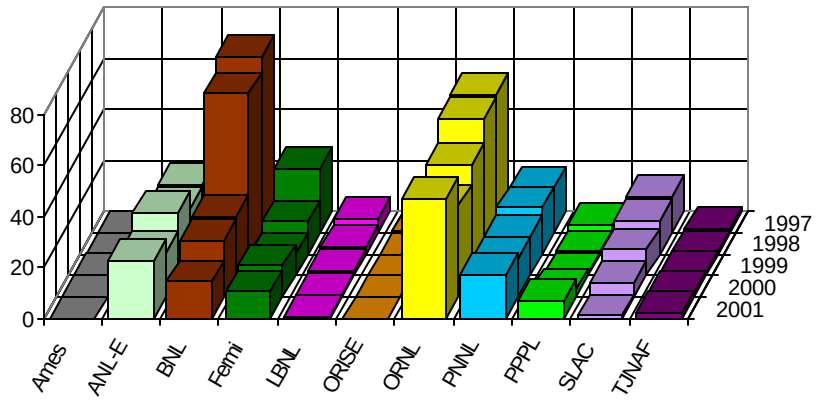
Radiological Control Profile for the Office of Science Laboratories 1997-2001

Collective Dose at SC Laboratories (Person-Rem)



Office of Laboratory Operations
and Environment, Safety and Health (SC-83)
Office of Science
U.S. Department of Energy

Executive Summary

Looking back at the trend over the past five years, the collective dose from all Office of Science (SC) laboratories has dropped about 40 percent overall, from 209 person-rem in 1997 to 125 person-rem in 2001. By comparison, the collective dose at all Department of Energy (DOE) laboratories dropped just over nine percent in the same period--from 1,360 person-rem in 1997 to 1,231 person-rem in 2001.

During 2001, the collective dose increased at 4 of the 11 SC laboratories -- Argonne National Laboratory-East (ANL-E), Oak Ridge National Laboratory (ORNL), Pacific Northwest National Laboratory (PNNL), and Princeton Plasma Physics Laboratory (PPPL). The increase at ANL-E is attributable to an increased workload at the Alpha-Gamma Hot Cell Facility (AGHCF), which is used for analysis of irradiated nuclear fuel. At ORNL, the increase was due to the Beryllium Reflector change out at the High Flux Isotope Reactor (HFIR). The workload at the PNNL Radiochemical Processing Laboratory increased approximately 22 percent during the year, while their collective dose increased 15 percent. The increase at PPPL was a result of increased decontamination and decommissioning (D&D) work at the Tokamak Fusion Test Reactor (TFTR).

In 2001, there were seven workers who had an annual dose exceeding 1,000 millirem, which is 20 percent of the DOE limit. In the previous year, only three workers were in this category. All seven workers were technicians analyzing irradiated nuclear fuel at the AGHCF.

The number of workers who received an annual dose between 250 – 1,000 millirem per year also increased in 2001. This was largely attributable to the replacement of the beryllium reflectors at the High Flux Isotope Reactor (HFIR) and the increased D&D work at PPPL, in addition to the fuel analysis at the AGHCF.

Most workers who were monitored for radiation exposure at SC laboratories received no measurable dose at all. Of those who did, approximately 80 percent received less than 100 millirem per year (the threshold when a dosimeter must be issued). More than 98 percent of those who had a measurable dose received an annual dose under 500 millirem, which is one-tenth of the DOE annual limit of 5,000 millirem (5 rem).

Reportable occurrences for radiation exposure, personnel contamination and loss of control of radioactive material do not show any clear trend, although they generally correspond to the amount of work performed. Off-site doses to members of the public from releases of radionuclides to the environment are all well within regulatory limits. Some SC laboratories have issues with legacy contamination in groundwater and soils from historical releases of radionuclides, but there are no issues of non-compliance with applicable standards for protection of the public.

Introduction

This is a current assessment of the performance of the SC laboratories with respect to radiological control. It provides a five-year retrospective look at occupational radiation exposures and radionuclide releases to the environment at the 11 SC laboratories, including results for all DOE employees, contractors, subcontractors, and visitors. The scope of the report includes occupational doses for all workers at each facility, and is not limited to just those funded by SC.

The occupational exposure data in this report is taken from the DOE Radiation Exposure Monitoring System (REMS), which serves as the central repository of radiation exposure information for DOE Headquarters. The REMS data is available on the web at http://rems.eh.doe.gov/ and is also published annually in the DOE Occupational Radiation Exposure Report. Information on radionuclide releases to the environment was taken from the Annual Site Environmental Reports.

Excellence in Radiological Control

The Department strives to maintain radiation exposures to its workers and the public below administrative control levels and regulatory limits, and to further reduce these exposures to levels that are "As Low As Reasonably Achievable" (ALARA). The ALARA methodology considers both individual and group doses and involves a cost/benefit analysis that considers social, technical, economic, practical, and public policy aspects of the overall goal of dose reduction.

To evaluate how well ALARA is being implemented for workers at SC laboratories, it is necessary to look at several different measures of occupational dose. The analysis in this report considers the total number of individuals who are monitored for dose, the number of those who actually receive a measurable dose, their average dose, and the group (or total collective) dose for all monitored individuals at all SC laboratories.

