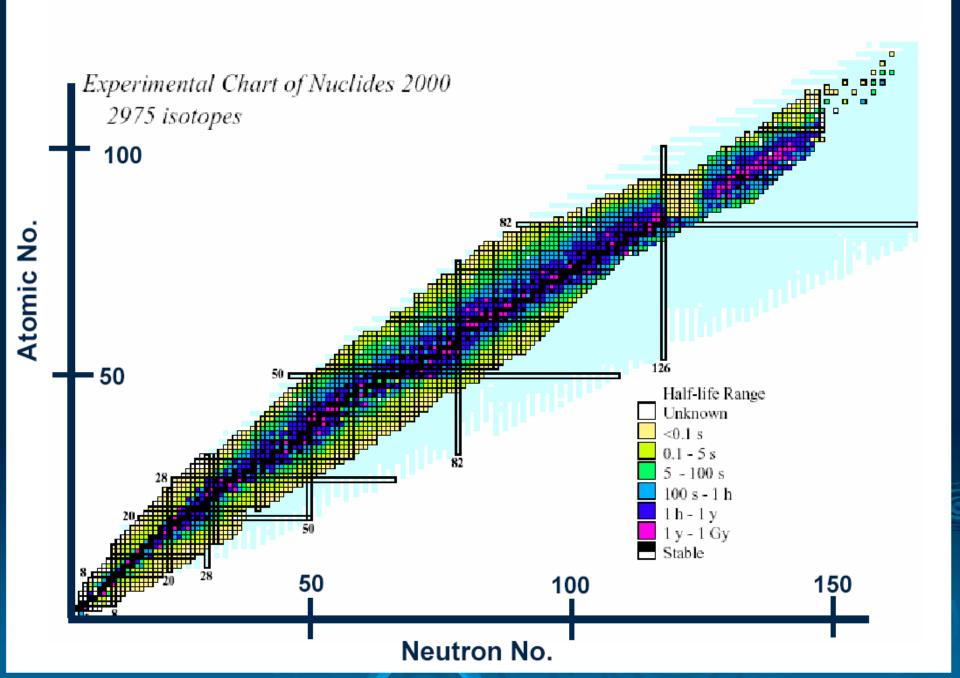
TOTAL MEGATONNAGES EXPENDED IN NUCLEAR TESTS, 1945-1996

	Atmosphere	Underground	Total
USA	141	38	179
Soviet Union	247	38	285
UK	8	0.9	8.9
France	10	4	14
China	21.9	1.5	23.4
Pakistan		(2 tests)	
India		(3 tests)	
TOTAL	427.9	82.4	510.3

Fission Yield Curve



Mass number



EQUIVALENTS OF 1 KILOTON OF TNT

•The complete fission of 56 grams of fissionable material produces:

•Fission of 1.45x10²³ nuclei

•3x10²³ atoms of fission products (two for each atom of fissionable material).

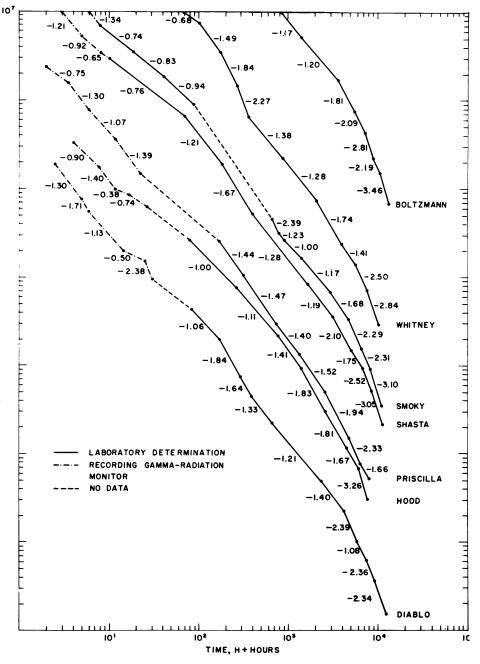
•One minute after the explosion this mass is undergoing decays at a rate of 10^{21} disintegrations/sec (equivalent to $3x10^{10}$ curies).

•Energy equivalents:

•1x10¹² calories

•4.2x10¹⁹ ergs

•1.15x10⁶ kilowatt-hours



Fallout Decay Curves

Gamma decay curves from seven tests from Operation Plumbbob. This slide shows that nuclear decay follow the same basic curve t^{-1.2.}

Gamma Decay Curves Fallout from Seven Shots.

