BOEING

Presenting the

Rocketdyne Worker Health Study

September, 1997

About Epidemiology

Epidemiology

Since epidemiologists look only at groups of people, these studies will not tell why an individual has a disease. Many factors, including lifestyle, environment and genetics, usually play a role in developing a disease.

Epidemiology is the study of disease among groups of people who have certain characteristics in common. Epidemiological studies help scientists understand whether exposure to a specific factor may increase the risk for certain diseases. Epidemiologists use the term "risk factor" to describe anything that increases the risk of disease.

For example, cigarette smoking is associated with the risk of heart disease but is not the only risk factor. High blood pressure and high cholesterol are also associated with an increase in the risk of heart disease. A person without the particular risk factor is considered "unexposed."

DEFINITIONS

A Cohort is a group of people who share similar characteristics within a defined period of time

Cohort studies help to answer the question: "Is the exposure(s) likely to have affected the rate of disease or death among the group being studied?"

A Retrospective Cohort Study

Most epidemiological studies of worker health are cohort studies. **Cohort** studies are used to look at differences in exposure and the frequency (rate) of disease or death in a group over time.

Since the Rocketdyne study uses historical data to look back at workers over time, it is a **retrospective** cohort study.

In the Rocketdyne study UCLA researchers looked for relationships between workplace exposure to radiation and chemicals, and various causes of death. The first phase of the study looked at exposure to radiation, asbestos and hydrazine. The study of other chemical exposures to the study group will be released at a later date.

Collecting Data

Rocketdyne gave researchers information about workers who were monitored for radiation exposure at our Santa Susana, Canoga Park, and DeSoto facilities. Researchers used the following available information about the workers:

- potential occupational exposures
- smoking
- gender, age, race
- other risk factors

MANY SOURCES WERE USED

Employee Records
radiation and chemical exposure, employment status, medical history, and pension (to track retired workers)

Interviews
with some current and former employees

Death Certificates
when and of what causes workers have died

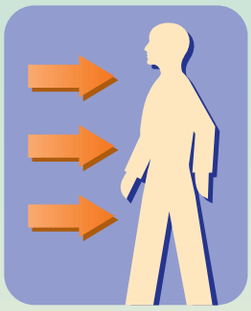
Measuring Radiation Exposure

The primary focus of the UCLA study is the effect of "ionizing radiation" on the health of Rocketdyne radiation workers. Ionizing radiation consists of energy or small particles, such as gamma rays and beta and alpha particles, that are emitted during atomic decay and from X-ray machines. Ultra-violet radiation, visible light, lasers, infra-red radiation (heat), microwaves and radio waves are forms of non-ionizing radiation which were not included in the UCLA report.

EXPOSURE

"Exposure" or "dose" refers to how much radiation is absorbed by a person's body. Radiation exposure may be external or internal. The UCLA study considered both.

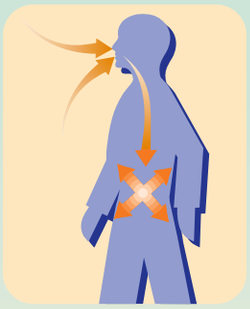
External Radiation



Rocketdyne workers have always been provided film badges if their work required them to enter a "Radiation Area" or if they are likely to receive more than 1mSv (100 mrem) in any one year.

External radiation exposure occurs when radiation penetrates or enters the body from the outside (usually gamma radiation, X-rays and neutrons). External radiation to workers is directly measured using "film badges" or dosimeters the workers wear on their bodies. These badges measure the accumulated radiation over a period of time (quarterly) to maintain a record of an individual's external radiation.

Internal Radiation



Rocketdyne workers involved with work in "Airborne Contamination Areas" or with unencapsulated radioactive material, where inhalation of these materials is possible, are given bioassays and whole body scans on a quarterly basis.

Radioactive material can enter the body by inhalation (breathing), ingestion (eating or drinking) or through open wounds. Internal radiation exposure is usually by alpha particles, beta particles and gamma radiation.

There is no direct way to measure internal radiation exposure. The quantity of radioactivity in the body can be estimated by:

measuring the radioactivity in bioassays *(urinalysis or fecal analysis)*

whole body scans *(measurement of gamma radiation leaving the body)*

From these analyses, the internal radiation exposure to different organs can be estimated.

QUESTIONS

Why do some workers have more exposure than others?