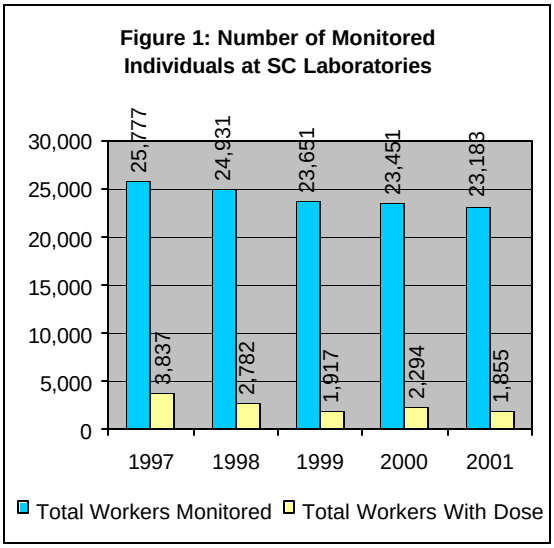
One characteristic of a good ALARA program is that the majority of worker dose should be at relatively low levels, with only a small percentage of workers receiving the higher doses that come close to approaching administrative control levels. For this reason, this report also includes a dose distribution, which shows the frequency distribution for the total number of exposed workers at selected ranges of dose.

Another characteristic of a robust radiological safety program is that, for a constant workload, both individual and group doses should drop over time, as experience and lessons learned combine to improve radiological work practices. This analysis provides a five-year retrospective of occupational and environmental radiation exposures to evaluate where reductions have occurred. It is important to note here that an increase in dose does not necessarily indicate a problem, if it can be attributed to increased work activity rather than a decrease in radiation control practices.

Number of Monitored Individuals

Personnel dosimetry is required for DOE workers who are likely to receive a dose greater than 100 millirem per year. Also, visitors are monitored at half that limit (50 millirem per year) if they are members of the public and not employees.

In practice, however, most sites prudently provide dosimetry in excess of this requirement, for reasons of administrative convenience, legal liability, and security. While the total number of monitored individuals gives a good indication of the overall scope of the dosimetry program, it is not necessarily a good indicator of the actual exposed work force.



The total number of monitored individuals at all SC laboratories trends slightly down, from 25,777 in 1997 to 23,183 in 2001 (see Figure 1). However, only a fraction of those monitored actually received a measurable dose. The number of people with a measurable dose has dropped from 3,837 in 1997 to 1,855 in 2001.

Collective Occupational Dose

The collective dose, or total radiation dose, is the sum of all annual doses received by every individual with a measurable dose. It is typically measured in units of person-rem, and it includes doses to visitors, as well as DOE employees, contractors, and subcontractors. The collective dose is monitored by DOE as one measure of the overall performance of radiation protection programs.

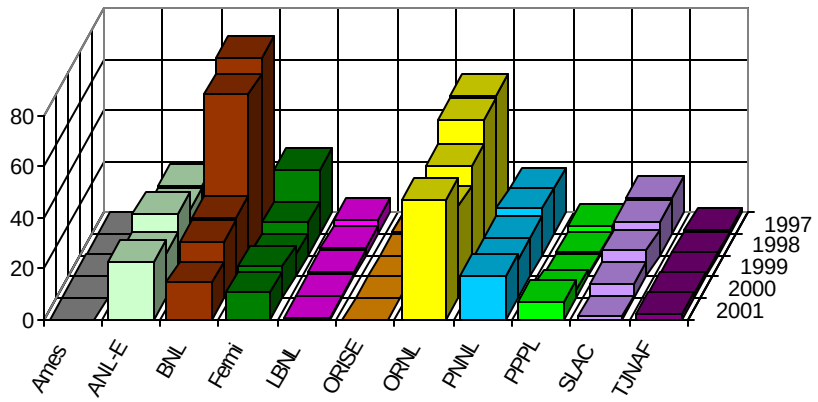
During 2001, the collective dose went up significantly at ANL-E, ORNL, PNNL, and PPPL. Looking back at the trend over the past five years, the collective dose from SC laboratories has dropped overall, from 209 person-rem in 1997 to 125 person-rem in 2001 (see Figure 2).

The collective dose at ANL-E increased to 23 person-rem in 2001, up from 17 person-rem the previous year. Irradiated nuclear fuel analysis at the AGHCF is the major contributor to dose at ANL-E.

Brookhaven National Laboratory (BNL) has reported the largest reductions in total person-rem. The collective dose at BNL has dropped about 80 percent, from 69 person-rem in 1997 to 14.6 person-rem in 2001. The drop is attributable to a major reduction in dose at the Alternating Gradient Synchrotron, and the shutdown of the High-Flux Beam Reactor and the Brookhaven Medical Research Reactor.

The collective dose at Lawrence Berkeley National Laboratory (LBNL), has dropped over 85 percent--from 5.2 person-rem in 1997 to 0.7 person-rem in 2001. The laboratory has a number of policies within the framework of Integrated Safety Management (ISM) that have contributed to this reduction in dose. Radiation safety professionals perform a 'walk down' on any operation that yields a dosimeter reading exceeding 50 millirem to any worker, looking for opportunities to reduce the dose. Also, the LBNL Radiation Safety Committee meets quarterly, and the 'top ten' doses are presented and reviewed to ensure that the doses are commensurate with the work.

Figure 2: Collective Dose at SC Laboratories (Person-Rem)



The collective dose at ORNL decreased about 30 percent between 1997 and 2000, but rose again in 2001 during the replacement of the beryllium reflectors at the HFIR. The major contributor to the collective dose at ORNL is the work at the HFIR and the Radiochemical Engineering Development Center. The laboratory has an ALARA Engineering Group that proactively reviews any task that is predicted to have a collective total effective dose equivalent (TEDE) exceeding 300 person-millirem. Any task that predicts a collective TEDE greater than 1,000 person-millirem must also be reviewed by the Radiological Support Services Complex Leader. The laboratory also has an Administrative Control Limit of 600 millirem for individual doses.

At PNNL, the collective dose increased from 15.4 person-rem in 2000 to 17.6 person-rem in 2001. The increase is attributed to an increased workload at the Radiochemical Processing Laboratory during the year. The workload increased approximately 22 percent, while the collective dose increased only 15 percent.