Historical Radiation Exposure Guide Development

1929 - U.S. Advisory committee on X-Ray & Radium Protection formed (forerunner of NCRP)

- **1931 -** USACXRP publishes first recommendations 0.2 R/day
- **1934 ICRP recommends permissible dose of 0.2 R/day**
- 1936 USACXRP recommends reduction in permissible dose to 0.1 R/day
- 1942-1945 Manhattan Engineering District formed
- 1948 0.3 R/wk
- 1950 0.3 rem/wk

Brief History of External Whole Body Exposure Guides for Public

Year	Exposure guide	Reference
1951	3.0 R/10 Weeks	AEC (Buster-Jangle Operation)
1953	3.0 R/10 weeks	AEC Safety Booklet-March 1953
1955	3.9 R/year	AEC (Teapot Operation)
1957	0.5 rem/year	NCRP (NBS HB-59)
1958	5.0 rem/30 years	ICRP Pub No. 1
1959	0.5 rem/year	NCRP (NBS HB-69) ICRP Pub. No.2
1960	0.170 rem/year (group) 0.5 rem/year (individual)	FRC Report No.1
1971	0.170 rem/year (group) 0.5 rem/year (individual) 0.1 rem/year student	NCRP Report No. 39
1977	0.5 rem/year	ICRP Pub No. 26
1987	Freq. Exposure 0.1 rem/year Infreq Exposure 0.5 rem/year Remedial action when freq. Exp > 0.5 rem	NCRP Report No. 91
1991	0.1 rem/year (individual)	ICRP Pub. No. 60
1993	0.1 rem/year	NCRP Report No. 116
1997	0.015 rem/year (individual)	USEPA/OSWER No. 9200 (cleanup criteria)

The primary contributors to Fallout in So. Utah

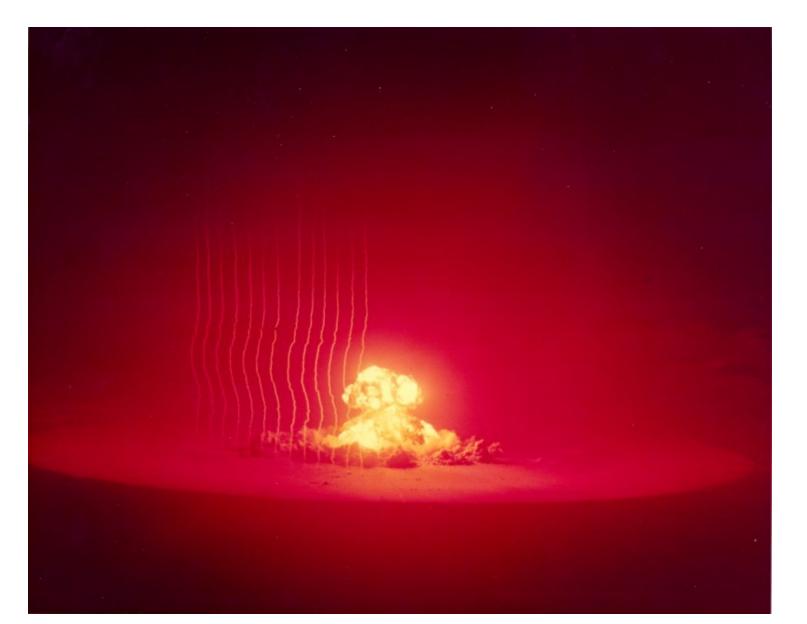
CUMULATIVE EXTERNAL EXPOSURE (Roentgen, R) FOR SELECTED UTAH COMMUNITIES