Total recorded exposure depends on...

- **whether or not the employee had exposure prior to joining Rocketdyne/AI.**
- **how long the employee was employed as a radiation worker.**
- **the specific job function (e.g., x-ray cell radiographers would typically have lower exposure than research reactor workers).**

When did the cohort get most of its radiation exposure?

Researchers looked at annual exposure records for workers monitored for radiation exposure between 1950 and 1993. The majority of radiation exposure was probably received either from pre-Rocketdyne/AI employment or from working at Rocketdyne/AI nuclear energy research facilities during the 1960s.

UNITS

The following are per unit doses to which individuals in the U.S. could be exposed.

Source: (EPA document # 402-K-92-004 August 1993)

	mSv	*mrem*
One chest x-ray	*0.1*	*10*
Mammogram	*0.3*	*30*
Upper and lower gastrointestinal series x-ray	*14*	*1,400*

Radiation exposure (both internal and external) is usually measured in units of millirem or one thousandth of a rem (mrem). This unit of measurement is an expression of the amount of energy absorbed in human tissue. An alternate unit used to measure radiation exposure is the milli-Sievert (mSv). A milli-Sievert is 100 times larger than a millirem.

Both units of measurement include the different relative biological effects of different kinds of radiation. For example, 1 mSv of gamma radiation has the same effect as 1 mSv of x-rays.

The following shows how to convert from millirem to milli-Sievert and vice-versa.

1 millirem = 0.01 milli-Sievert
1 milli-Sievert = 100 millirem

Background Radiation & Comparisons

The general population is exposed to an estimated 3.6 mSv (360 mrem) of ionizing radiation per year. This exposure results from everyday sources such as the sun (cosmic rays), radon from the ground, elements in soil and water, food and consumer products (e.g., building materials). These sources are called background radiation. Medical/dental x-rays are another source of exposure to ionizing radiation. Although the level of these exposures may vary from person to person (for example, the radiation effect of the sun is greater at higher altitudes), it is a useful benchmark from which to evaluate a workers exposure to occupational radiation sources.

The following are average **lifetime** doses (70 years) to which the U.S. population is exposed.

	mSv	mrem
Cosmic rays (sea level)	19	1,900
Cosmic rays (Denver–higher altitude)	37	3,700
Soil and Rock	20	2,000
Living in stone, concrete or masonry building	5	500
Food, water and air	27	2,700
Radon	140	14,000
Total from natural background	210	21,000

Looking At Risk

To determine whether Rocketdyne radiation workers exposed to radiation have died at rates greater than expected, researchers compared the worker group with other groups of people and made comparisons within the study group. The researchers calculated **Standardized Mortality Ratios (SMR)** to look at the relative risk of disease between the Rocketdyne study group and the outside comparison group, and **Rate Ratios (RR)** to see if death rates vary based on different levels of exposure among the Rocketdyne study group.

Comparisons With Outside Groups

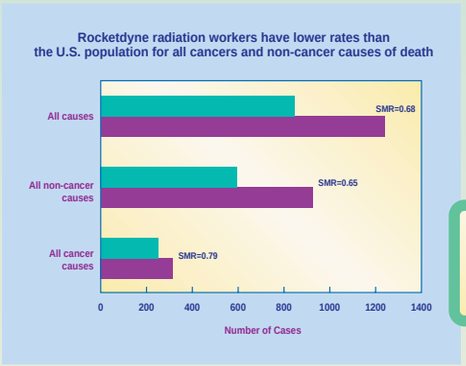
How many Rocketdyne radiation workers would have been expected to die of specific diseases when compared to the

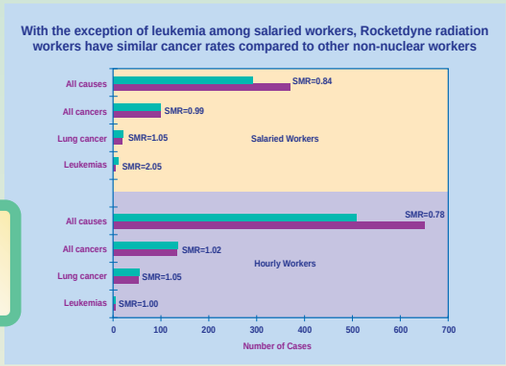
► **U.S. Population**

Are Rocketdyne radiation workers dying of specific diseases at greater rates when compared to

► **Non-nuclear Worker Groups**

(based on National Institute of Occupational Safety & Health (NIOSH) Data)





These charts show **Standardized Mortality Ratios** *which compare the number of deaths observed in the Rocketdyne study group with the expected number of deaths in the comparison groups.*

$$\text{SMR} = \frac{\textit{Observed}\ \text{Number of Deaths}}{\textit{Expected}\ \text{Number of Deaths}}$$

If the study group has a death rate greater than the comparison group, the SMR will be greater than 1.0.