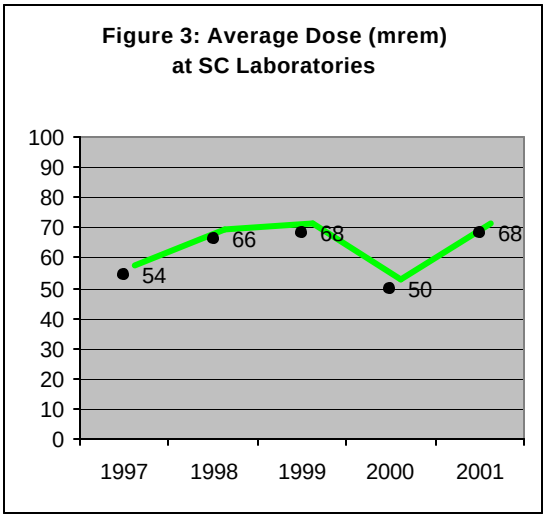
The collective dose at PPPL increased from 2.9 person-rem in 2000 to 7.4 person-rem in 2001 because of increased D&D work at the Tokamak Fusion Test Reactor (TFTR).

The collective dose from SC accelerator laboratories and single-purpose laboratories represented only a small fraction of the total. Of the three accelerator laboratories, Fermilab had the largest collective dose: 10.7 person-rem in 2001. Fermilab has reduced their collective dose almost 60 percent, from 25 person-rem in 1997 to 10.7 person-rem in 2001. The collective dose at Stanford Linear Accelerator Center (SLAC) has dropped over 90 percent, from 14.2 person-rem in 1997 to 1.4 person-rem in 2001. The collective dose at Thomas Jefferson National Accelerator Facility (TJNAF) has risen slightly from 1.4 person-rem in 1997 to 2.3 person-rem in 2001 as the lab came fully on-line.

Both the Ames Laboratory and the Oak Ridge Institute for Science Education have maintained the smallest collective doses of any SC laboratory, running at less than 0.5 person-rem every year.

Average Measurable Occupational Dose

The average measurable dose is one of the five DOE-wide ISM effectiveness measures, and it is calculated by dividing the collective dose by the total number of individuals with a measurable dose. The average dose for all SC facilities has ranged between 54 to 68 millirem during the last five years (see Figure 3).



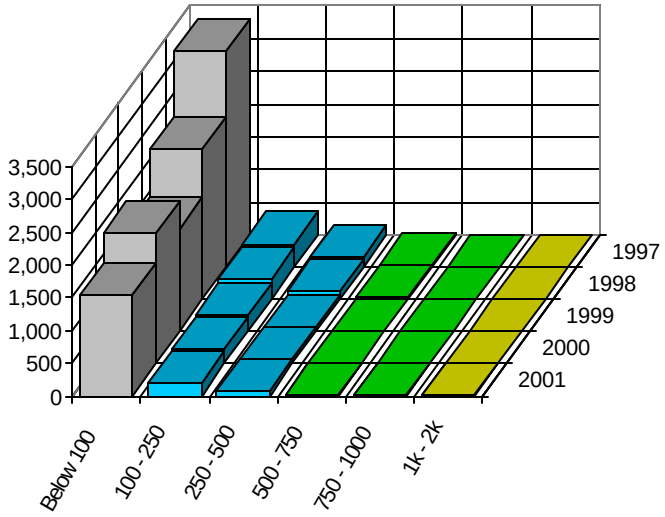
While the average measurable dose is one useful indicator for dose to workers (and visitors) at SC laboratories, it can be misunderstood if taken out of context. For example, the average dose can drop if there is an overall increase in the number of workers who receive very low levels of measurable dose. This may give a mistaken impression that doses are dropping, when in fact they are rising.

Also, since the average is calculated by dividing by the total number of workers with a measurable dose, the average may not be very sensitive to increases in dose to small numbers of workers, which may be of concern. In order to provide a more complete picture of radiation exposures, the following section presents exposure data as a frequency distribution showing the number of workers at selected intervals of annual dose with trends over the past five years.

Occupational Dose Distribution

Of all workers at SC laboratories who receive a measurable dose, the majority received an annual dose of less than 100 millirem, which is the DOE threshold for requiring dosimetry (see Figure 4). For the last five years, at least 80 percent of all workers at SC laboratories fell into this category. Also, for this same time period, more than 96 percent of all workers had a dose of less than 500 millirem per year, which is one-tenth of the annual limit of 5,000 millirem in 10 CFR 835.

Figure 4: Dose Distribution for SC Laboratories (1997-2001): Total Number of Workers in Each Dose Range



Dose Range (millirem/year)

The number of workers who received an annual dose exceeding 1,000 millirem increased from three in 2000 to seven in 2001. All seven workers were involved with analyzing irradiated nuclear fuel at the Alpha-Gamma Hot Cell at ANL-E. A major contributor to dose is the repair of remote manipulators, which are over 40 years old, and have a design life of two years.

There was also an increase in the number of workers who received an annual dose of between 250 – 1,000 millirem per year in 2001. The increase was largely attributable to the replacement of the beryllium reflectors at the HFIR and the increased D&D work at PPPL, in addition to the fuel analysis at the AGHCF.