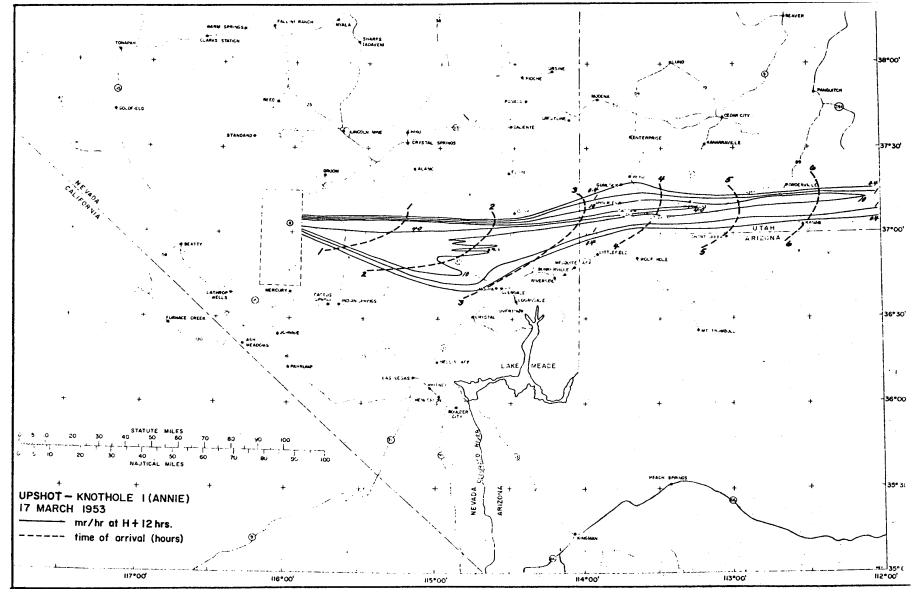
COMMUNITY	Exposure (R)	COMMUNITY	Exposure (R)
Beaver	0.25	Milford	0.10
Bryce Canyon	0.56	Mount Carmel	0.94
Cedar City	0.64	Mount Carmel Junction	0.85
Desert Range Exp. Station	0.10	Orderville	1.60
Enterprise	0.79	Paiute Indian Reservation	0.30
Garrison	0.88	Panguitch	0.70
Glendale	1.40	Parowan	0.42
Hamilton Fort	0.80	St. George	3.70
Hilldale	0.44	Santa Clara	4.30
Hurricane	3.50	Shivwits	3.60
Kanab	1.60	Springdale	2.70
La Verkin	3.70	Virgin	1.60
Lund	0.50	Zion Lodge	1.20

FALLOUT IN SOUTHERN UTAH - WASHINGTON, IRON, KANE, AND BEAVER COUNTIES

City	Event Name	Historical Dose Estimate	Percent of Total
St. George, UT (Washington County) total	Annie (UK) Simon (UK) Harry (UK) Tesla (Teapot) Zucchini (Teapot) Priscilla (Plumbbob) Smoky (Plumbbob) Morgan (Plumbbob)	0.35 0.01 2.50 0.10 0.04 0.03 0.66 0.01 3.70	0.09 0.00 0.68 0.03 0.01 0.01 0.18 0.00
Cedar City, UT (Iron County) total	Fox (TS) Harry (UK) Apple I (Teapot) Zucchini (Teapot) Priscilla (Plumbbob) Smoky (Plumbbob)	0.02 0.25 0.03 0.10 0.03 0.21 0.64	0.03 0.39 0.05 0.16 0.05 0.33
Kanab, UT (Kane County) total	Simon (UK) Harry (UK)	0.05 1.55 1.60	0.03 0.97
Orderville, UT (Kane County) total	Harry (UK) Tesla (Teapot) Apple I (Teapot) Priscilla (Plumbbob) Smoky (Plumbbob) Morgan (Plumbbob)	1.40 0.08 0.02 0.04 0.04 0.02 1.60	0.88 0.05 0.01 0.03 0.03 0.01
Beaver, UT (Beaver County) total	Fox (TS) Met (Teapot)	0.05 0.20 0.25	0.20 0.80

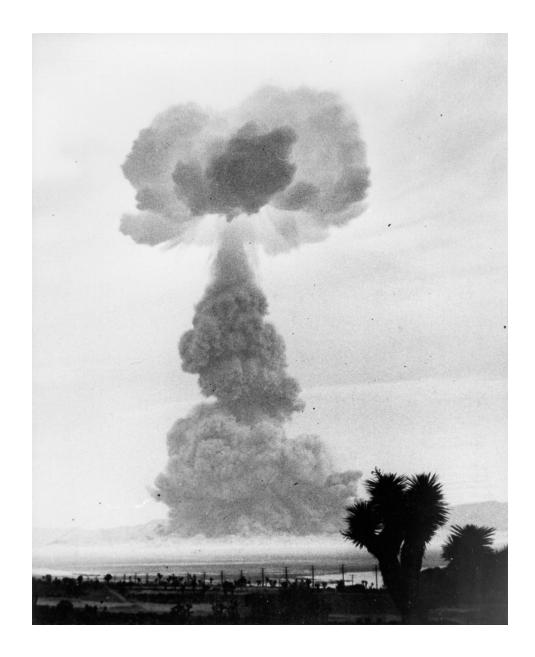
ANNIE (Operation Upshot-Knothole) – March 17, 1953





OPERATION UPSHOT-KNOTHOLE, ANNIE Event, March 17, 1953. Fallout pattern 1956.