Comparisons Among The Rocketdyne Study Group

Does increased exposure to radiation increase the risk of dying from specific diseases?

Researchers compared death rates among the higher exposure groups to those of the lower exposure groups by calculating Rate Ratios.

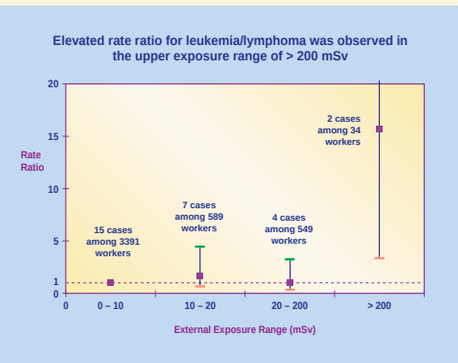
► **Workers** *were grouped into four categories based on their external exposure level. (Rocketdyne Health Physics Monitoring Program)*

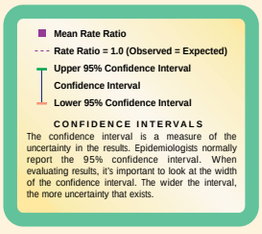
External Exposure Range (mSv)
0 – 10
10 – 20
20 – 200
>200

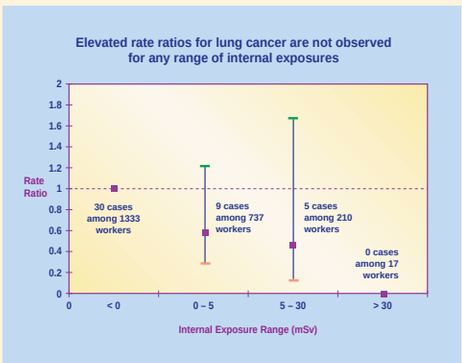
$$\text{Rate Ratio} = \frac{\text{Rate in } \textit{higher} \text{ exposure group}}{\text{Rate in } \textit{lower} \text{ exposure group}}$$

It tells researchers

- If the death rate among workers increases with increased exposure.
- How strong the relationship is between an exposure and that disease.







These charts show the **Rate Ratios** *for workers with different exposure levels.*

If the Rate Ratio is

- **equal to 1.0,** the relative risk for disease is **the same** in both the study group and the comparison group.
- **less than 1.0,** the relative risk is **lower** for the study group than the comparison group.
- **greater than 1.0,** the relative risk is **higher** for the study group than the comparison group. The higher the number is above one, the stronger the association between exposure and risk of dying from a specific cause.

For example, a rate ratio of 1.2 would indicate a 20% higher risk for the study group.

If the rate ratios are calculated based on a small number of cases, there is less certainty about the true value of the risk.

Evaluating the Results

Interpreting the results of the worker health study depends on how well researchers accounted for other risk factors or sources of bias that may have affected the results. It's necessary to look carefully at both how the study was designed and how it was carried out.

Bias

Bias is the presence of some flaw in the design of the study or the way it was conducted that results in some systematic error.

Chance

Since epidemiologists make comparisons between groups that are based on samples from larger populations, this always adds an element of uncertainty to the results.

Confounders

A confounder is some factor which is associated with the exposure and by itself might increase the risk of that disease. Confounders can include behavioral factors such as smoking, genetics, and other environmental or occupational exposures.

In the Rocketdyne study, bias may have resulted either from the way the Rocketdyne or control population was selected (selection bias), or the way that information was collected (observation or information bias).

Any sample will, by chance, differ at least a little from its parent population. For example, the National Institute of Occupational Safety and Health (NIOSH) cohort was used in this study as a sample of all industrial workers, but it was not identical to the Rocketdyne population to which it was compared. At least some of the differences between compared groups may be due to this sampling effect.