Unplanned Radiation Exposures

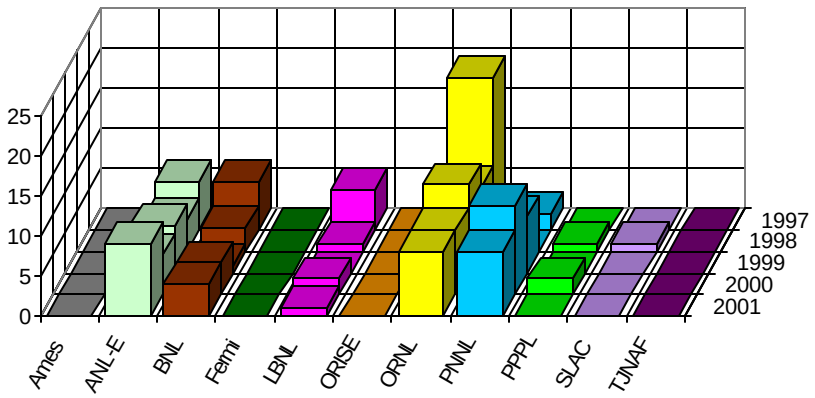
During the past five years, there were eight reported occurrences of unplanned radiation exposures at SC laboratories. During the same time, a total of 92 of these kinds of occurrences were reported DOE-wide. There was only one occurrence in 2001, which resulted in a worst-case estimated dose of 35 millirem to one worker at ORNL, from x-ray exposures during testing of a radiofrequency power supply. The highest dose reported from any of these occurrences was 1,240 millirem for an employee at Fermilab, but it is believed that this dose is an artifact caused by inadvertently leaving the dosimeter on top of a cabinet containing a radiation source.

Personnel Contamination

In addition to unplanned radiation exposures, sites are also required to report occurrences of personnel contamination. Although these kinds of occurrences do not cause any significant dose, they are tracked as a performance indicator for conduct of operations. An increase in the number of contaminations may indicate a degradation in radiological control practices, if not otherwise attributable to a change in work activities.

There were 143 occurrences of personnel contamination for SC during the past five years, as compared to 1,481 for all of DOE. These occurrences were predominately at the five SC multi-program laboratories (see Figure 5). The other laboratories reported a combined total of four occurrences during the last five years. There was an upward trend in occurrences of personnel contamination at PNNL in 2000, which was investigated and traced to a ventilation malfunction at the Radiochemical Processing Laboratory's 600 Annex. The contamination issues have since been mitigated, and the number of personnel contamination occurrences dropped in 2001.

Figure 5: Occurrences at SC Laboratories for Personnel Contamination

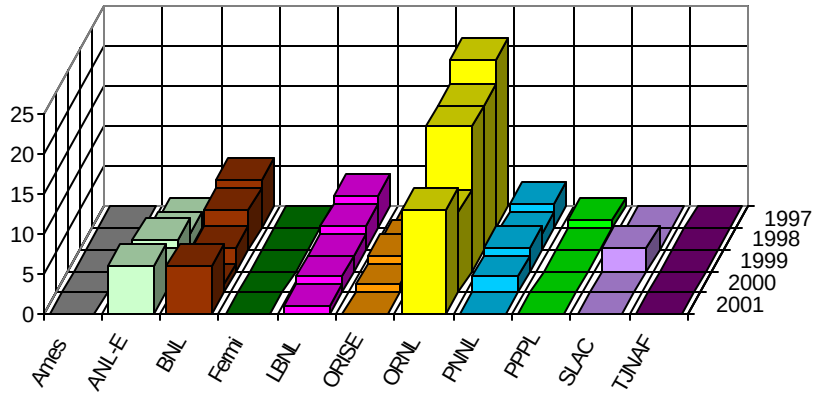


Loss of Control of Radioactive Material and Spread of Contamination

In addition to personnel contamination, sites also report occurrences of loss of control of radioactive material, and/or spread of contamination. Like personnel contamination, these occurrences do not cause significant dose, but are used as a performance indicator for conduct of operations.

There were 147 reported occurrences for this category during the past five years at SC laboratories, as compared to 1,523 reported DOE-wide. These occurrences were also predominately at the five multi-program laboratories (see Figure 6). The other laboratories had a combined total of only eight occurrences during the last five years. Overall, ORNL had the largest number of occurrences in this category.

Figure 6: Occurrences at SC Laboratories for Loss of Control of Radioactive Material & Spread of Contamination

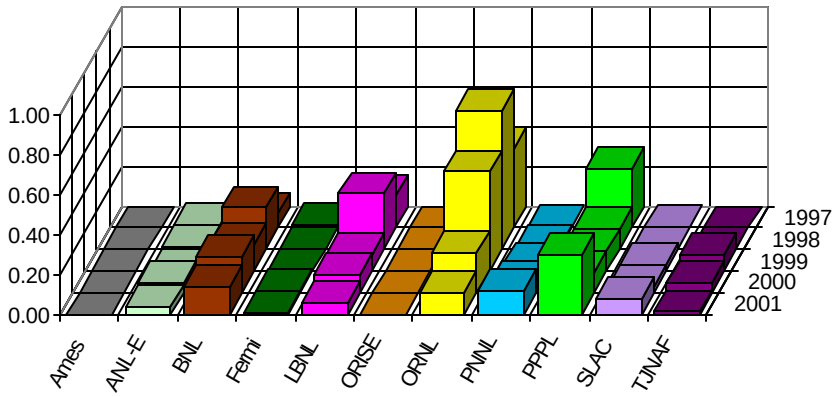


Environmental Releases of Radionuclides

All DOE facilities are required to demonstrate to the Environmental Protection Agency (EPA) that radionuclides released to air do not cause a dose greater than 10 millirem per year to any member of the public. This standard is found in the National Emission Standards for Hazardous Air Pollutants (NESHAPS) standard 40 CFR 61, Subpart H. This dose of 10 millirem per year is too small to measure because of the much higher natural background radiation (around 300 millirem per year) and must be calculated annually, using EPA-approved computer codes such as the Clean Air Act Assessment Package – 1988 (CAP88) or equivalent.

Over the past five years the dose to the maximally exposed individual has remained less than one millirem per year at all SC laboratories (see Figure 7). In 2001, the largest dose was at PPPL (0.3 millirem, or 3 percent of the limit).