HARRY (Operation Upshot-Knothole) – May 19, 1953



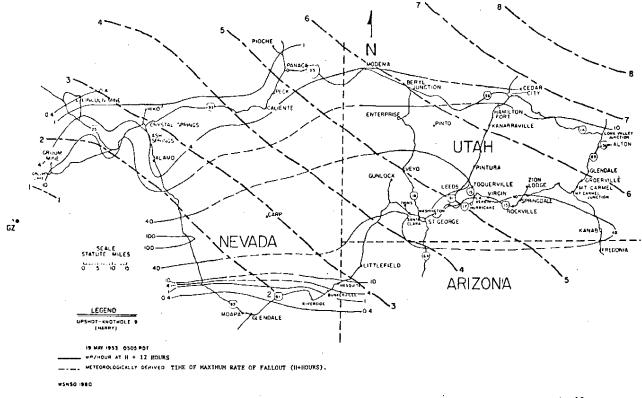


Figure 9. Extended range fallout pattern contours (mR/hr at H + 12 hours) and meteorologically derived time of maximum rate of fallout (H + HOURS).

OPERATION UPSHOT-KNOTHOLE, HARRY Event, May 19, 1953. Fallout pattern reanalyzed by Weather Service Nuclear Support Office in 1980.

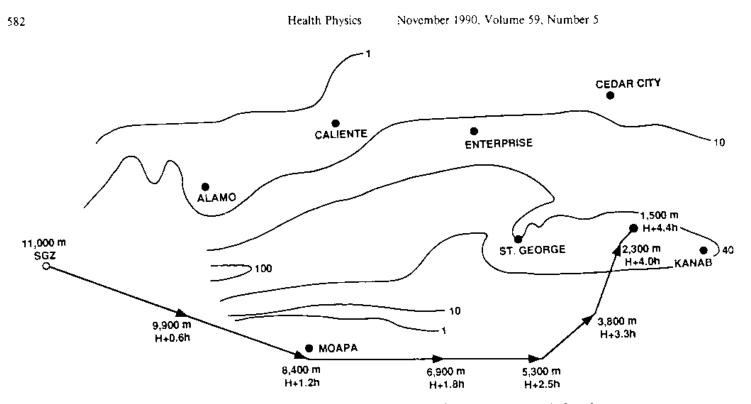
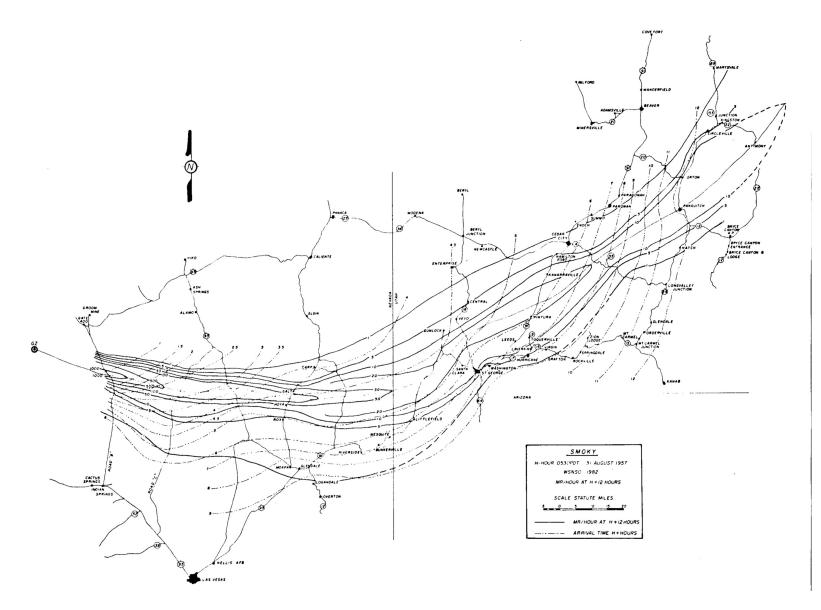


Fig. 3. Fallout particle trajectory (path), shown by the heavy line with arrowheads, as it falls from 11,000 m ASI. to 1,500 m ASL in 4.4 h. The numbers by the arrowheads are the altitude of the particle and the time (H + h) it reached that altitude. Thin lines are fallout contours (mR h⁻¹ at H + 12 h) from the WSNSO HARRY analysis.