Failure to control for confounders may result in over or underestimates of the risks from exposure.

Epidemiology is a complex science. Understanding what the results mean is not always straight forward. Scientists may disagree about the statistical results and whether the occurrence of disease is related to an exposure. Most chronic diseases have multiple causes. Identifying the contribution of individual risk factors is difficult to do.

Exploring the following **questions** is important to put the results of the Rocketdyne Study into context for workers, the public and the scientific community.

Did researchers account for the important factors that could affect the results?

How well a study was performed can be evaluated, to some degree, by examining how well the study was designed to prevent or anticipate common problems resulting from bias, chance and confounding.

Are the results consistent with other studies?

The Rocketdyne study was designed to be similar to earlier studies of the nuclear industry. Comparing the results of the Rocketdyne study to these other studies is important.

How strong is the relationship between exposure and disease described by the relative risk?

If the exposure is associated with a large increase (or decrease) in the risk of disease, there is a stronger association and therefore it is less likely that the effect is due to bias or some unknown factor.

Is the relationship stronger at higher exposure levels?

If higher doses or exposures are associated with higher rates of disease, a dose-response relationship is said to exist, strengthening the relationship between exposure and disease.

Is it clear that the disease happened after exposure?

The exposure must be shown to have occurred before the disease and be consistent with what is known about the latency period for the disease.

Is the relationship biologically likely?

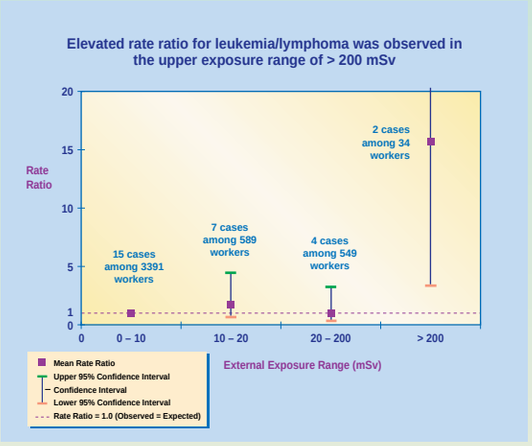
There must be a credible scientific and biological explanation for how the exposure could have caused the disease.

Results of the Study

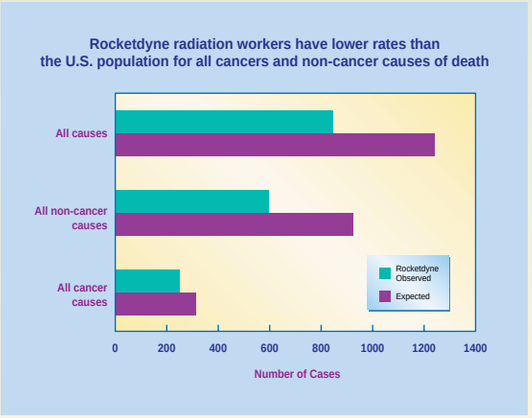
To review the study, we hired nationally known experts in the fields of epidemiology, biostatistics, radiation research and oncology (study/treatment of cancer) to help us understand what the study means and to evaluate the strengths and limitations of the study.

Here is what these experts have told us:

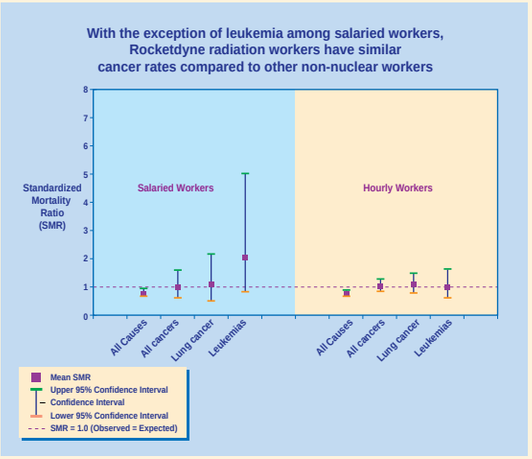
The study found an increase of combined leukemia/lymphoma (hemato- and lymphopoietic cancers) for workers with the highest radiation exposures (greater than 200mSv external radiation exposure).