Figure 7: NESHAPS dose at SC Laboratories (mrem/y)



In addition to complying with the NESHAPS standard for releases to air, DOE facilities must also comply with the DOE dose limit of 100 millirem per year for members of the public from all pathways (DOE Order 5400.5, Radiation Protection of the Public and the Environment). Important pathways which are evaluated include releases to both groundwater and surface waters (e.g., drinking water, eating fish, swimming, wading, and shoreline use). Some SC laboratories have outdoor radiological soil contamination from legacy releases which can contribute to the water pathways if the radionuclides migrate from the soil.

At ANL-E, the only significant location where radionuclides attributable to operations (primarily tritium and strontium-90) have been found in off-site water was Sawmill Creek below the wastewater outfall. Although this water is not used for drinking purposes, a 50-year effective dose equivalent of 0.016 millirem was calculated in 2001 for a hypothetical individual ingesting all drinking water at the radionuclide concentrations measured at that location.

There is a groundwater tritium plume at BNL which is associated with the High Flux Beam Reactor (HFBR). The portion of the plume with concentrations exceeding the drinking water standard of 20,000 pCi/L extends from the HFBR approximately 2,500 feet to the south. Activated soils containing tritium and sodium-22 have been created near a number of Alternating Gradient Synchrotron (AGS) experimental areas as the result of secondary particles (primarily neutrons) produced at beam targets and beam stops. There are also strontium-90 plumes associated with the Waste Concentration Facility and the Brookhaven Graphite Research Reactor (BGRR), which is no longer in operation. Strontium-90 has been routinely detected in groundwater in the Former Landfill, Animal/Chemical Pits and Glass Holes areas at concentrations above the

drinking water standard of 8 picoCuries per liter (pCi/L). The annual effective dose equivalent to an individual was calculated to be 2.5 millirem in 2001, from all pathways.

The release of tritium at LBNL has been an issue with local environmental groups. There is a groundwater tritium plume originating at the National Tritium Labeling Facility (now closed) which covers the areas of Buildings 31, 75, 76, 77 and 78. Tritium has been detected above the drinking water standard (20,000 pCi/L) in only one monitoring well, but this plume does not extend off-site or contribute to public dose.

There are large areas of outdoor radiological soil contamination at ORNL from legacy releases. The majority of these releases are from legacy waste disposal and aging underground process waste lines. The major radionuclides are Strontium-89, Strontium-90, Cesium-137, and tritium. Weekly surveys are conducted to measure the dose rate at these outdoor areas. The measured dose rates are typically less than 0.001 mrem/hour, with a maximum around 0.3 mrem/hour. In 2001, the worst-case analysis of public exposure to waterborne radionuclides gives a maximum possible individual dose of about 3.7 millirem for all pathways combined (e.g., drinking water, eating fish, swimming, wading, and shoreline use).

The Hanford Site has legacy soil and groundwater contamination, some of which is located at or near PNNL facilities. However, this contamination is primarily the result of historical Hanford weapons production activities, not PNNL activities. There have not been any known releases of radionuclides to groundwater or surface waters from PNNL that resulted in a significant off-site dose to members of the public.

There is a substantial tritium inventory at PPPL for fusion research. In August 1995, PPPL began to monitor tritium levels in on-site groundwater more comprehensively; all measurements have been well below the EPA drinking water standard.

All of the SC accelerator laboratories routinely monitor groundwater samples for tritium, with all measurements well within permitted levels. Surface water monitoring at Fermilab during 2001 showed tritium concentrations to be well within the DOE Derived Concentration Guides (DCGs) for allowable radionuclide releases to surface waters (2000 pCi/ml), and no radionuclides were detected in samples taken at the site boundary. Tritium discharged in wastewater from SLAC is regularly monitored and remains well within regulatory limits. Groundwater samples have been monitored at TJNAF since 1987, and no accelerator-produced activity has been detected.

The single-purpose labs (Ames Laboratory and the Oak Ridge Institute for Science Education) have not reported any radionuclide releases to groundwater or surface water, nor any legacy contamination in soil.

Laboratory Profile Sheets

The following section is one-page synopses for each of the 11 SC laboratories, briefly discussing their radiological operations and a summary of the occupational radiation exposures for the past five years. Contractual performance measures for radiological control are also noted, including both dose and contamination control, as applicable.

The dose distribution tables are highlighted in color in order to make them easier to read, and to help facilitate comparison of one laboratory with another. The highlight colors are the same as those used in Figure 4, "Dose Distribution for SC Laboratories" (0-100 mrem is gray, 100-500 mrem is blue, 500-1000 mrem is green, and 1000-2000 mrem is yellow).

Ames Laboratory

In 2001, Ames had the lowest collective dose among all SC laboratories. The radiological work at Ames includes use of x-ray devices, remediation of legacy contamination, stewardship of radioactive materials, and intermittent research involving small amounts of radioactive materials. There are currently 14 x-ray systems and approximately 70 trained x-ray workers. Radioactive materials work has been minimal over the past five years, with primary use consisting of sealed source materials and irradiated metals. No radioactive materials research activities were conducted during 2001. Ames Laboratory radiological activities are subject to a readiness review process and ALARA committee review as ISMS mechanisms.

