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OCCUPATIONAL RADIATION HEALTH RISKS: FOLKLORE AND FACT

An Assessment of the Health and Mortality
Studies of Federal Nuclear Workers
in the United States

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INTRODUCTION

In the fall of 1977, a study published in the Health Physics Journal ignited a firestorm of debate over the cancer risks of low-level ionizing radiation. The outcome of this debate has important ramifications for the civilian and military nuclear programs for decades to come. By addressing the human health legacy of the past four decades of nuclear activities, this debate could also affect future radiation protection standards for millions of people.

At the center of the controversy is a 36 year follow-up of 30,000 workers at the Energy Department's Hanford nuclear operations in eastern Washington performed by Drs. Thomas F. Mancuso, Alice Stewart and George Kneale. In 1977 Mancuso, Stewart and Kneale (MSK) reported an association between radiation exposure and excess deaths from cancer of the bone marrow (multiple myeloma), pancreas, and lung. Moreover, the risk of dying from radiation-induced cancer at Hanford appears to be 10 to 30 times greater than current protection standards assume.(1)

Mancuso's funds were severed by the Department of Energy (DOE) and unsuccessful attempts were made to confiscate his data. Several papers critical of the MSK study were generated by researchers sponsored by the DOE and the Nuclear Regulatory Commission (NRC).(2) The contract originally held by Mancuso was transfered to Oak Ridge Associated Universities (ORAU), Battelle Northwest Laboratory (BNL) and Los Alamos National Laboratory (LANL).

Although much has been reported about the political controversy surrounding the termination of Dr. Mancuso's contract, the public and the scientific community in general know very little about the scientific debate over occupational radiation risks that has been raging for the past eight years.

As a result, an official "folklore" about the Mancuso study has tended to obscure several important scientific issues. For example, DOE sponsored researchers persist in conveying the false notion, which is now discredited, that Mancuso et al. have published only one paper. Several papers by MSK (all using an internal control) were subsequently published in refereed scientific journals. They have answered the initial wave of criticisms and have also reported other important findings.(3)(4)(5)(6)(7)(8)(9) These more recent analyses are based on an enlarged data base and more refined analytical methods. For the most part, detractors of MSK have either remained silent about these recent papers or misrepresent their conclusions. Another "folklore" is that Mancuso's own data shows that radiation cancer risks are consistent with official protection standards. The fact is that several of Mancuso's critics have found an excess risk of bone marrow cancers at Hanford following radiation exposures. But, as we shall see, the data used by these critics are strikingly different in content and quality. On the other extreme the "folklore" that MSK found an "epidemic" of radiation induced cancer is equally erroneous. The proportion of radiation-related cancers identified by MSK is only 5 to 7 percent.

Perhaps the most important question obscured by these false perceptions is: What are present holders of DOE contracts finding in the data that Mancuso helped assemble on about 600,000 radiation workers at several DOE sites? In the

fall of last year, the Environmental Policy Institute (EPI) released official reports indicating that DOE's nuclear workers at several locations are experiencing greater than expected risks of dying from malignant cancers. Much of this information was outlined in a May 1984 Epidemiological Project Summary of studies funded by DOE under contract with Oak Ridge Associated Universities (ORAU) and the University of North Carolina (UNC).(10) Eight out of twelve populations under study were found to have excess cancer death rates -- most of which were described as "significant."(see appendix A)

DOE officials and their contractors have characterized these findings as preliminary and inconclusive. Dr. C.C. Lushbaugh, then supervisor of the ORAU/UNC studies stated "we don't think anybody should have alarm about them... we just don't consider them substantive conclusions."(11) A formal written response echoing Lushbaugh, was also prepared by Dr. Robert Goldsmith of DOE's Office of Health and Environmental Research in the form of "fact sheets."(12)

THE HANFORD SURVEY

The DOE "Fact Sheets" mention that DOE contract researchers have established a correlation between excess deaths from multiple myeloma and radiation exposure at Hanford but contend that the number of cases are not large enough to be significant. Goldsmith implies that radiation risks among DOE workers are being shown to be consistent with official standards.(13) This begs question: why are the findings of MSK different than those of the DOE researchers?

An answer can be found partly in the different methods used by DOE researchers and MSK to analyze the DOE worker data. According to Dr. Goldsmith DOE researchers "use standard occupational epidemiology methods. That is, the mortality experience of the entire group of workers is compared to that of the United States general population (SMR study)." Then if a significant excess appears of certain tumors, according to Goldsmith a subcohort or "nested" case/control study is done.(14)

The use of the SMR method has been subject to criticisms by non-DOE scientists and was the focus of an investigation convened by Colorado governor Richard Lamm in 1983.(15) According to Diane Eisenberg, a University of Wisconsin epidemiologist whose critique led to the Lamm Panel review,

> "the hypothesis being tested... is unsuitable for an occupational hazard investigation. Asking whether workers at Rocky Flats or any industrial plant experience greater mortality than would be expected based on U.S. death rates'... generally guarantees a negative finding, except for occupational risks of very great magnitude. Industrially employed populations are characterized by lower mortality rates than the general population. This widely recognized phenomenon, termed the healthy worker effect' is commonly attributed to a combination of the following factors; general population rates include invalids and hospital and hospital patients, many employers conduct pre-employment health screening, which directly selects for good health..."(16)(emphasis added)

In particular the magnitude of the "healthy worker effect" among DOE nuclear employees was reported by DOE researchers as early as 1979.(17) According to Eisenberg, "it is acknowledged that these low mortality ratios cannot be

interpreted simplistically as evidence of no occupational risk..."(18)

The "healthy worker effect" has also been found by researchers at the National Institutes of Occupational Safety and Health (NIOSH) in their study of radiation workers at the Portsmouth Naval Shipyard in Kittery, Maine. "We found an ultrahealthy worker effect [at Portsmouth]." says a NIOSH epidemiologist. "There was a double selection. First there was a selection to get into the shipyard and second, selection to become a monitored worker."(19)

In a recent paper Mancuso et al,(20) report that "46 percent of the most dangerous jobs [at Hanford] are performed by people who have professional or technical qualifications." They conclude that "the high ratio of professional to manual workers is clearly a reason for the industry having fewer observed than expected deaths." Thus, the healthiest people (by virtue of their professional status) are being sent into some of the most dangerous jobs at Hanford.

Even DOE researchers acknowledge among themselves that the SMR approach has it limitations. For example, an unpublished report(21) of the Los Alamos National Laboratory states that comparing DOE worker death rates with those of the general public is "a relatively insensitive technique."

Surprisingly, in the same paper, the authors suggest that a statistical method first introduced by Mancuso, Stewart and Kneale in 1979 is a more sensitive indicator of radiation-induced cancers among DOE workers.(22) They falsely attribute this method to Ethyl Gilbert, a statistician at BNL, who first advocated it at a 1981 conference.(23)

The MSK method was developed from a method by Cox(24) for testing the beneficial effects of drugs during clinical trials. It is applied to Hanford data by following all live and dead workers in time on a step by step life-table basis while simultaneously controlling for several factors that might be competing with radiation as the cause of cancer.

There are three crucial factors in studying DOE radiation workers that underscore the importance of the MSK method. First, the average recorded dose to most workers in the DOE nuclear program is relatively low. Second, in all nuclear facilities, the ratio of professional to manual workers is higher than the average in other industries, and at Hanford the ratio is even higher for men in dangerous than safe working environments. Finally, the proportion of cancers linked to radiation by MSK is relatively small (5 to 7 percent).

Thus, even if radiation cancer risks at Hanford have been underestimated by ten times, cancer effects among DOE workers could easily be too small to be recognized in any analysis of deaths which is geared to crude comparisons with the general population. This also applies to subcohort "nested" case/control studies where the lack of statistical power is also a major shortcoming. By using the Cox method, MSK have discovered that workers over 40 years of age are more sensitive to radiation induced cancer. They also estimate that the average dose required to double the normal risk of dying from all radiation-induced cancer is 15 rads, and that the dose response is superlinear.(25)

Instead of comparing a small number of deaths (derived by comparing DOE worker deaths with general U.S. rates), with an equally small number of controls, the MSK method analyses the entire Hanford work force by following all live and

dead workers forward in time with control of all job-related mortality risks other than radiation.

Another important issue is how DOE researches handle workers who can't be traced for study. They assume that hundreds of workers who are lost to the follow-up are alive and well. According to Eisenberg, "if any real effects do exist, this primitive assumption will dilute and mask them."(26) Findings ways to deal with untraceable workers is a major concern for epidemiologists and has been studied extensively. But DOE researchers dismiss it's importance and claim that such an adjustment will not be "significant in changing basic conclusions."(27) This guarantee of negative research results reflects poorly on investigator objectivity, particularly since no efforts are being made to empirically substantiate this claim. Moreover, according to Eisenberg, "better knowledge of deaths among...untracable individuals must unequivocally lead to a increase in the 'observed' figure and a decrease in the 'expected' figure."(28)

Far more important however is the fact that there <u>are</u> major differences in the data used by MSK and their critics. For example most of the critiques of the MSK study are based on fewer deaths than subsequently reported by MSK. The first MSK report was based on 400 cancer deaths between 1943 and 1972. Subsequent MSK papers are based on 1033 cancer deaths spanning 1943-79.(29) Most critics, however, have persisted in publishing attacks of the MSK analyses on 400 cancer deaths.(30) DOE sponsored scientists consistently fail to cite the more recent MSK papers. The smaller data base used by several MSK critics explains why they have found fewer excess cancer cases than MSK.