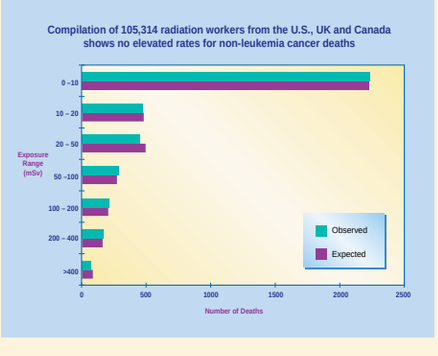
The study found that Rocketdyne radiation workers had lower death rates from all causes and from some specific causes (i.e., heart disease) when compared to the U.S. population.

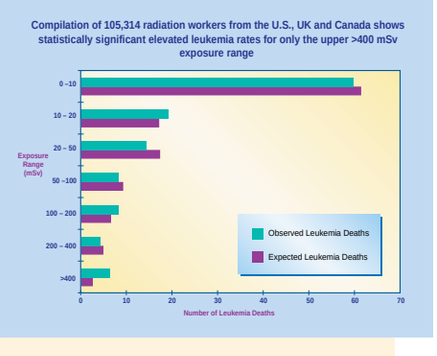


Rocketdyne salaried and hourly radiation workers have similar cancer mortality rates compared to other non-nuclear workers. However, salaried radiation workers appear to have elevated rates for leukemia.



The findings for leukemia in the high exposure range are consistent with findings from similar studies that looked at worker radiation exposure.





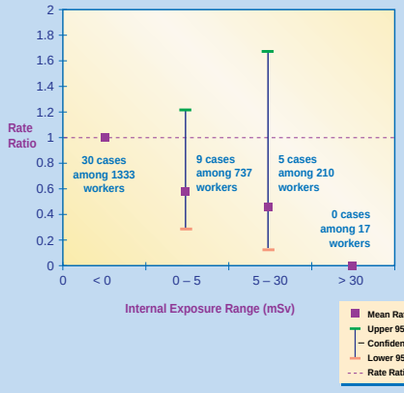
These two charts represent over 100,000 radiation workers from the U.S., UK and Canada. These charts do not include data for Rocketdyne radiation workers.

Results of the Study
(Continued)

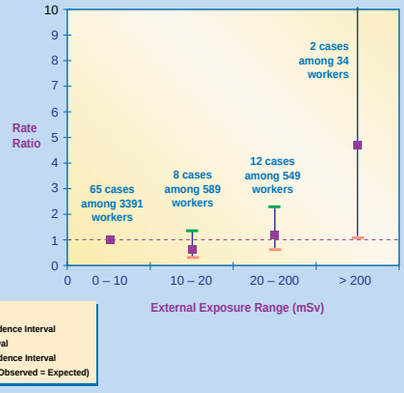
Here is what these experts have told us:

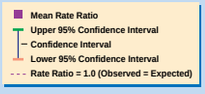
The reported lung cancer results are contradictory. If there was an association for lung cancer, it would likely be from internal exposures since inhalation is the major pathway to the lung. Yet the study found a lower relative risk as internal exposures increased and a higher relative risk from external exposures above 200 mSv.

The study found a decreasing risk for lung cancer as internal exposures increased



The study found a higher risk for lung cancer in the highest external exposure range

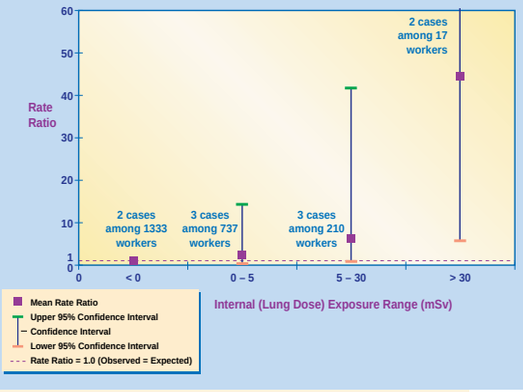




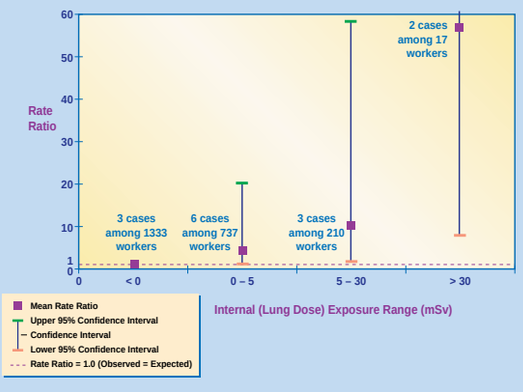
All of the findings associated with internal exposures are questionable and difficult to interpret. The UCLA study suggests an increased risk for leukemia/lymphoma and upper aerodigestive tract cancers in all internal exposure ranges. Experts questioned these reported results for the following reasons:

- The UCLA researchers calculated a lung dose based on internal exposure, which is not directly related to and cannot be used to make assumptions about exposure to other organs (i.e., stomach or bone marrow).
- These cancers have not been associated with internal radiation exposure in the majority of other radiation studies.
- Average internal doses in this study were small (2.1 mSv), as were the number of deaths among the internal exposure group. Authors of the recently published Oak Ridge National Laboratory (ORNL) epidemiologic study, with a larger average lung dose (82.1mSv), indicated that results related to internal exposures should not be relied on.
- The grouping of upper aerodigestive tract cancers has not been used in the majority of other studies and the anatomic sites in the grouping do not share common biological or exposure features.

Elevated rate ratios for leukemia/lymphoma were suggested in all internal exposure ranges



Elevated rate ratios for upper aerodigestive tract cancers were suggested in all internal exposure ranges



Interpreting The Results

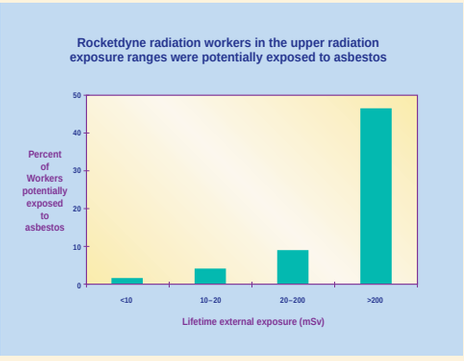
Our reviewers raised some important questions about the report and what it means.

The increase in leukemia/lymphoma in the highest external radiation exposure range (>200mSv) is consistent with other studies. For internal comparisons in the Rocketdyne study, leukemia death rates were not analyzed separately. These results would be clearer to interpret if the researchers had not grouped leukemia and lymphoma together.

The findings of an association between exposure to internal radiation and leukemia/lymphoma and upper aerodigestive tract cancers have not been reported in the majority of other studies and are difficult to interpret. Internal doses in this study were very small, as were the number of deaths among the internal radiation exposure group. UCLA cautions that the results for internal exposures are less reliable because of these low doses and small number of deaths. Researchers from other similar studies that looked at higher exposures and larger study groups have recognized the limitations of data associated with internal radiation exposure.

There is a problem with the way internal exposure data was used. For internal exposure, researchers estimated lung doses only, which cannot be used to make assumptions about exposure to other organs. The results for internal exposures in this study are misleading because of the limitations of the methodology used to estimate these exposures.

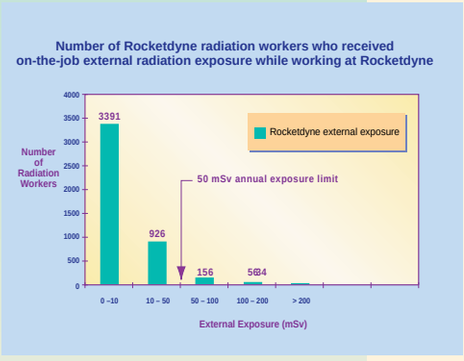
There are some unknowns about the workers which might affect results. This includes pre - and - post Rocketdyne employment history regarding radiation and chemical exposures, and whether employees smoked. For example, radiation workers with the higher radiation exposures were also potentially exposed to asbestos. Therefore, asbestos exposure may be "confounding" the lung cancer results. The researcher's results do not adequately address this.



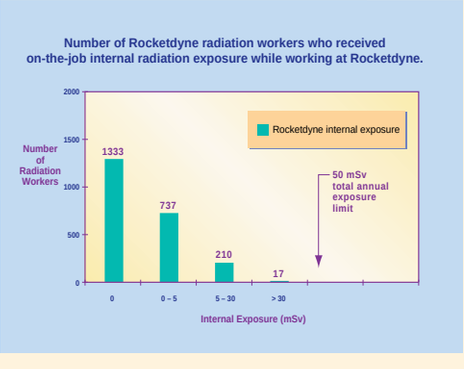
What Does This Mean To Me, The Employee?