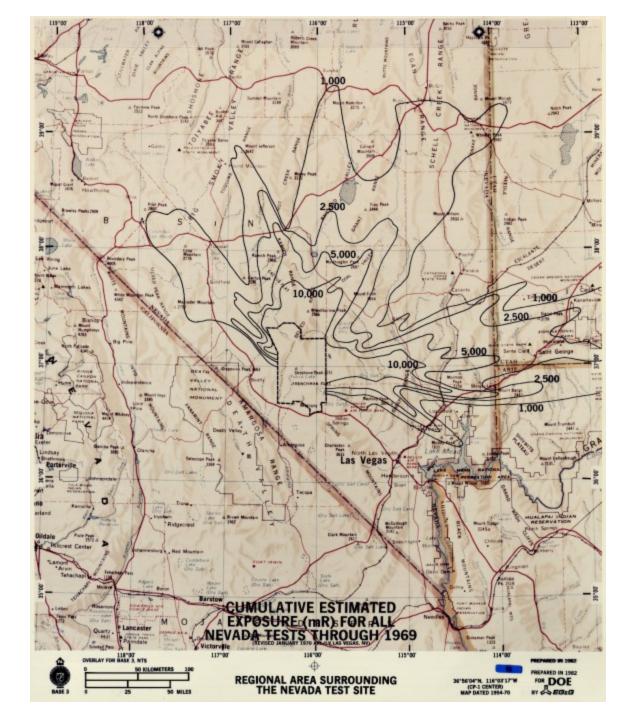
OPERATION UPSHOT-KNOTHOLE, HARRY Event, May 19, 1953. Fallout particle path shown by heavy line with arrowheads.

SMOKY (Operation Plumbbob) – August 31, 1957





OPERATION PLUMBBOB, SMOKY Event, August 31, 1957. Fallout pattern reanalyzed by Weather Service Nuclear Support Office in 1982.



Cumulative Estimated Exposure (mR) for all Nevada Tests Through 1969

Soil Concentration Levels for Selected Cities

SOIL CONCENTRATION LEVELS FOR NATUALLY OCCURRING RADIONULCIDES AT THESE SPECIFIC LOCATIONS GAMMA SPECTROSCOPY ANALYSIS

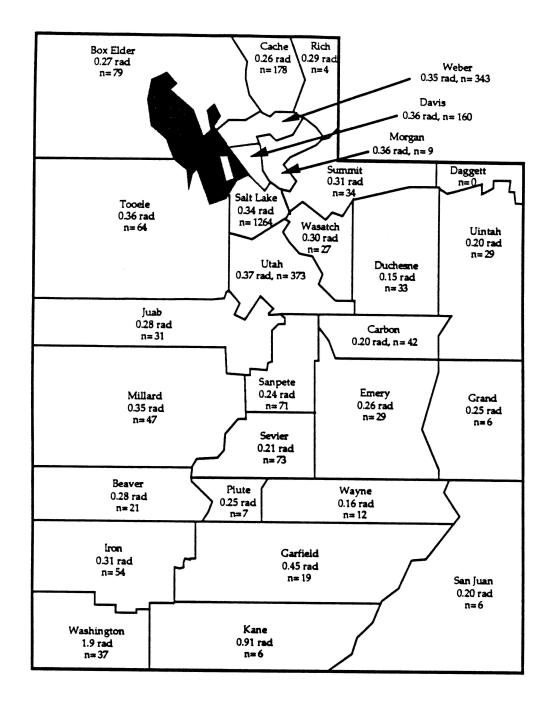
City, State	Sample Number	U-238 (pCi/g)	Th-232 (pCi/g)	K-40 (pCi/g)
Cedar City, UT	E-35	2.30	2.16	46.90
Kanab, UT	E20A	3.28	2.93	70.60
St. George, UT	EML3	2.00	1.82	56.50
Beatty, NV	BE32	4.94	6.54	116.70
Las Vegas, NV	SH07	4.13	2.53	40.10
Kingman, AZ	FM01	3.62	6.14	102.70
Mesa, AZ	NM25	3.73	4.49	80.80
Los Angeles, CA	BA29	2.29	4.46	75.90
Farmington, NM	NM21	3.27	3.14	92.80
Albuquerque, NM	AQ01	3.16	3.02	59.30
South Rim-Grand Canyon, AZ	FM08	4.08	4.01	62.70
Flagstaff, AZ	FM45	3.67	4.11	57.40