Occupational Radiation Dose Distribution (1997-2001)

Ames — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	123	6	110	18	117	6	0	0	0	0	0
1998	113	2	20	10	111	2	0	0	0	0	0
1999	109	3	230	77	106	1	2	0	0	0	0
2000	122	13	311	24	109	13	0	0	0	0	0
2001	123	11	165	15	112	11	0	0	0	0	0

Contractual Performance Measures for Radiological Control:

Ames uses the average total effective dose equivalent (TEDE) to measure the effectiveness of management commitments to ALARA. The rating is based on the average TEDE per person who received a measurable dose, as follows:

Outstanding = less than 30 millirem
Excellent = 30-42 millirem
Good = more than 42 and less than 79 millirem
Marginal = between 79-91 millirem
Unsatisfactory = more than 91 millirem

Argonne National Laboratory – East (ANL-E)

In 2001, ANL-E had the second highest collective dose among all SC laboratories. The collective dose increased from 17 person-rem in 2000 to 23 person-rem in 2001, attributable to an increased workload at the AGHCF, used to analyze irradiated nuclear fuel. The number of individuals in the dose range of 1k – 2k millirem/year also increased from 3 in 2000 to 7 in 2001. A large part of the dose increase is attributable to repair work on remote manipulators at the AGHCF; the manipulators are over 40 years old, and have a design life of two years. The Argonne Tandem Linac Accelerator System (ATLAS) contributes little to the collective dose (less than 0.1 person-rem for the last five years).

Occupational Radiation Dose Distribution (1997-2001)

ANL-E — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	3,053	238	19,021	80	2,815	186	34	14	1	2	1
1998	2,938	182	17,715	97	2,756	127	40	11	1	2	1
1999	2,888	187	24,583	131	2,701	126	34	14	8	3	2
2000	2,824	183	17,244	94	2,641	140	27	8	5	0	3
2001	2,819	187	23,033	123	2,632	136	32	10	1	1	7

Contractual Performance Measures for Radiological Control:

Performance expectations for the laboratory include the collective dose equivalent to monitored individuals and also the number of radioactive contaminations and contaminated individuals. The contract provides that a joint committee of Argonne Area Office (AAO) and ANL representatives appointed by the AAO Manager and the ANL Director, respectively, will review the occupational radiation protection performance measures quarterly and agree on adjustments to performance expectations as necessary to account for changes in scope of radiological work.

Brookhaven National Laboratory (BNL)

In 2001, BNL had the fourth highest collective dose of all SC laboratories. The collective dose at BNL dropped from 22.3 person-rem in 2000 to 14.6 person-rem in 2001. This decrease is attributable to a major reduction in dose at the AGS and the shutdown of the HFBR and the Brookhaven Medical Research Reactor (BMRR).

Approximately three-fourths of the collective dose at Brookhaven is from operation of the AGS, which is now used in conjunction with the Relativistic Heavy Ion Collider (RHIC), in addition to fixed target programs involving high-intensity protons or heavy ions. Until recently, repairing broken radioactive equipment was the major source of radiation exposure at AGS. The dose reductions at AGS are attributable to major improvements in accelerator equipment design, accelerator upgrades and an active ALARA program.

Occupational Radiation Dose Distribution (1997-2001)

BNL — Total Workers In Each Dose Range (mrem) >

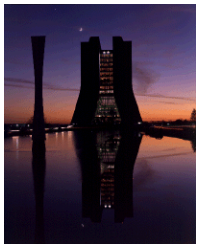
Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	5,984	1,463	68,948	47	4,521	1,274	117	56	14	2	0
1998	5,596	1,055	62,965	60	4,541	885	101	50	15	4	0
1999	5,653	521	23,371	45	5,132	453	59	7	2	0	0
2000	5,484	430	22,384	52	5,054	363	57	8	2	0	0
2001	5,037	385	14,582	38	4,652	349	28	8	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for ALARA collective dose goals. An Outstanding rating is awarded for under-running ALARA goals by more than 20 percent and an Unsatisfactory rating for over-running by more than 40 percent.

Another measure is for the number of radioactive contaminations reportable under Occurrence Reporting & Processing System (ORPS), which provides an Outstanding rating for four or fewer occurrences and an Unsatisfactory rating for 17 or more.

Fermilab



The collective dose at Fermilab dropped from 12.3 person-rem in 2000 to 10.6 person-rem in 2001. The proton beam used at Fermilab has greater potential to produce prompt radiation and induced radioactivity than the electron beams used at SLAC and TJNAF. For this reason, Fermilab tends to have a higher collective dose than either SLAC or TJNAF. It is commendable that the ALARA program at Fermilab has managed to cut the collective dose by more than half since 1997, despite the increased intensity at which the accelerator now operates to better support the physics research program. Most of the collective dose results from work around activated equipment; when the accelerator is operating and this kind of work decreases, the collective dose drops.

One employee was assigned a dose of 1,240 millirem (for work done in 1999), but it is believed that this dose is an artifact caused by inadvertently leaving the dosimeter on top of a cabinet that contained a radiation source. The dose was reported to the NTS and ORPS, and is documented in Occurrence Report CH-BA-FNAL-FERMILAB-2000-0003.

Occupational Radiation Dose Distribution (1997-2001)

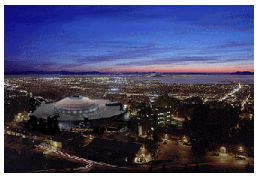
Fermi — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	2,365	859	24,970	29	1,506	822	29	6	2	0	0
1998	2,066	441	12,790	29	1,625	421	15	5	0	0	0
1999	1,051	227	8,740	39	824	211	13	2	0	0	1
2000	1,361	406	12,340	30	955	390	14	1	1	0	0
2001	1,344	368	10,650	29	976	352	13	3	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for managing collective dose. The 2002 measure rates a collective dose of less than 10.5 person-rem as Outstanding.

Lawrence Berkeley National Laboratory (LBNL)



In 2001, LBNL had the lowest collective dose among all the SC multi-program laboratories, and the dose has trended dramatically down during the past five years. The laboratory has a number of policies within the framework of ISM that contribute to maintaining occupational radiation doses ALARA. Radiation safety professionals perform a 'walk down' on any operation that yields a dosimeter reading exceeding 50 millirem to any worker. Also, the LBNL Radiation Safety Committee (RSC) meets quarterly, and the 'top 10' doses are reviewed to ensure that the doses are commensurate with the work performed. The RSC also evaluates dose trends for each building.