The study found an increased risk for radiation workers with the highest external radiation exposure (greater than 200 mSv). This group consists of 1% of the study group (49 radiation workers) when both pre-Rocketdyne and Rocketdyne exposure is considered. Fewer than 1% (34 radiation workers) received greater than 200 mSv external exposure while working at Rocketdyne.

If you have had a lifetime exposure below 200 mSv external radiation exposure, you are not in the group that was identified as a high risk group.



The findings for internal radiation exposure are difficult to interpret. Because of this, it is also difficult to identify a high risk group. Our experts have told us that the findings for internal exposure should not be relied on because of the method used to estimate the level of exposure.



There are other considerations unique to each individual that could affect risk. These include your genetic makeup and family history; your lifestyle (whether you smoke or drink alcohol) and your overall work history - the kinds of jobs you have had before and after working at Rocketdyne.

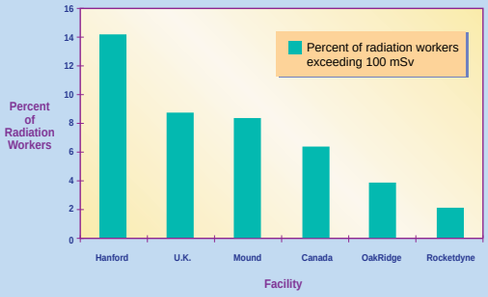
Since the results of the Rocketdyne worker health study do not tell an individual what his or her risk is, it is important for our radiation workers to have information about their own radiation exposure. Current and former Rocketdyne radiation workers can call (818) 586-6140 or (818) 586-5766 for information about their radiation exposure.

If you have any general questions please call (800) 808-1160

Radiation Work at Rocketdyne

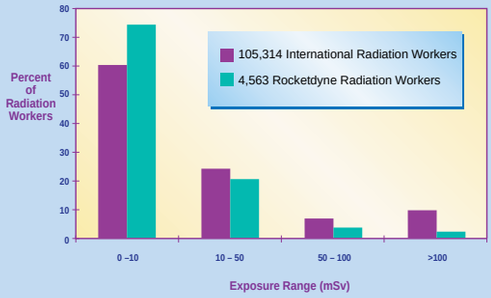
Our radiation workers were continuously **monitored** for radiation exposure. We have always operated in accordance with the **regulatory standards** in place at any given time. The concern for protection of employee health has always driven our workplace exposure programs.

Rocketdyne has the smallest percentage of radiation workers in the upper exposure range (>100 mSv) compared to other nuclear facilities studied in the US, UK and Canada



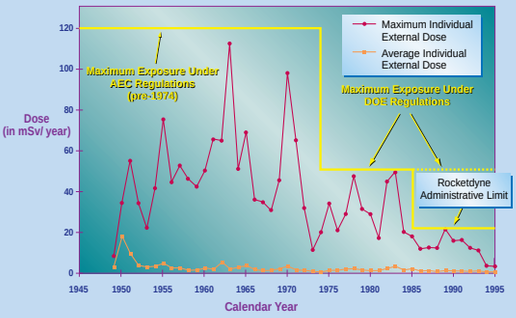
Overall, the Rocketdyne radiation workers studied had lower exposures than other groups in similar studies.

Rocketdyne radiation workers received less on-the-job exposure than workers at other facilities studied in the U.S., UK and Canada. Only 2% of radiation workers received greater than 100 mSv



- ***As science and technology improved, we made our limits more protective than the established regulatory standards (40% of the regulatory limits).***
- ***No one has ever exceeded the allowable annual limits for external exposure.***

Rocketdyne exposures were less than regulatory limits and as low as reasonably achievable



- ***Today, Rocketdyne does not conduct any nuclear work. Worker exposure to radiation is very limited. The only associated activities are x-ray operations and cleanup of facilities used in former nuclear operations.***
- ***We continually look at all Rocketdyne operations to ensure the safest possible workplace for our employees and to protect the surrounding community and environment. We have aggressively achieved a significant reduction and elimination of chemicals used, and continually look for ways to protect worker health.***