An even more serious problem in the evaluation of Hanford data by MSK critics is expressed in a 1979 report to the Nuclear Regulatory Commission (NRC). The report found major deficiences in a version to the Hanford data used by several MSK critics. An official study done for the NRC by Kinetic Research Inc.(31) reported that the Hanford data provided by the DOE to several critics "would have provided a serious problem in the interpretation of any analyses conducted." The most prominent analysis of this data was published by Hutchinson, McMahon, Land and Jablon in the August 1979 Journal of Health Physics.(32) Their analysis was has been widely distributed. According to the NRC report, Dr. Charles Land of the National Cancer Institute, "had originally requested data from the Oak Ridge Processing Facility. Oak Ridge had some version of the data collected in the Mancuso study for the Hanford employees." The authors of the NRC report noted that a similar set of data was provided to the NRC for review in 1978. "As a consequence of the numerous data handling efforts," the Kinetic report states, "it is extremely difficult to determine precisely what the available data represents." The Kinetic Research group then asked the DOE for clarification but "our request for additional data was not implemented."

As an alternative, the NRC contractors compared data being used by Dr. Mancuso and by Dr. Land. Most importantly, Kinetic's comparison indicated that "the data we have received [from Land] has doses and time intervals which are not possible in the data collection scheme preported to have been followed in the Hanford study."

In a strongly worded conclusion, this NRC report states," unfortunately, examination of the data and investigation of the background material... has led to the conclusion that the data provided is not a consistent, reliable and authentic representation of the true facts concerning the mortality and exposure experience of Hanford workers. In particular, the data does not represent the reported state of the data maintained at its most reliable source."(33)

The implications of the Kinetic Research Inc. report are clear: While efforts were made to confiscate Mancuso's data, the DOE provided a different set of data to several DOE funded critics which was of dubious quality. Nonetheless, analyses based on this flawed data were published as criticisms of Mancuso et al. The same analyses were cited by the national academy of sciences BEIR III committee to dismiss the MSK study.(34) Moreover, the NRC report raises equally serious questions about the quality of the data currently being generated by the DOE contractors on other populations. (see appendix B)

At the heart of DOE's conflict-of-interest is their policy on data utilization. Investigators responsible for studying DOE occupational cohorts are not allowed direct access to the source data and therefore have no means to verify its completeness and accuracy. By not having direct access, these investigators are not in the position to prevent destruction of records which may prove valuable for research. Companies which operate DOE nuclear facilities have the primary responsibility for developing and properly preparing DOE worker data. All of this research data is put at the discretion of Oak Ridge Associated Universities -- a government-owned-contractor- operated facility which predominantly employs former DOE management and research personnel.

Under this system, the DOE and its contractors who bear liability for claims of latent radiation injuries are responsible for screening and processing data which may affect the outcome of such claims -- now in the billions of dollars.

DOE defends its data utilization policy as a way to comply with the Privacy Act. However, public health agencies like the National Institutes for Occupational Safety and Health (NIOSH) have no such restrictions on its investigators who perform health hazard evaluations and industry-wide studies. DOE's selective interpretation of the Privacy Act allows researchers who have close ties with the DOE access to the original data while holding more independent researchers at arms length. Without independent checks, this data utilization system is open for abuse.

DOE's deliberate preemptive exclusion of independent researchers by use of the Privacy Act excuse bears further examination. Their data utilization policy cannot be evaluated without factoring in a major reason for DOE's existence. That is the design, production and testing of nuclear weapons. Nuclear weapons officials have for decades argued effectively against the involvement of independent public health agencies in assessing and regulating DOE nuclear activities. A 1981 report of the Los Alamos National Laboratory suggests that such a change could bring about "an effective curtailment" of nuclear weapons production.(35)

Studies that suggest the design basis for DOE nuclear facilities (several of which are over 30 years old) pose significant occupational cancer risks is in

direct conflict with DOE's mission to develop nuclear weapons as inexpensively and quickly as possible.

The Hanford survey of MSK is the first major occupational study which has raised the possibility that DOE's nuclear facilities may require extensive overhauling. By establishing a correlation between increased cancer risks and radiation exposures well below the current limit of five rem per year [external penetrating radiation], the health and economic implications of the MSK findings are far reaching. This fact was underscored recently, by Dr. William Loewe, a radiation physicist at DOE's Lawrence Livermore National Laboratory who wrote that if exposure limits are significantly reduced, "there are tens of billions of dollars to be spent in the commerical and defense nuclear industries..."(36)

The current occupational exposure limit of five rems per year is based on extrapolations from high dose human studies -- principally the Life Span Study of the Japanese atomic bomb survivors. In recent years, several major questions have been raised about this study. (see appendix C)

When taking several factors into account the cancer risks among the A-bomb survivors may be too low. They include:

- o radiation doses to the survivors are now found to be 2 to 3 times greater than previously thought;(37)
- o cancer incidence data on the survivors suggest that cancer mortality risks may underestimating risks by a factor of 2;(38)
- o adoption of the more conservative relative risk model increases the A-bomb survivors risk by a factor of 2;(39)
- o a new wave on long latency cancers has also increased risk factors.(40)

Perhaps the most fundamental question being raised is: Can the Japanese A-bomb Survivor Study be used to extrapolate radiation cancer risks at low-doses? The long-term effects of tissue destructive high doses such as those received by the A-bomb survivors may be quite different than those which cause damage to single cells. Unlike the survivors, the Hanford workers did not receive these serious high doses and were individually monitored for radiation exposure. There is also an absence of excess leukemias at Hanford, a pronounced effect among A-bomb survivors. This may indicate that leukemia is more closely related to higher doses.

What the two groups have in common, however, is a dose-related excess of the long-latency multiple myeloma or bone marrow cancer. Althought it was not believe to be radiation related in the mid-1970's, multiple myeloma has become the most prevalent long-latency cancer among the A-bomb survivors.(41)

The DOE recognizes the possibility that low dose effects may differ from high dose effects in their 1984 Epidemiologic Project Summary of the DOE occupational cohort studies conducted by ORAU/UNC. The summary states, "radiobiological and epidemiological evidence suggest these risks differ from those associated with simple or fractionated high does on which current estimates are based."(42)

It is clear that, if the Hanford findings of MSK can be replicated in a similarly large and old worker population using the same methods, the days of the Japanese A-bomb survivor study serving as the main reference for low-level radiation risks are numbered.

LEUKEMIA MORTALITY AT OAK RIDGE NATIONAL LABORATORY

Last year, the Review,(43) an official publication of the Oak Ridge National Laboratory (ORNL) editorialized: "our operations do not threaten the health of people; in fact epidemiological studies indicate that ORNL employees have lower death rates from many diseases, including most cancers, than does the U.S. population as a whole. In addition statistics show that one of the safest places one can be is not at home or on trips but working at ORNL." This latter claim that ORNL is a "health farm" is not borne out by the research.

In September 1984 draft paper,(44) researchers from ORAU and UNC reported that maintenance and engineering workers at ORNL are experiencing greater than expected risks of dying from leukemia. These risks were shown to be associated with duration of employment and to have a gradient with dose of external penetrating radiation. The study was conducted among 8,375 white male ORNL workers who died between 1943 and 1977. Deaths of ORNL workers were compared with general population rates. Although, the authors note that ORNL workers as a whole show a "non-statistically significant" leukemia risk (49% increased risk) they concede that "these results are indicative of the healthy worker effect and the favorable influence on health" due to the "high socioeconomic status" of ORNL workers.

In addition to an SMR analyses, the authors used a more sensitive method that adjusts for the "healthy worker effect" by "internal comparisons of mortality (Standardized Risk Ratios)". When this method of comparing ORNL workers against each other is used, the risk of dying from leukemia increased with dose up to five rads (radiation absorbed dose). None of the leukemia cases had exposures over 5 rads. However, the risk at five rads is 276 percent greater than expected. (see table 1)

ORNL workers in maintenence jobs who worked less than 10 years show an increased risk of leukemia of 91 percent. If they worked longer than 10 years, the risk is 212 percent greater. Engineering jobs showed a similar increased risk of 148 percent and 140 percent respectively. (see table 2)

The authors find that "results from the analyses ... according to work experience in the various jobs categories indicate possible associations of leukemia risk with long duration employment in engineering and maintenence jobs" They indicate that further investigation of the leukemia cases will focus on "specific chemicals exposures encountered by workers in these jobs." And that additional follow-up ORNL workers "should provide useful information concerning the dose-effect relationships of radiation with specific causes of death."