SOIL CONCENTRATION LEVELS FOR CESIUM-137 AND PLUTONIUM-239/240 IN SPECIFIC LOCATIONS

PLUTONIUM-239/240 IN SPECIFIC LOCATIONS			
	Sample	Cs-137	Pu-239/240
City, State	No.	(nCi/m ²)	(nCi/m ²)
Cedar City, UT	E-35	67.8	1.8
Kanab, UT	E20A	72	2.1
St. George, UT	EML3	80.3	3
Beatty, NV	BE32	36.2	5.9
	01107	10.0	0
Las Vegas, NV	SH07	40.2	2
Kingman, AZ	FM01	52.3	1.2
		02.0	1.2
Mesa, AZ	NM25	41.8	0.9
,			
Los Angeles, CA	BA29	40.8	0.9
Farmington, NM	NM21	46.2	1.3
Albuquerque, NM	AQ01	61.2	1.2
South Rim-Grand Canyon, AZ	FM08	91.2	2.6
Flagstaff, AZ	FM45	82.4	1.8

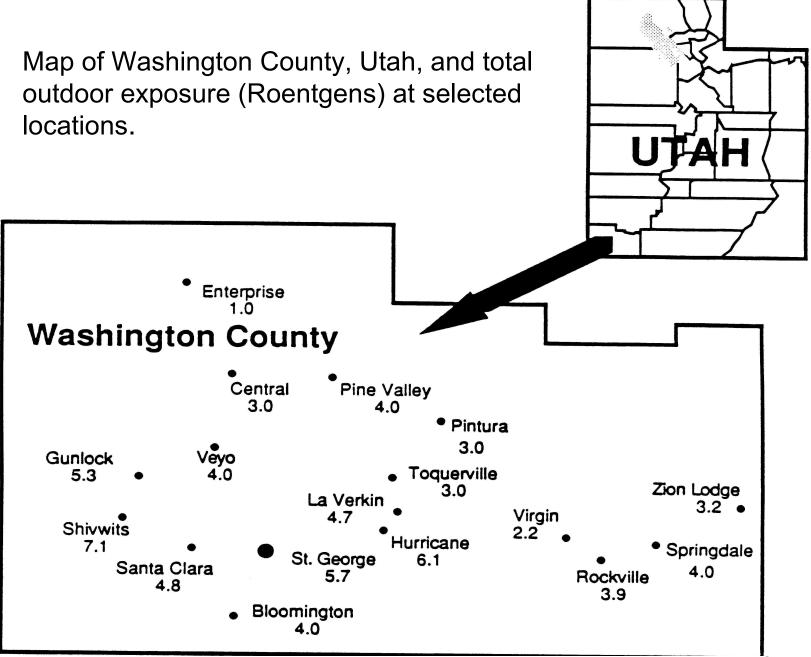
Summary of Thyroid Cohort Study Dosimetry Based on Residence in 1965, n=3545.

WASHINGTON CO. UTAH	GRAHAM CO. ARIZONA	LINCOLN CO. NEVADA	OVERALL
1896	1369	280	3545
17	1.3	5.0	9.8
7.2	0.36	2.8	2.5
0.0	0.0	0.0	0.0
461	45	84	461
704	14	88	443
	CO. UTAH 1896 17 7.2 0.0 461	CO. UTAH CO. ARIZONA 1896 1369 17 1.3 7.2 0.36 0.0 0.0 461 45	CO. UTAHCO. ARIZONACO. NEVADA18961369280171.35.07.20.362.80.00.00.04614584



Map of Utah showing the of bone average mean (rad) marrow doses to subjects (n) who remained in a single county during the entire period of fallout and for whom no assumptions were needed to reconstruct residential history. "n" includes only subjects who were born before 1952 and who died after 1958, thus accumulating the total potential exposure from Nevada Test Site fallout.