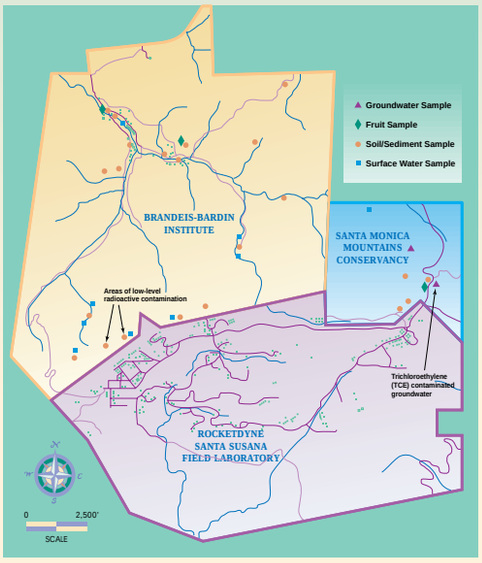
What do the Results of This Study Mean to the Neighboring Community?

The Rocketdyne Worker Health Study looked at employee exposure records. Similar exposure data does not exist for the neighboring communities. Results of this study should not be used to draw conclusions about potential exposures to the community. However, we have performed offsite sampling in communities surrounding the Santa Susana Field Laboratory over the last 40 years.

This extensive environmental monitoring of soil, air and water has demonstrated there has not been exposure to radioactivity that could impact public health in the neighboring communities.

Beginning in 1992, we undertook an extensive study of properties neighboring the Santa Susana Field Laboratory to ensure our activities have not adversely impacted public health or the environment. Results from this study provide information on potential exposure pathways and levels.

The results of the study show that exposure offsite to surrounding community members was and is unlikely.



Types of Samples:

Over 260 samples of soil, surface water, groundwater, and fruit and vegetation were taken on neighboring properties.

More than 70 samples were taken from background areas located from 1.5 to 13 miles from the site.

This study was conducted on behalf of Rocketdyne by an independent consultant and in participation with state and federal agencies and neighboring property owners.

If past operations had resulted in an impact to the environment outside of the Santa Susana Field Laboratory, historical and current monitoring would be able to detect it.

The Study Found:

Soil

Low-level radioactive contamination in two areas near the field laboratory's northwestern boundary. These are areas of steep terrain inaccessible to the general public.

Experts Noted:

- "EPA has determined the radionuclides do not pose a threat to human health or the environment." *–U.S. Environmental Protection Agency, EPA Update July 1995*
- "… all radionuclide concentrations measured by the DHS laboratory…were determined to be in the range of what is normally found in the California environment…The levels of tritium measured by the DHS laboratory…do not pose a risk to the public health…" *–California Department of Health Services*
- "I would agree that it is not a health risk." *–Joel Cehn, Radiation Physicist*

Groundwater

- Solvents, primarily Trichloroethylene (TCE), have been found in the groundwater to the north of the field laboratory within several hundred feet of the property line.
- Tritium was detected in one offsite well just to the northwest of the property line, but significantly below allowable levels for drinking water.

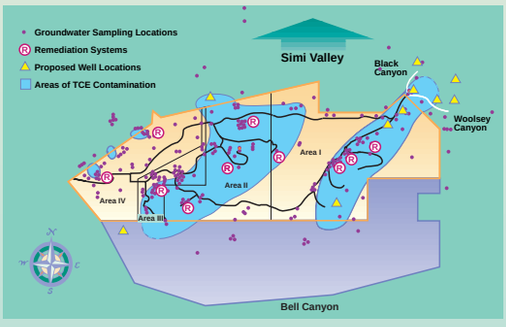
Groundwater is **not** used as a drinking water supply. Drinking water for surrounding communities comes from Northern California and the Eastern Sierras, which is provided by the municipal water district.

Groundwater Cleanup Program

Beginning in 1984, Rocketdyne initiated an extensive groundwater investigation and cleanup program to:

- Identify and prevent the spread of contaminated groundwater.
- Remove the contamination (industrial solvents - primarily TCE) and treat the groundwater.
- Recycle the treated groundwater for use in industrial operations at the field laboratory.

The system consists of more than 235 monitoring locations and natural springs, 37 of which are outside our property line, ranging in depth from approximately 20 to 2300 feet.



About 500,000 gallons of groundwater are pumped and treated every day.

Over 1 billion gallons of groundwater have been treated since the program was initiated.

For additional information about Rocketdyne's environmental monitoring and cleanup programs, call (818) 586-6742 or (800) 808-1160.

For more information about this publication please contact:

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