Dr. Goldsmith, has downgraded the importance of the leukemia risks at ORNL by stating, "sixteen cases of leukemia were found among white males who worked [at ORNL] between 1943 and 1972, whereas nine were expected, based on U.S. rates. Four of the sixteen were chronic lymphocytic leukemia, a type not

associated with exposure to radiation. Statistically, twelve cases are not significantly different than nine."(45)

On the surface this declaration seems reasonable. However, it is misleading to change the observed number of cases without making commensurate changes in the expected number of the specific disease type. Dr. Goldsmith implies that 12 of the leukemia deaths are the type associated with radiation (i.e. myeloid), but the expected number of cases for for myeloid leukemia is 6.2 not 9.(46) Based on age-adjusted rates, this represents a nearly twofold excess of leukemia deaths which is statistically significant (p. .05)(47) It also represents an increased leukemia risk of 96 percent (SMR 1.96).

Regardless, of uncertainties about the role of radiation and hazardous chemicals, the risk of dying of leukemia for certain workers at ORNL has been found by DOE contractors to be significant. To claim that it is safer to work at ORNL than staying at home is an irresponsible distortion of research.

CANCER RISKS AT ROCKY FLATS

On October 19, 1982, Rockwell International,(which operates the DOE's Rocky Flats nuclear weapons facility near Denver, Colorado) issued a press release heralding the findings of a DOE study indicating that "Rocky Flats has a healthy workforce." The study, done by George Voelz et al.(48) of Los Alamos National Laboratory (LANL) was based on an analysis of deaths between 1952 and 1979 among of 7,112 white males who worked at Rocky Flats. After comparing Rocky

Flats deaths with general U.S. rates. "the plant population is 50 to 75 percent better than the national average," the Rockwell release proclaimed. The Voelz study was subsequently reported in newspapers around the country.

A year later Rockwell International repeated this claim in a final draft of the "Rocky Flats Long-Range Utilization Study" mandated by congress.(49) There was "no evidence of increased cancer mortality" among Rocky Flats workers, Rockwell concluded, when in fact, Voelz et al. found a significantly increased brain tumor risk.

An eightfold increase in brain tumors at Rocky Flats was first reported by Dr. Carl J. Johnson in 1980.(50) In a later paper based on cancer incidence data provided by Rockwell International, Johnson reported an increased incidence of melanoma (6 cases vs. 2.17 expected), brain tumors (13 cases vs. 1.6 expected) and lung cancer (29 cases vs. 23 expected). The melanoma and brain tumor risks were statistically significant.(51)

A "Blue Ribbon Committee" reviewing the utilization study asked Dr. Alice Stewart of the University of Birmingham, England to review the Voelz paper. Dr. Stewart is a world renowned authority on radiation health effects and was the first to identify pregnancy x-rays as a cause of childhood cancer. She is also, (as mentioned earlier) associated with the analysis of the Hanford data assembled by Dr. Mancuso. According to Dr. Stewart:

> "Voelz and his associates are careful to explain that their study had a limited objective. This is no excuse to set a limited and outdated objective: to make a series of elementary mistakes and attempt to conceal new and

> important evidence relating to brain tumors. There has however, been uncritical acceptance by Rockwell International in circumstances which leave the uncomfortable feeling that the DOE is encouraging its scientists to make light of an important public health issue and making it all but impossible for outsiders to realize that a unique opportunity to study the effects of repeated exposures to plutonium is being thwarted."(52) (emphasis added)

An additional review was done by Ms. Diane Eisenberg of the University of Wisconsin Medical School. Ms. Eisenberg concurred with Stewart in even stronger terms by stating:

> "The Voelz study employs a crude research approach lacking coherence and validity. That one cause of death (brain tumors) exhibits significant elevation under such blunt analytical tools is surprising. The present study provides no evidence for lack of cancer risks in the industry. A state-of-the-art analysis employing valid techniques of occupational cancer epidemiology is needed to determine whether the population is experiencing elevated cancer risks associated with exposures."(53)

Specifically, the stated purpose of Voelz et al was to discover whether 7,112 men from Rocky Flats were experiencing more deaths (1952-79) than expected from general U.S. rates using a Standardized Mortality Ratio (SMR). In performing this type of analysis Voelz et al: (1) failed to correct for the "healthy worker effect" when it was known to exist among DOE workers; (2) assumed that 627 workers lost to the follow-up were alive and healthy; and (3) eliminated 8 out of 16 cases of brain tumors because they were doubtfully malignant without making necessary adjustments in the expected figures. (A similar ploy used by Goldsmith).

In her critique, Stewart notes that "if correct procedures had been followed the paper would have shown a significant difference between expected and observed numbers of neoplasms (25 percent excess) which was largely the result of brain tumors (281 percent excess) and leukemia or lymphoma (83 percent excess)."(54)(see table 3)

After the release of the Stewart and Eisenberg critiques, Colorado Governor Richard Lamm convened a panel of experts to examine the Voelz study. In their final report of March 21, 1984,(55) the panel found "in the judgement of the committee [the Voelz paper] is flawed in terms of methodology, but that is typical of preliminary surveys of occupational mortality. Specifically the committee found weaknesses in regard to statistical evaluation death certificate data analysis and insufficient data on those persons listed in the 'lost-to-followup' category." The committee also reviewed three subsequent papers by LANL and took issue with their contention that the brain tumor excess is due to factors other than radiation. "An unanticipated association is certainly less convincing of causality than a hypothesized one but should not be casually dismissed. The lack of statistical significance does not change the fact that [LANL] observed an association between external radiation and brain tumor risk. This is not in an of itself proof of a causal association but would be consistent with such a relationship." (56) The Committee also found that the Voelz study was "introduced by Rockwell in a way which, without explanation of the special situation which occasioned it,

suggested that working at Rocky Flats was a particularly healthly activity." They cited the "failure in the Rockwell press releases to explain the healthy worker effect" as it influenced the outcome of the study.(57)

The committee finally concluded that "the National Institute of Occupational Safety and Health is the appropriate agency to conduct this type of overreaching study. Such research would be in accord with the legislative mandate of NIOSH."(58)

CANCER INCIDENCE AT LAWRENCE LIVERMORE NATIONAL LABORATORY

In 1977, a preliminary survey of cancer incidence performed by the California Department of Health Services reported that employees at DOE's Lawrence Livermore National Laboratory (LLNL) were experiencing a 3 to 4 fold excess of malignant melanomas (skin cancer).(59) The study found that the excess was limited to LLNL employees and did not extent to the surrounding communities. A follow-up study concluded in April 1980 reaffirmed the 1977 findings.(60)

The study has been funded by the DOE through LLNL. However, in 1982, as the California health department was embarking on a more detailed case/control study, DOE's funds were cut in half forcing the state to seek additional funds from private foundations. At the same time, the effort to disprove the melanoma findings at LLNL was given ample funding through the laboratory's overhead budget.

In July of 1984, Dr. Donald Austin and Peggy Reynolds of the Health Department's Cancer Epidemiology Section in a third report stated:

> "1. The previously reported excess of malignant melanoma is real.
> 2. Constitutional risk factors for MM predict risk of LLNL employees to the same degree as in the general population.
> 3. Malignant melanoma disease characteristics among the LLNL cases are similar to those of malignant melanoma cases in the general population.
> 4. A variety of occupational risk factors are causually associated with malignant melanoma among LLNL employees. Five of these factors can substantially account for the observed excess."(61)

Of the five occupational factors, radiation exposure applied to about two-thirds of the cases of MM, and would be expected to produce an excess risk of MM of about 88 percent.

"This factor is causually related to the MM excess," Austin and Reynolds concluded. Other occupational factors included working at a non-nuclear weapons testing site near the LLNL (33 percent of the cases), which would be expected to produce an excess risk of about 45 percent. Exposure to volatile chemicals (35 percent of the cases), duty at the Pacific Test Site (13 percent of the cases), and chemist duties (13 percent of the cases) also predicted increased risks between 13 percent and 34 percent.(62)

In February 1985, a paper in the Western Journal of Medicine by Reynolds and Austin(63) indicated that LLNL workers bear higher risks of contracting not only malignant melanoma but also cancers of a salivary gland, rectum, and nervous system. This study population consisted of all active LLNL workers between the ages of 20 and 69 years of age who resided in the San Francisco-Oakland area. Excess salivary gland cancer risks were shared by male and female LLNL employees

as was malignant melanoma. Excess cancers of the rectum were found only in women, while excess nervous system cancers were found only in men.

Reynolds and Austin conclude that the "overall cancer experience of active LLNL employees does not appear to differ greatly from the general population in the San Francisco-Oakland Bay area. A small number of sites would be expected to appear to be in excess or deficit in this cohort by chance alone. This is likely to be an explanation of the observed cases for rectal cancer in women and cancers of the nervous system in men."

They also state, "The excess indidence for malignant melanoma of the skin is also not likely to be due to chance..."

LUNG CANCER AND LEUKEMIA INCIDENCE AT THE SAVANNAH RIVER PLANT

The DOE "fact sheets" do not mention the 1976 findings by the E.I.DuPont de Nemours and Co. of excess leukemia lung cancer incidence of employees at DOE's Savannah River Plant (SRP).(64) Based on cancer incidence data spanning 1956-74, the DuPont study found that "among male employees, 32 cases of cancer of the lung occurred compared with 32 expected from company rates. However, 18 of these occurred in salary employees where only 11.1 were expected, an excess which is statistically significant." Additionally, "eleven cases of leukemia occurred among male employees." Nine cases were found among wage employees where 4.2 were

expected.(65) Wage and salaried male workers at SRP showed a combined risk of contracting leukemia that was 69 percent greater than expected for non-nuclear DuPont employees. For SRP wage workers the risk was 114 percent greater while salaried workers showed no elevated risk.