The collective dose from the 88-Inch Cyclotron has been reduced by 96 percent since 1998 (from 1.0 to 0.04 person-rem), and now contributes only six percent to the site total. New CR-39 dosimetry is now being used in any areas with positive neutron readings on albedo dosimeters. The improved accuracy of CR-39 has helped reduce the magnitude of recorded neutron doses.

Occupational Radiation Dose Distribution (1997-2001)

LBNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	1,879	128	5,247	41	1,751	117	9	2	0	0	0
1998	1,992	76	2,912	38	1,916	75	1	0	0	0	0
1999	1,781	46	1,822	40	1,735	41	5	0	0	0	0
2000	1,835	44	1,114	25	1,791	42	2	0	0	0	0
2001	1,694	21	682	32	1,673	21	0	0	0	0	0

Contractual Performance Measures for Radiological Control:

A performance measure is in place to manage occupational radiation dose, which provides an Outstanding rating for no individual exposures in excess of 500 millirem without an increase in workload (unless authorized in writing by the Radiological Control Manager). Also, an Outstanding rating requires that the number of individual exposures exceeding 100 millirem must be less than or equal to the control level of 10, plus the average individual positive dose is less than the control level of 50 millirem, all without an increase in workload.

The LBNL performance measure for reportable occurrences of personnel contamination provides an Outstanding rating for a weighted number of contaminated individuals less than or equal to 4.0 (with unusual occurrences having a weighting factor of 1.5, and off-normal at 1.0). The performance measure for control of radioactive material and spread of contamination provides an Outstanding rating for 2.0 or less weighted occurrences (with unusual occurrences using a weighted factor of 1.5 and off-normals 1.0).

Oak Ridge Institute for Science and Education (ORISE)

In 2001, ORISE had the lowest number of monitored employees and the second lowest collective dose for all SC laboratories. For the last five years, ORISE has never had a dose exceeding 100 millirem. The only sources of radiological exposure are some sealed sources for calibration, and some environmental samples for analysis.

Occupational Radiation Dose Distribution (1997-2001)

ORISE — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	49	12	370	31	37	12	0	0	0	0	0
1998	55	1	20	20	54	1	0	0	0	0	0
1999	48	8	42	5	40	8	0	0	0	0	0
2000	94	58	299	5	36	58	0	0	0	0	0
2001	87	55	327	6	32	55	0	0	0	0	0

Contractual Performance Measures for Radiological Control:

A performance measure is in place for worker radiation dose, to assess the effectiveness of the ORISE personnel exposure program and to document the ALARA Program is in place and active. The average ORISE employee occupational dose is calculated by dividing the collective total effective dose equivalent for all monitored ORISE employees by the total number of employees with a measurable dose. A rating of Meets Expectation is assessed for the quarter if the average dose falls below 10 millirem and a rating of Does Not Meet Expectation is assessed if the average exceeds 10 millirem.

Beginning in January 1999, ORISE began using the Luxel Thermo Luminescent Dosimeter (TLD) with a threshold of millirem, compared to the previously used K-100 TLD that had a threshold of 10.0 millirem. This increased TLD sensitivity has resulted in a statistically higher dose per individual.

Oak Ridge National Laboratory (ORNL)

In 2001, ORNL ranked highest in both collective dose and average measurable dose among all SC laboratories. The major contribution to the collective dose at ORNL is the work at the HFIR and the Radiochemical Engineering Development Center (REDC). The Holifield Radioactive Ion Beam Facility (HRIBF) and the Oak Ridge Electron Linear Accelerator (ORELA) contribute little to the collective dose (approximately 0.335 person-rem in 2001).

The collective dose increased from 36 person-rem in 2000 to 47 person-rem in 2001, because of the Beryllium Reflector change out at the HFIR. The ALARA goal for this project was about 34 person-rem, and the actual dose received was only about 20 person-rem. If the dose from the beryllium replacement project were not included, the collective dose would have dropped to 27.5 person-rem in 2001.

Occupational Radiation Dose Distribution (1997-2001)

ORNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	6,828	591	54,059	91	6,237	430	107	41	8	4	1
1998	6,388	527	53,005	101	5,861	389	79	43	10	3	3
1999	6,159	506	43,740	86	5,653	376	89	28	9	2	2
2000	5,954	371	35,848	97	5,583	258	77	27	8	1	0
2001	5,345	389	47,039	121	4,956	255	73	43	14	4	0

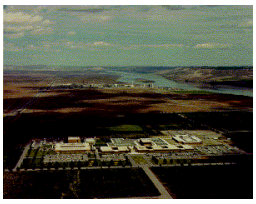
Contractual Performance Measures for Radiological Control:

Performance measures are in place for both worker radiation dose and radiological operations. The measure for worker radiation dose is based on the average measurable dose; ratings range from Outstanding for 90 millirem or less, to Marginal for more than 110 millirem.

The radiological operations measure is based on five factors:

- the number of radiological workers that exceed their ORNL ALARA goal by five percent
- the number of radiological workers exceeding 30 percent of any dose limit in 10 CFR 835
- the number of occurrences for radiation exposure
- the number of occurrences for personnel contamination
- loss of control of radioactive material or spread of contamination

Pacific Northwest National Laboratory (PNNL)



The collective dose at PNNL ranked third highest in 2001 among all SC laboratories. The collective dose increased from 15.4 person-rem in 2000 to 17.6 person-rem in 2001. The increase in collective dose is attributed to an increased workload at the Radiochemical Processing Laboratory during the year. The workload increased approximately 22 percent, while the collective dose increased only 15 percent.