Leukemia Study



Leukemia Study

Release information from DOE/NV 317

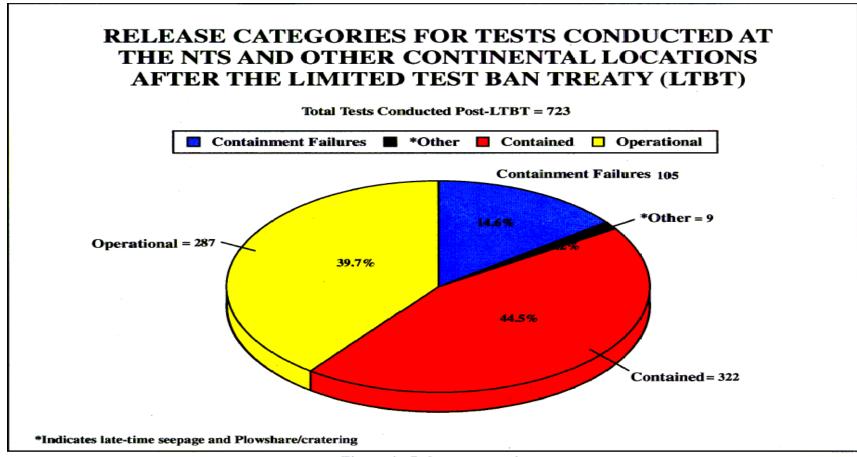
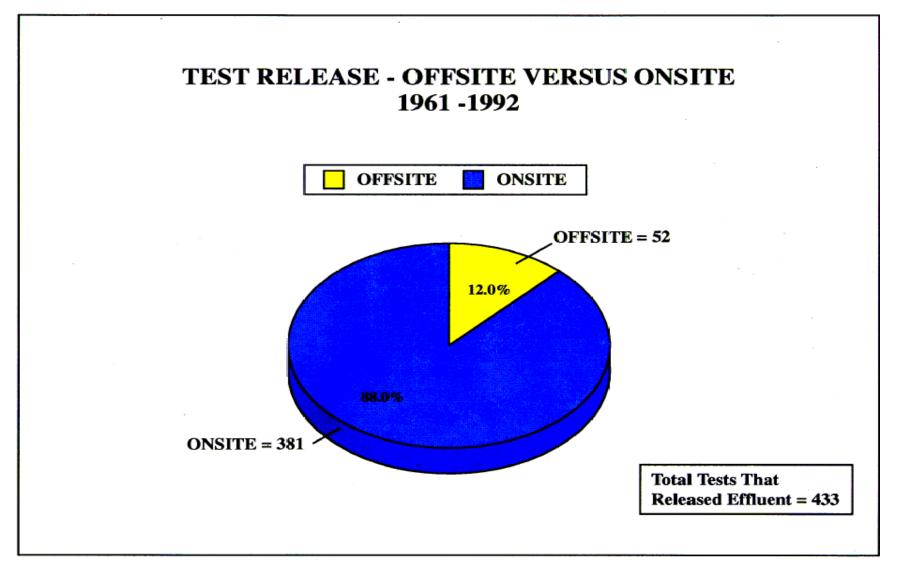


Figure 1. Release categories.

Information from DOE/NV 317



Test:	BANEBER	RY		
Date:	12/18/70	Sponsor:	LRL	
Time:	0730 PST	Depth of Burial:	912 ft	
Location:	NTS U8d	Purpose:	Weapons Related	
Туре:	Shaft	Yield:	10 kt	
Release Detected:	Offsite	Type of Release:	Test	
Test Release a	nt R+12 Hours, in C	uries: 6.7 x 10 ⁶		

Isotopes Identified in the Release: Gross fission products

Cloud Direction: Northeasterly, parts of the cloud moved over Nevada, Utah, and Wyoming; another fraction moved towards California

Maximum Activity Detected in Air Offsite: 230 picocuries of ¹³¹I per cubic meter and 3,400 picocuries of ¹³³I per cubic meter of air at Stone Cabin Ranch, Nevada