On August 20, 1976 SRP manager N. Stetson forwarded a copy of the Dupont study to Dr. Clarence Lushbaugh,(66) Medical Director of Oak Ridge Associated Universities (ORAU) who then asked statistician Edythalena Tompkins to review the findings. On August 26th, Tompkins drafted a report which dismissed the lung cancer findings as an "artifact" but stated that "the apparent risk for leukemia among male wage employees appears real." She urged that "the arguments against this risk being occupationally related need to be expanded."(67) For the next eight years, this information was suppressed while the DOE placed the SRP worker study on the "back burner."

In the fall of 1983, the 1976 Dupont study came to light at a meeting of consultants of the DOE concerning epidemiological studies relative to SRP. I was a member of that committee. Those present included Dr. Goldsmith and researchers from ORAU. At the meeting, a Dupont statistician presented a reanalysis of the 1976 study which showed no increased risk of leukemia. However, Dupont and DOE failed to produce the original study. (the Tompkins analysis was unknown to the committee, at the time.)

It was discovered by the Committee members during the Dupont presentation, that the excess leukemia findings were erased by changing the statistical test for significance without proper justification. Moreover, Dupont

officials refused to reveal who authored this reanalyses. In the report filed to the DOE by the Committee members it was the unanimous view that DuPont's switch in significance testing was "inappropriate" and that a non DuPont/DOE party should analyze these data.(68)

CANCER MORTALITY AT THE OAK RIDGE Y-12 WEAPONS PLANT

In the DOE "Fact Sheets", Dr. Goldsmith states that the findings of excess cancer mortality among Oak Ridge Y-12 workers are not "statistically significant."(69) He cites a 1980 analysis based on 4, 988 while male workers published in an "in-house" proceedings of ORAU in 1980.(70)

Goldsmith failed to mention more recent Y-12 findings contained in an "in-house" proceedings of DOE epidemiological contractors held in Rockville, MD on April 13, and 14, 1982.(71)

Here a different set of conclusions were reached about the cancer risks of Y-12 workers. Based on a study of 6400 (instead of 4,988) workers, Dr. Lushbaugh notes that "significant standardized mortality ratios (SMR) were observed for brain cancer individuals employed 5 to 10 years (SMR 5.89, deaths =6) and leukemia and aleukemia in individuals less than 40 years old (SMR =10.37, deaths=2). The SMR was close to significance for brain cancer in 40 to 65 year olds (SMR = 2.17,deaths = 8)."(72) Thus a statistically significant risk of brain tumors for workers employed 5 to 10 years at Y-12 was 489 percent greater than expected. Leukemia and aleukemia risks were over 900 percent greater than expected.

DEATH RATES AT THE TENNESSEE EASTMAN Y-12 FACILITY

Between 1943 and 1947, the Tennessee Eastman Corporation (TEC) operated the Oak Ridge Y-12 electromagnetic uranium separation facility for the U.S. government. The TEC Y-12 plant produced the first highly enriched uranium that was used in the atomic bomb dropped on Hiroshima, Japan in 1945. Exposure to high levels of uranium dust was common at the facility. Tennessee Eastman employed an estimated 19,000 women who as of 1982 were part of a retrospective mortality study by a ORAU/UNC. Data on the TEC Y-12 women has been assembled to include deaths up to 1977. This survey may represent the largest study of women occupationally exposed to ionizing radiation in the United States.

In 1980, the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR III) reported that women may be twice as sensitive to radiation-induced cancer of the breast and thyroid than men. Thus, the study of TEC Y-12 women may provide valuable clues about the increased radiation sensitivity of women.(73) That is, of course, if adequate radiation data has been recorded.

Unfortunately, DOE officials and contractors have not publically referred to the study of the TEC Y-12 women. Mention of it is conspicuous in its absence in the DOE "fact sheets." In April of 1982, preliminary findings on the TEC Y-12 women were presented by Dr. C.C. Lushbaugh at the DOE epidemiological contractors

workshop in Rockville, Md. Based on an internal comparison (Proportional Mortality Ratio) of deaths collected up to 1973, Lushbaugh reported " an increase in respiratory disease, particularly pneumonia, and a possible increase in lymphopietic cancer [blood forming organs], brain cancer, cancer of the uterus, cervix and skin."(74) White males exposed over the age of 45 who worked at this facility were also found by DOE to bear high risks of lung cancer from uranium exposure even after smoking was factored in.(75)

EXCESS DISEASE AT THE FERNALD, OHIO URANIUM PROCESSING PLANT

In the DOE "Fact sheets", Goldsmith does not mention the significant findings at DOE's Fernald, Ohio facility. The ORAU/UNC Project Summary is unequivocal on this matter. It states, "when comparing wage and salaried workers who were older than 36 years of age at hire, there is an elevated SMR of digestive cancers among wage workers and this elevation is statistically significant." The summary also cautions that "digestive cancers are significantly elevated for workers in the highest and lowest exposure jobs."(76)

Another study of the Fernald workers has found " an association between exposure to uranium and the development of non-malignant respiratory disease [fibrosis of the lung]."(77) Public discussion of these findings was initiated in the summer of 1984 by the union representing the Fernald workers after they received a copy of the study from a non-DOE source. At the same time, Dr.

Lushbaugh was testifying on behalf of the Areojet Corporation before the National Labor Relations Board (NLRB) against workers at another uranium processing plant seeking job reinstatement.(78) Despite being a supervisor of the Fernald study which found a correlation between fibrosis of the lung and exposure to uranium dust, Lushbaugh told the NLRB, under oath "our studies up to date have not borne out those effects. In other words, succinctly, working in uranium dust atmospheres have not caused pulmonary pneumonoconiasis or some kind of fibrotic lung disease of emphasema, et cetera." [emphasis added](79) Dr. Lushbaugh was chosen to take over from Dr. Mancuso after directing a study for the National Aeronautics and Space Administration (NASA) of radiation exposures to cancer patients. In 1975, Lushbaugh reported to NASA that this "prospective study" of radiation damage to cancer victims was "sorely needed to defend existing environmental and occupational exposure constraints from attack by well meaning but impractical theorists."(80)

THE OAK RIDGE WELDERS STUDY

Absent in "fact sheets" is the Oak Ridge welder study. As of 1982, this study is of 1302 white male welders employed at various Oak Ridge nuclear facilities between 1943 and 1977. The study was reported by Lushbaugh at the 1982 workshop in Rockville, and showed an excess that "appears to be due to emphysema with a significantly high SMR of 2.61 [161 percent increased risk]."(81) Welders are subjected to a unique risk because of exposure to metal fumes.

THE DOE 5+ REM STUDY

Again not mentioned in the "fact sheets" are the results of a DOE study of 2,529 white male workers who received a total cumulative dose of external penetrating radiation of over 5 rems. According to the 1984 ORAU/UNC Project Summary there was a "significantly elevated SMR for cancer of the rectum (6 cases observed, 2 cases expected).(82) It is not clear if these workers are being eliminated from other DOE studies. If high dose workers are not being included this will skew risk estimates. Additionally, several DOE studies have eliminated from study those workers who have been employed at more than one DOE facility.

DOE POPULATIONS NOT UNDER STUDY

Although DOE has a study of workers at different DOE facilities who have recorded cumulative doses over 5 rems, not all workers at facilities where radiation exposure may have been high are being studied. In particular, studies of all workers at the Nevada Test Site and Idaho National Engineering Laboratory are conspicuous in their absence. The Nevada Test Site workers, participated in the detonation of atmosphere and underground nuclear explosions. They were sent in to high radiation zones retrieve instruments shortly after the detonations. They also handled radioactive scrap, and bore risks of being in high radiation fallout fields.

The NTS workers are an important population to study because they received the same kinds of exposures as the military personnel who participated in

atmospheric weapons tests. Millions of dollars are being spent to assemble and analyze incomplete data on the military participants in nuclear tests. Yet, the data on the NTS workers in the possession of Reynolds Electric Company is far more complete and extensive and can be studied at considerably less cost. Perhaps DOE's reluctance to study the NTS work force, stems from concern over liability from claims filed by families of deceased NTS workers.

The same can be said about workers at INEL. This facility has experienced large environmental releases of radioactivity and also a severe reactor accident where two workers died and several workers were exposed in the post-accident clean-up. Another high dose group is the J.A. Jones construction workers at Hanford. Although Dr. Mancuso repeatedly tried to include this population into his study, DOE refused to cooperate. Recently, DOE has agreed to assemble and analyze data on the J.A. Jones construction group upon the urging of the Washington state health department. Construction workers have been used extensively in clean-up jobs after major accidents at DOE sites. For example, in early 1971 at the Savannah River Plant, about 850 construction people were involved in the manual clean-up of the K reactor process room after a reactor source-rod melted over the reactor top. The source-rod released about 80,000 curies of radioactivity, severely contaminating the area.