Occupational Radiation Dose Distribution (1997-2001)

PNNL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	1,725	288	17,573	61	1,437	243	33	9	2	1	0
1998	1,718	263	18,289	70	1,455	205	43	11	4	0	0
1999	1,609	236	15,569	66	1,373	190	30	15	1	0	0
2000	1,396	174	15,378	88	1,222	133	20	18	3	0	0
2001	1,470	207	17,639	85	1,263	160	29	15	3	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place to manage unplanned dose, spread of radioactive contamination, and loss of control of radioactive material as part of their evaluation of the effectiveness of ISM. An "Unplanned Dose" is defined as any occupational dose exceeding the expected dose by a value of 100 millirem or more, or any single unplanned dose onsite to a minor, student, or member of the public that exceeds 50 millirem.

"Spread of Radioactive Contamination" is defined as the number of instances of uncontrolled unwanted (nonlegacy) spread of radioactive contamination, meeting the criteria of DOE M 232.1-1A, Section 9.3, Group 1D, Off-Normal Event, Items 1-4. "Loss of Control of Radioactive Material" is defined as the number of losses of accountability of a sealed or unsealed radioactive source that meets the criteria of DOE M 232.1-1A, Section 9.3, Group 1D, Off-Normal Event, Items 5 or 6.

An Outstanding rating requires zero Unplanned Doses, three or fewer instances of Spread of Radioactive Contamination, and one or zero instances of Loss of Control of Radioactive Material.

Princeton Plasma Physics Laboratory (PPPL)

The collective dose at PPPL increased last year, from 2.9 person-rem in 2000 to over 7.4 person-rem in 2001, because of increased D&D work at the TFTR. The D&D work began in 1999 with removals of peripheral equipment, located some distance from the tokamak. As the project continued, removal work moved progressively closer to the activated machinery. In 2001, most activities were performed on the machine itself, including actual removal of parts of the tokamak and coils.

Occupational Radiation Dose Distribution (1997-2001)

PPPL — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	381	88	2,943	33	293	81	6	1	0	0	0
1998	275	35	1,080	31	240	33	2	0	0	0	0
1999	406	34	817	24	372	33	1	0	0	0	0
2000	466	59	2,941	50	407	51	8	0	0	0	0
2001	484	108	7,420	69	376	87	11	9	1	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for both collective dose and personnel contamination control. A total effective dose equivalent of 0 to 4 person-rem for routine operations and 0 to 8 person-rem for D&D is rated as Outstanding.

A total of zero contamination events is rated as Outstanding. Contamination events are defined as the number of skin or clothing contamination events (excluding protective clothing contamination) in which workers or visitors are contaminated with radionuclides that meet or exceed the criteria in PPPL documents implementing DOE Order 232.1.

Stanford Linear Accelerator Center (SLAC)

The collective dose at SLAC dropped from 5.8 person-rem in 2000 to only 1.4 person-rem in 2001. The collective dose at SLAC was less than that of Fermilab and TJNAF.

The majority of the worker dose comes from maintenance activities. In 1997, SLAC began replacing original beamline equipment which was slightly activated after 20 years of use. Replacing the aged, activated equipment has helped reduce radiation exposures overall; the collective dose at SLAC has dropped every year for the last five years.

In 2000, SLAC experienced an unexpectedly large number of small positive doses (most less than 10 millirem) for some workers who normally receive no measurable dose. The results could not be attributed to any known exposures or quality control problems, and a new dosimetry system was instituted. As a result, the number of workers with doses below 100 millirem decreased.

Occupational Radiation Dose Distribution (1997-2001)

SLAC — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	2,069	117	14,175	121	1,952	79	20	15	1	2	0
1998	2,283	157	13,137	84	2,126	126	19	12	0	0	0
1999	2,493	104	10,192	98	2,389	78	17	7	2	0	0
2000	2,423	489	5,766	12	1,935	482	7	0	0	0	0
2001	3,155	35	1,368	39	3,120	32	3	0	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for unplanned radiation exposures and personnel contamination control. An Outstanding rating requires no occurrences of ORPS-reportable radiation doses or contamination. An unplanned radiation exposure includes a dose in excess of 100 millirem/year to nonradiological workers.

A second measure is for compliance with occupational radiation dose limits in 10 CFR 835, with an Outstanding rating for no occupational doses to radiological workers in excess of 500 millirem, no general employee dose over 50 millirem, and a total collective dose less than 70 percent of the previous three-calendar-year running average.

Thomas Jefferson National Accelerator Facility (TJNAF)

The collective dose at TJNAF rose slightly last year, from 1.6 person-rem in 2000 to 2.3 person-rem in 2001. This increase may be attributed to a growing and maturing physics program. The number of monitored individuals and the total number of workers with a measurable dose also increased. Approximately two-thirds of the monitored individuals at TJNAF are visitors.

There is a "Level of Concern" set at 60 millirem per quarter; any individual dose exceeding this level triggers an ALARA review.

Occupational Radiation Dose Distribution (1997-2001)

TJNAF — Total Workers In Each Dose Range (mrem) >

Year	Total Workers Monitored	Total Workers With Dose	Total Person - mrem	Avg. Dose (mrem)	Total With No Dose	Below 100	100 - 250	250 - 500	500 - 750	750 - 1000	1k - 2k
1997	1,321	47	1,370	29	1,274	44	2	1	0	0	0
1998	1,507	43	1,039	24	1,464	42	1	0	0	0	0
1999	1,454	45	1,370	30	1,409	43	2	0	0	0	0
2000	1,492	67	1,616	24	1,425	66	1	0	0	0	0
2001	1,625	89	2,317	26	1,536	87	2	0	0	0	0

Contractual Performance Measures for Radiological Control:

Performance measures are in place for the number of reportable and recordable exposures to radiation as off-normal occurrences; this measure weights unusual occurrences by a factor of five.

Another measure requires a peer review of the Radiological Control Program in even-numbered fiscal years.