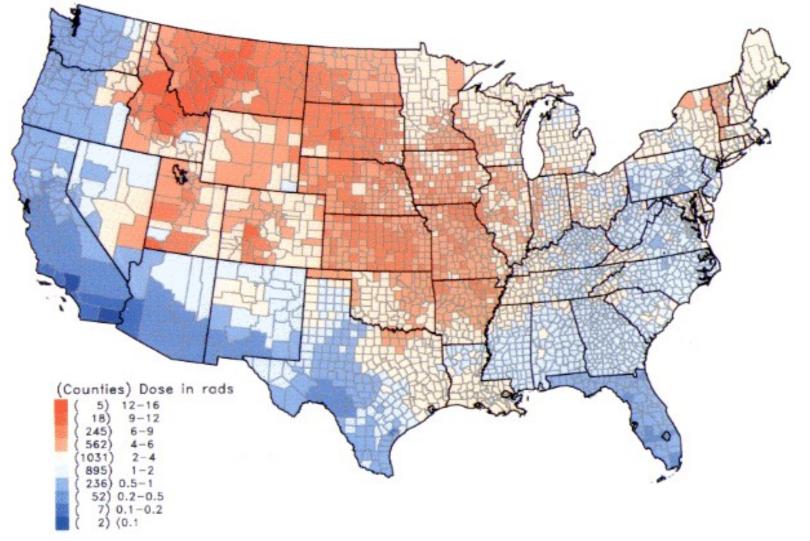
Maximum Gamma Exposure Rate Detected Offsite: Less than 1 mR/h in populated areas; 0.6 mR/h at Stone Cabin Ranch, Nevada

Maximum Iodine Level Detected Offsite: 810 picocuries of ¹³¹I per liter in milk at the McCurdy Ranch near Beatty, Nevada

Maximum Distance Radiation Detected Offsite: 0.05 mR/h at Austin, Nevada

Release Summary: Venting occurred from a fissure near surface ground zero at H+3.5 minutes. The effluent venting rate steadily decreased with time, but visible vapor continued to emanate from the fissure for 24 hours after the detonation.

Per capita thyroid doses resulting from all exposure routes from all tests (Ref. NIH lodine Study)



Health Physics Society Position on Risk of Cancer resulting from Exposure to Ionizing Radiation - Apr.,1999

- 1. Health effects have primarily only been observed in populations exposed to high doses at high dose rates.
- 2. The Life Span Studies of the Japanese survivors, exposed at high doses and high dose rates, form the most significant basis for estimates of risk from radiation.
- 3. The risk (i.e., chance) that any given cancer is related to a given radiation exposure depends on the amount of that exposure (i.e., dose) as well as other factors such as type of cancer, age at exposure, gender, and time since exposure.
- 4. The lowest doses at which an increase in any type of cancer is attributed to radiation exposure in the Japanese studies is greater than the 5 rem (0.05 Sv) used by the VA as a screening level for compensation evaluations.
- 5. The risks on a "per dose basis" of exposure to low dose, low dose-rates are less than those due to high dose, high dose-rates.

From these scientific facts the Society makes the opinion that there is no justification for assuming a presumptive causation of a cancer without consideration of all factors listed in #3 above, including dose.

Statement on Cancer and Radiation Dose by the Council of Scientific Society Presidents – Wingspread Conference 1997, Racine, WI

"A substantial body of scientific evidence demonstrates statistically significant increases in cancer incidence for acute whole-body exposures of adults to ionizing radiation at doses of about 10 rem and greater."

Attributable Percents from Various Risk Factors

Attributable Percents

Risk Factor	Percentage (%)
Tobacco	30
Adult diet / obesity	30
Sedentary lifestyle	5
Occupational factors	5
Family history of cancer	5
Viruses and other biologic agents	5
Perinatal factors / growth	5
Reproductive factors	3
Alcohol	3
Socioeconomic status	3
Environmental pollution	2
Ionizing / ultraviolet radiation	2
Prescription drugs / medical procedures	1
Salt / other food additives / contaminants	1

Harvard Report on Cancer Prevention. Cancer Causes Control 7 (suppl 1), 1996

Take Home Messages

- Everyone is exposed to ionizing radiation
 - From Natural Background
 - From Fallout
- Exposure/Dose is variable
 - Lifestyle
 - Geographic location
- Most Utah Residents received relatively modest exposures/doses from Fallout
- Risk is proportional to the size of the Dose