SUMMARY AND CONCLUSIONS

The DOE worker studies are important because they represent the future basis for low-level radiation risks and standards. According to DOE "this project provides an opportunity to evaluate scientifically the risks to human health, particularly the cancer risks of protracted exposure to low doses of ionizing radiation...It also is a basis for evaluating the efficacy of current radiation protection standards."(82)

Unfortunately, federal nuclear agencies downplay the importance of the DOE worker studies and are considering an increase in occupational radiation exposures.(83)

In a candid but disturbing comment on the priorities of the federal nuclear program, Dr. William Loewe of DOE's Livermore National Laboratory stated recently, "there are tens of billions of dollars to be spent in the commercial and nuclear defense industries if protection standards were to be changed."(84) Lowe succinctly characterizes the kind of pressure that compromises objective research funded and supervised by the Energy Department.

As this report documents, DOE's control over radiation epidemiological studies, reflects an inherent bias which has taken the forms of misleading statistics and crude analytical methods then used to support spurious claims about the lack of health risks at DOE nuclear installations. Commensurate with these distortions, the DOE and its contractors have suppressed studies which are

unfavorable to official views and have selectively eliminated high-risk groups from study.

DOE officials have publically attacked independent scientists, while internally acknowledging that the methods used by these same scientists are superior.

At the heart of DOE's conflict of interest is their data utilization policy. Under DOE's system, the DOE and its contractors who bear liability for claims of latent radiation injury are solely responsible for screening and processing data which may affect the outcome of such claims - now in the billions of dollars. Researchers responsible for analyzing the DOE worker data are denied direct access to the source data and have no means of verifying the data's accuracy or completeness. They also are not in the position to prevent the destruction of records which prove useful for their research. Although DOE claims that they are merely complying with the Privacy Act, such restrictions on data access are not applied by the National Instiitute of Occupational Safety and Health. Without independent verification of the DOE's worker data, this system is open for abuse.

Unfortunately, there is evidence that DOE has abused its data utilization system. In 1979 a contractor of the nuclear regulatory commision reported that DOE circulated a version of the Hanford data which was not only significantly different from that of Mancuso's, but was so flawed that it could not be used for valid analysis. Yet, several critics of Mancuso et al. used this data.

Removal of the DOE from the funding and supervision of epidemiological research is necessary for the development of objective radiation protection policies. It will also perform a service for both sides of the radiation health effects debate.

Finally, the fact that Mancuso et al. have succeeded in publishing several analyses in respected archival journals,(despite formidable efforts by Government nuclear agencies to discredit them) is evidence of growing acceptance of their study. It shows that Mancuso Stewart and Kneale continue to pass the test of independent peer reviews, which in and of itself is sufficient grounds for resumed federal funding of this crucial independent research.

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TABLE 1. Standardized rate ratios (SRRs) for selected causes of death according to radiation dose category for 0 and 10 year latency intervals

Cause of death/ latency (yrs)	Dose Category (rems)							
	0*		0.00-0.999		1.00-4.999		≥5	
	(Obs)	SRR	(Obs)	SRR	(Obs)	SRR	(Obs)	SRR
All Causes								
0-yrs	(221)	1.00	(380)	0.89	(243)	1.00	(60)	0.68
10 yrs	(193)	1.00	(351)	0.94	(164)	0.84	(46)	0.70
All Cancers								
0-yrs	(37)	1.00	(78)	1.07	(55)	1.28	(13)	0.84
10-yrs	(34)	1.00	(73)	1.06	(36)	0.97	(11)	0.90
Leukemia								
0-yrs	(2)	1.00	(4)	0.96	(9)	3.76	(0)	0
10-yrs	(2)	1.00	(6)	1.38	(6)	2.70	(0)	0
Prostate Cancer								
0-yrs	(4)	1.00	(5)	0.57	(5)	1.04	(0)	0
10-yrs	(4)	1.00	(6)	0.65	(4)	0.94	(0)	0

* Reference Category

Source: Checkoway, H. Et al., "Radiation, work experience and cause-specific mortality among workers at an energy research laboratory," University of North Carolina and Oak Ridge Associated Universities, p. 24.

TABLE 2. Standardized Rate Ratios (SRRs) for Leukemia (ICD 204-207) mortality according to length of employment in various job categories

	Length of Employment (yrs)					
	1*		1-9		10+	
Job Category	Obs	SRR	Obs	SRR	Obs	SRR
1. Radioisotopes and radiation machinery	16	1.00	0	0	0	0
2. Chemical Operations	16	1.00	0	0	0	0
3. Monitoring	16	1.00	0	0	0	0
4. Biology	16	1.00	0	0	0	0
5. Chemistry	14	1.00	1	0.79	1	0.66
6. Physics	15	1.00	1	1.08	0	0
7. Engineering	12	1.00	2	2.48	2	2.40
8. Administration	14	1.00	2	2.29	0	0
9. Maintenence	9	1.00	4	1.91	3	3.12
10. Shipping & Recieving	16	1.00	0	0	0	0
11. Other	13	1.00	3	2.31	0	0
12. Unknown	15	1.00	1	1.26	0	0

* reference category includes persons who never worked in a particular job category

Source: Checkoway, H. et al. " Radiation work experience abd cause-specific mortality among workers at an energy research laboratory," University of North Carolina and Oak Ridge Associated Universities, P. 27.

TABLE 3

OBSERVED AND EXPECTED DEATHS OF 7,112 ROCKY FLATS WORKERS (1953-79)

	Observed No.	Expected No.	SMR (O/E x 100)
(1) As presented by Voelz et al [1]			
All Deaths	452	831.53	54
Malignant Neoplasms	107	167.07	64
Digestive Organs	28	42.61	66
Respiratory Organs	35	60.55	58
Brain & Spinal Cord	8	6.50	123
Bone	—	0.89	—
Thyroid	1	0.34	292
Leukemia and Lymphoma	13	18.20	71
Benign and Unspecified Neoplasms [2]	8	2.41	332*
(2) Alternative Presentation of the Same Data [3]			
All Deaths	452	452.0	100
Fatal Neoplasms	115	92.0	125*
Other Causes of Death	337	360.0	94
Cancer of - Digestive Organs	28	23.1	121
Cancer of - Respiratory Organs	35	32.9	106
Cancer of - Brain & Spinal Cord	16	4.2	381
Cancer of - Other Solid Tumors	23	21.4	105
Leukemia & Lymphoma	13	9.9	183

(1) Assuming strict comparability between ascertained deaths of Rocky Flats workers and national vital statistics

(2) According to Voelz et al, all brain tumors were fatal

(3) With 672 men lost to follow-up it is only safe to assume comparability between ascertained deaths from specific causes.

* significant at the 1 percent level

SOURCE: Stewart, A.M., "An Update of Epidemiologic Studies of Plutonium Workers by Voelz et al.," January 1983, p. 3

APPENDIX A

THIS WEEK

High cancer rates found in nuclear plants

Catherine Caufield

CANCER rates are higher than average in four nuclear facilities run by the US Department of Energy (DOE) according to unpublished documents. The documents, shown to *New Scientist*, give credence to the controversial contention that the risk of cancer from low-level radiation is many times greater than officially admitted in the US and Britain. They will fuel demands in the US that all research into the health effects of radiation be moved from the DOE to the Department of Health and Human Services.

The new evidence is contained in internal "project summaries" covering most of the projects in the DOE's Health and Mortality Study. The "major research result" cited is that "excess mortality due to site/type specific cancers (leukaemia, lung, brain, digestive tract, prostate, Hodgkin's disease) and excess nonmalignant respiratory disease morbidity were found among workers exposed to uranium dusts and/or radiations from other internal and external sources".

The document continues: "This project provides an opportunity to evaluate scientifically the risks to human health, particularly the cancer risks, of protracted exposure to low doses of ionising radiation. Radiobiological and epidemiological evidence suggests these risks may differ from those associated with simple or fractioned high doses on which current risk estimates are based."

The summaries cover all 21 investigations of DOE nuclear facilities being carried out by Oak Ridge Associated Universities (a think tank connected to the DOE's Oak Ridge National Laboratory) and the University of South Carolina. Another seven studies are being conducted by Los Alamos National Laboratory and Battelle Northwest Laboratory, both DOE facilities. Excess cancers among nuclear workers have been found in three-quarters of the 12 studies that have so far yielded major research results. All four DOE plants examined have excess cancers. The results are that:

- Workers at the Oak Ridge National Laboratory have a 49-per-cent excess leukaemia mortality compared to the general public. "Leukaemia mortality did demonstrate a gradient with increasing radiation dose."
- Janitors, labourers, maintenance men and construction workers at the laboratory have a "significant excess risk" of radiation-associated cancers.
- Workers at Oak Ridge's Y-12 Tennessee Eastman uranium-processing plant between 1943 and 1947 had "significant excess of deaths from lung cancer when compared to US white male rates".
- Workers at Oak Ridge's Y-12 Union Carbide weapons plant had "excess death for cancer of lung, brain and central nervous system, Hodgkin's disease, and other lymphatic tissue".
- Workers at Oak Ridge's gaseous diffusion plant exhibit "excess deaths due to lung and brain cancers and respiratory disease".
- Workers at the DOE's Fernald, Ohio, uranium-processing plant, have a 36-per-cent excess of digestive cancers. Also, "there is an association between exposure to uranium and the development of non-malignant respiratory disease events".
- A study of 2529 workers at various DOE facilities who were reported to have received more than five rems of radiation in a year found six cases of cancer of the rectum, when only two were expected.

In addition, a 1976 study of employees at the DOE's Savannah River Plant (operated by DuPont) found a 60-per-cent excess of lung cancers in male white-collar workers, and a 114-per-cent excess of leukaemia among male blue-collar workers, as compared to DuPont's workforce as a whole.

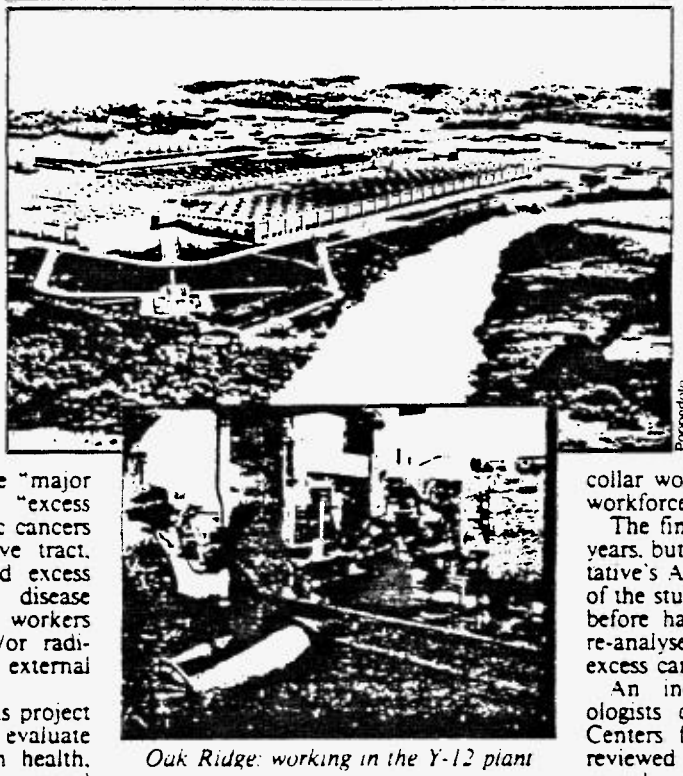
The findings were kept secret for seven years, but last year the House of Representative's Armed Services Committee learnt of the study and asked to see it. The week before handing it over, DuPont officials re-analysed the data in such a way that the excess cancers disappeared.

An independent panel of epidemiologists convened by the government's Centers for Disease Control in Atlanta reviewed the DuPont study and unanimously condemned the "switch of statistical analysis . . . as inappropriate". The group also recommended that the data be re-analysed by scientists unconnected to the DOE or DuPont.

The DOE denies that there is any evidence linking the excess cancers found in the Health and Mortality Study to radiation exposure. Dr Robert Goldsmith, the department's chief epidemiologist, said this week: "None of the excesses show a correlation with external, low-level radiation exposure." This conflicts with the statement in the unpublished project summary that the evidence of the studies suggests that current risk estimates may be too low, and with the finding that leukaemia mortality at Oak Ridge National Laboratory is explicitly linked to radiation exposure.

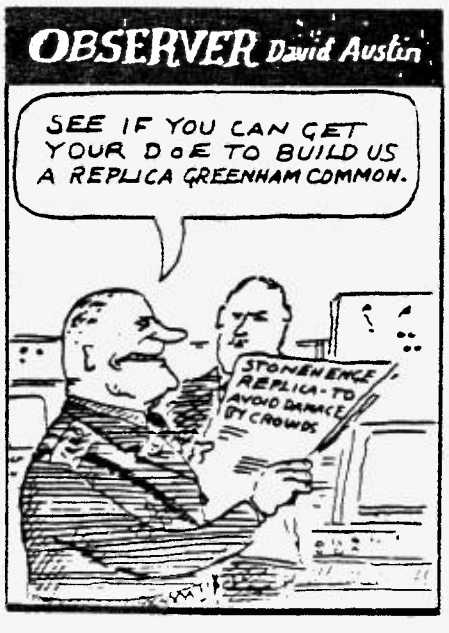
The DOE's study of workers' health began in 1964, when Dr Thomas Mancuso of the University of Pittsburgh was given a contract to examine workers at the Hanford nuclear facility in Washington state. In 1977 Mancuso and his colleagues published their findings. The risk of radiation-induced cancer, they reported, might be from 10 to 30 times greater than current exposure limits assume. But the statistical analysis that Mancuso used to reach this conclusion has been the subject of some controversy, and all subsequent DOE health studies have been conducted by the department's own scientists.

Now Congressman Tim Wirth, whose Colorado constituency includes the DOE's Rocky Flats nuclear weapons facility, ▶



Popperfoto

Oak Ridge: working in the Y-12 plant



▶ has introduced a bill to transfer power to conduct epidemiological studies of the effects of radiation to the Secretary of Health and Human services. "The DOE doesn't have the objectivity to conduct these investigations," said Steve Coffin, one of Wirth's aides.

The bill has the support of union leaders at the major nuclear facilities. In a letter to Congressional representatives they say, "while we are being reassured by DOE and its contractors that there are no major health problems in the DOE workforce, evidence to the contrary has been accumulating since 1974".

But the DOE will fight hard to keep control of the almost $60 million a year it now spends on research into the health and environmental effects of radiation. "My office is totally independent of the weapons programme," said Charles Eddington, associate director of the department's office of health and environmental research. He angrily rejects accusations of bias. "But Congress has said that we should conduct research in support of energy-development technology and the nuclear weapons programme. That is a mandate," he said.

"This is long overdue for those of us within the DOE jurisdiction," said Jerry Harden, President of the Rocky Flats Steelworkers Union. But Harden is philosophical about the bill's chances. "The DOE is very protective and normally things just don't go very well when you try to erode their territory." □

Plutonium twist

FRESH controversy over the fate of plutonium produced in British nuclear reactors was sparked this week in evidence from the Campaign for Nuclear Disarmament (CND). The evidence, which will be discussed at the Sizewell-B public inquiry this month, includes a detailed examination of exchanges of fissile material between Britain and the US under the 1958 Mutual Defence Agreement.

This evidence has been researched by Dr Ross Hesketh, the former CEGB scientist who was sacked for his public criticism of official assurances that plutonium from the British civil nuclear programme has been used to make nuclear weapons in the US.

Hesketh claimed that between six and seven tonnes of plutonium from British civil reactors have been exported to the US. He estimates that between two and three tonnes have already been put into warheads and that the remaining plutonium could well be used for weapon manufacture in the future.

His research suggests that at least six of Britain's nine magnox stations have been used to make plutonium for nuclear weapons.

As an added twist to the tangled plutonium story, CND is using an interview with one of the "fathers" of the British nuclear programme and a former CEGB chairman, Lord Hinton, now dead. He claimed that the board had misled the inquiry over the fate of British plutonium.

This point is strongly denied by the board which reiterated this week that it had always relied on government assurances about plutonium deals with the US and any possible military use. □

Cutbacks jeopardise Landsat work

Debora Mackenzie

THE LANDSAT programme, the most advanced project for studying Earth from space, is in turmoil following the continued pressure from the US government for the programme to be self-financing. If the US removes subsidies altogether (a decision has been postponed until after the presidential election in November) then the private companies could pull out altogether and the programme will flounder. And yet if privatisation of Landsat goes ahead, then non-profit making projects which are vital for many Third World countries could end.

The US government, which controls most of the Earth-observation satellites, has tried to encourage the private sector to run them since 1979, when President Carter proposed taking 10 years and $1 000 million to shift the Landsat programme to a private company. It argues that remote sensing should pay its own way, or at least that taxpayers should not provide the remote pictures of oil, gas and mineral deposits that benefit companies.

But valuable resources are only part of what Landsat sees. The rest, from marine pollution to the state of world agriculture, is what Livio Marelli of the European Space Agency last week called "the biggest advantage of remote sensing". It is this aspect of remote sensing that some observers at a conference held this week in Paris feel could fall victim to commercialisation.

The Landsat programme suffered a setback in July when the US Office of Management and Budget refused to approve a $500-million subsidy offered by the commerce secretary, Malcolm Baldridge, to the seven companies bidding to take on Landsat—lower than the $1000 million subsidy first suggested. The US congress recessed last week without having decided whether to give the programme a compromise subsidy of $250 million.

As a result of the cut, one of the two leading bidders, Kodak in partnership with Fairchild Corporation, withdrew its bid. The winner by default was Eosat, a joint venture of Hughes Aircraft and RCA. Nevertheless, Eosat said it would have to cut the programme back because of the lower subsidy. As a result, Landsat 6 will be little different from Landsat 5, which is expected to function until 1987. Landsat 6 should be launched in 1988.

The "value-added" companies, which have an $80-million-a-year business turning raw Landsat data into processed information for individual clients, can cope with a year-long gap between Landsat 6's launch and Landsat 5's demise. If it is any longer, their business is threatened. If Congress still vetoes any Landsat subsidy, then Eosat will not fly any satellites at all. This would throw thousands of scientists and technicians out of work.

Bill Kuipers of Eosat explained last week that "the only way to make remote sensing commercially viable is to increase the current market for its products, and the way to do that is with better sensors providing higher resolution in more spectral bands". However, at the same Paris conference a colleague of Kuipers, Warren Nichols, did admit that Landsat 6 will not be radically different from Landsat 5, because of the cuts in subsidies.

The US government's pressure to commercialise Landsat so that it is self-financing also poses some problems for Third World countries which use Landsat data for non-commercial projects. Lacking the funds generated by commercial ventures, these countries will find it difficult to pay the high prices demanded by private companies for satellite time.

Nichols said that Landsat 6, if it is built, will phase out the low-density data link used by Landsat 5's multi-spectral scanner and keep only the high-density band used by its thermatic mapper.

This means that the world's ground stations, few of which are now equipped to receive data from the thermatic mapper, will have to spend between $4 million and $10 million each to receive the signal. One problem is that it takes 200-300 megabytes of computer storage to process one thermatic image. The remote sensing centre at the UN's Food and Agriculture Organisation, for instance, currently has only 90 megabytes of store.

NASA

Landsat satellite: no room for Third World

Remote sensing users in the Third World could be the losers if, as intended, Spot, France's commercial bid to compete with Landsat, and Eosat start building satellites more in line with the requirements of in the developed world. Tom Ory of Daedalus Corporation, which is building Spot's sensor, sums up the changing attitude towards remote sensing: "The whole game now is to switch science-motivated general satellites to user and economy motivated specialised satellites."

Now, two-thirds of Landsat's work is sold outside the US. Much of this is bought by aid agencies which use it to monitor Third World agriculture, pollution, deforestation, urban growth—a whole range of large events which can be cheaply and effectively monitored from space.

ESA's Marelli said: "We now have a picture of the world evolving under our eyes. If this switches to a campaign to spot particular (financial) targets, we won't." □

APPENDIX B

Technical Report Documentation Page

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4. Title and Subtitle

Health Effects of Low Level Ionizing Radiation

5. Report Date: January, 1979

6. Performing Organization Code:

8. Performing Organization Report No.:

7. Author(s) David Redmond, Lawrence A. Klimko, and Keith Friedman

9. Performing Organization Name and Address
Kinetic Research, Inc.
6613 Seybold Road
Madison, WI 53719

10. Work Unit No. (TRAIS):

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U. S. Nuclear Regulatory Commission
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15. Supplementary Notes

DRAFT

16. Abstract

This paper reports the results of an analysis of a data tape provided by the Nuclear Regulatory Commission purported to contain selected information including mortality, exposure, and work history data for workers employed at the Hanford Atomic Facility who were deceased by the end of 1972.

The intent of the study was to analyze this data for dependencies of death due to cancer on exposure to ionizing radiation with proper control for other variables provided. If possible, dose response relationships were to be derived. The analysis methods used included descriptive univariate analysis, discriminant analysis, categorical analysis, and linear logistic regression.

Unfortunately, examination of the data and investigation of background material discovered during the project concerning this data and its sources, has lead to the conclusion that the data provided is not a consistent, reliable and authentic representation of the true facts concerning the mortality and exposure experience of Hanford workers. In particular, the data does not represent the reported state of the data maintained at its most reliable source. Therefore, while analysis of the data can be and is presented, one should not, and we do not, presume that the results of this analysis accurately reflect relationships which exist in the real world.

17. Key Words	18. Distribution Statement
Ionizing Radiation, Epidemiology, Health Effects of Ionizing Radiation, Occupational Health, Radiation Dosimetry, Logistic Models, Radiobiology, Hanford Atomic Facility, Cancer, Carcinogenesis	Document is available to the public through the National Technical Information Service, Springfield, Virginia, 22161.

19. Security Classif. (of this report)	20. Security Classif. (of this page)	21. No. of Pages	22. Price
Unclassified	Unclassified		

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2.1 Summary of Primary Conclusions From the Background Review

Two primary conclusions have been developed from our background review of the data. The first is that neither all of the data elements (variables) nor all the available cases have been provided to us for a thorough and complete analysis. This conclusion, in and of itself, is obviously of particular concern since the detail and accuracy with which any analyses can be conducted and subsequent interpretations developed is impeded.

The second primary conclusion is that the authenticity and reliability of the data provided to us for analysis has not been adequately established. Clearly, this conclusion presents problems in making statements about the true "state of nature" based on observations obtained from the data.

It cannot be overemphasized that the above conclusions can significantly influence the understanding and interpretation of the analyses presented in the following sections.

2.2 Historical Background

It has become apparent during the project that the exact background details of the data are not fully known by the Nuclear Regulatory Commission (NRC). The written documentation provided to us at the beginning of the project shown in its entirety in Figure 1, was inadequate for a thorough understanding of the data and would have provided a serious problem in the interpretation of any analyses conducted. As a result, we have made an effort to identify some of the historical and technical aspects of the data. A brief review of the historical aspects of the data will be provided here.

The study was motivated, at least in part, by a series of events. An understanding of the project can be facilitated by a brief chronological presentation of the events preceding it. Our understanding of this sequence of events is presented below.

In 1964 the Atomic Energy Commission initiated and funded a program entitled, "The study of the lifetime health effects and mortality experience of employees of AEC contractors" under the direction of Dr. Thomas Mancuso at the Universtiy of Pittsburgh's School of Public Health. This program AT(30-1)-3394 was continued under contracts CHAT(11-1)-3428 and E(11-1)-3428 when the Energy Research and Development Administration (ERDA) was established incorporating the AEC. The stated purpose of the study was to:

> "The objective of this study is to follow cohort employee populations of selected AEC Contractor installations, to test the feasibility of using personnel, employment, medical and radiation records in establishing the relationships, if any, between mortality

Format of Tape

Cols.	Content
1-4	age at death (to nearest tenth)
5-6	year of initial employment
7-8	final year of employment
9-11	total years of employment (to nearest tenth)
12-14	cause of death (primary cause) ICD 8th revision
15	race 0 = non-white, 1 = white
16	sex 0 = female, 1 = male
17	exposure code 0 = non-exp, 1 = exp.
18-23	cumulative lifetime dose
24-29	cumulative dose 3 years before death
30-35	" " 5
36-41	" " 10
42-47	" " 15
48-53	" " 20
54-59	" " 25
60-61	year of death

Figure 1. Copy of the documentation provided with the data by NRC.

patterns and levels of radiation exposure. The reason for the study is the absence of empirically tested information pertaining to human populations exposed to recorded low levels of radiation over long periods of time. The procedure devised for the test runs is: to establish a series of cohorts of populations at each facility, those continuously employed as well as those separated, for each year, by tracing these individuals and sibling controls through Social Security records to determine those who have died and their place and date of death; to obtain death certificates to establish age-sex specific death rates; and to analyze causes of death for those with radiation exposure and work-connected health hazards in comparison to appropriate non-exposed controls. The following AEC Contractor facilities have been selected for the test runs: Oak Ridge X10, Oak Ridge Y12, Oak Ridge K25, Hanford and several small feed materials plants. These facilities provide large populations with long intervals of operation. Pilot studies of radiation exposure records of persons exposed in atomic energy facilities will be carried out to determine the average occupational exposure of these populations and appropriate confidence limits in exposure estimates for individuals and various sub-populations."

One of the facilities considered by the Mancuso study was the Hanford Atomic Facility in Richland, Washington. Around 1974 Dr. Milham of the Department of Public Health for the State of Washington reported (Ref.2) that his analysis showed an increased incidence of cancer in persons who had worked at Hanford and died in Washington, relative to other persons in the State of Washington. This report spurred analysis of the data which was being collected by Mancuso's study group. Eventually Mancuso, et. al., prepared a paper (Ref.1) which reported a relationship between cancer and low level ionizing radiation. At the same time his contract was terminated by ERDA. In the ensuing furor other persons analyzed the same or similar data including S. Marks of the Battelle Northwest Laboratories (Ref.3) and C. Land of the National Cancer Institute (Ref.4). In addition, Congressional hearings were held (Ref.5). Apparently the NRC was not in a position to address the issue at the hearings and this subsequently led to the current program.

In this program NRC decided to use the data employed by Land, rather than study the Hanford data stored at Hanford. Thus, a brief review of the origin of Land's data is in order.

Land had originally requested data from the Oak Ridge Data Processing Facility. Oak Ridge had some version of the data collected in the Mancuso study for the Hanford employees. It is not known to us how or when the data given to Land got from Hanford to Oak Ridge. Land requested, apparently in late 1976, a set of variables for analysis. The rationale for the variables selected is not known to us.

It was reported to us that the Land data resided on disk at the Harry Diamond Laboratories and that a copy of this file was put on tape for NRC in early 1978. A copy of the NRC tape was then given to us. As a consequence of the numerous data handling efforts, from Hanford to HEHF, to Oak Ridge, to Land, to Harry Diamond Labortories, to NRC to Kinetic Research, Inc. it is extremely difficult to determine precisely what the available data represents. In an effort to alleviate this problem we requested additional data. Our request for additional data was not implemented. As an alternative course of action, we compared the characteristics of the data received to that used in Land's study and in Mancuso's study. The key findings of the comparison are presented below. A more detailed presentation of the results appears in section 2.6.

While the frequency of each cause of death in our file matches Land's (Ref. 4) data, except for two cases which have no cause of death, there is a discrepancy on the year of death. Land reported that his data was to include deaths through 1973, while in the data received by us the most recent year of death is 1972. Our cumulative doses can be shown to be significantly different than Mancuso's reported in Ref. 1. Unfortunately, we were unable to compare cumulative dose frequencies with those in Land's data.

In respect to sample size, we have more cases than Mancuso (Ref.1), the same number of cases as Land (Ref.4), and fewer than reported by Mancuso in later reports (Ref.6 and 7). Perhaps most importantly, we have shown that the

data we have received has doses in time intervals which are not possible in the data collection scheme purported to have been followed in the Hanford study (Ref 8, 9, 10). Specifically there are 138 cases which have reported dose subsequent to the final year of employment. The details and ramifications of this finding are discussed more fully in section 2.4.3.

APPENDIX C

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The effects of the bombings of Hiroshima and Nagasaki continue. Shinji Takahashi discusses the Hibakusha's sufferings, and Robert Alvarez reviews the implications of survivor studies for radiation standards.

Radiation standards and A-bomb survivors

by Robert Alvarez

THE DEBATE over radiation health effects has been subject to an interesting paradox. Instead of providing reassurance, human studies that span several years often increase uncertainties about radiation risks. A case in point is the Life Span Study of the Japanese atomic bomb survivors. For more than 33 years, the U.S. government has supported this important follow-up of the 1945 nuclear bombings of Hiroshima and Nagasaki. Since 1975, the study has been funded jointly by the United States and Japan under the auspices of the Radiation Effects Research Foundation.

The survivor study consists of 79,736 people who were exposed to estimated doses of 0 to 400 rads (radiation absorbed dose) and who were alive in October 1950 when the follow-up began. By the mid-1970s, the survivor study had reached what many in the radiation protection community thought was a major landmark. It had become the main scientific reference for low-level external penetrating radiation risk estimates. Now several basic assumptions about the survivor study have come under serious questioning. This may have major ramifications for the civilian and military nuclear industries.

In 1981 the radiation protection community was jolted when researchers at the Department of Energy's Lawrence Livermore Laboratory reported that radiation exposures from neutrons in Hiroshima were significantly lower than previously believed. Dose reconstructions based on the 1957 Plumbob nuclear test series at Nevada also came under question. Radiation doses to the survivors may have been two to three times lower.

Reliance on cancer mortality risk estimates is also under criticism in light of data from tumor registries in Hiroshima and Nagasaki indicating an incidence of radiation-induced cancer two times greater. The shift away from an absolute to the more conservative relative risk model for radiation-induced cancer by some scientists increases the risk by another factor of two. Additionally, a new wave of long-latency cancers is now being reported among the survivors, indicating that the worst may not yet be over.

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In the May *Bulletin* radiation epidemiologists Dr. Alice Stewart and George Kneale raise perhaps the most fundamental question of all: Does the Japanese A-bomb survivor study have any value in deriving risk estimates for low-level radiation?

On the basis of data published by the Radiation Effects Research Foundation in 1978, Stewart and Kneale suggest that Foundation analysts have confused long-term effects of tissue-destructive high doses with single-cell low-dose effects. If they are correct, the method of linear extrapolation from high-dose studies for low-level radiation risk estimates is invalid.

ACCORDING to Stewart and Kneale, the Radiation Effects Research Foundation failed to account for two important factors. The first was the elimination of those in a poor state of health or nutrition. This "healthy survivor" effect, although recognized in studies of disasters, was discounted in 1950 because it was thought that if there was such an effect, the survivors' death rate from all causes would have been lower than the death rate among other Japanese. It was then assumed that all acute health damage from the bombings had ended by 1950.

In Hiroshima, the "healthy survivor" effect may have been intensified by a severe typhoon which killed hundreds of convalescents a few weeks after the bombing. In both cities, the absence of food, water, antibiotics, shelter and sanitary conditions certainly added to the risk of dying during the early aftermath of the bombings.

For years the "healthy survivor" effect bothered epidemiologists who had privileged access to the survivor data. In a *Confidential* report to the British Medical Research Council, written in 1959 after a site visit to Hiroshima and Nagasaki, W.M. Court-Brown, Richard Doll and A.G. Baikie noted:

> It must be presumed that many of those killed in Hiroshima would have developed leukaemia if they had survived so that *the surviving population is a selected one* and unless the selection was random in relation to dose, this would have introduced a bias into the subsequent incidence of various types of leukaemia and so affected the comparability of the two series [emphasis added].

The second major factor cited by Stewart and Kneale was the long-term residual damage from high doses which may have extended well beyond 1950. Many survivors who suffered radiation destruction of their bone marrow, a vital immune system organ, did not fully recover and had parts of their marrow replaced with scar tissue or sustained permanent but subtle damage to marrow stem cells. Survivors with less than normal amounts of active bone marrow are more prone to die from all causes, especially infections. This phenomenon, according to Stewart and Kneale, raised the survivors' overall death rate to levels higher than expected for groups which had undergone a disaster—thus creating a false appearance of normality.

By showing that non-cancer mortality follows abnormally shaped dose/response curves, Stewart and Kneale have been able to test their "healthy survivor" hypothesis. They also point to evidence of widespread bone marrow damage in the form of excess dose-related deaths from aplastic anemia—an acute form of radiation injury which depresses marrow production of white and red blood cells. The Radiation Effects Research Foundation rejected all exceptional findings for blood diseases other than leukemia as misdiagnoses. When they reclassified several of these deaths as leukemias, however, the number of aplastic anemias was still higher than expected.

After correcting for these two competing forces, Stewart and Kneale imply that ten times more people died from A-bomb radiation after 1950 and that more than two-thirds of the deaths were from diseases other than cancer. The Foundation claims that between 1950 and 1974 only 415 people died, all from cancer.

In 1970, Stewart and Kneale inadvertently challenged the survivor study when they published childhood cancer risk estimates based on the *in utero* exposure of British children in their massive Oxford Survey of Childhood Cancers. A single x-ray, they reported, given during pregnancy could initiate a cancer in childhood.

Their findings were disputed by Seymour Jablon and Dr. Hiroo Kato of the Radiation Effects Research Foundation. After analyzing data on A-bomb survivors exposed *in utero*, Jablon and Kato concluded that the survivors showed no significant risks of childhood cancer. By 1979, however, the U.S. Food and Drug Administration rejected the Foundation data and advised medical doctors against the routine use of fetal x-rays. By their action, the Food and Drug Administration implicity recognized that the Japanese A-bomb sur-

Courtesy Los Alamos National Laboratory

Thermonuclear detonation during the Pacific tests in 1958.

vivors constituted an abnormal population not suitable for their regulatory purposes.

Although Energy Department researchers continue to dispute Stewart and Kneale's *in utero* findings and the Nuclear Regulatory Commission has yet to issue formal standards to protect pregnant mothers, Food and Drug created a major crack in the foundation of the radiation standard system. But even Kato is now wavering on this point. In March 1983, at a symposium in Middletown, Pennsylvania, he presented survivor data which suggest a cancer effect from *in utero* exposure.

IF INDEED the survivor study can't be used to establish low-level radiation standards, what are the alternatives? The answer may be found among the 600,000 people who have worked in federal nuclear facilities since the 1940s. Unlike the survivors in Japan, U.S. radiation workers received low-level exposures which were individually measured and reported. The sample size of the Energy Department radiation workers is also large enough to dispel criticism of small numbers.

Radiation health effects among federal nuclear workers also appear to be different from those of the A-bomb survivors. Employees at the Hanford Plutonium Works in the state of Washington, for the most part, did not receive bone marrow destructive doses of radiation and show higher cancer risks than those based on extrapolations. There is also an absence of excess leukemias, a pronounced effect among A-bomb survivors. This may indicate that leukemia is more closely related to higher doses.

What the two groups have in common, however, is a dose-related excess of the long-latency multiple myeloma or bone marrow cancer. Although it was not believed to be radiation related in the mid-1970s, multiple myeloma has become the most prevalent long-latency cancer among the survivors.

If greater importance is to be given to radiation workers, these health studies now under control by the Energy Department should be transferred to a public health agency like the National Institutes of Occupational Safety and Health. The conflicts inherent in employer-directed health effects research are well known. The Department of Energy's record in this area leaves much to be desired since its major interest in radiation stems from its statutory mandate to develop nuclear weapons and to promote nuclear energy. In fact, all radiation epidemiological research, including the survivor study, should be taken from Energy and put into a public health agency. Currently, Energy funds over 60 percent of all radiation health effects research.

The Japanese A-bomb survivor study should be opened up to an independent peer review process which includes views at variance with official radiation risk estimates. Stewart and Kneale have consistently been denied access to relevant source data of the Radiation Effects Research Foundation to further test their hypothesis, despite the fact that they have assembled the largest case/control study on childhood cancer and radiation in the world.

If these changes are made, public health, as well as both sides of the radiation health effects debate, stands to benefit in the long run. □